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Species: Concepts and Categories

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Abstract: **Species is considered as a basic unit of biological classification. The species problem goes back to early Greek philosophers and naturalists like Hippocrates, Plato and Aristotle who paid their attention to biological classification. Aristotle was considered as Father of biological classification. As far as species is concerned, his idea was a kind of typological or essentialism. Linnaeus, a great taxonomist was considered as father of taxonomy and the main proposer of typological species concept. Occam did not believe in typological species concept and proposed Nominalistic species concept. However, both these concepts of species could not be accepted by naturalists, biologists and evolutionists. An entirely new species concept emerged after this which was based on reproductive isolation and is called as biological species concept. and is considered as a most widely accepted concept of species although it has certain difficulties in its application. Even Darwin also believed in this species concept. After this period, a number of concepts of species have been suggested by numerous evolutionary biologists: evolutionary species, recognition species, phenetic species, phylogenetic species, ecological species, genetic species, genic species, cohesion species etc. The species is defined in different ways in different concepts of species but none of the species definition is flawless. Darwin, in his transmutation notebook, recognized the reality of species, on the basis of the criterion of non-interbreeding. As a consequence of this, he identified the acquisition of reproductive isolation as the mark of completion of the transition from permanent variety to the status of good species. Different terms related to species such as superspecies, polytypic species, monotypic species, subspecies, semi-species, sibling species, chronospecies, sympatric species, allopatric species, parapatric species and cryptic species have also been explained. In this article various concepts of species which define species in different ways and different terms related to species including intra specific categories are briefly described.**

Index Terms: **Concepts and definitions of species, Darwin's concept of species, biological species concept, polytypic species and intraspecific categories**

I. Introduction

Since the early ages of the living world, man has been using classification in his normal life. The term species has been undefined initially for more than three centuries. The term species is a Latin for 'Kinds'. Since ancient time, naturalists and philosophers felt the necessity for certain basic units according to which the existing biodiversity on earth may be elaborated and quantified. But the development of a scientific theory of classification is relatively recent phenomenon. Simpson (1961) and Mayr (1969) have elaborated on the historical development of taxonomy and its concepts. In early days, even Greek philosophers like Hippocates, Plato and Aristotle realized the necessity of biological classification. Hippocrates described the types of animals, Plato believed in classification which is also referred to as theory of forms and used 'Edios'for forms or types. Aristotle was considered as father of biological classification. As far as evolution is concerned, he proposed the principle of "Ladder of Life' – a series in which organisms are arranged in order of increasing complexity. Aristotle studied morphology, embryology, habits and ecology. He also suggested that habits and bodily parts are to be taken into consideration for classification. As far species concept is concerned, his idea was essentially a kind of typological species concept or essentialism. Species are one of the basic units to compare in almost all areas of biology, from anatomy, to behavior, development, ecology, evolution, genetics, molecular biology, palaeontology, physiology, and systematics. Largely, the importance of species stems from its significance in systematics which is a science all the branches of biology rely on (de Queiroz, 2005). Literature on systematics and taxonomy always refer to issues about species and speciation. Species are crucial in many biodiversity issues: much of conservation, biodiversity studies, ecology, and legislation concerns this taxonomic level (Mallet, 2007). There are a large number of concepts of species which define species in different ways (Mallet, 2007; Singh,2012; Nisha et al. 2021).

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Linnaeus (1707-78), a great taxonomist and called as father of taxonomy, believed in the older essentialism (typological species concept) for whom a species has a fixed existence and is unchangeable type (essence). He also became popular for proposing binomial nomenclature. The typological concept of species based on his concept is called as essentialist species concept. After Linnaeus another concept of species was proposed by Occan which was popular in France in the 18th century. According to Occam and his supporters, nature produces only individuals and nothing more and species does not exist in nature, it is only a mental concept of human. All of the older definitions of species including those of Buffon, Launch and Cuvier stress on the morphological similarity of individuals. Both these concepts have been rejected. The presence of sibling species has clearly raised important objections to the typological species concept because different species may be morphologically similar but reproductively isolated (Singh 2012, 2016). Interestingly, in spite of the facts that many evolutionists believed in morphological species concept, an entirely new species concept had started to emerge in seventeenth century. It is important to mention the name of Ray (1686) who believed in morphological species concept but his characterization of species also incorporated the germ of biological species concept and he considered the reproductive relationship to be the main species criterion (Mayr, 1966). It is important that Koelreuter (1761) also gave stress on interbreeding and producing fertile offspring as the species criterion. Buffon also considered the sterility barrier as species criterion which prepared the way for biological species concept (instead of morphological similarity). Later on, the biological species concept was developed as a result of contribution of Merrem, Voist, Walsh and many other naturalists and taxonomists of nineteenth century.

