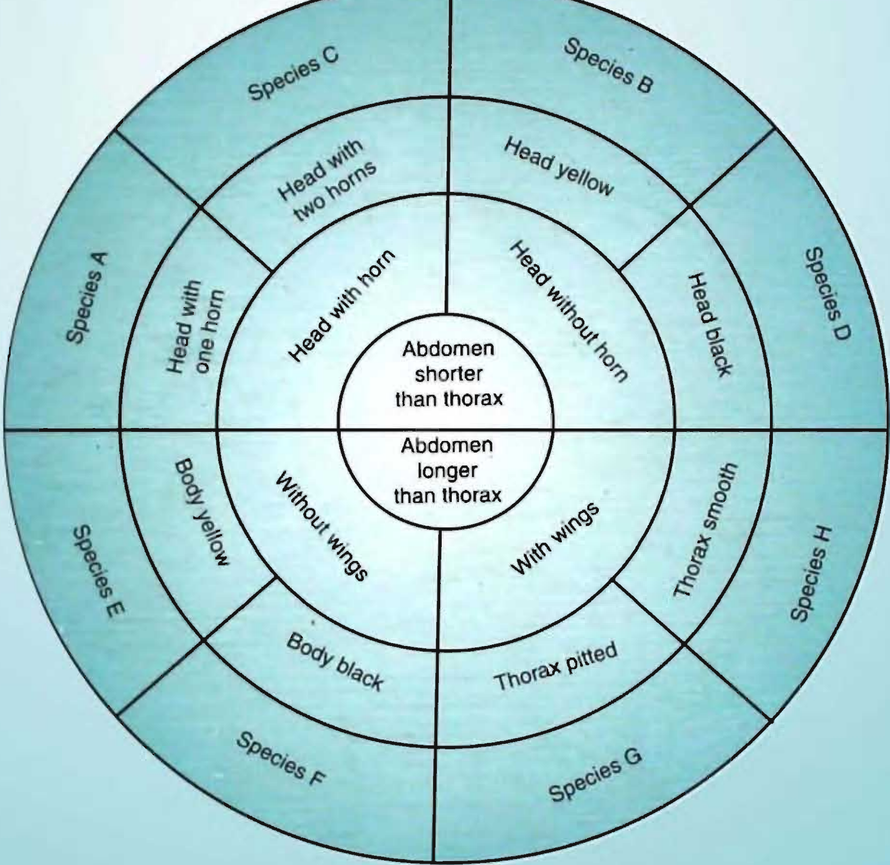
An introduction to
TAXONOMY

T. C. NARENDRAN



Zoological Survey of ndia

An Introduction to
TAXONOMY

T. C. NARENDRAN

Professor & Head of the Department of Zoology (Retired),
University of Calicut, Kerala - 673 635, India.

Edited by the Director, Zoological Survey of India, Kolkata

सत्यमेव जयते

AICOPTAX
Zoological Survey of India
Kolkata

CITATION

Narendran, T.C. 2006. *An Introduction to Taxonomy* : 1-80 (Published by the Director, *Zool. Surv. India*, Kolkata)

1st Published : March, 2006

Reprinted : June, 2009

ISBN 978-81-8171-218-9.

PRICE
India : Rs. 100.00
Foreign : $ 5; £ 3

Published at the AICOPTAX Centre (Mollusca) by the Director, Zoological Survey of India, 234/4, A.J.C. Bose Road, 2nd MSO Building, Kolkata - 700 020 and funded by the Ministry of Environment & Forests, Govt. of India. Printed at Calcutta Repro Graphics, Kolkata - 700 006.

FOREWORD TO THE 2ND EDITION

Zoological Survey of India, Govt. of India, published the book *'An Introduction to Taxonomy'*, authored by Prof. T C. Narendran, in 2006. The book proved its merit as a handy volume explaining in brief the essence of the science of taxonomy, and today no other book of its kind commands such a rising tide of demand. The book was so well received by the taxonomic workers in the country that all the copies were sold out very quickly, making it an instant success.

The growing readership of the book is a reflection of the positive attitude of the poeple in the field of biology towards the study of taxonomy and systematics, recognizing its contemporary significance in the scientific inventorying/documenting the biodiversity wealth. A realization to that notion needs to be spread to a larger segment of the people, especially the young and educated generation, in the country. Zoological Survey of India strives for making it a reality through the publication of such user-friendly scientific and popular volumes/handbooks, such as *'An Introduction to Taxonomy',* which is one of the prime mottos of this institution.

In this context, Zoological Survey of India finds it very relevant to bring out the reprint of the publication so as to keep pace with its demand and usefulness in the study of taxonomy.

Kolkata
June, 2009

Dr. Ramakrishna
Director
Zoological Survey of India

FOREWORD TO THE FIRST EDITION

The merit of a discipline is recognized by the benefits it renders in a crisis. With the ever-increasing human interference over biosphere, we are heading towards such a crisis of losing our valuable biodiversity at a rapid and an alarming rate. The international community of policy makes and scientists has now acknowledged that the loss of biodiversity has serious economic and social costs. In the Convention on Biodiversity of 1992 and later in several new global agreements, the message of conservation and sustainable use of biodivesity has been on the prime agenda. The sole reference system for Biodiversity interpretation is catered by the science of Taxonomy. Thus species, the basic unit in any taxonomic hierarchy is the lone versatile currency to recognize and characterize the enormous biodiversity on our planet. A strong basework in taxonomy of diverse groups is the only way to address the multidimensional challenges underlying the issues of biodiversity conservation. Though the mammoth task of characterizing the 10 to 13 million species on Earth is already initiated by the global taxonomic community, the fact that the number of active field systematists and taxonomists are very limited has emerged as a serious impediment to the progress of the initiative.

The discipline of taxonomy has often been much neglected and has been lacking the deserving distinction, while allied fields claim the applause, through contributions made by taxonomists. It is unfortunate that taxonomy is yet to gain a place among popular disciplines. Till date, there has been only very few Indian publications dealing with the science of taxonomy. In this regard, a publication, elaborating in an efficient, yet, simplified manner, on the subject is indeed not only a much welcome venture, but also a needed one. Prof. Narendran, the author of this book, is the winner of the prestigious 'E. K. Janaki Ammal National Award for Taxonomy' for the year 2004. With more than 250 research publications, he has been an important contributor to the description of India's faunal biodiversity. Currently he is a member of committee for Collaborative Research of National Biodiversity Authority.

This book 'An Introduction to Taxonomy' will enlighten the students, researchers and the scientific community, on the various taxonomic issues, principles, practices and methodology. The volume also substantiates the relevance of taxonomy in different arenas on the forefront of international concern, like biodiversity conservation and Integrated Pest management. The book equips the reader with a thorough understanding on the subject, also kindles curiosity and interest, vital to shaping of fresh, promising talents in the field.

I am extremely happy to note that this publication has been brought out by the co-ordinator, AICOPTAX-Mollusca, Zoological Survey of India funded by the Ministry of Environment & Forests. Thanks are due to Sri Rati Ram Verma, Publication Production Officer, Zoological Survey of India, for bringing out the publication in a record time.

March, 2006
Kolkata

J.R.B. Alfred
Director
Zoological Survey of India

CONTENTS

Dedicated to my doctoral students
(both past and present)
for their love, affection and sincerity

INTRODUCTION

The most serious problem before us in the 21st century is the preservation of our biodiversity in order to feed billions of new mouths over the next several decades and save the rest of life. Our growing demands for food, medicine, clothing and other similar essential items will always urge us to understand and exploit the world's biodiversity. Unfortunately the world's biodiversity is fast depleting, largely due to the negligence of human race. The famous spokesman of conservation of world's biodiversity, Edward O. Wilson (2003), (Professor of Pellegrino University and Hayward University) recently cautioned that "Over the past half a billion years the planet lost perhaps one species per million species each year including everything from mammals to plants and today the annual rate of extinction is 1000 to 10000 times faster. If nothing more is done, one-fifth of all the plant and animal species now on earth could be gone or on the road to extinction by 2030" As worrisome and serious as this is for all of us, our vast ignorance of the magnitude of world's biodiversity is another worrisome fact. Fewer than two million species of organisms are scientifically identified and named while an estimated 5-100 million (Wilson, 2003) or more await discovery. It has been often said that at the current pace of taxonomic research, it may take 500 -1000 years or more before all the species of the world are identified and described The reason hindering the pace of identifying and describing earth's organisms is the steady decline of active taxonomists all over the world. Taxonomy encompasses the science of classification including identifying, describing and naming of organisms. It is the study of kinds and diversity of organisms and of any and all relationships among them. Taxonomists are thus the scientists whose expertises provide data on the identification, description, distribution and relationships of life on earth.

Extinction and loss of biodiversity can be prevented only if we know the basic units that are species and their relationships. Taxonomy provides discovery and identification of these basic units and their relationships. Taxonomists are involved in both basic and applied research since it is central to life sciences, as it provides the fundamental framework that allows scientists to compare their findings with those on other living organisms. In particular, the names of species are the keys to communication concerning biodiversity as they provide access to accumulated knowledge concerning all life forms. Taxonomy involves not only collecting, identifying, naming new species and developing sound classification but also analysis of biological variations, biogeography, evolutionary biology and host-parasitic relationships. Thus Taxonomy and biodiversity are so intimately connected.

It is high time that we reset our priorities and make an earnest effort to give due importance to research in Taxonomy. We have already lost millions of organisms and we cannot afford to lose any further. We have lost valuable time and we should act now as a global efforts at a larger scale similar to the human genome project for the development of systematics so that we can document our biodiversity and initiate steps to conserve it.

The governments of the world that recognize the need for conservation of biological diversity have affirmed the existence of a taxonomic impediment to sound management and conservation of biodiversity. Removal of this impediment is a crucial rate-determining step in the proper implementation of convention's objectives. There is an urgent need to train and support more taxonomic experts in order to discover and understand world's biodiversity. Taxonomic perspectives should be developed by the policy makers of the governments to achieve sustainable development and conservation of biodiversity. It is high time that we reset our priorities and make a beginning to give due importance to research in systematics. We have lost so many millions of organisms already and we cannot afford to lose any further. We have lost valuable time and we should act now to regain the past glory of systematic studies in order to save not only our biodiversity but also for ourselves.

Taxonomy forms one of the core subjects of study for the master's degree students in biology. Very small number of books is available for catering to the needs of the students. All we have is either textbooks, which are meant for researchers in systematics, or the ones which are too complicated for the postgraduate or graduate students to comprehend. Here in this textbook an attempt has been made to strike a balance between fundamental details and recent developments in Taxonomy. Special attention has been given to simplify the whole text. It is hoped that this book will not only solve many of the doubts of students who really want to study Taxonomy, but also will be a source of inspiration for future research.

CHAPTER 1

TAXONOMY AND ITS IMPORTANCE

Taxonomy is the science of classifying organisms. The word "Taxonomy" was first proposed by French Professor A. P. de Candolle as 'Taxonomie' in 1813 and 'Taxeonomie' in 1819. However, the word Taxonomy has been in use for the last 170 years and the words 'Taxonomie' and 'Taxeonomie' are considered 'long forgotten names' The word Taxonomy originated from the Greek words "taxis" meaning "arrangements" and "nomos" meaning "law" Mayr (1971) considers taxonomy as the theory and practice of classifying the organisms. The term 'Systematics' originates from the Latinized Greek word 'Systema' as applied to systems of classification developed by Carolus Linnaeus in 1735. Simpson (1961) defined Systematics as the scientific study of the kinds and diversity of organisms and of any and all relationships among them. Various specialists have given various definitions to these terms but the fact remains that today both terms are used interchangeably in the fields of animal and plant classification. It is in this restricted sense in which Systematics is used in this book.

1. Importance of Taxonomy to Biodiversity and Conservation

Approximately I million species of animals and 0.5 million species of plants have so far been ideniified and described by taxonomists during the last 230 years. This forms only 10% or less than 10% of the world's organisms (Winston, 2000). It may take several thousand years to identify and describe the remaining species if the number of bonafied taxonomists is not increased from the present state. It is believed that several hundreds of species may become extinct before we discover them. In order to know which species are endangered or threatened we must know what they are and what we have to conserve. Herein lies the importance of taxonomy. The greatest threat to taxonomy is that it is considered as an outdated science that doesn't need the best of minds. Another is that taxonomy doesn't need hard work. These criticisms are mainly from workers of other disciplines such as Molecular biology, Developmental biology, Reproductive physiology, Biotechnology etc. However, these criticisms do not stand because of the reasons mentioned above. Taxonomy needs hard field oriented work often in dangerous situations. Only an intelligent scientist can make correct analyses of various taxa and it needs year's expertise to identify a species authentically. It is ironic to note that often the very same persons who criticize taxonomy wants prompt and urgent identification of the specimens they want to work with.

2. Importance of Taxonomy in Research and Studies

Before starting any kind of studies, one needs to know the correct scientific name of the organisms on which one is going to study. This is important because the correct scientific name of the organism is a functional label using which various pieces of information concerning that organism, including all the past work done on it, can be retrieved and stored ensuring easy reference (Narendran, 2000). To give an example how a research effort could land in trouble if the organisms involved are not identified by bonafide taxonomists, an interesting real but sad story which happened in a South Indian University is sighted. A professor (a non-taxonomist) gave a research problem on the reproductive physiology of two species (?) of crabs to two different students (one student had to work with one species and the other on another species). Both these students worked on their respective species of crabs for two years and then the guide (research supervisor) got these specimens identified by a specialist who found that the two 'species' of crabs represented one species as the differences involved were only variations. This had resulted in utter confusion and finally one student had to change the topic of his research after wasting two years. This clearly shows how important it is to get one's specimens identified by a bonafied taxonomist before one starts working on it.

3. Importance of Taxonomy to Medicine

Taxonomic identification of the organism, which causes or transmits disease, is absolutely essential for effective treatment. A few years ago a patient was sent to the author by a doctor of a medical college with a request to let him know what insect causes the blisters on his body. Though the doctor's treatment was effective in healing the blisters, they occurred time and again. On seeing the blisters, the author could easily identify that the blister beetles caused the blisters and the patient was instructed to remove or destroy the beetles, which were coming to his bedroom at night, being attracted to light. When the beetles were prevented, removed or destroyed, the blisters never reappeared. In a different instance, another doctor sent a small girl to this author for identifying an insect that caused skin eruptions and itching. She was advised not to play with her pet dog since the problem was caused by the bite of the dog flea *Ctenocephalides canis.*

The work of Nathen Charles Rothschild the renowned taxonomist on flea species in collaboration with L. Fabian Hist, a health officer in Sri Lanka resulted in the discovery that the prevalent rat-fleas of India and other regions of the Orient did not constitute a single species and the geographic distribution of different species of rat-fleas in India was one of the most important factor governing the spread of plague. Taxonomists contributed greatly to the successful control of malaria in Europe by providing correct identification of anopheline species of mosquitoes connected with disease causing parasites (Narendran, 2000).

There are several species and infraspecific categories of plants that are used in Ayurvedic medicine. The traditional practitioners used some crude or native methods (a kind of taxonomy?) to identify each variety of plants. Scientific taxonomic identification of these plants has contributed greatly in recent times to the preparation of Ayurvedic medicine in much more effective ways.

4. Importance of Taxonomy to Agriculture and Pest management

Taxonomy plays a major role in the management of crop pests by biological means. The correct identification of both the pest and its natural enemies is of utmost importance when the natural enemies are imported or transferred from one region to another in order to bring about biological control of the pests. Taxonomists through their research and assistance can help biological control workers by :

1. Providing correct identification of pest species and information on its probable home.

2. Directing and conducting surveys for natural enemies existing in the original home of the pest.
3. Making an inventory of natural enemies and alternate hosts of the natural enemies in the country of introduction.
4. Providing catalogues, revisions, handbooks, host-parasite lists, identification keys etc.
5. Help the biological control workers to find pertinent information hidden under obsolete species name and
6. Help to differentiate between introduced and indigenous natural enemies in order to properly document the effect of biocontrol programmes.

Schauff and LaSalle (1998) described several types of errors biological control workers make if they don't have the help of taxonomists. They may inadvertently import a species of natural enemy that may be already present in the country of introduction. They may spend several days studying the biology of a species that may have already been done under an unpublished or published synonym of the species. The biocontrol workers may spend a lot of money and effort in shipping, curation, breeding, etc. of wrong species of natural enemies such as hyperparasites or natural enemies that don't attack target hosts but are generalists which may attack non-target host etc.

5. Identification of the pest

Correct identification of the target pest is the most important step to be taken before initiating any biological control programme. For this a taxonomist's help is absolutely essential. Once the species is correctly identified, its original home can be ascertained and all available information on its biology, natural enemies, distribution etc can be retrieved and stored.

A wrong identification of the pest can lead (this usually happens when the identification is not made by a bonafide specialist) to unnecessary wastage of time, energy and money in searching and finding the natural enemies of the pest in question. An interesting example showing such a mistake in the beginning of a biological control programme of a serious pest and later success of the biological control of the pest when a taxonomist's help was obtained is known from Kenya (Africa). *Planococcus kenyae* (Le Pelley) (Homoptera : Pseudococcidae) was a serious pest of coffee and various other food crops. It was misidentified as *Planococcus citri* (Russo) and *Planococcus lilacinus* (Cockerell) and one year was spent in futile search for the natural enemies of these pests in four different continents. The deemed natural enemies of these pests were introduced into Kenya but they failed to establish there and the biological control programme ended in failure. Only after the pest was correctly identified by a specialist as a new species (*Planococcus kenyae*) occurring in the nearby countries viz. Uganda and Tanganyika, a search was conducted in these countries and effective natural enemies were imported to Kenya which resulted in the complete control of the pest (Le Pelley, 1943).

6. Identification of natural enemies

As in the case of pests, identification of the natural enemies of the pest is also very important in the biological control of pests. A good example of the initial failure of a biological control programme due to misidentification of an insect parasitoid is given by Rosen and DeBach (1973). *Aonidella aurantii* (Maskell) (Homoptera : Diaspididae) was a serious pest of Citrus in California, U.S.A. Various species of Aphelinids attacking this pest in the Oriental Region was misidentified as *Aphytis chrysomphali* (Mercet) (Hymenoptera : Chalcidoidea: Aphelinidae) which is an efficient parasitoid already present in California. For several years repeated attempts were made to find out the effective endoparasitoids of the pest ignoring the species of *Aphytis* present in the Oriental Region. Finally a taxonomic study revealed that those species of *Aphytis* present in the Orient were not *Aphytis chrysomphali* but two distinct species *viz. Aphytis lingnanensis* Compere and *A. melinus* De Bach which are efficient biological control agents of *Aonidella aurantii*. Later by the use of these efficient parasitoids, successful biological control of the pest could be achieved after fifty years since the pest problem started.

7. Detection of culture contamination

In biological control programmes the taxonomist's help is not restricted to preintroduction period. It is absolutely necessary for detecting contamination of mass culture of natural enemy species in the case of invertebrates like insects. A non-taxonomist may not be able to detect if the culture of a species of natural enemy is contaminated by similar looking species which may be inefficient or even harmful in biological control programmes. Hence continuous monitoring of the culture by a Taxonomist is necessary to avoid contamination of culture. Rosen and DeBach (1973) gave a good example of such a contamination of culture of the efficient natural enemy *Prospaltella perniciosi* Tower (Hymenoptera : Aphelinidae) used against the pest San Jose scale *Quadraspidiotus perniciosus* (Comstock) (Homoptera : Diaspididae) in Europe. Mass cultures of the efficient and imported natural enemy species, *Prospaltella perniciosi* Tower (Hymenoptera : Aphelinidae) were apparently invaded in Germany by an inefficient species, viz. *Prospaltella fasciata* Melenotti and as a result instead of releasing *P. perniciosi, P. fasciata* were released by mistake during 1956-1958 before the true identity of the species was determined.

8. Misidentification of Efficient Natural Enemy

A taxonomist's help is necessary for correcting the misidentification of any efficient natural enemy used in biological control programmes. This is very essential to ascertain their effective use and to assign credit where it is due. Several years ago the author happened to examine the specimens of an efficient *Brachymeria* species used in biological control of *Atteva fabrieciella*, a major pest of *Ailanthus exelsa* in Uttaranchal state. This was misidentified as *Brachymeria nephantidis* Gahan a parasitoid attacking the Black Headed Caterpillar Pest of Coconut *Opisina arenosella* Walker in Peninsular India. On studying the specimens of this species at the Forest Research Institute, Dehra Dun, the author could find that this species of *Brachymeria* was not *B. nephantidis* but as a new species, *B. atteviae* Joseph, Narendran and Joy (Narendran, 1989).

9. Importance of taxonomic collections in Pest Management

Taxonomic collections have very great significance since they may prove to be of immense value in biological control projects. Pemberton (1941) gave an excellent example to show the value of taxonomic collections in biological control. The Fern Weevil, *Syagrius fulvitarsis* Pascoe (Coleoptera: Curculionidae) became a major pest of Sadleria ferns (an edible vegetable) in Hawaii in 1920 and all efforts to control the pest became futile. Literature failed to reveal the original home of the pest and as a result search for its natural enemies at its original home was not possible. In 1921, while studying an old private insect collection, Pemberton found a single specimen of *Syagrius fulvitarsis* with a label containing the date of collection as 1857 and name of locality in Australia. This provided the clue to search and find out *Ischiogonus syagrii* Fullaway (Hymenoptera: Braconidae) a parasite attacking the larvae of *Syagrius fulvitarsis*. Introduction of this braconid in Hawaii for biological control of the pest resulted in complete success. Thus the preservation of taxonomic collection proved to be very important in the success of a biological control programme. The data written on the label of a single specimen in 1857 in Australia helped directly, in the successful biological control of the pest in Hawaii 65 years later.

10. Importance of taxonomic literature in Pest management

In order to find out various pieces of information such as locality, distribution, hosts, diagnostic features, natural enemies, etc., one has to search the relevant taxonomic literature that may either provide full or in part the necessary information sought for. The taxonomic literature has great use in pest management programmes. There are several examples in the history of biological control projects to show how important the taxonomic literature is in solving pest problems. Blackwelder (1967), gives an interesting account of how taxonomic literature helped in controlling the weed *Opuntia* in Australia. The prickly pears were brought to Australia for use as hedge fences. Soon they spread to alarming numbers and reached the status of a serious weed. The speed at which the weed spread was so enormous that their increase has been called "one of botanical wonders of the world"(Blackwelder, 1967). Within 20 years the cactus spread from 10 million to 50 million acres. Entomologists and botanists searched various taxonomic literatures for all pertinent information such as the various species involved, their distribution, habits and especially their natural enemies. As a result, they found out about 160 different kinds of natural enemies of these prickly pears. Out of the 12 most promising ones introduced to Australia, *viz., Cactoblastis cactorum* (Berg) (Lepidoptera : Phycitidae) described in 1887 from South America proved to be the most successful. Thus an insect discovered and described 65 years ago, became instrumental, half a century later in saving Australia from prickly pears.

11 Importance of Taxonomy in Quarantine

In order to prevent accidental or otherwise introduction of plants and animals to a country from another country, governments have established quarantine laboratories in every nation. These quarantine agencies inspect every plant or animal brought to the respective countries. With the help of taxonomists the quarantine agencies determine whether the imported plant or animal is harmful or not and based on their advise, prevent the entry of harmful plants and animals.

12. Importance of Taxonomy to National Defense

In these days of germ warfare, it is essential to identify the organisms introduced into a country by the enemies. For each soldier it is necessary to have some basic knowledge of taxonomy to recognize the local fauna and flora with which he has to work so that contact with disease spreading animals or plants can be avoided. Making available the valuable contributions by taxonomists over the years can make the identification of dangerous organisms in the war areas easy.

13. Importance of Taxonomy to Fisheries

In order to find out the edible varieties of aquatic organisms, taxonomist's help can be sought for better prospects. Taxonomic knowledge of organisms that form food for fishes can help the fishermen to locate the localities where these organisms are abundant. The distribution of each aquatic organism can be found out from the relevant taxonomic publications or with sharing the unpublished information the specialist can provide.

14. Importance of Taxonomy to Parasitology and Veterinary Science

As in the case of identification of parasites of man, a taxonomist's contribution will be of great help in veterinary science also. A thorough taxonomic revision of these parasitic organisms will be of much use for practitioners of veterinary and as medical sciences. Thus taxonomy, parasitology, veterinary and medical sciences are all interconnected and interdisciplinary and one cannot exist without the other. Herein lies the importance of taxonomy to other branches of science.

