GENES, SPECIES, ECOSYSTEMS: THE LEVELS OF BIODIVERSITY

BRIDGE

The structure and organisation of biodiversity

AGENZIA ITALIANA PER LA COOPERAZIONE ALLO SVILUPPO

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"We should preserve every bit of biodiversity as priceless while we learn to use it and come to understand what it means for humanity. ".

– Edward Osborne Wilson

American biologist (1929-2021)

Biodiversity...

Convention on Biological Diversity

It is the variety of organisms at all levels, from that of genetic variants belonging to the same species to the range of various species, genera, families and the highest taxonomic levels. The term biodiversity also includes the variety of ecosystems, that is, the set of communities of organisms present in a particular habitat and the physical conditions in which they live.

E. O. Wilson: Biodiversità, 1992

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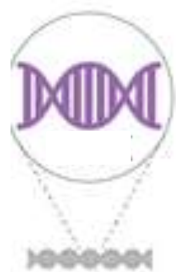
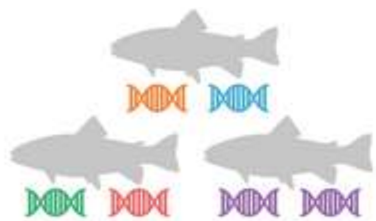
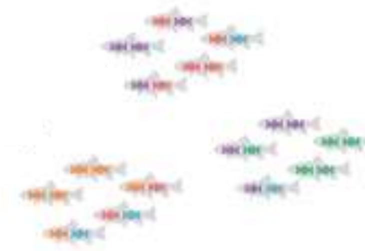
Genetic diversity



DNA



INDIVIDUALS



POPULATIONS

Gene

An inherited unit located in chromosomes which, through interaction with the internal and external environment, controls the development of a character or phenotype. Can be self-replicating and passed on to descendants. Each gene controls one or more characteristics, such as eye and hair colour, blood clotting rate, etc.

Allele

The same gene may appear in different variants, or alleles. Alleles control the same character but can lead to products that are quantitatively or qualitatively different. Diploid cells have two copies of the same gene, each passed on from one parent.

Gene pool

The set of all alleles of the whole set of genes belonging to all individuals making up a population at a given time.

The gene pool varies continuously due to the birth and death of individuals in the population and mutations occurring in reproductive cells.

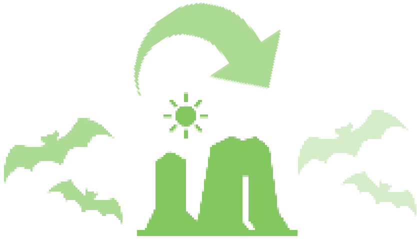
Genetic diversity

Genetic diversity is the biological variation that occurs within species. It enables species to adapt when the environment changes.

Great genetic diversity - a large gene pool - positively influences the resilience of species and consequently the functioning of ecosystems.

Gene diversity at the species level decreases when the species are reduced in number (e.g. if only a few individuals remain) and/or when the individuals are all very similar to each other (e.g. because they are related, as in the case of inbreeding depression).

When species are depleted in their genetic diversity, their adaptation potential and long-term survival is endangered.



The most effective way to counter the loss of genetic diversity is to maintain large and well-connected populations. Small and isolated populations rapidly lose genetic variability resulting in reduced adaptive capacity, lower resilience and low long-term survival potential.

Specific diversity

Specific diversity represents the complex of species that inhabit a certain region and the relationships that exist between them.

Specific diversity includes:

