

ENVIRONMENTAL SCIENCE / BIOLOGY • STUDY NOTES



UNIT 3

Biodiversity and Wildlife

- 1 Biodiversity — Definition, Types and Value
- 2 Biodiversity Indices — Shannon & Simpson
- 3 Conservation — In-situ and Ex-situ
- 4 Conservation Priority — Hotspot, Megadiversity, Sensitive Ecosystems
- 5 Indigenous Knowledge and PBR — Basic Concepts

Comprehensive notes • Diagrams • Practice Questions with Answer Key

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1 Biodiversity: Definition, Types and Value

The foundation concept for the entire unit

1.1 Definition

The term **Biodiversity** (short for *Biological Diversity*) was popularised by **Walter G. Rosen (1985)** and later by **E.O. Wilson**. It refers to the totality of genes, species and ecosystems in a region.

CBD DEFINITION (1992)

"Biodiversity is 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."

In simpler terms, biodiversity is the **variety and variability of life on Earth** — encompassing every living organism, the genetic differences among them, and the ecosystems they form.

1.2 Types (Levels) of Biodiversity

Biodiversity is commonly studied at three hierarchical levels:

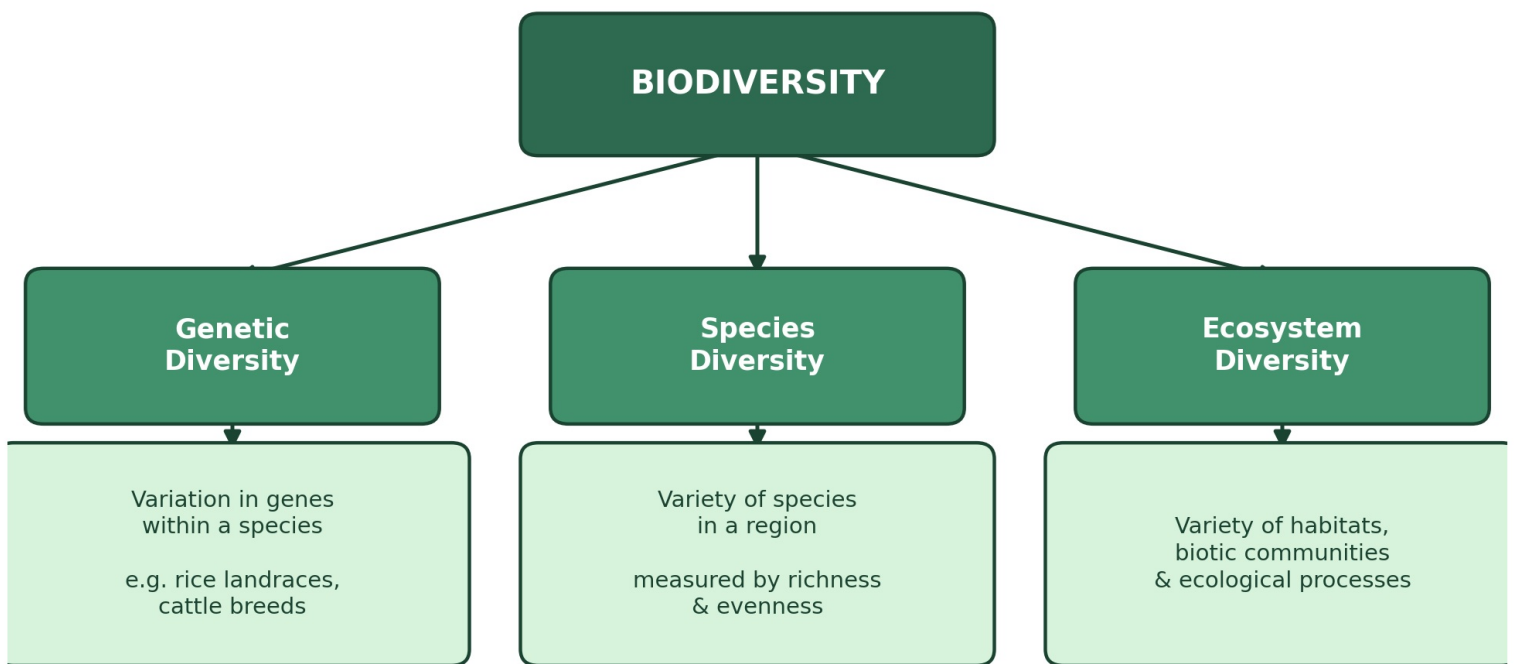


Fig 1.1 — The three levels of biodiversity: genetic, species and ecosystem diversity

(a) Genetic Diversity

Variation in genes (alleles) within a single species or population. It is the raw material for evolution and adaptation, and determines a species' resilience to disease, climate change and environmental stress.

