

Plant responses

Revision notes · Phytochrome, auxin (IAA) and gibberellins bring about plant responses by changing transcription; core practical 18 tests amylase in grains.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

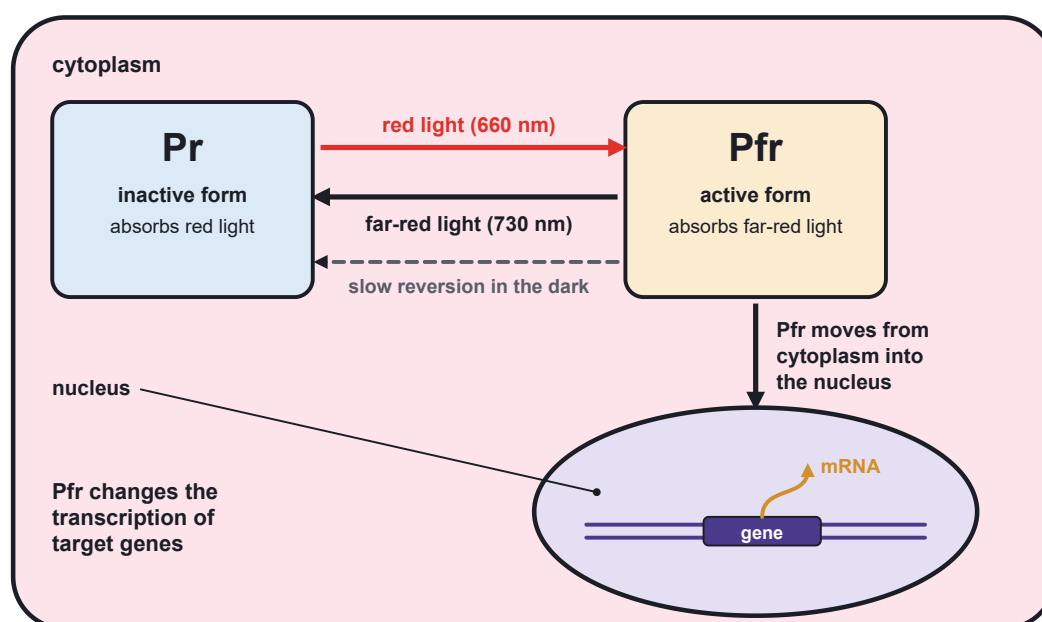
Plant responses Spec 8.11, 8.12 A Level only

Phytochrome Spec 8.11

Phytochrome is a pigment protein that allows plants to detect the amount and quality of light, and the length of day and night. It exists in two interconvertible forms:

The two forms of phytochrome			
Form	Absorbs	Converted to	Activity
Pr	Red light (wavelength about 660 nm)	Pfr	Inactive
Pfr	Far-red light (wavelength about 730 nm)	Pr (also slowly in the dark)	Active

In sunlight there is more red than far-red light, so most phytochrome is in the active Pfr form. Under the shade of leaves, which absorb red light, far-red light dominates and Pfr is converted to Pr.



The **phytochrome** cycle between inactive Pr and active Pfr.

Effect on transcription: active Pfr moves from the cytoplasm into the nucleus. There it interacts with **transcription factors**, proteins that control whether RNA polymerase can transcribe particular genes. This switches some genes on and others off, so the plant makes different proteins and the response changes.

- **Germination**: in light-requiring seeds, red light and Pfr stimulate germination; far-red light inhibits it, so seeds buried too deep or in shade stay dormant.
- **Stem elongation**: in shade, low Pfr lets stems elongate rapidly towards the light; in light, Pfr inhibits elongation, giving short, sturdy shoots with expanded leaves.
- **Flowering**: short-day plants flower only when the night is longer than a critical length, and long-day plants only when it is shorter. A flash of red light in the night prevents flowering in a short-day plant, but a following flash of far-red light cancels the effect.

Exam tip: Do not say that Pfr is 'made by' far-red light. Red light converts Pr to Pfr. Link Pfr to transcription factors and gene expression to gain the mark for 'effect on transcription'.

