What is a Species? An Endless Debate

Uttam Saikia, Narayan Sharma and Abhijit Das

Everybody is familiar with the ubiquitous term 'species'. But what is a species? Undeniably, this is one of the most complex dilemmas in the history of biology. There is no other concept in biology as elementary yet controversial as the concept of species. In practice, a species is regarded as the fundamental unit of comparison in all biological disciplines like systematics, evolution, ecology, ethology, physiology, and genetics. However, little agreement exists in the scientific community regarding the nature of species, whether it is a real entity or a cultural artifact, its biological significance or how to delineate a species. This article is a review of the seemingly endless debate on the species concept and its implications.

(left) Uttam Saikia is working at High Altitude Zoology Field Station, Zoological Survey of India, Solan, Himachal Pradesh.

(right) Narayan Sharma is a research scholar in National Institute of Advanced Studies, IISc Campus, Bangalore. His area of research is primate ecology and behaviour.

(center) Abhijit Das is a research scholar in Utkal University, Orissa. His research interest includes taxonomy and biogeography of herpetofauna of Northeast India.

The Species Concept: Historical Perspective

Since olden times, naturalists have felt the need for a unit by which diversity of life form on Earth can be described and measured. Early naturalists and philosophers like Pluto and Aristotle initiated the process of classifying biological objects based on typological essentialism i.e., every species (species is the Latin word for kind) should conform to certain predetermined ideal "type". Anything not similar to a particular type is considered a different species. This is known as typological species concept although in a strict sense it is not a concept but merely a guideline for delimiting species taxa. This approach, however, could not account for geographical variations among conspecifics (of the same species) as well as sympatric (cohabiting) groups, closely alike, but belonging to different species. Thus, apart from taxonomic utility, it did not have much biological value. In early decades of the twentieth century, the systematics community began to perceive the natural world in evolutionary terms. This novel outlook, in essence, was promoted by the Darwinian ques-

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tion "why" and "how" variations among organisms might have occurred. These thoughts took the shape of the now well-known Biological Species Concept. Under this concept, phenotypically similar, allopatric (occurring in different geographical locations) populations are lumped as single species. During the middle of the twentieth century, the American paleontologist G G Simpson proposed another alternative in which he envisaged species as a lineage of ancestral-descendent sequence of population. This concept came to be known as Evolutionary Species Concept. Concurrently, with the advent of phylogenetic systematics (cladistics), some workers envisaged species from phylogenetic perspective (the role of species is in phylogenetic analysis). These perspectives are collectively termed as Phylogenetic Species Concepts. In recent time, another concept called Genetic Species Concept has gained prominence which visualizes and delineates species in terms of genetic uniqueness although the origin of this concept can be traced back to very early part of 20th century when William Bateson introduced the idea in 1909.

Three Connotations of Species: Concept, Category and Taxon

'Species' is a very ambiguous term in biology referring to three distinct, though inter-related, entities and this multiuse of parlance is a source of much confusion. It refers to species concept, species category and species taxon. It is of paramount importance to distinguish these three terms in order to clearly appreciate any discussion on species and speciation. There are enormous disparities in the way different workers look at the concept of species. Some perceive species as evolutionary lineage, some as fundamental units of biological organization, whereas, others see it as a device for protection of integrity of gene pools and so on.

'Species concept' is basically a part of evolutionary theory concerning questions like what constitutes a species and its biological or evolutionary significance.

Categories are different levels recognized in the Linnaean hierarchy of classification, like order, family, genus, species, etc. Categories are constructs of biologists for convenience and are somewhat arbitrary or subjective. However, as pointed out by Mayr, the species category (the basic level in Linnaean hierarchy in whose terms diversity of organisms are described) is probably the only category whose boundary can be objectively defined, i.e. higher categories lack the usually clear-cut demarcation of species. It is erroneous to assume that the species category is the same as the species concept. As a rank in Linnaean scheme of classification, species category is ideally applicable to all sexually and non-sexually reproducing organisms but the biological species concept is not applicable to asexual species. Thus, 'species category' is a class/level in this hierarchy containing taxa of species rank and is very different from the species concept. However, as Wiley suggested, "The definition of the word species (species category) will be built on a species concept and the concept itself will profoundly affect the way in which investigators view the origin of the species they study".