- Example: Thousands of rice (*Oryza sativa*) landraces in India; different cattle/goat breeds; blood-group variation in humans.
- High genetic diversity → better adaptive potential; low genetic diversity → higher extinction risk (e.g. cheetahs, which show very low genetic variability).

(b) Species Diversity

Variety and abundance of different species within a given region. It has two components:

- **Species richness** — the total number of species present.
- **Species evenness (equitability)** — how uniformly individuals are distributed among those species.

Species diversity is further classified spatially:

- **Alpha (α) diversity** — diversity within a single habitat/community.
- **Beta (β) diversity** — rate of change/turnover of species between habitats along a gradient.
- **Gamma (γ) diversity** — total diversity across a large landscape/region ($\alpha + \beta$).

(c) Ecosystem (Ecological) Diversity

Variety of habitats, biotic communities, ecological processes, and the complexity within each ecosystem — e.g. forests, grasslands, deserts, wetlands, coral reefs, and the interactions (energy flow, nutrient cycling) occurring within them.

EXAM TIP

Sometimes a fourth level — **molecular diversity** — is also mentioned in advanced texts, referring to variation at the DNA/protein level. Most syllabi, however,

1.3 Value of Biodiversity

Biodiversity has enormous value to humankind, conventionally divided as follows:

Value Type	Description	Example
Consumptive Use Value	Direct use of resources harvested and consumed, not traded in the market	Firewood, fodder, wild fruits gathered by local/tribal people
Productive Use Value	Commercially harvested and sold products (market value)	Timber, fisheries, medicinal plants sold in markets
Social / Cultural Value	Value linked to social, religious, spiritual or cultural life	Sacred groves, sacred animals (peacock, cow)
Ethical / Existence Value	Value in the mere existence of species, independent of human use (right to exist)	Conservation of an endangered species with no known "use"
Aesthetic Value	Value derived from the beauty and recreational appeal of nature	Eco-tourism, bird-watching, wildlife photography
Option Value	Potential, yet-undiscovered value/use of a species in the future	An unstudied plant that may later yield a life-saving drug

These are also broadly grouped into:

- **Direct value** — consumptive & productive use values (tangible, marketable).
- **Indirect value** — ecosystem services such as pollination, water purification, climate regulation, soil formation, carbon sequestration, flood control, and nutrient cycling.

QUICK RECAP
3 Levels: Genetic → Species → Ecosystem | **6 Values:** Consumptive, Productive, Social, Ethical, Aesthetic, Option | **2 Broad Categories:** Direct & Indirect

2 Biodiversity Indices: Shannon & Simpson

Quantitative measurement of species diversity

2.1 Why Measure Diversity Numerically?

Simply counting species (richness) is not enough to compare communities, because two communities with the same number of species can look very different if one is dominated by a single species while individuals are evenly spread in the other. **Diversity indices** combine **richness (S)** and **evenness** into a single comparable number.

2.2 Shannon-Wiener Diversity Index (H')

Also called the Shannon-Weaver index; originally developed for information theory (Claude Shannon, 1948) and adapted to ecology. It is the most widely used diversity index and is sensitive to **rare species**.

$$H' = - \sum (p_i \times \ln p_i)$$

where p_i = proportion of individuals of the i^{th} species (n_i/N); N = total number of individuals of all species

- Typically ranges from 1.5 to 3.5 in natural communities; rarely exceeds 4.5.
- Higher H' = higher diversity (more species, more evenly distributed).
- $H' = 0$ when only one species is present (no diversity).
- Maximum possible value:** $H'_{\text{max}} = \ln(S)$, reached when all species are perfectly equally abundant.

RELATED: PIELOU'S EVENNESS INDEX

$J = H' / H'_{\text{max}} = H' / \ln(S)$ — ranges from 0 (no evenness) to 1 (perfect evenness).