15. Importance of Taxonomy in conservation of Plants and Animals

Though opinions differ on the number of estimated species of animals and plants living on earth, the middle of the road assumptions places it at 13.6 million (Cherian, 1996) and of these only 1.75 million species has so far been named and described by taxonomists and this has taken over 250 years. It is estimated that at the present rate it may take about 1000 years to complete the alpha taxonomy of various fauna and flora existing in the world. Besides mass destruction of habitats, especially forests in tropical countries are causing destruction and eventual extinction of large number of species. Even by the most conservative estimate, the rate of loss of species is shocking—the number of species that disappears each year is at least 27000, each day it is 74 and each hour it is 3! (Gadagkar, 1998). It is high time that we reorient our priorities and start to document our faunal diversity before it is gone (Gupta, 1987). There is an implicit principle of human behavior important to conservation: the more we know of an ecosystem, the less the chances of our destroying it (Narendran and Cherian, 2002). As the Senegalese conservationist Baba Dioum has said "In the end we will conserve only what we love, we will love only what we understand, we will understand only what we are taught" Hence let us learn first the alpha taxonomy to know what we have and then decide which one is endangered and which one is to be conserved.

CHAPTER 2

TAXONOMIC IMPEDIMENTS AND PROBLEMS TO OVERCOME

Introduction

The *taxonomic impediment* is a term that describes the gaps in knowledge in our taxonomic system, the shortage of trained taxonomists and curators and the impact of these deficiencies on our ability to manage and use our biological diversity (ABRS, 1998). The fourth meeting on convention of biological diversity held at Darwin, Australia in 1998 stated that the various countries, which participated in the meeting, affirmed the existence of a taxonomic impediment for the proper management and conservation of world's biodiversity. Removal of this impediment is absolutely essential not only for discovering and understanding the world's biological diversity but also for global efforts to conserve our biodiversity. The Global Taxonomy Initiative (GTI) promotes necessary steps to remove taxonomic impediments. The various impediments and problems are briefly dealt with below.

Impediments for building up taxonomic collections and its maintenance

Taxonomic collections have been developed through hard field oriented efforts by professional and amateur taxonomists. These collections are seats of permanent information storage and unique scientific records of biological diversity of organisms. These collections serve as a ready reference for systematic research and accurate identification of organisms. The collections of specimens represent a record of genetic and morphological diversity, geographical distribution and other biological information. In several instances, these collections represent many species, which have become extinct and thus remain as the only record of these extinct species. These collections provide fundamental information for various aspects of human enterprise, including agriculture, health, pollution control and conservation. They form the basis for taxonomic studies such as description of new species, revisions, dichotomous keys, preparation of checklists, maps and monographs. The information housed in taxonomic collections all over the world should be made available to the countries of the origin of the specimens. Unfortunately there are several taxonomic impediments for building up taxonomic collections in various institutes and museums. Till the recent past, taxonomic collections were considered a non-functional storage of dead specimens of taxonomist's hobby, like stamp collection, by physiologists, molecular biologists, biotechnologists and others. One late professor of invertebrate animal reproductive physiology told this author "all taxonomic collections should be immersed in Arabian Sea" Another molecular biologist proclaimed that taxonomic studies (except molecular taxonomy) would be extinct in the near future. Such ignorant 'intelligentia' fail to appreciate the importance of the preservation of taxonomic collections. In addition, at times some individuals representing conservation enforcement agencies in their over-enthusiasm for conservation, place impediments in building up collections of organisms by genuine researchers of taxonomy (Narendran and Cherian, 2002). At times, even otherwise knowledgeable persons, who are supposed to know that taxonomic studies are essential, subscribe to the misconception that collecting species of fauna and flora for systematic studies will cause them extinction! There are millions of nanofauna, which can be seen only under the microscope and these have to be collected and studied in the laboratory. As for determining ecotypes, biotypes, sibling species, ecological races, etc. collecting samples from different localities is a prerequisite for indebth taxonomic studies (Narendran and Cherian, 2002). Too much stringent restrictions preventing collection and movement of specimens and type materials can have damaging implications on taxonomic research. The main principle should be that bonafide taxonomists must be permitted to collect and freely exchange specimens for taxonomic research. Every step should be taken to ensure that national and international legislation does not impede these activities of the taxonomists. All those who understand the basic truth that taxonomy is the foundation for all meaningful research in biology must be committed to the protection of taxonomic research from undue legislations.

Shortage of manpower

At no time has there been a greater need for taxonomists than now, when the crisis facing biodiversity is escalating. Decision 11/8 of the Second Meeting of the Conference of the Parties to the Convention on Biological Diversity, identified the lack of taxonomists as a significant impediment to the implementation of the convention at the national level. The task facing taxonomists is so great that it may require approximately 5000 taxonomists to complete merely the taxonomic listing of 5 million species in 25-30 years if one taxonomist can deal with 1000 species. Today when the need for a taxonomic stock taking of earth's biodiversity is becoming increasingly urgent, the number of bonafide taxonomist is declining. In this connection, it is worth quoting Gahan (1923) who stated in the contest of writing on the taxonomy of world insects "the tremendous worldwide interest in economic entomology has resulted in the swelling of the number of economic workers to a veritable army, while the number of systematists has apparently not kept pace" This statement is still very much relevant today in the context of fauna and flora of the world where the number of taxonomists has not increased much even after 78 years and these few are confronted with several millions of species whereas the non-taxonomist researchers have disproportionately increased several fold. So there is no wonder if large percentage of determinations is left with only generic names and many species names end up with a question mark. The number of taxonomists and the resources at their disposal are certainly inadequate for the magnitude of the task before them. Most of the world's taxonomists are based in North America and Europe. In developing countries, specialist taxonomists are very few and among these most are not suitably trained in taxonomic theory and practice. This is a critical problem that needs to be addressed on a worldwide basis. Taxonomists are mostly employed in museums, herbaria, universities and some government departments. Thus in most countries employment of taxonomists is heavily dependent on government funding that supports such institutions. Enough employment opportunities are to be created in every country for taxonomists. Though a country cannot afford to employ a large number of taxonomists all of a sudden yet at least an attempt has to be made in this direction.

Lack of funding for taxonomic research

Finding financial support is one of the most important problems in the field of taxonomic research. Funding agencies and universities should earmark enough funds for taxonomic research. Students can be given scholarships and fellowships for taking up research in taxonomy. Sufficient financial support should be given to universities to promote the development of taxonomic specialist cadres (Ananthakrishnan, 2000). In addition to these enough funds should be set apart for taxonomists to visit international centres for research. However, despite these suggestions, the present state of the world economy and the general attitude of the governments to cut public expenditure make it doubtful whether there will be enough and adequate funding for taxonomic work. In such a situation, it is worth securing funding from the private, commercial and non-governmental sectors. In this connection, it is worth quoting Bennet (1994) who stated "Can intellectual property and farmer's rights be used to raise funds, or will they obfuscate cooperation? Can income from the benefits of biotechnology be used to finance collections, research and taxonomy? To what extent can we reduce costs and increase efficiency in the use of existing resources? Or must we accept the discipline of poverty and reality and establish fewer priorities in areas where success and economic rewards are more likely or where diversity is most threatened? The way forward will inevitably involve a combination of new funding, greater efficiency, clearer priorities and difficult decisions"

Lack of training in taxonomy

Short as well as long term courses should be offered to students and working entomologists for undertaking taxonomic research. For instance, undergraduate and postgraduate students can be given different levels of projects on taxonomy under the guidance of teachers who have competence in taxonomy. Apart from this, short duration (1-3 months) courses on taxonomy can be conducted regularly for the benefit of working entomologists to start faunistic studies. Taxonomy should be introduced as a compulsory core subject in the syllabi and curriculum of graduate and postgraduate students of life sciences. Besides, taxonomy can also be offered as a special subject at master's level as suggested by the University Grants Commission of India (1990).

Lack of library facilities

For studying taxonomy of any group of animals or plants, all relevant literature, both old and new has to be procured. Even papers, however lousy they may be, published 100 years ago is also important in taxonomic research. Nothing is outdated in taxonomy. Unfortunately, libraries of most third world countries, where rich and diverse fauna and flora await discovery, lack adequate library facilities. Taxonomic descriptions of tropical organisms published by western scientists in western journals are often not available to scientists of these countries. The back volumes of many journals such as zoological records, etc. are not available in most libraries of these developing and under developed countries. This situation must change for the progress of taxonomic research in these countries. Steps may be taken to allocate enough funds for the national libraries to procure old research papers so as to reprint and republish them. Since most of these papers are more than 100 years old, there may not be any copyright restrictions.

Impediments in publishing taxonomic work

Publishing taxonomic work is a very important necessity for knowing the biodiversity. Each new taxon found out needs nomenclature validity and for this, taxonomic description should be published. Revisions, monographs, catalogues, keys, etc. will be very helpful for other workers of biology or applied biology. Unfortunately, there are several impediments in overcoming this difficulty. At present, there are very few journals in the world and especially in the third world countries for exclusively publishing lengthy taxonomic papers such as monograph, revision or reviews. The few journals available are confronted with large number of backlog or other constraints. Most of the foreign journals make page charges that are not affordable to workers of South and Southeast Asia. Hence in order to publish large revisions as well as catalogues we need more exclusive journals meant only for publishing taxonomic work. Catalogues are very important for any worker to start taxonomic work. Revisions will be extremely useful for assessing the taxonomic status of the fauna or flora involved. Keys will help not only taxonomists but also other scientists to identify the concerned organisms. Hence in order to remove the impediments in catering to the need of taxonomists in publishing their work, steps may be taken in bringing out more research journals with help from government or societies or boards.

International cooperation

For a taxonomic revision of a group, it is better to undertake a study of a large geographical area such as Oriental, Palaearctic, Nearctic, Ethiopian, etc. Such revisions comprising any such large area will be more useful when compared to small regional studies since the fauna and flora of a small region such as a part of a country or state will not be isolated from the nearby regions. Such taxonomic work can be done only with international cooperation. For instance if a taxonomist in India wants to revise Chalcididae of the Oriental Region which comprises South and South East Asia, he has to base his studies not only on the material he collected in India but also on several specimens collected by other foreign workers from different parts of the Oriental Region available on loan. Various International Museums of America and Europe store millions of specimens, which are unidentified up to species or genus level. Such collections representing various geographical regions can be made use for monographic or revision work. For this, International cooperation is absolutely necessary. The author's experience has shown that unlike many major world museums of Europe and North America, the national institutions of his native country are very unhelpful in loaning materials of specific groups requested by bonafide taxonomists .If these national institutes (such as the Indian Agricultural Research Institute, New Delhi, Zoological Survey of India, Calcutta, and Forest Research Institute, Dehradun, etc) can cooperate with the bonafide taxonomists all over the world by loaning materials, it would result in advancement of taxonomic research in the country. Thus both the museum (and institute) and the taxonomist will be benefited. The loaning institute can enrich its identified collections and the taxonomist also stands to gain.

Development of Taxonomic Centers

Though taxonomic research centres already exist in several countries of the world, they are few in number compared to other branches of science. There is an urgent need today to develop more such centres, especially in the tropics where rich diversity of fauna and flora exist. The existing facilities are extremely inadequate to cater to the needs of identification of millions of organisms yet to be discovered. Development of various taxonomic centres and coordination between the various experts are necessities, which cannot be delayed any further if we want to save our biological diversity. Unless there is a global initiative for removing these taxonomic impediments, we cannot achieve anything substantially in this direction. In this context, it is worth noting that the developing countries can be assisted by developed countries by giving grants to develop infrastructure facilities and expertise in taxonomic research. The United states department of Agriculture, Washington, D. C. has rendered tremendous help to various third world countries for taxonomic research by giving financial grants under public law 480 (P. L. 480) in the recent past. Such supports can go a long way in the development of taxonomic research in the third world countries.

Need for efficient international networking

In 1974, The Entomological Society of America proposed a "National Plan" for disseminating information on systematics and for improving efficiency in the management of resources for systematics through more effective communication among taxonomists and between taxonomists and user community (Miller, 1994). However, the plan was evolving without realistically assessing its feasibility (Kim, 1989). UNDP/FAO developed technical cooperation networks (TCNs) to promote institutional collaboration between countries. BIONET-INTERNATIONAL is a global network for biosystematics of arthropods, nematodes and microorganisms. It offers great hope to developing countries as a solution to their need to establish sustainable self-reliance in biosystematics. Apart from other uses, Bionet-International offers assistance in the training of taxonomists, rehabilitation of existing collections and records to save valuable references for research and to facilitate identification services. Bionet-international helps in the development and use of computer-aided and automated taxonomic tools (especially in the identification of organisms) to speed up training and to make taxonomy widely available and more easily useable by non-specialists.

Emerging technologies in database management and expert systems along with the use of Internet have great scope for systematic research and information services. Thompson *et al.* (1993) has already promoted biological diversity information bases combining relational databases, expert systems and image processing. Miller (1994) suggested involving an interactive system that reflects the continuing experience of systematists and users made available through Internet. For those with full Internet access, CD-ROM or electronic file transfer distribution could be used.

Taxasphere and inventorying

Article 7(a) of the Conservation of Biological Diversity (CBD) states that the countries, which signed the biodiversity document, have to undertake an inventory of their biological diversity in order to provide fundamental information on the distribution and abundance of biodiversity. Such data are necessary for the long-term sustainable management, use and conservation of biodiverse areas (Gauld, 1999; Stork & Samways, 1995). For biodiversity harvesting and bioprospecting, inventory has a major role to play. To know what is present in a conserved area is a primary necessity to evaluate the status and importance of the conserved biota, particularly when screening for natural chemical activities (Reid *et. al.*, 1993; Gauld 1999). For biodiversity prospecting it is absolutely essential to identify the involved organisms at species or subspecies level, for extracting identical samples, for a specific chemical activity. Similarly it is essential to have a thorough knowledge of species present in an ecosystem for future high technological uses of biodiversity (Gauld, 1999; Janzen, 1993; Vane Wright, 1996). Those nations, which have the taxonomic capacity for identifying their own biota, will be certainly in an advantageous position in collaborating with pharmaceutical prospecting and with similar non-damaging harvesting activities.

Inventorying the world biota involves both Extensive and Intensive inventories. The former deals with easily recognizable organisms such as mammals, birds, trees, butterflies, etc. and the latter mainly concentrates on identifying even the small organisms such as diatoms, lichens, fungi, etc. There are too few taxonomists in the world to undertake the inventory of world biodiversity. It is practically impossible for the taxonomists to cope with the task of such a magnitude, within a realistic time schedule. It is not easy to alter this situation. In such a situation, the taxonomists already available must focus attention on groups that are more important than on others. It is not that some groups have more importance than others but certain groups have greater importance in maintaining diversity of other organisms (LaSalle & Gauld, 1993). However, this point of view may pose some serious problems since one should have a thorough knowledge of the biology of organisms in order to make a selection. Gauld (1999) suggests that groups selected must be representative of the spectrum of taxic variation in an area. It should be representative of microhabitats in an area and it should represent the tropic diversity of an area. Besides other factors such as user community demands, economic importance, special social needs, etc. are also to be taken into account while selecting a group or groups and this should be balanced against what expertise is available.

The main taxonomic impediment in biodiversity inventorying of the world biota is the cost involved. According to a recent estimate, 75 billion U. S. dollars are necessary to discover, describe and classify the world's 10-30 million species. The question is whether we should spend this amount to inventory and describe our biodiversity or let most of them vanish before we know them? It needs serious thinking to arrive at firm conclusions and reorienting our priorities.

The Desired End Product

There are many requirements for removing the taxonomic impediments in taxonomic research. They can be summarized as follows :

1. Taxonomic collections should be developed in all countries and they should be properly maintained by qualified taxonomists.
2. Sufficient employment opportunities for taxonomists should be established on a worldwide basis.
3. Enough financial assistance should be provided for taxonomic research.
4. Training courses for taxonomic research should be established.
5. Taxonomy should be included as a compulsory subject in the curriculum and syllabi at the graduate and postgraduate levels.
6. National and International libraries should store taxonomic back volumes as well as

recent literature of all groups or at least of those groups of fauna or flora where taxonomic research is planned to take place or is already in progress.

7. National and International centres for taxonomic research and identification should be developed and repositories for storing the collection, especially types should be established

8. Fellowships and other financial grants should be given to taxonomists to visit international museums for examination of types, etc

9. Enough funds should be given to taxonomists or to journals for meeting the cost of publishing taxonomic monographs and revisions and

10. Finally, all efforts for creating awareness on the importance of taxonomy among students and public should be taken so that the impediments for development of sound taxonomy can be removed gradually without prolonged difficulties.

It seems that only by taking these urgent steps will one begin to develop the field of taxonomy into something more than a neglected discipline of science, which so often leaves the present problems unsolved and the work on the future almost untouchable. Even by the most conservative estimate, the rate of loss of biological diversity is shocking—number of species doomed each year is at least 27,000. Each day it is 74 and each hour it is 3! (Gadagkar, 1998; Wilson, 1992). Gadagkar (1998) states "What then should intelligent human beings do? How should educated, enlightened citizens of the world respond? What should young students aspiring for a career in biology do? Should we do nothing (which is usually the easiest thing to do) and let most of the 10-30 million species disappear once and for all from the face of the earth and carry with them unknown chemical treasures and life saving drugs, produced by millions of years of biological evolution? Or should we continue to catalogue and describe and save as many species as possible, at the present pace...?"

It is high time that we set our priorities straight and attempt for a global initiative for development of taxonomic research. Unless we do this now, we may not even know how many species have become extinct before we find them out. More and more students should take up taxonomy as their carrier and enough opportunities and job prospects should be made available to such students by the governments.

CHAPTER 3

TAXONOMIC COLLECTIONS AND COLLECTING

The most important tool for taxonomic studies is the collection of materials for study. For any kind of taxonomic studies, specimens collected form the fundamental basis for work. In order to start a taxonomic study of any group, a taxonomist should first of all collect the concerned specimens from as diverse localities as possible. If specimens are not collected from diverse localities, morphological or other variations will pose problems, which may lead to improper assessment of taxa. Seasonal variation, variation in the developmental stages, host-parasite relations, etc should all be taken into account while collecting specimens for studies. The larger the collections a taxonomist makes, the lesser will be the difficulties he may face in analyzing and weighing the characters. More specimens are needed for identifying a species or subspecies that shows individual and geographical variations. Apart from collecting, a taxonomist can also enlarge his collections by getting specimens which are already collected by other professional or amateur taxonomists and preserved in various museums and institutes. Most of the International museums will co-operate with a bonafide taxonomist by sending their collections (both determined and indetermined) on loan for studies. By such co-operation, the taxonomist and the loaning institute are benefited. The loaning institute can enrich its identified collections and the researchers also stand to gain (Narendran2001). Thus both specimens collected by the taxonomist and borrowed from museums should form the basis for study. Though borrowed specimens at times may be insufficient in knowing the variations, host data, etc., yet it will help the taxonomist a great deal in his revision since it may require many years of effort for a single worker to have the broad geographic range represented in a museum collection which might have been accumulated through several years or even centuries. These museum collections may contain specimens collected from areas inaccessible owing to their remoteness or for political reasons. While some taxonomists depend mostly on loaned material for their studies, others are satisfied only with the specimens they collect. Both loaned and self-collected material should form the basis for a good taxonomic revision.

Methods of Collection

Methods of collection differ from group to group. Innumerable methods are described in different taxonomic monographs and manuals. New methods are always emerging for every group of organisms. Depending on the group, one has to follow the relevant books for studying the various techniques. Specialists use different types of traps and equipments for collecting their groups. Some of the following books or papers may be useful for studying the collecting techniques. British Museum (1936) on various groups, Borror and Delong (1955). on insects, Narendran (2001) on insects, Knudsen (1966) on plants and animals, Williams, Laubach and Laubach (1979) on mammals, Van Tyne (1952) on birds, Kirby (1950) on protozoans, Kunmmel and Raup (1965) on fossils, Steyskal, Murphy and Hoover (1987) on insects and mites, Noyes (1982) on insects and Singh (1999) on plants.

A taxonomist while collecting specimens of his special group can also collect specimens of related groups without much difficulty. Specimens of other groups can be given to specialists who are interested in their taxonomy either as loan or on mutual exchange so that both specialists are benefited.

Because of large-scale destruction of natural habitats taxonomists should try to survey areas that are likely to be disturbed and destroyed, so that fauna or flora can be collected and documented before they become extinct. Hence collecting from habitats, which are likely to be disturbed, must also receive emphasis. While collecting, every effort should be made to collect unbiased population samples (Mayr and Ashlock, 1991). Aberrant forms alone cannot form the basis for taxonomic studies. The taxonomic description should include individuals showing sexual dimorphism.

Labelling

While collecting specimens information on exact locality, altitude, latitude and longitude of that particular locality, status of habitat whether disturbed or undisturbed, type of vegetation in the case of animals, type of hosts in the case of parasites, etc., should be recorded as far as possible in labels of specimens. Temporary labels can be written in the field itself and these can be replaced leisurely by permanent labels in the laboratory. However care must be taken while changing labels since it is likely to cause errors. The exact name of the locality is very important for each specimen. The recording of a locality can be made in the following way in the case of animals : If the locality is "Muthanga" an area of Wayanad wild life sanctuary in Kerala, the collector is T.C. Narendran and the date of collection is 2nd June 2002, it can be written as follows :

INDIA : Kerala,
Wayanad : Muthanga
Coll. T.C. Narendran
2.vi.2002.

It is desirable to write the name of the country in capitals and all others in normal letters. While writing the date many taxonomists write the month in lower case roman letters and the day and year in Arabic letters. Though this style is not compulsory, many taxonomists usually follow it for easy usage and convenience. The second label can have the host data, latitude, longitude etc. The third label or fourth label can be the determination label. A number should be given to each specimen as it has been found to be of great use to know the details about the specimen from the register when other labels are destroyed or become illegible. A reviser can add his label without changing the original label if he wants to change the original name of the taxon, although some taxonomists believe that it is inappropriate to do so in the case of Type specimens. Though there is no hard and fast rule for such an arrangement and much depends on one's convenience, most of the taxonomists (especially taxonomic entomologists) follow this style, which I find can be applied to all forms of animals. The data in addition to locality that are needed depends upon the given group. Some taxonomists do not take pains to record additional data, which may prove to be of great value later. Hence effort should be made by all taxonomists to find extra time to record additional data. While recording the exact locality for a specimen, if that locality is not well known, its position relative to a well-known place should be added to the label. For instance, if the specimen is collected from Kohinoor, a small locality near Calicut University campus, it can be written as follows :

INDIA : Kerala
Kohinoor
near Calicut Univ. Campus

In the case of herbarium labels, the label is usually pasted on the lower right corner of the herbarium sheet. The size of a label varies from 5x10 cms or 10x15 cms. The information recorded in herbarium label usually is as follows : Name of institution, scientific name, common or vernacular name, family, locality, date of collection, collection number, name of collector, habit and habitat including field notes.

Preservation and Curation of Collections

It is the primary duty of all taxonomists to preserve and curate the specimens he studies. For repositories and museums, usually curators will be present to look after collections. Preservation of specimens is gaining more and more importance since they serve as a kind of ex-situ conservation. Since more and more species are becoming extinct, these preserved collections will serve as relics to study the species that once-existed. The methods of preservation and curation of collections differ from group to group. Some of the references worthy of reading for studying these methods are: Tikader, 1986 (on animals), Borror and Delong, 1955 (on insects), Singh, 1999 (on plants), Knudsen, 1966 (on plants and animals), Dowler and Genoways, 1976 (on animals), Mayers, 1956a and 1956b (on animals), Braddburry, 1984 (on micro-organisms), Corliss, 1963 (protozoa), etc.