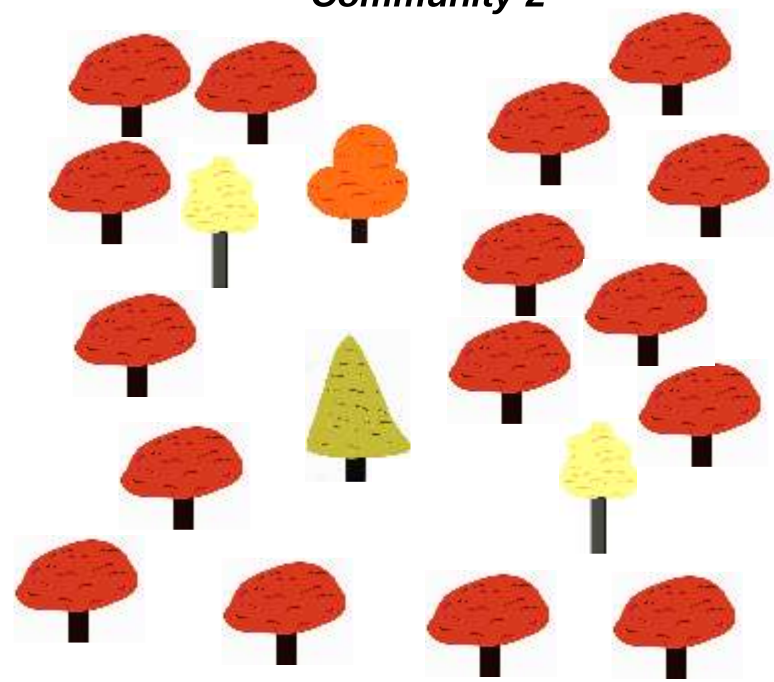
1. species richness: the number of species present in a given region
2. taxonomic or phylogenetic diversity: the genetic relationship between different groups of species present
3. species evenness or equitability: how equal the abundances of species are.

Biodiversity is not only related to the greater or lesser number of species present in a given area, but also to their relative abundances: an ecosystem dominated by a single species has a lower biological diversity than another in which the species are all equally abundant. To measure diversity at a specific level it is therefore necessary to count the number of species and estimate the number – or the proportion – of individual organisms that make up each of them.

Specific diversity

Community 1

Community 2



Green: 25% Orange: 25% Red: 25% Yellow: 25%

Green: 5% Orange: 5% Red: 80% Yellow: 10%

The two communities have the same species richness, n = 4 (and in this specific case also the same number of individuals, for simplicity), but have a different equitability (or relative abundance).

Community 1 has greater specific diversity because the relative abundance of different species is more uniform.

Ecosystem diversity

Ecosystem diversity refers to the set of all environments (or better, all ecosystems) present in a certain region and the processes that characterise them.

It therefore considers the functions of different species, their interactions and mutual influences with the surrounding environment.

The high degree of complexity of ecosystems makes it difficult to make quantitative measurements of diversity.

However, it is possible to evaluate an ecosystem on the basis of its productivity, the richness of species, the biomass contained in the different trophic levels, the energy flows by which the latter are connected, the speed of cycling of an element, its capacity to carry out a specific process (e.g. soil consolidation, water storage, carbon dioxide organication).

Although ecosystem diversity is a very general concept and our ability to describe it is still in its infancy, it represents an essential component of biological diversity and as such should be carefully considered in any biodiversity assessment.

Ecosystems

Ecosystems with high levels of biodiversity are more stable in the face of external disturbances.

An ecosystem is defined as the *complex of living organisms, the physical environment in which they live, and all their interrelationships in a particular unit of space*.

Each ecosystem is composed of:

a biotic component (from βίος = "life"), formed by all the living beings that it hosts

an abiotic component (from α + βίος = "without life"), which includes minerals, climate, soil, water, sunlight, and all the other non-living elements that characterize it

These two components are connected by two main forces: the flows of matter and energy within the ecosystem.

Ecosystems vary in size: some are small enough to be contained in single drops of water while others are so large that they encompass entire regions.

Ecosystems

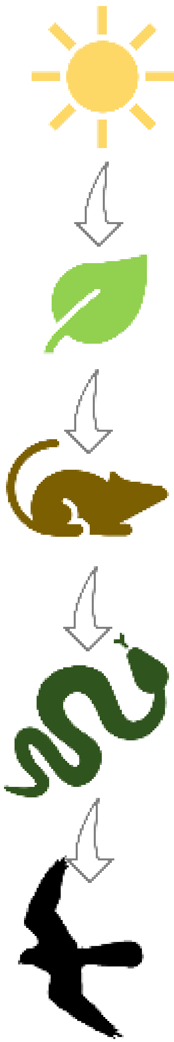
Energy flows

The primary source of energy for most ecosystems is radiant energy from the sun. The energy of sunlight is used by the autotrophs in the ecosystem (those that can produce their own food).

