- Triple Science Content only in purple
- Triple Science and Higher Content Only in blue

7 Ecology and the Environment

Communities

- A **community** is made up of all the different species (plants, animals, microorganisms) that live together in a **habitat** and interact with each other.

Ecosystem:

- An **ecosystem** is the interaction between a **community** of organisms and their **environment** (both living and non-living components).
    - Ecosystems are made up of **biotic** (living) and **abiotic** (non-living) factors.

Interdependence:

- Species within a community rely on each other for things like food, shelter, pollination, and seed dispersal. This is called **interdependence**.
    - If one species is removed or its population changes significantly, it can affect the whole community.

Stable Communities:

- In a **stable community**, the population sizes and environmental factors stay relatively constant, with **small changes** that balance each other out over time (e.g., tropical rainforests).

Abiotic Factors

- **Abiotic factors** are **non-living** factors that can affect the organisms in a habitat.

Examples of Abiotic Factors:

1. **Light Intensity**:
    - Affects the rate of **photosynthesis** in plants.
    - Plants in shaded areas may be adapted to lower light conditions.
2. **Temperature**:
    - Can limit the range of species found in an ecosystem.

- Warmer temperatures may increase the speed of reactions in living organisms, leading to faster growth.

3. **Water Availability**:
    - Essential for all life. In areas with little water, plants and animals must be specially adapted to survive.
4. **Soil pH and Mineral Content**:
    - Affects plant growth. Some plants prefer acidic soil, while others thrive in alkaline conditions.
    - Lack of essential minerals (e.g., nitrates) can limit plant growth.
5. **Wind**:
    - Wind can affect the shape of trees and plants, as well as the rate of transpiration in plants.
6. **Carbon Dioxide Levels** (for plants):
    - CO_2 is needed for **photosynthesis**. A lack of CO_2 can limit plant growth.
7. **Oxygen Levels** (for aquatic organisms):
    - Dissolved oxygen in water is vital for aquatic life. Low oxygen levels can harm fish and other water organisms.

Biotic Factors

- **Biotic factors** are **living** components that can affect organisms in a habitat.

Examples of Biotic Factors:

1- Food availability: Less food → smaller populations; more food → population growth

2- Predators: Introduction of new predators can reduce prey species

3- Pathogens: Diseases can reduce population if species have no immunity

4- Competition:

- Intraspecific: same species compete for resources

- Interspecific: different species compete

Adaptations

- **Adaptations** are special features or characteristics that help an organism survive and reproduce in its environment.

Types of Adaptations:

1. **Structural Adaptations**:
    - **Physical features** of an organism's body.
    - Example: Polar bears have **thick fur** and a layer of **fat** (blubber) to insulate them from the cold.
2. **Behavioural Adaptations**:
    - **Ways an organism acts** to survive.
    - Example: Many birds migrate to warmer areas during the winter to avoid the cold and find food.
3. **Functional Adaptations**:
    - **Internal processes** of the organism that help it survive.
    - Example: Desert animals may produce **concentrated urine** to reduce water loss.

Extremophiles:

- Some organisms, called **extremophiles**, are adapted to live in **extreme conditions** such as very hot temperatures, high salinity, or high pressure (e.g., bacteria in hot springs or deep-sea vents).

General Plant Adaptations in extreme weathers:

- Water storage tissues (succulent leaves/stems)

- Reduced leaf surface area to prevent water loss

- Deep or widespread root systems to reach as much water as possible

- Protective coatings (waxy cuticle)

Organisation of an Ecosystem

Levels of Organisation

- Organisms within ecosystems are organised into different **levels** based on how they interact with each other and their environment.

1. **Individual**: A single organism.
2. **Population**: A group of individuals of the same species living in the same area.
3. **Community**: All the populations of different species living together in a habitat.
4. **Ecosystem**: A community of organisms interacting with each other and with their **abiotic** environment (non-living factors such as water, soil, and air).

Energy Transfer in an Ecosystem:

- Energy flows through ecosystems in **food chains** and **food webs**.
    - **Producers** (e.g., plants) make their own food through photosynthesis.
    - **Consumers** (e.g., herbivores and carnivores) get their energy by eating other organisms.
    - **Decomposers** break down dead organic matter and recycle nutrients back into the ecosystem.

