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Introduction

Overview

- Earth hosts vast life diversity: 20,000+ ant species, 300,000+ beetles, 28,000 fishes, 20,000 orchids.

Memory Aids

- Remember: "Millions of species, millions of forms".

Quick Checkpoints

- What is the scale of species diversity on Earth?

Biodiversity

Definition and Levels

- Biodiversity: Variety of ecosystems, species, biotypes, and genes with interactions.
- Term coined by Walter G. Rosen (1985), popularised by Edward Wilson (1992).
- Varies by environment and species tolerance.
- Over 1.5 million species described; many more undiscovered, especially in tropics.
- Three levels: Genetic diversity, Species diversity, Ecological diversity.

Levels of Biodiversity

Genetic diversity

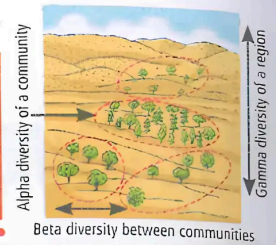
- It is the diversity in the number and types of genes and chromosomes within same species and variations in genes and their alleles within same species.
- Variations in the genes of a species increases with increase in size and environmental parameters of the habitat.
- Genetic diversity results in polymorph formation and is useful in adaptation to changes in environmental conditions.
- E.g., 50,000 genetically different strains of rice and 1,000 varieties of mango present in India.

Species diversity

- Variety in the number and richness of species of a region comprises species diversity.
- Number of species per unit area is called **species richness** and number of individuals of different species represent **species evenness**.
- It influences biotic interactions and stability of the community.

Ecological diversity

- Biodiversity on a wider scale includes variations in the biological communities, the ecosystem of existing communities and interactions among these levels.
- It is of three types: alpha, beta and gamma diversity.



Alpha diversity

Species diversity within a community or habitat, depends on species richness and evenness.

Beta diversity

Diversity between communities due to replacement of species with change in the habitat.

Gamma diversity

Diversity in ranges of communities due to diverse habitats or ecosystems over a total landscape or a geographical area.

Memory Aids

- Genetic = genes variation; Species = number & variety; Ecological = ecosystem variety.
- Alpha = within habitat; Beta = between habitats; Gamma = across regions.

Quick Checkpoints

- What are the three hierarchical levels of biodiversity?
- Who coined and popularised the term biodiversity?

Global Species Diversity

Key Facts

- Estimated 7 million species globally (Robert May).
- Animals: 70% of species; Plants: 22% including algae, fungi, bryophytes, gymnosperms, angiosperms.
- Insects are 70% of animal species; 7 out of 10 animals are insects.
- Fungi species outnumber combined fishes, amphibians, reptiles, mammals.