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The 'species taxon' is the practical application of species category through systematics. In other words, species taxon is a concrete biological entity which is formally recognized as per standard taxonomic procedure. For example, the taxon *Homo sapiens* refers to human species and is a solid biological entity comprising individuals of the human race. Species taxa are individuals or biopopulations which can be delineated from other species taxa. As pointed out by Bock (2004), recognition of species taxa, the real units in nature, is almost always based on criteria in addition to those used as the defining criterion for the species concept and even for the species category. In practice, no single set of rules exists to recognize species taxa that can be applied equally to all organisms. Delimitation of species taxa will depend upon the way we define species category although many 'arbitrary' decisions may be involved in the process.

The Species Problem

"No one definition [of species] has as yet satisfied all naturalists; yet every naturalist knows vaguely what he means when he speaks of a species." The above statement of Darwin (see *Box* 1 for Darwin's view on species) probably best illustrates the state of perplexity that exists till today concerning the nature of spe-

Box 1. Darwin and Species Concept

Although Charles Robert Darwin (1809-82), the father of evolutionary theory by natural selection devoted his lifetime understanding the process of evolution, he probably never attempted to define any categories in Linnaean hierarchy (including species) used by taxonomists. In fact, despite the title, his seminal work *On the Origin of Species* did not define species either. But from his writings, Darwin appeared to have a typological species concept and in some of his writings, he apparently expressed doubt on the reality of species too. In *Origin of Species*, Darwin wrote (not seen, quoted from others) "I look at the term species as one arbitrarily given, for the sake of convenience, to a set of individuals closely resembling each other... it does not essentially differ from the term variety which is given to less distinct and more fluctuating forms. The term variety, again, in comparison with mere individual differences, is also applied arbitrarily, for convenience sake". He reiterates "we shall have to treat species in the same manner as those naturalists treat genera, who admit that genera are merely artificial combinations made for convenience." Darwin considered species as a part of the continuum from local varieties, geographic races and subspecies, through species to genera and higher taxa. He probably believed that a species concept is unnecessary as gradual evolution can account for diversity of life. Thus, as far as Darwin and species concept is concerned, the state of affairs is best articulated by Daniel Pauly "we are on our own when we discuss the species concept: the master is not going to help us."

cies. Essentially, what is a species? Species concept is one of the most fundamental notions in biology, yet the most complex and contentious of all. The concept has been debated vigorously, nonetheless biologists are far from reaching a consensus on the issue and judging by the current state of affairs, it is not expected to resolve any time soon. As pointed out by Ernst Mayr, the "*species problem" is basically two fold. The first quandary is theoretical, i.e. how to define species category or what concept to adopt and the second one is applied i.e. how to apply this concept in demarcation of species taxa*." From a theoretical standpoint, there are many reasons why scientists are unable to find a common ground over the species concept. Somebody has identified as many as 24 species concepts in contemporary literatures and many of these alternative concepts are significantly incompatible to one another.

Many of the existing species concepts are based on different biological properties. For example, the biological species concept is based on reproductive isolation, the ecological species concept is based on niche separation, genetic species concept relies on genetic isolation, evolutionary species concepts view species as ancestor-descendent lineage with unique evolutionary roles and tendencies. One version of the phylogenetic species concept gives emphasis to diagnosability while another stresses on monophyly. Some of these concepts appear to accommodate certain groups of organisms better than others. For example, the biological species concept cannot account for non-sexually reproducing organisms. Another bias is that, support for a particular concept is correlated with personal research interests of the individuals concerned. For instance, an ecologist will vouch for a concept relying on niche separation or a geneticist will go for a concept founded upon genetic differences. On the practical side, a practicing taxonomist needs a species concept (rather a species definition) which is convenient for him/her in delimiting species taxa and hence will opt for a concept based on morphological diagnosability. Since different species concepts employ different criteria for species recognition, applying one criterion for species recognition may result in something that is different when other criteria are employed and there is a chance of much chaos. Mayr stated that most debates about species concepts are actually debates about how one groups individuals into a species taxon, rather than debates over the ranking of taxa (into categories). Considering the immense diversity of life forms, a unifying species concept that addresses equally well all these conflicting issues, appears somewhat unrealistic, if not impossible.