2.3 Simpson's Index (D)

Developed by **Edward H. Simpson (1949)**. It measures the **probability that two individuals randomly selected** from a community belong to the **same species**. It is more sensitive to the abundance of the most **dominant** species than to rare ones.

$$D = \sum p_i^2 \quad (\text{proportion form}) \quad \text{or} \quad D = \sum [n_i(n_i-1)] / [N(N-1)] \quad (\text{sample form})$$

Because D itself measures **dominance** (D increases as diversity decreases), it is usually converted into a true diversity measure:

- Simpson's Index of Diversity** = $1 - D$ (probability that two random individuals belong to *different* species; ranges 0-1, higher = more diverse)
- Simpson's Reciprocal Index** = $1 / D$ (ranges from 1 to S ; higher = more diverse)

2.4 Worked Example

Consider two hypothetical plant communities, each with 5 species ($S = 5$) and 100 individuals ($N = 100$), but different abundance patterns:

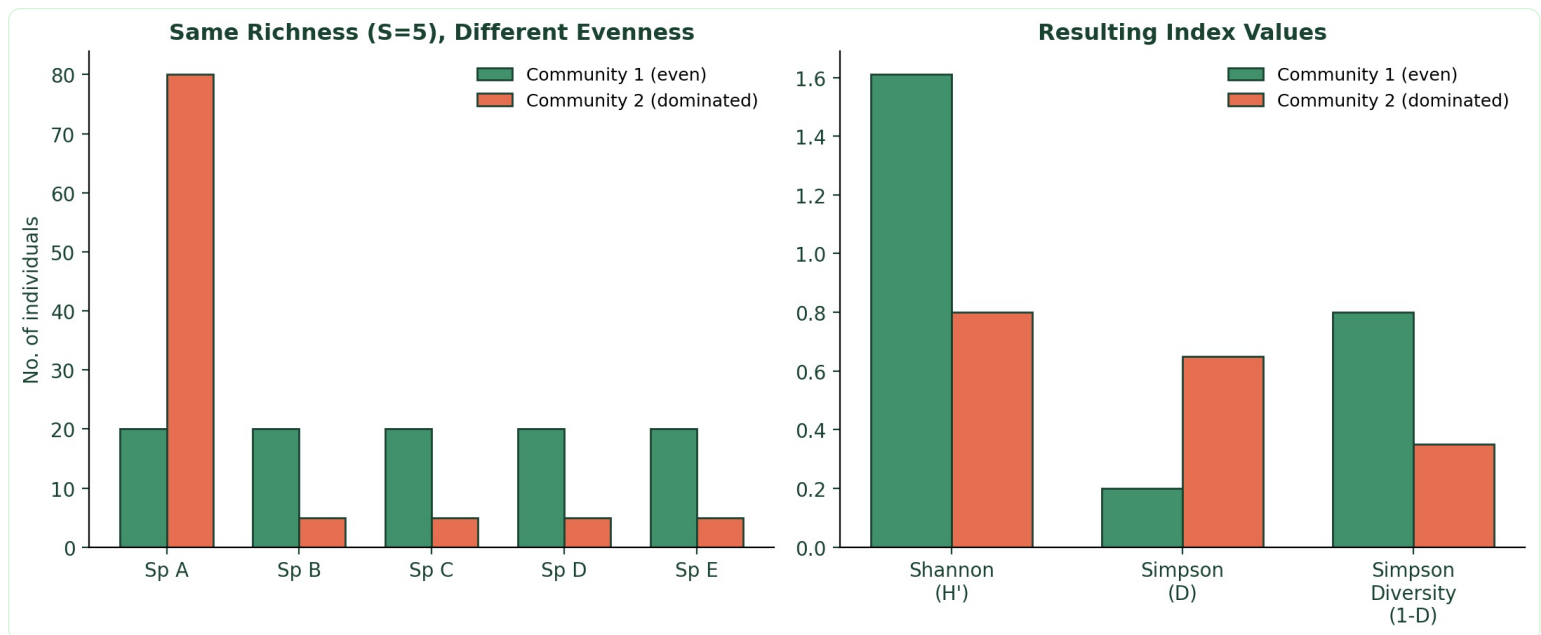


Fig 2.1 — Left: species abundance distribution in an "even" vs a "dominated" community. Right: resulting Shannon (H'), Simpson (D) and Simpson Diversity ($1-D$) values.

Community 1 (even): 20, 20, 20, 20, 20 individuals $\rightarrow H' = \ln(5) \approx 1.61$ (maximum possible for $S=5$); $D \approx 0.20$; $1-D \approx 0.80$

Community 2 (dominated): 80, 5, 5, 5, 5 individuals $\rightarrow H' \approx 0.80$; $D \approx 0.65$; $1-D \approx 0.35$

Both communities have identical **richness** ($S = 5$), but Community 1 is far more diverse because it is more **even** — this is exactly what the indices are designed to capture.

2.5 Shannon vs Simpson — Comparison

Feature	Shannon-Wiener (H')	Simpson's Index (D)
Basis	Information theory	Probability theory
Sensitivity	More weight to rare species	More weight to abundant/dominant species
Range	Usually 1.5–3.5 (theoretically 0–ln S)	D: 0–1 (dominance); 1–D: 0–1 (diversity)
Interpretation	Higher value = higher diversity	Higher D = lower diversity (dominance); higher 1–D = higher diversity
Ease of calculation	Requires logarithms	Simpler, uses only squares/products

EXAM TIP

A common question is: "Which index is more influenced by rare species?" → **Shannon-Wiener**. "Which index is more influenced by dominant species?" → **Simpson's**.

