# 2.2.4 [HL]
# Nutritional Roles of Organisms and Productivity

# 2.2.4 Objectives

- Distinguish autotrophs from heterotrophs
- Distinguish photoautotrophs from chemoautotrophs
- Outline ecological productivity

# Starter

Define these terms

1. Autotrophs
2. Heterotrophs
3. Photoautotrophs
4. Chemoautotrophs

# Autotrophs VS Heterotrophs

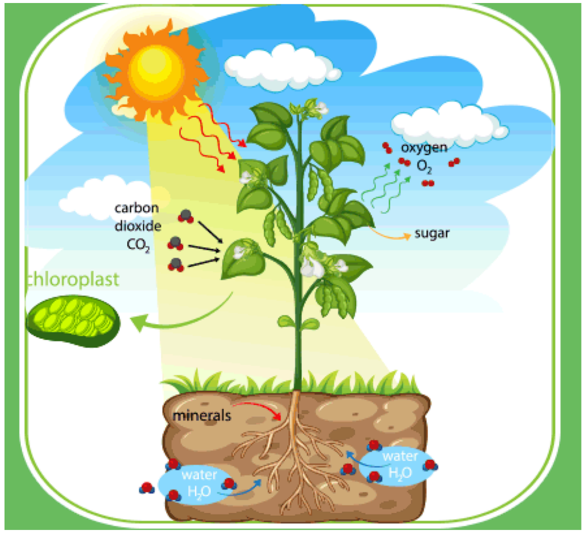
**Autotrophs**

- Producers – synthesize carbon compounds from inorganic sources of carbon and other elements.
- All autotrophs are producers, including plants, algae and photosynthetic bacteria.
- Types: Photoautotrophs and chemoautotrophs
  - Photoautotrophs acquire energy by processing sunlight with nutrients through photosynthesis.
  - Chemoautotrophs synthesize energy by converting inorganic substances through a chemical reaction called chemosynthesis. Chemoautotrophs get energy from inorganic molecules, such as sulfur or iron, by oxidizing them

**Heterotrophs**

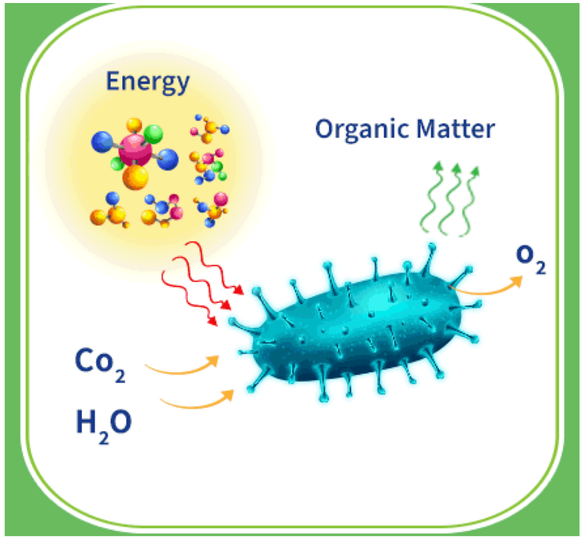
- are consumers that obtain carbon compounds from other organisms.
- All living organisms can be classified as autotrophs or heterotrophs.

# Types of autotrophs




PHOTOAUTOTROPHS

Organisms that use sunlight energy to create their own food are called photoautotrophs. All green plants are photoautotrophs but not all producers use sunlight to make food. For example, some bacteria use chemical energy rather than sunlight to make sugars




CHEMOAUTOTROPHS

Chemosynthetic bacteria are part of the nitrogen cycle. Giant tube worms (*Riftia pachyptila*) live on or near deep-sea hydrothermal vents. They have a symbiotic relationship with chemosynthetic bacteria using hydrogen sulfide and CO2 to produce sugars

# Ecological Productivity

Productivity in ecosystems

- Production of biomass per unit area per unit time
- Productivity occurs at each level of a food chain
- Depending on where productivity occurs, it is referred to as **primary** productivity or **secondary** productivity