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Ernst Mayr and the Biological Species Concept (BSC)

Probably few biologists ever had an enduring influence on systematics and evolutionary biology as a whole and especially on the development of species concept as Ernst Mayr (1904–2005). In his ‘Systematics and Origin of Species’, Mayr proposed that ‘‘*species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups*’’ which is well known as Biological Species Concept (BSC) to modern day biologists. However, Mayr never claimed the credit for BSC and it was in fact Theodosius Dobzhansky who first vouched for the concept and emphasized

Box 2: The Process of Speciation

By definition, speciation is the production of new daughter species. For some, speciation means transformation of one species to another (phyletic speciation), an idea championed by Lamarck which is also known as vertical tradition. For others led by Darwin (horizontal tradition), speciation implies multiplication of species or the origin of diversity. Darwin viewed speciation as a gradual process and was of the opinion that the same process eventually gives rise to an evolutionary novelty or higher taxa when enough differences pile up. In his view, races, species, genera and families are nothing more than different degrees of phylogenetic divergence. But, how this poky process of evolution brings about morphologically discontinuous entities like species is still a big riddle. In the post Darwin era, thinkers like Dobzhansky, Muller and Mayr, explained that organic diversity is the outcome of the adaptation of life to environmental multiplicity and all the evidences from other biological disciplines support the idea. Scientists have fiercely debated over several modes through which new species may arise in nature, the most prominent being 'allopatric' and 'sympatric' speciation.

Allopatric speciation has been accepted as the most prevalent mode of animal speciation. Allopatric speciation as explained by Ernst Mayr: "*A new species develops if a population which has become geographically isolated from its parental species acquires during this period of isolation characters which promote or guarantee reproductive isolation when the external barriers break down.*" According to this proposition, geographic isolation of allopatric population is a necessary precursor of species formation. Mayr envisaged that the reproductive barriers separating members of different species are divided into prezygotic and postzygotic isolating factors. It is this reproductive isolation in concert with selection and genetic drift that creates and expands the morphological gap between different species.

Sympatric speciation is defined as the origin of isolating mechanisms (i.e., the evolution of a barrier to gene flow) within the dispersal area of the offspring of a single deme (i.e., among the members of an interbreeding population). To put simply, it is the formation of species in the absence of geographical barriers. Sympatric speciation can happen if mutations cause immediate reproductive barriers in segments of species. Otherwise, disruptive selection favoring expression of different traits in a highly partitioned environment may bring about differentiation amongst the members of the same species and consequent speciation. Although sympatric speciation is theoretically feasible, empirical evidences for this mode of speciation are rare. One of the most credible example of sympatric speciation is Nicaraguan crater lake Cichlid species *Amphilophus zaliosus*. In a recent report in *Nature,* scientists have demonstrated that *A. zaliosus* originated from the ancestral species *A. citrinellus* in the lake Apoyo within less than 10000 years through sympatric speciation and concluded that ecological disruptive selection might have played a major role in this speciation event.

its role in understanding the process of speciation (see *Box* 2). It is pertinent to mention here that BSC is somewhat a misnomer. Mayr used the term 'biological species concept' as it was based on an important biological property of organisms, i.e,, reproductive isolation. In his own words "This species concept is called biological not because it deals with biological taxa, but because the definition is biological. It utilizes criteria that are meaningless as far as the inanimate world is concerned". However, for that matter many other modern species concepts are also based on different biological properties of organisms (genetic isolation, monophyly, etc.) and thus are no less biological than Mayr's concept. Mayr proposed that a species is discerned by three distinct properties:

1. The members of a species constitute a reproductive community. The individuals of a species recognize each other as potential mates and seek each other for reproduction.
2. A species is an ecological unit. The members of a species interact as a cohesive unit with other species in the common environment.
3. A species is a genetic unit consisting of a large inter-communicating gene pool. Individuals are merely a way for temporary storage of a small portion of that gene pool.

Mayr envisaged 'reproductive isolation' as the criterion for delimiting species taxa. If individuals of two populations are able to interbreed, this indicates that they belong to the same species, failure of which implies that they belong to different species. Individual members of species possess some genetic, ethological or ecological isolating mechanism that prevents interbreeding with members of different species; in a way maintain gene pools of individual species. Each species, thus, is limited by its genetic endowment.