Cataloguing Collections

Depending on the group of organisms, cataloguing of specimens differ. In higher vertebrates, an individual number will be given to each specimen and the relevant information will be given in a card, which will be filled in a card catalogue. Cataloguing is usually done on the basis of geographical area of the specimen/specimens. This is done after authentically identifying the specimen/specimens at the species level or genus level. In groups where large numbers of specimens are present, it is not very practicable to catalogue each specimen. In the case of insects and similar groups each number will be allotted to each set of collections consisting of a set of specimens from a given locality or area. These lot numbers will reflect the notes of the museum or collector containing the detailed information on the locality, etc. Specimens stored in liquid medium are also usually catalogued by lots. However, in the case of type specimens, each type (especially holotype, lectotype, etc.) will be catalogued by all international museum and repositories. Each type number will refer to the notes giving details as to who designated the type, its date of collection, etc. In the case of Herbarium, an index register will be present in which all the genera of the herbarium are listed alphabetically and against each genus, a family number and a genus number will be given.

The collections are usually arranged according to the latest accepted classification. The unidentified collections are usually kept separately. A well arranged museum collection would serve the purpose of a catalogue in itself. Since it takes considerable time for the preparation and maintenance of collection catalogues, it is not desirable to attend to this work to that extent when it interferes with the research on collections. However it is necessary to keep at least temporarily a list of the accessions until a full catalogue is prepared when time permits.

Kinds of Collections

There are several kinds of museum collections. They can be dealt with individually as follows :

1. Survey collections

This is usually based on surveys of a particular group or a geographical area. For studying biodiversity of a large group of a large area, it is usually necessary to devote more time (months or years) for making a satisfactory collection of the specimens. For instance, for studying the biodiversity of insects of Silent Valley National Park, it is necessary to collect almost all orders of insects which are present in the area and it will take years to identify each specimen up to species level. Herein lies the greatest difficulty, generally the biodiversity worker will be having a list of specialists working in each group and they will be contacted for specific identification "Since the success of any survey depends on accurate and fairly prompt identification, this is the most important part of the work" (Mayr *et.al* 1953).

2. Collections for general exhibition

Several museums exhibit various types of animals and plants for the general public. Each item is identified (sometimes classified broadly) and labeled with both scientific and vernacular names. Usually these exhibits may contain only morphologically peculiar or rare, large specimens. Microscopic forms are not usually included in general exhibits for public.

3. Collections for teaching students

Most colleges and universities may maintain identified collections for teaching graduate and postgraduate students. Usually there will be only limited representation of each family in such collections. Most universities and colleges in the underdeveloped or developing countries do not have trained curators for looking after these collections and thus most of these collections are eventually destroyed because of lack of proper care. The replenishment of specimens comes from the collections made by the students every year as part of their curriculum work.

4. Identified collections

In quarantine stations, the officials often come across emigrant or accidentally introduced organisms (mostly invertebrates like insects or plant materials). To find out the identity of the intercepted organism, consultation with the specialist is often called for. If there is an authentically identified collection in the quarantine station, it will be easy for the officials to identify the introduced organism in most cases without the help of specialists. Although such collections may not be having full representation of all relevant species, still they may be of help for the identification of common species which are intercepted repeatedly. Such reference collections can be developed over a period of time by getting the intercepted materials identified by specialists and returned to the quarantine stations. With such a good reference collection, the quarantine officials can identify the intercepted specimens by experience and this will save a lot of time and inconvenience in getting the specimens identified by specialists.

In order to identify pest organisms also, identified collections will be of great value for other institutions where pest problems are dealt with. Such centres are very few in developing and underdeveloped countries.

5. Research collections

Research collections form the most important category of collections as they serve as the focal points for taxonomic research. Most museums accumulate large collections by sending their taxonomists for collection expeditions and surveys. These collections are of great value not only to the museum taxonomist but also for other taxonomists of other institutions since the latter can get these collections on loan. Apart from the museum taxonomists, other amateur collectors and volunteer workers also augment the research collections. These research collections should be preserved with great care. The research collections may be located in the private custody of a taxonomist, in a private institution, in a university museum or in any other public institution. It is the duty of the taxonomist to hand over his private collection to a bonafide museum or institute on or before the time of his retirement from active research.

6. Type collections

A new species is described based on a type specimen or specimens. The types should be curated with utmost care. Whenever a doubt arise regarding the identity of a species or genus, examination of the type is necessary to confirm its real identity. The holotypes, lectotypes, neotypes and syntypes should be preserved with utmost care since these types are irreplaceable. It is not desirable to include other types such as paratypes, plesiotypes, etc. in this category. The primary types have to be deposited in recognized international or national repositories. The types should be numbered individually and they should be kept as a separate collection in order to get special attention as well as to facilitate rapid transfer to safer places in case of emergency. During the Second World War when the German Air force bombed Europe, many repositories transferred their types to underground cellars and thus saved them from the bombing attacks. Some of the compound walls of some of these museums still show the marks left by these bombings. Every taxonomist should make it clear through publication the name and address of the repository where he has deposited his types. Many scientists believe that the type is the property of science and no worker has the right to retain a type in his private collection after the completion of his studies on it. In most repositories, the types are catalogued alphabetically according to the genus or species in the case of invertebrates such as insects. A card index by genera and another by species are provided in order to save time in searching for the required type.

7. Damaged collections

It is not uncommon to see improperly preserved or damaged specimens along with good specimens in many collections of museums and institutes. Is it desirable to keep them or not is debatable. It is argued that repositories and museums will be better off without damaged specimens. To assess the degree of damage, help of concerned specialist is necessary. The best way to remove the useless specimens will be to request a specialist to remove them when he/she revises the group. However, there is another point of view that there is no harm in keeping a damaged specimen if it is a single specimen of rare taxa since one never knows whether it will prove useful one day when more and more techniques are developed to study such specimens in future.

Exchange of Collections

In order to build up a good collection of different groups, exchanges of specimens between museums and between specialists can be helpful. Exchanges are most desirable in groups where there are innumerable series of specimens available. Exchanges are particularly useful between two different countries since the areas of a foreign country are not readily accessible. Exchanges sometimes become absolutely necessary in order to build up a complete identified collection. Many taxonomists send extra or duplicate specimens to museums and institutes while returning the loaned specimens as a mark of gratitude for the cooperation the museums has extended to the specialist. By cooperating with a good taxonomist by sending collections on loan, museums can benefit not only in getting their specimens identified but also by getting such donated specimens.

CHAPTER 4

IDENTIFICATION

Identification is the utilitarian aspect of taxonomy. Identification up to the species level is a difficult task. There is a difference in the nature of identification by a specialist and the non-specialist. The non-specialist may include those who plan to study taxonomy in order to specialize on a group or others who require the name of a particular species for other kind of studies or work. For instance, an applied entomologist who wants to identify a particular pest or its parasites may use the available general textbooks to sort out at least up to family, superfamily or order level and not go beyond this level even if monographic keys, etc. are available, since it needs knowledge on the taxonomy of the group for determining the specimens up to species level authoritatively .It is better for such non-taxonomists to seek the help of specialists for knowing the species name.

Students who start specializing on the taxonomy of a group should take the following steps :

1 Studying general text books dealing with the principles and practice of taxonomy.

2. Study the available literature on the group he intends to work on.

3. Learn the terms and other relevant data used to describe the taxa of the given group.

4. Accumulate sufficient material (particularly unidentified material) by collecting and through loan from museums.

5. Noting down all relevant literature of the given group (in index cards) from the year 1700 onwards to the present day. Each card should contain the name of the author of the paper, year of publication, full title of the paper, name of the journal (name of publisher if it is a book), volume number and pages, etc. If an abstract of the paper is available, that can be also included on the card.

6. Literature of the past work can be obtained by using various records such as zoological records, botanical records, biological abstracts, entomology abstracts, etc. Besides these, catalogues, compact discs, etc. are extremely useful.

After following these mentioned steps, a beginner (in some cases a specialist also do the same when he starts to revise a new group) can start sorting out his material into different tentative species (without names) giving numbers to each species. For instance, species 1, species 2, etc. or genus 1, genus 2, etc. After the available specimens are sorted out temporarily into various unnamed species, the beginner can run each of his numbered species using available keys. If no workable key is available, the taxonomist can prepare his own tentative key leading to different numbered species. Later, after identifying all the species by the methods described below, this tentative key can be replaced with workable permanent key with correct names of each species.

Identification using Taxonomic Key

A taxonomic key consists of hierarchically arranged diagnostic information that presents alternatives with reference to features of various taxa (a taxon is a taxonomic unit such as species, genus, etc.—Narendran, 2000). The main objective of a taxonomic key is to separate and segregate characters in such a way as to provide a series of alternative choices. By comparing an unidentified specimen, feature by feature with the key couplets, one gradually eliminates all the non-agreeing subgroups and arrives at the one which agrees. For example, let us assume that there is a genus called 'A' which contains 4 species which are A1, A2, A3 and A4. Now to identify a specimen of the genus 'A' at hand one can run the available dichotomous key to species as shown below :

1. Abdomen shorter than thorax 2
 (This means go to couplet no. 2)
= Abdomen longer than thorax 3
2. Head with two strong horns projecting forwards A1
= Head without horns projecting forwards A3
3. Thorax with single spine on dorsal side A2
= Thorax without spine on dorsal side A4

Now let us presume that our specimen has abdomen longer than the thorax and thorax is without a spine on dorsal side. In that case, we look at couplet No. 1, to go to couplet no.3 and find that our specimen belongs to species A4. However, if our species had abdomen longer than thorax and 2 spines on dorsal side of thorax, then it would run to couplet no. 3 but would not fit into description of either species A2 or A4. In such a case, it may be an undescribed or new species and let us name it A5. Now an updated or modified key can be prepared to accommodate this new species A5 as follows :

1 Simple Dichotomous Key

1. Abdomen shorter than thorax 2
= Abdomen longer than thorax 3
2. Head with 2 horns projecting forwards A1
= Head without any horn projecting forwards A3
3. Thorax with spine or spines on dorsal side 4
= Thorax without any spine on dorsal side A4
4. Thorax with one spine on dorsal side A2
= Thorax with two spines on dorsal side A5

The above described keys are known as simple dichotomous keys. There are several modifications of the dichotomous key such as bracket key, serial key, indented key, grouped type key, combination key, branching key, box type key, circular key, pictorial key, etc. The salient features of these keys are as follows :

2. **Bracket Key**

The simple dichotomous key can be slightly modified in such a way that the key can be run both forwards and backwards. This is the best key among all other types. The only disadvantage of this type is that the relationship of the divisions is not clear to the eye like indented key. The above mentioned simple Non-bracket type key can be modified into bracket type as follows :

1. Abdomen shorter than thorax 2
= Abdomen longer than thorax 3

2(1) Head with two horns projecting forward A1
= Head without horns projecting forwards A3

3(1) Thorax with spine or spines on dorsal side 4
= Thorax without any spine on dorsal side A4

4(3) Thorax with single spine A2
= Thorax with two spines A5

3. **Indented Key**

In this type of key, the relationships of the divisions are clear to the eye. The above mentioned key can be modified into indented key as follows :

A. Abdomen shorter than thorax
B. Head without horns A3
BB. Head with two horns A1
AA. Abdomen longer than thorax
B. Thorax with dorsal spine
C. Thorax with single spine A2
CC. Thorax with two spines A5
BB. Thorax without spine
C. Head with yellow bands A4
CC. Head without yellow bands A6

(Here I have added one more species, *viz.* A6, in order to make the key look more balanced)

This type of key is more difficult to prepare and a little confusing for a beginner especially when the key is a very large one comprising more than 50 species. In such case, the alternatives are widely separated and waste space.

4. **Serial Key**

1(4). Abdomen shorter than thorax

2(3). Head with two horns A1

3(2). Head without horns A3

4(1). Abdomen longer than thorax

5(8). Thorax with spine

6(7). Thorax with single spine A2

7(6). Thorax with two spines A5

8(5). Thorax without spine

9(10). Head with yellow band A4

10(9). Head without yellow band A6

This type of key is similar to the indented key in having species arranged according to the number of key characters in common. However this type of key also has the disadvantage of having alternatives widely separated.

5. Branching Key

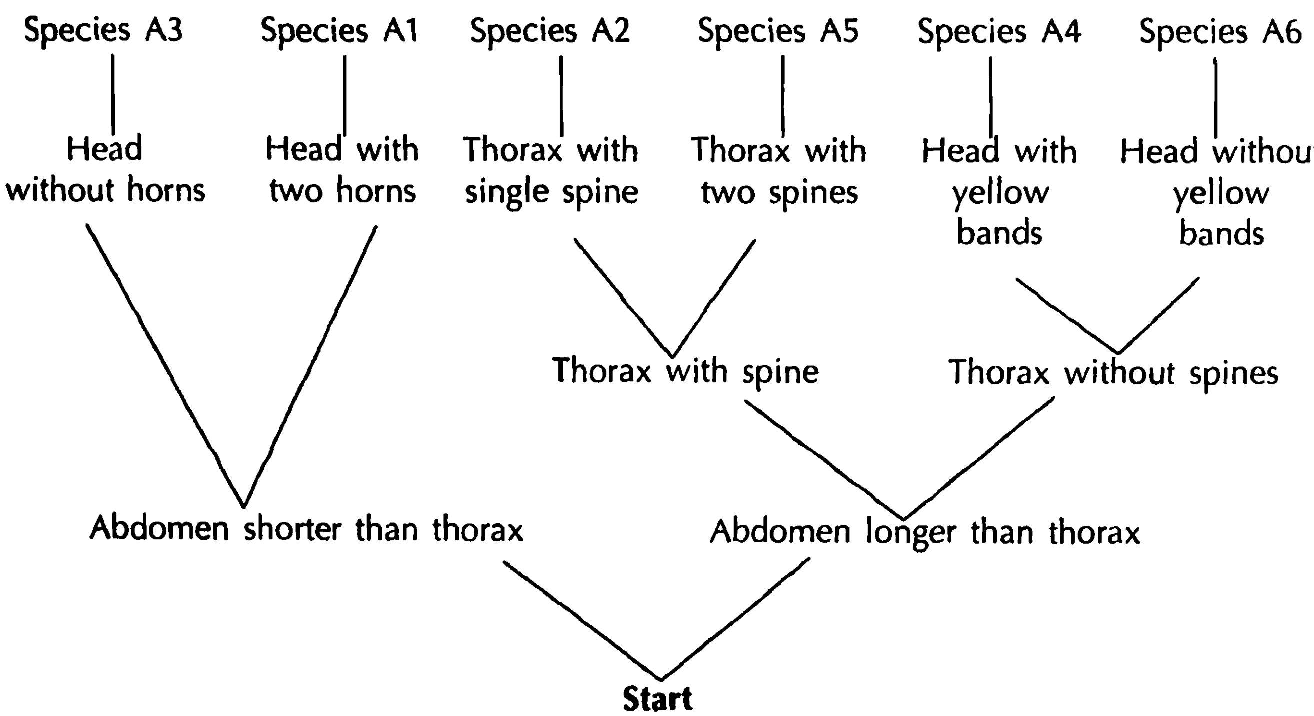


Fig. 1. Branching key

This key is mainly meant for non-specialists and is meant for small groups. The field workers may find this very useful for quick identification of common species.

6. Circular Key

This key (Fig. 2) is mainly for non-specialists and is meant for small groups. The field workers may find this key very useful for quick identification of common species. For this type of key the students may refer Mayr *et al.* (1953).

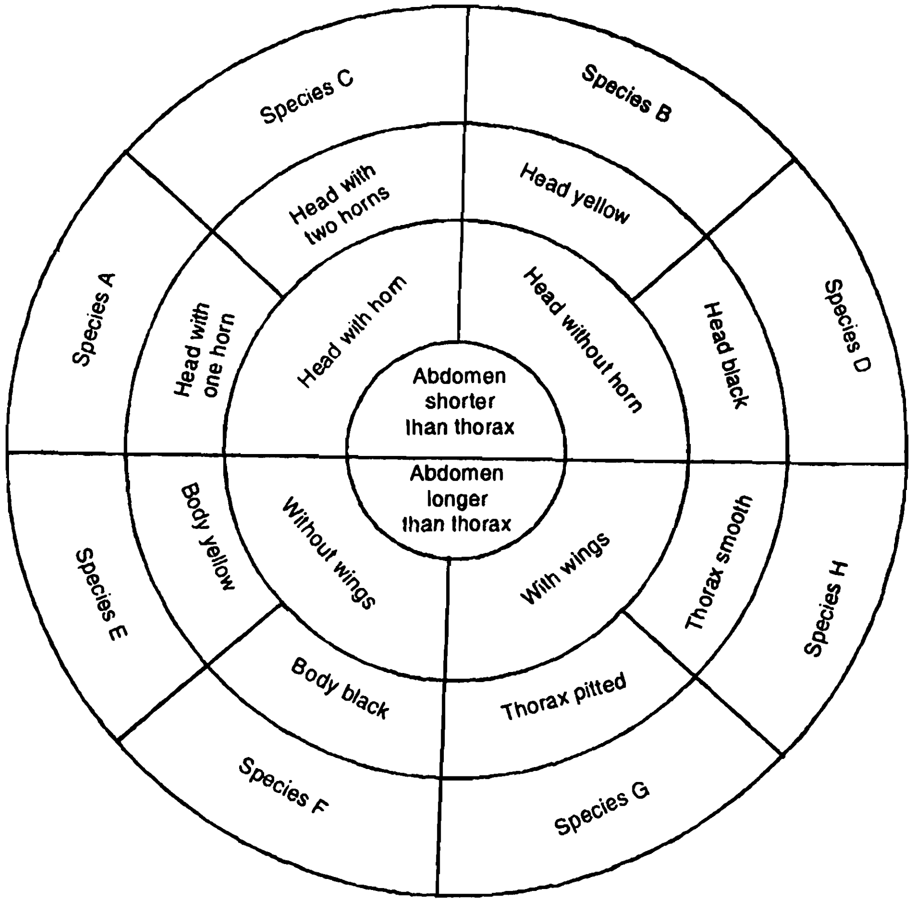


Fig. 2. Circular Key

7. **Box Key**

As in above mentioned keys, this is very useful for field workers.

<table>
<tr><td>SpeciesA3</td><td>SpeciesA1</td><td>SpeciesA2</td><td>SpeciesA5</td><td>SpeciesA4</td><td>Species A6</td></tr>
<tr><td>Head without horns</td><td>Head with two horns</td><td>Thorax with single spine</td><td>Thorax with two spines</td><td>Head with yellow bands</td><td>Head without yellow bands</td></tr>
<tr><td colspan="2" rowspan="2">Abdomen shorter than thorax</td><td colspan="2">Thorax with spine</td><td colspan="2">Thorax without spines</td></tr>
<tr><td colspan="4">Abdomen longer than thorax</td></tr>
</table>

8. **Multi Entry Key**

These keys are used mainly for the identification of plants. This includes window cards, margin punched cards, tabular keys and taxonomic formulae. The window cards consist of a pack of cards, each card representing one character state and the printed numbers of each card represent each taxon. When appropriate holes are punctured on each card, identification process can be started. By closing unselected holes by placing cards one after the other, the user finally reaches where there will be only a single hole representing a taxon. The margin punched card is a modification of the window card. Here the edge of a card is punched and each card represents a taxon. This type of identification procedure is useful only in the case of non-taxonomists for the identification of a few common taxa. In tabular keys, a list of characters and taxa are provided. By cross checking with each character in the tabular key the identification can be proceeded. Hedge and Lamond (1972) published a multi entry key to Turkish genera of Apiaceae in the Flora of Turkey. In this, the authors gave taxonomic formulae which contain alphabetical formula band on specific combination of alphabets. In this method, various characters are represented by alphabets. Each taxon thus gets a unique alphabetic formula usually arranged in alphabetic order (as in a dictionary). Based on the characters of the undetermined plant, its taxonomic formula is constructed. The identification can be made by locating the formula of the unknown plant in the alphabetic list.

0	0	0	0	5	6	0	0	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50

Fig. 3. Window Card

A window card for a particular habit of some genera of a family of plants.

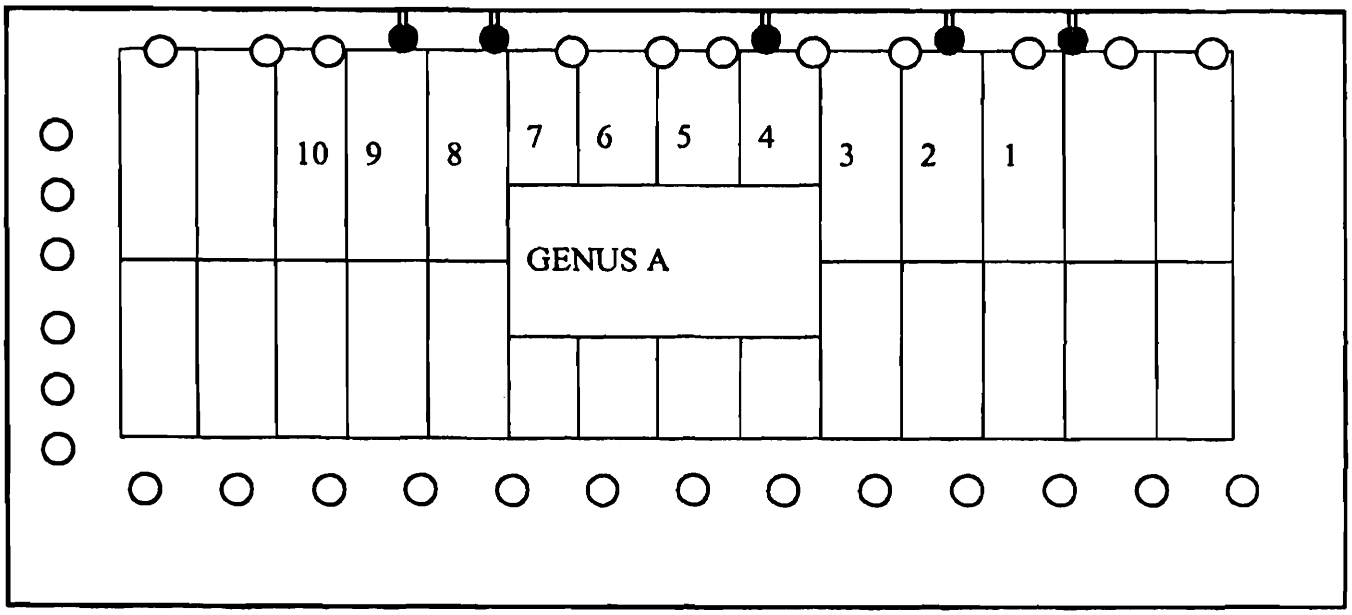


Fig. 4. Margin Punch Card

Margin punched card for a genus A. only the attribute (1 to 10) represented in the examples is pictured. Many more attributes can be added along with the vacant holes to make the identification process more workable and easy.

9. Computer Key

In recent years, computer technology has been used for constructing dichotomous or other type of taxonomic keys and running such computer keys is far easier than running the non-computer keys. For constructing computer keys, other pieces of information, figures and photographs can be fed in the computer and by using appropriate programmes which can be designated. It is easier and less time consuming to compare the characters of the unknown taxa with the characters of the known taxa using the computer. For this, the scanners of the computer can observe and record the characters of the indetermined taxa and compare these with those of the already known taxa and provide enough details for making conclusions. Apart from this, DELTA (Description language for taxonomy) is a useful system of programmes for recording taxonomic descriptions for processing by computer. The delta programme key generates conventional identification keys.

The main purpose of the key is to aid in identification. A good taxonomic key will have the following features :

1 It must be workable. Many keys do not have firm alternatives for instance:

Body reddish brown......................1

Body light brown..........................2.

This is confusing since the given specimen may sometime look intermediate between both characters and the given specimen may fit in both couplets. Keys which contain such confusing characters make it not workable and may result in wrong identification.

2. It should be illustrated as far as possible. A good key will refer to figures for each character so that it will be easy for identification.
3. Each couplet must contain reasonable number of alternate characters. It must not be too lengthy or too short.
4. It should contain characters which can be seen clearly without dissecting the specimen. Some taxonomists use hidden or internal features which one cannot see without dissecting the specimens. It becomes impossible if there is only a single type (viz, a holotype or a lectotype) since types are not supposed to be dissected (except very rarely in special cases by skilled specialists)
5. The key should be workable in reverse direction also.
6. It should not contain couplets which are overlapping. For instance :

Length of the body .... 10-20 mm

Length of the body.................. 18-25 mm

This will be confusing when one gets a specimen measuring a length of 10–20 mm.

7. For identification of sexually dimorphic organisms, characters should be included in such a way that both types of dimorphic specimens can be identified. In the case of trees and dioecius plants it is better to have two types of keys based on vegetative and reproductive characters and male and female flowers respectively.
8. Vague statements such as body small, body large, etc. will confuse the user and the taxonomists should clearly state the exact range of size.

