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General Principles of Systematics (Taxonomy) and Animal Classification

This world comprises a great number of living and non-living objects. The group of living organisms of the world exhibits a great diversity and variations. Living world or animate objects are animals and plants. The variations in plants and animals have posed a great problem to human being for their study, *i.e.*, how to recognise them with their differences and similarities. Therefore, from the beginning of the human civilization people felt the necessity of arranging them by studying not only the morphological aspects but up to some extent their anatomy also. With the development of world civilization and various discoveries including the apparatuses, subcellular structures and subatomic particles have created another problem in the methods of systematic arrangement of animate objects. Now, their arrangement includes their anatomical, histological, embryological, physiological, cytological, cytochemical, genetical, ecological, palaeontological, geographical and evolutionary aspects also.

The term systematics is derived from Latinised Greek word–*systema*–as applied to the systems of classification developed by early naturalists, notably **Linnaeus** (*Systema Naturae*, First Edition, 1935).

According to **Simpson,** "*Systematics is the scientific study of kinds and diversity of organisms and of any and all relationships among them.*"

Systematics includes taxonomy, identification, classification and nomenclature and all other aspects of dealing with different kinds of organisms and data accumulated about them is also included in systematics.

ORIGIN AND DEVELOPMENT OF SYSTEMATICS

The origin and development of systematics and human civilization started simultaneously, *i.e.*,civilization of human being is the systematics or in other words we say that in our daily life those people who maintain their houses systematically that means they are civilized. As the knowledge developed they started naming the plants and animals according to their own choice.

The clue for the earliest classification comes from **Vedas** and **Upanishads** (1500 BC to 600 BC). In Vedas and Upanishads, several technical terms are used in the description of plants and plant parts, both morphologically and anatomically. Plants of medicinal importance were collected and studied. **Charaka** and **Susruta**, the two eminent ancient Indian scholars and ayurvedic physicians, contributed a lot to our knowledge of diversity and utility of organisms. One of the remotest works dealing with plant-life in a scientific manner is the **Vrikshayurveda** (science of plants and plant-life) compiled by **Parasara**, even before the beginning of Christian era, which formed the basis of botanical teaching and medical studies in ancient India.

Several early Greek scholars notably **Hippocrates** (460–377 B.C) and **Democritus** (465–370 B.C.) made observations on animals but their classification was not useful. Later on **Aristotle** (384–322 B.C.) also studied the living organisms, *viz.*, plants and animals and gave statement on classification that "*animals may be characterized according to their way of living, their action, their habit and their bodily parts*". He classified the major groups of animals as birds, fishes, insects and whales. **Aristotle** is called the "Father of biological taxonomy." **Theophrastus** (370–385 B.C.) who was the student of **Plato** and then of **Aristotle**, is known as the "Father of Botany", classified all plants on the basis of form and texture and divided them into trees, shrubs, under-shrubs and herbs. His classification was strictly artificial and in his "**Historia Plantarum**" he has classified and described 480 plants. **Albertus Magnus** (1193–1280) recognised the differences with the help of crude lenses in between the monocotyledons and dicotyledons and recognised the classification of

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Theophrastus. **Otto Brunfels** (1464–1554), a German, first recognised the Perfecti and Imperfecti group of plants based on the presence or absence of flowers respectively. **Jerome Bock** (1498–1554), another German, classified the plants into trees, shrubs and herbs. **Andrea Cesalpino** (1519–1603) taxonomically classified plants on the basis of habit and subdivided them on the characters of fruits and seeds.

Gaspard Bauhin (1560–1624) classified the plants on the basis of texture and form. He was first to find out the **binomial nomenclature** although it is usually credited to **Linnaeus.** In the history of systematics **John Ray** (1627–1705) has done a great job. Before him the classification was baseless and there was not any strong scientific background. **John Ray** travelled widely in Europe with **Francis Willougby** (1635–1672). They not only observed and collected plants and animals, but also planned to classify them. Unfortunately, Willougby died prematurely and later John Ray published his **Historia Generalis Plantarum** in three volumes between 1668 and 1704. In this book John Ray described accurately and in meticulous detail and catalogued over 18,000 plants. He was the first person who recognised the difference between genus and species, and through valuation of both similarities and dissimilarities in animals arrived at a more natural higher classification than of the former persons. After John Ray, the most remarkable man in the field of taxonomy was **Carolus Linnaeus** (1707–1778) who is often referred to as the "Father of Taxonomy" for his outstanding contribution in this field. Linnaeus visited many European countries and made careful observations on the plants and animals. He published his scheme of classification in his famous book **Systema Naturae** in 1753. The 10th Edition of this book was published in 1758 and the 1st January of that year marks the beginning of the consistent application of what is known as the **"binomial system of nomenclature"**. This system which introduces the principles of naming an organism by two words, was first proposed by **Linnaeus** and is universally followed today. This work of Linnaeus became the foundation of systematics. He also laid down the clear delimitations for species.

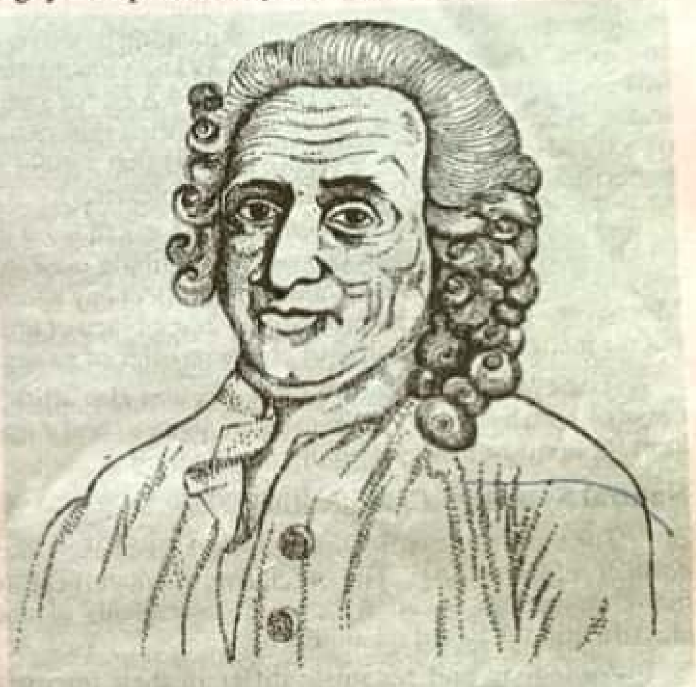

Fig. 2.1. Carolus Linnaeus (1704—1778).

Jean Baptiste Monet de Lamarck (1744–1829) wrote **Flore Francoise** in 1778 in which he laid down the principles of his concept of natural classification. **Charles Darwin** (1809–1882) a great evolutionist, on the basis of his extensive studies and with the help of convincing evidences gathered on the Voyage of the Beagle, explained the origin of species through natural selection. The evolution theories of Lamarck and Darwin not only greatly influenced Linnaean classical systematics but also totally rejected the pre-Lamarckian idea of the fixity of species. **Ernst Haeckel** (1866) introduced the method of representing phylogeny by means of trees or branching diagrams.

Sir Julian Huxley (1940) introduced the new term **"New Systematics"** which incorporates the results of recent studies in various branches of life sciences in systematics which modify some of the older ideas of classical systematics. Today the definition of species is based on population because the development of population genetics which in turn influenced the further development of population systematics.

UTILITY OF SYSTEMATICS (TAXONOMY)

No scientific ecological survey can be carried out without the most painstaking identification of all the species of ecological significance. A similar dependence on systematics is true for other areas of science. Even the experimental biologists have learned to appreciate the necessity for sound taxonomy. The systematists can fill many gaps in our knowledge. There are more than one million

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species of animals and more than half million species of plants described in the biosphere. In addition, there must be a large number of plant and animal species yet to be described. Without the knowledge of systematics the discovery of new species of plants and animals is not possible and we cannot know much about the organisms of our surroundings. Therefore, there is a great necessity or utility of systematics.

SYSTEMS OF CLASSIFICATION

There are three different systems of classifications which have been proposed so far by different taxonomists. They are: (i) Artificial; (ii) Natural;(iii) Phylogenetic.