How Materials Are Cycled

- Materials (e.g., carbon, water, nitrogen) are **constantly cycled** between the living and non-living components of ecosystems.

The Carbon Cycle:

- The **carbon cycle** ensures that carbon is continually recycled between living organisms and the atmosphere.

1. **Photosynthesis**: Plants take in **carbon dioxide (CO_2)** from the atmosphere and use it to make carbohydrates.
2. **Respiration**: Animals, plants, and decomposers return CO_2 to the atmosphere when they respire.
3. **Combustion**: Burning fossil fuels releases stored carbon back into the atmosphere as CO_2.
4. **Decomposition**: When organisms die, decomposers break them down, returning carbon to the soil and atmosphere.

The Water Cycle:

- The **water cycle** moves water between the atmosphere, land, and bodies of water.

1. **Evaporation**: Water from oceans, lakes, and rivers turns into water vapour.
2. **Condensation**: Water vapour cools and forms clouds.
3. **Precipitation**: Water falls back to Earth as rain, snow, or hail.
4. **Transpiration**: Plants release water vapour from their leaves into the atmosphere.
5. **Runoff and infiltration**: Water flows over land or seeps into the ground, eventually returning to bodies of water.

The Nitrogen Cycle:

- The **nitrogen cycle** ensures nitrogen is recycled for use by living organisms.

1. **Nitrogen fixation**: Nitrogen-fixing bacteria in the soil or root nodules convert nitrogen gas from the atmosphere into nitrogen compounds plants can use.
2. **Decomposition**: When organisms die or release waste, decomposers return nitrogen to the soil in the form of ammonium.
3. **Nitrification**: Nitrifying bacteria convert ammonium into nitrates, which plants absorb.
4. **Denitrification**: Denitrifying bacteria convert nitrates back into nitrogen gas, releasing it into the atmosphere.

Decomposition

- **Decomposers** are microorganisms (e.g., bacteria and fungi) that break down dead organisms and waste products, returning important nutrients to the soil.

Conditions that Affect Decomposition:

1. **Temperature**: Warm temperatures speed up decomposition because microorganisms work faster. Extreme temperatures can slow down or stop decomposition.
2. **Oxygen Availability**: Decomposers need oxygen to respire. Less oxygen (e.g., in waterlogged soils) slows down decomposition.
3. **Moisture Levels**: Decomposers need water to carry out their processes. Decomposition is slower in dry conditions.
4. **Presence of Decomposers**: The more decomposers present, the faster decomposition occurs.

Importance of Decomposition:

- Decomposition recycles essential nutrients, such as **carbon**, **nitrogen**, and **phosphorus**, making them available for producers (plants) to use.
- Decomposers help maintain the **balance** of an ecosystem by breaking down dead material and waste.

The Role of Decomposers:

- Decomposers release **enzymes** that break down complex materials into simpler substances.
- **Detritivores** (e.g., earthworms, maggots) feed on dead organic matter and help break it down into smaller pieces, speeding up the decomposition process.

1. Composting

- **Definition:** Composting is the process where **microorganisms (bacteria and fungi)** break down **organic waste** (like plant material, food scraps) into a **nutrient-rich soil improver called compost**.

- **Process:**
    - Organic waste is collected in a compost heap or bin.
    - Microorganisms decompose the waste, releasing energy in the form of **heat**, which helps speed up decomposition.
    - Over time, the waste turns into **humus**, which can be added to soil to improve fertility.

- **Importance:**
    - Reduces waste going to landfills.
    - Returns nutrients (like nitrogen, phosphorus) to the soil.
    - Improves soil structure and water retention.

2. Methane Gas

- **Definition:** Methane (CH_4) is a **flammable gas** produced when **organic matter decomposes in anaerobic conditions** (without oxygen).
- **Sources:**
    - Swamps, wetlands (natural)
    - Landfills (waste decomposition)
    - Anaerobic digestion in **biogas generators**
- **Significance:**
    - Methane is a **greenhouse gas** contributing to global warming if released into the atmosphere.
    - Can be **captured and used as a fuel**, providing a renewable energy source.