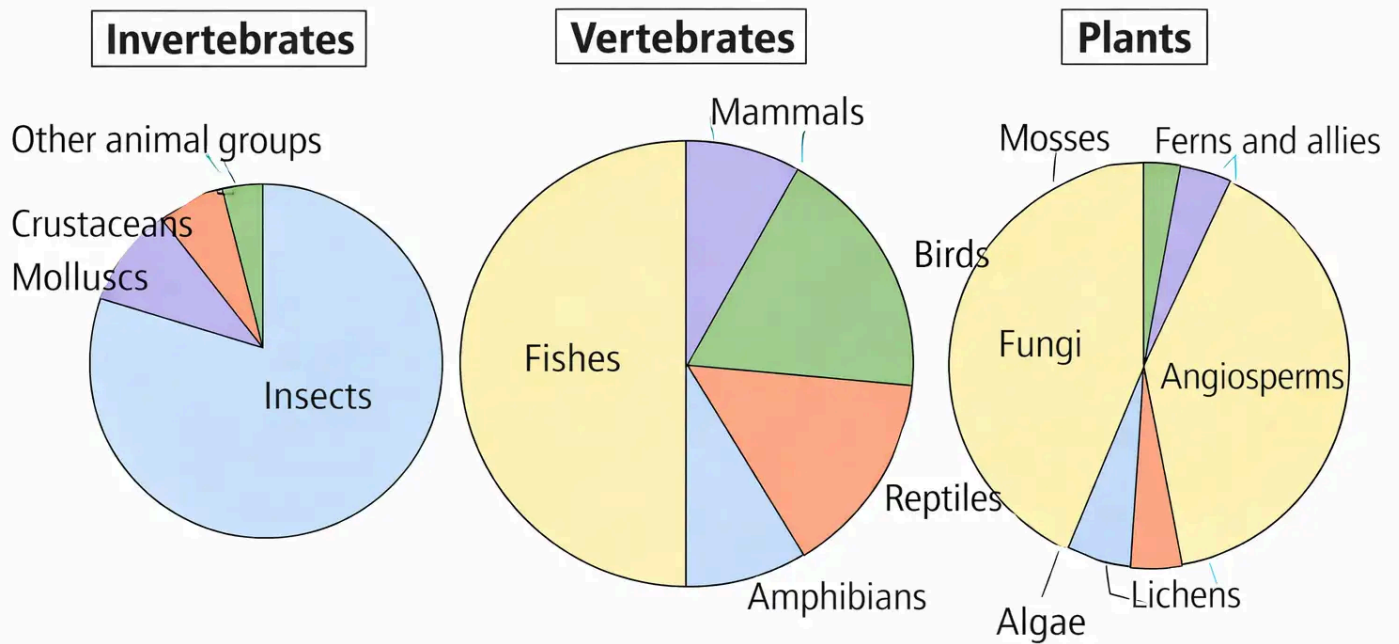


Fig.: Global biodiversity : Proportionate number of species of major taxa of invertebrates, vertebrates and plants.

Memory Aids

- Remember: "7 million species, 70% animals, 70% insects among animals".

Quick Checkpoints

- What percentage of global species are animals?
- Which animal group is most species-rich?

Biodiversity in India

Highlights

- India has 2.4% of world land but 8.1% of global species diversity.
- One of 12 mega-diversity countries.

- Divided into 10 biogeographical regions including Himalayas, Western Ghats, Deccan Peninsula, etc.
- Recorded: 45,000 plant species, twice as many animal species.
- Estimated undiscovered: 100,000+ plants, 300,000+ animals.
- Endemic species confined to regions, e.g., Western Ghats amphibians.

Memory Aids

- India: "Small land, big diversity".

Quick Checkpoints

- What percent of global species diversity does India hold?
- What are endemic species?

Patterns of Biodiversity

Latitudinal Gradients

- Species diversity decreases from equator to poles.
- Tropics (23.5°N to 23.5°S) have highest species richness.
- Examples: Colombia (1400 bird species), New York (105), Greenland (56).
- Amazon rainforest: richest biodiversity with 40,000+ plants, 125,000+ invertebrates.
- Reasons for tropical richness: long speciation time, stable environment, more solar energy.

Species Area Relationship

- Species richness increases with area but up to a limit.
- Relationship follows log scale: $\log S = \log C + Z \log A$.
- Z value usually 0.1-0.2; higher for continents.