Artificial System of Classification

This type of classification is based upon characters of convenience without relation to phylogenetic significance; classification based upon characters erroneously presented to indicate phylogenetic relationship; also classification based on a single arbitrarily chosen criterion, instead of an evolution of the totality of characters known as artificial classification. This system of classification was adopted by **Pliny** in the first century A.D. for animals on the basis of habitats, *e.g.*, land, air and water. Accordingly animals were classified into two categories on the basis of their flying ability: (i) animals that can fly and (ii) animals that cannot fly. In the first group unrelated animals like butterflies, birds and bats were placed together.

The classification of plants on the basis of habit into (i) herbs, (ii) undershrubs, (iii) shrubs and (iv) trees is also an artificial one. The criteria used in this classification, although very simple and easy to follow are arbitrary and do not reflect any natural relationship existing among the organisms. Moreover, it leads to heterogeneous assemblage of unrelated organisms under one heading and does not do justice to the totality of characteristics of an organism.

The system adopted by Linnaeus was also artificial in which the plants were classified on the basis of number and arrangement of stamens and carpels. Closely related species of organisms are kept far apart in this system of classification.

Natural System of Classification

The natural classification may be defined as "*Classification based on characters which indicate natural relationships*". The organisms of a natural systematic category agree with one another in so many characters because they are descendants of one common ancestor. The natural system of classification is based on similarity.

Zoologists and botanists differ in their interpretation of the implication of this system of classsification. According to zoologists, the natural system of classification includes the phylogenetic and evolutionary trends which are evident in the word "natural". Botanists hold the opinion that the natural system does not necessarily include phylogenetic trends of plants. Here they proposed the **"phylogenetic system"** of classsification separate from the "**natural system**" to include the evolutionary trends in plants. The "natural system" of classification of the plant kingdom was proposed by **George Bentham** (1800–1844) and **Joseph Dalion Hooker** (1817–1911).

Phylogenetic System of Classification

The phylogenetic system is based on the evolutionary and genetic relationship of the organisms. It enables us to find out the ancestors or derivatives of any taxon. Our present-day knowledge is insufficient to construct a perfect phylogenetic classification and all the present phylogenetic systems are formed by the combination of natural and phylogenetic evidences. This system is adopted by **Adolph Engler** (1844–1930) and **Karl A.E. Prantl** and **John Hutchinson** (1884–1974) in classifying the plants.

NOMENCLATURE

Nomenclature is defined as the system of naming of plants, animals and other objects or groups of plants, animals and other objects. Scientific names are the language of taxonomists. When a taxonomist identifies and describes the natural group of animals, he gives appropriate scientific names to the groups. Common names do not serve the purpose because a particular animal is known by different names in different parts of the world. For example, the bird that we know as gauraiya in India and Pakistan, is known by different names in other countries, house sparrow in England; Pardal in Spain; Musch in Holland; Suzune in Japan and so on. Moreover the common name may be used for different kinds of animals. For example, the name kenchua is used both for the earthworm and *Ascaris*. On the other hand, a scientfic name is universally used for a particular species or particular

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group of animals. For example, gauraiya or house sparrow is termed *Passer domesticus* by zoologists throughout the world.

To ensure that one scientific name stands for one particular kind of animal everywhere and is the only name for that organism, the taxonomist must see the following: (1) The name chosen for an animal has not been already given to some other animal or plant. (2) The animals and plants have been described in such detail that another taxonomist can determine from the description exactly the kind of animal to which the name has been given. (3) The animal or plant has been duly placed in the system of classification establishing its relationships.

Binomial Nomenclature

The history of binomial system of nomenclature is very long. Two centuries before Christ, **Cato** used two names for plants in his **De Re Rustica.** But he had no knowledge that genera were usually composed of several species. Later, two ideas developed with the evolution of the idea of nomenclature. One was to translate the descriptive Greek nouns used for genera into Latin. As a result of this translation into Latin the generic name consists of two words. These were called binary generic names. The other tendency was to use descriptive phrases for specific names. These tendencies in conjunction gave rise to a polynomial system of nomenclature. According to this system the name of a plant was composed of several words in a series which bore a brief description of the plant. For example, Bentham used the name **Caryophyllum saxatilis, folis gramineus umbellatis corymbis** to represent the **Caryophyllum** which grew on rocks, with grass-like leaves and flowers in umbellate corymbs. This was the system of cumbersome.

In the middle of the sixteenth century, a number of binary generic names were changed by Brunfels to single ones. **Dodonaeus** and **Gaspard Bauhin** later followed in general the binomial system but it is usually credited to **Linnaeus** who used it more than hundred years later in his **Species Plantarum.** According to this binomial nomenclature, long names were cut short so that they could be used with greater convenience. This system postulates that every individual of plant and animal kingdom consists of only two words in Latin; the first word designating the genus and the second, the additional epithet, that signifies the particular species with that genus. It is also known as two naming system or binary system. For example, the genus of modern horse is *Equus*. Among its species are *Equus caballus* and *Equus asinus*. The word *caballus* and *asinus* standing above have no meaning in taxonomy ; they are not names of species or any thing else. Only when they are part of a binomial combination, they are meaningful taxonomically and then it is the combination that is the name of the species. Often, specific names of animals and plants are given in honour of some persons. If the person honoured is a man the specific name ends in "i". For example, the earthworm, *Lumbricus friendi* is named after Rev. H. Friend. If the person honoured is a woman, the specific name ends "ae". Sometimes, the specific name indicates a locality (*e.g.*, indica for Indian) or colour (*e.g.*, niger for black).

In scientific literature, it is a general practice to write a specific name followed by the name of the person who first described the species and the year when he did so. For example, the scientfic name of man is written as *Homo sapiens* **Linnaeus**, 1758. If the species, after its publication, is transferred to any other genus or the generic name is changed the first author's name is written in brackets (parenthesis). For example, *Panthera leo* (Linnaeus) means that species *leo* was originally assigned by Linnaeus to some other genus (*Felis*).

Trinomial Nomenclature

This system of nomenclature is employed to name the subspecies. In classification the subspecies is a category below the species. The subspecies name is also a Latin or Latinised word and follows the name of the species to which it belongs. For example, the specific name of the house crow, which occurs throughout India, Pakistan, Burma and Ceylon is *Corvus splendens*. The house crows of India and Pakistan, Burma and Ceylon differ with each other in minute morphological features and are, thus, separated as distinct subspecies. The Indian and Pakistani house crow has been assigned the subspecific name *Corvus splendens splendens*, the Burmese house crow, *Corvus splendens insolens* and the Ceylonese house crow, *Corvus splendens protegatus*. The full scientific name of subspecies is, therefore, a trinomial name consisting of three names: the names of genus, the species and subspecies itself.

Rules of Nomenclature

In 1898, the **International Congress of Zoology** organised an International Commission on Zoological Nomenclature to formulate a set of rules, which would be binding for all taxonomical

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publications. The aim of International Code of Nomenclature is to make the stability in naming the taxa, avoiding the use of names which may cause error, ambiguity or confusion.

The standardisation and legislation of nomenclatural practices are usually made at International Botanical and Zoological Congresses. This is done in order to put the nomenclature of the past in order and to provide guidelines for that of the future.

A few commonly followed rules and recommendations which may be considered as the essentials of a code of nomenclature are given below :

1. The system of nomenclature adopted is the binomial system to indicate the specific name and trinomial for subspecific name.
2. The name of the genus is a single word in a nominative singular and must begin with a capital letter. The name of the species may be a single or compound word and must begin with a small letter.
3. The name of the author, who first publishes the name when describing it, should follow the species name and should rarely be abbreviated and is printed in roman type.
4. The scientific names of animals and plants must be different.
5. The names must be in Latin or Latinised form and are usually printed in italic type.
6. Within the animal and plant kingdom, no two genera can have the same name, and whithin a genus, no two species can have the same name.
7. The generic or specific name first published is the only one recognised. All duplicate names are synonyms.
8. When the name of the genus is not the one under which a species is placed by the original author, or if the generic name is changed the original author's name is written in parenthesis.
9. The formation of family and subfamily names follow rules which are different in the Zoological and Botanical Codes.
10. A name must retain its original spelling,obvious errors and misprints may be corrected; diacritic marks are dropped.
11. A name may be based on any part of an animal or a plant, or on any stage of an organism's life history.