Under Darwin's theory of evolution (Darwin, 1859), species evolved rather than being created. Darwin's materialistic, morphological definition of species was central to his theory of natural selection. Varieties have the same general characters as species but they can be distinguished by the discovery of intermediate linking forms and a certain degree of small differences (Mallet ,1995). To Darwin, species did not differ essentially from varieties within species but were distinguishable in that they had developed gaps in formerly continuous morphological variation (Mallet, 2010). In the 150th anniversary of the Darwin's 'Origin of Species', we appear to be returning to fuller appreciation of what Darwin meant (Mallet, 2010). Kottler (1978) has clearly stated that there is definite evidence from his transmutation note books that Darwin had some sort of biological species concept accepting the reality of species in some sense, was aware of problem of speciation (the reality of species) and recognized the role of isolation in the process of speciation. Mayr (1976) has reached the conclusion in his most recent remark on Darwin's view on species and speciation that he believed in geographic speciation which was consistent with earlier concept of species as reproductively isolated populations. Interestingly, Darwin also recognized that acquisition of reproductive isolation marked the attainment by an isolated variety of species rank and hence completion of speciation (Kottler, 1978). Thus, Darwin gave importance to reproductive isolation and hence biological species concept. In his transmutation note books, Darwin realized the reality of species on the basis of criterion of non-interbreeding. As a consequence of this biological species concept, Darwin recognized that acquisition of reproductive isolation was the mark of completion of transformation of permanent variety to the status of good species. In these notebooks, Darwin came close to distinguishing the modification from the multiplication of species while using Galapagos Islands as a model, he suggested his theory of speciation based on geographic isolation (Kottler, 1978).

Biological species concept was clearly formulated by Jordan, Mayr and Dobzhansky (Singh, 2012). Based on biological species concept, a species is defined as a group of potentially or actually interbreeding natural populations which are reproductively isolated from other such groups (Mayr, 1940). However, Dobzhansky (1950), being an evolutionary geneticist, defined species as a reproductive community of sexually and cross-fertilizing individuals which share a common gene pool. Although it is most widely accepted concept of the species, it has certain difficulties in its application. Such as insufficient individual information, uniparental reproduction and evolutionary intermediacy. The biological species concept became very popular species concept in twentieth century. However, more than twenty species concepts have been suggested by evolutionists, naturalists and taxonomists from time to time (Mayr & Ashlock, 1991; Mallet, 2007; Singh, 2012; Nisha et al., 2021).. Some of the concepts of species are briefly described in this article. In addition to the species concepts, certain terms related to species (intra species categories) are also described here briefly.

II. Concepts of Species

In the literature, more than twenty concepts of species have been described (Mallet, 2007; Singh, 2012; Nisha et al., 2021). The species are defined in different manners in different concepts of species. Some concepts of species are described briefly below:

1. Typological/Morphological/ Essentialistic Species Concept: This is the first concept of species which was explained in detail by Linnaeus and his followers in eighteenth century. Plato and Aristotle also emphasized the typological species concept or essentialism. According to this concept, there is limited number of types or universals and all the members of a species constitute a class. It is also called as essentialist species concept which is referred to as essentialism. It is based on the amount of morphological variations used by the taxonomists. This concept considers the species as a constant unit and does

not allow any change during the course of time. It is a known fact that there are individual variations within the species and different species may be morphologically similar as in the case of sibling species which are reproductively isolated, the typological or morphological species concept cannot be accepted. It is of historical significance.