Comparing the identified specimen with previous description

After using the key, if the specimen is identified as belonging to an already known species, then the next step is to compare the specimen, character by character with the original description (and redescription if available). If the specimen agrees well with the available description of that species, then we can conclude that our specimen at hand is say, A3, etc. However, if the available descriptions of that species are poor or inadequate, we have to proceed to the next step (Narendran, 2000). In the case of taxa for which dependable keys are not available, then also the specimens should be compared with the published description of all the species of the genus or all the genera of the family depending on the taxon for which identification is sought. This comparison of each character with all the descriptions of known species is a time consuming and laborious task and if this could be programmed into a computer the comparison can be done in a matter of seconds.

Comparing the identified specimen with authenticated specimens

If an authentically identified reference collection is available, the identifier should compare his identified specimen with authentically identified specimen of that species for reconfirmation of the identification. It is possible that after identification of a specimen using key and description, there may still be some differences between the identified specimen and the authentically identified specimen of the same species. In such a case, a thorough analysis of the characters of the specimen and the detailed comparison of these characters with the original type specimen of the species is essential for unequivocal identification of the specimen (Narendran, 2000).

Requesting help from specialists

All the methods discussed about are not always easily followed. One often comes across many problems when attempting to identify the specimens. Some of these problems are :

1. The key may not be workable.
2. There may not be a key at all available or published so far.
3. There may not be an authentically identified specimen.
4. The available descriptions are too inadequate for recognition of the taxa.

When one is confronted with these problems, the next step would be to find out who is the bonafide specialist on the taxonomy of the group and seek his help. The problem becomes aggravated when there is no such bonafide specialist (as is often the case with many groups of organisms today). In such cases, the only possible way is to be satisfied with the identification at higher categories such as genus or even family level with temporary determination as *Poderus* sp. A or Phasmidae sp.1, etc.

Identification through Internet

Recently several web sites provide information on various taxonomic groups, giving descriptions, diagnosis, pictures, catalogues etc. Taxocom is an active forum of all animal and plant taxonomists of the world. Any member can seek the help of other specialist members for identification of specimens and for consultations, etc. There are several other forums also such as "Parahym" etc. that can be of much help for the identification of parasitic Hymenoptera, etc.

CHAPTER 5

CLASSIFICATION

History of Classification

The earliest record of animal and plant classification dates back to the vedic period (c.3100 BC–2500 BC) in India. Both plants and animals were recorded in Sanskrit language and for the same reasons information contained in these records hardly reached South and South-east Asia. For convenience in tracing the history of classification, the same can be dealt with under the following heads :

Animal Classification

Since the Vedic period the earliest record of animal classification is that of Charaka (600 BC) and Parastapada (500 BC). It need not be explained that their classification was very broad and very fundamental. The classification of animals outside the Indian subcontinent can be said to have begun with Aristotle during the period 384–322 BC. It was he who used the terms Diptera and Coleoptera in insects and these are still valid today. The Aristotelian concept remained for 2000 years without much change. Since then Brunfels (1530) and Bauhin (1623) made changes in the Aristotelian concepts. Ray (1666-1704) made drastic changes in the classification of Aristotle. Willughby (1635-1672) and Reaumur (1683-1757) classified birds and insects in an advanced way. In the eighteenth century, Buffon (1707-1788) and Linnaeus (1707-1778) made great contributions to the animal classification and Linnaeus is known today as the Father of Taxonomy. He postulated 'downward classification' (described hereunder in this chapter). Linnaeus was born in Sweden and his real name is Carl Linne which was later latinised as Carolus Linnaeus. The binomial nomenclature was propounded by Linnaeus who published his classical work '***Systema Naturae***' in 1758. In the middle of eighteenth century, the Linnaen system of downward classification was replaced by 'upward classification' mainly by Buffon (1749), Lamarck, Darwin, Cuvier and other post-Linnaean zoologists.

Microtaxonomy and Macrotaxonomy are the two terms used often in animal classification. Microtaxonomy is the classification at the species level whereas the Macrotaxonomy is the classification of higher taxa.

Plant classification

As in the animal classification, plant classification also can be said to have started from Vedic period in India. In the post-vedic period, several early workers classified plants in different ways. Theophrastus (370 BC to 285 BC), the Greek disciple of Plato and Aristotle, classified plants into four major groups. He was followed by the Indian scholar Parasara (250 BC to 120 BC) who classified plants into several families (Ganas). Before the eighteenth century, the names of the following scholars such as Secundus (23 AD to 79 AD), Dioscorides (first century AD), Magnus (Ca 1193-1280 AD), Caesalpino (1519-1603), Jung (1587-1657), Bauhin (1560-1624) and Ray (1627-1705) stand prominent in plant classification. Linnaeus (1707-1778), Michael Adanson (1727-1806), Lamarck (1774-1829), Antoine (1686-1758), Bernard (1699-1776), Joseph (1704-1779), Candole (1778-1841), Brown (1773-1858), Bentham (1800-1884), Hooker (1817-1911), Eichler (1839-1887), Engler (1844-1930), Prantl (1849-1893), Bessey (1845-1915), Haillier (1868-1932), Wettstein (1862-1931) and many others made significant contributions to plant taxonomy.

Kinds of Classification

Classification is the grouping of organisms into classes owing to their shared characteristics. It is the arrangement of individuals into groups based on the similarities among them. There are several kinds of biological classifications. The major kinds of classification are the following :

1. **Downward Classification** : Linnaeus and others like Caesalpino and Rivinus, classified a larger group (superordinated) into several lower subordinated groups by dichotomy. For instance, Animals are divided into two viz. one group with blood and the other group without blood. Animals with blood are again divided into those with hairs and those without hairs, etc. This type of logical division depended entirely on the sequence in which the differentiating characters were used and this was entirely artificial. This type of classification is known as 'Downward classification' This method however was not of very practical use in the case of larger Fauna and considerable difficulties are there in classifying these animals. As a result, it was replaced by post-Linnaean taxonomists by another method known as upward classification. In this method, taxa are assembled into groups of similar species (or related species) forming a hierarchy of higher taxa by again grouping similar taxa of the next lower rank (Blackwelder, 1967).

2. **Horizontal and Vertical Classifications** : These classifications are applied mainly to animal groups. When a sequence of species (a lineage) are recognized on a time axis of evolution and classified as a genus, it is termed as 'Vertical classification' When only the end species (not the lineage) and other sequences are grouped together as a genus it is termed as horizontal classification.

3. **Natural Classification** : In this type of classification each group is recognized by having a maximum number of common features or characteristics and conclusions can be made. In contrast to this, if the classification is based on very few common features or illusory discontinuities and acceptable deductions cannot be made, then it is known as artificial classification. Blackwelder (1967) defines 'Natural Classification' as the one in which the groups are recognized by having a maximum number of attributes in common with their limits set by discontinuities in the diversity and capable of yielding the maximum number of correct deductions about correlations of other features.

4. **Cladistic Classification or Phylogenetic Classification** : In the evolution of a taxon, a sequence of kinds can be seen at different periods of time and this sequence of kinds is

called a 'Lineage' If we start from the recent taxon and trace it back through its lineage we can see its history and this is known as Phylogeny. The cladistic or phylogenic classification is based on phylogeny of the involved organisms and depends on the phylogenetic branching. Henning (1950) based his classification on genealogy (= history of the descent of taxa). Mayr and Ashlock (1991) stated that "A cladislic classification consists of a nested hierarchy of increasingly more inclusive holophyletic taxa; this hierarchy corresponds to a hierarchy of increasingly more inclusive synapomorphies." In this type of classification the phylogeny is reconstructed (cladistic analysis) by analyzing the synapomorphic characters. Synapomorphy denotes a homologous character shared by two or more taxa and believed to have been present in the nearest common ancestor but not in the earlier ancestors nor in the taxa outside this group. In this type of classification the sequence of branching events in the evolutionary history of the group is determined and based on this, a cladogram is constructed. The cladists who follow Hennigs believe that branching results when speciation takes place and only two new phyletic groups originate. Each of these groups can be recognized by its synapomorphic characters. Each species ceases to exist when it splits into two daughter species. The species form the base point of a cladistic analysis and each holophyletic taxon (holophyletic means pertaining to a group that consists of all the decendants of its most recent common ancestor) is derived from a particular stem species (Mayr and Ashlock, 1991). Each character of a taxon must be evaluated to see whether it is apormorphic (derived) or plesiomorphic (primitive), since the plesiomorphic characters do not help in locating branching points in a cladogram, they are usually ignored in cladistic analysis. A character can be considered as apomorphic when it is found only in a particular taxon. Recently a few taxonomists separated cladistic classification and phylogenetic classification into two different ones (Christoffersen, 1995). Owing to the greater frequency of homoplasy in plants and scarcity of diagnostic morphological characters for higher taxa, a cladistic classification is rather difficult in botany where phenetic methods predominate.

5. **Phenetic Classification** : This classification is primarily based on similarities and dissimilarities of characters without any weighting of these characters. Here the total number of characters is more important than the quality of each character used. In this type of classification even a single character used sometimes become very important if that one is stable than many other variable characters. In such a case the use of a single firm character will result in the natural grouping as the using of all the variable and firm characters together. According to Adanson (1763), the use of maximum number of characters is desirable. The phenetic method is sometimes called Neo-Adanson classification.

6. **Evolutionary Classification** : Blackwelder (1967) considers evolutionary classification and phylogenetic classification are synonymous and represent classification based on features derived from a common ancestor. However, Simpson (1961) and Mayr & Ashlock (1991) consider both as different. Here the latter view is followed. Accordingly in evolutionary classification, taxa are not delimited on the basis of groups that consist of all the descendants of its most recent common ancestor (Holophyletic) but through an assessment of resemblance and difference (provided they are monophyletic). In evolutionary classification, monophyly

is not used as a method for delimiting taxa. Paraphyletic (= pertaining to a monophyletic group that does not contain all the descendants of that group) taxa are not considered in evolutionary classification. In this type of classification, taxa are delimited and ranked on the basis of totality of synapomorphic and plesiomorphic characters together. Such a classification gives a much broader basis for comparisons. Autopomorphic (= pertaining to one or two derived characters found in one or two sister groups) characters are taken as important characters in delimiting and ranking taxa in evolutionary classification. The catagorical ranking of taxa is based on the degree of differences. Thus in evolutionary classifications, all kinds of homologous characters are used in ranking. According to Mayr & Ashlock (1991), monophyly and totality of shared characters cannot be applied simultaneously but one after the other. Usually totality of shared characteristics can be tested for first recognizing provisional taxa and these provisional taxa can be tested for monophyly (presence of synapomorphies, explanation of homoplasies, etc.). After the ancestor-descendant relationships of these taxa are established, a phylogram can be constructed.

7. **Biological Classification** : Biological classification is that kind of classification in which the organisms are classified into ordered groups based on the similarities and inferred descent. Here the organisms are arranged on the bases of logical conclusions of their evolutionary succession. Blackwelder (1967) considers that biological classification includes natural, artificial, evolutionary (or phylogenetic), horizontal and vertical classifications.

8. **Omnispective Classification** : Most taxonomists today practice this classification. In this approach, an experienced taxonomist takes into account all the available features but decide to use only some readily available ones for classification. It is a workable system of classification. The main feature of this classification system is that it is based on comparative data drawn from individual organisms and all the available data are used as far as necessary. An experienced taxonomist knows which all data available are variable and which of them are not useful for classification. This classification "is all-seeing or all-considering system" (Blackwelder, 1967).

9. **Hierarchical Classification** : In this type of classification, the organisms are arranged in groups or categories in a hierarchic scale so that all organisms can be classified in a taxonomic hierarchy, in an ascending rank from species (or infraspecific categories) to the Kingdom. Thus the great multitude of organisms in nature can be brought into a clear workable comprehensive system and organisms can be understood and remembered more readily than remembering all the individual units separately. In this type of classification, the lower units (for instance species) are arranged into upper category (for instance into genera) which is more separable among each other in an ascending hierarchy. Linnaeus was the first to propose a practical and usable hierarchical classification of animals. He recognized five categories, viz., class, order, genus, species and varieties. Later more and more animals were discovered and the number of known animals grew, the following additions such as Family (between genus and order) and Phylum (between class and kingdom) came into

existence. Today the generally accepted categories in the animal kingdom are the following :

Kingdom
Phylum
Subphylum
Super class
Class
Cohort
Superorder
Order
Suborder
Superfamily
Family
Tribe
Genus
Subgenus
Species
Subspecies

In plant kingdom it is as follows (Sivarajan, 1985) :

Kingdom	-	Plantae
Division		Phytae (eg. Magnoliophyta)
Subdivision		icae (eg. Pinicae)
Class	-	opsida (eg. Magnoliopsida)
Subclass		ideae (eg. Magnoliidae)
Order		ales (eg. Geraniales)
Suborder		incae (eg. Geranineae)
Family	-	aceae (eg. Ranunculaceae)
Subfamily	-	oideae (eg. Rosoidea)

The concept of species and the concept of higher categories are different. The species exists in nature as products of reproductive isolating mechanisms. The higher categories are arbitrarily formed groups with gaps between categories much wider among them. The limits of the higher categories are subjective. However these higher categories appear to have biological and structural basis with some objective criteria (Mayr *et al.*, 1953).

Units of classification

There is considerable difference of opinion as to what is the basic unit of classification of organisms. While many believe that the species is the basic unit of classification, a few others think that it is individuals that are arranged into species and animals.

It is argued that individual does not represent species than species represents the phylum. The individual is only one of the members of a species and hence individual cannot form the basic unit of classification. However in the case of fossils, often the individuals are the only remnants to be classified and they may represent a species or higher categories.

The levels above species are known as higher categories. There is no clear cut yard stick for ranking higher categories. There have always been differences of opinion in ranking a particular taxon as a higher or lower one. The cladists and the evolutionary taxonomists differ in ranking the taxa. The evolutionary taxonomists do not consider that every holophyletic lineage is a separate taxon as considered in the cladistics.

The evolutionary taxonomists base their recognition of taxa and their ranking on the following criteria (Mayr & Ashlock, 1991).

1. The gaps between taxa resulted by evolutionary process such as speciation, extinction, adaptive radiation, etc. The greater the gaps, the better the ranking.
2. The degree of difference between taxa. If the differences are more the ranking will be more reliable.
3. The uniquencess of adaptive zone. The gap between two taxa will be more distinct if they occupy two different adaptive zones.
4. The size of a taxon is often taken into consideration while splitting it into two or several taxa in higher categories. This should be taken with utmost care. In this process, the role of two kinds of taxonomists, *viz.* the splitters and the lumpers are worth noting. While the splitters usually consider every slight difference in creating a taxon, the lumpers will try to combine the existing categories to form a larger taxon. A middle position between these two categories will be ideal in the assessment and weighing the taxa. Mayr & Ashlock (1991) sides with the lumpers since they believe that lumpers try to produce a classification in which the emphasis is placed on relationship and which avoids burdening the memory with too fine a division of taxa.
5. The equivalence of ranking in related taxa should be taken care of by the taxonomists while ranking the taxa. It is not advisable to change the rank of a single taxon, say families to that of an order, resulting in raising the ranks of all other higher categories with scant consideration of the other families in the same taxonomic group. It is always worth having a general consensus among all leading taxonomists of the said group before making any such vast changes.

The process of ranking

There is often disagreement among taxonomists of a group in determining the appropriate rank for each recognized taxon of higher categories based on the degrees of differences found among taxa. Pheneticists consider the overall resemblances to rank organisms. Cladists following Hennig (1966) introduce a new rank at each branching point of the cladogram. Evolutionary taxonomists base their ranking giving stress to major gaps in evolution.

CHAPTER 6

APPROACHES IN TAXONOMY

1 External Morphology

The external morphology in general is the phenotypic expressions of a large part of genotype and depending on the external morphology, generally provides reliable conclusions. The morphological method is a traditional method that requires less sophisticated technology and facilities for studying taxonomy. Traditionally both animal and plant taxonomy have been mainly dependent upon external morphology. Since it is not easy to obtain in a short period of time, information from other type of approaches such as molecular biology, biochemistry, etc., taxonomy has to depend on its traditional method of basing its evaluation on external morphology. Commenting on the importance of morphological approach in taxonomy, a taxonomist friend of mine recently gave an interesting example. He argued that suppose a person has been bitten by a snake, one can easily find out whether it is a poisonous snake or a non-poisonous snake by looking at the external morphology (especially of the head) of the snake rather than wait for molecular or biochemical information for identification and immediately start treatment. Besides this, there are innumerable nanofauna or flora which are available to the taxonomist, only as a single specimen (containing a taxon) and in such a case dissecting or damaging any part for molecular or biochemical studies is not feasible or advisable, since destruction of the single available specimen (or type) will hinder the future identification of such specimens or species. Taxonomy based on external morphology has been in use for several centuries and there is a well-standardized terminology to describe the characters. In recent times, scanning electron microscopy has great scope in taxonomy for studying external morphology. Transmission electron microscopy (TEM) is also of great value in taxonomic studies in groups like Protozoa. Thus great advances have been made in recent years in the morphological approach in taxonomy. Hence taxonomy based on morphology cannot be completely replaced by other approaches like molecular taxonomy, chemotaxonomy, etc. That is why Ogura (1964) and Cronquist (1975) stated that morphology in general will continue to reign taxonomically supreme for many more years to come.

2. Anatomical Approach

Studies on anatomy of animals and plants, have also been used for taxonomic studies whenever possible. Anatomy provides several useful characters in all groups of animals and plants for studying their taxonomy. However, the extent to which such studies are applicable varies from group to group. Paleontologists have always used the internal skeleton to identify the higher organisms. Similarly, exoskeleton has always been a good source for taxonomic discrimination in many lower forms of animals. The internal structure of leaves is of great use in taxonomic studies of many plants. Anatomical approach can be supportive for taxonomy based on external morphology.

3. Approaches based on Developmental Biology

Developmental biology offers various characters for taxonomic studies. Immature stages like egg, larva, pupa, embryos, etc. provide excellent features that can be made use of in taxonomic studies. Comparative embryology can be of use in determining taxonomic characters of phylogenetic significance. The various developmental processes such as cleavage pattern, gastrulation, etc. may be used for discriminating various taxa. A careful comparison of immature stages or embryos may help in separating identically similar species that resemble their adult form in all external morphological features. Though there can be different identification schemes for immature stages, embryos and adults, there cannot be two classifications for a given group of organisms. In such cases, a single classification should be developed based on proper weighting of both adult and immature stages. Embryological characters are very reliable since they are not subjected to adaptive stresses. In plants, micro and megasporogenesis are important phenomena of embryology and these are of much use in studying taxonomy of many plants. Ontogeny of the ovules has been of great use in studying taxonomy of several plants. Similarly, development of embryo sac is also a good character of taxonomic value in plant taxonomy. For both plant and animal taxonomists, embryological characters are very useful in the analysis of evolutionary trends in the delimitation of taxa.

4. Molecular taxonomy and Biochemical approach

Molecular taxonomy can be defined as the detection, description and differences in molecular diversity within and among taxa. Chemotaxonomy or biochemical systematics is a sub discipline of molecular taxonomy. The molecular taxonomy includes analyses of isozymes, molecular cytogenetics, immunology, DNA-DNA hybridization, restriction analyses or sequencing nuclear and mitochondrial DNA sequences (Hoy, 1994). Turner (1966) divided molecular taxonomy into Micromolecular and Macromolecular taxonomy. The former is the study of distribution and biosynthetic inter-relationship of amino acids, alkaloids, terpenes, etc. for resolving systematic problems. Macromolecular taxonomy is the study of molecules like DNA, RNA, polysaccharides and proteins for solving taxonomic problems especially of higher categories.

In 1960's electrophoresis of proteins provided new characters for taxonomic analysis (Hoy, 1994). Gel electrophoresis of proteins could reveal the presence of functionally similar forms of enzymes or isozymes. Protein electrophoresis is useful for analyzing several genes from several individuals and this technique is useful for analyzing taxonomic characters and classification.

Immunological techniques can give qualitative and quantitative estimates of differences in amino acid sequence between homologous proteins (Maxson and Maxson, 1990). Precipitin reaction is widely used in taxonomy of microorganisms. It consists of the formation of a precipitate when an antigen and the corresponding antiserum are brought together. The precipitin reaction and its application in taxonomy is based on the fact that proteins of taxon, whether a plant or animal will be showing a stronger reaction with the antibodies of a closely related taxon than to those of one more distantly related (Boyden, 1943). Serological experiments so far done tend to agree with many recent taxonomic conclusions. For instance, the plant genus *Liriodendron* had been found to be quite distinct from other members of the family Magnoliaceae (Johnson & Fairbrothers, 1965). Peptide finger printing is found to be a promising method in studying the taxonomy of lower level plants (Boulter and Derbyshire, 1971). In this method, carbomethylated protein hydrolyzed into peptides by incubating with proteolytic enzymes is separated and consequently detected by using chromogenic substances. Each protein will have a characteristic distribution map of peptides. Differences in the finger printing or map can be used for detecting differences in proteins and this can be of use in delimiting taxa or detecting resemblances and affinities between taxa. Based on such studies, Boulter and Derbyshire (1971) could find out how the plant genera *Vicia* and *Lathyrus* differed from each other and from other genera.

The DNA-hybridization technique helps to determine the total overall similarity and differences of two taxa (Sibley and Ahlquist, 1983, 1985). This method involves creating hybrid DNA molecules by slowly cooling a mixture of denatured DNA from two different sources (Hoy, 1994). This method is as follows: The DNA is isolated and forced of all proteins and RNA. Then the purified DNA is fragmented into short pieces. Then by a procedure known as generating C_0t curve (Britten *et al.*, 1974) the single copy DNA is separated from repetitive DNA and the fragmented single copy DNA from one species is labeled with a radioactive isotope and hybridized with unlabelled DNA from the same species and from different species. The former hybridization with the same species DNA is known as homoduplex reaction or hybridization, while the latter with different species is known as heteroduplex reaction or hybridization. When the hybridization is complete the mixture is gradually cooled. The homologous single stranded pieces of two DNA's will pair while the non-matching pieces will remain in solution. This will clearly show what percentage of the DNA will pair and what percentage has become sufficiently different during evolution to pair no longer. Sibley and Ahlquist (1983, 1985) stated that it took about 5 million years of divergence for the genomes of two species (in birds) to become different in one percent of their base pairs and based on these studies a dendrogram of all avian families were constructed.

DNA sequencing : The DNA sequences can be used to study many taxonomic problems from infraspecific variability to the phylogeny of all organisms. The basic method of sequencing DNA involves four procedures (Hoy, 1994).

1 Cloning and preparing template DNA.
2. Performing the sequencing reactions
3. Gel electrophoresis of the samples and
4. Compilation and interpretation of data.

In identifying the sequences of promoters (= A region of DNA crucial to the accuracy and rate of transcription initiation), protein coding sequences and non-coding regions of DNA, it is possible to find similarities and differences between organisms.

Restriction fragment length polymorphism (RFLP) analysis provides information on the difference between nuclear and mitochondrial DNA. RFLP analysis can be used to analyse species boundaries, geographic variation and phylogenies. Recently, RFLP analysis has been simplified by employing another technique called PCR–RFLP (PCR = Polymerase chain reaction = a method of amplifying DNA by means of DNA polymerases).

Molecular clock is a concept according to which molecules evolve in direct proportion to time so that differences between molecules in two different species can be used to estimate the time elapsed since the two species last shared a common ancestor (Hoy, 1994). Zuckerkandl and Pauling (1965) found that the rate of molecular evolution was approximately constant over time in all lineages and sequence coding of these conserved molecules could be used to assess the evolutionary distance between organisms.

