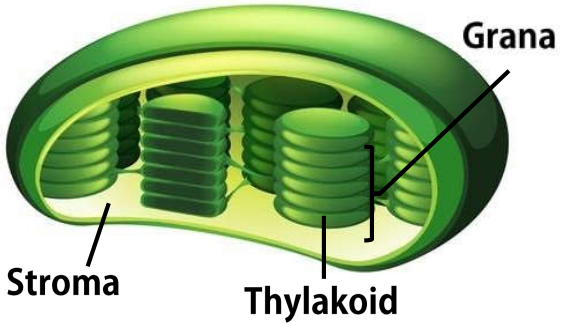
Photosynthesis

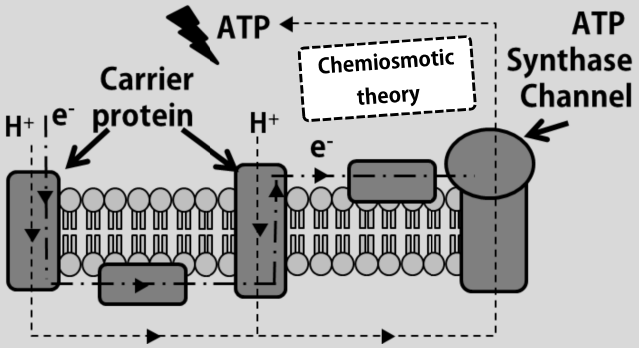
The Basics
- → Split into light-dependent and light-independent steps.
- → Oxygen produced in light-dependent step.
- → Sugars produced in series of reactions called Calvin cycle.
- → Energy is required, and is supplied by ATP from electron transport chain.



Light-dependent – 1
- → Stage of photosynthesis that relies on sunlight.
- → Light falling on the chlorophyll causes **photoionisation** of the chlorophyll molecule.
- → During photoionisation, electrons are excited and freed from the chlorophyll and passed on to a series of electron carriers.
- → Passing on of electrons causes production of ATP and reduced NADP.

Light-dependent – 2
- → Two electrons leave from each chlorophyll molecule.
- → Electrons pass along the electron transfer chain – **thylakoid membrane**.
- → **Photolysis** also takes place – splitting a water molecule into protons, electrons and oxygen.
- → The electrons replace those lost from the chlorophyll.
- → Protons and electrons are used to produce reduced NADP.

Electron transport chain
- → Electrons from chlorophyll passed along electron transfer chain, losing a small amount of energy.
- → Energy allows transport of protons from stroma across thylakoid membrane.
- → Forms concentration gradient of protons.
- → Protons diffuse down gradient, through ATP synthase, **producing ATP**.



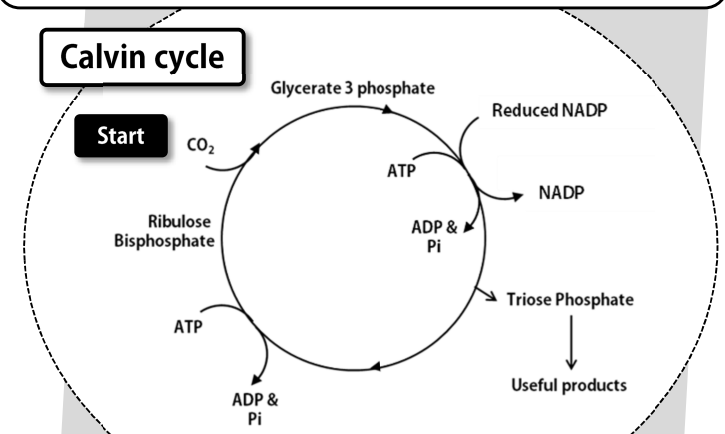
Photolysis

$2H_2O \rightarrow 4H^+ + 4e^- + O_2$

Light-independent in stroma

Series of reactions known as the Calvin cycle.
CO_2 reacts with **ribulose bisphosphate** (RuBP) forming two molecules of **glycerate 3-phosphate** (GP) – catalysed by **rubisco**.
GP gets reduced to **triose phosphate** – needs reduced NADP and ATP.
Triose phosphate used for –
- → Sucrose for transport / cellulose for storage.
- → Amino acids / triglycerides.
- → Most converted to glucose – respiration.
- → Some used to replenish RuBP.