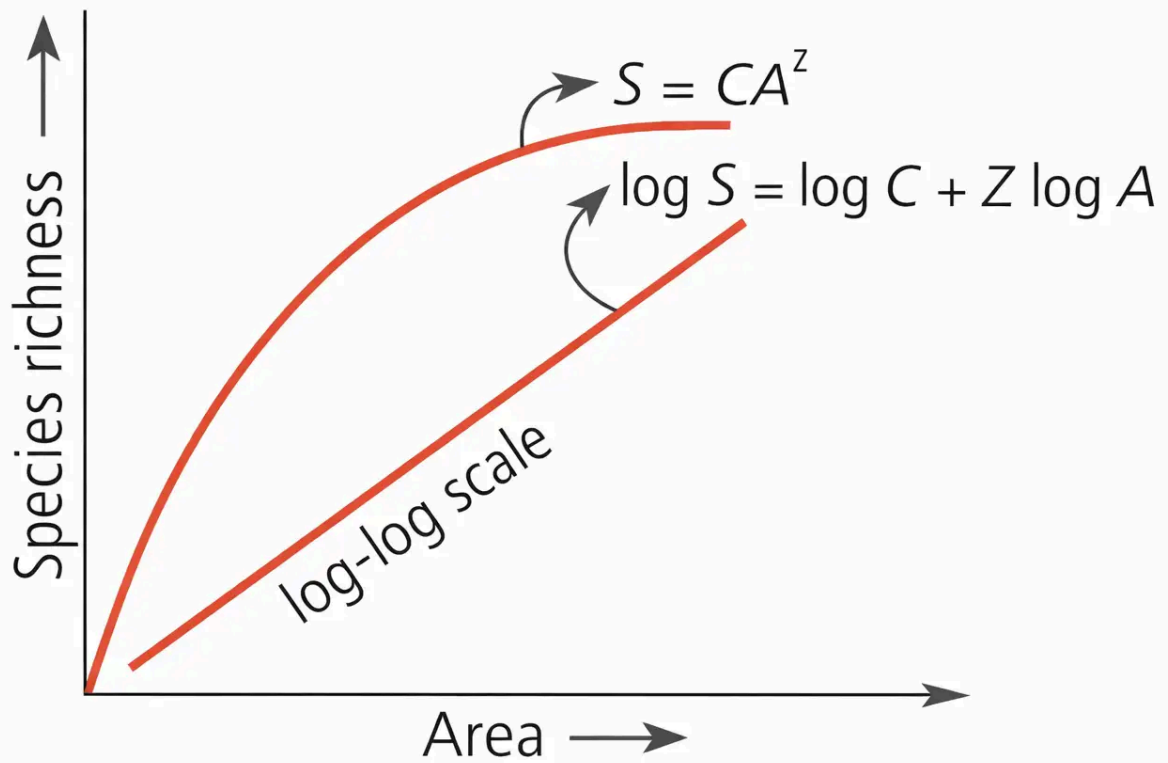


Fig.: Species-area relationship

Memory Aids

- Latitudinal: "More species near equator".
- Species-area: "Bigger area, more species".

Quick Checkpoints

- How does species diversity change with latitude?
- What is the species-area relationship?

Importance of Species Diversity

Benefits to Ecosystem

- Ecological stability: Diverse ecosystems resist stress and alien species invasion.
- Higher productivity in ecosystems with more biodiversity.

- Maintains ecosystem health via checks, feedbacks, keystone species.
- Rivet popper hypothesis: Loss of species weakens ecosystem like rivets in a plane.

Memory Aids

- Think: "More species = stronger ecosystem".