Demerits of Molecular Taxonomy

Genome mapping in taxonomic discrimination : For identifying two unknown organisms or species or subspecies, it would be extremely difficult to use this method. The main difficulty arises from the distribution of variability within and between species. In order to use genetic variability to differentiate taxonomic groups one would need to know what specific sites are diagnostic for the groups. These sites would have to be different between the groups while being invariant within the groups. Since each individual's genome is quite variable with respect to another individual of the same species/subspecies (depending where in the genome one looks) it is possible that the variation seen at certain sites could be shared across taxonomic groups just by chance. The 2% dissimilarity between nearest species of Chimpanzees and humans derives from a "crude" genomic comparison based on how disassociated DNA molecules from the groups cross-hybridize (form a double stranded molecule with one strand from each species). Unfortunately, there does not appear to be a strict numerical relationship that one can use to relate levels of similarity/difference and membership in taxonomic groups, even though many have tired to find one. The level of variation seen within one taxonomic group can be equal to or greater than that measured between groups, especially if the groups have been separated for a long period of time. Long periods of independence allow variability within groups to accumulate. As the genome is not infinite and because variability is not uniformly distributed across the genome, groups that have been separated for long periods of time can, by chance, have similarities that would group them together rather than separate them. This is known as *homoplasy* and is one of the major stumbling blocks of molecular systematics (Wollenberg per comm., 2000).

Though molecular approach has its usefulness, it has its drawbacks too. They cannot be applied in many cases where the taxa especially of nanofauna are in rare numbers, sometimes a single old preserved specimen representing a species (a type specimen) may be present and it is not possible to study the molecular taxonomy of it because of several taxonomic reasons and rules. This is applicable in many cases of fossils also. Besides this, in most cases where taxa are classified using molecular methods, different classifications are arrived at because of universality of **Mosaic evolution** that denotes different rates of evolutionary change in the same group of organisms for different structures, organs or other components of phenotype (Mayr & Ashlock, 1991).

5. Karyological Approach

Chromosomal characters have often been used by botanists and zoologists for taxonomic discrimination and evolutionary studies for about a century. Karyological studies have been made use of by plant taxonomists much more than animal taxonomists.

The main criteria used in this approach are (Stebbins, 1950) :

1. basic chromosome number
2. form and relative size of different chromosomes of the same set
3. number and size of satellites and secondary constrictions
4. absolute size of the chromosomes and
5. euchromatin and heterochromatin.

Chromosomal studies are useful in comparison of closely related species especially in lower taxa. Sibling species often differ greatly in their chromosomal characters. In the higher taxa, chromosomal pattern may be of extreme importance in establishing phyletic lines. However, Karyological approaches too show many problems in taxonomical studies. In plants and in many animals (though polyploidy is rare in animals), the chromosomal numbers and other features vary in the same taxa. The closely related species may show considerable rearrangement and many species are polymorphic for the very chromosomal differences which in other cases differentiate closely related species (Kapoor, 1998). While many reproductively isolated species of a genus may have similar type of chromosome structure (differing only in the nature of genes), many biotypes of species may differ in the same traits like banding pattern, in the chromosomes. Karyological approach too has drawbacks and one should be careful in using them in determining the limits of a taxon.

6. Numerical Taxonomy

Numerical taxonomy is an approach in which classifications are based on greater number of characters from many sets of data in order to produce an entirely phenetic classification. Here the classification is based on phenetic similarities (also called Numerical phenetics) and maximum number of characters (morphological, biochemical, molecular, behavioural, developmental, karyological, etc.). Every character is given equal weight. In this approach, distinct taxa can be recognized since correlations of characters differ in the various groups of organisms under study. Since numerical taxonomy is mainly based on the principles propounded by Adanson (1727-1806) it is often called **Neo-Adansonian principle.** Various other terms such as 'Taxonometrics', 'Taxonometry', 'Taximetry' and 'Taxemetrics' are also used for numerical taxonomy. Numerical taxonomy has several advantages. Application of this method requires no previous knowledge of the studied taxon. Various computer programmes can be applied for the operation of numerical methods. Students of numerical taxonomy are of the opinion that classification based on numerical taxonomy is more reliable and natural since their classification is based on more characters than the other types of classifications.

Inspite of the usefulness and advantages of numerical taxonomy, it has several demerits also. This method takes considerable time to complete. In many groups large number of variable morphological characters are not available. Since unweighted characters are used in numerical taxonomy, it would be affected by parallelism and convergence (Sokal, 1985), mosaic evolution, etc. As in the case of molecular or biochemical approach, here also numerical taxonomy can be done only if there are sufficient specimens to study. For the same reasons numerical taxonomy cannot replace classical taxonomy based on morphology and this classical taxonomy is here to stay for a long time to come.

7. Ecological Approach

Gause's rule states that no two species with identical ecological requirements can co-exist in the same place (Lack, 1949). Every species has its own ecological niche. However if two or more species co-exist in the same area, they usually avoid competition by differing in their species specific requirements and this phenomenon is known as "**Competitive exclusion**' (Mayr, 1963). In many groups of organisms, every species of the genus differs ecologically from related species. Ecological characters are of great value in separating sibling species. Hence it is always desirable to include atleast some information (when available) on the ecology in every research paper containing the description of a taxon. Many species have specific food preferences and this can be of great help in taxonomic discrimination. Ecological differences are noted among populations of the same species, which have a wide distribution. Care should be taken to analyse and study every such instance.

Zoogeography is also helpful in determining the identity of a taxon especially at species level. Except for a few species, most species differ from every zoological realm unless and otherwise there are instances of migration or accidental introduction. Thus it is not very likely to see a South American species of insect in the South east Asia and *vice versa*. Thus zoogeography can help a great deal in the identification of a taxon. Many species of organisms have species specific parasites and by studying these parasites, many sibling species of their hosts can be detected. In the key to species of several groups of insects, the presence and absence of carina on the tergites is often taken into account for identifying taxa. Similarly symbionts, commensals, etc. also show specificity in many groups and these may be also helpful in the identification of taxa.

Specificity in host reaction can also of use in taxonomy. Galls produced by various cynipids, cecidomycids, etc. are specific in their nature. Each Ficus has its own specific agaonid wasp (Agaonidae) for pollination. The ficus species and its specific agaonid wasp is a typical example of co-évolution. No ficus can thrive without its specific agaonid wasp and no agaonid wasp can thrive without its specific ficus.

8. Ethological Approach

Many species even though look alike in their external features, may differ widely in habits. Differences in mating habits have been widely used in determining various species in many groups of insects. Cross breeding experiments have been of great help in determining the limits of various taxa. Sympatric and allopatric species can be determined by the reproductive isolation. The differences in the calls and songs of birds and insects have proved to be of great value in determining subspecies or species in these groups. Apart from these behavioural characteristics, nest building, nature of nests, material used for nest, nocturnal or diurnal habits, cannibalism, food specificity, feeding habits, etc. are also important behavioural factors which can help in the identification of a taxon. However, ethological approach has not developed much as a taxonomic tool. When developed it can definitely help classical taxonomy to a great extent.

CHAPTER 7

NOMENCLATURE

The term nomenclature originated from two Latin words, *viz*. "nomen" meaning "name" and "clatare" meaning "to call" and 'nomenclature' literally means "to call by name" It is merely naming of all levels of taxa for easy communication among scientists, especially biologists. Once a name is given to a taxon it becomes a label with which all available information on it can be retrieved, ensuring easy reference. The rules concerning the names and naming of taxa is collectively known as code of nomenclature.

History of Nomenclature

The rules of nomenclature may be said to have been framed for the first time by Linnaeus (1737, 1751) even though several others had proposed several kinds of nomenclature before him. Linnaeus developed the binomial system of nomenclature. Since the Linnaean rules have so many inadequacies, the need to develop internationally accepted rules and regulations was deeply felt. In 1843, the British Association for the advancement of science appointed a committee to formulate a general set of rules for zoological nomenclature. As a result the committee put forth a set of rules known as **"Strickland code"** (named after one of the committee members). Thus the first and reliable code of zoological nomenclature came into existence. In 1889, the first zoological congress adopted a code proposed by Raphail Blanchard and this was the beginning of the present international rules. In 1901 at the fifth international zoological congress, international rules of zoological nomenclature was formed and adopted. Since then several modifications and emendations were made by subsequent international congresses in zoology.

In the case of plant nomenclature, the International Botanic Congress in 1866 appointed the French botanist Alphonse de Candole to draw up a general set of rules for botanical nomenclature. Candole submitted a report to the botanical congress in 1867 and the congress accepted the report in its Paris meeting and the code of botanical nomenclature came into existence. This code was known as 'Paris Code' or the 'Candollian Code' After the establishment of 'Strickland code' and 'Candollian Code' several changes have taken place in these codes. They were subjected to additions, deletions and modifications. Currently code of zoological nomenclature was prepared by the International Union of Biological Sciences (IUBS) and published by the International Trust of Zoological nomenclature, C/o the Natural History Museum, London in 1985. In the case of code of botanical nomenclature, Paris code was replaced by Rochester code (1892), Vienna code (1905), American code (1907) and finally the Cambridge code (1930). The Code has since been emended at every international botanical congress. It is essential that every taxonomist possess a copy of the 'International Code of Zoological nomenclature' if he is working in Zoology and International code of botanical nomenclature' if he specializes in Botany.

Since, it is not the purpose of this book to give all the rules of zoological and botanical codes, only a few important rules are discussed below.

1. The nature of Scientific names

The zoological nomenclature is independent of botanical nomenclature and vice versa. A general principle of both zoological and botanical nomenclature is that scientific names of organisms is uninominal for subgenera and all higher categories, binomial for species and trinomial for subspecies.

Latin is the language used for all biological nomenclature. The reason for using Latin is that it is not spoken in any country and national bias for any national language can be avoided. However, both the zoological and botanical codes of nomenclature permits to choose names of taxa from any language and source but stipulates that they should be in Latinized form.

The scientific names of animals from subgenera and above are uninominal. These are either pleural nouns or adjectives used as nouns for name categories above genus. Singular nouns are used for genus and subgenus. The code of zoological nomenclature stipulates standardized endings of different levels of taxa as follows :

Superfamily	:	-oidea (eg. Chalcidoidea)
Family	:	-idea (eg. Chalcididae)
Subfamily	:	-inae (eg. Chalcidinae)
Tribe	:	-ini (eg. Chalcidini)

The code does not stipulate endings for higher categories above superfamily or to genus or species in common except that the ending should be in Latin or Latinized form. However, as per the code of botanical nomenclature, the endings are as follows (Shivarajan, 1985).

Division	:	-phyta (eg. Magnoliophyta)
Subdivision	:	-icae (eg. Pinicae)
Class	:	-opsida (eg. Magnoliopsida)
Subclass	:	-ideae (eg. Magnoliideae)
Order	:	-ales (eg. Geraniales)
Suborder	:	-ineae (eg. Geranineae)
Family	:	-aceae (eg. Ranunculaceae)
Subfamily	:	-oideae (eg. Rosoideae)
Tribe	:	-eae (eg. Roseae)
Subtribe	:	-inae (eg. Rutaceae subtr. Rutinae)

There are no common endings suggested for genus, species and infraspecies categories, except that all ending should be in Latin or in Latinized form. For the sake of brevity, this discussion will be restricted to the names of species and genera.

2. Species and Infraspecies names

The standard use of binomial nomenclature consisting of a generic name and a specific name was adopted by all major codes of zoological and botanical nomenclature. The scientific designation of organisms is binomial for species and trinomial for subspecies. The author's name which follows a species or subspecies name is not considered as a part of the scientific name. A scientific name of a species or subspecies becomes valid only if it is published as per the codes of nomenclature. It must be accompanied with description or diagnosis which will enable to differentiate the taxon from related taxa. In botany, a Latin diagnosis is to be given for every new taxon. The names published before January 1, 1758 is known as pre-Linnaean names and these are considered as invalid names. A scientific name should never be used anywhere until it is published as per the international rules of nomenclature. Sometimes authors send off two papers, one describing a new species and another using the name of this new species. They presume that the paper describing the new species will be published before the other paper – sometimes it is and sometimes it isn't. In the latter case, the name becomes a *nomen nudum* (= invalid name).

In the binomial nomenclature, the first word is the genus name and it begins with a capital letter whereas the second word is the species name and is not capitalized. Thus the scientific name for human is *Homo sapiens*. The author who first describes the species should follow the scientific name though the author's name is not considered as part of the scientific name. The name of the species when used for the first time in subsequent research papers should be followed by the name of the author who described it. Thus the name of the humans may be written as *Homo sapiens* Linnaeus since Linnaeus described the species. However, in a research paper this rule (ie. Use of the name of the author of the species) is not necessary every time the name of the species is mentioned in the paper. The name of the author of the species is usually mentioned on the first mentioning of the species in the paper. Subsequent mentioning of the species name in the same paper need not necessarily contain the name of the author of the species along with the name of the species.

All scientific names should be underlined when written or typed. They should be either in italics or in bold face when printed. The generic name can be abbreviated after it is used in complete form for the first time in the paper. For instance, *Antrocephalus narendrani* Sureshan can be abbreviated when used in subsequent lines as *A. narendrani*. Since names are in Latin or in Latinized form, the case ending of the species must agree grammatically with the generic name. Thus, the descriptive adjective *aureus*, meaning golden, retains its case-ending – us if in conjuction with a masculine generic name, for example *Dirhinus*, but changes to case ending *–a* if the generic name is feminine (for example *Eurytoma aurea*) and to case ending *–um* if the genus name is of neuter gender (for example *Eusandalum aureum*). Some adjectival case endings are the same with both masculine and feminine generic names but differ in the case of neuter gender generic names. Thus the species name *keralensis* can be used with masculine (eg *Dirhinus keralensis*) or feminine generic names (eg. *Brachymeria keralensis*) and changes to *keralense* in the case of neuter gender generic name (eg. *Pachyneuron keralense*).

It is not possible to distinguish Latin adjectives as a class by their endings. The Latin adjectives usually end in the following letters such as *a, e, m, r, s* and *x*. *Eg. rugosa, glabrum, puparum, claviger, oliracea, gibbus, gentiles, zingiber, plaustre, anceps, stóm, tenax, anceps, laevis* etc. Rarely Greek adjective is used as an epithet. Here the adjective can end in *a, e, n, r, s or y*. Lists of examples for Latin and Greek are given by Brown (1956).

There are several kinds of names used in taxonomy and some of them are discussed below :

Descriptive names : Based on any character of the taxon, a name can be given. For example the species name *'gigantica'* or *'giganticus'* indicating the giant size, *'globosa'* indicating the round shape or globe like shape, *alba* (feminine gender) or *albus* (masculine) or *album* (neuter) indicating the white colour, etc.

Ecological name : According to the habitat or habit of the species, names can be given such as *'subterraneus'* (= living underground), *arboricola* (= tree living) or according to the manner of living such as *'aggregatus'* (= living in groups), *'parasitus'* (= parasitic habit), etc.

Geographical name : Names based on the locality where the type specimen was collected or on general distribution of species are called geographical names. For example, for Kerala, *'keralensis'*, *keralicus*. Such geographical names are very useful even if several species of the genus are from the same locality since the geographical name clearly indicates the original locality or region of the 'type' of the species or general distribution of the species. Hence geographical names (and names based on characters) should be given high priority in naming a new species if the names are not preoccupied.

Patronymic names : Species names can also be based on names of persons. Generally these names are given in honour of an eminent person or of a significant contributor to the concerned field or of a person who collected the specimen concerned. It can also be based on a person who has helped the researcher considerably in his work. However, patronyms should always be used with restraint. In naming a species after the name of a person, the person's name (usually the surname) is taken as the stem of a Latin noun, and to this stem a genitive ending is added. These endings are 'i' in the case of masculine name (example *nathani* from Nathan, *cheriani* from Cherian, *rahimani* from Rahiman, etc.) and *ae* in the case of feminine gender *seethae* from Seetha, *sarae* from Sara, *jameelae* from Jameela, etc.).

Names without meaning : Sometimes Latinized names based on arbitrary combination of letters with or without original meaning (eg. *'fantana'*, *'gentana'*, *'kalona'*, etc) can be used in order to avoid undesirable implications of meaningful names or in situations where relevant descriptive or geographical names are already occupied.

Undesirable names : Very long names are always inconvenient to use and should be avoided. Similarly facetious names or those likely to cause religious or personal offense are also to be avoided.

Other kinds of names : Apart from the above described categories of names, names based on host organisms (eg. *'opisinae'* from *Opisina*, 'rosae' from *Rosa* and *'lantanae'* from *Lantana*) or mythological names (eg. *'arjunai'* from Arjuna) or words from other languages (such as Latinized Sanskrit words *'anupama'* meaning unique) can also be used.

When a species contains several subspecies, it is known as Polytypic species. If it contains no subspecies, it is monotypic. A subspecies is a geographical or ecological population of a species which differ taxonomically from other such populations of the species. A subspecies is a population of several biotypes (=races) of a species. In animal taxonomy subspecies is the only taxonomic category that is really valid and recognized, even though many recent animal taxonomists are reluctant to consider the subspecies as valid taxonomic unit. The name 'variety' is used only sparingly and in most cases as synonymous with subspecies. In botanical nomenclature, the term 'variety' denotes a morphologically distinct population which occupies a smaller restricted geographical area when compared to the larger regional area of subspecies. The term 'variety' is also used for mere variations (or variants) which do not have any standing as a taxonomic unit.

The names of subspecies come under 'Trinomial' category. The name of the subspecies is written immediately following species name :

eg. *Brachymeria podagrica podagrica*

Brachymeria podagrica rufoflagellata

Here the first mentioned *B. podagrica podagrica* is known as 'Nominate subspecies' When a species is divided into several subspecies, the subspecies which consists of the topological (Topotype = A specimen collected at type locality) population becomes nominate subspecies and its subspecific name is the same as the name of the species. The name of the subspecies should co-ordinate with the name of the species. Excluding subspecies, in all other infraspecific categories like 'varieties', 'castes', etc. naming is not advisable in the case of animals. As per article 45 (g) of the code of zoological nomenclature, a new name published for a 'variety' or form may be either a subspecific (if published before 1961) or infraspecific (if published after 1960) name.

3. Genus Group Taxa

The genus group includes all taxa at the ranks of a genus and subgenus. A 'genus' is a taxonomic category that contains one or more species of presumably common phylogenetic origin and the genus is separated from related genera by a decided gap. As in the case of species, reproductive isolation does not exist in the generic rank. [A species is a morphologically and biologically identical population which does not reproduce with other similar population of the same genus. An exception to this rule is the case of 'Ring species' in which the populations of adjacent areas reproduce while population of distant areas does not reproduce. The chalcid wasp, *Melittobia assemi* Dahms reproduce with the population of Seychelles island and that of Kerala, the same population does not reproduce with the Okinawa (Japan) population. There are a number of ring species in birds also].

An author who publishes a new generic name should always make a clear statement of diagnosis and how the new genus differs from other related genera. The generic name is uninominal consisting of a single word in the nominate singular written with a capital initial letter. As in the case of species name, the generic name should also be in Latin or in Latinized form of Greek or other language. The following are a few examples of the kinds of names used for genera.

1. Mythological name : eg. *Venus, Diana*
2. Proper names used by Ancients : eg. *Cleopatra*
3. Modern patronymics with proper suffix.
4. Names terminating with a consonant take the ending *ius, ia,* or *ium* (eg. *Boucekius, Boucekia, Boucekium* etc).

a) **names** terminating with the vowels *e, i, o, u,* or *y* will have the ending *us, a,* or *um* (Eg. *Mania, Rijoa, Vijaya, Varghesium, Muthua* etc.).

b) **names** terminating with 'a' will take the ending 'ia' (eg. *Ramaia*).

c) With patronymics consisting of two words, only one should be used (eg. *'Edwardsia'* or *'Ericsia'* from Edward Eric' *'Ramadasoma'* from Ramdas Menon).

d) Names of ships: These should be treated in the same manner as modern patronymics (eg. *'Vikrantia,' 'Gangotrius'*).

e) Names of plants: (eg. *Rosaia* from *Rosa*).

f) Names of places: (*Indiania, Papuania*)

g) Words taken from languages other than classical (eg. *Tanushyama* from Sanskrit; *Tenka* from Czech).

h) Words formed as arbitrary combination of letters (with or without original meaning). (eg. *Tenaxia, Yandella, Deadra*).

i) Names formed by anagrams of already existing names: (*Culicta* from Calicut, *Rekala* from Kerala).

j) Names formed by adding a prefix or suffix to an already used name eg. *Pseudotorymus* (from *Torymus*), *Neohaltichella* (from *Haltichella*), *Torymoidellus* (from *Torymoides*) *Aphebetoideus* (from *Aphebetus*).

k) Many taxonomists name a genus based on one or more distinctive characters of morphology or biology.

Gender of a generic name : This is usually decided by the original author. In case the original author did not mention the gender of a genus when he erected the genus or later, it becomes necessary for the subsequent worker to determine the gender, the International commission of Zoological or Botanical nomenclature can fix the gender under the plenary powers. If the name is of Greek or Latin origin, the gender can be determined based on the type of ending of the name. If the name is from Indo-European language having genders, it takes the gender of that word [Article 30(h) (i)] If the generic name is not coming in the above mentioned categories, it is to be assumed to be masculine, unless its ending is clearly a natural classical feminine or neuter one and in such case it will be considered as that gender [Article 30lb)]. If the name is a patronym (eg. *Maniella, Ramanus*), it take the gender of the Latin ending.

When the name of the subgenus is raised to a separate genus and if this new genus is based on any generic synonym, the type species of this new genus must be chosen from this particular synonym. If there are no subgenera and if there is no genus group name based on any of its species, then a new name has to be given and a type-species has to be chosen. The subgeneric name is not considered one of the words in the binominal name of a species or a trinomial name of a subspecies (Article 6).

4. Synonyms and Homonyms

If more than one name is given to a taxon, all these names are known as synonyms. Among these synonyms, the first published valid name is the senior synonym and the subsequent ones are junior synonyms. There are two kinds of junior synonyms: one kind is based on names proposed for the same specimens or new names for supposedly preoccupied names. These are known as 'Objective synonyms' The second kinds of synonyms are synonyms, only in the opinion of one or more workers of the group. They are known as 'Subjective synonyms'

Example 1

Senior synonym: *Dirhinus auratus* Ashmead, 1905.

Junior synonym: *Dirhinus cercinus* Husain & Agarwal, 1981. (Narendran synonymized, 1989).

Example 2

Senior synonym : *Aerias* Walker, 1847

Junior synonym : *Australomphale* Girault, 1922 (Boucek synonymized, 1988).

Homonyms arise when the same name is used for two or more different taxa. Here, too, the senior homonym is the first published valid name.

Example 1

Senior homonym : *Sycophila karnatakensis* (Joseph & Abdurahiman, 1968)

Junior homonym : *Sycophila karnatakensis* (Mukerjee, 1981)

Example 2

Senior homonym : *x–us* Jones, 1950

Junior homonym : *x–us* Rao, 1960

The senior homonym is valid and the junior homonym needs a **Replacement name**. As per the code of ethics in systematics, any zoologist who finds out the homonym must by way of professional etiquette inform the author of the junior homonym (in the example 1 Mukerjee) and give the said author an opportunity to propose a replacement name. If the said author is not alive, the reviser can propose a name and in that case it will be courteous to name the taxa after the author of the junior homonym. Example: *Sycophila mukerjeei* Narendran if Narendran is the reviser. In such cases the original author (in this case Mukerjee) of the junior homonym loses the species since it will be now associated with the name of the reviser (here Narendran). A typical example of homonymy which appeared in 1992 is reproduced below to show the bad practice (ethics) still prevailing among some taxonomists.

In 1884 Cameron published a species, viz. *Coruna panamensis* and in 1988a Narendran published *Grisselliella panamensis*. In 1992 Delvare synonymized *Grisselliella* with *Coruna* and the valid species became *Coruna panamensis* Narendran 1988a. Since the species name viz. *panamensis* is preoccupied by *panamensis* Cameron, it was the duty of the reviser (in this case Delvare) to inform the author of the junior synonym (in this case Narendran) to change the name since the author is alive or at least change the name as *Coruna narendrani* Delvare. But this reviser (Delvare) did not follow this simple code of ethics and instead gave a new name *Coruna bouceki* Delvare 1992 after his friend. Such instances of bad ethics are rarely met with in taxonomy.

Meaning of Authors name in brackets

Typically, a species name is followed by the surname of the describing author eg. *Panicum dactylon* Linnaeus. If a reviser viz. Persoon transferred the species *dactylon* to the genus *Solanum* then the name of the author of the species is enclosed in brackets. Thus *Solanum dactylon* (Linnaeus) will be the correct way of representing the species. Another convention is to add the name of the reviser who transferred the species to another genus after the original author's name in brackets. For instance in the above mentioned example of *Solanum dactylon* it will be as follows:

Solanum dactylan (Linnaeus) Persoon. Adding the reviser's name in such cases is strictly followed in Botany but not in Zoology.