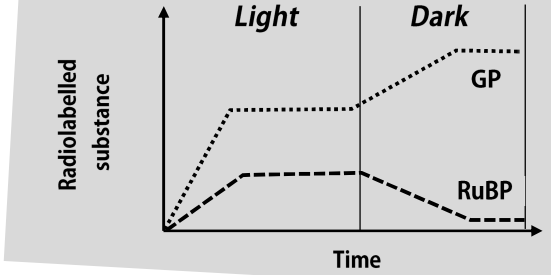
Calvin cycle



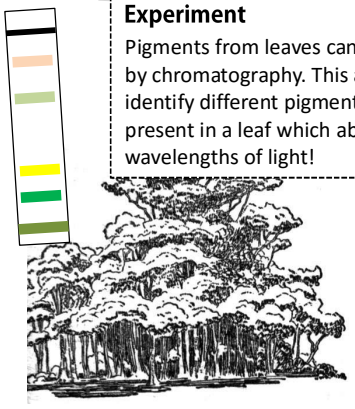
Limiting factors

Describes any factor that limits the productivity of photosynthesis.
Typically, these are:
- → light intensity, CO_2 concentration, temperature, water availability.

Can manipulate these for increased farm productivity.



Experiment
Pigments from leaves can be separated by chromatography. This allows us to identify different pigments that are present in a leaf which absorb different wavelengths of light!



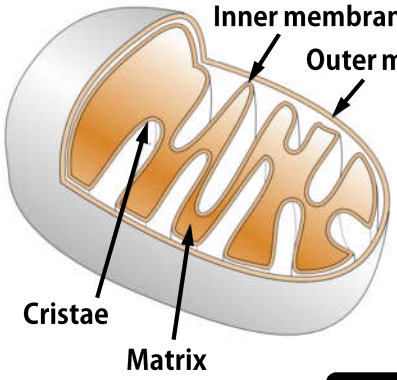
Word cloud

Chloroplast
Chlorophyll
Photoionisation
Photolysis
Ribulose bisphosphate
Glycerate 3-phosphate
Rubisco
Triose phosphate

Experiment
Can use dehydrogenase enzyme activity from isolated chloroplasts to test photosynthesis efficacy when varying numerous factors.

Respiration

The Basics
- Parts split to glycolysis, link reaction, electron transport chain and Krebs cycle.
- Glycolysis and link reaction are anaerobic.
- Electron transport chain in mitochondria requires O_2.
- Aerobic requires O_2 and forms more energy.



Word cloud

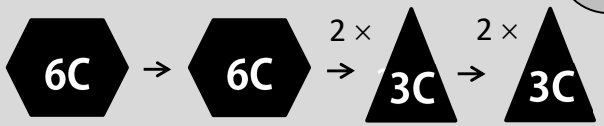
Glycolysis
Phosphorylation
Triose phosphate
Pyruvate
Acetate
Acetyl coenzyme A
ATP synthase

Glycolysis

Happens in the cytoplasm — O_2

- Start of both anaerobic and aerobic respiration.
- Converts glucose to glucose phosphate **using** ATP.
- This process is called **phosphorylation**.
- Glucose phosphate forms two molecules of **triose phosphate**.
- Triose phosphate converted to pyruvate – producing two ATP molecules each.
- Reduces NAD to **reduced NAD** in the process.

+2 ATP



Glucose → Glucose phosphate → 2× Triose phosphate → 2× Pyruvate

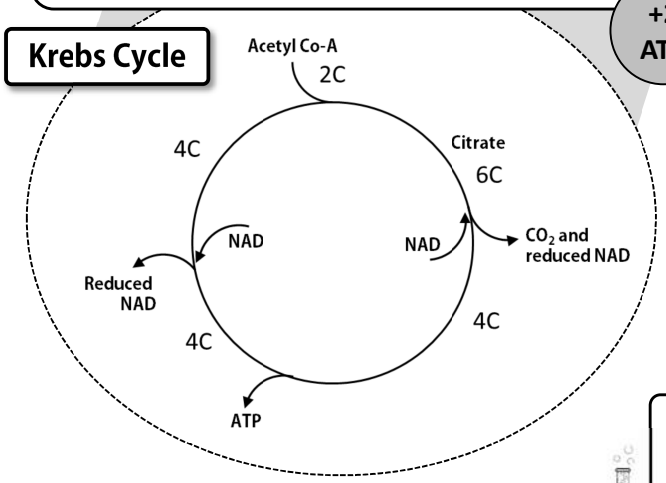
Krebs cycle

Happens in the matrix — O_2

- Takes acetyl coenzyme A from link reaction.
- Reacts with a four-carbon molecule, releasing the coenzyme.
- Six-carbon molecule formed.
- Series of oxidation-reduction reactions breaks the 6 C molecule to a 4 C.
- 2 C molecule released as CO_2.
- Series of oxidation-reduction reactions form reduced coenzymes and ATP.
- **Note**: this is not the main source of ATP!
- Krebs cycle's role is to **produce reduced coenzymes** for the electron transport chain.

