Chloroplasts are the site of photosynthesis in green plants. This is the process by which carbon dioxide and water are converted into organic chemicals using light as a source of energy. Oxygen is produced as a very useful by-product of the reaction.

This Factsheet explains how the structure of a chloroplast is designed to enable it to carry out its functions effectively and reviews recent exam questions on this topic.

Exam Hint: – You may be asked to identify the different structures in a chloroplast so make sure you learn the diagram.

Chloroplasts are organelles bounded by a double membrane – this separates the contents of the chloroplast from the rest of the cell, allowing the photosynthetic reactions to take place without interference from chemicals in the cytoplasm.

Extract from Chief Examiner’s report
Many candidates appear to believe that chlorophyll and chloroplasts are tissues.

Plate-like membranes, called lamellae (thylakoids) run along the length of the chloroplast from end to end – these are the site of the light-dependent reactions.

Chlorophyll molecules (and other pigment molecules) that absorb light energy are situated on the lamellae. At intervals, extra lamellae are inserted to form structures called grana (singular: granum). A chloroplast contains approximately 3000 lamellae - they increase the surface area available for the attachment of extra pigment molecules to trap more light energy. The pigment molecules are arranged in such a way that they do not shade each other so that the maximum amount of light energy can be absorbed.

The lamellae:
- Provide a large surface area for the attachment of the enzymes and co-enzymes involved in the electron transfer chain of the light dependent reactions.
- Partition the stroma so that different chemical reactions can take place without interfering with each other.

Exam Hint:– Whenever a structure or cell possesses extra membranes it increases the surface area available, in this case for the attachment of extra pigment molecules, but in other cells it can increase the rate of absorption (e.g. microvilli of kidney tubule cells, cristae in mitochondria for attachment of extra stalked particles).

The biconvex shape of the chloroplast is yet another way of increasing surface area to maximise absorption of light energy.

Sometimes in the exam you will be presented with an electron micrograph of a chloroplast. Usually, the first question simply asks you to label it.

Typical Exam Question
Label parts A B & C

Answer
A - stroma;
B - granum / grana / thylakoids;
C - starch (grain);

Pigment molecules absorb light energy which ultimately becomes converted to chemical energy incorporated into the glucose and other compounds produced as a result of photosynthesis. Chlorophyll a and chlorophyll b absorb only certain wavelengths of light and therefore only a certain amount of the energy falling on the chloroplast. Xanthophyll, carotene and phaeophytin are accessory pigments that absorb light of other wavelengths, ensuring more energy is trapped by the chloroplast.

The pigment molecules form clusters called photosystems. Each photosystem consists of a central chlorophyll molecule called the primary pigment molecule. Located around this are several hundred accessory pigment molecules – light energy absorbed by all these molecules is transferred to the central primary pigment molecule.
Isolating chloroplasts

**Typical Exam Question**
Starting with some lettuce leaves, describe how you would obtain a sample of undamaged chloroplasts. Use your knowledge of cell fractionation and ultracentrifugation to answer this question.

**Markscheme**
1. Chop up (accept any reference to crude breaking up);
2. Cold;
3. Buffer solution;
4. Isotonic / same water potential;
5. Filter and centrifuge filtrate;
6. Centrifuge supernatant;
7. At higher speed;
8. Chloroplasts in (second) pellet;

The lamellae are embedded in a watery matrix called the **stroma**. The stroma contains numerous starch grains, lipid droplets, enzymes, dissolved salts, ribosomes and a circular strand of DNA. It is in the stroma that the light-independent reactions take place.

The **DNA** enables chloroplasts to replicate themselves when the cell divides, ensuring new cells receive the correct number of chloroplasts.

Ribosomes produce proteins for use by the chloroplasts, particularly the enzymes required for the photosynthetic reactions. The ribosomes occur in the stroma, attached to the lamellae, or in groups called polyribosomes.

**Exam Hint:** a synoptic question may ask you about the structure of a chloroplast and then go on to the chemical reactions involved, so make sure you understand the light-dependent and light-independent reactions.

The light-dependent reactions produce ATP and NADPH which are required for the subsequent synthesis of carbohydrates in the light-independent reactions.

**Summary**
Chloroplasts are highly specialised cell organelles, their structure reflecting their function.

Make sure you understand how the following structures are designed to enable photosynthesis to be carried out as efficiently as possible:
- double membrane
- lamellae
- pigment molecules
- stroma
- DNA
- ribosomes

Some Chief Examiners like to set questions using unfamiliar diagrams. This doesn’t make the questions any harder – you just need to keep calm and work them out.

In green plants most of the chloroplasts are found in the leaf mesophyll, mainly in the palisade cells. These are located near the top of the leaf where most light falls.

**Exam Hint:** – a synoptic question may ask you about the structure of a chloroplast and then go on to the chemical reactions involved, so make sure you understand the light-dependent and light-independent reactions.

The light-dependent reactions produce ATP and NADPH which are required for the subsequent synthesis of carbohydrates in the light-independent reactions.

**Summary**
Chloroplasts are highly specialised cell organelles, their structure reflecting their function.

Make sure you understand how the following structures are designed to enable photosynthesis to be carried out as efficiently as possible:
- double membrane
- lamellae
- pigment molecules
- stroma
- DNA
- ribosomes

Some Chief Examiners like to set questions using unfamiliar diagrams. This doesn’t make the questions any harder – you just need to keep calm and work them out.