Biodiversity conservation strategies fall into two broad approaches, based on **where** the organism is protected.

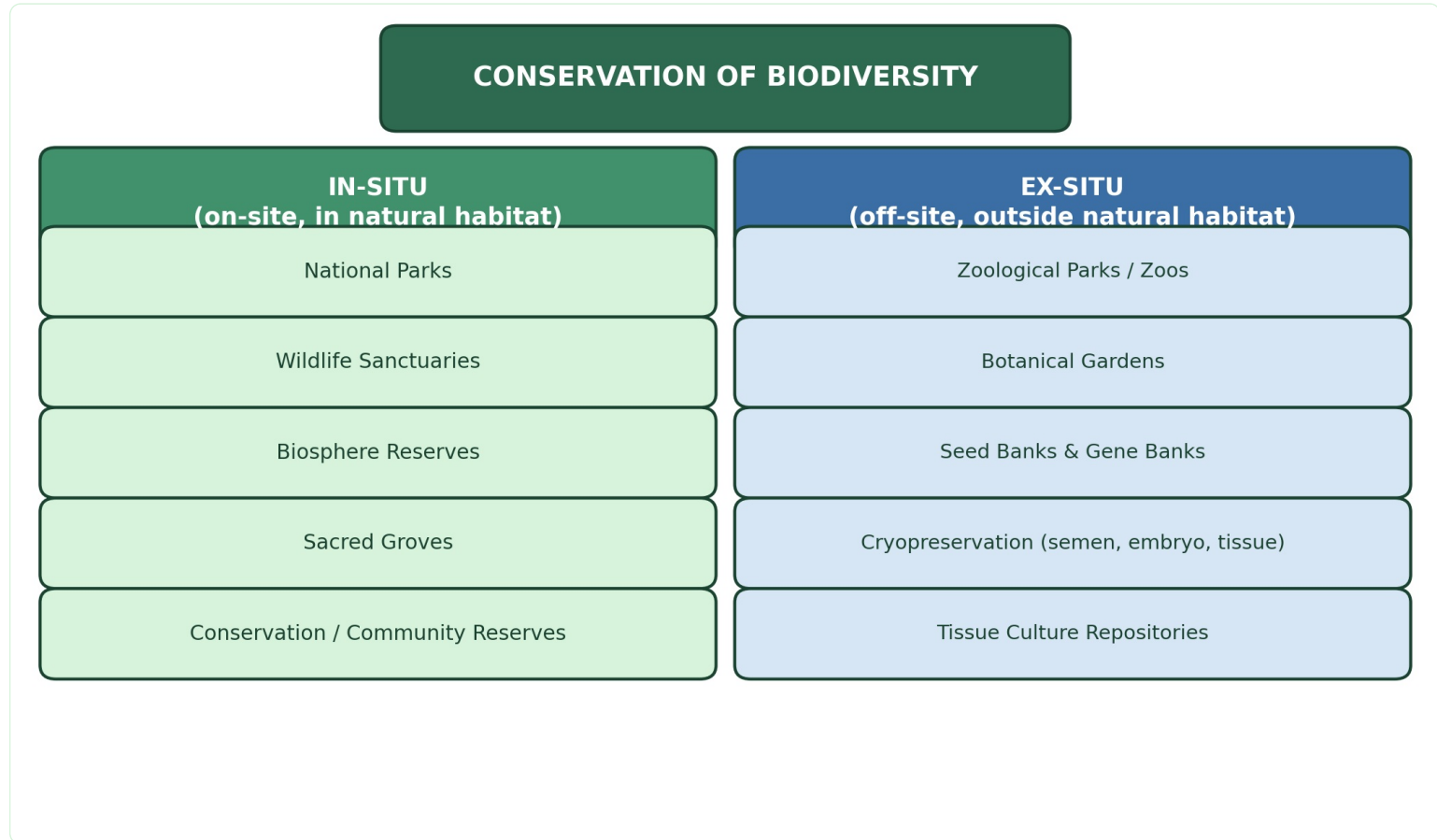


Fig 3.1 — In-situ vs Ex-situ conservation: mechanisms used under each approach

3.1 In-situ Conservation ("on-site")

DEFINITION

Conservation of species **within their natural habitat**, protecting the whole ecosystem so that the species conserves itself along with associated flora, fauna and ecological processes.