RECOMMENDATIONS

To make new names the following suggestions are followed :

1. A name should be in Latin or easily converted into Latin form.
2. A name should not contain less than three and more than twelve letters.
3. A name should be easy to pronounce.
4. The name given should preferably describe some characteristics of the organism.
5. A name should not be derived from two languages.
6. A name should not be frivolous.

FAMILIARITY WITH TAXA

According to **Darwin** (1850), "All organic beings are found to resemble each other in descending degree, so that they can be classed in groups under groups". All major groups of animals can individually be subdivided into smaller and smaller subgroups. Within the vertebrates we can distinguish subgroups such as birds and mammals; within the mammals, carnivores and rodents; within the carnivores, those that are dog-like, those that are cat-like and so forth. If one wants to construct a classification of these species, this classification is not arbitrary. The task of classification then is the delimitation of these groups and their arrangement in an orderly sequence, *i.e.*, **hierarchy**.

SYSTEMATIC HIERARCHY

Since the number of animal and plant species is very large, it is not possible to either know them individually by their names or to refer them in the literature. This necessitated arranging them into **categories** and **taxa** of different grades. Then arranging these categories and taxa in an ascending order so that a higher category includes one or more lower categories and higher taxa include one or more lower taxa.

Linnaeus was the first taxnomist to establish a definite hierarchy of taxonomic categories recognised within the animal kingdom. These are **classes, order, genus, species** and **varieties**. The

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varieties, used by Linnaeus as an optional category of various types of intraspecific variants, was eventually discarded or replaced by the species. These few categories sufficed to cope with small number of animals and plants known at that time. However, as the number of known species increased and with it our knowledge of the degrees of relationship of these species, the need arose for a more precise indication of the taxonomic position of species and inserting additional ones among them. Most are formed by combining the original category names with the prefixes super or sub. Thus, there are superorder, superfamilies and subfamilies, etc. The most frequently used additional new category name is perhaps the term tribe for a category between genus and family. Vertebrate palaeontologists also used in routine the category cohort between order and class. Some authors used terms for additional subdivisions, such as **cladus, legio,** and **sectio.** Some used infraclass below the subclass and infraorder below the suborder. The generally accepteu categories are the following :

Kingdom
Phylum
Subphylum
Superclass
Class
Subclass
Infraclass
Cohort
Superorder
Order
Suborder
Infraorder
Superfamily (-oidea)
Family (-idae)
Subfamily(-inae)
Tribe(-ini)
Subtribe
Genus
Subgenus
Species
Subspecies

Indicated in the parenthesis are the standardized endings for the names of tribes, subfamilies, families and superfamilies.

The systematic hierarchy or Linnaean hierarchy as it is commonly known, with its need for arbitrary ranking has often been attacked as an unscientific system of classification. Alternate methods, such as numerical scheme have been proposed but have not found favour among taxonomists, primarily for following two reasons :

(i) Assigning definite numerical values to taxa demands a far greater knowledge of the relationships of taxa than can be inferred from available evidences.

(ii) An assignment of such values would freeze the system into a family which would preclude any further improvement.

It is the very subjectivity of the Linnaean hierarchy which gives it the flexibility required by the incompleteness of our knowledge of relationships. It permits the proposal of alternate models of relationships and gives different authors an opportunity to test which particular balance between splitting and lumping permits the presentation of maximum amount of information. Like any other scientific theory it will for ever be provisional.

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TAXON AND CATEGORY

Taxon (Plural : Taxa.). The taxa are the groups of animals generally groups of species. The words insects, fishes, birds, mammals in animals; algae, fungi, ferns, mosses, grasses, etc., in plants are the groups of organisms. These are the concrete objects of classification. Any such group of such population is called taxon. But in ordinary usage only the so called basic categories (genus, family, order, class, phylum, kingdom), are treated as such groups. The supertaxa at all lelvels are treated as groups of the basic taxa (a superclass as a group of classes) and the subtaxa at all levels as a subdivision of the basic taxa (a suborder as a section of the order).

According to **Simpson,** " *A taxon is a group of real organisms recognised as a formal unit at any level of a hierarchic classification.*"

According to **Mayr** (1964). "*A taxon is a taxonomic group of any rank that is sufficiently distinct to be worthy of being assigned to a definite category.*"

Category. The group of animals are taxa. Each taxon is placed at some level in hierarchy. A category designates rank or level in a hierarchic classification. It is a class, the members of which are all the taxa assigned a given rank.

A category can be higher or lower than some other one, so we may speak of a higher category. The categories have names, but these are terms and not names in biological nomenclature. They are kingdom, phylum, class and so on. It is an error to state "this animal belongs to category Mammalia", Mammalia is the name of taxon not of category.

TAXONOMIC CATEGORIES

Species. Species is the most important category in the taxonomic hierarchy. It is the basic unit in taxonomy and also in evolution. Its definition has long been one of the major problems of taxonomy. Several definitions and aspects are discussed about the definition of species.

According to **Blackweldler**, the species can be defined as follows: (i) One of the groups,the one placed in the category called the species level (a species group), (ii) The category or level at which the species groups are placed (the species level).

Two main definitions are given for species. These are as follows :

Biological species. Biological species are usually defined as groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups. This gives theoretical groups which can seldom be distinguished in practice.

Simpson has pointed out that all the definitions of animal species give us biological species. He, therefore, prefers the name genetical species for this and cites also biospecies. (It should be noted that populations do not interbreed, only individual animals and plants interbreed).

Genetical species. Genetical species are groups of interbreeding populations which are reproductively isolated from each other. They are, thus, the same as biological species. For example, in *Homo sapiens*, the *sapiens* is a species of *Homo*.

Genus. The taxa placed in the genus category are the genera. These are groups of species brought together by the taxonomists as evidenced by the fact that generic name is a part of each name of each of the included species.

The genus is involved from naming of the first species of whose name it forms the first part. Again it is possible to say that a genus is any group of species included under the one generic name by any taxonomist. This is completely subjective, but it is approximately the working definition which is the basis of most taxonomic work. The genus cannot properly be described as the next higher level above the species, because it is common and always possible to use subgenera between the genus and species, and to use also sections or other informal categories.

A pragmatic definition of the genus states, "*A genus is a taxonomic category containing a single species or a monophyletic group of species, which is separated from other taxa of the same rank (other genera) by a decided gap.*"

The genus *Felis* includes the golden cat (*Felis temincki*) the fishing cat (*Felis viverrina*) and the leopard cat (*Felis bengalensis*).

Family. This is a taxonomic category containing one or more related genera and which is separated from other related families by important and characteristic differences.

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The family **Felidae** which includes the lion, the leopard, the tiger and all types of cats belonging to different genera. This family is distinctly separate from the family **Canidae** which includes dogs and foxes.

Order. The order is the basic category of what has been called the order group which includes also superorders, the suborders, the infraorders and taxa at any other levels interpolated between superfamily and infraclass. In many phyla, orders are very well known groups, but in some phyla they are less well known than the classes, whereas classes do have a fairly evident uniformity throughout the animal kingdom. The orders of vertebrates, for example, are scarcely comparable to families in insects and levels vary in other groups. For example, the order Carnivora includes families Felidae and Canidae.

Class. The class is the basic category of what has been called the class group which included also superclasses and infraclasses, as well as any others interpolated among these. In the animal kingdom as a whole, the classes are undoubtedly the best known taxa, even the phyla being subject to more differences of the opinion. A class is generally a subdivision of a phylum. For example, the order Carnivora includes the lion, the cat, etc., are included in the class Mammalia.

Phylum. The taxa placed in the phylum category are the phyla, subdivisions of the kingdom. They may be assembled into superphyla or subdivided into subphyla. The phylum Porifera includes three classes such as Calcarea, Hexactinellida and Demospongia.

Kingdom. This is the highest taxonomic category. All animals are included in the animal kingdom and all plants are included in the plant kingdom.

SPECIES AS A CATEGORY

The importance of the term species in all fields of biology is so immense that it deserves special consideration. It has already been stated that individual organisms which have many features in common and are able to breed only amongst themselves are encompassed by the term species.

The definition of species is not restricted only to the taxonomists. Nowadays the other fields of biology also consider the species to a great extent. Cytologists, geneticists, ecologists, biochemists and others have also defined the species. The definitions given by different workers are as follows :

Allopatric species. The species inhabiting different geographical areas.

