Gravitropism

Gravitropism is particularly marked in germination; plumules and hypocotyls are negatively gravitropic, and radicles are positively gravitropic. The adaptive significance of this is obvious: seeds are randomly orientated when they land, and the only way the plumule can reach light it cannot 'see' is to grow upward. Radicles need to grow downwards to reach a more permanent water supply and to secure better anchorage for the shoot system. With successive branchings most roots lose much of their gravisensitivity; secondary roots tend to grow roughly horizontally and later branches tend to be insensitive to gravity. Shoots also tend to become less sensitive to gravity with successive branchings.

Controlling the gravity stimulus

Unlike light, gravity cannot be switched on and off. A solution is to place a seedling on a slowly rotating wheel called a **klinostat** (Fig. 5.12).

If the klinostat rotates every 15 minutes or less, the direction of gravity changes faster than the radicle can respond, and it grows straight along the axis of rotation. By stopping the klinostat for varying periods of time the effect of the duration of a gravity stimulus can be investigated. In this way it has been found that the klinostat must be stopped for a certain minimum *presentation time* (usually several minutes) for any response to occur, an observation that gives clues to the mechanism of detection (see below).

Note: A klinostat is *not*, as is commonly stated, an adequate control for demonstrating gravitropism because it changes the plant's orientation with respect to *every* possible unidirectional stimulus; gravity is not selectively eliminated.

How is gravity detected?

In animals, gravity detection involves small grains of mineral material called **statoliths.** Because they are denser than cellular structures they tend to sink downwards, stimulating receptors. There is good evidence that in plants, the function of statoliths is performed by starch-storing plastids called *amyloplasts.* Since they are denser than the surrounding cytoplasm they tend to sink onto cytoplasmic membranes, which in some way is thought to trigger the gravitropic response (Fig. 5.13). Evidence supporting the statolith hypothesis includes the following observations:

- Amyloplasts are present in all gravity-sensitive plant organs, and are particularly abundant in the most sensitive parts, such as root caps and the nodes ('joints') of aerial stems of grasses. In stems of other plants they occur in the cells just outside the vascular tissue. Some plants never produce storage starch but produce amyloplasts in the root cap, e.g. onion.

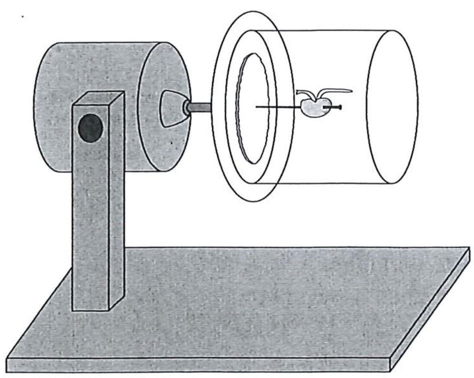

Fig. 5.12 A klinostat

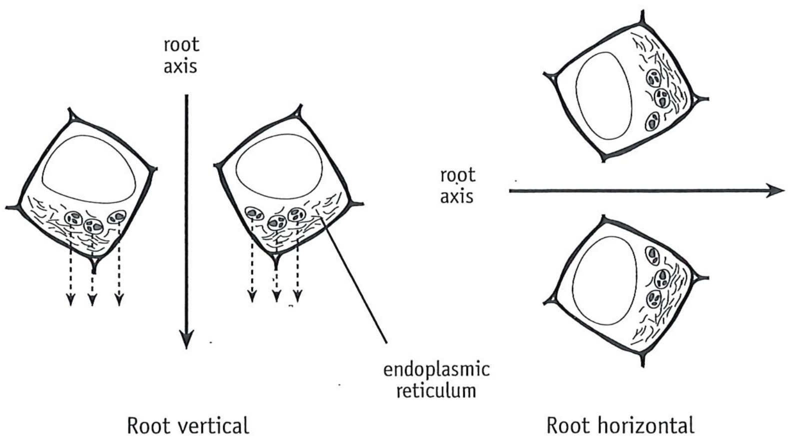

Fig. 5.13 Effect of orientation on amyloplasts in root cap cells

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- When radicles or coleoptiles are treated with *gibberellin* (which stimulates starch digestion in amyloplasts), gravisensitivity is lost. When gibberellin is removed, starch is resynthesised in the amyloplasts and gravisensitivity is regained.
- Presentation times for different plant organs are very similar to the times taken for amyloplasts to settle.
- The effect of temperature on presentation time and the rate of starch sinking are very similar (Fig. 5.14).

