- biologists today still have no clear idea of how many extant species exist. 
- only about three million species in total have been described, and only about 1.5 million of these in any great detail. 
- estimates of the number of species actually present range from 5 million to over 100 million. 
- why is there this great degree of uncertainty? 

1. **many species groups are very poorly studied.**
- notably here are microorganisms and parasites. 
- parasitologists estimate that perhaps between 30-40% of all species are parasitic. 
- obviously, a great number of these are undescribed - they represent extrapolations from the parasitic fauna known from well-studied groups like birds and mammals. 

2. **many environments are poorly sampled.**
- tropical environments - both terrestrial and aquatic are poorly studied. 
- the deep-sea is another. 

3. **as molecular approaches are applied to identifying species boundaries, more and more “cryptic species” are observed.**
- a cryptic species is indistinguishable from another species at the morphological level, but is distinguishable at the genetic level. 
- the existence of fixed genetic differences is *de facto* evidence that the two species do not interbreed (if they did, the genetic differences would be eliminated). 
- cryptic species are identified by genetic criteria, but are similar to the older term “sibling species”. 

**Species concepts**

1. **The Typological Species Concept (TSC, Linnaeus).**
- the typological species concept was developed by the systematists - most notably Linnaeus in the mid 18th century 
- a typological species may be defined as a **group of individuals that differ from other groups by possessing constant diagnostic characters**. 
- the typological species concept gets its name from the process, initiated by Linnaeus, of collecting a representative, or “type” specimen for a given species, and preserving it in a museum collection. 
- this “type” specimen of the species was thus used as the yardstick for identifying diagnostic characters of that species that differentiate it from other species.
- the typological species concept has three main difficulties:

1. **polymorphism within populations**
   - conspicuous visible polymorphisms present problems.

2. **variation among population**
   - it forces one to identify geographical populations that differ by one diagnostic character from other populations as different species.

3. **sibling or cryptic species**
   - these are species that are virtually indistinguishable in appearance but do not interbreed.

2. **The Biological Species Concept** (BSC, Dobzhansky, Mayr)

- this species concept had its origin with Darwin, but was not popularized until the modern synthesis by Dobzhansky and Mayr.
- based on the observation that populations of different species often coexist with one another in the same region, but do not interbreed.

Mayr (1940) defined the BSC as “**species are groups of actually or potentially interbreeding natural populations that are reproductively isolated from other such groups**”.

Dobzhansky (1937): **species are the largest and most inclusive reproductive community of sexual and cross-fertilizing individuals that share a common gene pool**.

- this is clearly the concept that Darwin believed (as seen in his notebooks).
- a clear advantage of the BSC is that species status has little to do with the degree of phenotypic difference exhibited between species.
- it also has a clear biological and genetic meaning.
- Mayr divided the BSC into the “**nondimensional**” and the “**multidimensional**” species concept.

**The nondimensional species concept:**
- this concept can be applied only to species that are **sympatric** and **synchronous** (i.e., inhabiting the same region at the same time).
- the nondimensional species concept is ideally suited to identifying sibling species that coexist in the same area but do not interbreed.
- the disadvantages of this concept are that it does not allow us to deal with cases in which the species are not sympatric or coincident in time.
- this is where the multidimensional species concept comes into play.

**The multidimensional species concept:**
- the multidimensional species concept deals explicitly with populations that are **allopatric** and/or **allochronic** (i.e., inhabiting different regions and/or not overlapping in time).
- the important feature of this definition is whether or not the populations have the potential to interbreed.
- if they do, then they are classified as the same species.
- if not, they are recognized as distinct species.
- the acid test remains, however, the capacity for interbreeding.
- the pooling of the nondimensional and multidimensional species concepts results in the biological species concept.
- the BSC represents the most influential and popular species concept in use today.
- it is not, however, universally accepted and suffers from a number of deficiencies.

**Problems with the BSC**

1. **Not applicable to asexual species.**
   - this eliminates the BSC from being applicable to many organisms that reproduce asexually.

2. **Hybridization commonly occurs in nature.**
   - the ability of different groups of organisms to interbreed varies considerably, and this contributes further confusion to the question of biological species.
   - many species of freshwater fishes, waterfowl, and terrestrial plants are capable of hybridizing with other species.

3. **Difficult to establish.**
   - for sympatric species, the BSC does not have a problem - the two species exist in the same region but do not interbreed and thus are recognized as good biological species.
   - for allopatric populations, there is a problem.
   - the BSC classifies two geographical populations of organisms as a biological species because they can potentially interbreed.
   - this issue of the “potential” to interbreed is the problem, because we cannot carry out the necessary crosses to establish this fact for many species.
   - furthermore, just because we can successfully cross individuals (say in the laboratory, or in a zoo) from two geographically distinct populations does not necessarily mean that such matings would occur in nature.
   - examples include wholphins, ligers, and tigons!