Sympatric species. The species normally occupying the same geographical areas.

Morphospecies. "These are ones established by the morphological similarity regardless of other considerations" **(Simpson).**

Biospecies and genetical species. A group of inter-breeding populations which are reproductively isolated from other such group.

Sibling species. It is a term applied to pairs or groups of very similar and closely related species. When applied to closely related species (in phylogenetic sense) this expression refers to hypothetical species, these cannot be dealt with in taxonomy but can be useful in speculations on evolution.

Taxonomic species. A species which has been provided a specific name under the International Rules of Nomenclature.

Evolutionary species. These are lineages (ancestral descendent sequences of populations) evolving separately from each other and with their own unitary evolutionary roles and tendencies.

Polytypic species. Polytypic species are those which consist of two or more subspecies.

Monotypic species. Monotypic species consist of a single subspecies.

OUTLINE CLASSIFICATION OF ANIMALS

The animals have been classified in various ways by different authors. The classification which follows is based on the classification proposed by **Meglitsch, P.A.** (1972). In this classification, only larger groups have been taken into consideration.

KINGDOM ANIMALIA

This is the largest group of animal classification. It includes the entire animal population (fauna) of the world. It is divided into two subkingdoms : **Protozoa** and **Metazoa.**

Subkingdom A. Protozoa

About 50,000 species. Acellular microscopic animals. Solitary or colonial. Specialized cell organelles. Single to many nuclei. Nutrition holozoic, holophytic or saprozoic or parasitic. Freshwater, marine or moist terrestrial.

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Phylum 1. Protoza (First animals). Characters as those of the subkingdom.

Subkingdom B. Metazoa

Multicellular animals. Body comprises many cells, usually arranged in layers or tissues. It is divided into three branches: Mesozoa, Parazoa, Eumetazoa.

Branch I. Mesozoa

Cellular animals having the structure of a stereoblastula,composed of surface layer of somatic cells and interior reproductive cells.

Phylum 2. Mesozoa (Middle animals). About 50 species. Worm-like, small. Symmetry bilateral. An external layer of ciliated digestive cells surrounding one or several reproductive cells. Parasitic in cephalopods and other invertebrates.

Examples : *Dicyema, Rhopalura*, etc.

Branch II. Parazoa

Animals of cellular grade of organization with incipient tissue formation. Interior cells of several different kinds. There is no mouth or digestive tract and no organ systems are pressent. The body is porous with one to many internal cavities lined by choanocytes. Sessile, marine, a few freshwater. Solitary or colonial.

Phylum 3. Porifera (Pore-bearers).About 5,000 species. Characters as those of the branch.

Examples : *Scypha or Sycon, Euplectella, Hyalonema, Euspongia*, etc.

Branch III. Eumetazoa

Animals of tissue or organ-system grade of organisation with mouth and digestive tract (except when lost by parasitic degeneration). Interior cells of several kinds. Body not porous and without cavities lined by choanocytes.

Grade I. Radiata

Eumetazoa with primary radial symmetry. Tissues are present and organ-systems are incipient. Mesoderm, usually derived from the ectoderm, is present as an incipient tissue, without a high degree of cellular specialisation.The only body space is the digestive cavity, which has a mouth, but no anus.

Phylum 4. Cnidaria (Coelenterata). About 10,000 species. Symmetry radial, biradial or radio-bilateral. The mouth is encircled by tentacles bearing nematocysts. No rows of ciliated plates. Body cavity as coelenteron. Sessile or free swimming. Solitary or colonial. Marine or freshwater.

Examples : *Hydra, Obelia, Aurelia, Metridium*, Corals, etc.

Phylum 5. Ctenophora (Comb-bearers or Comb-jellies). About 90 species. Symmetry is biradial. Tentacles when present, do not encircle the mouth. No nematocysts. Eight radial rows of ciliated swimming plates. Free-swimming and marine.

Examples : *Pleurobrachia, Coeloplana, Ctenoplana*, etc.

Grade II. Bilateria

Eumetazoa with bilateral symmetry, or those with embryonic bilateral symmetry later modified into radial symmetry. Organ-system grade of organisation. Mostly with a well-developed mesoderm of endodermal origin. Mostly with body spaces other than the digestive cavity. Mouth and anus generally present. Bilateria is divided into two divisions: Protostomia and Deuterostomia.

Division A. Protostomia

Bilateria in which the mouth arises from the blastopore or from the anterior margin of the blastopore. Protostomia is subdivided into three subdivisions : Acoelomata, Pseudocoelomata, and Coelomata.

Subdivision 1. Acoelomata

No body cavity or coelom. Space between the body wall and digestive tract is filled with mesenchyme. Excretory system of protonephrida with flame bulbs.

Superphylum Acoelomata

Bilateria without a coelom. With mesenchyme between the body wall and digestive tract. Excretory system of protonephridia with flame bulbs. Body unsegmented or consisting of a strobila, with youngest segment toward the head.

Phylum 6. Platyhelminthes (Flatworms). About 12,700 species. Body dorsoventrally flattened. Anus and circulatory system absent. Free living or parasitic. Terrestrial, freshwater or marine.

Examples : *Planaria, Fasciola, Taenia*, etc.

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Phylum 7. Nemertinea or Rhynchocoela (Ribbon worms). About 750 species. Body slender, soft, very elastic and covered with cilia. No segmentation. Mouth anterior with a long eversible proboscis. Digestive tract complete with anus. Circulatory system present. Free-living. Mostly marine, few terrestrial and freshwater.

Examples : *Cerebratulus, Stichostemma*, etc.

Subdivision 2. Pseudocoelomata

Space present between digestive tract and body wall but this space is a pseudocoel (remnant of the blastocoel) and not a coelom. Anus present with or without protonephridia, flame bulbs present or absent.

Phylum 8. Acanthocephala (Spiny-headed worms). About 500 species. Minute parasitic worms. Proboscis protrusible (eversible) with recurved spines. No digestive tract.

Examples : *Echinorhynchus, Gigantorhynchus*, etc.

Phylum 9. Entoprocta (Moss animals). About 60 species. Digestive tube U-shaped. Mouth and anus close together lying within a region surrounded by ciliated tentacles. Sessile. Mostly marine, few freshwater. Solitary or colonial .

Examples : *Pedicellina, Loxosoma, Urnatella*, etc.

Superphylum Aschelminthes

An assemblage of pseudocoelomates. All have anterior mouth, posterior anus and straight digestive tube.

Phylum 10. Rotifera (Wheel animalcule). About 1,500 species. Microscopic. Anterior end with a ciliated corona. Pharynx with internal jaws known as trophi. Protonephridial system with terminal flame bulbs. Mostly freshwater, some marine.

Examples : *Brachionus, Philodina, Rotatoria*, etc.

Phylum 11. Gastrotricha (Hairy stomach worms). About 150 species. Microscopic. Ventral surface flattened and ciliated. Cuticle with spines, plates or scales and unsegmented. Pharynx tubular devoid of trophi. Freshwater and marine.

Examples : *Chaetonotus, Macrodasys*, etc.

Phylum 12. Kinorhyncha (Jaw-moving worms). About 60 species. Small. More or less spiny without superficial cilia. Body unsegmented with the anterior end an introvert. Marine.

Examples : *Echinoderes, Pycnophyses*, etc.

Phylum 13. Nematoda (Round worms). About 10,000 species. Body rounded, slender, covered by a continuous cuticle, often tapered at ends. Cilia absent. Epidermis divided into four or more chords. Only longitudinal muscles in the body wall. Long muscular pharynx having triradiate lumen. Free-living or parasitic. Freshwater or marine or in soil.

Examples : *Ascaris, Rhabditis, Enterobius, Ancylostoma, Wuchereria*, etc.

Phylum 14. Nematomorpha (Horse-hair worms). About 230 species. Body long slender, cylindrical with dorsal and ventral epidermal chords. Gonoducts joining the intestine. Larval stages parasitic and adults free-living.

Examples : *Gordius, Nectonema*, etc.

Subdivision 3. Coelomata

Animals with a true coelom and usually well-developed ectomesoderm. Excretory organs are protonephridia with or without nephrostome. Anus present.

Superphylum Inarticulata

Unsegmented, coelomate protostomes.