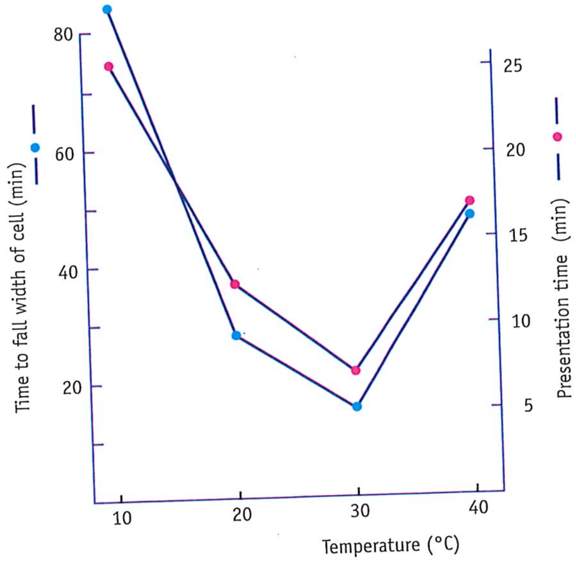

Fig. 5.14 Effect of temperature on presentation time and rate of amyloplast sinking

Transmission of the signal

When amyloplasts sink against the lower side of a cell, some kind of signal must be generated, which then passes to the zone of cell elongation. The experiments shown in Fig. 5.15 suggest that in both radicles and coleoptiles, gravitropism involves the vertical movement of a growth regulator.

As in phototropism, auxin seems to be the 'messenger'. When agar blocks are placed in contact with upper and lower halves of a horizontal coleoptile tip, more auxin is collected from the lower block (Fig. 5.16).

Experiments suggest that, in roots, bending is due to a growth-inhibitor moving from the root cap (Fig. 5.17):

- Removal of half the root cap of a vertical radicle causes it to bend towards the intact side.
- Insertion of a transverse piece of metal foil into one side of a vertical radicle just behind the tip causes it to bend away from the foil.

These experiments suggested that a growth-inhibitor passes back from the root tip along the lower side, and it was later established that the growth inhibitor in roots is auxin.

Auxin is synthesised in the youngest leaves and transported to the roots in the phloem. In a horizontal

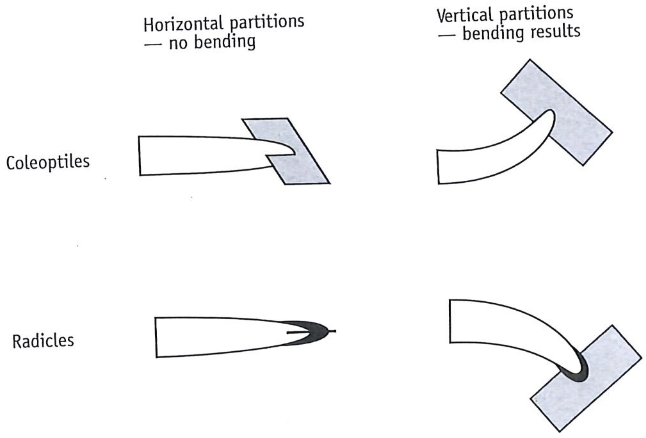

Fig. 5.15 Evidence that gravitropism involves the vertical movement of a growth regulator

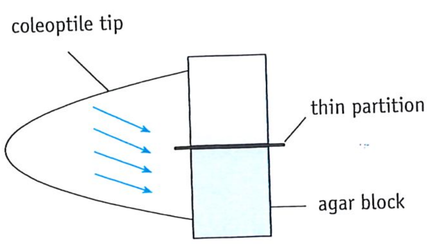

Fig. 5.16 Evidence that auxin is vertically transported in a horizontally placed coleoptile tip

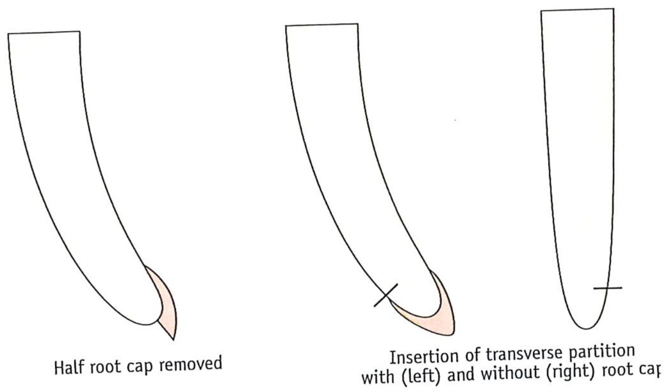

Fig. 5.17 Evidence that gravitropism in roots involves a growth inhibitor

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radicle, auxin is transported from the root cap along the lower side of the radicle, inhibiting elongation and causing the root to bend downward (Fig. 5.18).

