8.6 Plant responses

Why and how plants respond to the environment using plant hormones

Tropic movements versus nastic movements

Just as animals do, plants need to respond to the external environment – both to living (**biotic**) and non-living (**abiotic**) factors. Responding to the environment allows plants to survive for longer by avoiding predation or reaching favourable conditions. There are two types of movements relating to plants:

- **tropisms** are the **tropic movements** (directional responses) seen in plants, in response to a variety of possible stimuli, including:
  - **chemotropism**: directional response to chemicals
  - **phototropism**: directional response to light stimuli
  - **thermotropism**: directional response to temperature
  - **hydrotropism**: directional response to water
  - **thigmotropism**: directional response to touch
- **nasties** are the **nastic movements** (non-directional responses) which plants have in response to stimuli, including **chemonasty**, **photonasty**, **thermonasty**, **hydronasty** and **thigmonasty**

Plant growth substances

But what controls plant responses? **Plant hormones** (more accurately named **growth substances**) coordinate plant responses to environmental stimuli. Like animal hormones, plant hormones are chemical messengers that can be transported away from their production site and sent to act in other areas, where they are first detected by receptors on target cells or target tissues. The table below compares the action of plant hormones with animal hormones:

Plant growth substances	Animal hormones
• site of production: interestingly, effectively any cell in the plant is able to produce any plant hormone • method of transport: multiple methods (e.g. diffusion, gaseous transport, in the phloem, etc) • modes of action: receptors on target tissues bind to the chemicals • effects: different growth substances have multiple, unpredictable effects	• site of production: specialised endocrine glands in the body produce specific hormones • method of transport: hormones are secreted into the bloodstream and travel in the blood • modes of action: receptors on target tissues bind to the chemicals • effects: one-specific effect or more per hormone (some have multiple effects, e.g. adrenaline)

How plants grow

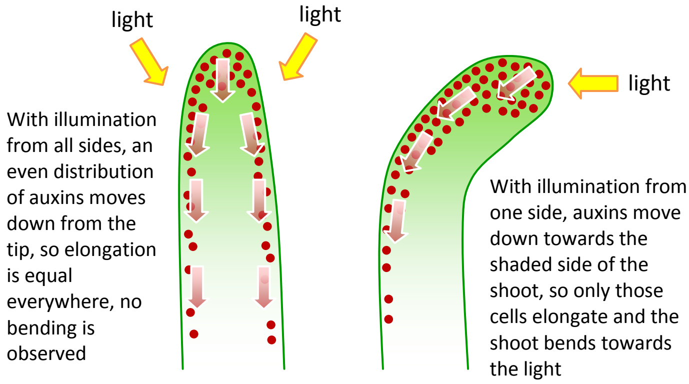
Due to the cell wall present in plant cells (which animal cells lack), plant cells are limited in their ability to expand and divide unlike animal cells. For this reason, *growth* only occurs at certain places in the plant, where there are groups of immature cells that are still capable of division: these regions are known as **meristems**:

- **apical meristems** are located at the tips of the roots and shoots, responsible for root and shoot growth
- **lateral meristem** (or the **cambium strip**) is a cylindrical chunk of meristem cells around the stem or trunk
- **lateral bud meristems** at the 'nodes' in the stem where shoots derive (the *buds*)

Cell division occurs in the meristems, but plant growth is due to both cellular division and **cell elongation**. Certain hormones in the plant trigger cell division, whilst others trigger cell elongation.

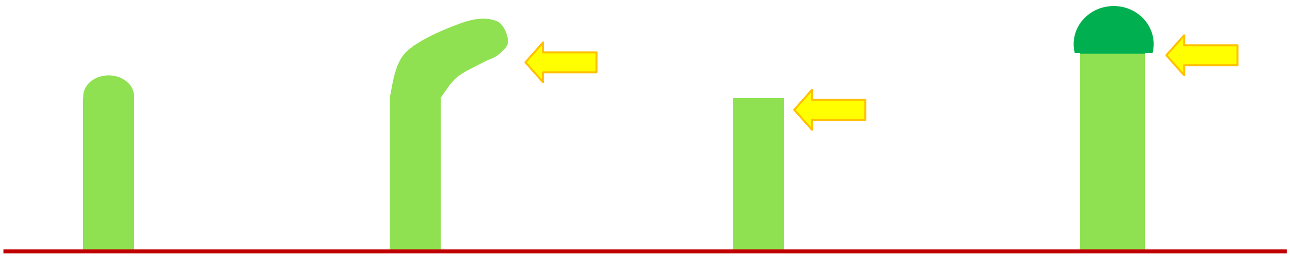
Phototropisms

During a phototropic response, a shoot of a plan bends towards a light stimulus. This happens because the shaded side of the shoot elongates much faster than the illuminated side, which pushes the end of the shoot towards the light. Simple experiments have produced evidence for phototropic mechanisms in shoots, as shown on the following page.