Phylum 15. Priapulida. About 8 species. Body surface covered with spines and tubercles. Proboscis anterior. Urinogenital pores separate from the digestive tube in both sexes. Protonephridia terminating in solenocytes joining the gonoducts. Marine.

Example : *Priapulus.*

Phylum 16. Sipunculida (Peanut worms). About 275 species. Body elongated and cylindrical with retractile anterior introvert. Short hollow tentacles around the mouth. No segmentation or setae. Anus dorsal. Marine.

Examples : *Sipunculus, Phascolosoma*, etc.

Phylum 17. Mollusca (Soft-bodied animals). About 1,28,000 species. Body soft covered by mantle usually with an anterior head and a ventral muscular foot. Mantle se

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DEFINITION

The Protozoa may be defined as *'microscopic, acellular animalcules existing singly or in colonies, without tissues and organs, having one or more nuclei. When in colonies, they differ from Metazoa in having all the individuals alike except those engaged in reproductive activities'*.

GENERAL CHARACTERS

1. The protozoans are small, generally **microscopic** animalcules.

2. Simplest and primitive of all animals with very simple body organisation, *i.e.*, **protoplasmic grade** of organisation.

3. **Acellular** animals, without tissues and organs.

4. Body **naked** or covered by **pellicle** but in some forms body is covered with **shells** and often provided with internal skeleton.

5. Protozoans are **solitary** or **colonial**; in colonial forms the individuals are alike and independent.

6. Body shape variable; it may be spherical, oval, elongated or flattened.

7. Body protoplasm is differentiated into an outer **ectoplasm** and inner **endoplasm.**

8. Protozoans may have one or more nuclei; nuclei may be **monomorphic** or **dimorphic**, vesicular or massive. **Vesicular** nuclei are commonly spherical, oval or biconvex, consist of a central body, the **endosome** (nucleolus) encircled by a zone of nuclear sap.

9. Locomotory organelles are **pseudopodia, flagella, cilia** or none.

10. **Nutrition** may be **holozoic** (animal-like), **holophytic** (plant-like), **saprozoic** or **parasitic.** Digestion **intracellular,** takes place inside the food vacuoles.

11. **Respiration** occurs by **diffusion** through general body surface.

12. **Excretion** also occurs through general body surface but in some forms through a temporary opening in the ectoplasm or through a permanent pore, the **cytopyge.**

13. **Contractile vacuoles** perform **osmoregulation** in freshwater forms and also help in removing excretory products.

14. **Reproduction** asexual or sexual; **asexual reproduction** occurs by binary fission, multiple fission, budding or sporulation and **sexual reproduction** is performed by gamete formation or conjugation.

15. **Life cycle** often exhibits alternation of generation, *i.e.*, it includes asexual and sexual phases.

16. **Encystment** usually occurs to tide over the unfavourable conditions and it also helps in dispersal.

17. The single celled body of Protozoa performs all the vital activities of life and, therefore, no **physiological division of labour** is exhibited by them.

18. The protozoans exhibit mainly two modes of life, **free-living** inhabiting freshwater, salt-water and damp places, and **parasitic** living as ecto- and endoparasites. They are also **commensal** in habit.

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trypanosomes make their way to the fly's salivary gland. In the salivary glands they become attached to the walls and undergo another rapid phase of multiplication by longitudinal binary fission and develop into **crithidial forms.** The crithidial forms are characterized by a shorter flagellum and undulating membrane. Flagellum and undulating membrane do not extend in the hinder part of the body. Kinetoplast and basal granule are situated above the nucleus towards the anterior end. Here the development continues for 2–5 days and the crithidial forms produce **metacyclic forms** (Trypanosome forms) which are now infective. These metacyclic forms pass down through the ducts and hypopharynx. When the fly bites a man, the metacyclic forms enter the blood of man along with the saliva of the fly. The whole cycle in the fly usually takes 2–30 days.

TRANSMISSION

Transmission from one vertebrate host to another is effected by an intermediate host which is a blood-sucking fly, *Glossina palpalis* (Tsetse fly). The transmission occurs in two ways.

1. Mechanical or direct transmission. When a tsetse fly (carrier fly) bites a man infected with *Trypanosoma,* some *Trypanosomes* stick to the proboscis of the fly and when the fly bites another man the *Trypanosomes* are introduced into his blood, provided the time between two successive bites does not exceed 24 hours. Such a transmission is termed mechanical or direct as the fly acts merely as a mechanical carrier and parasites do not undergo any changes in it.

2. Cyclical transmission. When the fly sucks the blood of an infected man, the parasites along with the blood enter the midgut of the fly, remain there for two days and start multiplying. Parasites can be inoculated in the blood of another man only after undergoing through a set of stages. This type of transmission is known as cyclical transmission.

RESERVOIRS

Trypanosomes are harmless to their natural vertebrate hosts which are wild antelopes, pigs, buffaloes, etc. These wild antelopes and referred mammals are not harmed by the parasite, hence, they act as **reservoir hosts** from which infection is spread by the **vectors** or intermediate hosts.

PATHOGENICITY AND SYMPTOMS

The bite of an infected fly is usually followed by itching and irritation near the wound, and frequently a local dark red lesion develops. In blood, the parasite multiplies and absorbs nutrients from it. After a few days, fever and headache develop, recurring at regular intervals accompanied by increasing weakness, loss of weight and anaemia. Usually, the parasites succeed in penetrating the lymphatic glands. Because of its infection, the lymphatic glands swell and after it the parasites enter the cerebrospinal fluid and brain causing a sleeping sickness like condition. Development of lethargic condition and recurrence of fever are the symptoms of its infection.

DISEASE

Trypanosoma causes **trypanosomiasis;** most commonly referred to as **sleeping sickness** leading to coma stage and finally resulting into the death of the patient. In fact, two types of diseases are caused by *Trypanosoma* which are essentially similar in symptoms. These are **Gambian and Rhodesian sleeping sickness.** The Gambian sleeping sickness occurs in western part of Africa and its vector is *Glossina palpalis,* while Rhodesian sleeping sickness occurs in rest of Africa and its vector is *Glossina morsitans.* The only difference between the two is that the latter is more rapid causing the death of the patient within 3–4 months of infection.

DIAGNOSIS

The diagnosis is confirmed by examining fresh or stained peripheral blood or by examining the cerebrospinal fluid obtained by lumbar puncture or by examining the extract of enlarged lymphatic glands.

TREATMENT (THERAPY)

Arsenic and antimony compounds were until recently the drugs for treatment of **trypanosomiasis,** but now they are rarely used except for late stages when the parasites have invaded the central nervous system. Two drugs, **Bayer 205** (also called **Antrypol, Germanin** or **Suramin**) and **Pentamidine** or **Lomidine** are now widely used for both treatment and prophylaxis of human infections. These drugs are low in toxicity, effective in treatment, and prevent reinfection for several months.

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PREVENTION (PROPHYLAXIS)

The following measures are suggested for preventing the infection of this parasite.

1. **By eradicating the vectors.** The infection of this parasite can be checked by completely eradicating the secondary host (Tsetse fly). For this, the endemic areas should be kept clean and regular spray of insecticides like DDT is suggested which help in eradicating the fly.