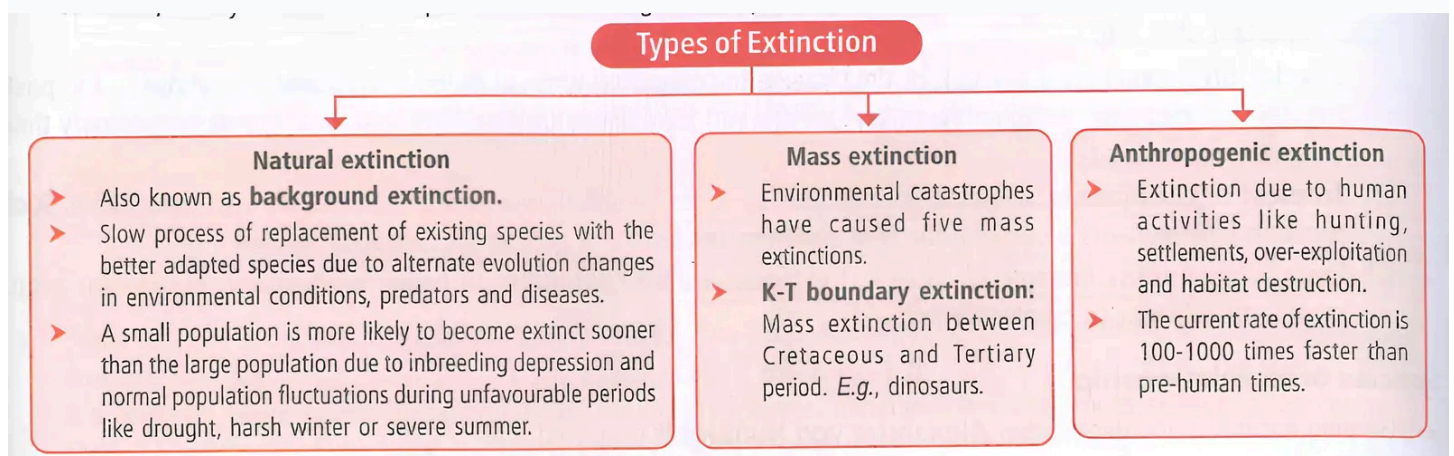
Quick Checkpoints

- Why is species diversity important for ecosystem stability?
- Explain the rivet popper hypothesis.

Loss of Biodiversity

Causes and Effects

- Rapid decline due to human activities.
- IUCN Red List (2004): 784 species extinct in last 500 years.
- 15,500+ species currently threatened worldwide.
- Extinction rates 100-1000 times faster than pre-human times.
- Five mass extinctions in history; current trend may wipe out half species in 100 years.



Memory Aids

- Extinction types: Natural (slow), Mass (catastrophic), Anthropogenic (human-caused).

Quick Checkpoints

- What are the types of extinction?
- How fast is current extinction compared to natural rates?

Causes of Biodiversity Loss

Main Causes

- "Evil Quartet": Habitat loss & fragmentation, over-exploitation, alien species invasion, co-extinction.
- Habitat loss: Deforestation, wetland filling, urbanization reduce species habitats.
- Fragmentation disrupts species interactions, affects large-territory animals.
- Over-exploitation: Excessive hunting/fishing reduces populations, risks extinction.
- Alien species: Non-native invasives outcompete natives, e.g., Water hyacinth, Nile Perch.
- Co-extinction: Extinction of one species causes dependent species to vanish.

Other Causes

- Disturbance & degradation: Fires, pests, human clearing.
- Pollution: Pesticides cause biomagnification; heavy metals and oil spills harm species.
- Intensive agriculture: Habitat loss and reduced genetic diversity.
- Forestry: Pure tree plantations reduce forest biodiversity.

Memory Aids

- Remember "Evil Quartet" for main causes.

Quick Checkpoints

- What are the main causes of biodiversity loss?
- How do alien species affect native biodiversity?

Red List Categories

Extinction Risk Levels

- Extinct: Species completely gone, e.g., Dodo.
- Critically Endangered: Very high risk, e.g., Pigmy Hog.
- Endangered: High risk, e.g., Lion-tailed Macaque.
- Vulnerable: Population declining, risk in medium term, e.g., Clouded Leopard.
- Extinct in Wild: Absent in natural habitat.
- Lower Risk: Threatened but stable.
- Data Deficient: Insufficient data for assessment.
- Rare Species: Naturally small populations, always at risk.
- Not Evaluated: No assessment done.
- Indeterminate: Risk present but cause unknown.

Memory Aids

- Order: Extinct < Critically Endangered < Endangered < Vulnerable < Lower Risk.

Quick Checkpoints

- What does 'Critically Endangered' mean?
- Which category means species is extinct in the wild?

