2 Photosynthesis, food chains and cycles

Green plants produce their own food by **photosynthesis**. All other living organisms depend either directly or indirectly on green plants for their food. This food is passed on from one living organism to the next through **food chains**.

Photosynthesis

Photosynthesis *is the process by which green plants convert carbon dioxide and water into glucose by using energy from sunlight absorbed by chlorophyll in chloroplasts.*

Oxygen is produced as a by-product. The process can be summarised by the following **word equation**:

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{by chlorophyll}]{\text{energy from sunlight absorbed}} \text{glucose} + \text{oxygen}$$

Photosynthesis occurs in any plant structure that contains **chlorophyll**, i.e. which is green; however, it mainly occurs in the **leaves**. Chlorophyll molecules in the **chloroplasts** of leaf cells absorb the energy from sunlight and use it to convert carbon dioxide, absorbed from the air, and water, absorbed from the soil, into **glucose** and oxygen.

Fate of the products of photosynthesis

The plant uses the **oxygen** and **glucose** produced during photosynthesis for various different functions.

Oxygen

The **oxygen** is used by the leaf cells in **respiration**. Excess oxygen diffuses out of the leaves into the air.

Glucose

The **glucose** can be used in a variety of ways:

- It can be used by the leaf cells in **respiration** to release energy.
- It can be converted to **starch** by the leaf cells and stored. The starch can then be converted back to glucose and used, e.g. during the night.
- It can be converted to other useful **organic substances** by leaf cells, e.g. amino acids and protein, vitamins or chlorophyll.
- It can be converted to **sucrose** and **transported** to other parts of the plant such as growing parts and storage organs, where it can be converted to:
  - **Glucose**, and used in **respiration** to release energy.
  - **Starch**, and **stored** in seeds, e.g. wheat and rice; in fruits, e.g. breadfruit; and in tubers, e.g. English (Irish) potato and sweet potato.
  - **Amino acids** and **protein**, by the addition of nitrogen from nitrates and sulfur from sulfates obtained from the soil. Protein is then used for **growth**.
  - **Lipids**, and **stored**, mainly in seeds, e.g. peanuts and soya beans.

Food chains

Energy from sunlight enters living organisms through **photosynthesis** occurring in green plants, which are also known as **producers**. This energy is incorporated into the **organic food molecules** produced by the plants and is passed on to **consumers** through **food chains**.

*A **food chain** is a diagram showing the flow of food and energy from one organism to the next.*

A food chain includes:

- A **producer**, i.e. a green plant.
- A **primary consumer** that eats the primary producer.
- A **secondary consumer** that eats the primary consumer.
- A **tertiary consumer** that eats the secondary consumer.
- Some food chains may also include a **quaternary consumer** that eats the tertiary consumer.

Consumers can also be classified according to what they consume:

- **Herbivores** consume plants or plant material only, e.g. cows, grasshoppers, snails, slugs, parrot fish, sea urchins.
- **Carnivores** consume animals or animal material only, e.g. lizards, toads, spiders, centipedes, eagles, octopuses, sharks.
- **Omnivores** consume both plants and animals, or plant and animal material, e.g. hummingbirds, crickets, humans and crayfish.