2. Care should be taken to keep the reservoir hosts free from its infection.

3. Preventive medicines should be taken frequently and periodically which help to a great extent from its infection.

TABLE 13.1 : LIST OF SOME PATHOGENIC TRYPANOSOMES

S.No.	Name of species	Name of primary host	Site in primary host	Name of secondary host or vector	Name of disease	Distribution
1.	*Trypanosoma gambiense*	Man	Blood	*Glossina palpalis* (Tsetse fly)	African sleeping sickness	Central Africa
2.	*T. rhodesiense*	Man	Blood	*Glossina morsitans* (Tsetse fly)	Rhodesia sleeping sickness	South-eastern coastal areas of Africa
3.	*T.cruzi*	Man (children)	Blood	*Triatoma* (Bug)	Chagas' disease	South and Central America
4.	*T. brucei*	Horses, mules, donkeys, camels, cattle, swines and dogs	Blood	*Glossina morsitans* (Tsetse fly)	Nagana	Africa
5.	*T. evansi*	Horses, mules donkeys, cattle, camels, elephants	Blood	*Tabanus or Stomoxys*	Surra in horses	Widely distributed
6.	*T. equinum*	Horses	Blood	Tabanid fly	Mal de Caderas	South America
7.	*T.equiperdum*	Horses and donkeys	Blood	No intermediate host. Transmission takes place from host to host during sexual act.	Dourine	Widely distributed
8.	*T.hippicum*	Horses and mules	Blood	Flies	Murrina or Derren gadera	Panama
9.	*T. vivax*	Ruminants and horses	Blood	*Glossina* spp.	Virulent	Central and East Africa
10.	*T. simiae*	Pigs, monkeys, sheep, goats	Blood	*Glossina* spp.	Virulent	Africa

REVISION QUESTIONS

1. Describe the structure and life history of *Trypanosoma gambiense*.
2. Give an account of the structure of *Trypanosoma* as seen under electron microscope.
3. Describe the polymorphic forms, mode of transmission and pathogenic effects of *Trypanosoma*.
4. Describe some species of *Trypanosoma* in the following headings: Name of species, Name of primary host, Name of secondary host, Site of infection, Name of disease caused and distribution.
5. Write a note on various control measures of *Trypanosoma* infection.

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Trypanosoma

The genus *Trypanosoma* (Gr., *trypanon*= auger, *soma=body*) is parasitic in the blood of most of the vertebrates like fishes, amphibians, reptiles, birds and mammals. Many species of genus *Trypanosoma* are **pathogenic,** while many species are **non-pathogenic.** The disease caused by *Trypanosoma* is called **trypanosomiasis.** Of all the species of *Trypanosoma,* only three species are pathogenic in man, *viz., Trypanosoma gambiense, T. rhodesiense* and *T. cruzi. T. gambiense* and *T. rhodesiense* live as parasite in the human blood and cause a deadly disease known as **sleeping sickness** in Africa, while *T. cruzi* causes the **chagas' disease** in childern in South America. Their transmission from one vertebrate host to other takes place by invertebrate blood-sucking animals like insects and leeches. These animals are referred to as **vectors.** Here we shall describe the structure and life cycle of a well known parasite *Trypanosoma gambiense* which causes a very serious disease in man known as **African sleeping sickness.**

TRYPANOSOMA GAMBIENSE

SYSTEMATIC POSITION

Phylum	...	**Protozoa**
Subphylum	...	**Sarcomastigophora**
Superclass	...	**Mastigophora**
Class	...	**Zoomastigophorea**
Order	...	**Kinetoplastida**
Genus	...	*Trypanosoma*
Species	...	*gambiense*

HISTORICAL BACKGROUND

Valentine was the first to report *Trypanosoma* in the blood of a Trout. **Gruby** established the genus and **Lewis** reported it from the blood of rat. **Evans** and **Bruce** described *Trypanosama* from the blood of horses, camels and cattles. **Forde** (1901) first observed this parasite in the blood of man. It was again confirmed by **Dutton** (1902). **Castellani** reported this parasite in the cerebrospinal fluid of man. Then, **Bruce** and **Nabarro** established the relationship of the disease sleeping sickness with this parasite. **Bruce** also discovered that the disease is transmitted by tsetse fly.

DISTRIBUTION

The different species of *Trypanosoma* are reported from Central and West Africa, Nigeria, Congo and Central America. Commonly, areas near the rivers and lakes having low marshy land have the greatest incidence of infection because the insect vector inhabits in these areas.

HABIT AND HABITAT

Trypanosoma gambiense lives as a parasite in the blood, lymph, lymph nodes, spleen, or cerebrospinal fluid of man and in the intestine of blood-sucking fly *Glossina palpalis* (Tsetse fly).

STRUCTURE

Shape and size. *Trypanosoma gambiense* has a slender, elongated, colourless, sickle-shaped and flattened microscopic body which is tapering at both the ends. The anterior end is more pointed than the posterior end which is blunt. Its body length varies from 15 to 30 microns and width from 1 to 3 microns. The shape and size of its body vary with the form in which it exists.

Pellicle and undulating membrane. The body is covered by a thin, elastic and firm **pellicle.** It maintains the general shape of the body. The pellicle is made of fine fibrils which run along the whole length of the body. These fibrils are called **microtubules.** The pellicle is pulled out into an irregular membranous fold to one side when its flagellum beats. This fold is called **undulating**

membrane, which is supposed to be an adaptive structure for locomotion in a viscous environment (blood, lymph) where it lives.

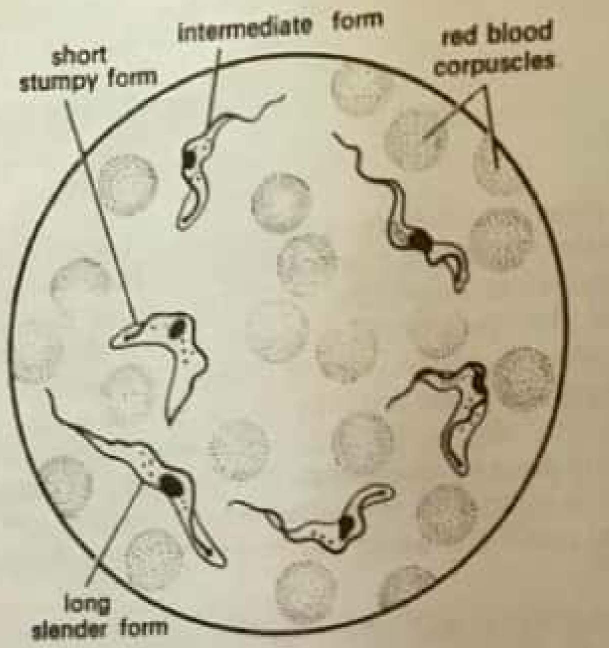

Fig. 13.1. *Trypanosoma gambiense*. Human blood smear to show its various forms.

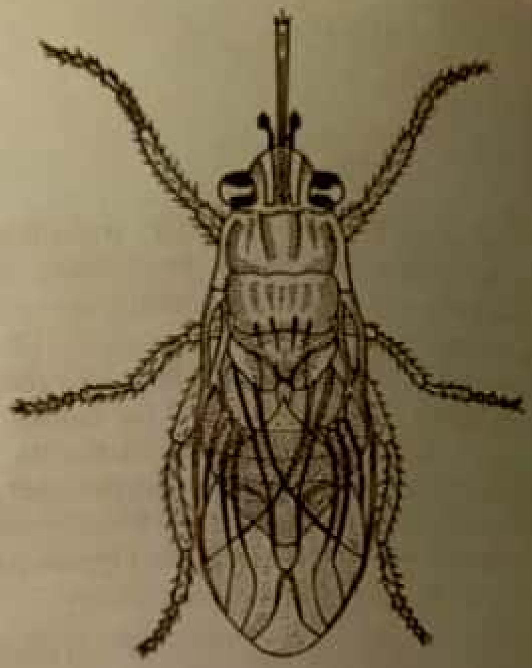

Fig. 13.2. Tsetse fly.

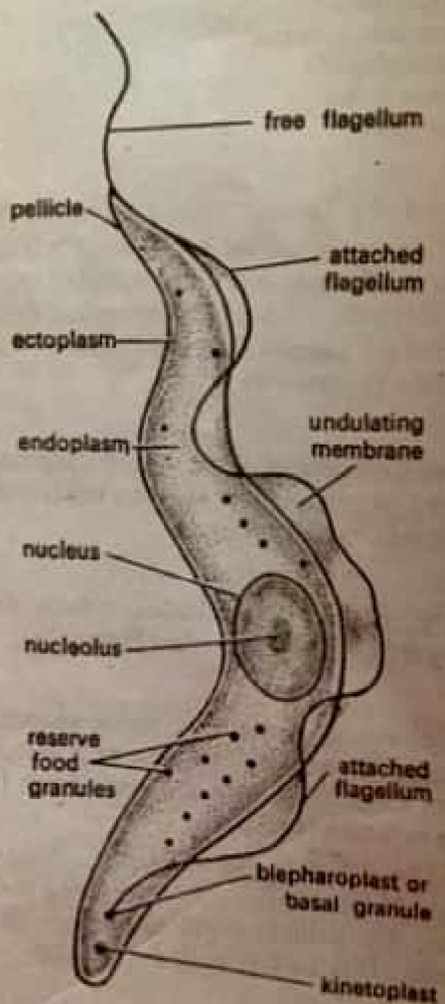

Fig. 13.3. *Trypanosoma gambiense*.