+2 ATP

Krebs Cycle

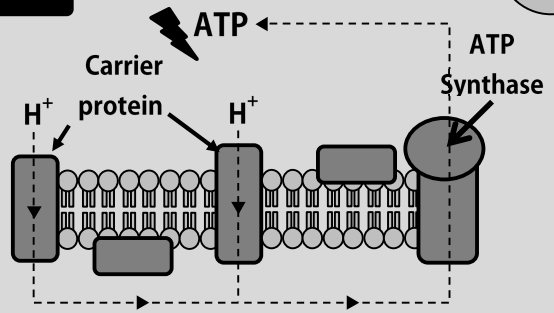


Electron transport chain

Happens on the Cristae — O_2

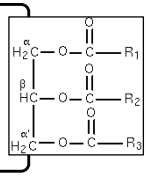
- Takes place on the **cristae** of mitochondria.
- Reduced coenzymes from the Krebs cycle **pass electrons** on to the electron transport chain.
- **Energy** from electrons used for **active transport** of protons to space between inner and outer membranes (and **heat**).
- High concentration of protons **causes diffusion** through **ATP synthase** – producing ATP.
- Oxygen combines with the protons and electrons to form water.

+32 ATP



Other substrates?

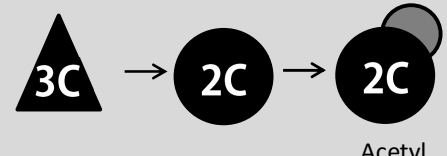
- If there is insufficient glucose, then some cells respire using lipids or proteins as a substrate.
- Think about it – if you want to lose weight, you cut out sugar, and your body burns the fats instead!



The link reaction

Happens in the matrix

- First of the aerobic reactions, linking **glycolysis** and **Krebs cycle.**
- Pyruvate enters matrix by active transport and is oxidised – forms **acetate –** producing **reduced NAD**.
- Acetate combines with coenzyme-A : **acetyl coenzyme A**.
- Two carbons from acetyl coenzyme A fed into Krebs cycle.



Pyruvate → Acetate → Acetyl Coenzyme-A

Anaerobic respiration

- Produces ATP without oxygen – only glycolysis step.
- Not as efficient – 2 ATP per glucose molecule.
- Reduced NADP cannot be oxidised without oxygen, glycolysis could stop…
- **However**, lactate (animals) or ethanol/CO_2 (plants and microorganisms) is produced, which allows reduced NADP to become NADP.
- As a result, glycolysis can continue.

Anaerobic or Aerobic?

- Conversion of pyruvate to acetate requires oxygen.
- Where oxygen is insufficient anaerobic respiration takes place.
- In animals, reduced NAD converts pyruvate to lactate.
- In plants and microorganisms, pyruvate is converted to ethanol and CO_2.

Only glycolysis takes place – only 2 ATP molecules produced!

- Reduced NAD is converted back to NAD so that glycolysis can keep happening

Experiment

Respiration rate can be measured in single celled organisms or invertebrates. Measure CO_2 or ethanol release (in aerobic respiration) following exposure to a named variable, or change in gas volume (in aerobic respiration).

Energy Transfer and Nutrient Cycles

The Basics

- Energy is passed throughout ecosystems.
- The energy is passed from autotrophs, who produce their own food, to heterotrophs, who consume the autotrophs.
- Trophic levels are levels at which organisms feed.
- Vital elements are cycled through ecosystems.
- Balancing ions is very important – fertilisers are often used.

GPP, NPP and R

- Gross primary production (GPP) is the amount of energy stored in plant biomass at a certain time and place.
- Net primary production (NPP) is the amount of energy that remains in a certain area at a certain time after respiratory losses (R):

NPP = GPP – R

So what? *NPP is important!*

This is the amount of energy available for the plant to reproduce and grow. It is also available to the next trophic level as nutrition!

