ANY natural calamity—a drought, a fire, a flood or a new disease—would have a tough job wiping out everything alive. The reason? All living things are a little bit different from each other. While some will perish, there will be others who would have certain genes or characteristics that will help them survive the calamity. This variability, also known as biological diversity, is a big defence mechanism essential for the survival of nature in all its pristine glory.

Biodiversity or biological diversity refers to the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Exactly how many species of life exist on earth is not known. However, estimates range from 3 million to 100 million. There are 1,435,662 identified species all over the world. A large number of species are yet to be identified. The identified species include 751,000 species of insects, 250,000 of flowering plants, 281,000 of animals, 68,000 of fungi, 30,000 of Protists (unicellular and colonial eukaryotes), 26,900 of algae, 4,800 of bacteria and other similar forms and 1,000 of viruses.

Disappearance of ecosystems is leading to loss of habitat for several species. Approximately 27,000 species become extinct every year. Majority of them are small tropical organisms. Extinction of species leads to further destruction of fragile ecosystems. If this trend of biodiversity depletion continues, one-fourth of the world’s species may be gone by the year 2050.

Exploring Biodiversity
The term biodiversity, which represents the very foundation of human existence, was coined by Walter G. Rosen in 1985 for the first planning meeting of the ‘National Forum on Biodiversity’ held in Washington, DC in September 1986, the proceedings of which brought the notion of biodiversity to the attention of a wide field of scientists and others. However, the credit for popularizing this word goes to E.O. Wilson who is often called the “Father of Biodiversity”.

There are three levels of biodiversity:

Genetic diversity: This includes genetic variation within species, both among geographically separated populations and among individuals
within a single population. This genetic diversity is the result of different modes of adaptation in different habitats, providing organisms and ecosystems with the capacity to recuperate after change has occurred. Thus, genetic diversity can be viewed and compared at three levels:

(i) Genetic variability between individuals within population.
(ii) Genetic variability among population within species, and
(iii) Diversity among species.

Species diversity: This denotes the variety of species on earth from acellular viruses to single celled microorganisms like bacteria, mycoplasmas, actinomycetes etc. to multicellular plants and animals. For proper functioning of a particular community or ecosystem, species diversity is very essential. In a community the survival of all species is interrelated to the existence of other living organisms.

Ecosystem diversity: This refers to variations in biological communities in which the species live, the ecosystem in which communities exist and interactions among these levels. Ecosystem diversity is reflected in diverse biogeographic zones such as lakes, deserts, coasts, estuaries etc.

Threatened Diversity
The Earth’s biological wealth or biological diversity is the entire complement of life that has survived nearly 4 billion years of evolution. However, in recent times, the ever-increasing loss of this biological wealth has posed serious threat to the very existence of mankind. The prevailing illiteracy, poverty, lack of scientific
development, burgeoning population etc. are some of the factors responsible for the degeneration of biodiversity.

In the last half billion years of the history of Earth’s life, five great episodes of extinction have already decimated a variety of living organisms including the mammoth dinosaurs. The first was in the Ordovician period (448 million years ago), the second in the Devonian (365 million years ago), the third in the Permian (286 million years ago), the fourth in the Triassic (210 million years ago) and the fifth in the Cretaceous period (66 million years ago).

The first four episodes of extinction are believed to have been caused by climatic change and the fifth by a giant meteorite crash. The sixth extinction, which we are facing today, is due to human activities. Scientists have estimated that human activities are likely to eliminate approximately 10 million species by the middle of this century.

Tropical rainforests, known as the ‘lungs of the Earth’, are the storehouse of biodiversity covering only 7% of the Earth’s geographical area but supporting more than half of the world’s identified species. Since most of the rainforests are located in developing countries, increasing pressure of population is leading to rapid depletion of forests. Tropical forest cover is being lost at the rate of about 0.16 billion hectare per decade. Twelve rainforests and eight wilderness areas (four in the tropics and four outside of the tropics in Mediterranean type climate) of the world have been identified as hot spots (those areas of the world that have rich biodiversity and high levels of endemism but are at immediate threat of species extinction and habitat destruction).