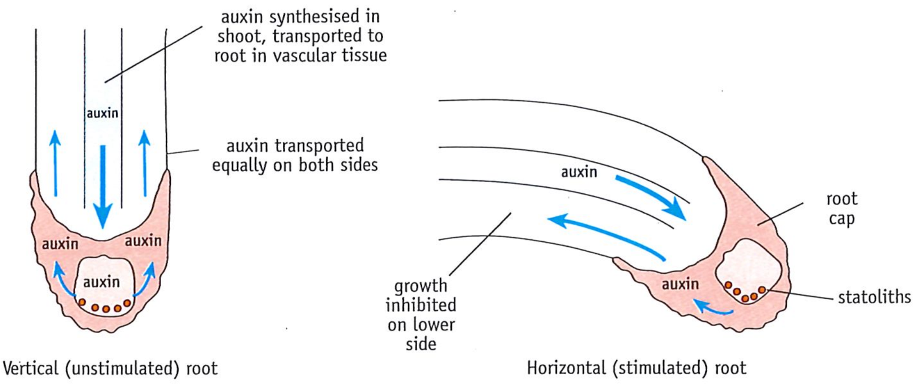

Fig. 5.18 Mechanism of gravitropism in a root

Thus the mechanism of gravitropism in shoots and roots is essentially similar, except that auxin is a growth stimulator in shoots and an inhibitor in roots (Fig. 5.19).

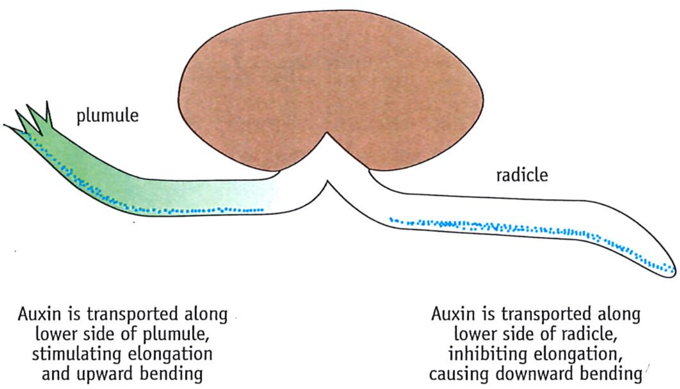

Fig. 5.19 Gravitropism in a germinating bean

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Summary of key ideas in this chapter

- Plants cannot move rapidly because their cell walls prevent rapid change of cell shape (except by sudden loss of turgor).
- Most movements of shoots and roots are bending movements called *tropisms*, brought about by one side elongating faster than the other.
- Tropisms are named according to the type of stimulus (e.g. *gravitropism*), and the direction of movement (*positive* tropisms towards the stimulus, *negative* tropisms away).
- A tropism involves three phases: detection of the stimulus, transmission of some form of signal to the elongating region, and the response itself.
- The principal substance involved in phototropism and gravitropism is auxin.
- Auxin transport is *active*, and away from the root or shoot tip.
- A unidirectional light stimulus brings about the lateral transport of auxin towards the shaded side of a young shoot. It is then transported along the shoot and promotes cell elongation.
- Gravity results in transport of auxin to the lower side of a shoot or root. This is followed by stimulation of cell elongation in shoots and inhibition of cell elongation in roots.

Test your basics

Copy the following, filling in the missing words.

1. Growth movements in a direction relating to the direction of a stimulus are called ___*___.
2. Growth away from light is called ___*___ ___*___.
3. Growth towards gravity is called ___*___ ___*___.
4. A movement in response to the intensity of a stimulus (rather than its direction) is called a ___*___ movement.
5. In phototropism in a coleoptile or stem, ___*___ is transported down the shaded side, and stimulates ___*___.
6. In phototropism, plants are most sensitive to blue light and are insensitive to ___*___ light.
7. The light-sensitive pigment in phototropism is an orange protein called ___*___.
8. In gravitropism, gravity is detected by downward pressure exerted by ___*___, which act like statoliths. In roots these are located in the ___*___ ___*___.
9. In response to gravity, auxin is transported along the ___*___ side of a stem or root.
10. In stems and coleoptiles, auxin ___*___ elongation. In roots it ___*___ elongation.

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