Key mechanisms in India

- **National Parks** — strictly protected areas; no human activity/grazing/private rights allowed (e.g. Kaziranga, Jim Corbett).
- **Wildlife Sanctuaries (WLS)** — protected areas allowing some regulated human activity (e.g. grazing, collection of forest produce under permit).
- **Biosphere Reserves** — large multi-use areas with a **core zone** (strictly protected), **buffer zone** and **transition zone**, designed to conserve biodiversity while allowing sustainable use and research (e.g. Sundarbans, Nilgiri).
- **Sacred Groves** — patches of forest protected by local communities for religious/cultural reasons; informal but effective in-situ conservation.
- **Conservation & Community Reserves** — buffer/connector areas declared with community/private land involvement (added under the Wildlife (Protection) Amendment Act, 2002).

Advantages

- Protects the entire ecosystem, not just target species — conserves co-evolved interactions.
- Allows natural evolution and adaptation to continue.
- Generally more cost-effective for large-scale, long-term conservation.

Limitations

- Requires large areas of land; conflicts with human land-use needs.
- Species remain vulnerable to poaching, disease, natural disasters within the habitat.

3.2 Ex-situ Conservation ("off-site")

DEFINITION

Conservation of components of biodiversity **outside their natural habitats**, typically as a last resort for critically endangered species or to conserve genetic material.

Key mechanisms

- **Zoological Parks / Zoos** — captive breeding of endangered animals (e.g. Project Tiger captive-breeding support centres).

- **Botanical Gardens & Arboreta** — living collections of plant species for study and conservation.
- **Seed Banks / Gene Banks** — long-term, low-temperature storage of seeds/germplasm (e.g. National Bureau of Plant Genetic Resources, NBPGR, New Delhi).
- **Cryopreservation** — storage of gametes, embryos, tissues at ultra-low temperature (liquid nitrogen, -196°C).
- **Tissue Culture Repositories** — in-vitro conservation of plant genetic material, useful for species with recalcitrant (non-storable) seeds.

Advantages

- Provides a controlled, safe environment; useful for captive breeding & reintroduction programmes.
- Essential when the natural habitat is destroyed or the population is critically low.

Limitations

- Conserves only the target organism, not the ecosystem or ecological interactions.
- Risk of reduced genetic diversity, loss of natural behaviour, and difficulty in eventual reintroduction.
- Expensive to maintain over long periods for large numbers of species.

EXAM TIP

In-situ and ex-situ methods are **complementary, not competing** — ex-situ populations often act as an "insurance policy" / genetic reservoir that can be reintroduced into restored in-situ habitats (e.g. Gharial and Vulture breeding-and-release programmes in India).

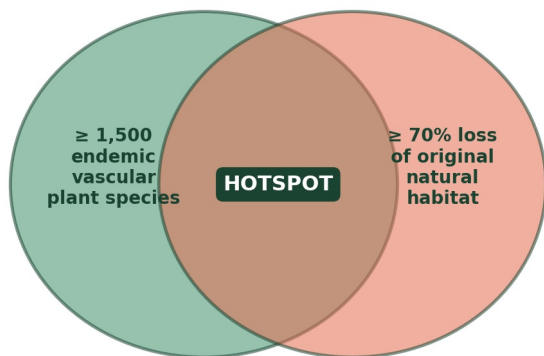
Because conservation resources (funding, land, manpower) are limited, ecologists prioritise regions that give the greatest "return" in terms of biodiversity saved. Three key prioritisation concepts are used:

4.1 Biodiversity Hotspots

DEFINITION

A biodiversity hotspot is a biogeographic region that is both a significant reservoir of **endemic species** and is under severe **threat** from habitat loss. The concept was introduced by **Norman Myers in 1988** and refined by Conservation International.

Criteria for a Biodiversity Hotspot (Norman Myers)



High endemism + High threat = Conservation priority

India's 4 Biodiversity Hotspots

1. Himalaya

Eastern & Western Himalaya; Rhododendron, red panda

2. Indo-Burma

NE India; freshwater turtles, gibbons

3. Western Ghats & Sri Lanka

Lion-tailed macaque, Nilgiri tahr

4. Sundaland (Nicobar Is.)

Extends into SE Asia; endemic flora

Fig 4.1 — Criteria for identifying a biodiversity hotspot (left) and India's four recognised hotspots (right)

Two qualifying criteria (both must be met)

1. Must contain at least **1,500 endemic species of vascular plants** (i.e. $\geq 0.5\%$ of the world's total) found nowhere else.
2. Must have lost **$\geq 70\%$ of its original (primary) natural habitat/vegetation**.