Of the twenty hot spots of the world reported so far two of them belong to India. The Eastern Himalayas and Western Ghats are the two hot spots of biodiversity in India. India is referred as a ‘mega-diversity’ nation due to its rich floral and faunal wealth.

If rational conservation measures are not undertaken soon, 90% of these habitats could be destroyed in the near future. This would amount to a potential loss of 15,000 to 50,000 species every year or 50 to 150 species every day. Tropical deforestation will be the single greatest cause of species extinction in the next half century. A virtual "Extinction Epidemic" seems to be looming large threatening to disturb the normal evolutionary process.

All over the world, about 60,000 species of plants and 2000 species of animals are on the verge of extinction. Though the great majority of the species are plants, there are also several species of animals as well that are threatened. This includes fishes (343), amphibians (50), reptiles (170), invertebrates (1355), birds (1037) and mammals (497).

The disappearance of species also means a reduction of genes from the gene pool. This reduction in the genetic
resources of the Earth is known as genetic erosion. The twentieth century has witnessed a loss of 75% of the genetic diversity of crop plants. High yielding varieties have occupied more than 60% area of wheat and rice lands.

Genetic erosion occurs due to:

(i) Crop number: Originally a large number of plants were utilized for different uses. However, gradually the number of exploitable plants has decreased. For instance, out of 3000 food plant species only 150 were commercialized. Agriculture is dominated by only 12 species out of which four yield more than 50% of the total (Rice, Wheat, Maize, Potato).

(ii) Crop varieties: There is a tendency to incorporate the maximum good characters in a single variety. As soon as a better variety is developed the same is distributed far and wide and brought in use. Consequently the local indigenous varieties are discarded and their specific genes are lost forever.

Genetic erosion is a matter of serious concern as it could hamper the crop improvement programme. The traditional varieties of crops and their wild relatives possess several useful genes, which may be exploited for the improvement of crop varieties through crop breeding. The maintenance of a diversity of crops with different characteristics gives the community a buffer stock of food in case droughts or floods or pests attack or a disease occurs.

Causes of Biodiversity Degeneration
There are several factors responsible for the degeneration of biodiversity, the primary among them being destruction of habitat and habitat fragmentation leading to species movement to other habitat where they find it difficult to adapt. Another major reason is extensive hunting of wild animals and over exploitation of plants and trees in the wild.

According to the Global Biodiversity Strategy (WRI/IUCN/UNEP 1992) there are six fundamental causes of biodiversity degeneration:
1. Unsustainably high rates of human population growth and natural resource consumption.
2. Steadily narrowing spectrum of traded products from agriculture and forestry and introduction of exotic species associated with agriculture, forestry and fisheries.
3. Economic systems and policies that fail to value the environment and its resources.
4. Inequity in ownership and access to natural resources, including the benefits from use and conservation of biodiversity.
5. Inadequate knowledge and inefficient use of information.
6. Legal and institutional systems that promote unsustainable exploitation.

Species-specific Conservation
The concepts of endemic species, high-impact species, conservation-focus species, and indicator species play a very important role in the conservation of biodiversity.

Endemic Species
Endemic species are those with restricted distributions. An endemic species is not necessarily rare or restricted to a small range. This is dependent on the area over which endemism is measured. Although plant endemics have been recognized and
investigated extensively, less attention has been given to endemic animals. Endemic species are, however, increasingly recognized as being an important focus for conservation attention as the threats to narrow-ranged species become more apparent. Furthermore, endemic species are the major components of hot spots of diversity, and form the basis for selecting priority conservation areas.