***Trophic level** refers to the position or level that an organism occupies in a food chain.*

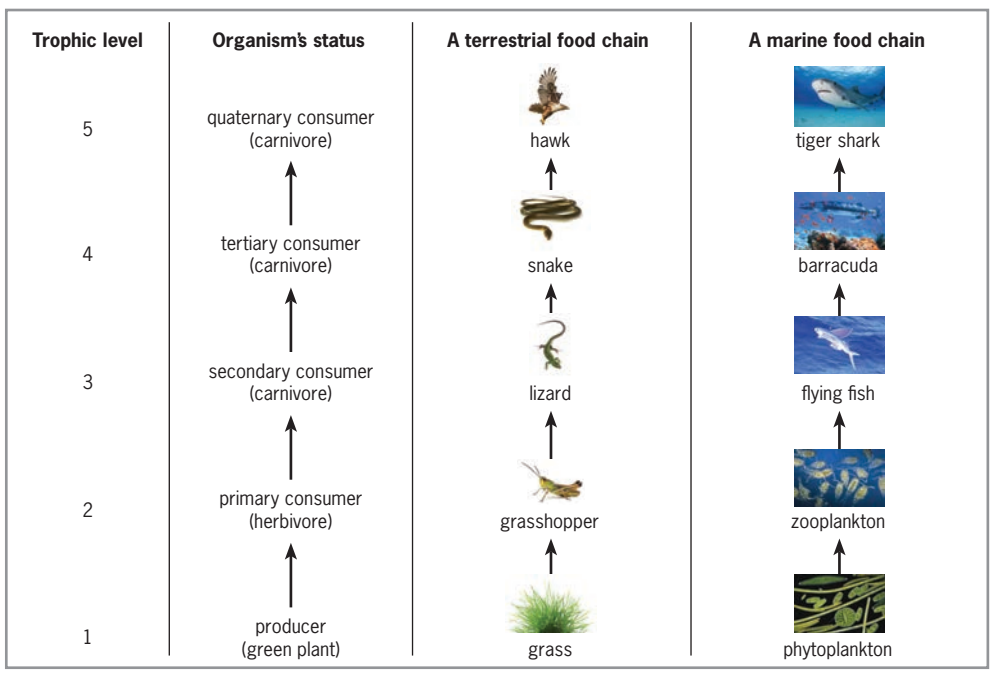

Figure 2.1 *Examples of food chains*

Food webs

Any environment usually has more than one producer and most consumers have more than one source of food. Consequently, food chains are interrelated to form **food webs**.

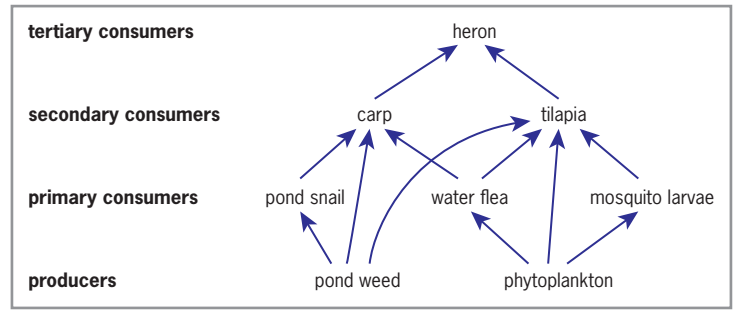

Figure 2.2 *An example of a food web from a freshwater lake*

Dependence of other living organisms on plants

All other living organisms, including **humans**, depend both directly and indirectly on plants for **food** since plants are the only living organisms capable of producing organic food molecules from simple inorganic molecules, i.e. carbon dioxide and water. When a human eats any food of **plant origin**, e.g. fruits, vegetables, cereals and nuts, he or she is depending **directly** on plants. When a human eats any food of **animal origin**, e.g. meat or fish, he or she is depending **indirectly** on plants.

Energy transfer in food chains

Not all the energy incorporated into organic food molecules made by green plants during photosynthesis is passed along a food chain, some is **used** and some is **lost** at each trophic level.

Some of the food produced by **plants** is used by the plants in **respiration**. This releases energy that the plants use in **life processes**. The rest of the food is used by the plants for **growth** or is **stored**.

When plants are eaten by herbivores, some of the organic matter that contains energy is lost in **faeces** and some is lost in organic **excretory products**, e.g. urea. Some is used in **respiration** during which the stored energy is released and used in **life processes**, or is lost as **heat**. The remaining food that contains energy is used to **build body tissues** or is **stored**, and is then passed on to the next trophic level when herbivores are consumed. This then continues at each trophic level in a food chain.

Organisms that are not consumed eventually **die**. These dead organisms and the organic matter in faeces and excretory products are **decomposed** by decomposers, which release the energy during **respiration**. **Energy**, therefore, flows from producers to consumers and decomposers in **one direction** and is not recycled. In general, only about **10%** of the energy from one trophic level is transferred to the next level.