Flagellum. Flagellum is single in *Trypanosoma*, *i.e.*, it is **uni-flagellate**. The flagellum arises from the **basal granule** situated near the posterior end of the body. The flagellum runs forward and remains attached all along the length of the body marking the boundary of undulating membrane. After reaching the anterior end of the body, the flagellum becomes free and hangs freely as **free flagellum**. Structurally, the flagellum is like that of *Euglena's* and consists of the **axoneme** enclosed in a thin cytoplasmic sheath.

Kinetoplast. Just posterior to basal granule, there is a small, spherical or disc-shaped **parabasal body** or **kinetoplast** which contains extranuclear DNA and, hence, it is a self-duplicating body. The kinetoplast is related to locomotion.

Cytoplasm. Its cytoplasm is differentiated into ectoplasm and endoplasm. The cytoplasm contains numerous scattered greenish refractile deep staining granules called **volutin granules**. The volutin granules are metabolic food reserves and generally consist of glycogen and phosphates. In addition, cytoplasm also contains some small **vacuoles** having hydrolytic enzymes in them and all other cellular components like Golgi body, mitochondira, endoplasmic reticulum and nucleus.

Nucleus. A single, oval or spherical and vesicular nucleus **(trophonucleus)** is seen in the middle of its body. The nucleus contains a large **endosome** surrounded by chromatin.

Electron structure of *Trypanosoma*. Vickerman (1965) has studied the structure of *Trypanosoma* under electron microscope. He has noticed a pocket-like structure

LOCOMOTION

Trypanosoma gambiense performs its locomotion by the wavy movements of the undulating membrane and by the flagellum. They swim (in blood and lymph) in the direction of the pointed end of the body, being propelled by the wave motions of the undulating membrane.

NUTRITION

Nutrition is saprozoic. *Trypanosoma gambiense* feeds by osmotrophy on the blood and tissue fluids of its host. It digests the sugars by the enzymatic action. The nourishment is absorbed through the general body surface from the blood and intercellular fluids of the tissues.

RESPIRATION

Respiration is basically anaerobic because it lives in an environment without oxygen. The absorbed glucose undergoes glycolysis to release energy necessary for metabolic activities.

EXCRETION

The metabolic waste products are directly diffused out through its pellicle or general body surface into its external environment, *i.e.*, blood and lymph of the host. The osmoregulatory mechanism is altogether wanting due to its parasitic mode of habit.

REPRODUCTION

Trypanosoma gambiense reproduces asexually by longitudinal binary fission. Sexual reproduction is not known in this species.

Longitudinal Binary Fission

In the longitudinal binary fission (Fig. 13.6), the division is initiated by basal granule (blepharoplast) and followed by the kinetoplast. Next, a new flagellum begins to grow out along the margin of the undulating membrane. The nucleus then divides and this division is followed by the longitudinal division of the cytoplasm, commencing from the anterior end and extending backwards till the daughter individuals separate. By repeated division, the parasites increase in the blood of the vertebrate host until the blood is swarmed with them.

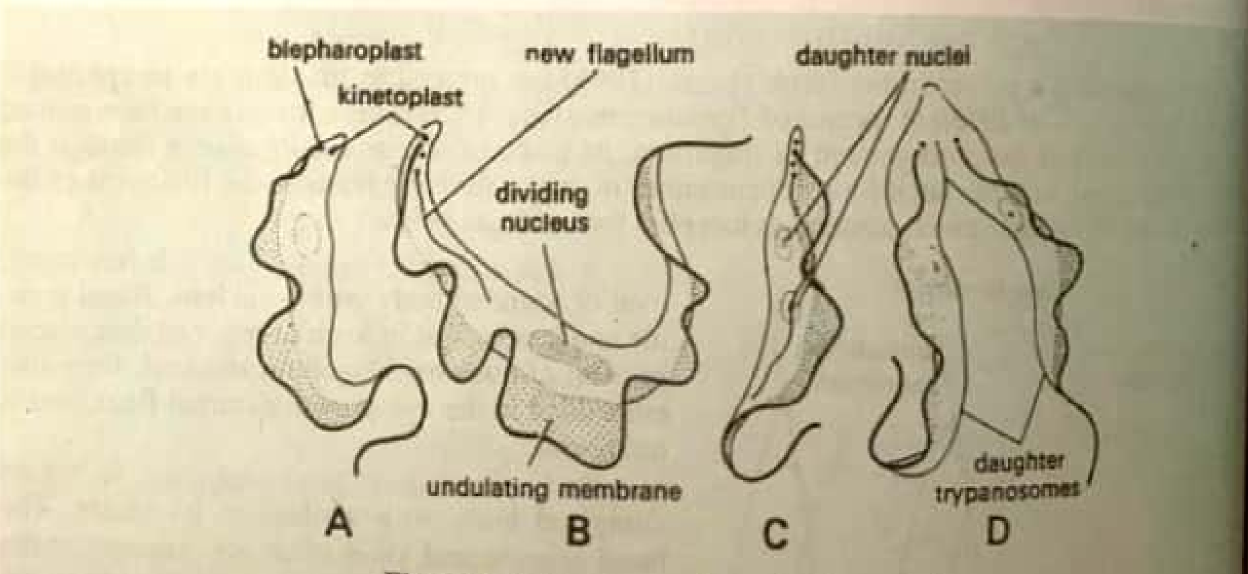

Fig. 13.6. *Trypanosoma*. Stages in binary fission.

LIFE CYCLE

The life cycle of *Trypanosoma gambiense* is completed within two hosts, *i.e.*, digenetic (Gr., *di*=double; *genos*=race), a primary vertebrate and secondary invertebrate host or vector. The vertebrate host is man and the invertebrate host is blood sucking fly, *Glassina palpalis* (Tsetse fly). *Trypanosoma gambiense* lives harmlessly in the blood of antelopes.

Part of Life Cycle in Man

When an infected fly bites a man it inoculates a few parasites in the blood of man. The parasites first live in the blood of the infected man, but later find their way into the cerebrospinal fluid. While the parasites are in the blood, the infected man develops a kind of fever termed Gambia fever, but when they reach the cerebrospinal fluid, various nervous symptoms are produced in the patient leading to a lethargic condition, which has given the name sleeping sickness to the disease. The parasites

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multiply by longitudinal binary fission in the blood and produce three forms of individuals, *viz*. (i) long and thin forms with a free flagellum, (ii)short and stumpy forms with a reduced flagellum and (iii) intermediate forms. It has been observed that the parasites periodically increase and decrease in number in the blood of man. During the period of decrease the short and stumpy forms, which have great resisting power, survive the period of depression and the rest die. These short and stumpy forms are capable of development in the intermediate host, *Glossina palpalis* (Testse fly).