Endemics may be categorized according to their spatial distribution, inferred evolutionary age and affinities, and abundance. Engler (1882) provided one of the first classifications of endemics according to their evolutionary age as follows:

(i) **Neoendemics:** Comprising clusters of closely related species and sub-species that have evolved relatively recently. For example, the hundreds of species of Cichlid fishes in Lake Malawi.

(ii) **Palaeoendemics:** Comprising phylogenetically highly ranking taxa, usually monotypic sections, sub-genera or genera that may be regarded as evolutionary relics. For example, *Welwitschia mirabilis* of the Namib Desert.

**High-impact Species**

Some species have more influence on ecosystems than others. Their impact and abundance may change over time, with other species replacing them in their influential position. Two groups are especially relevant to biodiversity conservation – keystone species and exotic invasives.

**Keystone species:** Keystone species are species that maintain the structure and organization of the community. These are in fact species that allow large numbers of other species to persist in the community. To protect keystone species is a priority for conservation efforts, because if a keystone species is lost from a conservation area, numerous other species might be lost as well.

Among the most obvious keystone species are top predators, since they are often important in controlling herbivore populations. In many regions where man has hunted gray wolves to extinction, deer populations have exploded. Consequently enhanced grazing has led to elimination of many herbaceous plant species. The loss of these plants was detrimental to the deer and to other herbivores, including the insect community that fed on the plants.

Many tropical trees like *Ficus religiosa* (Peepal), *Ficus bengalensis* (Bargad), *Ficus glomerata* (Gular), *Ficus carica* (Anjeer) and *Ficus racemosa* (Pakar) serve as keystone species in the functioning of vertebrate communities. The flowers of these tree species are pollinated by small highly specialized wasps (*Blastophaga* spp.), which mature inside the developing fruits. These tree species also provide a reliable source of food to primates, birds and other fruit-eating vertebrates, even during the dry season.

Therefore the identification and preservation of keystone species is important for the maintenance of biodiversity.

**Exotic invasives:** These are newly appearing species either in natural or human-influenced ecosystems. They may be almost any type of organism that become, for example, a new pathogen, vector, weed or invasive animal. Monitoring the spread and impact of these invasives is a crucial component of biodiversity conservation.

**Conservation-focus Species**

Since biodiversity conservation is a pragmatic science with a management component, it is important to note those species that flag conservation efforts. There are three general categories:—threatened, umbrella & flagship species.

**Threatened species:** The dwindling species of plants and animals have been categorized for conservation purposes:

1. **Endangered species:** Species that are in danger of extinction and whose survival is unlikely if the causal factors continue to be operating. Their numbers have been reduced to a critical level or whose habitats have been so drastically reduced that they are deemed to be in immediate danger of extinction.

2. **Critically endangered species:** Species facing extremely high risk of extinction in the wild in the immediate future.

3. **Vulnerable species:** Species likely to move into the endangered category in the near future if the causal factor continues to operate.

4. **Rare species:** Species at risk because of low numbers.

5. **Indeterminate species:** Species in danger of extinction but the reason is not known.

6. **Threatened species:** Species that are often genetically impoverished, of low fecundity, dependent on patchy or unpredictable resources, extremely variable in population density, persecuted, or otherwise prone to extinction in human-dominated landscapes.
For plants, botanical gardens and seed banks are the traditional forms of off-site conservation.

7. Insufficiently known species: Species that probably belong to one of the conservation categories but are not sufficiently known to be assigned to a specific category.

8. Extinct species: Species that are no longer known to exist in the wild. Searches of localities where they were once found and of other possible sites have failed to detect the species.

9. Extinct species in the wild: Species known only to survive in cultivation, in captivity or as naturalized population (or populations) well outside the past range.

10. Conservation dependent species: Species not Critically Endangered, Endangered or Vulnerable but are the focus of a continuing species-specific or habitat-specific conservation programme targeted towards the species in question, the cessation of which would result in the species qualifying for one of the threatened categories above within a period of five years.