Biodiversity Conservation

Concept and Importance

- Protection and scientific management of biodiversity to maintain optimum levels.
- Ensures sustainable benefits for present and future generations.
- Reasons to conserve biodiversity:
 - **Narrowly utilitarian:** Direct economic benefits like food, medicine, industrial products.
 - **Broadly utilitarian:** Ecosystem services like oxygen production, pollination, aesthetic value.
 - **Ethical:** Every species has intrinsic value beyond economic use.
- Red List purpose:
 - Raise awareness of biodiversity threats.
 - Provide global index of biodiversity decline.
 - Identify species at high risk of extinction.
 - Set conservation priorities and actions.
 - Inform about international agreements like CBD and CITES.

Table : Some important examples of threatened species in India

Category	Plants	Animals
Critically endangered	<i>Berberis nilghiriensis</i>	<i>Pescula salvania</i> (Pigmy hog)
Endangered	<i>Bentinckia nicobarica</i>	<i>Ailurus fulgens</i> (Red panda)
Vulnerable	<i>Cupressus cashmeriana</i>	<i>Antelope cervicapra</i> (Black buck)

Memory Aids

- "Narrow" = direct benefits (food, medicine).
- "Broad" = ecosystem services (oxygen, pollination).
- Ethical = intrinsic value of all species.
- Red List = awareness + action + global index.

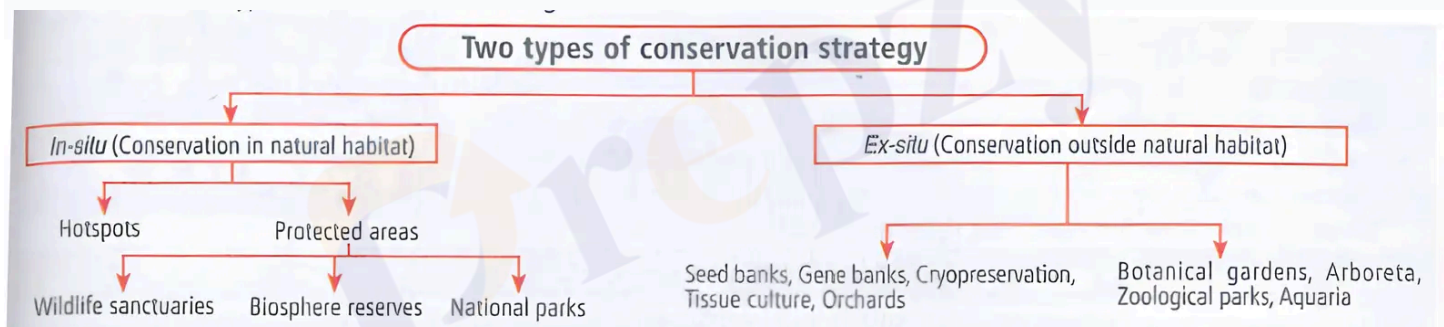
Quick Checkpoints

- What are the three main reasons to conserve biodiversity?
- What is the purpose of the Red List?
- How does biodiversity benefit humans economically?

Conservation Strategies

Types and Methods

- Two main types: In-situ and Ex-situ conservation.
- **In-situ:** Protect species in natural habitats (hotspots, protected areas).
- **Ex-situ:** Protect species outside natural habitats (seed banks, gene banks, botanical gardens, zoos).



Memory Aids

- In-situ = "in place" protection.
- Ex-situ = "out of place" protection.
- Hotspots and protected areas are natural refuges.
- Gene banks and seed banks preserve genetic material.

Quick Checkpoints

- What are the two main conservation strategies?
- Give examples of in-situ conservation methods.
- What is ex-situ conservation?

In-situ Conservation

Definition and Types

- Protection of whole ecosystems and biodiversity in natural habitats.
- Two types: Hotspots and Protected Areas.
- **Hotspots:** Areas rich in unique species, sensitive to human impact; 34 globally, 3 in India.
- **Protected Areas:**
 - National Parks: Strict wildlife protection, no farming or grazing.
 - Biosphere Reserves: UNESCO zones - Core (no human activity), Buffer (limited research), Transition (sustainable use).
 - Sanctuaries: Protect animals, allow limited human use like grazing.
- India's sacred groves protect rare endemic species; found in Meghalaya, Rajasthan, Western Ghats, Madhya Pradesh.