Another convention is followed by some revisers. Here the reviser puts the original generic name after the author's name to show under which genus the species was originally described.

Eg. *Brachymeria lasus* Walker (*Chalcis*)

If the author's name or the date of publication is put in square brackets it indicates that the name has not been taken from the original publication. The use of square brackets shows that the name is taken from sources other than the original work. There should not be any coma, semicolon or colon between the name of the species and the name of the author. However there should be a coma between the name of the author and the year of publication. For instance: *Ormyrus shonus* Narendran, 1999.

The Law of Priority

According to this rule, the valid name of a taxon is the oldest available name applied to it, provided it conforms with the rules of nomenclature. The rule of priority is to promote stability of the names. The word 'Priority' actually denotes 'priority of publication' When more than one correct name is available for a taxon, the valid name will be the earliest legitimate name in the same rank. This can be illustrated by the following example. The insect species *Epitranus erythrogaster* was described by Cameron in 1888 and the same species was described by several authors as follows:

Epitramus erythrogaster Cameron, 1888

Anacryptus sculpturatus Crawford, 1910

Anacryptus kankauensis Masi, 1933

Arretoceroides ceylonensis Mani, 1936

Since Cameron's name *E. erythrogaster* is the earliest legitimate name, it is accepted as the valid name (senior synonym) and according to law of priority all others become its invalid names (junior synonyms). Another interesting case is as follows: Cameron in 1897 described a species, viz. *Hockeria maculipennis* (under the generic name *Temnata* which is a synonym of *Hockeria*) since the name is already preoccupied by *maculipennis* (De Steffani, 1887) a case of homonymy has arisen here. The name *H. maculipennis* Cameron had to be changed. The new name available was its junior synonym *Hockeria tristis* Strand, 1911 which was then selected as the valid name for *Hockeria maculipennis* described by Cameron.

If two names for the same taxa is published simultaneously, the first reviser can select the better known name than the other one even if this one (the latter little known one) has line or page precedence (which is not priority). If a new name is spelled in more than one way in the original publication, the first reviser has to select the spelling which is most commonly used.

Rejection of names

A published name which does not meet the requirements of rules of nomenclature is considered a *Rejected name*. Anyone (or more) of the following situations lead to the rejection of names.

1 ***Nomen nudum*** : A published name which does not meet the requirements of rules of nomenclature. Names published after Linnaen period should have diagnosis or description followed and in the case of genera with a designation of type species. A manuscript name is an unpublished *nomen nudum*.

2. ***Nomen confusum*** : This is used for a name (mostly in Botany) which is based on a type consisting of two or more entirely discordant elements. If an author publishes (unknowingly or knowingly) a new taxa based on a type specimen of plant which has a bud with inflorescence of another taxa attached artificially by a person purposely or not, the name is known as nomen confusum and will be rejected as per code of nomenclature.

3. ***Nomen dubium*** : When a name of a nominal species for which available evidence is insufficient to permit recognition of the taxonomic species to which it was applied, then that name is known as *nomen dubium* and will be rejected. It is an available name whose genus cannot be identified and this name although is a correct name of some species but which one is not known.

4. ***Nomen oblitum*** : If a senior synonym has not been used for 50 years or more since its formation, it is considered as a 'long forgotten name' and loses its validity as per the pre-1973 code of zoological nomenclature. In such a case, the competing junior name which was widely used during that period becomes the valid name. However, there were strong criticisms in the commission for this rule and it was later specified that such junior names had to be used by at least five different authors in at least ten publications during this 50 year period in order to make the rare senior name invalid.

5. ***Nomen conservanda*** : When widely used junior names are considered valid against strict priority of using many little known senior synonyms, these junior names are considered names or *nomina conservanda* by the code of zoological and botanical nomenclature.

6. ***Nomina rejecta* or *rejicienda* or *rejicunda*** : When a name is rejected by the commission of zoological or botanical nomenclature it is known as rejected name.

7. ***Nomina ambiguum*** : In botany a name will be rejected when it is used for different taxa and become a source of mistake.

Names of Hybrid Plants

If the names are given for hybrid plants, the name is indicated by multiplication sign between the names of taxa and the expression is known as 'hybrid formula'

Eg : 1. *x-us indicus* x *y-us orientalis*

2. x-us x y-us

A hybrid may be interspecific or intergeneric. For an intergeneric hybrid, a distinct generic name is given and name is formed as a 'condensed formula' by using the first part or whole of one parental genus and last part (or whole) of another genus (but not the whole of both genera) (Singh, 1999). A cross sign is placed before the generic name of the hybrid.

Eg. Agropogon from *Agrotis* and *Polypogon*. The name may be written as follows :

X *Agropogon* (*Agrotis X Polypogon*).

Tautonyms

Tautonym is a name of a species (or subspecies) in which the specific epithet or subspecific epithet exactly repeats the generic name.

Eg : 1. *x-us x-us x-us*.

Eg : 2. *Tumidicoxa tumidicoxa tumidicoxa*

The use of such name is permitted in Zoology but not in Botany.

Nomen novum or Replacement name

When an original name is preoccupied, a new name or a replacement name has to be given. This happens in the case of homonyms.

Preoccupied names

Preoccupied name is a name already in use for another taxon. It is the name of a junior homonym.

BIOCODE

There are five different international codes of nomenclature. They are:

a) International Code of Zoological Nomenclature (ICZN) for animals.

b) International Code of Botanical Nomenclature (ICBN) for Plants.

c) International Code for the Nomenclature of Bacteria (ICNB) or Biological Code (BC).

d) International Code of Nomenclature for Cultivated plants (ICNCP).

e) International Code of Virus classification and Nomenclature (being finalized).

In this book, only the ICZN and ICBN are considered. Since there are five different codes of nomenclature and they differ in some or many aspects, it always creates confusion in the minds of taxonomists and others in the proper interpretation of rules. Recently, a great deal of discussions has been made from different quarters to develop a uniform biological code by harmonizing all the available codes. The drafts of this code has already been prepared in 1995 by the International committee for Bionomenclature and published from the Royal Ontario Museum, Canada.

The type and its importance

In nomenclature, an object that serves as basis for the name of a taxon is known as the type. The methodology used for fixing a type is known as 'typification' and the type may or may not be the most typical member of the taxon. It only fixes the name of particular taxon and the two are permanently and intimately associated. In taxonomy a species is held to have only one correct name and the type associated with that name is the type of that species. The type forms the basis for taxonomic description and the taxonomic description contains mainly the features of the type. The type of a genus is the type species and the type of a family is the genus. The type helps the reviser to find out the real features of the species when the original description of the species is poor or inadequate. The type of the species belongs to science when it is published and it no longer becomes the sole property of the author. Every bonafide taxonomist is entitled to examine the type when required. In many cases the type shows only part of the characters of the species. The type specimen is specifically chosen by the original author or a later taxonomist. The type-series of a species consists of all the specimens on which the original author bases his species (except any that he considers as variants).

Kinds of Types

Mayr *et al.* (1953) and Blackwelder (1967) gave accounts of several kinds of types. However the code of Zoological Nomenclature recognizes only the following six types :

1. **Holotype** : It is a single specimen selected by the original author to represent the taxon and so designated or indicated as the 'type' at the time of publication of the original description.

2. **Paratype** : After labeling the holotype, any remaining specimen(s) of the holotype series can be labeled paratypes in order to identify the individuals of the original type series.

3. **Lectotype** : If a type series contain more than one specimen and a holotype has not been designated, any subsequent worker may designate one of the specimens as the lectotype.

4. **Syntype** : If the author did not designate a holotype or lectotype but based his original description of a new species on single specimen or group of specimens, they are known as syntypes.

5. **Neotype** : If no holotype, lectotype or syntype is known to exist (or has been lost), then the first reviser of the group may select a specimen which is fully fitting to the original description of the species. A type specimen chosen in this manner is called a neotype.

6. **Allotype** : According to the rule 72 A of Zoological code the term 'allotype' may be used to a 'paratype' specimen of the opposite sex to the holotype. Most recent workers have abandoned this term in their works.

The code of Botanical Nomenclature recognizes the following kinds of types :

1. Holotype, 2. Paratype, 3. Lectotype, 4. Syntype and 5. Neotype.

All these are the same as for zoological nomenclature. In addition to the above, the following types are also recognized by the botanical code. They are:

1. **Isotype** : This is a specimen which is a duplicate of the holotype with the same collection data of the holotype.

2. **Epitype :** A specimen or illustration selected to serve as an interpretative type when the holotype, lectotype or neotype (all original materials associated with the validly published name) cannot be critically identified for the purpose of application of the name of the taxon.

Type designation

An author when publishes a new species, the following data concerning the holotype should be given :

1. The exact collecting locality and other information on the labels of the specimen.
2. Its sex.
3. Its developmental stage, caste, if the taxon includes more than one caste.
4. In the case of parasites, name of the host species.
5. Name of the collector.
6. Collection in which the holotype is present (Repository) and any collection number or register number assigned to it.
7. Altitude of the type locality or depth in meters below sea level at which the holotype is collected.
8. In the case of fossil species, geological age.
9. Size of holotype or size of one or more relevant parts or organs.

The term 'Typology' and 'Type method' are entirely different. The former is a concept (Type concept) which is based on the idea that all members of taxonomic category confirm to a 'type' and this 'typology' concept does not recognize variation within the taxa. The latter term 'Type method' is the method by which the name for a taxon is preserved by fixing a definite specimen as the 'Type' and thus the name for the taxon is undoubtedly associated with this fixed specimen of the taxon.

CHAPTER 8

PUBLICATION

A scientific name becomes valid when it is published according to the code of nomenclature. According to the latest rules, in order to get a name of a new taxon valid and published, the name should have a diagnosis which will help to differentiae the new taxon from other taxa.

A work is to be regarded as published :

1 If it is issued publicly for the purpose of providing a permanent scientific record.
2. It must be obtainable when first issued, free of charge or by purchase to any institution or individual who might desire it.
3. If the paper in produced before 1986, it must have been produced on paper with an ink of a quality and durability by conventional printing so as to become a reasonably permanent document.
4. A work produced after 1985 by a method that does not employ conventional printing is to be accepted within the meaning of code if it meets the other requirements mentioned above.

Not withstanding the condition 1-4 mentioned above, none of the following procedure constitutes a publication :

1 Hand writing reproduced by some mechanical or graphic process (if after 1930 as per code of zoological nomenclature).
2. The publication in news papers is not considered effective publication (in botany).
3. Microfilms, proof sheets and computer printouts are not considered as effective publication for a name to become valid or available.
4. A printed pamphlet for distribution only to colleagues or students.
5. A thesis or any other document deposited in a library or other archive.
6. The date of publication is the date on which the publication is mailed to research workers or institutions or to subscribe or placed on sale or distributed free of charge. For instance, if a volume of a journal of the year 1986 is mailed only in 1989, it is considered as published in 1989.

Eg. Though the publication containing the description of the new genus *Tanushyama* Narendran (Hymenoptera : Chalcididae) was sent to the journal 'Bioscience Research Bulletin' in 1987, the journal was printed and mailed only in 1989. In the meantime another author, *viz.* Dr. Z. Boucek published the same taxon in a separate publication in 1988 under the name *Steninvreia* Boucek. Thus the genus name *Tanushyama* Narendran became a junior synonym of *Steninvreia* Boucek even though the volume of the journal in which the genus *Tanushyama* appeared, has the year 1986 printed on it, but the actual year of publication of the volume was 1989 and not 1986.

If more than one name is published for the same taxonomic unit in the same research work or book or journal etc. the name printed on the earlier pages of the concerned publication will have precedence. If two or more names are printed in the same publication, the first appeared name will take precedence. However, the priority can be decided by the first reviser giving serious consideration to the recommendations of latest code of nomenclature. If one of the two competing names is based on a better description or is based on better type material or is better known or has some other nomenclatural advantage, this name can be selected by the first reviser. Chronological priority is not involved in the case of simultaneous publication and is replaced by designated priority in Zoology (Mayr & Ashlock, 1991).

Valid name and available name

There is a clear difference between the valid name and the available name. The latter denotes that the name is properly published according to the requirements of the code. It may be a valid or invalid name. The valid name denotes that it is not preoccupied by a senior synonym or homonym and it is published in accordance with the provisions of the code.

Kinds of Publications

There are various kinds of taxonomic publications. Each kind has its own importance and usefulness. The following are the main kinds of publication :

1. Short Research Papers

In this type, the taxonomist usually publishes description of a single or a few genera or subgenera or species or subspecies or combines all of these or some. It may or may not contain a key for identification. It may also contain a brief checklist of taxa dealt with. Some other short papers may contain sometimes new host records or distribution or any other matter of taxonomic importance. When a group is worked out almost completely and published as a monograph or revision, it may be necessary to publish the description or descriptions of one or two or more new taxa discovered later as a separate short paper or papers since there will not be any scope for the immediate publication of a larger kind. Sometimes an animal or plant may become important economically and identification becomes urgent and in such case it will be absolutely essential to publish its description if it is a new taxon. In such case, the taxonomist publishes short papers giving the description of such species. There are several other similar occasions when it is necessary to publish short taxonomic papers. However publishing many short papers is not desirable when it is possible to produce a monograph or revision. The publication of many such short papers when one would be sufficient is a problem all taxonomists must confront with, not only in their conscience but in the eyes of their colleagues (Narendran, 1988b).

2. Revision

The revision is a restudy of a complete unit of a particular group of taxa. This involves examination of all the relevant types of known (or published) taxa and reevaluation of the status of the published taxa. It also involves publication of new taxa discovered in the group. Such revisions may contain redescriptions or diagnosis of little known taxa, list of synonyms of each taxon, new synonymy, new combinations, new names etc. along with keys.

A revision usually deals with a Superfamily or family or part of a family. It can also deal with a genus or a species group. Generic revisions and species revisions are usually published by most taxonomists. The following are few examples of revisions :

Bouček, Z. and T.C. Narendran. 1981 Indian Chalcid Wasps (Hymenoptera) of the genus *Dirhinus* parasitic on synanthropic and other Diptera. *Syst. Ent.,* (London) **6** : 229-251

Bouček, Z. 1951 The first revision of the European species of the family Chalcididae (Hymenoptera). *Acta. Ent. Mus. Natn. Pragae* 27, Suppl., **1** : 5-108.

Hayat, M. 1983. The genera of Aphelinidae of the World. *Syst. Ent.,* **8** : 63-102.

Lasalle, J. 1994. North American genera of Tetrastichinae (Hymenoptera : Eulophidae).

3. Monograph

This is the most important among all taxonomic publications. It involves revision of the taxa selected for the monographic work, brief biology and behaviour, distribution, catalogue or checklists, affinities, phylogeny, etc. The monograph gives detailed treatment of morphological and geographical variation of relationships. A monograph usually requires at least a minimum of 3-5 years for completion.

Examples of monographs are :

Michener, C.D. 2000. The bees of the world. John Hopkins University Press, Baltimore Maryland : 1-913.

Narendran, T.C. 1999. Indo-Australian Ormyridae (Hymenoptera: Chalcidoidea) A systematic monograph. Department of Zoology, University of Calicut : 1-227.

4. Faunal/Floral Works

It mainly consists of a list of names of a group of taxa of a particular area or region. It may include information on geographical distribution. It need not make any clarification of taxonomic problems. It often becomes very useful if it also contains quantitative data and ecological comments. The report of expeditions also belongs to the category of faunistic papers. The faunal works also give opportunities to describe new species and genera.

Example of faunal works

a. Fauna of India and Adjacent countries covering many groups of animals, published by the Zoological survey of India, Calcutta.

b. Saldanka, C.J. & Nicolson, D.H. 1978. Flora of Hasan District, Karnataka, India Aravind pub. Co., New Delhi.

5. Synopses and Reviews

These include short summaries of current knowledge of a group. They help to compile all scattered information on a group together in one volume or paper. The synopsis and reviews form a good foundation for further detailed revisions and monographic works.

Examples

a. Burks, B.D. 1971 A synopsis of the genera of the family Eurytomidae. *Trans. Amer. Entomol. Soc.,* **97** : 1-89.

b. Rao, R.R. & B.A. Razi, 1981 *A synoptic Flora of Mysore District.* New Delhi.

c. Noyes, J.S. and Hayat, M. 1984. A Review of the genera of Indo-Pacific Encyrtidae (Hymenoptera : Chalcidoidea). *Bulletin of the British Museum (Natural History) Entomology,* **48**(3) : 131–195.

6. Handbooks and Manuals

This is primarily meant for identification of fauna or flora in the field. Here important key characters are provided and amply illustrated. No descriptions of taxa are provided except brief diagnoses of known taxa. An illustrated key is usually provided.

Example :

a. Grissell, E.E. & Schauff, M.E. 1990. *A handbook of the Families of Nearctic Chalcidoidea (Hymenoptera).* Entomological Society of Washington, Washington, D.C. : 1-85.

b. Bond, J. 1947. *Field guide to birds of the West Indies.* The Macmillan Company, New York : 1-257.

7. Catalogues and Checklists

A catalogue consists of an upto date list of names of a particular group of taxa with detailed references on it. It also includes information on Type locality, depository, hosts, distribution, etc. A checklist in the other hand does not contain references and other information such as hosts, type information, etc. It consists of only a list of valid names and synonyms with year of publication and a broad indication of geographical distribution. The style of checklists usually varies slightly from group to group.

The catalogues and check lists are extremely useful to know how many species or genera are reported from an area, what are the synonyms etc. involved, known host record, type depository, etc. If a catalogue is available, lot of time can be saved from searching zoological or botanical records or other abstracts.

Examples

Subba Rao, B.R. & Hayat, M. 1986. A catalogue of chalcidoidea of India and the adjacent countries. *Oriental Insect* 20 : 1-429.

Sasidharan, N. 1997. Forest Trees of Kerala – A checklist. *KFRI Handbook* No. 2. Kerala Forest Research Institute Peechi.

8. Atlases

Atlases consists of illustrations of the species of various taxonomic groups. They may be diagrammatic or actual drawings or photographs or semi-diagrammatic drawings. Atlases are very useful when the description of a taxon is inadequate to show the characters clearly.

Major features of Taxonomic publications

Descriptions

In taxonomic publications, description of new taxa is one of the most important aspects. In olden times, the authors used only very superficial morphological characters, which they could observe with their naked eyes or through crude hand lenses. Microscopes were not available for them to study microscopic organisms or microscopic structures of large organisms. For the same reasons, their descriptions were mainly brief and unhelpful for proper identifications and conclusions. In later years, microscopes were invented and more and more morphological features were studied and described. Today scanning electron microscope provides excellent opportunity to study the detailed external morphology of organisms.

When a new taxon is described, its description should contain three divisions or parts. The first part is "Diagnosis" Under diagnosis, the salient features by which the taxon can be distinguished from all related taxa are provided. The second part contains the "General description" Under this, detailed morphological features (both important and unimportant) are given. The more detailed the description, the better it will be for easy recognition of the taxon. One set of unimportant features of today may prove to be important, sometimes in future. Hence detailed description of all characters whether important or not should be given under this part. For a good taxonomic description, the author needs to have a thorough knowledge of the taxa concerned. He should know the latest terminology. A beginner in taxonomy can learn to describe a taxon by studying the various published descriptions of related taxa by good workers in the same field of specialization. He can take all or part of all points from all these papers and add his own selection of characters of the taxa.

The sequence of characters in a description differs from diagnosis to general description. In diagnosis, only the important diagnostic characters according to their order of importance are given. This order of importance is decided by the author. In full description, the details may vary from group to group but always in a uniform pattern. For instance, in the taxonomic descriptions of species of Chalcidoid wasps (Insecta: Hymenoptera: Chalcidoidea), usually the colour of the species is given in the first paragraph after the body length. In the case of some other groups, colour is given only at the end of the description. The second paragraph gives details of head and its appendages. In the third paragraph, details of thorax and its appendages are given. In the fourth paragraph, abdomen and its apical associated structures are described. The sequences of characters under each category differ from group to group. The third part of general description is known as "Discussion or Remarks" Under this, the author compares the taxon with related taxa giving its similarities and differences. Details on Hosts, habitat, distribution and material examined are provided before discussion. The description should be supplemented and supported with good illustrations of the diagnostic features of the taxon. Some of the features which cannot be amply and appropriately described can be illustrated by giving a drawing or photograph of the relevant part.

The description published by an author of a new taxon for the first time is known as the "Original description" All subsequent descriptions of the same taxon by the same or other author are known as 'Redescription" Redescription of a poorly described taxon is perhaps of greater importance than description of a new taxon. The specimen or specimens on which a redescription is based should be clearly indicated in order to make sure by the subsequent authors that the specimen on which the redescription is made actually the same as the originally described taxon. Mayr *et. al.* (1953) states that the name "Plesiotype" can be given to the specimen on which a redescription is based if that is identified from the available description without actually seeing the type.

Preparation of Taxonomic papers

Title : the title should contain the main finding of the paper. It should consist of the scientific name of the groups treated such as Order, Family, etc. in parenthesis or rarely by a well known common name, a geographical area or locality. The following are examples of good titles:

1. "Three new species of Chalcid parasitoids (Hymenoptera: Eulophidae) of Western Ghats of North Kerala (India)"
2. "A generic revision of the megachiline bees of Western Hemisphere (Hymenoptera: Megachilidae)"
3. "A review of the ants (Hymenoptera : Formicidae) of India"

The following are some examples of bad titles for taxonomic papers.

1. "A new mammal from Asia"
2. "On some Indian insects"
3. "Additions to the flora of Africa"

Such titles will not be of use for cataloguing, abstracting, etc. and specialists will not be able to understand whether these papers contain organisms of their interest or specialization, since the titles are vague and non - specific.

Author's name : The title is followed by the author's name and full address including E-mail ID, if there is any. It is always better to use the same name in all papers without making any modifications or changes. Degrees and titles of authors are usually avoided. When more than one author is involved, the priority of becoming first, second, third, etc. of authorship depends on the nature of contribution each author has made. An author who contributed largely to the paper becomes the first author and the one who contributed least becomes the last one. When all the authors equally share the work, then the authorship is arranged either in alphabetical order or according to seniority in position or age.

Abstract : A relatively short paragraph giving the important findings of the paper should be given in abstract in all taxonomic papers.

Keywords : Many research journals insist that keywords should be given. Usually not more than 8 words are given as key words. For instance, if the paper deals with a new species of a Eulophid parasitoids from Kerala, the keywords can be as follows: "New species, Eulophidae, Kerala, India."

Introduction : All taxonomic papers should contain the scope of the paper, a brief review of the past work on the taxa dealt with in the paper and the reason for undertaking the study.

Materials and methods : Under this, details of collection methods, curating and laboratory equipments used, etc. should be given. Well known methods may be referred to by name and reference. Only new methods need to be given in detail.

Body of the text : This should contain scientific name of each taxon to be followed by list of synonymies, statement of generic types, descriptions, keys to concerned taxa, statement of type localities, etc. mentioned earlier.

Synonymy : In revisions, reviews and in monographs, it is customary to give the complete synonymy of every species/genus in the case of known taxa. New synonymy is usually cited in the following sequence of data: original scientific name, author, date of publication, reference, type locality and present depository. The names of the authors who synonymized the taxa should be mentioned in parenthesis.

Example :

Antrocephalus cariniceps **(Cameron)**

Coelochalcis cariniceps Cameron, 1911. *Soc. ent.,* **26** : 4. Saraswak : Kuching (BMNH) (Narendran, 1985 transferred to *Antrocephalus).*

Coelochalcis denticollis Cameron, 1911 *Soc. ent.,* **26** : 5. Borneo (BMNH) (Narendran, 1986 synonymized).

Sabatiella neduganiensis Mani & Dubey, 1974. *Mem. School Ent. Agra,* No. **3** : 21 India: Nilambur (USNM) (Narendran, 1998 synonymized).

Acknowledgements : This is usually given at the end of the paper before 'References' However, in some papers, acknowledgements are given in the beginning or in the 'Introduction' or 'Preface'

References : This should come at the end of the paper. The author's name with initials, year of publication, full title of the paper, followed by name (or international abbreviation) of the journal, volume number and pages should be given. Each journal has its own style in giving the references.