11. Near threatened species: Species not Critically Endangered, Endangered, Vulnerable or Conservation Dependent but close to qualifying for Vulnerable.

12. Least concern species: Species not Critically Endangered, Endangered or Vulnerable and not qualifying for Conservation Dependent or Near Threatened.

13. Data deficient species: There is inadequate information to make a direct or indirect, assessment of the risk of extinction based on the distribution and/or population status of the species. A species in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Listing in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

14. Not evaluated species: The species has not yet been assessed against the criteria.

Umbrella Species: These are species whose occupancy area (plants) or home range (animals) are large enough and whose habitat requirements are wide enough such that if they are given a sufficiently large area for their protection, they will also bring other species under that protection. Many of the world’s nature or game reserves were created principally for large mammals or birds and have inadvertently become reserves for other species with smaller ranges, particularly invertebrates.

Flagship Species: These are popular charismatic species that serve as symbols and rallying points to stimulate conservation awareness and action. At the larger scale these include animals such as condors, pandas, rhinos, large cats and large primates, while at the smaller scale they include orchids, cacti and invertebrates such as large butterflies and stick insects. Flagship species may serve as both indicators and/or umbrella species and also provide a highly visible reminder of the progress of a particular conservation management plan.

Indicator Species

Certain species flag changes in biotic or abiotic conditions. It is important to inventory these sensitive species because they themselves can become important monitors. Indicator species reflect the quality and changes in environmental conditions as well as aspects of community composition.

Biological indicators can be used in ecological evaluation, especially for communities, indicating areas of conservation interest. Indicator species are also used in environmental assessments and in the preparation of environmental sensitivity maps. There are basically five types of biological indicators:

- **Sentinels:** Sensitive species introduced into atypical conditions as early-warning devices.
- **Detectors:** Species occurring naturally in the area of interest that may show measurable response to environmental change.
- **Exploiters:** Species whose presence indicates the probability of disturbance or pollution.

Accumulators: Species that accumulate chemicals in their tissues.

Bioassay organisms: Selected organisms sometimes used as laboratory reagents to detect the presence and/or concentration of pollutants.

**Biodiversity Conservation Strategies**

Conservation of biodiversity is the planning and management of biological resources in a way so as to secure their wide use and continuous supply, maintaining their quality, value and diversity. The World Conservation Strategy has suggested the following steps for biodiversity conservation:

1. Preservation of species that are endangered.
2. Prevention of extinction through sound planning and management.
3. Preservation of varieties of food crops, forage plants, timber trees, livestock, animals and their wild relatives.
4. Identification, safeguarding and protection of habitats of wild relatives where species feed, breed, nurse their young and rest.
5. Regulation of international trade in wild plants and animals.

Biodiversity conservation strategies could be categorized as *in situ* conservation and *ex situ* conservation strategies.

**In situ Conservation Strategies**

*In situ* species conservation measures usually emphasize the protection and management of ecosystems and communities to avert the loss of resident species. Most species are a part of complex food-web (interlocking pattern of food chain) systems composed of several other species, some of which may be crucial for the existence of the target species. Since these relationships are poorly understood, protection of habitat is the only alternative left for the conservation of the species.

It is also significant to manage species for genetic resources to ensure that they have the range of genetic variation required to survive in a changing environment.
A programme of ecosystem protection and management is mainly addressed at the level of biotic communities, species and their relationship, whereas a programme of genetic resource use and protection is geared toward managing genetic variation within and between populations.

The maintenance of species genetic diversity can be achieved only by the protection of large populations in several different areas, while the conservation of a species *per se* may be possible through the protection of a single sample of an ecosystem with a much smaller species-population size. Conservationists are faced with three options in deciding whether and how to conserve the genetic diversity of targeted species:

(i) To provide the habitat area needed for survival and continued adaptive evolution without active intervention.

(ii) To accept extinction, or remove the species from the environment to collections, botanical and zoological gardens, or other reserves, when habitat area requirements cannot be satisfied.