Significance of the Biological Species Concept: Answering the Darwinian Question 'Why'

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Charles Darwin was puzzled by the immense diversity and discontinuity of the natural world which promoted him to ask "Why are there species?" In fact, every naturalist asks the same "why" question, in Mayr's words "Why is the total genetic variability of nature organized in the form of discrete packages, called species or why the organic world is not a single community?" The

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biological species concept has convincing answers to these "why" questions. The adaptive values of different gene combinations in different environmental set-ups vary and only a minute fraction of any possible gene combinations have significant adaptive values ('Adaptive peak' in Dobzhansky's parlance) to be selected by natural selection. According to the biological species concept, a biological species is an assemblage of well integrated and harmonious genotypes. Genes from the pool form harmonious combinations after becoming co-adapted by natural selection. Any indiscriminate mixing of genes from different gene pools would lead to the collapse of these harmonious gene combinations. Reproductive isolation is the mechanism that prevents this genetic intermixing through prevention of interbreeding among members of different species. Reproductive isolating mechanisms bar wanton formation of gene combinations, keeping existing genotypes close to the adaptive peaks. Thus, an organization of diversity of life into species permits the protection of well-balanced and well-adapted gene pools.

Biological Species Concept and Asexual Species

From the standpoint of BSC, species is viewed as a group of populations capable of exchanging genes. However, in those organisms that reproduce by obligatory asexual mode, gene exchange is barred by the very method of reproduction. Genotype of such a pure line or clone can only be changed by mutations. The BSC evolved along with evolutionary theory and genetics. The fact that sexual reproduction is important for evolutionary change and that an overwhelming majority of organisms are sexually reproducing led reproductive isolation as the major focal point in BSC and obviously is not applicable to asexually reproducing organisms. Dobzhansky noted that as in sexually reproducing organisms, variations in asexual organisms are also discontinuous and aggregations of more or less clearly distinct, constant genotypes can be seen which reproduces alike when allowed. These genotypes are concentrated around some 'adaptive peaks' in the field of gene combinations and may be treated as species, genera and so on.

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Genetic Species Concept: This is one of the oldest concepts and was originally proposed by Bateson (1909) and later rehashed by various workers like Dobzhansky, Muller, Nei, Baker and Bickham. Very recently, Baker and Bradley defined genetic species as "as a group of genetically compatible interbreeding natural populations that is genetically isolated from other such groups". Under this concept, speciation is the outcome of accumulation of genetic changes in two lineages causing genetic isolation. Several mechanisms like sequence divergence in genes that are not functional in combination with genotypes in the sister species, cytoplasmic–nuclear incompatibility, genetic changes that lead to behavioral changes or changes in pheromones and odors associated with conspecific recognition and chromosomal rearrangements that produce infertile or less-fertile hybrids may lead to genetic isolation.

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The primary feature of genetic species concept is *genetic isolation* as compared to *reproductive isolation* of BSC although both the concepts overlap otherwise. There may be situations where genetic isolation evolves between two populations without reproductive isolation. In such situations, BSC would recognize the two populations as single species whereas genetic species concept would distinguish them as different species. In practice, genetic species concept uses genetic data especially DNA sequence data from mitochondrial and nuclear genome to identify species and define species boundaries and is quite useful in identifying cryptic species (*Box* 3). With the availability of fast and cheaper DNA sequencing techniques and initiatives like GenBank, genetic profiling of Earth's biodiversity is not an impossible proposition now. Contemporary proponents of genetic species concept argue that higher resolving power of DNA database permits more freedom in applying genetic species concept to demarcate species and species boundary than other available database and can be of immense significance in understanding Earth's biodiversity.

Evolutionary Species Concept: The evolutionary species concept was formulated by paleontologist G G Simpson, who wanted

Box 3. The Problem of Cryptic Species: Need for an Integrative Taxonomy

Cryptic species are a group of morphologically indistinguishable but separate species that are recognized as single species. There are many examples of cryptic species in animal groups ranging from deep sea clams to higher mammals which were uncovered by molecular analysis and later corroborated with morphological or ecological data. Sometimes cryptic species have very subtle differences that are simply overlooked by investigators. Good sampling methodology and very detailed study of specimen is necessary for recognition of such species. For example, two new species of agamid lizards namely *Calotes htunwini* and *Calotes irawadi* were recently identified from Myanmar by scientists of California Academy of Sciences which were earlier recognized as *Calotes versicolor*. This was possible due to increased sampling effort and application of recent molecular techniques. The prevalence of cryptic species is a major hindrance in accurate estimation of biodiversity and their conservation. Scientists predict that many new species waiting to be discovered in the coming time are cryptic species and supplying names to these hidden species thus is the first step towards their universal recognition and protection.