3. Biogas Generators

- **Definition:** A biogas generator is a system that produces **biogas (mainly methane) from organic waste** using **anaerobic digestion**.
- **How it Works:**
    - Organic waste (manure, food waste, plant material) is placed in a **sealed tank** called a digester.
    - Microorganisms break down the material **anaerobically**, producing **biogas** and a nutrient-rich **slurry**.
    - Biogas is **collected** and can be used for heating, cooking, or generating electricity.
    - The slurry can be used as a **fertiliser** for crops.
- **Advantages:**

- Produces **renewable energy**.
- Reduces **greenhouse gas emissions** by capturing methane.
- Provides **fertiliser**, reducing the need for chemical fertilisers.

Impact of Environmental Change

- Environmental changes, both natural and human-caused, can have significant effects on ecosystems and the organisms living within them.

Types of Environmental Changes:

1. **Temperature Changes**:
    - Changes in temperature can affect the **distribution** of species. Some species may migrate to more suitable areas, while others may struggle to survive.
    - Global warming is causing **climate change**, leading to shifts in ecosystems and habitats.
2. **Water Availability**:
    - Changes in rainfall patterns can lead to **droughts** or **flooding**, affecting both plants and animals.
    - Species that rely on specific water conditions may die out if those conditions change significantly.
3. **Atmospheric Gas Composition**:
    - Changes in the levels of **carbon dioxide (CO_2)** and **pollutants** like sulfur dioxide can affect ecosystems.
    - Increased CO_2 contributes to **global warming** and **ocean acidification**, while pollutants can cause **acid rain**, which damages plants and aquatic habitats.
4. **Human Activities**:
    - **Deforestation**, **pollution**, and **urbanisation** destroy habitats, reduce biodiversity, and affect ecosystems' ability to cycle materials.
    - **Overfishing** and **hunting** can deplete populations, leading to the collapse of ecosystems.

Effects of Environmental Changes:

- Changes in an ecosystem can lead to **extinction** of species that cannot adapt to the new conditions.
- **Biodiversity** may decrease as some species disappear, making ecosystems less stable and more vulnerable to future changes.

Biodiversity

- **Definition:** Biodiversity is the **variety of living organisms** in a particular area, including plants, animals, fungi, and microorganisms.

- **Importance:**

  - Helps ecosystems **remain stable**.
  - Ensures resources for **food, medicine, and raw materials**.
  - Supports **ecosystem services** like pollination, nutrient cycling, and climate regulation.

Waste Management

- **Purpose:** To **reduce the impact of human activity** on ecosystems and biodiversity.

- **Methods:**

  - **Recycling**: Reusing materials reduces habitat destruction and pollution.
  - **Composting**: Organic waste returns nutrients to the soil.
  - **Landfill management**: Proper containment prevents pollution and methane release.

3. High Biodiversity & Land Use

- **High biodiversity** usually occurs in **ecosystems with minimal human disturbance**.
- **Land use conflicts:**
  - **Agriculture, urbanisation, and industry** often destroy habitats and reduce biodiversity.
  - Monocultures (single crops) reduce **species variety**, making ecosystems less stable.

4. Peat Bogs

- **Definition:** Wetland areas with accumulated **partially decomposed plant material** (peat).

- **Environmental Importance:**
    - Store **carbon**, reducing CO_2 in the atmosphere.
    - Provide **unique habitats** for specialised species.

- **Problems with peat extraction:**

    - Releases **stored carbon**, contributing to global warming.
    - Destroys **habitats**, lowering biodiversity.

5. Deforestation

- **Definition:** Clearing forests for agriculture, timber, or urban development.

- **Problems:**
    - Loss of **habitats** → reduced biodiversity.
    - Less **CO_2 absorption** → contributes to climate change.
    - Increased **soil erosion** and reduced soil fertility.

6. Global Warming

- Caused by **increased greenhouse gases** (CO_2, methane) from human activity.

- **Effects on ecosystems:**
    - Changes species distribution.
    - Alters food webs.
    - Increases extinction risk for species that cannot adapt.
    -

Causes: **Rising** sea levels, Melting of ice caps

Maintaining Biodiversity

Positive human interactions:

- **Protected areas** (national parks, nature reserves).
- **Breeding programmes** for endangered species.
- **Reforestation** and habitat restoration.
- **Sustainable land management**, like crop rotation and agroforestry.

Negative human interactions:

- Pollution, overfishing, overhunting.
- Urbanisation and monoculture farming.
- Release of invasive species.