(iii) To manage the population size and population structure of the threatened species, which is the principal objective of the *in situ* conservation.

There are four *in situ* genetic resource conservation strategies:

1. **Little or no management**: This strategy depends chiefly on National Parks and other protected areas or unprotected areas with minimal human perturbation to maintain the population sizes and structures necessary to protect genetic integrity in wild species or populations of wild relatives of crop plants. 

2. **Moderate management**: This strategy depends on protecting traditional forms of activities and animal harvesting to maintain habitat and human practices that have shaped species diversity and have at least for some manipulated species contributed to genetic diversity. For instance, in Brazil, rubber tappers are permitted to tap rubber trees, however, there is complete restriction on other activities like logging, agriculture etc.

3. **Intermediate management**: Where biological resources have been extensively manipulated over long periods of time, continued human intervention may be required to maintain species and genetic diversity. For instance, in the 1950s, scientists in Israel tried to protect natural populations of *Avena* from disappearing by preventing grazing. However, since a number of *Avena* species had coexisted with grazing pressures for several thousand years, their survival strategies and life-history traits had come to reflect these pressures. The control on grazing almost led to their extinction. This case, therefore, is an ideal example of the dangers of over-protection when species that have co-evolved with disturbances, including anthropogenic disturbance, suddenly lose those factors in their environment.

4. **Intensive management**: This strategy is targeted at domesticated or semi-domesticated species. Since the diversity of domesticated or semi-domesticated species is largely the result of human breeding, the population structure needed to maintain animal varieties and land races of crops can be maintained only through intensive human management. Retaining this genetic diversity *in situ* requires several approaches. One approach is to retain at least some traditional agricultural practices. A second strategy is to integrate more diverse cropping and breeding systems into modern agriculture. Finally, the conservation of natural and semi-natural habitats where wild relatives of crop species are known to exist is another strategy that is pursued.

While the principles of *in situ* management for the protection of genetic resources are well known, relatively few areas are actually managed for these purposes. In the Garo Hills of India, gene sanctuaries (areas within the centre of diversity protected from human interference) for wild relatives of citrus crops have been established and similar reserves for fruit trees are managed in other parts of India, and in China. India has several orchid reserves, Ethiopia maintains conservation areas for wild coffee, and a reserve dedicated to the protection of wild chillies (*Capsicum annuum*) is maintained in the Coronado National Forest in Arizona (USA).

**Ex situ Conservation Strategies**

For centuries, gardens, zoos and menageries have been repositories for valuable plants and animals. Although they were often created for the aesthetic pleasure of the rulers of kingdoms and countries that sponsored expeditions, frequently these gardens, zoos and menageries served a more practical purpose. They became centres for the propagation and acclimatization of collected plants and animals that could be valuable to humans in their new environment.

As agricultural and other research institutions developed independent germplasm collections in the first half of the twentieth century, the role of botanical and zoological gardens in conservation was gradually restricted to species with little or no apparent economic value. However, botanical gardens, zoological parks and aquaria have played an increasingly vital new role as many plant and animal species face an increasingly threatened and uncertain future in the wild.

There are now more than 1500 botanical gardens and arboreta all over the world, and together they maintain the largest assemblage of plant species outside nature. While no overall assessment of the diverse array has been conducted, a botanic gardens database developed for the Botanic Gardens Conservation Strategy provides some idea of the biodiversity assets they contain.

As many as 80,000 species (about one-quarter of the world’s higher plants) are cultivated in botanical gardens, zoological gardens, zoos and menageries, and therefore play a very important role in the conservation of biodiversity.
There are 1,435,662 identified species all over the world. A large number of species are yet to be identified.

gardens, with individual gardens housing anything from a few hundred to many thousands of species. For example, the Royal Botanic Gardens at Kew in the United Kingdom hold about 38,000 species (about 10% of which are threatened), more than most countries have in the wild.