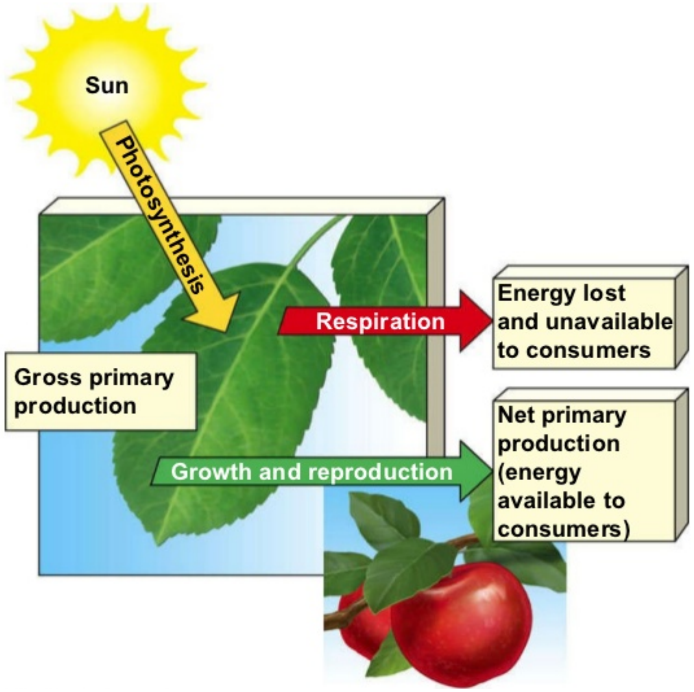
# Primary VS Secondary productivity

## Primary productivity

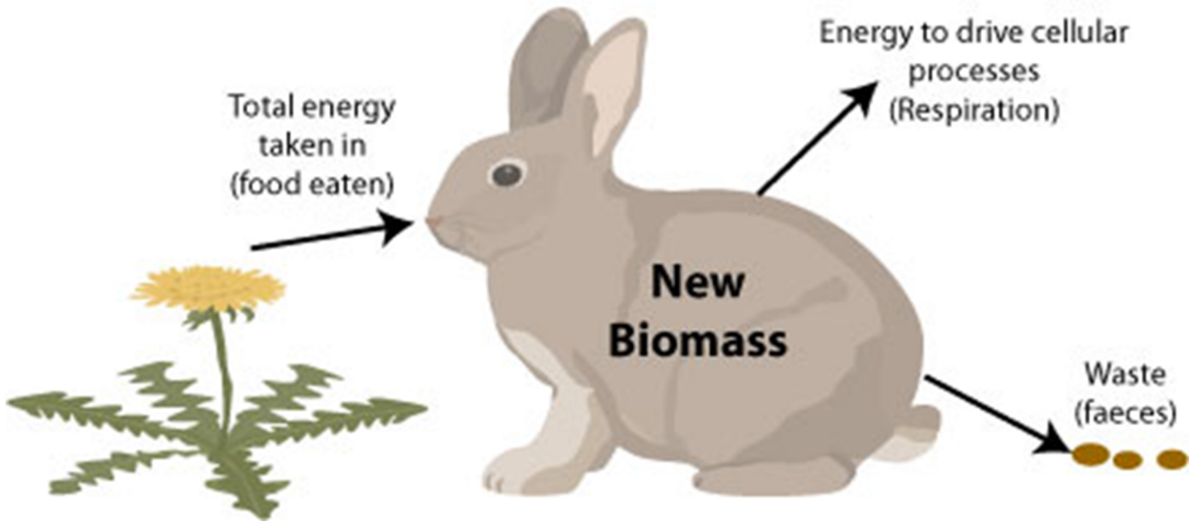
- the gain by producers (autotrophs) in energy or biomass per unit area per unit time.

## Secondary productivity

- the biomass gained by heterotrophic organisms, through feeding and absorption, measured in units of mass or energy per unit area per unit time.



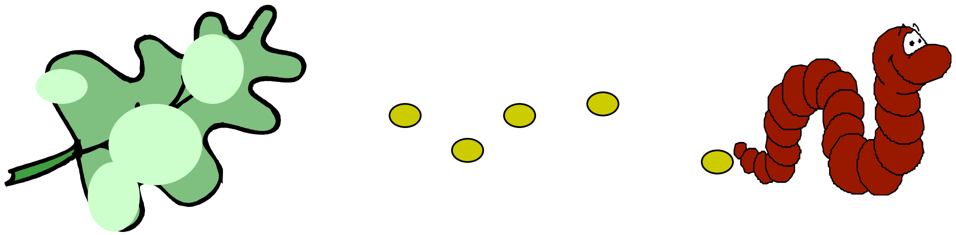

**Primary productivity**




**Secondary productivity**

# Gross productivity

- The total gain in energy or biomass per unit area per unit time.
- Unit = kg $m^{-2}$ $y^{-1}$ or KJ $m^{-2}$ $y^{-1}$
- Total energy captured or "assimilated" by an organism.
- Plant (*Gross Primary Productivity*)
    - GPP = sunlight energy used during photosynthesis
- Animals (*Gross Secondary Productivity*)
    - GSP = food eaten - energy in faeces



# Net productivity

- The gain of energy or biomass per unit area per unit time remaining after allowing for respiratory losses (R).