Since morphological characters feature prominently in classification of the natural world, most of the times cryptic species are overlooked owing to their indistinguishable morphology. However, it is important to understand that speciation is not always accompanied with morphological change. Extreme environmental conditions might impose stabilizing selection on morphology and preclude any morphological changes during speciation and thus can result in morphologically static cladogenesis (speciation without morphological change). In some cases, morphological differentiations may not arise due to recent ancestry. Although recent explosion of molecular data has been the major driving force in unearthing cryptic species, it is no panacea for species recognition. The idea that molecular taxonomy will replace classical taxonomy is an overstatement as some suggest. Techniques like DNA barcoding can indeed help in resolving problems like cryptic species but not a complete tool on its own. Molecular data is best utilized to supplement morphological, ecological, behavioral, biogeographical data to recognize natural species across all taxa. The future of research in biodiversity and taxonomy lies in promoting an integrative approach of utilizing all available resources to delimit species (Integrative taxonomy) rather than a solely DNA-based approach.

Figure A.. Calotes cf emma, a species complex probably harboring several cryptic species. Photo credit: Abhijit Das

Figure B. Molecular studies have revealed cryptic species in Green Pit Vipers. Photo credit: Narayan Sharma a species concept with a temporal dimension as an alternative to the non-dimensional biological species concept. He defined evolutionary species as, "A lineage (an ancestral-descendant sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies". However, later Simpson abandoned the concept and it was E O Wiley who reinvented it. According to this concept, species are individuals rather than classes and are historical, spatial and temporal entities. A significant corollary that follows the evolutionary species concept is that all organisms in the present and past belong to the same species, i.e. they belong to the same lineage. Evolutionary species differs from supraspecific taxa in the fact that the former is a lineage or continua whereas the latter is a group of lineages linked by past continua and thus are historical constructs. To be evolutionary species, morphological differences between species is not necessary although it does not preclude such differences. Critiques of evolutionary species concepts argue that it does not provide any yardstick for the placement of isolated population since every isolated population fulfils evolutionary species definition of single lineage that maintains its identity. Besides, there is no way to determine evolutionary fate (which is a thing of future) and tendencies of any population.

Phylogenitic Species Concept: There are several concepts based on phylogenetic systematics (cladistics) which are together referred as Phylogenetic Species Concept. One version of phylogenetic species concept can be traced to the writings of Willi Hennig (1966) which was later conceptualized and defended by Eldredge and Cracraft, Nelson and Plantick and most recently by Wheeler and Plantick. They define species as the smallest aggregation of (sexual) populations or (asexual) lineages diagnosable by unique combination of character states. According to the proponents of this concept, phylogenetic species are the basic units of formal scientific nomenclature, Linnaean classification and organic evolution. They are the end product of evolution in all sexually or asexually reproducing forms. Another version of phylogenetic species concept propounded by Mishler and Brandon and freshly

Species concepts	Proponents	Core attribute
Nominalist species concept	Occam	Species are subjective bracketing together of individuals or populations under a name and are thus arbitrary constructs.
Typological species concept	No particular proponent, Linnaceus followed it	Species is an entity that differs from others by constant diagnosable differences. To be ascribed to a species, individuals must conform to certain predetermined 'type', otherwise termed as difference species.
Recognition species concept	HES Paterson, 1985	The members of a species are tied together by the fact that they recognize each other as belonging together and reproduce only with each other.
Cohesion species concept	A Templeton	A concept proposed to combine reproductive isolation, ecological selection and ecological compatibility.
Hennigian species concept	Hennig, 1950 Willmann, 1985	Species are reproductively isolated natural populations or group of populations. They originate via the dissolution of the stem species in speciation event and cease to exist either through extinction or speciation.
Ecological species concept	Van Valen, 1976	Species are a set of organisms exploiting a single ecological niche (adaptive zones). ESC assumes that ecological niches in nature occupy discrete zones, with gaps between them.