When a plant is exposed to a light source on one side of the shoot only, this causes plant hormones called **auxins** to redistribute largely along the *shaded* side of the shoot. Why exactly light causes this movement of auxins is still uncertain, although two enzymes (phototropin I and phototropin II) have been identified and associated with this. Auxins cause cells to elongate, which means that the cells on the shaded side of the shoot elongate much more than the cells on the illuminated side, resulting in a bend towards the light, as shown on the previous page.

There have been many studies into phototropisms, many of the first of which came from Charles Darwin. The diagram below outlines Darwin's experiments with phototropism.



a coleoptile before experiment (no growth at this point)

b when the light comes from one direction, there is clear growth and curvature towards the light

c when the tip is removed there is no growth or bending from the coleoptile

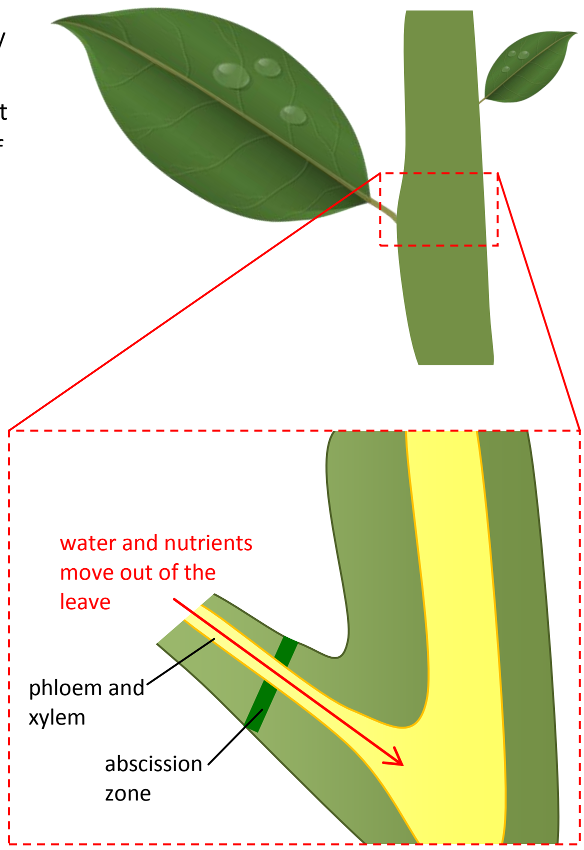
d tip is intact, but covered by an opaque cap, so no light gets through, shows growth but no bending

Looking at the **coleoptile** in **a**, before any growth has occurred, we can see how each condition affects the growth of the coleoptile. The yellow arrows represent the direction of light. In **b** we clearly see that there is growth and the shoot bends towards the light, which suggests evidence for phototropisms as explained above. Further evidence can from the fact that when, like in **c**, Darwin removed the tip, there was no growth or bending, and in **d** when the tip was covered by an opaque cap, preventing any light from reaching the tip, there was only growth but no bending.

Abscission

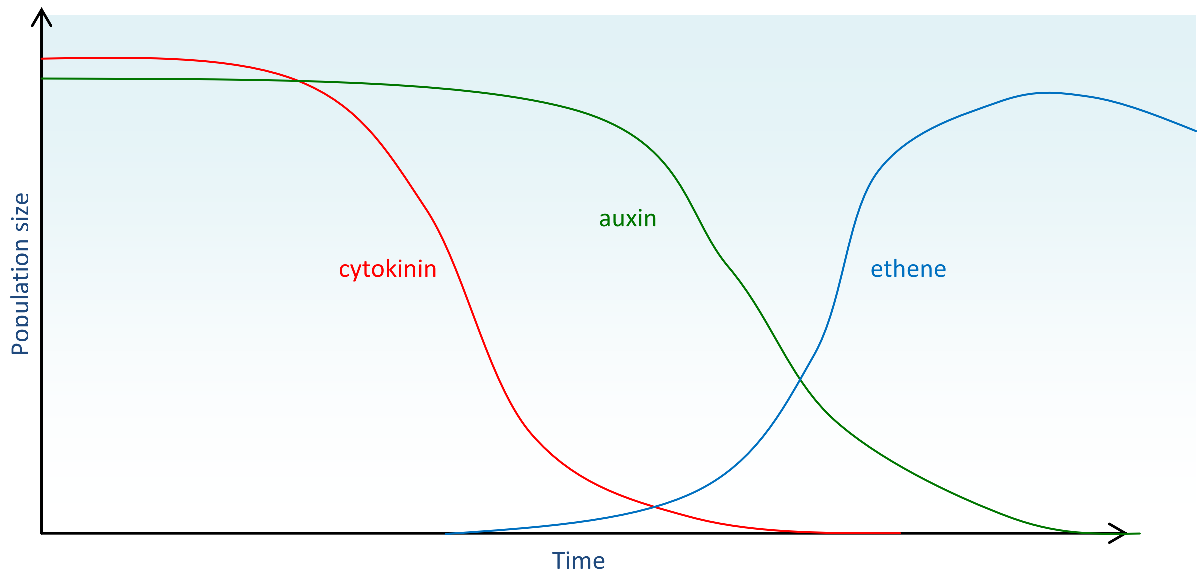
Leaf **abscission** (leaf drop) occurs in **deciduous** trees when the levels of certain chemicals drop. This is a complex process involving a number of hormonal responses:

1. levels of **cytokinin** in the plant drop in response to lower availability of nutrients and changing day lengths
2. the plant withdraws nutrient supplies from the leaf (since it is about to drop, nutrients are not wasted going to this area, and in terms of phloem transport, nutrients withdraw back into the stem)
3. **auxin** levels in the leaf drop in response to a drop in cytokinin
4. another hormone, antagonistic to auxin, called **ethene**, is activated and ethene production increases
5. this stimulates the production and release of **cellulase** enzymes in the **abscission zone** of the leaf



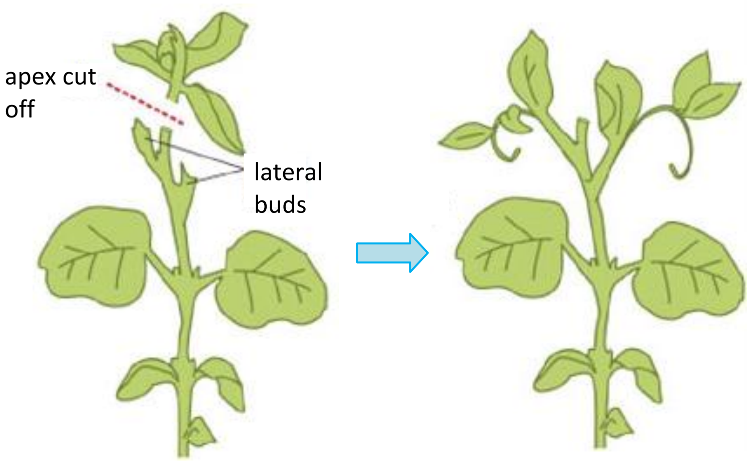
Cytokinin is a plant hormone which prevents **senescence** (the removal of nutrients, which causes aging and autumn leaf colour in leaves), which is why as levels of cytokinin drop, the nutrients withdraw through the phloem back into the main plant body (the stem). Auxins have a variety of effects on plants, as you have already seen, in this case though they inhibit the production of ethene, a hormone which stimulates the production of cellulase in the abscission zone for abscission to occur.

Cellulase is a digestive enzyme, which digests the cells in the abscission zone, eventually separating the leaf **petiole** from the stem. The graph on the following page shows the proportions of each of the above hormones over time during the process.



Apical dominance

If you cut the **apex** (shoot tip) of a plant off, the plan starts to grow side branches from lateral buds that were previously dormant. Researchers have suggested that this is due to auxins preventing the lateral buds from growing. This is called **apical dominance**: when the tip is removed, the concentration of auxins in the shoot drop and the buds grow.



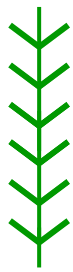
To test this, researchers took a plant cut its apex off. This should encourage the growth of shoots from the lateral buds, but the researchers applied a paste containing auxins to the cut end of the shoot, and the buds did not grow. This seems to support the hypothesis.

However, further experiments have shown that this is unlikely to be a simple cause-and-effect relationship, and that there are further processes involved.

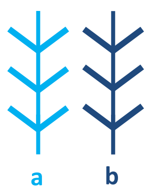
You should be familiar with apical dominance from *coppicing* in 7.7 Conservation, whereby new branches grow as a result of this process.

Gibberellins

Hormones called **gibberellins** affect plant grown by increasing cell division *and* cell elongation. They are most associated with *stem elongation*, although they are involved in a number of plant processes. It was research in Japan on the plant disease *bakanae* which sparked interests into gibberellins. The disease was caused by a fungus which made rice plants grow very tall. Studies isolated a group of chemicals (gibberellins).



This represents a normal, healthy pea plant at its regular adult height



Two mutant varieties of the pea plant are taken, both of which lack gibberellins:

- **a** lacks gibberellins because it lacks the precursor molecule which becomes gibberellin
- **b** lacks gibberellins because it lacks the enzyme which converts the precursor into gibberellin

When both varieties are grafted together they grew to a normal height

The above experiment shows how evidence of the effect of gibberellins can be shown experimentally. The importance of this experiment over using artificial gibberellin is that this proves the growth has occurred due to natural production of the hormone and natural processes in the grafted plant. Had gibberellin been artificially inserted, the results would have been less convincing.