

Phototropism and gravitropism in seedlings

Investigate and describe gravitropism and phototropism in shoots and roots

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). Teacher answers start on a new page.

Name

Date

Aim

To investigate how the shoots and roots of young seedlings respond to light from one side and to gravity.

Background

Phototropism is a response in which parts of a plant grow towards or away from the direction of the light source. **Gravitropism** is a response in which parts of a plant grow towards or away from gravity.

Shoots grow towards light and away from gravity (upwards). Roots grow away from light and towards gravity (downwards). These responses help the plant: the shoot reaches light for photosynthesis and the root grows down into the soil to take in water and mineral ions.

To investigate one response you must change only one factor. To test phototropism, the light must come from one side only. To test gravitropism, the seedlings must be in the dark, so light cannot affect the direction of growth, and their position relative to gravity is changed. A dish that is left upright, or lit evenly from above, is the **control** because it shows what normal growth looks like.

Hypothesis

Shoots will bend towards light from one side and upwards when a dish is turned on its side, because shoots grow towards light and away from gravity; roots will bend away from the light and downwards.

Variables

Independent	The direction of the stimulus: light from one side, or the dish turned on its side (compared with light from above, or upright in the dark)
Dependent	The angle through which the shoot bends from its starting direction ($^{\circ}$), and the direction of root growth
Control	• Species, age and size of the seedlings (cress, grown for 2 days in the dark before the test) • Number of seedlings measured in each dish (5) • Volume of water on the cotton wool, so each dish is equally damp • Temperature (all dishes in the same room at about 20 °C) • Distance of the lamp from the dishes (30 cm) and the type of lamp • Length of time left (3 days) • Light: dishes C and D are kept in the dark so that light cannot affect the direction of growth

Equipment

- 4 clear plastic Petri dishes with lids, each with the base lined with cotton wool and a filter paper on top
- About 30 cress seeds
- Modelling clay to hold the dishes upright
- 2 light-proof cardboard boxes: one with a window 2 cm wide cut in the left-hand side only, one with a window cut in the top

- 2 more light-proof boxes (or one large box) to keep dishes C and D in the dark
- LED lamp (it gives out little heat)
- Ruler graduated in mm
- Protractor
- Marker pen or glass-marking pencil for labelling and tracing
- Water in a beaker and a dropping pipette
- Clear sticky tape

Risk assessment

Hazard	Risk	Precaution
Mains electricity near water	Electric shock if the lamp or its cable gets wet	Keep the lamp and cable away from the water and wipe up any spills at once.
Mould or bacteria growing on the damp cotton wool	Harmful microorganisms may be breathed in or touched	Keep the lids on and taped. Do not sniff the dishes and wash your hands after handling them.
Cress seeds (may be treated with fungicide)	Harm if swallowed	Do not put seeds in the mouth. Wash your hands after handling them.