2. Nominalistic Species Concept: The typological species concept was straightway rejected by Occam and his followers who suggested the nominalistic species concept which was popular in France in 18th century. According to this concept, only individuals exist and species has no real entity. Bressey (1908) suggested that nature generates only individuals and nothing more. Species is merely a mental concept. This concept is also rejected because we know that species are not constructs of human.

3. Biological Species Concept: Typological or morphological species concept was given much emphasis by earlier naturalists, evolutionists, taxonomists and biologists. Because of morphological variations within the species, the presence of sibling species and the species is not a static unit, this species concept was rejected. In seventeenth century, certain important suggestions gave birth to the emergence of entirely new species concept i.e. biological species concept. It was Ray (1686) who was a believer in morphological species concept but his species characterization also embodied the concept of biological species considering the reproductive relationship to be the main species criterion (Mayr, 1966). Koelreuter (1761) suggested that all the individuals which interbreed among themselves and produce fertile offspring belong to the same species. Buffon in eighteenth century also prepared the way for biological species concept while emphasizing the importance of sterility barriers as species criterion. Naturalists and evolutionists of nineteenth century such as Merrem, Voigt, Walsh and others contributed significantly to shape the idea of biological species concept. Later on, it was clearly formulated by Jordan, Mayr and Dobzhansky (Singh, 2012), Based on biological species concept, a species is defined as a group of potentially or actually interbreeding natural populations which are reproductively isolated from other such groups (Mayr, 1940). However, Dobzhansky (1950), being an evolutionary geneticist, defined species as a reproductive community of sexually and cross-fertilizing individuals which share a common gene pool. Although it is most widely accepted concept of the species, it has certain difficulties in its application such as insufficient individual information, uniparental reproduction and evolutionary intermediacy. The biological species concept became very popular species concept in twentieth century (Singh, 2012). Recently, the biological species concept has been criticized also by saying that it is time to abandon the biological species concept (Wang et al., 2020; Wu et al., 2020). However, Butlin and Stankowsi (2020) while giving their own arguments said that “No”, it is not the time to abandon the BSC.

4. Evolutionary Species Concept: Palaeontologists have raised objections to biological species concept and are not satisfied with the definitions of species proposed by evolutionists who believe in biological species concept. It is mainly because of the reason that biological species concept has non-dimensional character. Palaeontologists argue that the definition of species must involve evolutionary criteria. For the first time evolutionary species concept was proposed by Simpson (1961) who has defined species as a lineage (an ancestral-descendent sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies. Mayr (1982) has criticized the evolutionary concept stating that it is definition of a phyletic lineage and not of the species. It may be applicable to isolated populations or incipient species. It certainly ignores the core of species problem and tries to delimit species taxa in the time dimension. Thus, Mayr did not accept the evolutionary definition of species and strongly advocated for the biological species concept. Wiley (1978,1981) made an attempt to make certain improvement in evolutionary species definition by making suggestions that no presumed separate, single, evolutionary lineage may be subdivided into a series of ancestral and descendent species. But this definition is of species taxon and not of species category. Thus, there are certain problems with evolutionary species concept: (i) in the fossils, historical fate and evolutionary tendency cannot be observed, (ii) it does not comment about reproductive isolation, (iii) it cannot explain the new species produced from the ancestral population maintains its identity, and (iv) it ignores polytypic species and sibling species (Mayr, 1982) and dichotomous speciation

5. Phenetic Species Concept: It has been elaborated by Sneath and Sokal (1973). In fact, It is upgraded, modified and numerical presentation of typological species concept based upon numerical characters and can be defined as populations designated by discrete clusters of phenotypic characters. It is a set of organisms that cluster at a particular distance from other such clusters. It is based on numerical taxonomy. Since there is no reason to suggest that any definite pattern of morphological pattern exists in natural populations, this concept has been dismissed by evolutionists who believe in neo-Darwinism.