3. **The Evolutionary Species Concept (ESC, Simpson, 1951)**
   - this is a species definition developed by paleontologists who required a definition that would allow them to identify fossil species.
   - from Simpson, an evolutionary species is “a lineage evolving separately from others with its own unitary evolutionary role and tendencies”.
   - the ESC has also been favored by many botanists who were unhappy with the inability of the BSC to account for uniparental and biparental species.

**Problems with the ESC**
1. Is arbitrary.
- the ESC is compromised by how one measures “unitary evolutionary role and tendencies”.
- therefore, a species that changes slowly in morphology over a period of time may still constitute an evolutionary species to one paleontologists, whereas another may decide that the form has changed enough so that the species now should be recognized as something different.

2. Descriptive, not mechanistic.
- the ESC has nothing to say about the mechanisms by which species are maintained or by which new species evolve.

4. The Phylogenetic Species Concept (PSC, Cracraft, 1983)

- unlike previous species concepts, the PSC is not concerned with the present properties of organisms or their hypothetical future.
- instead, it attempts to define species on the basis of a common phylogenetic history.

- from Cracraft, the PSC is “the smallest diagnosable monophyletic group of populations within which there is a parental pattern of ancestry and descent”.

- a monophyletic group is defined as being derived from a common ancestor and includes all descendants of that ancestor.
- advocates of the PSC use molecular phylogenies to identify distinct monophyletic groups.
- one main advantage of the PSC is that it applies to all kinds of organisms - both sexual and asexual.

Problems with the PSC:

1. What characters to use?
- should one identify species on the basis of neutral mutations?
- should genes reflecting the action of selection be given greater weight?

2. What level of divergence constitutes a species?

3. How do you distinguish between gene trees and species trees?
- phylogenies based on different genes may give different trees.
- the trick is to identify the tree that actually represents the true history of the species.

4. Does not address mechanism.

5. The Recognition Species Concept (RSC, Paterson, 1985)

- under this concept, species are also viewed as “the most inclusive population of biparental organisms which share a common fertilization system”.
- the recognition species concept was developed by Paterson to represent the obverse of the biological species concept.
- where the BSC stresses the processes in the development of reproductive isolation between populations, the RSC focuses on the processes that act to preserve a common fertilization system and thus maintain species identity.
- the RSC stresses the positive features of species that enable the two sexes to recognize each other as potential mates and successfully interbreed instead of focusing attention on the isolating mechanisms that cause the cessation of gene exchange.
- the focus is thus on **mate-recognition systems**.
- these systems include courtship displays, the timing of reproductive events, habitat selection that allow mates to come into contact with one another, neuroendocrine signals like pheromones, design of copulatory organs, and components of gamete incompatibility.

- unlike the BSC in which speciation is a process in which reproductive isolation evolves, under the RSC, speciation is viewed as a process in which different fertilization systems evolve.
- although reproductive barriers can arise as a by-product of speciation they are not viewed as an active part of the speciation process.

**Problems with the RSC**

1. Not applicable to asexual species.
2. Recognition systems often go awry (hybridization).

- these problems are the same as those faced by the BSC.
- despite these shortcomings, many evolutionary biologists feel is a decided improvement on the BSC.

**6. The cohesion species concept** (Templeton 1989)

- this species concept attempts to incorporate the strengths of the BSC, ESC and RSC and avoid their weaknesses.
- a species is defined as “the most inclusive population of organisms having the potential for cohesion through intrinsic cohesive mechanisms”.

- what are cohesive mechanisms?
- there are two classes of cohesive mechanisms:

**1. Genetic cohesive mechanisms**
- the two dominant mechanisms acting to maintain species integrity are **gene flow** and **stabilizing selection**

**2. Ecological cohesive mechanisms**
- this would include all aspects of the ecology of the species.
- these would include species abundance, its demographic stability, its fundamental niche, the strength of interactions with other species, etc.
- Templeton views the CSC as defining species in terms of genetic and phenotypic cohesion.
- it emphasizes the mechanisms that produce and maintain this cohesion and result in a stable, buffered species.
- in doing so, it can account for the cohesion of asexual species
- it can also deal with the problem of hybridization by emphasizing the factors that act to maintain species integrity in the face of intercrossing with closely related species.
- the CSC also helps us to view speciation as a process in which cohesion mechanisms are broken down and replaced with a different set.
- the CSC is another interesting development, but does not yet have a wide following.

**Problems with the CSC**

- the CSC needs a thorough understanding of the cohesive mechanisms at work within species.
- in this regard, it is decidedly worse than the BSC, which had only reproductive isolation on as its main focus.