Table 1. List of other species concepts not discussed in the text and their core attributes.

by Mishler and Theriot defines species as "the least inclusive taxon recognized in a formal phylogenetic classification. Organisms are grouped into species because of evidence of monophyly. Taxa are ranked as species because they are the smallest monophyletic group deemed worthy of a formal recognition". Monophyletic group as defined by these workers includes all and only descendents of a common ancestor (an organism, kin group or population that had spatio-temporal localization and cohesion) existing in any point of time. The evidences for monophyly for species recognition are primarily derived from corroborated patterns of synapomorphy (shared derived character) although other factors like geography are also taken into consideration.

Is a General Integrated Concept Possible?

The Holy Grail to the reconciliation amongst diverse and incompatible species concepts lies in a general species concept that is shared by most of the modern species concepts. The General Metapopulation Lineage Concept could well be regarded as such a reconciliatory effort. The origin of this concept can be traced back to the beginning of the twentieth century although it became established during the period of modern evolutionary synthesis[1] through the writings of greats like Dobzhansky, Simpson and Mayr. The general metapopulation lineage concept of species is in essence the synthesis of existing modern concepts incorporating their basic essentials. Under this concept, species is viewed both as metapopulation (sets of connected subpopulations) and as lineage (an ancestral-descendent sequence of population) and hence the term 'metapopulation lineage'. At some level of biological organization, population and lineage are very close to each other. If population is extended through the time dimension, it becomes lineage. At any instant (without extending through the time dimension), population represents an instantaneous cross section of the lineage. Most of the modern species concepts describe species either as metapopulation or as lineage. Since the coinages population and lineage are different temporal perspectives of the same basic entity, the concept of species as metapopulation lineage encompasses both the views. As for biological species concept of Mayr, limits of species (as metapopulations) are set in one way or another by interbreeding, i.e., sexual reproduction and hence it is unable to accommodate asexual organisms. The general metapopulation lineage concept suggests that asexual organisms either do not form metapopulation (agamospecies do not form population as defined by biologists, they form clones – Mayr) and hence do not form species or they form species the limits of which are set by processes other than interbreeding. Apart from seeking reconciliation amongst many

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[1] The period of modern evolutionary synthesis (1935–1970) is characterized by a new outlook into the process of evolution in the light of contemporary understanding in other branches of biology. Theodosius Dobzhansky is considered to be the pioneer of this movement. During that period, morphological, genetic, ecological and geographical studies were brought to bear upon the issues of hereditary variations and the origin of species. At a higher level, paleontologists applied the new knowledge acquired through these studies to address the problem of phylogeny and higher level relationship.

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An important consequence of general metapopulation concept of species is that it perceives species category as a fundamental level of biological organization.

modern species concepts, an important consequence of general metapopulation concept of species is that it perceives species category as a fundamental level of biological organization. Until now, species category was just another category in the Linnaean hierarchy like genera, family, order, etc. More explicitly, the taxa at all levels in the hierarchy were viewed as groups of organisms that shared particular traits but they were assigned to different ranks based on differences in relative inclusiveness. Under the present concept, species category is fundamentally different from those categories above and below it. For example, species are metapopulation lineages whereas genera are groups of species sharing a relatively common ancestry. The unique position of species category in taxonomic hierarchy is articulated by Mayr, ".... the species is as important a unit of biology as is the cell at a lower level of integration". "… it is the only taxonomic category for which the boundaries between taxa at that level are defined objectively.''

Kevin de Queiroz of National Museum of Natural History, Smithsonian Institute has advocated a different approach to the species problem which in his opinion conforms to the general metapopulation lineage concept of species. According to his 'General and Unified Species Concept', a species should be treated as a metapopulation lineage which is evolving separately from other lineage. Under this concept, those properties considered necessary for species recognition under different species concepts (reproductive isolation, genetic isolation, ecological isolation monophyly, diagnosability, etc.) are no longer considered essential properties for species recognition; rather they are recognized as contingent properties. To be considered a species, the only criterion is that a metapopulation lineage has to evolve separately from other lineage. However, the importance of those contingent properties is not underrated and they continue to serve as important evidence for assessing the separation of metapopulation lineages (species boundary). Besides, the various contingent properties can be used to define subcategories of the general species category, e.g., diagnosable species, reproductively isolated species, monophyletic species. Thus, under a general and unified species concept, contingent properties are not considered as essential species properties (a metapopulation lineage may or may not acquire them), rather are useful tools for delineating species boundary.