Globally there are now **36 recognised biodiversity hotspots**, covering only about 2.4% of Earth's land surface, yet harbouring over half of the world's endemic plant species.

India's 4 Biodiversity Hotspots

Hotspot	Location	Notable Species
Himalaya	Eastern & Western Himalayan ranges	Red panda, snow leopard, rhododendrons
Indo-Burma	North-eastern India and adjoining SE Asia	Freshwater turtles, gibbons
Western Ghats & Sri Lanka	West coast hill ranges of peninsular India	Lion-tailed macaque, Nilgiri tahr
Sundaland	Nicobar Islands (main body extends into SE Asia)	Endemic island flora and fauna

4.2 Megadiverse Countries

DEFINITION

A concept introduced by **Conservation International** to identify a small group of nations that together harbour the majority of the Earth's species richness and endemism.

Megadiverse Countries

17 Megadiverse Countries
harbour ~70% of world's
biological diversity

Concept: Conservation International

Based on species richness + endemism

Cover < 10% of Earth's land surface

India is 1 of the 17 megadiverse nations

Others: Brazil, Indonesia, China, Mexico,
DR Congo, Australia, etc.

Sensitive / Fragile Ecosystems

Wetlands

High productivity, flood buffer,
high species turnover

Coral Reefs

Narrow temp./pH tolerance;
'rainforests of the sea'

Mangroves

Coastal buffer, nursery for
marine fauna

Alpine / Montane zones

Slow recovery, endemic-rich,
climate-sensitive

Islands

High endemism, small
populations, invasive-species risk

Fig 4.2 — Megadiverse countries (left) and sensitive/fragile ecosystems (right)

- There are **17 megadiverse countries**, occupying less than 10% of the Earth's land surface, yet together holding roughly **70% of global biodiversity**.
- Selection is based on measures of species richness and endemism across plants, amphibians, reptiles, birds and mammals.
- **India** is one of the 17 megadiverse countries. Others include Brazil, Indonesia, China, Mexico, DR Congo, Australia, Peru, Colombia, etc.

4.3 Sensitive / Fragile Ecosystems

Certain ecosystem types are disproportionately vulnerable to disturbance due to narrow environmental tolerances, slow recovery rates, or high endemism, and therefore receive conservation priority:

Ecosystem	Why It Is Sensitive
Wetlands	High biological productivity; act as natural flood buffers; rapid species turnover; highly vulnerable to drainage/pollution
Coral Reefs	Extremely narrow temperature/pH tolerance ("rainforests of the sea"); susceptible to bleaching from warming/acidification
Mangroves	Coastal buffer against storms; nursery grounds for marine fauna; threatened by coastal development/aquaculture
Alpine / Montane Zones	Slow growth and recovery; high endemism; acutely sensitive to climate change (upslope habitat squeeze)
Islands	High endemism with small population sizes; extreme vulnerability to invasive species and habitat loss

EXAM TIP

Remember the difference in **scale**: a **Hotspot** is a *region* (endemism + threat); a **Megadiverse country** is a *nation* (overall richness + endemism); a **Sensitive ecosystem** is an *ecosystem type* (fragility/vulnerability) — three different lenses for setting conservation priority.

5.1 Indigenous / Traditional Knowledge (TK)

DEFINITION

The cumulative body of knowledge, practices and beliefs, evolved by local/indigenous communities over generations through direct interaction with their environment, and transmitted orally or by practice from one generation to the next.

Characteristics of Traditional Knowledge

- Holistic — integrates ecological, cultural, social and spiritual dimensions.
- Cumulative and dynamic — builds and adapts over generations.
- Place-specific — closely tied to local ecosystems and bioresources.
- Orally transmitted — often undocumented, at risk of being lost.

Examples of Indigenous Knowledge relevant to Biodiversity

- **Ethnomedicine** — use of specific plants/animal parts for healing (basis for several modern drug discoveries, e.g. Reserpine from *Rauvolfia serpentina*, used traditionally before pharmacological validation).
- **Traditional agriculture** — indigenous crop varieties, mixed cropping, seed-saving practices suited to local soil/climate.
- **Sacred groves and totemic protection** — community-enforced protection of specific forest patches or species.
- **Traditional resource-management systems** — rotational grazing, community fishing/hunting taboos and seasonal restrictions.