Auxin (IAA) Spec 8.11

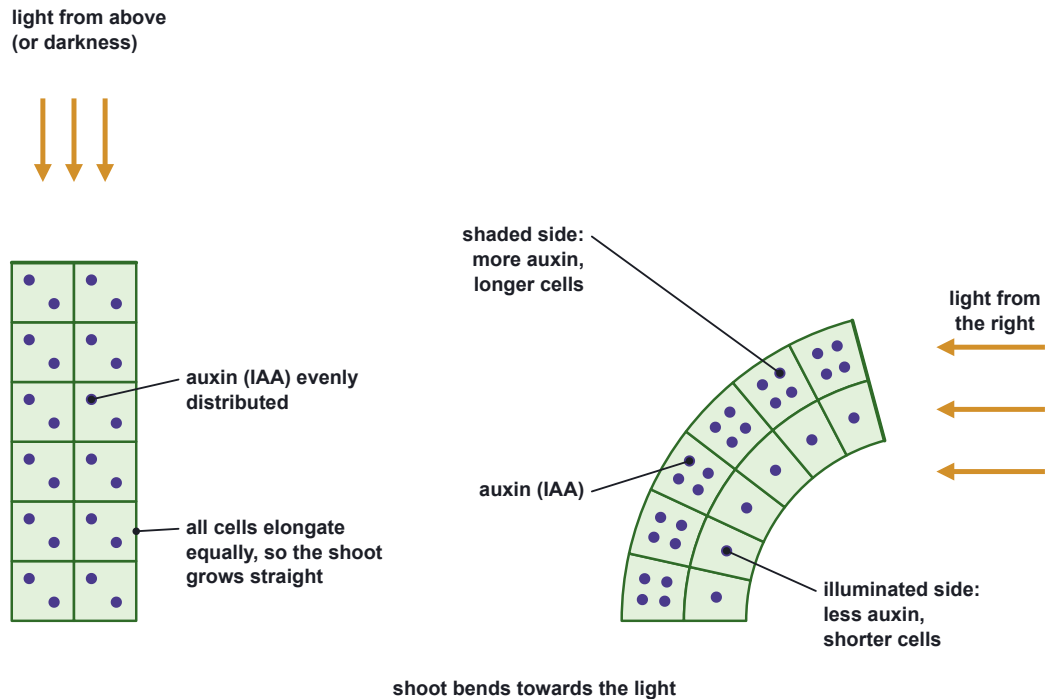
Auxin (IAA, indoleacetic acid) is made in the tip of the shoot and moves to the regions where cells are elongating. It acts on target cells by binding to receptors, which is how it affects **transcription** of genes.

Effect on cell elongation

1. Auxin binds to a receptor in a target cell. This leads to the breakdown of proteins that normally repress genes, so transcription factors are free to switch on genes for elongation.
2. Auxin stimulates the activity of proton pumps (ATPase), which move H^+ from the cytoplasm into the cell wall. The pH of the wall falls (becomes more acidic).
3. The acid conditions activate wall proteins called expansins, which loosen the hydrogen bonds linking cellulose microfibrils to other wall polysaccharides, making the wall more extensible.
4. Water enters the cell by osmosis and turgor pressure pushes the loosened wall outwards, so the cell elongates.

Phototropism and gravitropism

In **phototropism**, light causes auxin to be moved sideways to the shaded side of the shoot by carrier proteins. More auxin on the shaded side means those cells elongate more, so the shoot bends towards the light. In shoots **gravitropism** is negative: auxin accumulates on the lower side so the shoot bends upwards. In roots, the higher concentration of auxin on the lower side inhibits elongation, so the upper side grows faster and the root bends downwards (positive gravitropism).



Phototropism: more auxin on the shaded side, so those cells elongate more and the shoot bends towards the light.