The species concept has both theoretical and functional significance.

As evident from the above discussion, every concept on species has its own share of advantages and limitations and no one concept emerges as a clear winner. Besides, there is always an asymmetry between the real biological world and theoretical considerations (which are always ideal) in different species concepts. As Joel Cracraft of National Museum of Natural History, Smithsonian Institute pointed out, *one should be careful in justifying a particular species concept if it cannot accommodate the vagaries of real world data with aplomb.*

Concept Matters: Implications in Biodiversity Assessment and Conservation

By virtue of its very nature, the species concept has both theoretical and functional significance. To be able to individuate nature correctly is fundamental to systematics and biological science as a whole and has far reaching theoretical as well as practical consequences. The profusion of species concepts in biology has been a major hindrance in accurately inventorying Earth's biodiversity and their conservation. The different species concepts offer different, sometimes contradictory, interpretations of the biological world and thus, are a source of puzzlement in assessment of biodiversity. Any comparative biological study leaving aside questions like speciation will hinge on the way one looks at species. From the conservation point of view, a host of critical issues like estimating species diversity, endemism, and conservation effort needed for each unit to ensure long time survival. are dependent on a sound species concept. It is unfortunate that we are still fumbling on real entities like species whereas humanity needs to take urgent steps to arrest species extinction.

Epilogue

The essence of the 'species problem' is the fact that, while many different authorities have very different ideas of what species are, there is no set of experiments or observations that can be imagined that can resolve which of these views is the right one. This being so, the 'species problem' is not a scientific problem at all, merely one about choosing and consistently applying a convention about how we use a word. So, we should settle on our favorite definition, use it, and get on with the science [11].

Acknowledgement

This article is based on numerous published discussions on the subject, a few of which are cited in Suggested Reading.

Suggested Reading

[1] Q D Wheeler and R Meier (Eds.), *Species concept and phylogenetic theory: A debate*, Columbia University Press, New York, 2000.

[2] Kevin de Queiroz, Ernst Mayr and the modern concept of species, *Proc. Natl. Acad. Sci.*, Vol.102, pp.6600–6607, 2005.

[3] Ernst Mayr, What is a Species, and What is Not?, *Philosophy of Science*, Vol. 63, pp. 262–277, June 1996.

[4] D Pauly, Charles Darwin, Ichthylogy and the species concept, *Fish and Fisheries*, Vol.3, pp.146–150, 2002.

[5] E O Wiley, The evolutionary species concept reconsidered, *Syst. Zool.*, Vol.27, pp.17–26, 1978.

[6] J Walter Bock, Species: The concept, category and taxon, *J.Zool. Syst. Evol. Research*, Vol.42, pp.178–190, 2004.

[7] T Dobzhansky, *Genetics and the origin of species*, Columbia University Press, New York, 1937.

[8] D Bickford, D J Lohman, N S Sodhi, P K L Ng, R Meier, K Winker, K K Ingram and I Das, Cryptic species as a window on diversity and conservation, *Trends Ecol. Evol.*, Vol.22, No.3, pp.148–155, 2006.

[9] O D Wheeler, Systematics, the scientific basis for inventories of biodiversity, *Biodiv. & Conserv.*, Vol.4, pp.476–489, 1995.

[10] R J Baker and R D Bradley, Speciation in mammals and genetic species concept, *J. Mamm.*, Vol.87, No.4, pp.643–662, 2006.

[11] J Brookfield, *Genet. Res.*, Vol.79, pp.107–108, 2007.

Address for Correspondence
Uttam Saikia,
Narayan Sharma* and
Abhijit Das**
High Altitude Zoology Field
Station Zoological Survey
of India
Saproon, Solan
H.P.173211, India.
Email:
uttamsaikiazsi@rediffmail.com
*narayansharma77@gmail.com
**abhijitdas80@rediffmail.com