6. Ecological Species Concept: Van Valen (1976) suggested the ecological species concept which is explained by him as “a species is a lineage which occupies an adaptive zone minimally different from that of any other lineage in its range and which evolves separately from all other lineages outside its range. Species are maintained for the most part ecologically, not reproductively.When a species is a set of organisms adapted to a particular set of resources which is called as a niche (adaptive zone) in the environment, gives the concept of Ecological species. It has also been explained by Coninvaux (1986) who stated that a number of related populations, the members of which compete more with their own kind than the members of other species. Under this concept, it is presumed that the ecosystem tends to remove the overlapping species to avoid the competition between them so that in no case two species occupy one niche. Thus, two or more species cannot occupy the same niche. The emphasis is given under this species concept that selection favouring the efficient niche utilization is the basic cause which leads to speciation. However, there are certain problems linked with this species concept such as: (i) it denies the existence of cryptic species,(ii) there is theoretical assumption regarding prevalence and not properly defined, (iii)

in a number of species there are local populations which occupy different niche but as per this concept all such populations have to be designated as separate species, and (iv) under this concept all sympatric species which occupy the same niche have to be recognized as same species.

7. Phylogenetic Species Concept: This concept was independently developed by Eldredge and Cracraft (1980) and Nelson and Patnick (1981) and offered the key to recognition of elements of phylogenetic analysis. Under this definition, a species is a smallest diagnosable cluster of individual organisms within which there is a parental pattern of ancestry and descent (Cracraft, 1983). It essentially delineates species as a group of organisms by a unique ancestry. There is a problem with this species definition because it is just another form of morphological species concept and it does not explain which character/characters should be taken into consideration while separating a species. According to Nelson and Plantick (1981), it is simply the smallest detected samples of self-perpetuating organisms that have unique sets of characters. Nixon and Wheeler (1990) modified as the smallest aggregation of populations (sexual) or lineages (asexual) diagnosable by a unique combination of character states in comparable individuals ((semaphoronts). The distinctive characteristic of the second group of species definitions developed within the context of phylogenetics systematic is a criterion of monophyly ((de Queiroz & Donoghue, 1990). Wheeler (1999) has suggested that since this concept is based on pattern of character distribution and is therefore consistent with the full range of possible evolutionary processes that contribute to creation of new species which includes both biotic and abiotic factors.

8. Recognition Species Concept: According to Patterson (1985), recognition species concept states that species have a specific mate recognition system and the species can be defined as population sharing common fertilization system in which the individuals recognize one another as their potential mate. In mate recognition system, there are the sets of anatomical, behavioural and chemical cues that allow males and females of a species to recognize each other for the purpose of mating. This concept has certain problems such as it cannot be applied to asexual species and fossils. Further, it is not possible to know whether geographically isolated populations can interbreed and it fails when individuals fail to recognize their own mates. Thus, it has been criticized also (see Mendelson & Shaw, 2012).

9. Cohesion Species Concept: It was suggested by Templeton (1989) who has stated that cohesion species concept combines different competing ideas of species from ecological, recognition and genealogical concepts. It is also suggested that it is closer to biological species concept. According to this concept, species is defined as the most inclusive group of organisms possessing the potential for genetic exchangeability. The spread of new genotypes through the gene flow is limited by genetic exchangeability and closely linked to premating and prezygotic barriers to sexual barriers because two groups of organisms are genetically exchangeable if the gene flow is free between the representatives of two groups. Thus, cohesion species concept defines species as an evolutionary lineage and classifies them through the evolutionary processes which limit the boundary of population under the microevolutionary forces such as gene flow, random genetic drift and natural selection. In case a mutation originates within a population, it may be fixed or eliminated because its fate is determined by random genetic drift and natural selection. Thus, two sets of evolutionary forces are recognized under cohesion species concept but BSC gives emphasis on only one factor ie. gene flow. However, there are certain problems with cohesion species concept: (i) as far as gene flow is concerned, it does not specify the external and internal barriers to gene flow, (ii) it claims its applicability to asexual organisms where there is no gene flow, (iii) it does not clarify how to delimit the open-ended lineage and (iv) it does not clarify about the type of gene flow affecting genetic exchangeability. Thus, there are criticisms of this species concept (see Endler, 1989; Harrison, 1998).