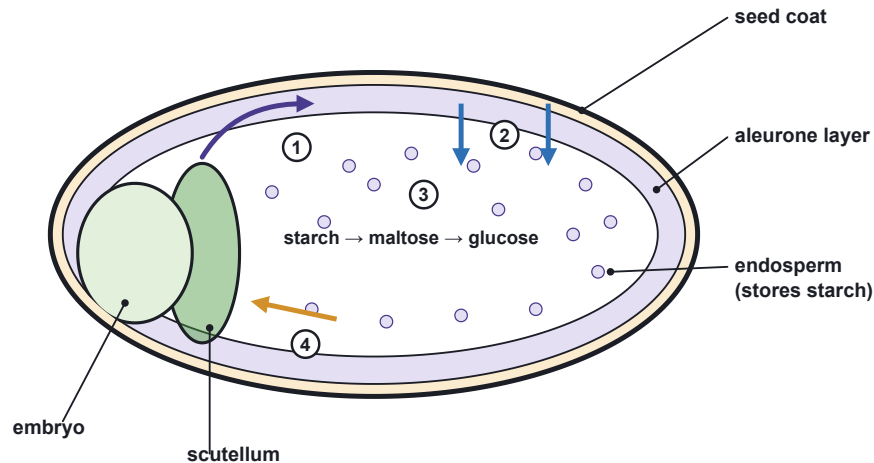
Common mistake: Light does not destroy auxin on the lit side. The auxin is redistributed to the shaded side, and cells there elongate faster.

Gibberellins Spec 8.11

Gibberellins are plant growth substances made in young leaves, shoot tips and embryos. They stimulate **stem elongation**, partly by promoting cell elongation and cell division, and trigger **germination** of seeds. Dwarf varieties of plants often make little gibberellin.

Germination of a cereal grain (such as barley)

1. The seed absorbs water and the embryo releases gibberellin.
2. Gibberellin diffuses to the **aleurone layer**, the outer layer of the endosperm, and binds to a receptor.
3. This causes breakdown of a repressor protein that normally stops transcription factors working, so the transcription factors can bind to the **amylase gene** and switch it on. Gibberellin therefore acts at the level of **transcription**.
4. The gene is transcribed and translated, so **amylase** is made and secreted into the endosperm.
5. Amylase hydrolyses starch in the endosperm to maltose, which is converted to glucose.
6. Glucose is transported to the embryo and used in respiration, releasing ATP for growth, and as a source of carbon for cellulose.



- ① the embryo releases gibberellin (GA), which diffuses to the aleurone layer
- ② GA switches on the gene for amylase in the aleurone cells; amylase is secreted into the endosperm
- ③ amylase hydrolyses starch to maltose, which is broken down to glucose
- ④ sugars move to the embryo (through the scutellum) for respiration and growth

Gibberellin from the embryo switches on amylase production in the aleurone layer.

Exam tip: A full answer links hormone, target cell, gene and enzyme: gibberellin, aleurone layer, transcription of the amylase gene, starch digestion.

Core practical 18: amylase in germinating cereal grains Spec 8.12

Core practical: Core practical 18: investigate the production of amylase in germinating cereal grains. Your teacher may use a variant of the method below, so check which apparatus and treatments you used.

The aim is to show that the germinating grain produces **amylase**, and that the embryo (through gibberellin) is needed to switch on its production.

1. Prepare agar plates containing starch, using sterile technique.
2. Surface-sterilise germinating barley grains (for example by soaking them briefly in dilute bleach and rinsing in sterile water), because bacteria and fungi on the grains also make amylase.
3. Cut the grains in half across the middle with a scalpel on a tile. One half contains the embryo, the other does not.
4. Place halves cut side down on the agar. For example: embryo halves; embryo-free halves; embryo-free halves with gibberellin solution; boiled embryo halves as a control.
5. Incubate at a constant temperature (for example 25 °C) for 24 to 48 hours.
6. Remove the grain halves and flood the plates with iodine in potassium iodide solution for a minute, then pour the excess off.
7. Starch turns blue-black. A **clear zone** where starch has been digested by amylase appears around each half. Measure the diameter of each clear zone.