  = The energy left over after organisms have used what they need to survive.
- All organisms have waste energy and respiratory loss given off as heat, metabolism (R) respectively.
- Plants and animals have to use some of the energy they capture to keep themselves growing:
  - They both move water and stored chemicals around
  - Plants make flowers, fruits, new leaves, cells and stems
  - Animals create cells and need to move muscles.
- Net productivity = Gross productivity - Respiration Energy

  or using symbols: **NP = GP - R**

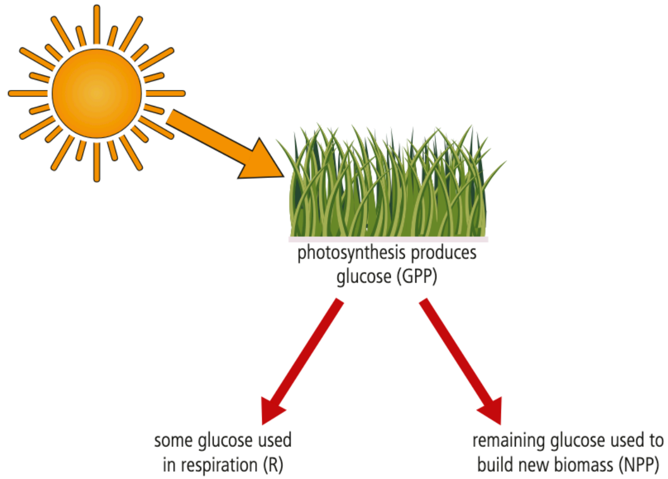
# Primary Productivity

- Gross Primary Productivity (GPP)

→ Gain in energy or biomass through photosynthesis per unit area per unit time.

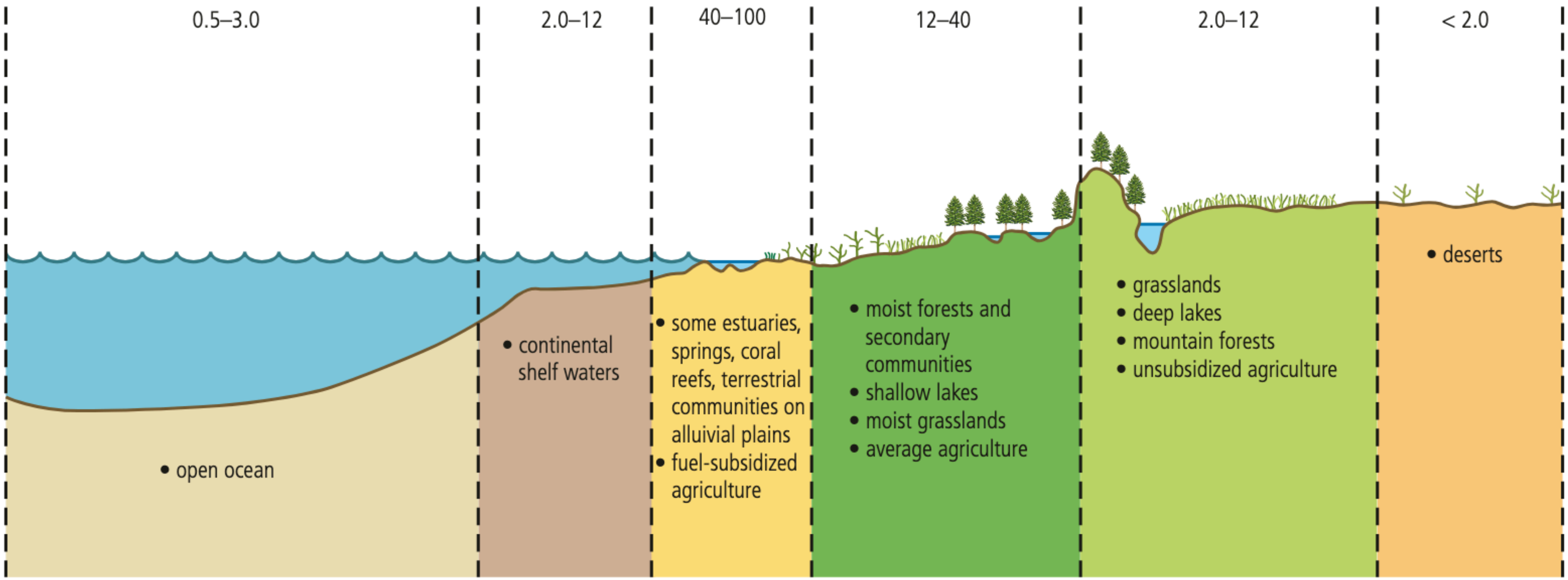
- Net Primary Productivity (NPP)