Reducing Negative Impacts on Ecosystems

- **Sustainable resource use:** Only take what can be naturally replenished.
- **Recycling and waste reduction** to prevent pollution.
- **Conservation projects:** Planting native species, protecting habitats.
- **Environmental legislation:** Laws to limit deforestation, pollution, and poaching.
- **Education:** Raising awareness of human impacts on biodiversity.

Trophic Levels in an Ecosystem

Trophic Levels

- **Trophic levels** represent the different stages in a **food chain**. Each level consists of organisms that share the same role in the flow of energy and nutrients.

Trophic Levels in a Food Chain:

1. **Trophic Level 1 – Producers**:
    - Producers are **plants** and **algae** that make their own food through **photosynthesis**.
    - They form the base of all food chains and provide energy for all other organisms.
2. **Trophic Level 2 – Primary Consumers**:
    - These are **herbivores** that eat the producers (e.g., rabbits, caterpillars).
    - They are the first level of **consumers**.
3. **Trophic Level 3 – Secondary Consumers**:
    - Secondary consumers are **carnivores** or **omnivores** that eat the primary consumers (e.g., foxes, frogs).
4. **Trophic Level 4 – Tertiary Consumers**:
    - These are **carnivores** that eat secondary consumers (e.g., hawks, lions).
    - Some are called **apex predators** because they are at the top of the food chain and have no natural predators.
5. **Decomposers** (Not part of a specific trophic level):
    - **Decomposers**, such as bacteria and fungi, break down dead organisms and waste, recycling nutrients back into the ecosystem.

Pyramids of Biomass and Energy Transfer

Pyramids of Biomass

- A **pyramid of biomass** shows the **total biomass** (amount of living tissue) at each trophic level in a food chain.
    - Biomass decreases as you move up the food chain because energy is **lost** at each level.

Features of a Pyramid of Biomass:

- The **base** of the pyramid represents the **producers** and is usually the **largest**, since they have the most biomass.
- Each level above the producers represents a consumer, and the biomass **decreases** at each step.

- **Biomass** refers to the **mass of living material**, measured in units such as grams per square meter (g/m^2).

Energy flow of the biomass eaten:

- Energy is transferred from one trophic level to the next, starting with **producers**.
- **Not all biomass is eaten:** Some parts (roots, bones, shells) are **not consumed**.
- **Not all energy is absorbed:** Some energy is **lost in waste** (faeces, urine).
- **Respiration:** Organisms use a lot of energy for movement, growth, and maintaining body temperature, which is **lost as heat**.

Efficiency:

- Only about **10% of energy** from one level is available to the next level.
- This is why pyramids **narrow at higher trophic levels** and there are **fewer top predators**.

Energy Transfer in Ecosystems

- **Energy** is transferred between trophic levels, but a large amount of energy is **lost** at each stage.

Energy Loss:

- Only about **10% of the energy** is transferred to the next trophic level. The rest is lost in various ways, such as:
    1. **Respiration**: Energy is used for movement, growth, and maintaining body temperature.
    2. **Excretion**: Energy is lost through waste products (e.g., faeces, urine).
    3. **Heat**: Energy is lost as heat, especially in warm-blooded animals.

Efficiency of Biomass Transfer:

- Biomass and energy transfer between trophic levels is **inefficient**. This is why food chains are generally short and ecosystems cannot support large numbers of predators at the top trophic levels.

Example:

- If 1000g of plant biomass is eaten by herbivores, only about 100g of this will be available as biomass to the carnivores that eat the herbivores.

Impact of Energy Transfer on Food Chains:

- The loss of energy at each trophic level explains why there are usually **fewer predators** than prey in ecosystems.
- The inefficiency of energy transfer also means that **apex predators** need a large number of prey organisms to survive.

Food Production

Factors Affecting Food Security

- **Food security** is about ensuring that the population has access to sufficient, safe, and nutritious food to maintain a healthy life.