Botanic Gardens Conservation International was established to coordinate the conservation activities of botanical gardens around the world. One of the most important roles botanical gardens can play is to participate in recovery programmes for endangered ecosystems. Re-stocking, reintroduction and restoration activities provide a critical link between ex situ and in situ efforts to sustainably use and protect biodiversity.

The role of zoos and aquaria is equally important. Currently there are approximately 700,000 individuals of 3000 species of mammals, birds, reptiles and amphibians in approximately 800 professionally managed zoos around the world. As with botanical gardens, the conservation role of zoos has been growing. Many zoos now have captive breeding programmes for endangered species and some, such as the National Zoological Park in Washington, DC actively participate in programmes to breed endangered species and reintroduce them into their natural habitats. Many major zoos, therefore, have made major investments in building facilities and developing technologies to establish breeding colonies of rare and endangered species.

Aquaria are perhaps the least advanced in captive breeding efforts. Currently, aquaria maintain approximately 6000 species of fish, most of them collected from the wild.

The sacred groves in India also play a major conservation role. Sacred groves are small patches of native vegetation traditionally preserved on religious grounds by local communities. These groves are mainly found in areas dominated by tribals and managed by local people. These are islands of greenery in the landscape protecting biodiversity and enhancing the environmental quality. Protection of groves of Khejri (Prosopis cineraria) trees in Rajasthan by Bishnoi community is an ideal example. Sacred groves are also found in the state of Maharashtra, Karnataka and Kerala.

The last two decades have also seen the re-evaluation of genetic resource conservation priorities for agricultural research institutions. In the past, these institutions were typically concerned only with the genetic resources of a new commercial crop and livestock species. A variety of factors, including genetic vulnerability, the high environmental costs associated with the use of high-yield varieties, and limited or depleted soil and water resources are stimulating these institutions to search for new uses for species utilized in the past and potential uses for some of the thousands of plant and animal species that are barely known to science.

Ex situ Conservation Technologies
A range of technologies and strategies are available to conserve species and genetic resources ex situ. For plants, botanical gardens and seed banks are the traditional forms of off-site conservation, and they maintain the bulk of the collections. Gene bank standards for conserving orthodox seeds (seeds which can withstand drying and freezing temperatures) have been established. However, for recalcitrant species (those species having seeds that do not tolerate drying or freezing temperatures), live collection in field gene banks is an alternative. For animals, the maintenance of live collections of breeding stock (or breeding nuclei) has been a traditional strategy.

Several sophisticated techniques have been developed during the past 60 years. Biotechnology has provided many new conservation tools and in vitro culture for both plant and animal species is rapidly becoming one of the more attractive alternatives.

Cryopreservation in liquid nitrogen at -196°C is also a promising alternative for both plant and animal species, although it is now largely experimental (For more details turn to page 45: Frozen Zoos). The major advantage of cryopreservation over conventional techniques is an absence of complicated temperature and humidity controls, freedom from pest and pathogen damage, and indefinite viability with no genetic damage. For animal species, embryos and semen are used in cryopreservation. Seeds, embryos, or tissues may be used in plant cryopreservation. Cryopreservation may prove to be cheaper than the maintenance of growing cultures, since it will make long term, even indefinite, conservation possible.

Another emerging and very promising technique is the conservation of isolated DNA. Among its advantages are that only minute quantities of material are necessary for conservation and the possibility of reintroducing the material into related genotypes or species is high. It can be used for endangered or even extinct species by taking samples of material from hair, bones, herbarium specimens or other material of the target species.

However, at present this approach is even more experimental than cryopreservation and should be viewed only as a future option for the conservation of genetic diversity. Indeed, conservation of DNA at low or ultra-low temperatures is now a routine process, but regeneration of whole organisms or even expression of particular genes in related genotypes/species is very difficult.

There are many conservation strategies to suit locations, habitats, and species. The ultimate aim has to be protecting species before they are lost to oblivion.

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