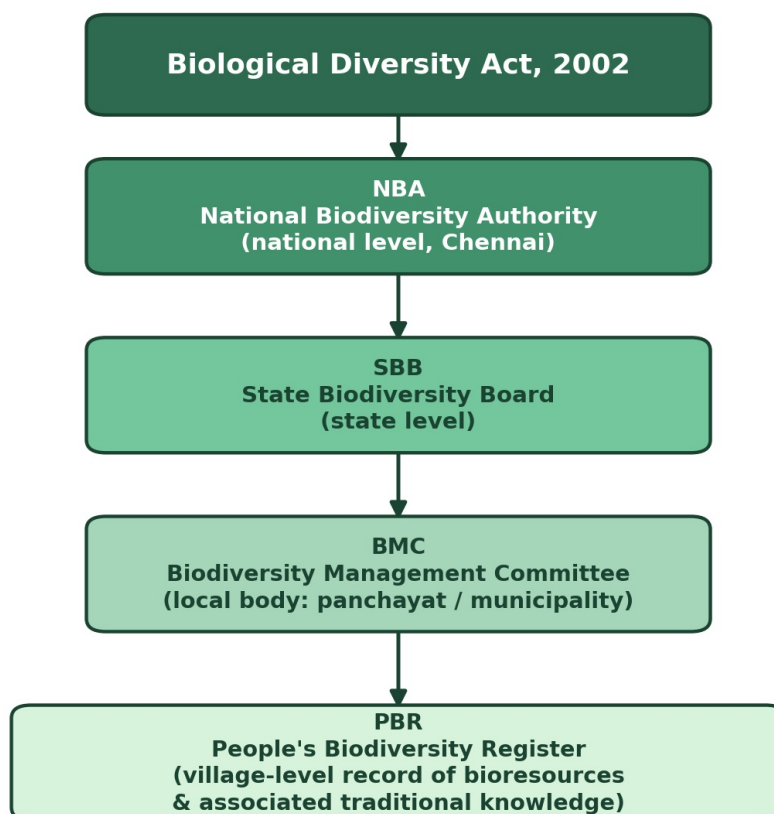
Why Indigenous Knowledge Matters for Conservation

- Provides fine-scale, long-term ecological data not captured by formal science.
- Underpins sustainable-use practices tested over generations.
- Serves as a starting point for bio-prospecting (search for useful compounds from biodiversity) — raising the need for **fair benefit-sharing** with knowledge holders.

5.2 Legal Framework: The Biological Diversity Act, 2002

India enacted the **Biological Diversity Act, 2002** (in line with its commitments under the **Convention on Biological Diversity, CBD 1992**) with three main objectives:

1. **Conservation** of biological diversity.
2. **Sustainable use** of its components.
3. **Fair and equitable sharing of benefits (ABS)** arising from the use of biological resources and associated traditional knowledge.



PBR is prepared & maintained by the BMC with help of local people, farmers, healers and knowledge-holders

Fig 5.1 — Institutional structure under the Biological Diversity Act, 2002, leading to the PBR

Three-Tier Institutional Structure

Body	Level	Key Role
NBA — National Biodiversity Authority	National (HQ: Chennai)	Regulates access to biological resources by foreign entities; advises Central Government; approval for IPR applications involving Indian biological material
SBB — State Biodiversity Board	State	Regulates access by Indian individuals/entities; advises State Government; oversees State-level conservation
BMC — Biodiversity Management Committee	Local (Panchayat / Municipality)	Promotes conservation, sustainable use and documentation of local biodiversity; prepares the PBR

5.3 People's Biodiversity Register (PBR)

DEFINITION
A **PBR** is a comprehensive, village/local-level record documenting locally available bioresources and the associated indigenous/traditional knowledge, prepared and maintained by the **Biodiversity Management Committee (BMC)** with participation of local people.

Typical Contents of a PBR

- List of locally available flora and fauna (wild and domesticated), including landraces and breeds.
- Traditional uses — medicinal, agricultural, culinary, cultural.
- Names of knowledge-holders/practitioners (e.g. traditional healers, farmers).
- Information on habitats, population status and local conservation practices.

Purpose & Significance

- Creates a legal, documented record that helps protect community rights over bioresources and knowledge (relevant for Access and Benefit Sharing, ABS, claims).
- Supports evidence in cases of **biopiracy** — unauthorised commercial use of traditional knowledge/bioresources without consent or benefit-sharing.
- Aids local-level conservation planning and monitoring of biodiversity status/trends.
- Feeds into the **National Biodiversity Authority's** registers and, indirectly, into national policy.

RELATED CONCEPT
Traditional Knowledge Digital Library (TKDL) — a searchable database (Ayurveda, Siddha, Unani, Yoga) created by India to prevent bio-piracy by giving patent examiners worldwide access to documented prior art, most famously cited in the successful challenge of turmeric- and neem-related patents.