Key Factors That Affect Food Security:

1. **Increasing Population**:
   - As the global population grows, the demand for food increases, putting pressure on food production systems.
2. **Changing Diets in Developed Countries**:
   - More people in developed countries are consuming **meat** and **processed foods**, which require more resources to produce than plant-based diets.
3. **Pests and Pathogens**:
   - **Pests**, such as insects, and **diseases** can reduce crop yields and livestock productivity, threatening food supplies.
4. **Environmental Changes**:
   - **Climate change** (e.g., changes in temperature and rainfall) can affect crop growth and livestock farming.
   - **Extreme weather events**, like floods or droughts, can destroy crops and reduce food production.
5. **Sustainability Issues**:
   - The overuse of land and **overfishing** can degrade natural resources, making it harder to produce food sustainably in the future.
   - The need for **sustainable farming** practices is increasing to ensure long-term food production.
6. **Cost of Agricultural Inputs**:
   - The cost of inputs like **fertilizers**, **pesticides**, and **machinery** affects food production. If costs rise, farmers may produce less food or be forced to charge higher prices.
7. **Conflicts**:
   - Wars and political instability can disrupt food production and distribution, leading to shortages in some regions.

Farming Techniques

- Farmers use different techniques to increase **food production** and **efficiency**, but these techniques must be balanced with concerns about sustainability and environmental impact.

Intensive Farming:

- **Intensive farming** increases the amount of food produced per unit of land by using:
  - **Fertilisers** to provide crops with essential nutrients (e.g., nitrogen, phosphorus).
  - **Pesticides** to kill pests that would otherwise reduce crop yields.
  - **Herbicides** to kill weeds that compete with crops for resources like sunlight and water.
  - **Controlled environments** (e.g., greenhouses, hydroponics) to maximise crop growth.

Livestock Farming:

- Animals like cows, pigs, and chickens are often kept in **factory farming** systems to maximise the amount of food produced in a shorter time.
  - Animals are kept in **small spaces** and fed on **high-protein diets** to promote faster growth.
  - This can increase food production but raises concerns about **animal welfare** and the impact on the environment, such as **greenhouse gas emissions**.

Fisheries and Sustainable Fish Stocks

- **Fish** are a valuable source of protein for many people, but **overfishing** is a major problem, leading to the decline of fish populations.

Methods to Maintain Fish Stocks:

1. **Fishing Quotas**:
   - Governments set **quotas** to limit the number of fish that can be caught. This helps prevent overfishing and ensures fish populations can recover and reproduce.
2. **Net Size Regulations**:
   - Fishing nets with larger mesh sizes are used so that younger, smaller fish can escape. This allows fish populations to **replenish**.
3. **Sustainable Aquaculture (Fish Farming)**:

    - Fish are bred and raised in controlled environments (e.g., fish farms). This reduces the pressure on wild fish populations.
    - However, fish farming can lead to pollution and the spread of disease if not properly managed.

Role of Biotechnology

- **Biotechnology** involves using living organisms or their products to improve **food production** and solve problems related to **food security**.

Examples of Biotechnology in Food Production:

1. **Genetically Modified (GM) Crops**:
    - Crops can be genetically modified to have **desirable traits**, such as:
        - Resistance to **pests** (e.g., Bt crops produce a toxin that kills insects).
        - **Drought resistance**, enabling them to grow in harsh conditions.
        - Enhanced **nutritional content** (e.g., Golden Rice, which is enriched with Vitamin A to help combat malnutrition).
2. **Mycoprotein**:
    - Mycoprotein (e.g., **Quorn**) is a high-protein meat substitute produced from **fungi** grown in **fermenters**.
    - It is a sustainable, low-fat source of protein that requires fewer resources to produce than traditional livestock.
3. **Genetically Modified Bacteria**:
    - Bacteria can be genetically engineered to produce **human insulin**, which is used to treat diabetes.
    - This is an example of biotechnology being used to produce **medicines** efficiently, but similar techniques can also be applied to improve food production.

Advantages and Disadvantages of Biotechnology

Advantages:

- **Increased yields**: GM crops can produce higher yields, helping to feed a growing population.
- **Reduced need for chemicals**: Crops genetically modified to resist pests or herbicides can reduce the need for chemical sprays, benefiting the environment.
- **Improved food quality**: Biotechnology can enhance the **nutritional value** of crops, addressing malnutrition in some parts of the world.

Disadvantages:

- **Environmental impact**: There are concerns that GM crops could cross-breed with wild plants, creating "superweeds" that are difficult to control.
- **Ethical concerns**: Some people are opposed to GM foods due to worries about potential long-term health effects and interference with natural processes.
- **Economic concerns**: Farmers may become reliant on large biotech companies for seeds, which could increase costs and reduce biodiversity in agriculture.