Preparation of manuscript : This can be prepared in the following ways :

1. Hard copy of white bond paper of A4 size.
2. Floppy diskette.
3. Compact diskette.

Illustrations : This may be in paper or through electronic mail (E-mail).

Proof Reading : Most scientific journals send the galley proof or page proof of the paper to the respective authors for necessary corrections before publishing them. Author's errors are his own responsibility. However, some substandard journals do not implement the corrections made by the author in the proof and put the above blame on the author.

CHAPTER 9

ETHICS IN TAXONOMY

Not only taxonomy but every branch of Science has a set of ethics to be followed. Hence ethics in taxonomy is only a part of the ethics for science as a whole (Pigman and Carmichael, 1950). Some of the important aspects of ethics to be followed by the taxonomists (and use of communities who seek help from taxonomists) are given below :

Credit

1. When specimens are donated for the study by a taxonomist at his request, the taxonomist must acknowledge the scientist or person who donated the specimen.
2. If any unpublished information received from any others are included in a publication, proper acknowledgements must be made by the author of the publication.
3. If a figure or photograph or any other illustrative material lent or donated by others should be acknowledged. Credit should be given to photographers or artists for their work even if they are paid for their works.
4. If a figure or a photograph is taken from a book or any publication the author should first get permission from the original author (from the publisher) for copying them and the help should be acknowledged in the forthcoming publication.
5. Credit should be given to the persons who collected the specimens.
6. If a senior professor or specialist or colleague is consulted for developing a research project or in the preparation of manuscript or for critically reading the manuscript and offering suggestions, satisfactory and apt acknowledgements should be mentioned in the publication. However, such acknowledgements should not be presented in such a manner that they also vouch for the author's opinion or statements.
7. At the concluding part, acknowledgement should be given for the financial assistance provided by funding agencies which provided the research grants for the work.
8. For facilities given, the head of Institution or authorities should be thanked.
9. If a homonym is discovered, the scientist who discovered the homonym may inform the author of the junior homonym and allow him/her to rectify the mistake. If the author of the junior homonym is not alive, the reviser can give a new name, preferably he can rename after the author of the category.

Lending and Borrowing of Specimens

1. When a researcher publishes a new taxon the type of the taxon (especially the holotype) becomes the property of science and it no longer is his private property. The type should be well protected by the institution which keeps it and bonafide specialist should be allowed to examine it, if he so desires. The author and the institution should have the obligation to respond to any request for information on types. If the authorities involved are unable to shoulder this responsibility, they should transfer their collection to any international repository. Unfortunately, many national repositories in India never follow this ethics and most requests from bonafide scientists remain unanswered.

Loan of Material

Most International Museums and Institutes in Europe and North America cooperate with bonafide taxonomists by giving their materials on loan, whereas the third world countries are not that helpful. A request for a loan of material or type often remains unanswered.

When specimens are given on loan the borrower should complete his studies as early as possible and label each specimen with proper determination labels and return them to the lender. While returning the specimens extreme care should be taken by the borrower in properly packing the material. Narendran (2001) has given a detailed account of packing and shipping of nanofauna of insects (particularly parasitic Hymenoptera). If the borrower would like to retain any specimen from the borrowed collection, he should get prior permission from the lender. However, in no case the primary types can be requested for retaining permanently by the borrower unless the lender willingly asks the borrower to retain them if the lending authority is planning to deposit the type in the borrowing institution if there is no permanent facility for the specimens in the lending institution. It is always better that an agreement on the division of the borrowed material be made at the initiation time of the lean so as to make it clear which specimen/specimens can be retained and which are/is not retained by the borrower.

Exchange of Materials

Exchange of specimens with other workers is always advantageous for a taxonomist since by this method he can enhance the diversity of taxa in his collection. It will not be in good taste to insist upon exchanging specimen for specimen. It will be always better to have a generous policy in exchanging material, trying always to help each other rather than exchanging the specimen as a business.

Collaboration and Cooperation with Fellow researchers

It is always better if fellow researchers know from each other what they are doing in order to avoid duplication of work. A few years ago two taxonomic chalcidologists worked on a revision of Aphelinid genera of the world without each other knowing what they were doing until both of these scientists published their works. This became a real waste of time and effort. It is always better not to do the taxonomy of a group of taxa in which another scientist is working. Of course this procedure should not be abused. For instance, if a taxonomist has worked on a group of taxa of his country for two or three years he should not be asked to stop his work by some one else from another part of the world on the pretext of his working in a world basis. There are a number of such instances where one who wants to do a world revision of a group, writes impolite (often arrogant letters) to the other taxonomist who works on a regional or country wise basis. The best way to solve the problem is either to collaborate with the regional worker or wait till the regional worker completes his work and publishes his findings.

Use of Language

A taxonomist should always avoid intemperate language in discussions or reference to the works of other workers. Mutual mistrust among fellow workers should not be allowed to end in using unethical language in scientific papers while criticizing. Even without using bad language one can politely point out the mistakes.

Similarly while naming a taxon it is not appropriate to make any indirect reference, or mock any religious or personal sentiments of others. For example: *Thomsonia knownothinga, Jehovahella eudemonia,* etc. are in bad taste and may hurt others. The commission of zoological nomenclature in 1948 Paris condemned the selection as a generic name a word which is an arbitrary combination of letters but appears to be bizarre or comic or otherwise objectivable in another language, other than Latin. The commission also ruled that names which may hurt others on political, religious or personal grounds in any language are prohibited and will be suppressed if the same is brought to the consideration of the International commission.

Ethics of Taxonomic Publication

An author of a taxonomic paper should not make an attempt to attack personally the work of others as pointed out earlier. Criticism can be done but only in a dignified and courteous manner. The mistakes of others committed can be pointed out or rectified in a constructive manner. By personal attack an author only loses his personal reputation than to the worker with whom he disagrees. Emotional phraseology and controversy should be avoided in taxonomic papers. Using the first person pronoun too often in a taxonomic work is in bad taste. Usually internationally recognized authorities can use first person pronoun in his papers but only occasionally. Referring to the merits of ones own work in the papers will also give chances to others to look down upon the user of such language. It is wrong to think that others will heed to ones own self ratings.

Authorship of taxonomic papers

It is not advisable to have several authors associated with a name of a single taxon. This will create difficulty in citing these names since it will be too lengthy and unwieldy. It is also unlikely that more than one actually collaborated in the identification of a new taxon. Some of the heads of institutions or departments compel the subordinate workers and students to put their names as first authors of the papers for which they have contributed nothing. Such practices are against all norms of ethics in taxonomy or in any other branch of science. The best way to deal with multiple authorship is to use only the name of the actual author who identify and describe the taxon with the name of the taxon and put all others as coauthors of the paper. For instance a paper entitled "A new species of *x-us albus*' can have multiple authors but the species name will have only one author *x-us albus* Jones sp. nov. This will give credit to all but not create confusion. Such practice is widely followed by most recent taxonomists.

Correspondance

A taxonomist often finds it essential to correspond with other taxonomists requesting for information on types, reprints of publication and references of taxa. While requesting reprints one has to be specific and should not ask in general terms. For instance, if one wants several reprints of the author he has to explain briefly in his letter how far he has done his work and what are his future plans. He should also include copies of his publication along with the request. Without giving such background knowledge an established worker may not be willing to spare his numerous research papers (reprints). When one receives the reprints, it should be acknowledged. If there is any expense incurred by the sender of the reprints, by way of postage, it is necessary for the recipient to offer the expenses involved. While requesting reprints, the title of the paper, journal in which it was published, and the year should be written clearly instead of requesting "all your research papers", etc. Most authors will not respond to such requests. Requests for loan of specimens should also be specific with brief description of the work so far done by the borrower and what he intends to do. He should also state that he will take utmost care in handling the specimens while studying them and pack them properly in the same way as they were received. The specimen should be returned as early as possible. All the specimens should be labelled with determination labels. While returning it will be nice to add a few paratypes or other identified specimens of the borrower as donation to the lending institution. This will be a good gesture for receiving further loan of material from the lending institutions.

While writing letters one should avoid including anything private which he otherwise does not like others to read. This is because all such letters may form semi official letters and it is likely that many others in the office or laboratory may also read these letters. It will be in the best interest of the sender of the letter to keep carbon copies of the letters he sends out, scientific record for future researchers for self defense. In recent times, most scientists prefer to use electronic mail though internet instead of the 'slug speed mail' However, both corresponding scientists should write for hard copies for files in the case of loan of materials and for other similar documents, for the safety of the lender as well as of the borrower.

Taxonomists and user communities

Not only the taxonomists who should follow the ethics in taxonomy as mentioned above, the user communities who seek help from taxonomist also should know some of the ethics they have to follow. Some of these are given below.

1. Some send specimens for identification to taxonomists without getting prior permission from them. As a result the sender may not get a prompt reply or he may not get his specimen identified quickly. This is because the taxonomist may be busy at that time and normally he would have asked the reader to wait for some time to send the material till he completes his ongoing work. In some other instances, the taxonomist may be out of station and his subordinate may inform the sender to wait till the taxonomist returns. It is always courteous to write first and ask for permission before sending the specimens.
2. Some users irritate the taxonomist by repeatedly sending reminders to them for speedy identification although the sender can state in his first letter politely how important the identification is for his urgent work. After all, the specialist does not owe any such service to the sender of specimens and he may be busy with other research work of his interest and there may be several other requests from several other sources for help.
3. Since most specialists agree to identify specimens free of charge just for the sake of science, it is courteous and sometimes expected that the sender of specimens allows the specialist to retain at least some of the specimens of his choice. This is only a small compensation for the free service by the specialist. Some senders are reluctant to extend such courtesies.
4. If there is any new taxon identified by the specialist, he has every right to publish the description of the new taxon since it is his expertise of several years' that helped in the identification of the specimens. Hence it is inappropriate on the part of the sender of specimens to publish the taxonomic description of the new species or genus before the specialist does it. The sender can at the most request the specialist to publish the new name and description as early as possible so that it can be validated and used for further work. In such cases, most specialists will oblige and some specialists may even put the sender's name as co-author of the paper, if the sender is interested in doing so. (However good workers who send specimens to specialists usually do request the

specialist not to include their names as co-authors since they have not contributed anything to the taxonomic study by the specialist or to the paper the specialist publishes).

5. Often senders do not take care in properly packing the specimens while dispatching them to the taxonomist. As a result, the taxonomist receives badly damaged specimens he will not be able to identify.
6. Some send unsorted materials containing several diverse orders or classes or families to a specialist who has specialized only in one particular order or subfamily or family. This gives added burden to the specialist for preliminary separation which the sender himself could have done before sending the specimens.
7. Some senders do not give relevant data on hosts, localities seasonal details, etc. of the specimens to the taxonomists. All such relevant data concerning the specimens, if available will help the specialist to identify the specimens more quickly and easily than without such data. Some students among senders of specimens may withhold such relevant details thinking that the specialist will publish them as 'new host record', etc. This is ridiculous since the specialist will be least bothered about publishing such small notes since he has much more important work to publish and he may have several hundreds of such unpublished host records, etc. with him.
7. Some senders usually send only very few specimens to the specialist even if they have plenty of specimens to spare. Sending as many specimens as possible will help the specialist to take care of the variations within the taxa and to dissect out one or two specimens to study the genitalia, mouth parts, etc.
8. Some senders after getting identification results from the taxonomist, fails to acknowledge this help while publishing papers mentioning the determination made by the taxonomist.

Suppression of relevant details

No good taxonomist will deliberately suppress any relevant details while publishing his findings. However this sometimes happen inadvertently or through carelessness. For instance, failure to include details of variation in taxa, failure to mention of specimens which show intermediate features of two relevant taxa, etc. Disclosing such information will prove helpful for future studies. When many scientists give help to a taxonomist, it is possible that he may fail to include the name of one or two scientists in the acknowledgement list inadvertently. This is not good etiquette and one has to be careful in not omitting anyone in acknowledging the help.

Similarly, a scientist may give details of an unpublished synonymy based on his own work to a reviser and the reviser may sometimes fail (unintentionally) to mention that the information is based on the unpublished information given by so and so. This action on the part of the reviser may not be deliberate but happens inadvertently. One has to be careful to see that such mistakes are not avoided.

Acknowledgements

The author is grateful to the authorities of the University of Calicut for facilities to work. He thanks Dr. P.T. Cherian, Former Additional Director, Zoological Survey of India, Chennai; and Sri. C. Radhakrishnan, Officer-in-Charge, Western Ghats Regional Station, Zoological Survey of India, Calicut for critically reviewing the manuscript. He also thanks his doctoral research students Dr. K. Rajmohana, Dr. K. Sudheer, P. Girish Kumar, S. Santhosh, M. Sheeba and M.C. Jilcy for assistance in the preparation of this work. The author also thanks Dr. K.P. Rajesh, Botany Department for providing various literatures on plant taxonomy.

CHAPTER 10

GLOSSARY RELATED TO TAXONOMY

(Note : Only important words used in taxonomy are given This includes also words which are not mentioned in this book but are used in taxonomy)

Affinity : Relationship

Agamic : A species or generation that does not reproduce sexually

Agamospecies : An asexual species whose members are of common origin

Allele : Any of the alternative expressions of a gene

Allochromatic species : Species which does not occur at the same time level.

Allopatric : Populations or species that occupy mutually exclusive geographic areas.

Allopatric hybridization : The crossing of individuals belonging to two allopatric populations in a zone of contact.

Allopatric speciation : Formation of species during geographical isolation.

Allospecies : A component species of a subspecies

Allotetraploid : An individual or species with the doubled chromosome number of a sterile species hybrid.

Allotype : A paratype of opposite sex of Holotype

Alpha taxonomy : The level of taxonomy concerned with the naming and describing of species.

Amphiploid : A polyploid produced by the chromosome doubling of a species hybrid (= an individual with two different sets of chromosomes).

Anagenesis : Divergent, or upward, evolution

Anagenetic changes : The accumulation of changes in ancestor-to descendant lineages.

Analogy : Phenotypic similarity that is due not to common descent but to similarity of function.

Apomixis : In plants reproduction by parthenogenesis.

Apomorphic : A more derived state in an evolutionary sequence of homologous characters.

A posteriori weighting : The empirical weighting of taxonomic characters on the basis of their proved contribution to the establishment of sound classification.

A priori weighting : The weighting of taxonomic characters on the basis of preconceived criteria, e.g. their physiological importance

Archetype : A hypothetical ancestral type constructed by means of elimination of specialized characters.

Artificial classification : Classification based purely on convenient characters without indicating any phylogenetic relationship.

Atlas : A method of presenting taxonomic materials by means of illustration.

Autopomorphic : Pertaining to Apomorphic characters found in only one or two sister groups.

Authority citation : The practice of citing the name of the author of a scientific name or name combination (e.g. *Brachymeria manjerica* Narendran) .

Available name : A name published in a manner that satisfies the requirements specified in Article 8 of code 20.

Beta taxonomy : A taxonomic level concerned with the arrangement of species into a natural system of lower and higher taxa.

Bibliographic reference : For nomenclatural purposes, the citation of the name of the author and date of publication of a scientific name, place of publication & journal with number, volume, etc.

Binary : Refers to designations consisting of two kinds of names

Binomen : The scientific designation of a species; consists of a generic name and a species name.

Binominal nomenclature : The system of nomenclature, adopted by the International Congresses of Zoology and Botany, by which the scientific name of an animal or plant, is designated by both generic name and a specific name.

Biological classification : The arrangement of animals or plants into taxa on the basis of inferences concerning their genetic relationships.

Biological race : Strains of a species which are alike morphologically but differ in some biological way.

Biological species : A concept of species based on the reproductive isolation

Biota : The flora and fauna of a region

Biotype : A population or group of individuals of identical genotype, a race.

Catalogue : An index to taxonomic literature arranged by taxa so as to provide information about the most important taxonomic and nomenclatural references to each taxon covered.

Category : In Taxonomy, designates rank or level in a hierarchic classification, or a class, the members of which are all taxa assigned a given rank

Chaetotaxy : The arrangement of bristles or setae.

Character : In Taxonomy any attribute of a member of a taxon by which it differs or may differ from a member of a different taxon.

Character index : A numerical value, compounded from the ratings of several characters that shows a degree of difference among related taxa.

Character matrix : A table of taxa and characters in which characters are coded to indicate the sequence from ancestral to derive.

Character state : One of at least two specific characters that constitute a signifier, such as long or short hair

Character transformation series : A series of homologous characters which, when placed into a primitive to derive sequence, becomes an evolutionary transformation series.

Checklist : A skeleton classification of a group listed by taxa for quick reference.

Cheironym : Manuscript name

Chronocline : A character gradient in the time dimension.

Chronospecies : A species delimited in the time-dimension division.

Clade : The species of a phyletic lineage that is derived from a single stem species.

Cladistics : A taxonomic theory by which organisms are ordered and ranked exclusively on the basis of joint descent from a single ancestral species

Cladogenesis : Branching evolution

Cladogram : A branching from a common ancestor, a branching diagram showing the development of a clade.

Classification : The grouping of organisms into classes owing to their joint possession of attributes.

Cline : A gradual geographic change of a character in a series of contiguous populations; character gradient

Cluster : Group of related or similar species

Clustering methods : Methods of grouping related or similar species into species groups or higher taxa.

Code : The International Code of Zoological Nomenclature.

Cohort : An indefinite taxonomic group used in different ways by different authorities, such a group between class and order

Competitive exclusion : The principle that no two species can coexist in the same locality if they have identical ecological requirements.

Complex : A term used for a number of related taxonomic units, especially those in which taxonomy is difficult or confusing.

Congeneric : A term applied to a species agreeing in all characters of generic value with others compared with it. A term applied to species of the same genus.

Conspecific : A term applied to individuals of the same species.

Contemporaneous species : Species occurring in the same time period.

Continuous variation : Variation in which individuals differ from each other by infinitely small steps.

Convergence : The acquisition of a similar character by two taxa whose common ancestor lacked that character.

Convergent polyphyly : Derivation of a group or taxon from only distantly related ancestors that also gave rise to other taxa.

Cope's rule : The generalization that there is a steady increase in size in phyletic series.

Cotype : see syntype

Crown groups : Late or terminal groups in a phyletic lineage

Cryptic species : see sibling species

Curation : Care in preservation of museum specimens

Data matrix : A tabulation of differences between species or other taxa

Delimitation : In taxonomy, a formal statement of characters of a taxon which see its limits.

Deme : An assemblage of taxonomically closely related individuals; a local population of species; the community of potentially interbreeding individuals at a given locality.

Dendrogram : A diagram with branches indicating the relationships of taxa in a classification.

Derived character : A character that differs materially from the ancestral condition

Description : In taxonomy, a more or less complete formal statement of the characters of a taxon without special emphasis on those which set limits to the taxon or distinguish it from coordinate taxa.

Designated priority : In cases of simultaneous publication of several names (more than one name for a taxon) the priority established by the first reviser.

Diagnosis : A statement of most important characters that distinguish a taxon from other similar or related taxa.

Dichopatric speciation : Division of a parental species by geographic, vegetation or other extrinsic barrier, with the isolated portions eventually reaching species status.

Dichotomous : Divided into two parts

Differential diagnosis : A statement of important features which are used for clear cut differentiation of a given taxon from other specifically mentioned equivalent taxa.

Discontinuous variation : Variation in which the individuals of a sample fall into definite classes that do not grade into each other.

Discriminant function : The sum of numerical values of certain diagnostic characters multiplied by calculated constants.

Downward classification : Classification from the largest class downward.

Ecological race : A local race that owes its most conspicuous attributes to the selective effect of a specific environment.

Ecophenotype : A non genetic modification of the phenotype in response to a particular environmental condition.

Ecospecies : A group of populations so related that they are able to exchange genes freely without loss of fertility or vigor in the offspring.

Ecotype : A term applied to races (usually of plants) of varying degrees of distinctness that owe their most conspicuous characters to the selective effects of the environment

Emendation : In taxonomical nomenclature, an intentional modification of the spelling of a previously published scientific name.

Equal weighting : The method that treats all taxonomic characters as equally important.

Essentialism : A concept of Plato, Aristotle and Linnaeus in which the observed diversity of universe reflects the existence of a limited number of types and the variation is not taken into account

Euclidean distance : A coefficient measuring the distance between two taxa in multidimensional space.

Evolutionary taxonomy : A kind of classification based on evolution of characters.

Exclusion principle (Gause's principle) : The principle stating that two species cannot coexist at the same locality if they have identical ecological requirements.

Ex-group : A group descended from a monophyletic group which renders that group paraphyletic.

Extrinsic isolation : The non genetic isolation of populations by extrinsic factors such as geographical isolation and the isolation produced by some host-plant mechanisms.

Family : A taxonomic division consisting one or more genera agreeing in one or a set of characters and so closely related that they are apparently descended from one stem.

Family group : Consisting of superfamily, family, subfamily, tribe and subtribe.

Faunal work : A publication in which taxa are included on the basis of their occurrence in a specified area rather than on the basis of relationship.

First reviser : The first author to publish a definite choice of one among two or more conflicting names or zoological interpretations which are available under the code of zoological nomenclature.

Formenkreis : A collective category of allopatric subspecies or species.

Gamma taxonomy : The level of taxonomy dealing with various biological aspects of taxa, ranging from the study of infraspecific populations to studies of speciation and evolutionary rates and trends.

Gause's principle or rule : see Exclusion principle.

Genotype : The genetic constitution of an individual or taxon. Use of this term in taxonomy as the type species of a genus is confusing and against the terminology of Code of nomenclature.

Genus (pl. Genera) : A taxonomic category that includes one or more species, presumably of one phylogenetic origin and separated from other related genera by distinct characteristics.

Geocline : A gradual or continuous change in a character over considerable area as a result of its adjustment to changing geographical barriers.

Geographic barrier : Any area that prevents gene flow between populations.

Geographic isolate : A population or group of populations that is prevented by an extrinsic barrier from free gene exchange with other populations of species.

Geographic race : A geographically delimited race, usually a subspecies.

Geographic speciation : The acquisition of isolating mechanisms by a population during period of geographic (allopatric) isolation.

Geographic variation : The differences between spatially separated populations of a species.

Gloger's rule : Races in warm and humid areas are more heavily pigmented than those in cool and dry areas.

Grade : A group of animals similar in level of organization.

Handbook : In taxonomy, a publication designed primarily to aid in field and laboratory identification rather than in the presentation of new taxonomic conclusions.

Hardy-Weinberg formula : The statement in mathematical terms that the frequency of genes in a population remains constant in the absence of selection, nonrandom mating, immigration, and accidents of sampling.

Heritability : The genetic component of phenotypic variability.

Hierarchy : The system of ranks in an animal classification indicating the categorical levels of various taxa.

Higher category : A taxonomic category from subgenus and above

Higher taxon : A taxon ranked in one of the higher categories

Holophyletic : Pertaining to a group that consists of all the descendants of its most recent common ancestor.

Holotype : A specimen on which the original description of the species is based by the original author.

Homology : A characteristic feature in two or more taxa which can be traced back to the same feature in their common ancestor

Homonym : A name identical in spelling with another and based on a different type. Two or more species with the same name.

Homoplasy : Possession by two or more taxa of a character by convergence, parallelism or reversal

Horizontal classification : Classification based on species which co-exist in time rather than species located on the same evolutionary line.

Hybrid belt : A zone of interbreeding between two species, subspecies, or other unlike populations.

Hybrid index : see character index.

Hybridization : Any cross-mating of two genetically different individuals.

Hypodigm : The entire material of a species available to a taxonomist.

Identification : The determination of the taxonomic identity of an individual

Incipient species : Populations that are in the process of becoming a separate species from the related populations but have not acquired all attributes of a species.

Indication : In taxonomy, the publication of certain types of evidence or cross references that establish the typification of a name and thus make it available (Code, Article 16).

Infraspecific : Within one species Eg. Subspecies, variety, biotypes etc

Infrasubspecific name : A name of an infrasubspecific form.

Introgression : The incorporation of genes of one species into the gene pool of another species by hybridization and back crossing.

Isophene : A line connecting points of equal expression of a geographically variable character.

Junior homonym : The more recently published of two or more identical names for the same taxon or different taxa.

Junior synonym : The more recently published two or more available names for the same taxon.

Key : Tabulation of diagnostic characters of taxa in dichotomous couplets for easy identification.

Key character : A diagnostic character of special utility in a key.