In green plants most of the chloroplasts are found in the leaf mesophyll, mainly in the palisade cells. These are located near the top of the leaf where most light falls.

**Exam Hint:** – a synoptic question may ask you about the structure of a chloroplast and then go on to the chemical reactions involved, so make sure you understand the light-dependent and light-independent reactions.

The light-dependent reactions produce ATP and NADPH which are required for the subsequent synthesis of carbohydrates in the light-independent reactions.

**Summary**
Chloroplasts are highly specialised cell organelles, their structure reflecting their function.

Make sure you understand how the following structures are designed to enable photosynthesis to be carried out as efficiently as possible:
- double membrane
- lamellae
- pigment molecules
- stroma
- DNA
- ribosomes

Some Chief Examiners like to set questions using unfamiliar diagrams. This doesn’t make the questions any harder – you just need to keep calm and work them out.
Untypical (but real) Exam Question
The light-dependent stage of photosynthesis takes place on thylakoid membranes in chloroplasts. These membranes are arranged into stacks known as grana. The diagram shows the arrangement of photosystems in the thylakoid membrane, and summarises the processes that take place there.

(a) What pigment is represented by P680 and P700? (1)
(b) Name the type of molecule represented by B. (1)
(c) Name the process in which water molecules are split. (1)
(d) What is the advantage of having membranes stacked into grana? (2)

Markscheme
(a) chlorophyll
(b) electron carrier / cytochrome / protein / electron acceptor / ferredoxin / plastoquinone;
(c) photolysis
(d) increases surface area; for absorption of light;

So even though the diagram looked horrific, the questions were actually very straightforward.

Position of chloroplasts in leaf tissue
The arrangement of chloroplast-containing cells and tissue within leaves also increases the efficiency of light capture.

Typical Exam Question
Explain how the palisade mesophyl cells within a leaf are well adapted for photosynthesis closely packed to absorb more of incident light; columnar shape / arranged at right angles to surface of leaf, to reduce number of light absorbing cross walls; large vacuole pushes chloroplasts to edge of cell; chloroplasts on periphery of cell, short (diffusion) path for carbon dioxide; chloroplasts on periphery of cell to absorb light; large number of chloroplasts / much chlorophyll, to absorb light; chloroplasts can move within cells to absorb as much light as possible; chloroplasts can move to prevent damage (in high light intensity); cylindrical cells resulting in air spaces; air spaces (between cells) to allow circulation of gases; large surface area for, gas exchange/diffusion; cell walls are thin, so short diffusion pathway/(greater) light penetration; air spaces act as reservoir of carbon dioxide; AVP; e.g. non pigmented vacuole to allow light penetration

Synoptic Questions
These questions require you to pull together your knowledge of different parts of the specification – to do some joined – up Biology thinking.

Typical Synoptic Question
Chloroplasts contain both polypeptides and ribosomes. An investigation was carried out to determine whether any of these polypeptides were synthesised by chloroplast ribosomes. An extract of isolated chloroplasts was obtained. The number of different, newly synthesised polypeptides produced in this extract was measured after incubating in the light and in the dark.

(a) Explain why isotonic saline solution was used to wash the isolated chloroplasts (2 marks)
(b) Radioactive amino acids were added to the extract. Explain why the use of radioactive amino acids would enable the investigators to find and identify the polypeptides which had been newly synthesised. (2 marks)
(c) It was found that more polypeptides were synthesised in the light than in the dark. Suggest an explanation for this. (2 marks)

Markscheme
(a) prevent excess water entering or leaving the chloroplasts / same water potential;
(b) amino acids would be used to synthesise polypeptides;
(c) ATP from photophosphorylation / photosynthesis / light dependent reaction needed;

Exam Hint: Questions about chloroplasts nearly always link them to other aspects of photosynthesis, so make sure you revise the light-dependent and light-independent reactions, action and absorption spectra and factors that affect the rate of photosynthesis. Data interpretation questions involving photosynthesis experiments and limiting factors are also common.
Practice questions

1. The diagram shows how some organelles may be distinguished from each other.

- Organelle A is found in prokaryotic and eukaryotic cells. It is the chloroplast.
- Organelle B is found only in eukaryotic cells.
- Organelle C is found in animal cells and in plant cells. It does not contain membranes arranged in stacks.
- Organelle D is found in plant cells. It contains inner membranes arranged in stacks.

Which organelle is the chloroplast? (1)

2. The diagram below shows the structure of a chloroplast, as seen using the electron microscope.

- **A** = accept
- **VP** = acceptable valid points

(a) Name the parts labelled A, B and C. (3)

(b) Give the letter of the structure where

(i) the light-dependent reactions of photosynthesis take place (1)

(ii) the light-independent reactions take place (1)

(c) Describe three ways in which structure C is adapted for photosynthesis (3)

3. Explain how chloroplasts carry out photosynthesis. (10 marks)

4. Many biologists believe that both chloroplasts and mitochondria evolved from prokaryotic organisms that inhabited the cytoplasm of eukaryotic host cells.

Suggest two structural features of mitochondria and chloroplasts that are also present in prokaryotic cells (2)