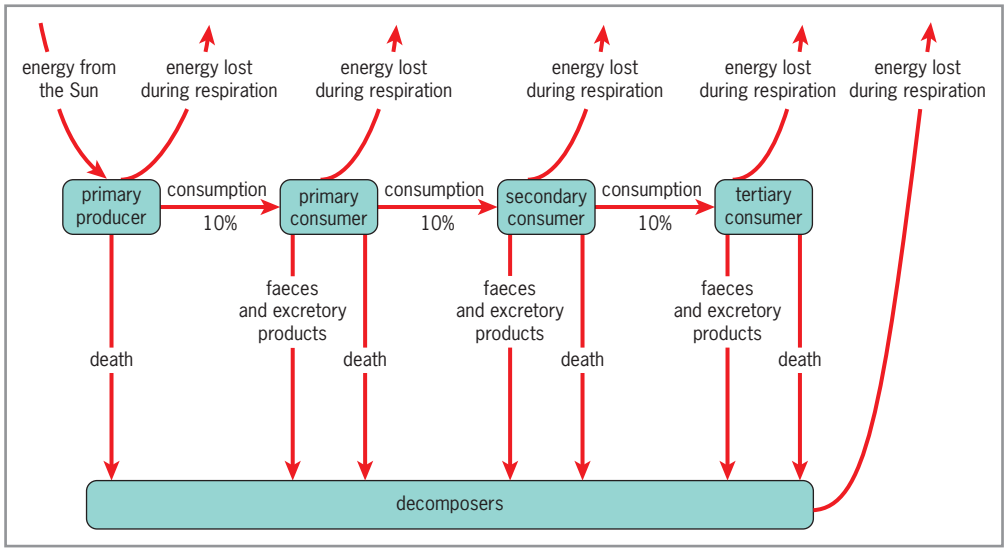

Figure 2.3 *Energy flow through a food chain*

Ecological pyramids

Because there is less energy and biomass (mass of biological matter) at each trophic level in a food chain, fewer organisms can be supported at each level. **Energy**, **biomass** and the **number of organisms** at successive levels can be represented by **ecological pyramids**. Due to the loss of energy and biomass at each level, food chains rarely exceed four or five trophic levels.

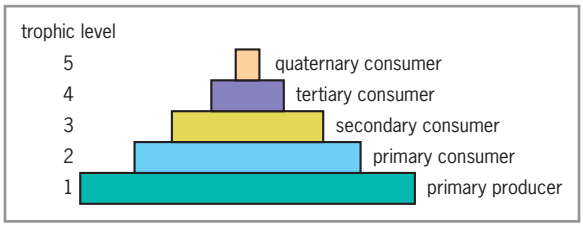

Figure 2.4 *Pyramid of energy, biomass or numbers*

Recycling of carbon and nitrogen in nature

The different **chemical elements** which make up the bodies of all living organisms, e.g. carbon and nitrogen, are continually **cycled** through these living organisms and their physical environment. Unlike the energy from the Sun, these elements are present in nature in **finite** amounts; therefore, recycling is essential to prevent them from gradually running out.

Decomposers are essential for recycling. These are microorganisms, i.e. bacteria and fungi, which feed on dead and waste organic matter causing it to **decompose**. Decomposers are also known as **saprophytes**.

The carbon cycle

The cycling of **carbon (C) atoms** occurs by them being converted into different **carbon-containing compounds**, including carbon dioxide (CO_2) present in the **air**, and various organic compounds, mainly carbohydrates, proteins and lipids, present in **living organisms**.

- **Carbon dioxide** is **removed** from the air and converted to organic compounds by green plants during **photosynthesis**.
- **Carbon dioxide** is **returned** to the air by:
  - **Respiration** occurring in all living organisms including plants, animals and decomposers.
  - **Combustion**, mainly of **fossil fuels** such as coal, oil and natural gas, though all materials containing organic compounds release carbon dioxide when burned, e.g. wood and paper.

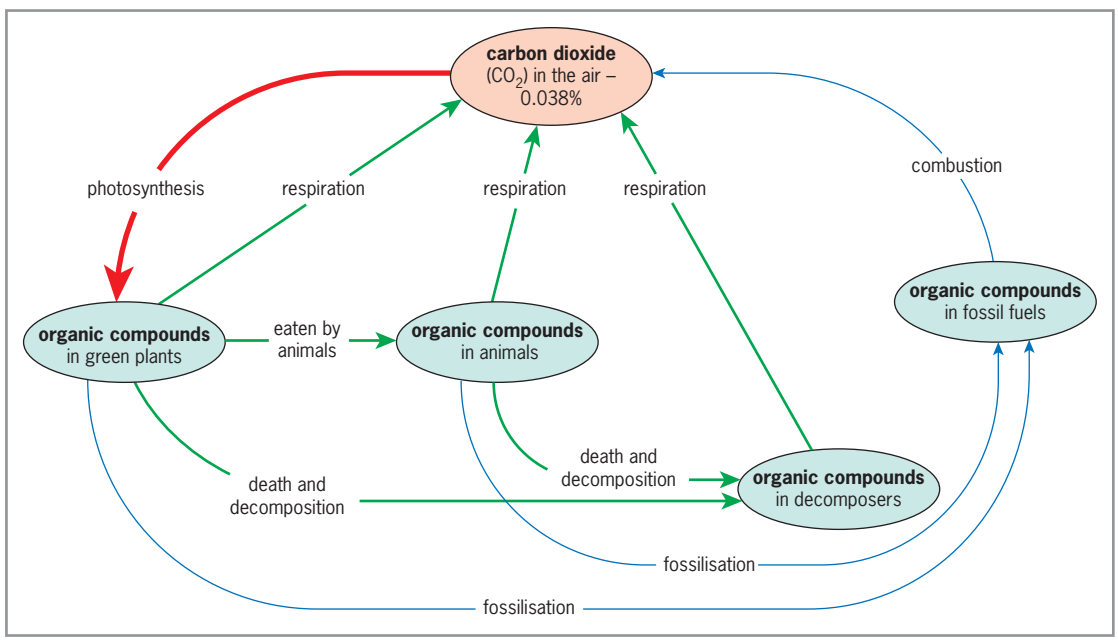

Figure 2.5 *A simplified carbon cycle*

The nitrogen cycle

Most living organisms are unable to use nitrogen (N_2) gas directly. The cycling of **nitrogen (N) atoms** occurs mainly by them being converted into different **nitrogen-containing compounds** including proteins present in living organisms, and ammonium (NH_4^+) compounds, nitrites (NO_2^-) and nitrates (NO_3^-) present in the soil.