Microorganisms in nutrient cycles

- Nutrient cycles are vital parts of ecosystems.
- Microorganisms are vital in cycling elements through the biosphere.
- **Saprobionts** are decomposers that digest decaying matter externally, and absorb the product.
- **Fungi** are saprobiotic organisms.
- By digesting externally, some of the chemicals are released to the environment.
- **Mycorrhizae** are a form of fungus that grow in and around plants.
- They extend into the soil, increasing the surface area of the plant roots for increased ion and water absorption.

The bottom of the food chain!

- Autotrophs synthesise organic compounds.
- Can be chemoautotrophs or photoautotrophs, these use chemical reactions / sunlight as a source of energy.
- Carbon dioxide from either the atmosphere or the seas is fixed to produce organic compounds.
- Plants use the products both as respiratory substrate and in building macromolecules.

Net production in consumers

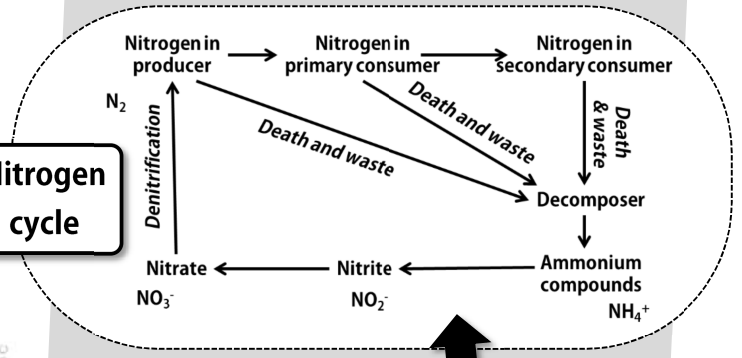
This is the amount of energy stored in consumers.
It takes into account losses by excretion and losses by respiration.

$$N = I - (F + R)$$

N is the net production, I is the total or ingested food, F is loss by faeces and urine and R is loss by respiration.

- Humans manipulate this by restricting animal movement and providing feed that is easily digestible so that more energy is converted to animal mass.

Nitrogen cycle



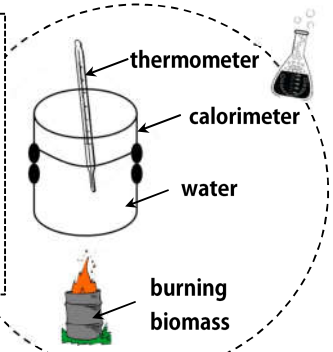
Biomass

- Biomass describes the total quantity, or mass, of all biological material in an area.
- The biomass of plants is made up of organic molecules and can be measured by drying the plants and weighing them.
- Can measure biomass in:
  Mass of carbon per unit area per unit time.
  Clearly biomass varies throughout the year!

Calorimetry experiment

Energy store can be measured with a calorimeter.

- A calorimeter burns biomass, and measures the change in energy transferred to water.
- Dry plant matter is weighed and burned in a chamber, surrounded by a water bath. The heat causes a change in the temperature of the water.
- Raising the temperature of 1 g of water by 1 °C equates to one calorie of energy.



Bacterial functions

Many bacteria play roles in the nitrogen cycle:

- Nitrificating bacteria convert ammonia and nitrite to nitrate.
- Denitrificating bacteria convert nitrates to nitrogen gas.
- Nitrogen fixers change nitrogen gas from the air into useable organic forms.
- Ammonificators decompose amino acids to ammonia.
- Ammonia reacts in the soil to become ammonium ions.

Fertilisers and their issues!

- Intensive farming causes losses of nutrients from the soil.
- **Fertilisers** reintroduce the ions and may be natural or artificial.
- Fertilisers can be washed into nearby water supplies. – this is **leaching**

Fertilisers in aquatic ecosystems:

- cause algae and pondweeds to grow quickly.

Fertilisers in aquatic ecosystems cause **eutrophication**.

- Considerable loss of oxygen from the habitat.
- Kills aquatic wildlife.

Word cloud

Producer, Consumer, Autotroph, Biomass, NPP, GPP, Net production, Net production, Saprobiont, Mycorrhizae, Nitrification, Denitrification, Eutrophication, Leaching

Phosphorus cycle