10. Genotypic Cluster Definition: It was Mallet (1995) who recognized that biological species concept is unacceptable because of gene flow between independently evolving units and suggested a pattern-based concept of species. He added genetics to the phenetic species concept which defines species as group of individuals with no intermediates, and suggested the genotypic cluster species definition according to which a species is a genotypic cluster that can overlap without fusing with its sibling. The term genomic cluster would perhaps be a probable synonym in today's postgenomic age.This is also applicable to uniparental organisms. However, if this genotypic cluster definition is accepted, it would result in the unwanted consequences that each genetically different clone will be designated as a separate species (Coyne and Orr, 2004).

11. Genic Species Concept: It was proposed by Wu (2001), a molecular evolutionary biologist who severely criticized the biological species concept and suggested that BSC should be abandoned. According to Wu, it is not the whole genome but a gene is the unit of species differentiation. Under this concept, speciation depends upon genes which are designated as speciation genes. Speciation genes are those genes which show a higher frequency of differentiation during the process of cladogenesis compared to other genes which play part in differential adaptation to varying environment. He defined genic species as group of individuals which are differentially adapted and upon contact fail to share genes controlling adaptive characters either by direct exchange or through intermediate hybrid population. In this concept, differential adaptation is a form of divergence in which alternative alleles of a gene have opposite fitness effect in two groups of individuals. Interestingly, genic species concept is applicable in both cases, biparental as well as uniparental organisms (for details see Blackman, 2016). This concept has also been criticized: it gives excessive and exclusive stress on differential adaptation caused by gene mutations and the role of random genetic drift cannot be excluded in speciation (Orr, 2001; Noor, 2002).

12.Genetic Species Concept: Baker and Bradley (2006) defined a species as a group of genetically compatible interbreeding natural population that is genetically different from any other such population. So, this definition is based on genetic similarity as morphological species concept is based on morphological similarity. Thus, there is emphasis on genetic

isolation and it becomes different from biological species concept where emphasis is on reproductive isolation. It has certain advantages over other concepts because it may lead to better understanding of biodiversity, evolution and speciation. The Bateson–Dobzhansky–Muller model, also known as Dobzhansky–Muller model, is a model of the evolution of genetic incompatibility, important in understanding the evolution of reproductive isolation during speciation and the role of natural selection in bringing it about. There may be some problem with this concept when genetic difference as determined by a person may not be enough to give a population the status of species although genetic difference is enough to recognize a new species. Further, the contamination of DNA samples may also create problem.

13.Differential Fitness Species Concept: There is an interesting piece of observation by Hausdorf (2011) based on that he suggested the differential fitness species concept which differs from biological species concept in respect of the exchange of the species-specific features which may not only be restricted by reproductive isolating mechanisms but also by divergent selective processes. In this regard, the differential fitness species concept is very close to Darwin's (1859) understanding of species than to the biological species concept (Hausdorf, 2011). He has explained in detail the differential fitness species concept. According to Hausdorf (2011), this species concept considers mutations in genes, chromosomal changes, selfish genetic elements such as transposable genetic elements, niche specifying genes, or sets of genes acquired by horizontal gene transfer. The differences may result from differential adaptation due to natural or sexualselection. However, it may also be due to random genetic drift or other nonadaptive factors like polyploidization. Interestingly, the features may be specifically adaptive for the niche of one group but maladaptive for the other group. Such type of incompatibilities could cause lowered fitness or disturbed physiological functions. Like the genic species concept, the differential fitness concept permits the reciprocal exchange of genes as far as these are not important for the characteristics which have negative effects on fitness in the other species. Hausdorf (2011) defined species "as groups of individuals that are reciprocally characterized by features that would have negative fitness effects in other groups and that cannot be regularly exchanged between groups upon contact".