- **Nitrogen** is **removed** from the air and converted into ammonium compounds by **nitrogen-fixing bacteria** in the soil and in the root nodules of legumes, e.g. peas and beans. The legumes use these compounds to make proteins.
- **Nitrogen** is **returned** to the air by **denitrifying bacteria** which convert nitrates in the soil to nitrogen.
- **Nitrate ions** in the soil are **removed** from the soil by **plants** and used to make protein. This protein is passed on to **animals** when the plants are eaten.
- **Nitrate ions** are **returned** to the soil by the decomposition of dead plants and animals by **decomposers (saprophytic bacteria and fungi)**. This decomposition forms ammonium compounds which are then converted into nitrites and nitrates by **nitrifying bacteria**.

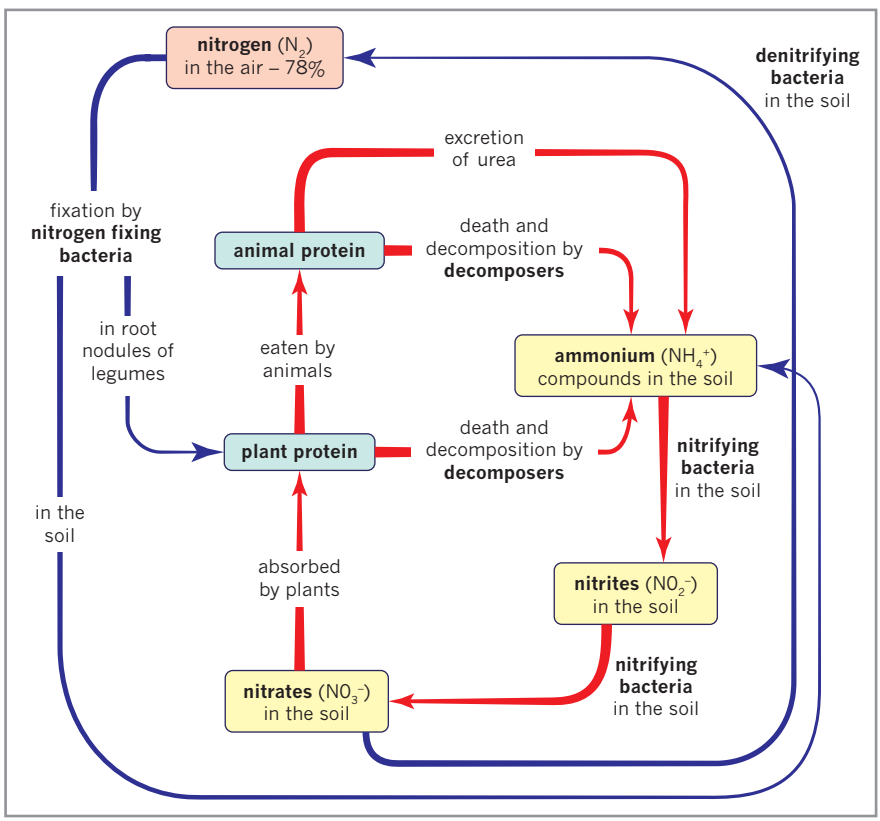

Figure 2.6 *A simplified nitrogen cycle*

Revision questions

1. Define the term 'photosynthesis' and give a word equation to summarise the process.

2. Suggest FOUR ways that the plant can make use of the glucose produced in photosynthesis.

3. **a** What is a food chain?

   b Some aphids were observed on the tomato plants in a garden and ladybird beetles were seen feeding on the aphids. The ladybirds were, in turn, being eaten by dragonflies which were, themselves, being fed on by toads. Use this information to draw a food chain for the organisms in the garden.

4. From the organisms in item **3 b** above, identify:

   a a carnivore **b** a herbivore **c** a producer

   d a primary consumer **e** a secondary consumer

5. When Jared eats a barracuda he only gets about 10% of the energy that the barracuda obtained from the flying fish it ate. Explain THREE reasons why so little energy is passed on to Jared.

6. Why is it important that elements such as carbon and nitrogen are recycled in nature?

7. Outline how carbon is recycled in nature.

8. Identify FOUR different types of bacteria responsible for recycling nitrogen in nature.

9. Explain each of the following:

   a How nitrates in the soil can be returned to the soil after being absorbed by grass growing in a field.

   b How bacteria can remove nitrogen from the air and return it to the air.