→ The gain by producers in energy or biomass per unit area per unit time remaining after respiration losses.




$$NPP = GPP - R$$

# Primary Productivity




Comparison of biomes in terms of primary production / $10^3$ kJ $m^{-2}$ $yr^{-1}$

# Calculate GPP…

*Aquatic plant placed in light conditions*

Amount of dissolved $O_2$ at the start of the experiment = 10 mg of $O_2$ per litre

Amount of dissolved $O_2$ at the end of the experiment = 12 mg of $O_2$ per litre

*Aquatic plant placed in dark conditions*

Amount of dissolved $O_2$ at the start of the experiment = 10 mg of $O_2$ per litre

Amount of dissolved $O_2$ at the end of the experiment = 7 mg of $O_2$ per litre

# Calculate GPP…

*Aquatic plant placed in light conditions*

Amount of dissolved $O_2$ at the start of the experiment = 10 mg of $O_2$ per litre

Amount of dissolved $O_2$ at the end of the experiment = 12 mg of $O_2$ per litre

Increase in dissolved $O_2$ = 2 mg of $O_2$ per litre

The increase in dissolved $O_2$ is a measure of NPP. The experiment lasted one hour and so the indirect measurement of NPP = 2 mg of $O_2$ per litre per hour (this could be used to estimate the amount of new biomass produced).

*Aquatic plant placed in dark conditions*

Amount of dissolved $O_2$ at the start of the experiment = 10 mg of $O_2$ per litre

Amount of dissolved $O_2$ at the end of the experiment = 7 mg of $O_2$ per litre

Loss of dissolved $O_2$ = 3 mg of $O_2$ per litre per hour

The loss of dissolved $O_2$ is a measure of respiratory loss (R)

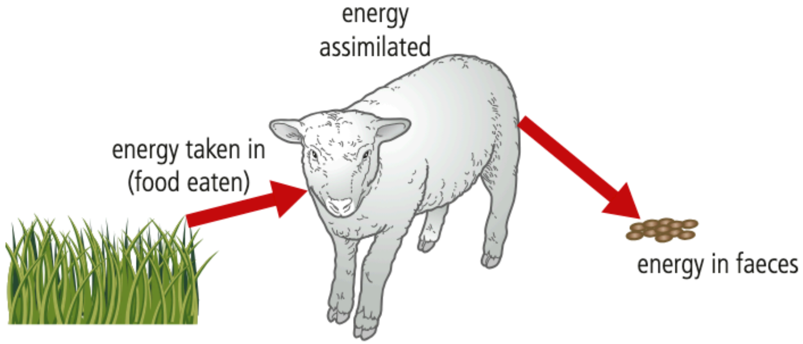
$$NPP = GPP - R, \text{ so } GPP = NPP + R$$

Therefore, indirect estimation of GPP = 2 + 3 = 5 mg of $O_2$ per litre per hour (this could be used to estimate the amount of glucose produced).

# Secondary Productivity

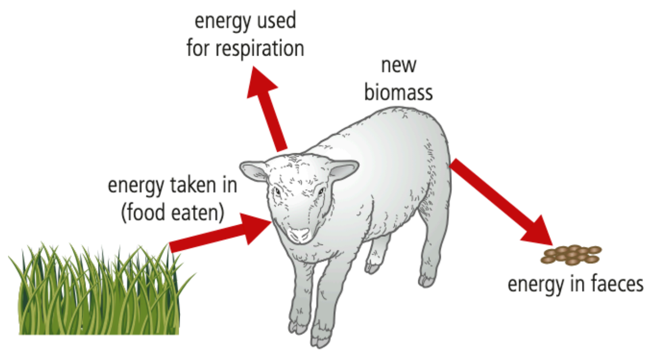
## Gross Secondary Productivity (GSP or gross assimilation)