Hotspots

- Hotspots are regions rich in biodiversity but are declared sensitive due to direct or indirect human interference.
- Biodiversity hotspots were originally identified by **Norman Myers**.
- Hotspots are determined by four factors: (i) Number of species or species diversity, (ii) Degree of endemism, (ii) Degree of threat to habitat and (iv) Degree of exploitation.
- Total number of hotspots all over the world are 34.
- India has thr6e hotspots: Indo-Burma region, Himalayas and Western Ghats-Sri Lanka.

Protected Areas

Areas especially dedicated to the protection and maintenance of biological diversity and of natural and associated cultural resources, maintained and managed through legal or other effective measures.

National Parks	Biosphere Reserves	Sanctuaries
<ul style="list-style-type: none">➤ Maintained by government and reserved for betterment of wildlife.➤ Various activities like cultivation, grazing, forestry, habitat manipulation are prohibited.➤ At present there are more than 100 National parks in India. <i>E.g.</i>, Kaziranga National Park in Assam, Bandipur National Park in Karnataka, etc.	<ul style="list-style-type: none">➤ Multipurpose protected areas.➤ Initiated by UNESCO under MAB programme*.➤ Biosphere reserves have three zones:➤ Core or natural zone: Undisturbed and legally protected area where no human activity is allowed.➤ Buffer zone: Limited human activity like research, education and resource utilisation are allowed.➤ Transition zone: Outermost region where human activity like recreation, cropping, forestry, etc., are allowed.	<ul style="list-style-type: none">➤ Tracts of land for conservation of fauna.➤ Grazing, cultivation, harvesting of forest products and private ownership is permitted.➤ More than 500 sanctuaries are present in India with 3.6% geographical area. <i>E.g.</i>, Malabar Wildlife sanctuary in Kerala, Karakoram Wildlife saccoved in Jammu and Kashmir, etc.

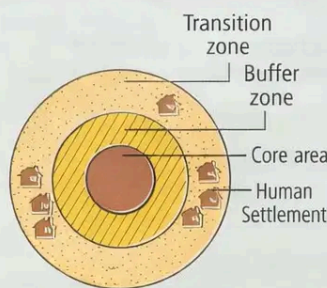


Fig.: Zonation in a terrestrial biosphere reserve

*Note: MAB (Man and Biosphere) Programme was initiated in 1971 by UNESCO (United Nations Educational Scientific and Cultural Organisation) but was introduced in India in 1986.

Memory Aids

- Hotspots = high diversity, high threat.
- National Parks = strict protection.
- Biosphere Reserves = three zones for balance.
- Sanctuaries = protection with limited use.
- Sacred groves = cultural conservation.

Quick Checkpoints

- What defines a biodiversity hotspot?
- What activities are allowed in biosphere reserve zones?
- Where are sacred groves found in India?

Ex-situ Conservation

Definition and Methods

- Conservation of species outside their natural habitats.
- Includes offsite collections and gene banks.
- **Offsite Collections:** Botanical gardens, zoos, wildlife parks breed and preserve species.
- **Gene Banks:** Maintain seeds, live plants, genetic material.
- **Seed Banks:** Orthodox seeds (dry/cold tolerant) and recalcitrant seeds (sensitive).
- **Orchards:** Maintain plants with recalcitrant seeds.
- **Tissue Culture:** Multiply plants using pollen, embryos; useful for endangered species.
- **Cryopreservation:** Freeze cells/tissues at -196°C for long-term preservation.