14.Gen-morph species concept-a new and integrative species concept: Hong (2020) proposed a new species concept that is known as gen-morph species concept, a new integrative gene concept for outbreeding organisms. He reviewed the prevailing species concepts such as biological, genetic, evolutionary and ecological which reflects the properties of species from diverse aspects and in different degrees. So far there is no species concept that is both theoretically rational and practically operational (Hong, 2020). While using the results of studies on the genus Paconia in morphology, biogeography, molecular phylogeny and reproductive behavior and also taking and referring the studies on some other plant groups and also incorporating the merits of prevailing species concepts into his consideration, Hong (2020) proposed a new species concept the gen-morph species concept for outbreeding organisms. a bridge linking morphological aspect with genetic and other aspects of species, proposal for a concrete morphological criterion for species definition, and considering quantitative and qualitative characteristics as equally valuable for species definition and introducing statistics into the concept to handle such characteristics. So, it is based on the results of plant species.

III. CATEGORIES OF SPECIES

Mayr and Ashlock (1991) have described a number categories of Species:

1. Superspecies: Superspecies are those species when allopatric populations are so distinct that there is no doubt about their having reached the level of species. There is a German term for such species Artenkreis. A superspecies consists of monophyletic group of closely related and essentially allopatric species. which are morphologically too different. For different components of superspecies another term is used ie. allospecies.
2. Sibling species: Those species which are morphologically similar but reproductively isolated (Singh, 2016).
3. Sub-species: An aggregate of phenotypically similar populations of a species occupying a geographic subdivision of the range of that species and differing taxonomically from other populations of the species.
4. Semi-species: Geographical isolate occasionally having intermediate status between species and subspecies showing some characters of species and some of subspecies. largely allopatric in distribution. These geographical isolates occasionally acquire various biological peculiarities and partial reproductive isolation.
5. Incipient species: A group of organisms that is about to become a separate species from other related individuals. The population showing beginning of speciation or has just completed the process of speciation.
6. Polytypic or Monotypic Species: Those species which contain two or more subspecies are known as polytypic species. The species which are not divided into subspecies are called as monotypic species.
7. Chronospecies: While discussing the evolutionary species concept, Mayr and Ashlock (1991) have suggested that when there is a sequence of morphotypes in a single phyletic lineage, and all have same unitary evolutionary role, are treated as chronospecies.
8. Ring species: A ring species is a connected series of neighbouring populations, each of which can sexually interbreed with closely related populations, but for which there exists two end populations in the series which are too distantly related to interbreed, though there is a potential gene flow between each linked population. Such non-breeding though genetically connected each of the populations may co-exist in the same region thus closing the ring (Nisha et al. 2021).
9. Sympatric species: Those species which occur in the same geographical area known as sympatric species (Singh, 2021).
10. Allopatric species: Those species which inhabit different geographical regions are called as allopatric species (Singh,

2021).

11. Parapatric species: Those species which are geographically isolated but may be in geographic contact in some areas (parapatry) are called as parapatric species (Mayr & Ashlock, 1991).

12. Cryptic species: For sibling species, the term cryptic species has also been used. Mayr and Ashlock stated that such very similar species are called as cryptic or sibling species. However, later, the term cryptic species has been used with different meaning: cryptic species for two or more species hidden under one species name, sibling species for two cryptic species that are closest relative of each other (Singh, 2016).

13. Species complex: Different terms are used such as species complex, species cluster, species sub-group and species group in which closely related species are grouped together. One very good example is given from Drosophila, the Drosophila bipectinata species complex which contains four species: D. bipectinata, D. parabipectinata, D. malerkotliana and D. pseudoannanassae which are closely related phylogenetically and hybridize in the laboratory producing fertile females and sterile males (Singh and Banerjee, 2016).