Method

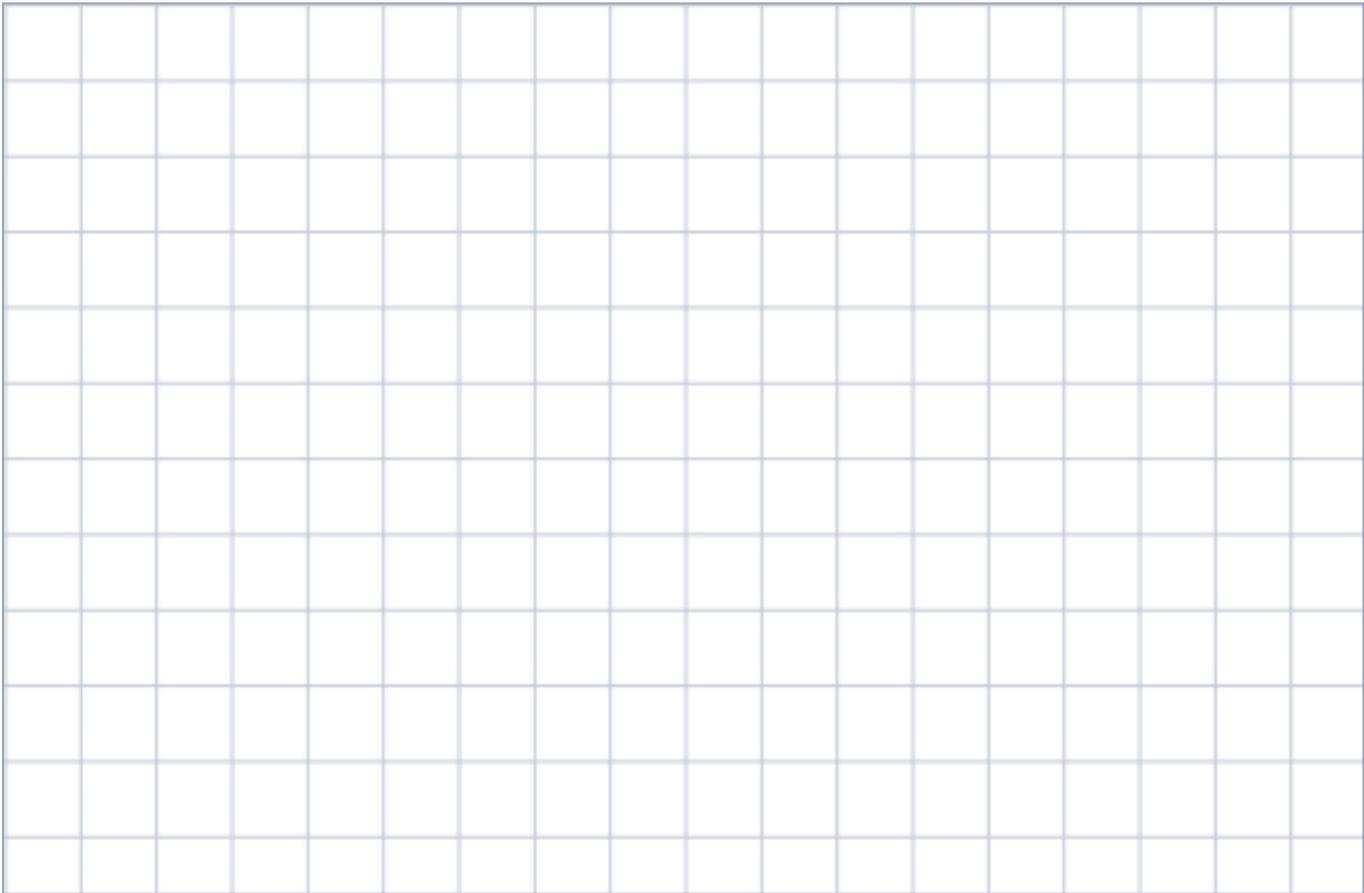
1. Label four Petri dishes A, B, C and D. Use a dropping pipette to damp the cotton wool and filter paper in each dish with 5 cm³ of water. It should be damp, not dripping.
2. Place 6 cress seeds, evenly spaced, in a straight line across the middle of the filter paper in each dish. Put on the lids and tape them in place.
3. Stand each dish on its edge, held with modelling clay, so that the line of seeds is horizontal. Keep all four dishes in a dark cupboard at about 20 °C for 2 days, until the roots and shoots are about 1 cm long.
4. Dish A (phototropism): put it in the box with the window in the left-hand side only. Stand the lamp 30 cm from the window so that light reaches the seedlings from the left.
5. Dish B (control for light): put it in the box with the window in the top, with the lamp 30 cm above, so that light reaches the seedlings equally from above.
6. Dish C (gravitropism): turn the dish through 90° so that the line of seeds is now vertical and the shoots point sideways. Put it in a dark box.
7. Dish D (control for gravity): leave the dish upright, in a dark box.
8. Leave all four dishes in the same room at about 20 °C for 3 days. Do not move them during this time.
9. After 3 days, take each dish out and lay it flat on a bench. Choose 5 seedlings in each dish and trace the outline of each shoot on the lid with a marker pen.
10. Use a protractor to measure the angle through which each shoot has bent from its starting direction (vertical for dishes A, B and D, horizontal for dish C). Record the angles to the nearest 1°.
11. Look at the roots in each dish and record in which direction they have grown (for example down, or away from the light).
12. Calculate the mean angle of bend of the shoots for each dish. Wash your hands.

Results

Results table: angle through which the shoots bent, and direction of root growth, after 3 days							
dish	angle of bend of shoot 1 / °	angle of bend of shoot 2 / °	angle of bend of shoot 3 / °	angle of bend of shoot 4 / °	angle of bend of shoot 5 / °	mean angle of bend / °	direction of root growth
A: light from one side							
B: light from above (control)							
C: on its side, in the dark							
D: upright, in the dark (control)							

Graph

Bar chart of mean angle of bend of the shoots (y-axis, label 'mean angle of bend / °', scale 0 to 90 with 10° per 1 cm) against the dish (x-axis, label 'dish', bars for A, B, C and D). Draw bars of equal width that do not touch, because the x-axis shows separate categories.