Table : *Ex-situ* conservation

Offsite Collection				
<ul style="list-style-type: none"> ➤ Live collections of wild and domesticated species in botanical gardens, zoological parks, wildlife safari parks, arboreta, etc. ➤ Botanical gardens and arboreta have a large variety of species of plants and some of them have seed banks, tissue culture facilities; and zoological parks have captive breeding programmes. ➤ Captive breeding helps to maintain the species which have become extinct in wild. As the number increases in captive breeding individuals are selectively released in wild. 				
Gene Banks				
Maintain stocks of viable seeds, live plants, tissue culture and frozen germplasm with widest range of genetic variability.				
Seed banks		Orchards	Tissue culture	Cryopreservation
Orthodox seeds	Recalcitrant seeds			
Seeds can tolerate reduced moisture content (5%), anaerobic conditions, low temperature (-10°C to -20°C). <i>E.g.</i> , cereals, legumes, etc.	Seeds cannot tolerate reduced moisture and low temperature. Seeds can only be stored for shorter duration after treatment with fungicides and in humid air and normal oxygen. <i>E.g.</i> , cocoa, jack fruit, coconut, etc.	All possible strains and varieties of plants with recalcitrant seeds are maintained. <i>E.g.</i> , litchi, oil, palm, etc.	Technique used for plants with recalcitrant seeds, variable seed progeny, seedless variety or where clone is to be maintained. Callus formation, embryoids, pollen grain culture and shoot tip culture are used for growing such plants. Maintains large number of genotypes in small area, rapid multiplication of endangered species and hybrid rescue. <i>E.g.</i> , banana, potato, etc.	Preservation of embryos, animal cells or tissues, gametes at -196°C (liquid nitrogen) indefinitely. Special techniques are used to revive the cryopreserved material. Endangered organisms are also cryopreserved to prevent extinction.

Memory Aids

- Offsite = gardens and zoos.
- Gene banks = genetic diversity storage.
- Orthodox seeds = dry and cold tolerant.
- Recalcitrant seeds = sensitive seeds.
- Tissue culture = rapid multiplication.
- Cryopreservation = ultra-cold storage.

Quick Checkpoints

- What is ex-situ conservation?
- How do seed banks differ for orthodox and recalcitrant seeds?
- What is the role of tissue culture in conservation?

International Efforts

Key Agreements and Organisations

- **Earth Summit (1992):** Promoted Convention on Biological Diversity (CBD), signed by 152 nations; India joined in 1994.
- Commitments:
 - Conserve biodiversity.
 - Manage biodiversity sustainably.
 - Share benefits equitably.
- **Earth Summit (Rio+20, 2012):** New sustainable development strategies.
- NGOs like Greenpeace support conservation globally.
- **Agenda 21:** Blueprint for sustainable development in 21st century.
- **World Conservation Union (IUCN):** Leadership in conservation.
- **World Wide Fund for Nature (WWF):** Conservation support.
- **CITES:** Restricts trade in endangered species, helps prevent poaching.
- UNESCO's Man and Biosphere (MAB) program supports biosphere reserves.

Memory Aids

- CBD = global biodiversity treaty.
- Agenda 21 = 21st-century sustainability plan.
- CITES = trade control for endangered species.
- IUCN and WWF = global conservation leaders.

Quick Checkpoints

- What is the purpose of the Convention on Biological Diversity?
- Which organisations support global biodiversity conservation?
- What does CITES regulate?

Biodiversity Conservation in India

National Efforts

- In-situ conservation managed by Ministry of Environment and Forests.
- Ex-situ conservation managed by National Bureau of Plant, Animal and Fish Genetic Resources.
- International Crop Research Institute for Semi-Arid Tropics (ICRISAT) conserves germplasm of key crops.
- Multiple centres maintain diverse crop varieties for conservation.

Memory Aids

- Ministry of Environment = in-situ.
- National Bureau = ex-situ genetic resources.
- ICRISAT = crop germplasm conservation.

Quick Checkpoints

- Who manages in-situ conservation in India?
- What is the role of ICRISAT?
- Which organisation handles ex-situ conservation?