Variables and controls	
Type	Detail
Independent variable	Treatment of the grain half (embryo present or absent, gibberellin added or not)
Dependent variable	Diameter, or area, of the clear zone / mm or mm ²
Controlled variables	Age, mass and type of grain; concentration and volume of starch agar; temperature; incubation time; volume and concentration of gibberellin and iodine
Controls	Boiled embryo halves (enzyme and gibberellin denatured) and agar with no grain, showing that the clear zone is caused by living tissue producing amylase
Safety	Scalpel: cut away from the body on a tile. Iodine solution stains and irritates: wear eye protection and wash spills. Sterile technique: tape the lids during incubation, open plates only briefly to remove the grains and add iodine, dispose of plates safely (for example by autoclaving) and wash hands.

To process results, measure the diameter of each clear zone in two directions at right angles and take the mean. Calculate the area from πr^2 and compare the mean area for each treatment. Repeat each treatment several times to identify anomalies and calculate a mean. Because a clear zone is only a rough measure of the amount of amylase, results are semi-quantitative.

Area of a clear zone

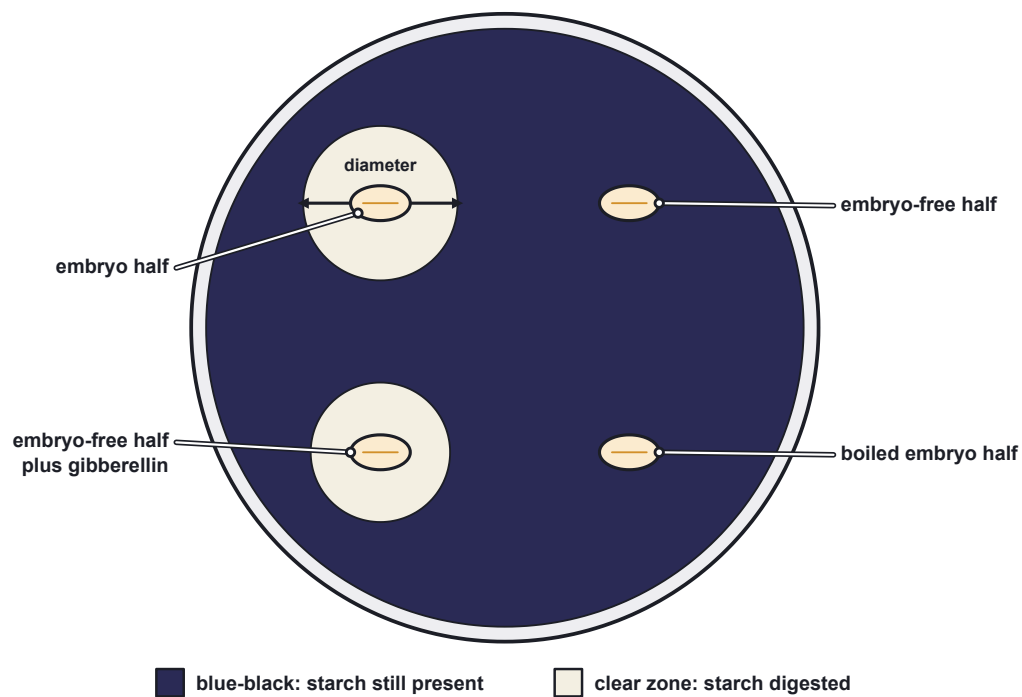
A clear zone has a mean diameter of 14 mm. Calculate its area.

$$1. \text{ radius} = 14 \div 2 = 7 \text{ mm}$$

$$2. \text{ area} = \pi r^2 = \pi \times 7^2 = \pi \times 49$$

Answer: 154 mm² (to 3 significant figures)

Maths skill: Area of a circle = πr^2 . Halve the diameter first, then square the radius, and give units (mm²).



Core practical 18: **clear zones** show where amylase has digested the starch.

Quick check

1. Which wavelength of light converts Pr to Pfr?
2. Which form of phytochrome is active?
3. How does auxin make cells elongate?
4. Where is amylase made in a germinating cereal grain?

Quick check answers

Plant responses

- 1 . Red light (about 660 nm).
- 2 . Pfr.
- 3 . It increases proton pumping into the cell wall; the acidic wall becomes more extensible and the cell takes in water.
- 4 . In the aleurone layer, under the control of gibberellin from the embryo.