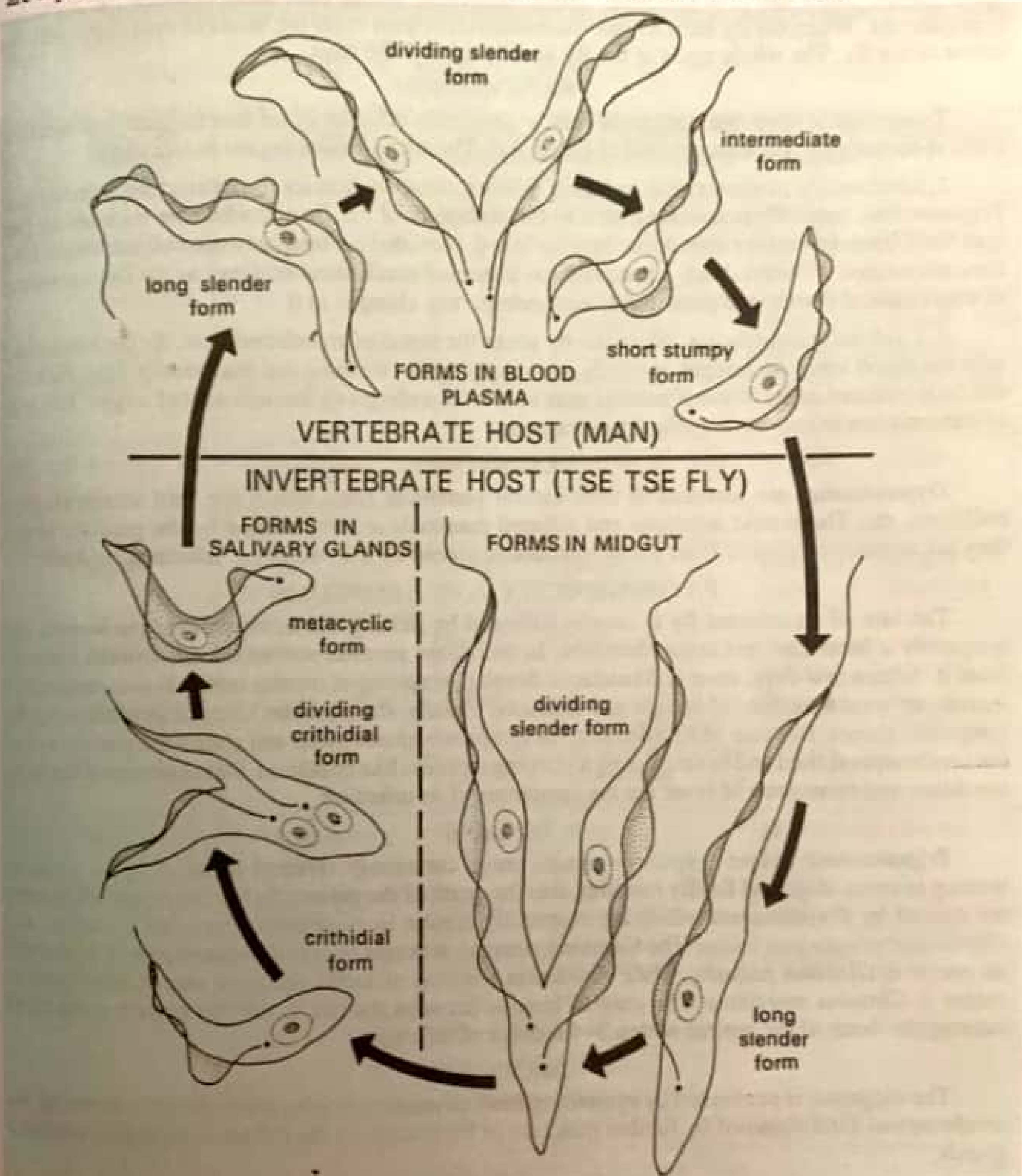

Fig. 13.7. *Trypanosoma gambiense.* Life cycle.

Part of Life Cycle in Tsetse fly

When a tsetse fly sucks the blood of an infected man, a number of parasites enter into the midgut of the fly along with the blood. These parasites remain in the midgut of the fly for a few days and start multiplying by longitudinal binary fission. After tenth to fifteenth day long slender forms appear in great numbers which move forward to the proventriculus. After several more days the

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at the posterior end near the basal body which is called the **flagellar pocket**. The flagellar pocket is believed to be the **reservoir** like that of *Euglena*. Its flagellum represents typical 9+2 internal fibrillar arrangement as in *Euglena*. A single, elongated, giant **mitochondrion** extends from its anterior to the posterior end of the body and, therefore, differentiated into anterior mitochondrion or **anterior**

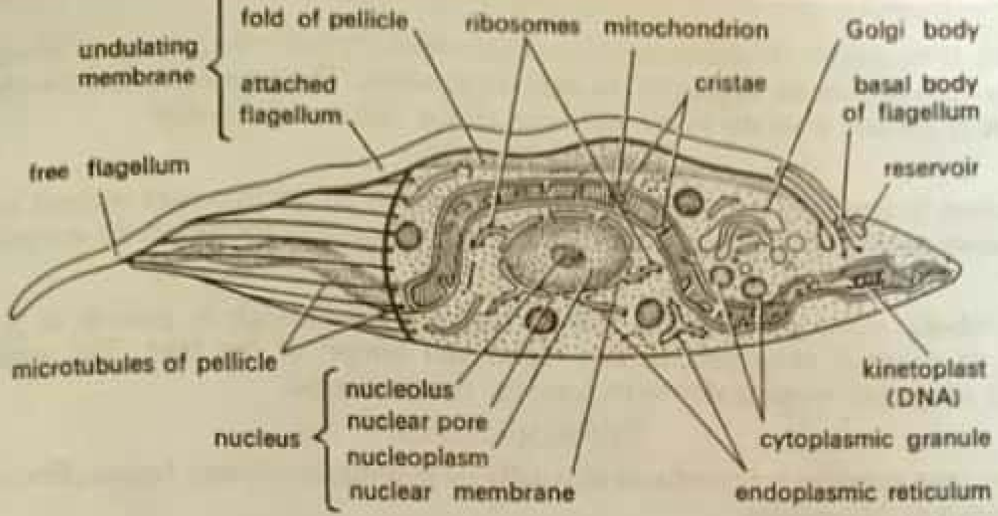

Fig. 13.4. *Trypanosoma*. An electron microscopic structure (diagrammatic).

chondriome and posterior mitochondrion or **posterior chondriome**. It is believed that near the basal granule, kinetoplast is formed by the posterior mitochondrion which has an extranuclear DNA. This DNA is double stranded. A single **Golgi body** is present between the flagellar pocket and the nucleus. The **nucleus** represents its typical structure having double layered nuclear membrane with nuclear pores. The **endoplasmic reticulum** is found either attached to outer nuclear membrane or free in the cytoplasm. The **ribosomes** are found attached to endoplasmic reticulum and also as free bodies in the cytoplasm.

POLYMORPHIC FORMS OF *TRYPANOSOMA*

Trypanosoma is a polymorphic form. **Hoare** (1966) has noticed as many as six morphologic stages in the life cycle of different species of *Trypanosoma* (Fig. 13.5). These forms have been named mostly on the basis of the arrangement of flagellum, its place of origin and its course through the body. However, two or more such forms occur either in one or both the hosts in the life cycle of the various species of *Trypanosoma*. Some polymorphic forms are as below :

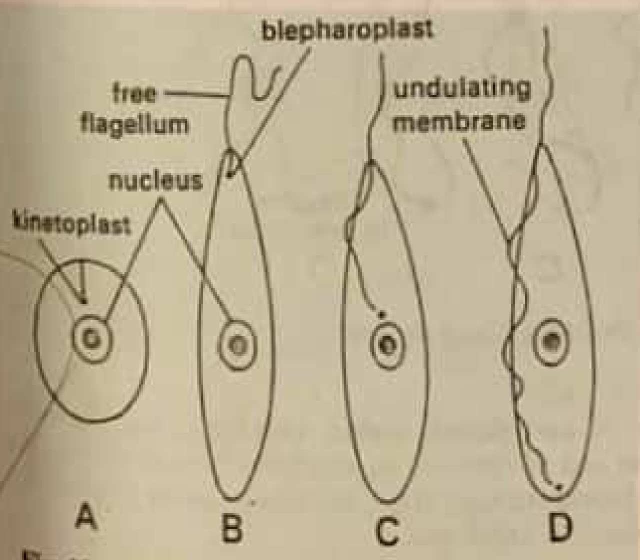

Fig. 13.5. *Trypanosoma*. Polymorphic forms. A—Leishmanial; B—Leptomonad; C—Crithidial; D—Trypanosome.

1. **Leishmanial (amastigote).** It has small, oval or rounded body with a nucleus. Basal granule and kinetoplast in form of reduced dots placed in front of nucleus. Flagellum reduced, fibre-like embedded in the cytoplasm; external flagellum is not found.

2. **Leptomonad (promastigote).** It has an elongated body with nucleus in its centre. The basal granule and kinetoplast are situated at the anterior end. A free flagellum originated from the basal granule and no undulating membrane is formed.

3. **Crithidial (epimastigote).** Its body is short, elongated but stumpy. The basal granule and kinetoplast are situated in front of nucleus which is central. A long flagellum arises from basal granule and becomes free anteriorly. Undulating membrane ill-developed.

4. **Trypanosome (trypomastigote).** Its body is elongated and slender. The basal granule and kinetoplast are situated at the posterior end of the body. Flagellum is large and becomes free anteriorly. The undulating membrane is well developed.

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