Composed largely of green vegetation, these organisms are capable of photosynthesis, that is, they can use the energy of sunlight to convert carbon dioxide and water into simple, energy-rich carbohydrates. Autotrophs use the energy stored in simple carbohydrates to produce more complex organic compounds, such as proteins, lipids, and starches, which maintain the life processes of organisms. The autotrophic component of an ecosystem is commonly referred to as the producer level.

The organic matter produced by autotrophs directly or indirectly supports heterotrophic organisms. Heterotrophs are also called consumers in the ecosystem. They cannot produce their own food, but they use, rearrange, and some of them decompose the organic materials built by autotrophs. All animals and fungi are heterotrophs, as are most bacteria and many other microorganisms.

Ecosystems



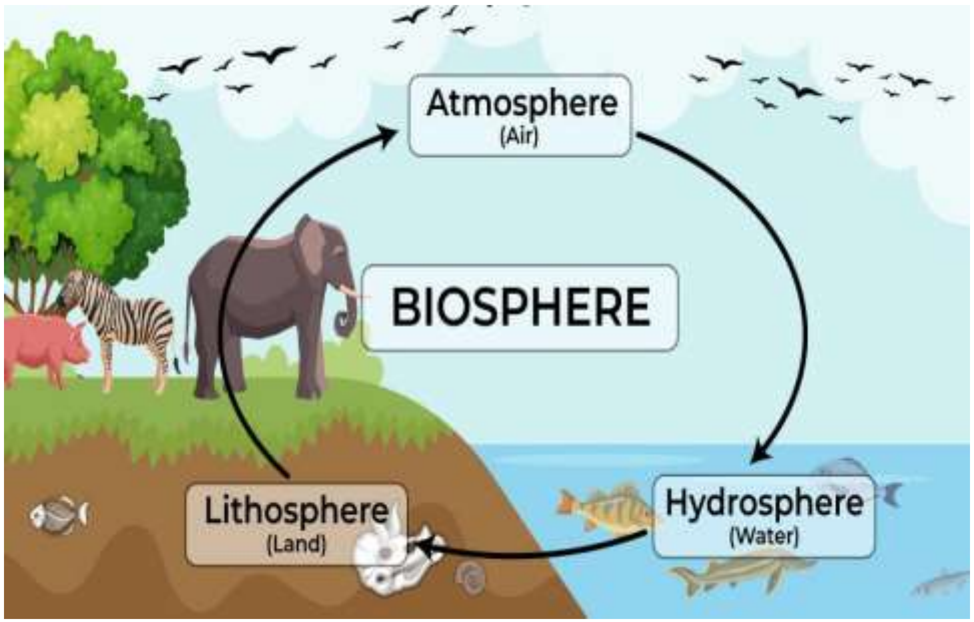
Trophic levels

Autotrophic and heterotrophic organisms occupy different trophic levels (τροφή, trophé = «nourishment») in the ecosystem:
producers: organisms that transform solar energy into chemical energy (autotrophs = plants)
primary consumers: organisms that feed on producers (heterotrophs, they take energy from an external source, they are animals and fungi)
secondary consumers: heterotrophic organisms like the previous ones, but that feed on primary consumers
possible third, fourth, etc. level consumers.

The flow of energy and organic matter through the various trophic levels constitutes a food chain.
A typical food chain in a prairie includes grass (producer) → mouse (primary consumer) → snake (secondary consumer) → hawk (tertiary consumer).
In fact, in many cases the food chains of biological communities overlap and interconnect, forming what ecologists call a food web.
The final link in all food chains are decomposers, those heterotrophs (such as scavenging birds and mammals, insects, fungi, and bacteria) that break down dead organisms and organic waste into smaller and smaller components, which can then be used by producers as nutrients.

A food chain in which the primary consumer feeds on living plants is called a grazing pathway, a food chain in which the primary consumer feeds on dead plant matter is known as a detritus pathway.

Ecosystems



Cycles of matter

Biogeochemical cycles involve the movement, mostly circular, of chemical elements through the biotic and abiotic compartments of ecosystems.