- GSP = food eaten – faecal loss
- GSP is the total energy gained through absorption in consumers



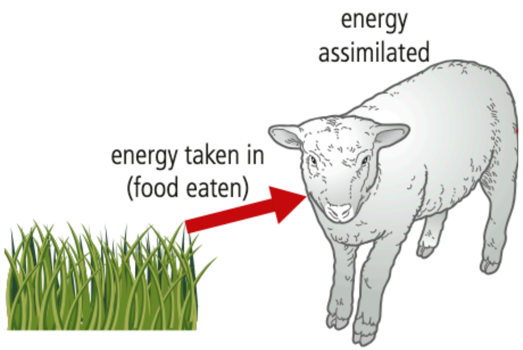

## Net Secondary Productivity (Net Assimilation)

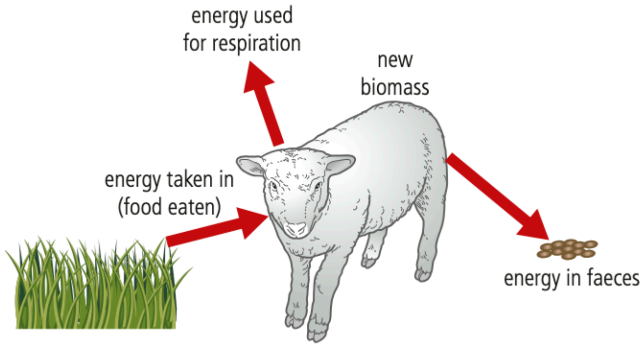
- The gain by consumers in energy or biomass per unit area per unit time remaining after respiration losses.




$$NSP = GSP - R$$

# Secondary Productivity
# Calculate the respiration, R




$$NSP = GSP - R$$

Day 1
Mass of grass = 15kg
Mass of sheep = 23 kg

Day 7
Mass of grass = 5kg
Mass of sheep = 27 kg
Mass of faeces = 0.8 kg

# Exercise

A sample including 10 stick insects was fed privet leaves for five days (Figure 2.75). The mass of the leaves, stick insects and faeces produced were measured at the start and end of the experiment. The data recorded are shown in Table 2.4.

**Figure 2.75** Stick insect on privet.

**Table 2.4** Data collected from an experiment using stick insects.

| | Start of experiment | End of experiment |
|---|---|---|
| **Mass of leaves / g** | 29.2 | 26.3 |
| **Mass of stick insects / g** | 8.9 | 9.2 |
| **Mass of faeces / g** | 0.0 | 0.5 |

# Exercise

A sample including 10 stick insects was fed privet leaves for five days (Figure 2.75). The mass of the leaves, stick insects and faeces produced were measured at the start and end of the experiment. The data recorded are shown in Table 2.4.

**Figure 2.75** Stick insect on privet.

**Table 2.4** Data collected from an experiment using stick insects.

| | Start of experiment | End of experiment |
|---|---|---|
| **Mass of leaves / g** | 29.2 | 26.3 |
| **Mass of stick insects / g** | 8.9 | 9.2 |
| **Mass of faeces / g** | 0.0 | 0.5 |

*Calculating NSP*

NSP can be calculated by measuring the increase in biomass in stick insects over a specific amount of time. The increase in the biomass of the 10 stick insects (NSP) is equal to the mass of food eaten minus biomass lost through cellular respiration and faeces.

In this experiment, NSP = mass of stick insects at end of experiment – mass of stick insects at start of experiment.

Over a five-day period: NSP = 9.2 – 8.9 = 0.3 g

Therefore, NSP = 0.3/5 = 0.06 g per day.

# Exercise

A sample including 10 stick insects was fed privet leaves for five days (Figure 2.75). The mass of the leaves, stick insects and faeces produced were measured at the start and end of the experiment. The data recorded are shown in Table 2.4.

**Figure 2.75** Stick insect on privet.

**Table 2.4** Data collected from an experiment using stick insects.

| | Start of experiment | End of experiment |
|---|---|---|
| **Mass of leaves / g** | 29.2 | 26.3 |
| **Mass of stick insects / g** | 8.9 | 9.2 |
| **Mass of faeces / g** | 0.0 | 0.5 |

*Calculating NSP*

NSP can be calculated by measuring the increase in biomass in stick insects over a specific amount of time. The increase in the biomass of the 10 stick insects (NSP) is equal to the mass of food eaten minus biomass lost through cellular respiration and faeces.