QUICK RECAP
TK = knowledge held by communities | BD Act 2002 → NBA (national) → SBB (state) → BMC (local) | BMC prepares the **PBR** | Goal: Conservation + Sustainable Use + Benefit Sharing



Practice Questions

Multiple choice, short answer and long answer — with answer key

A. Multiple Choice Questions (1 mark each)

- Who first introduced the concept of biodiversity hotspots?
(a) E. O. Wilson (b) Norman Myers (c) Charles Darwin (d) Aldo Leopold
- The Convention on Biological Diversity (CBD) was adopted in:
(a) 1972 (b) 1987 (c) 1992 (d) 2002
- Variation in genes within a species is called:
(a) Species diversity (b) Genetic diversity (c) Ecosystem diversity (d) Alpha diversity
- The rate of species turnover between two habitats along a gradient is termed:
(a) Alpha diversity (b) Gamma diversity (c) Beta diversity (d) Genetic diversity
- The Shannon–Wiener diversity index is calculated as:
(a) $D = \sum p_i^2$ (b) $H' = -\sum(p_i \ln p_i)$ (c) $J = H'/H'_{\max}$ (d) $1/D$
- Which diversity index is more strongly influenced by rare species?
(a) Simpson's Index (b) Shannon–Wiener Index (c) Both equally (d) Neither
- Simpson's Index of Diversity is expressed as:
(a) D (b) $1 - D$ (c) $\ln(D)$ (d) D^2
- Which of the following is an example of ex-situ conservation?
(a) National Park (b) Wildlife Sanctuary (c) Seed Bank (d) Biosphere Reserve
- The core, buffer and transition zone system is a feature of:
(a) National Park (b) Biosphere Reserve (c) Zoo (d) Sacred Grove
- A region qualifies as a biodiversity hotspot if it has lost at least:
(a) 50% (b) 60% (c) 70% (d) 80% of its original habitat
- The total number of biodiversity hotspots currently recognised worldwide is:
(a) 25 (b) 36 (c) 17 (d) 4
- How many biodiversity hotspots lie (partly or wholly) within India?
(a) 2 (b) 3 (c) 4 (d) 5
- The concept of "megadiverse countries" was introduced by:
(a) IUCN (b) Conservation International (c) CBD Secretariat (d) UNEP
- The 17 megadiverse countries together hold approximately what share of global biodiversity?
(a) 40% (b) 50% (c) 70% (d) 90%
- PBR stands for:
(a) Protected Biodiversity Range (b) People's Biodiversity Register (c) Plant Breeders' Rights (d) Priority Biodiversity Report
- Under the Biological Diversity Act, 2002, which body functions at the national level?
(a) BMC (b) SBB (c) NBA (d) TKDL
- The Traditional Knowledge Digital Library (TKDL) was primarily created to prevent:
(a) Deforestation (b) Biopiracy (c) Poaching (d) Overfishing

B. Short Answer Questions (3-5 marks each)

- Define biodiversity as per the Convention on Biological Diversity (CBD, 1992).
- Differentiate between alpha, beta and gamma diversity with examples.
- What is species evenness, and how does it differ from species richness?
- Write the formula for Simpson's Index and explain each term used in it.
- List any four in-situ conservation methods practised in India.
- Distinguish between in-situ and ex-situ conservation (any three points of difference).
- State the two criteria used by Conservation International to designate a biodiversity hotspot.
- Define "megadiverse countries." Name any four megadiverse nations besides India.
- What is a Biodiversity Management Committee (BMC)? State its main function.
- What is biopiracy? Explain briefly how the PBR helps in preventing it.

C. Long Answer / Essay Questions (8-10 marks each)

- Explain the concept and levels (types) of biodiversity with suitable examples. Discuss its ecological and economic value under appropriate headings.
- Compare and contrast the Shannon–Wiener and Simpson diversity indices. Illustrate the difference using a suitable numerical example.
- Describe in-situ and ex-situ conservation strategies with examples from India. Discuss the relative advantages and limitations of each approach.
- What are biodiversity hotspots? Discuss the criteria used for their identification and describe the biodiversity hotspots found in India.
- Discuss the role of indigenous/traditional knowledge in biodiversity conservation. Explain the institutional structure and significance of the People's Biodiversity Register (PBR) under the Biological Diversity Act, 2002.

6. "Sensitive/fragile ecosystems require special conservation priority." Justify this statement with reference to at least three fragile ecosystem types.

Answer Key — Section A (MCQ):
1-b 2-c 3-b 4-c 5-b 6-b 7-b 8-c 9-b 10-c 11-b 12-c 13-b 14-c 15-b 16-c 17-b