Cycles may include all or parts of the following environmental spheres:

the atmosphere, which is made up largely of gases including water vapor;

the lithosphere, which includes the soil and the entire solid crust of the Earth; the hydrosphere, which includes lakes, rivers, oceans, groundwater, frozen water, and (along with the atmosphere) water vapor; and the biosphere, which includes all living things and overlaps with each of the other environmental spheres.

There are basically two different types of biogeochemical cycles:

gas cycles (which involve those elements that are mostly stored in the atmosphere or hydrosphere, such as carbon, oxygen, and nitrogen) and sediment cycles (which involve elements stored in the lithosphere, or the Earth's crust and marine sediments, such as phosphorus and sulfur).

The pattern of biogeochemical cycles is circular in nature and is triggered by an input external to the ecosystem.

Ecosystems

Emergent Properties

Like all complex systems, ecosystems represent structural and functional units whose behaviour is not decomposable as the simple sum of their parts. There are aspects of ecosystems that are a direct consequence of complexity, such as the ability to self-regulate, self-organize, respond to disturbances by trying to self-preserve. These characteristics of the ecosystem as a complex and organized system are called emergent properties and result from the integration of various components. The production of matter, its recycling and, in a general sense, the functioning of ecosystems also exist as emerging characteristics, different from the sum of the individual contributions. Ecosystems are in a state of dynamic equilibrium with the environment and, when confronted with disturbance (changes in sedimentary regime, temperature or rainfall regime; introduction of alien species, spread of diseases, increase of predator populations, etc.) are characterized by:

Resistance: ability to resist disturbance.
Resilience: the ability to recover from a disturbance.

The resilience potential of the ecosystem is a factor in its stability, that is to say, its ability to remain intact and thus maintain its peculiarity in terms of structure, functions and processes.

Biodiversity hotspot

Biogeography

Biodiversity is not evenly distributed across the earth, but varies widely across the world and regions. Among the many factors affecting it, the diversity of living organisms depends primarily on temperature, precipitation, altitude, soil, geographical location and the presence of other species. The discipline studying the spatial distribution of organisms, species and ecosystems is biogeography.

Biodiversity gradient

Biodiversity is highest in the tropics and other localized areas (e.g., the Cape region of South Africa), while it is lowest in the polar regions: this phenomenon is called the latitudinal gradient in species diversity (LDG). A number of ecological factors contribute to the LDG, but the primary cause of the phenomenon is the higher average temperature at the equator compared to the poles.

Hotspot

A biodiversity hotspot is a geographic region with a high level of biodiversity that is at risk due to human activities. To qualify as a hotspot, a region must contain at least 0.5% or 1,500 endemic species and must have lost at least 70% of its primary vegetation. Across the world, 34 areas are classified as hotspots: most are forested areas and are located in the tropics.

5 ways to measure biodiversity

1) **Specific diversity:** **total number of species present in the area and equitability**

2) Genetic diversity: total variety of alleles in each species present

4) Endemic species: exclusive species of that territory

3) Ecosystem diversity: Total number of ecosystems in the area

5) Unique ecosystems : Ecosystems that are only present in this area of the world

– Convention on Biological Diversity (CBD)

International legal instrument for the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits arising from the use of genetic resources, ratified by 196 nations

In December 2000, the UN General Assembly proclaimed 22 May as International Day for Biological Diversity to increase understanding and awareness of biodiversity issues. The date was chosen to commemorate the adoption of the text of the Convention, on 22 May 1992, with the Final Act of the Nairobi Conference for the adoption of the agreed text of the Convention on Biological Diversity. Each year, the day is dedicated to a specific theme:

2024 – Be part of the Plan
2023 – From agreement to action: Build back biodiversity
2022 - Building a shared future for all life on Earth
2021 - We are part of the solution
2020 - Our solutions are in nature
2019 - Our biodiversity, our food, our health
2018 - Celebrating 25 years of biodiversity action
2017 - Biodiversity and sustainable tourism
2016 - Integrating biodiversity; supporting people and their livelihoods
2015 - Biodiversity for sustainable development
2014 - Biodiversity of the islands
2013 - Water and biodiversity