CONCLUSION

Species is a basic unit of biological classification and is derived from the Latin word meaning kind. Even the early Greek philosophers like Hippocrates, Plato and Aristotle paid attention to biological classification. Aristotle was considered as father of biological classification. As far as species is concerned, his idea was essentially typological or essentialism. Linnaeus called as father of taxonomy, proposed binomial nomenclature and believed in typological species concept (essentialism) and according to whom species reflects the existence of fixed unchangeable type (essence). The typological definition of species on the basis of concept of Linnaeus is called as the essentialist species concept. In this concept, the species remains unchanged. But now we know that species undergoes evolutionary change and showing morphological variations among individuals, this concept cannot be accepted. Further, the sibling species which are morphologically identical but show reproductive isolation, which also denies the acceptability of typological species concept. Later, a number of species concepts have been described and species is defined in different manner in different concepts. There was development of biological species concept which is most widely accepted concept of species although it has certain difficulties in its application and it has also been criticized by molecular biologists. There are a number of evolutionists, taxonomists, naturalists and biologists who have given much importance to the theory of evolution proposed by Charles Darwin and the concepts of species followed by him. Since Darwin believed in reproductive isolation, geographic speciation, interspecific hybrid sterility and transformation of varieties to the status of good species, it is rightly suggested by numerous evolutionists, biologists and naturalists that he followed biological species concept which is most widely accepted concept of species although it has certain difficulties in its application (Singh, 2012). Here it may be mentioned that the biological species concept has been criticized by suggesting that it is time to abandon the biological species concept by Wang et al. (2020) who believe in genic concept of species. On the other hand, Butlin and Stankowski (2020) has replied to the remark of Wang et al. (2020) by stating that it is not the time to abandon the biological species concept. In fact, Butlin and Stankowski (2020) have argued that there is actually no difference between genic concept and BSC, unless the BSC is tied to allopatric accumulation of reproductive isolation and the genic view is not (Singh, 2023).

Further, species categories such as polytypic species, sibling species, subspecies, semispecies, incipient species, monotypic, polytypic species, chronospecies, cryptic species, sympatric species, allopatric species, parapatric species etc are also briefly described.

Hong (2020) proposed an entirely new species concept considering the prevailing species concepts and morphological and genetic characterstics of species of plants which he has called a new and integrative species concept. Anderson (1990) has supported the ecological species concept by arguing in its favour that ecology plays an important role in most of the species concepts. He believes that there is overemphasis on reproductive isolation in biological species concept and too little attention to the role of ecology. Brothers (1985) who advocated in favour of evolutionary species concept has remarked that "Nevertheless, if such a concept could be found, one applicable to all of the various types of species that may exist, each of these being a special case within a general condition, then such a concept would be of far greater usefulness than a number of different concepts." In 1997, Mayden identified at least twenty-two species concepts currently in use. Different factors are considered important under different species concepts: reproductive isolation, morphological features, ecological requirements, genetic differences, evolutionary lineages etc. Ridley (1993) discussed seven species concepts (phonetic, biological, recognition, ecological, cladistic, pluralistic and evolutionary) and concludes that a combination of four (biological, recognition, ecological and cladistic) is ideal. On the other hand, King (1993) suggests eight (morphological, biological, recognition, cohesion, evolutionary, cladistic, ecological and phylogenetic) finally concluding that the biological species concept is the best. Since Darwin believed in reproductive isolation, geographic speciation, interspecific hybrid sterility and transformation of varieties to the status of good species, it is rightly suggested by numerous evolutionists, biologists and naturalists that he followed the biological species concept which is widely accepted concept of species although it has certain difficulties in its applications (Singh, 2023). de Queiroz (1999) argues that there is single, primary species concept that is adequate –applying across biodiversity and that is the general lineage concept. Mayden and de Queiroz are of the opinion that BSC and ESP are not competing rather they are complementary to each other. The biological species concept

which is based on reproductive isolation, is important in so far as it identifies the kind of lineages required by the evolutionary species concept. There is no need that each concept be individually adequate, applicable across biodiversity. The biological species concept based on reproductive isolation is applicable to sexually reproducing organisms (Richards, 2013). The BSC has also been criticized by Wu and others who support the genic species concept This concept has also been criticized: it gives excessive and exclusive stress on differential adaptation caused by gene mutations and the role of random genetic drift can not be excluded in speciation (Orr, 2001; Noor, 2002). Noor (2002) has asked "Is the biological species concept is showing its age? He further remarks that many evolutionary biologists are excited by the empirical results of Wu and others, few agreeing with the abandonment of the BSC, and none wholeheartedly embracing the new genic concept (Noor 2002).

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