In this experiment, NSP = mass of stick insects at end of experiment – mass of stick insects at start of experiment.

Over a five-day period: NSP = 9.2 – 8.9 = 0.3 g

Therefore, NSP = 0.3/5 = 0.06 g per day.

*Calculating GSP*

GSP can be calculated using the following equation:

GSP = food eaten – faecal loss

Food eaten = mass of leaves at start of the experiment – mass of leaves at end of the experiment.

Food eaten = 29.2 – 26.3 = 2.9 g

Also, faecal loss = mass of faeces at end of experiment = 0.5 g

Therefore, over a five-day period: GSP = 2.9 – 0.5 = 2.4 g

Therefore, GSP = 2.4/5 = 0.48 g per day.

GSP represents the amount of food absorbed by the consumer.

# Exercise

A sample including 10 stick insects was fed privet leaves for five days (Figure 2.75). The mass of the leaves, stick insects and faeces produced were measured at the start and end of the experiment. The data recorded are shown in Table 2.4.

**Figure 2.75** Stick insect on privet.

**Table 2.4** Data collected from an experiment using stick insects.

| | Start of experiment | End of experiment |
|---|---|---|
| **Mass of leaves / g** | 29.2 | 26.3 |
| **Mass of stick insects / g** | 8.9 | 9.2 |
| **Mass of faeces / g** | 0.0 | 0.5 |

*Calculating NSP*

NSP can be calculated by measuring the increase in biomass in stick insects over a specific amount of time. The increase in the biomass of the 10 stick insects (NSP) is equal to the mass of food eaten minus biomass lost through cellular respiration and faeces.

In this experiment, NSP = mass of stick insects at end of experiment – mass of stick insects at start of experiment.

Over a five-day period: NSP = 9.2 – 8.9 = 0.3 g

Therefore, NSP = 0.3/5 = 0.06 g per day.

*Calculating GSP*

GSP can be calculated using the following equation:

$$GSP = \text{food eaten} - \text{faecal loss}$$

Food eaten = mass of leaves at start of the experiment – mass of leaves at end of the experiment.

Food eaten = 29.2 – 26.3 = 2.9 g

Also, faecal loss = mass of faeces at end of experiment = 0.5 g

Therefore, over a five-day period: GSP = 2.9 – 0.5 = 2.4 g

Therefore, GSP = 2.4/5 = 0.48 g per day.

GSP represents the amount of food absorbed by the consumer.

*Calculating cellular respiration*

Respiratory loss (R) (the loss of glucose as cellular respiration breaks it down) can be calculated by rearranging the equation:

$$NSP = GSP - R$$

to:

$$R = GSP - NSP$$

Therefore, R = 0.48 – 0.06 = 0.42 g per day.

# Calculation Exercise

Complete the following table

| Producer | GPP (g $m^{-2}$ $Yr^{-1}$) | R (g $m^{-2}$ $Yr^{-1}$) | NPP (g $m^{-2}$ $Yr^{-1}$) |
|---|---|---|---|
| Algae | 15 | 5 | |
| Grass | 25 | 7 | |
| Sunflower | 28 | 8 | |
| Thistle | 35 | 7 | |
| Herb | 42 | 13 | |
| Shrub | 48 | 17 | |
| Bush | 55 | 38 | |
| Hedge | 73 | 59 | |
| Apple Tree | 157 | 86 | |
| Oak Tree | 594 | 346 | |

# Calculation Exercise

| Consumer | Food Eaten | Fecal Loss | GSP ($g\ m^{-2}\ Yr^{-1}$) | R ($g\ m^{-2}\ Yr^{-1}$) | NSP ($g\ m^{-2}\ Yr^{-1}$) |
|---|---|---|---|---|---|
| Flea | | 6 | | 2 | 10 |
| Beetle | | 9 | | 5 | 12 |
| Scorpion | | 12 | | 7 | 19 |
| Hare | | 17 | | 10 | 25 |
| Lynx | | 22 | | 11 | 36 |
| Cheetah | | 48 | | 14 | 47 |
| Hyena | | 67 | | 35 | 34 |
| Lion | | 95 | | 52 | 67 |
| Tiger | | 107 | | 43 | 85 |
| Bear | | 755 | | 545 | 426 |