Lapsus calami : In nomenclature, a slip of the pen, especially an error in spelling.

Lectotype : One of the syntypes which, subsequent to the publication of the original description, selected and designated through publication to serve as type.

Lumper : A taxonomist who emphasizes relationship in the delimitation of taxa and tends to recognize large taxa.

Macrotaxonomy : The classification of higher taxa (from genus, tribes, subfamilies and upwards).

Manuscript name : An unpublished manuscript name.

Material : In taxonomy, the specimens available for study.

Meristic variation : Numerical variation in characters that can be counted, such as vertebrae, scales, etc.

Microtaxonomy : The discrimination of species and their subdivisions : taxonomy at species level.

Minimal spanning tree : A tree in which each taxon is connected by a line to its most similar neighbour.

Molecular clock : The hypothesis that the rate of evolutionary change in DNA and other molecules is essentially constant over long periods of geological time. (This can be calibrated with the help of the fossil record).

Monograph : In taxonomy, an exhaustive treatment of a higher taxon in terms of all available information pertinent to taxonomic interpretation; usually include all information full taxonomic details, biology, distribution etc.

Monophyly : The information of a taxon through one or more lineages from one immediately ancestral taxon of the same lower rank.

Monotypic : A taxon containing only one immediate subordinate taxon. (eg. A genus with a single species or a species with a single subspecies (Nominate subspecies).

Morphospecies : A typological species recognized merely on the basis of morphological difference.

Morphotype : A phenotype recognizable by morphological characters.

Mosaic evolution : The evolution involving unequal rates for different structures, organs, etc of the phenotype.

Multivariate analysis : The simultaneous analysis of several variable characters.

Natural system : A system of classification which shows most closely the true relationship of included species.

Neotype : A specimen selected as the type when the original type or types are known to have been lost or destroyed or were suppressed by the Commission.

Neutral term : A taxonomic term of convenience (with no significance) such as "form" or "group"

New name : A replacement name for a preoccupied name. (*Nomen novum*)

New systematics : The biological or populational approach to systematics.

Nomenclator : A work containing a list of scientific names assembled for nomenclatural rather than taxonomic purposes.

Nomenclature : A system of names.

Nomen confusum : A name based on a type consisting of two or more entirely discordant elements.

Nomen conservandum : A name preserved by the Commission.

Nomen dubium : A doubtful name of a nominal species because the available evidence is insufficient to permit recognition of the species to which it was applied.

Nomen nudum : *A* published scientific name which does not meet the requirements for availability defined in Art.25 of the international Rules of Zoological Nomenclature (an invalid name).

Nomen oblitum : A name that is made invalid by the Code (Article 23b).

Nomen rejected : Rejected name.

Nomen vanum : An intermediate name.

Nominal taxon : A species, genus, etc. objectively defined by its type.

Nominate : Containing the type of the name of the higher taxon to which it is subordinate.

Non dimensional species : A non interbreeding species at a given place and time, not involving longitude, latitude or time.

Numerical phenetics : The methodology of grouping individuals into taxa on the basis of overall similarity.

Objective synonym : Each of two or more names based on the same type.

Official index : A list of names or works suppressed or declared invalid by the commission.

Official list : A list of names or works declared as available by the commission.

Onomatophore : Name bearer or type.

Order : A taxonomic group of related organisms ranking between family and class.

Original description : The summary of characters accompanying the proposal of a name for a new taxonomic entity in conformance with Art.25 of the Code.

Operational Taxonomic Unit (OUT) : A name for individuals, populations, species or higher taxa classified by numerical methods.

Out-group : A taxon, outside a given study group and preferably a sister group, "that is examined in the course of a phylogenetic study to determine which of two homologous characters" found within study group " may be inferred to be apomorphic" (Wiley 1981).

Panmictic : Randomly interbreeding population of individuals.

Parallelism : The independent acquisition of similar characters in related evolutionary lines.

Parallelophyly : Multiple independent derivations from the nearest common ancestral taxon.

Parapatry : Non overlapping geographic contact of populations with or without interbreeding.

Paraphyletic : Pertaining to a monophyletic group that does not contain all the descendants of that group.

Paratype : A specimen or specimens other than the holotype which was before the author at the time of preparation of the original description and was so designated or indicated by the original author.

Parsimony : The principle stating that the tree is best which is "shortest" that is, has the smallest number of character state changes (branching points).

Patristic character : Equals ancestral character.

Patronymic : In taxonomy a dedicatory name based on that of a person or persons.

Phenetic ranking : Ranking into categories, based on degree of overall similarity.

Phenetics : The classification based on appearances of organisms rather than on evolution from a common ancestor.

Phenon : A sample of phenotypically similar specimens.

Phenotype : The class in which an individual falls on the basis of visible characters.

Phyletic : Pertaining to a line of descent.

Phylogenetic systematics : Classification based on the branching pattern of phylogeny (known as Cladistics).

Phylogenetic tree : A graphic representation showing the descent relations of different organisms.

Phylogeny : The evolutionary history of an organism or taxonomic group.

Plenary powers : Special powers granted to the Commission.

Plesiomorphic : An ancestral character state.

Plesion : Rank assigned to a fossil taxon in Cladistics.

Polarity : The transformation series of a character from ancestral toward derived.

Polynominal nomenclature : A system of nomenclature in which the specific epithet of a species consists of several words.

Polyphyly : derivation of a taxon from two or more ancestral sources.

Polythetic : "Of taxa which are based on the greatest number of shared characters; no single character is either essential or sufficient to make an organism a member of the group, and no member of the taxon necessarily has all the attributes which jointly characterize the taxon"(Mayr & Ashlock,1991).

Polytopic : Occuring in different places as for instance, a subspecies composed of widely separated populations.

Polytypic : A taxon containing two or more taxa in the immediately subordinate category, such as a genus with several species and species with several subspecies.

Predictive value : Usefulness of a classification in making predictions on a newly employed characters or newly discovered taxa.

Primary homonym : One of two or more identical trivial names which, at the time of original publication, were proposed in combination with the same generic name(e.g.*X-ella nigra* Narendran, 2002 and *X-ella nigra* Sudheer, 2004).

Protein taxonomy : An approach to classify organism on the basis of differences in the structure of protein.

Priority : The principle that of two competing names for the same taxon below the rank of suborder, the one published first is valid.

Q technique : An analysis of association of pairs of taxa in data matrix.

Race : a biotype (local population below subspecies rank).

Rassenkreis (Rensch) : The German equivalent of polytypic species.

Revision : In taxonomy, the presentation of new findings or new interpretation integrated with previous knowledge.

Secondary homonym : Each of two or more identical specific names which at the time of original publication, were proposed in combination with different generic names but which, through subsequent transference, have come to bear the same combination of generic and species name.

Semispecies : A taxonomic group intermediate between a species and a subspecies, a group yet to attain a species ranks.

Senior homonym : The earliest published of two or more identical names for the same or different taxa.

Senior synonym : The earliest published of two or more available synonyms for the same taxon.

Sequencing : A cladistic method in which sister taxa are given the same categorical rank, the sequence to be determined by the amount of divergence from the ancestral stem species.

Sibling species : Cryptic species (= morphologically identical populations but biologically different or reproductively isolated.

Sister groups : In a dichotomous cladogram, the two holophyletic groups that descended from their common ancestor.

Speciation : formation of a species.

Species : Groups of interbreeding natural populations that is reproductively isolated from other such groups.

Species group : A group of closely related species.

Splitter : In taxonomy, one who divides taxa very finely into two or more different taxa.

Statute limitation : A provision in the Code, valid before 1973, to protect universally adopted junior names against revival of forgotten senior synonyms.

Stem groups : Early groups in a phyletic lineage.

Strickland code : A code of nomenclature prepared by a committee of the British association for the Advancement of Science under the secretaryship of H.E. Strickland and first published in 1842.

Subfamily : A taxonomic category intermediate between a family and a tribe.

Subjective synonym : Each of the two or more synonyms based on different types but of the same taxon.

Subspecies : A geographically defined aggregate of local populations which differs taxonomically from other such subdivisions of the species.

Substitute name : A name proposed to replace a preoccupied name and automatically taking the same type and type locality.

Substrate race : A local race selected to agree in its colouration with that of the substrate.

Superfamily : The taxonomic category below the order and immediately above the family.

Superspecies : A monophyletic group of closely related and entirely or largely allopatric species that is too distinct to be considered as a single species.

Sympatric : Two or more populations occupying the same geographical area or of a population existing in a breeding condition within the cruising range of individuals of another population.

Symplesiomorphy : The sharing of several ancestral characters by different taxa.

Synapomorphic : Pertaining to a uniquely derived apomorphic character that is found in two or more taxa under consideration.

Synchronic species : Species that occur in the same time dimension

Synonym : Each of the two or more different names for the same taxon.

Syntype : All the specimens in a type series before the author who described a species without designating a holotype.

Systematics : "The scientific study of the kinds and diversity of organisms and of any and all relationships among them" (Simpson 1961).

Taxon (pl.Taxa) : A taxonomic unit with a definite name.

Taxonomy : The science of classification.

Temoporal : Limited by time, lasting for a time only.

Topotype : A specimen collected at the type locality.

Transformation series : A series of homologous characters some of which were derived from others during evolution.

Tribe : A taxonomic category between subfamily and genus.

Trinominal nomenclature : An extension of the binomial system of nomenclature to permit the designation of subspecies by a name consisting of three words.

Trivial name : The second or third word in a binominal or trinomial system of nomenclature.

Type : A specimen on which forms the basis for describing a species.

Type designation : Determination of the type of a genus under Article 67.5 under the International codes of nomenclature.

Type method : The method of preserving the identity of a taxonomic category by basing a specimen or as the type.

Type species : The species that was designated as the type of a nominal genus.

Typology : In taxonomy the concept that all population of a category conform to a given morphological type.

Uninominal nomenclature : The designation of a taxon by a scientific name consisting of only a word for taxa above species level.

Upward classification : The grouping of populations and phena into species and of species into higher taxonomic rank.

Variety : Heterogeneous group of a taxon usually applied to infraspecific categories, not recognized by the Zoological Commission.

Vertical classification : Classification based on common descent tending to unite ancestral and descendant groups.

Weighting : A way of considering a character for classification based on phyletic information.

REFERENCES

ABRS, 1998. Australian Biological Resources Study (=ABRS), Environment Australia, Canberra ACT 2601 (Hard copy-ISBN : 0642568030 (web : *abrsweb@gov.au*)

Adanson, M. 1763. *Families des Plantes* Vol. **1**. Paris : Vincent.

Ananthakrishnan, T. N. 2000. Need for introspection Expertise crisis in insect taxonomy *Current Science* **79**(1) : 10.

Anonymous, 1990. Report of the Curriculum Development Centre in Zoology, University Grant Commission, New Delhi.

Bauhin, C. 1623. *Pinax theatri botanici*, Basel, 24 + 522 + 23 pp.

Bennett, A.1994. A review of Existing Identification Services and Future Needs, 57-66. *In* : The identification and characterization of Pest Organisms (D. L. Hawksworth ed. Wallingford: CAN International).

Blackwelder, R. E. 1967. Taxonomy – A text and Reference book. John Wiley & Sons INC. New York : 1-698.

Borror D. J. and D. Delong,. 1955. An Introduction to the study of Insects. Holt, Rinehart and Winston, New York : 1-1030.

Boulter, D. and Derbyshire, E. D. 1971 Taxonomic aspects of the structure of the legume proteins. *In*: Harborne. J.B., Butler, D. and Turner, T. (eds). *Chemotaxonomy of Legumenosae* London : 1-285-305.

Boyden, A. A. 1943. Serology and Animal systematics *Am. Nat.* **77** : 234-255.

Braddbury, S. 1984. An Introduction to the optical microscope. Oxford University Press, New York.

British Museum (Natural History), 1936. Instruction for collectors.

Britten, R. J., D. E. Graham, and B.R. Neufeld. 1974. Analysis of repeating DNA sequences by reassociation. *Methods Enzymol*, **29** : 363-418.

Broun, R. W. 1956. Composition of scientific words (Revised edition) Smithsonian Institution Press. Washington.

Brunfels, O. 1530. *Herbarium vivae eicones.* Argentorati, **1** : 8 + 266 + 28 pp.

Candolle, A. P. 1813. *Theorie elementaire de la Botanique*. Paris 500 + 27 p. Chez Deterville

Candolle, A. P. 1819. Theorie elementaire de la botanique, ou exposition des principles de la classification naturelle et de l'art de decrire et d'etud. Paris. *Rev. et. augm. Chez Deterville.*

Cato, P. S. 1986. Guidelines for managing bird collections. *Museology*, No. **7**, Lubbock TX : Texas Tech University, 78 pp.

Cherian, P.T. 1996. On hot spots, warm spots and hot specks. *Zoos Print*, **XI**(9) : 9-11.

Christoffersen, M. L. 1995. Cladistic taxonomy, phylogenetic systematics and evolutionary ranking. *Syst. Biol.*, **44**(3) : 440-454.

Corliss, J. O. 1963. Establishment of an International type slide collection of the ciliate protozoa. *J. Protozool.*, **10** : 247-249.

Cronquist, A. 1975. Some thoughts on Angiosperm phylogeny and taxonomy *Ann. Miss. Bot. Gard.*, **62** : 517-520.

Darwin, C. 1859. On the origin of species by means of natural selection, or the preservation of favoured races in struggle for life. London : John Murray (Facsimile ed. ayr, E. (ed). 1964. Cambridge, MA : Harward University Press).

De Stefani, T 1887. Un nuovo genere di Crabronidi ed altri imenotteri nuoviopoco cogniti raccolti in Scilia. *Naturalista Siciliano,* **6** : 59-114

Dowler, R.C. and H. H. Genoways. 1976. Supplies and suppliers for vertebrate collections. *Museology* No. **4**. Texas Tech University, Texas.

Gadagkar, R. 1998. Biology in the 21st century – back to stamp collection? *Scampus,* **98** : 5.

Gahan, A.B. 1923. The role of taxonomist in the present day entomology. *Proc. Ent. Soc. Wash.,* **25** : 69-78.

Gauld, I. D. 1999. Inventorying and monitoring biodiversity a taxonomists perspective., 14-16. *In* : Indexing World known species. Proceedings at the International symposium on Mediterranean biodiversity, Rome).

Gupta,V. K. 1987. Development of Taxonomic resources in the Tropics. *Insect Sci. Applic.,* **8** : 407-412.

Hedge, I.C. and Lamond, J.M. 1972. Umbelliferae. Multi – access key to the Turkish genera. *In* : P.H. Davis (ed.) Flora of Turkey. Edinburgh Univ. Press, Edinburgh. Vol., **4** : 171-177.

Hennig, W. 1950. *Grundzuge einer Theorie der Phylogenetischen Seystematic*. Deutseher Zentralvirlag. Berlin.

Hennig, W. 1966. Phylogenetic Systematics (translated by D.D. Davis and R. Zanger): University of Illinois Press. Urbana.

Hoy, M.A. 1994. Insect Molecular Genetics. An Introduction to Principles and Applications, Academic Press, New York.

Hungay, G. and M. Dingley, 1985. Biological Museum Methods. Vol. I Vertebrates, Vol.2. Plants, Invertebrates, and·Techniques. Academic Press. New York.

Janzen, D. H. 1993. Taxonomy : Universal and essential infrastructure for O.T development and management of tropical wildland biodiversity *In*: O. T Sandland, and P. J Schei,. (eds.) Proceedings of the Norway/UNEP Expert conference on biodiversity, Trondhun, Norway, 100–113, NNA, Trondheim.

Johnson, D. L. and Fairbrothers. D. E. 1965. Comparisons and interpretation of serological data in the Mongnoliaceae. *Bot. Gaz.,* **126**(4) : 260-269.

Kapoor, V. C. 1998. Theory and Practice of Animal Taxonomy (4th edition) 247 pp. Oxford& IBH Publishing Co. Pvt. Ltd. New Delhi.

Kim, K. C. 1989. Systematic resources and the Entomological Society of America. *Bull. Ent. Soc. Am.,* **35** : 170-176.

Kirby, H. 1950. Materials and Methods in the study of Protozoa: University of California Press. Berkeley.

Knudsen, J. W. 1966. Biological Techniques : Collecting preserving and illustrating plants and animals. : Harper & Row, New York.

Kummel, B and Raup, D. 1965. *Handbook of Paleontological Techniques*. W.H. Freeman. San Francisco.

Lack, D. 1947. Darwin's Finches. Cambridge University Press. London.

LaSalle, J. and Gauld, I. D. 1993. Preface : *In* : Hymenoptera and Biodiversity *In*: Lasalle, J and I.D. Gauld. (eds.) CAB International Wallingford.

Le Pelley, R. H. 1943. The biological control of a mealybug on coffee and other crops in Kenya. *Empire J. exp. Agric.,* **11** : 78-88.

Linnaeus, C. 1730. *Harticus uplandicus*. Lugduni Batavorum, Stockholm.

Linnaeus, C. 1735. *Systema naturae* (2nd ed.). Lugduni Batavorum Stockholm.

Linnaeus, C. 1737. Citica botanica. Leydon.

Linnaeus, C. 1737. *Genera plantarum*. Lugduni Batavorum. Stockholm.

Linnaeus, C. 1751.*Philosophica botanica*, Laurentii Salvii. Stockholm.

Linnaeus, C.1758. *Systema maturae*. Lugduni Batavorum. Stockholm. Editodecima, reformata Tan I. Laurentii Salvii, Holmiae.

Maxson,L. R. and R. D. Maxson 1990. Proteins II Immunological Techniques *In*: Molecular systematics. D. M. Hillis and C. Mortz (eds) Sinauer Assoc. Inc. Suderland, MA : 127-366

Mayr, E. 1963. Animal species and evolution. M. A. Hardward University Press. Cambridge.

Mayr, E. 1969. Principles of Systematic Zoology, McGraw-Hill, INC, New York.

Mayr, E. 1971. Methods and strategies in taxonomic research. *Syst. Zool.*, **20** : 426-433.

Mayr, E. and P. D. Ashlock, 1991 Principles of Systematic Zoology (2nd ed.). Mc Graw – Hill, INC. New York.

Mayr, E., E. G. Linsley, and R. L. Usinger, 1953. Methods and Principles of Systematic Zoology McGraw–Hill Book Company, INC, New York, Toronto & London : 1-336.

Miller, S.E. 1994. Development of World Identification Services: Networking. *In* : The Identification and characterization of Pest Organisms (Ed. D. L. Hawksworth) Wallingford. CAB International.

Narendran, T. C.1988a. A new genus of Chalcididae (Hymenoptera: Chalcidoidea) from the collections of United states National Museum of Natural History, Washington, D. C. *Journal of Bombay Natural History Society*, **85**(1) : 158-160.

Narendran, T.C. 1988b. Studies on Indian Chalcididae (Hymenoptera : Chalcidoidea). Dept of Zoology Publication, Calicut University, Tenjipalam : 1-60.

Narendran, T C. 1989. Oriental Chalcididae (Hymenoptera : Chalcidoidea) Zoological Monograph, Dept. of Zoology Publication, Calicut University, Tenjipalam.

Narendran, T C. 2000. Importance of Systematics. *Resonance*, **5** : 60-68.

Narendran, T.C. 2001 *Parasitic Hymenoptera and Biological Control.* Palani Paramount Publications, Palani : 1-201

Narendran, T C. and Cherian, P. T. 2002. On some misconceptions on conservation of Insects. *Zoos' Print*, **17**(1) : 687-688.

Noyes, J. S. 1982. Collecting and preserving Chalcid wasps (Hymenoptera: Chalcidoidea) *J. nat. Hist.*, **16** : 315-334.

Ogura, Y. 1964. Comparative morphology and Classification of plants. *Phytomorph.* **14** : 240-247.

Pemberton, C. E. 1941. Contribution of the entomologist to Hawaii's welfare. *Hawaiian Planters Record.*, **45** : 107-119.

Pigman, W. and E. Carmicahael, 1950: An Ethical code to Scientists, *Science June 16. page 643.1950*, Whahington, D. C.

Ray, J. 1686-1704. *Historia plantarum*, London, 3 vols.

Reid, W. V., Laird, S. A., Elmez, R. G., Sittenfeld. A., Janzen, D.H., Gollin, M.A. and Juma, G. 1993. (eds). Biodiversity Prospecting WRI Washington DC.

Rosen, D. and De Bach, P. 1973. Systematics, Morphology and Biological Control. *Entomophaga*, **18**(3) : 215-222.

Schauff, M. E. and J. LaSalle, 1998. The relevance of systematics to biological control :

protecting the investment in research *In*: M. P. Zalucki, R. W. I. Drew, R.W.I. and G.G. White, (eds). Pest Management – Future Challenges. *Proceedings of the Sixth Australasian Applied Entomological research Conference*, Brisbane. 425-436.

Sibley, C. G. and J. E. Ahlquist,. 1983. The Phylogeny and Classification of birds based on the data of DNA – DNA hybridization. *Current Orn.* **1** : 245-292.

Sibley, C. G., J. E. Ahlquist, 1985. The Phylogeny and Classification of the passerine birds, based on comparisons of the genetic material DNA. *In*: V. D. Ilyiechene (ed.). Proceedings of the 18th International Ornithological Congress. : Nauka Publications. Moscow : 83-123.

Simpson, G.G. 1961 Principles of Animal Taxonomy. Columbia University Press, New York.

Singh, G. 1999. Plant Systematics, - Theory and Practice. Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi.

Sivarajan, V. V. 1985. Introduction to Principles of Plant Taxonomy. Oxford & IBH Publishing Co., New Delhi,

Sokal, R. R. 1985. The Principles of numerical taxonomy: twentyfive years later, *In*: M. Goodfellow, D. Jones and F. G. Priest *Computer Assisted Bacterial Systematics* Society for General Microbiology. Academic Press, London UVS : 1-20.

Stebbins, G.L. 1950. Variation and evolution in plants. Columbia University Press, New York.

Steyskal, G. C., W. L. Murphy and E.M. Hoover, (eds.) 1987. *Insects and Mites: Technique for Collection and Preservation.* USDA/ARS. Misc. Publ. No. 1443. Washington, D.C.

Stork, N. E, and M. J. Samways. 1995. Inventorying and monitoring: Executive summery Pages 457–458 in VH Heywood and RT Watson, editors. Global biodiversity. Cambridge Univesity Press, England.

Thompson F. C., A. L. Norton, L. E. Carrol, and I. M. White 1993. The fruitfly biosystematic Information database *In* : Aluja, M. and Liedo, P. (eds) *Fruit Flies: Biology and Management* Springer – Verlag, New York : 1-7.

Tikader, B. K. 1986. Manual : Collection, Preservation and Identification of Insects and Mites of Economic importance *Zoological Survey of India*, Calcutta.

Turner, B. L. 1966. Chemosystematics: present and future. *In*: (ed. B.S. Seshachar). Newer trends in Taxonomy. *Bull. Nat. Inst. Sci.*, **34** : 189-211

Van Tyne, J. 1952. Principles and practices in collecting and taxonomic work. *Auk*, **69** : 27-33.

Vane-Wright, R. I. 1996. Systematics and the conservation of biological diversity. *Annals of Missouri Botanical Garden*, **83** : 47-57.

Williams, S. L., Laubach, R. and Lauback, C.M. 1979. A guide to literature concerning the management of recent manual collections. Lubbock. Texas Tech.

Wilson, E. O. 1992. The Diversity of Life. W.W. Norton company, New York.

Wilson, E. O. 2003. *What is nature worth for ?* Part-1, span XLIV-4 : 54-59.

Wilson, E. O. 2003. *What is nature worth for ?* Part-2, span XLIV-5 : 23-29.

Winston, J. E. 2000. Describing species : Practical taxonomic procedure for biologists. Columbia University Press, Columbia.

Wollenberg, K. 2000. Can we distinguish species/subspecies from the genome maps? Pers. Comm. Madsc. Network (Internet).

Wright. C .A. 1966.Experimental taxonomy : A review of some techniques and their applications. *Int. Rev. Gen. Exptl. Zool.*, **2** : 1-42.

Zuckerkandl, E. and Pauling, L. 1962. Molecular diseases, evolution, and genic heterogeneity, *In* : M. Kasha and B. Pullman, (eds). *Horizons in Biochemistry* : Academic Press. Chicago : 189-225.