Exam questions 10 questions · 25 marks

1 State the independent variable and the dependent variable in the investigation of phototropism using dishes A and B. **[2 marks]**

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2 State three variables that must be kept the same in all four dishes so that the investigation is a fair test. **[3 marks]**

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3 Dishes C and D were kept in the dark. Explain why. **[2 marks]**

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4 A student measured the angle of bend of five shoots in dish A. The angles were 52°, 48°, 56°, 44° and 60°. Calculate the mean angle of bend. **[2 marks]**

Answer =

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- 5** Table 14.1 shows the direction of root growth in the four dishes after three days. Describe what these results show about the responses of roots to light and to gravity. **[3 marks]**

Table 14.1

dish	treatment	direction of root growth
A	light from the left, dish upright	down and curving to the right
B	light from above, dish upright	straight down
C	dark, dish on its side	curved downwards
D	dark, dish upright	straight down

- 6** Name the two responses shown by the shoots in dishes A and C. **[2 marks]**

- 7** Dish D was an upright dish kept in the dark. Explain why this dish was included. **[2 marks]**

- 8** Explain why it is an advantage to a plant that its shoots grow towards light and that its roots grow downwards. **[3 marks]**

- 9** Suggest two ways to make the results of the investigation more reliable. **[2 marks]**

10 A student wants to find out whether the angle of bend of the shoots depends on how far the lamp is from the dish. Describe how the student could investigate this. **[4 marks]**

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Teacher answers

Practical skill 14: Phototropism and gravitropism in seedlings. The example results are practice data, not real measurements.

Example results

Example results (practice data)							
dish	angle of bend of shoot 1 / °	angle of bend of shoot 2 / °	angle of bend of shoot 3 / °	angle of bend of shoot 4 / °	angle of bend of shoot 5 / °	mean angle of bend / °	direction of root growth
A: light from one side	38	45	41	50	36	42	curved away from the light
B: light from above (control)	4	0	6	2	3	3	straight down
C: on its side, in the dark	70	82	75	68	80	75	curved downwards
D: upright, in the dark (control)	2	0	4	1	3	2	straight down

Conclusion

In dish A the shoots bent towards the light, by a mean of 42°, and the roots grew away from it, so shoots show positive phototropism and roots show negative phototropism. In dish B, where the light came from above, the shoots stayed almost vertical (mean 3°), so the bending in dish A was caused by the light coming from one side. In dish C, kept in the dark, the shoots bent upwards by a mean of 75° and the roots grew downwards, so shoots grow away from gravity and roots grow towards gravity. In the control dish D the shoots and roots grew straight, so the bending in dish C was caused by gravity. These results support the hypothesis. The responses help the plant survive: shoots reach light for photosynthesis, and roots grow down into the soil to absorb water and mineral ions and to anchor the plant.

Errors and improvements

Error	Effect on the results	Improvement
Only 5 seedlings are measured in each dish, and some seeds may be dead or grow more slowly than others (random error)	The mean angle may not be representative, and one odd seedling has a large effect on it	Use more seedlings in each dish (for example 10) and repeat the whole experiment, then calculate a mean. Ignore a clearly anomalous result when calculating the mean.
Measuring the angle of a curved shoot with a protractor is difficult (random error)	The angles are not very precise, so small differences between dishes are not reliable	Trace the shoot onto paper and measure the angle between the start direction and a straight line from the base to the tip, using the same method each time. Have the same person measure all the seedlings.
Light leaks into the boxes holding dishes C and D, or reflects around inside box A (systematic error)	Light, as well as gravity, may affect the direction of growth, so the results are less valid	Use boxes that are fully light-proof, line them with black paper, and check that no light enters.
The cotton wool dries out or becomes too wet in some dishes, or the temperature is not the same near the lamp	Seedlings in different dishes grow at different rates, so the angles cannot be fairly compared	Add the same volume of water to each dish at the start, use an LED lamp that gives out little heat, and check the temperature near each dish with a thermometer.

Mark scheme

One mark for each point unless a maximum is given. Words in brackets are not needed for the mark.

1. [2]

- independent variable: direction of the light / light from one side or from above (1)
- dependent variable: angle through which the shoots bend / direction of growth of the shoots (1)
- do not accept 'light' or 'bending' on their own

2. [3]

- type / species / age / size of seedlings (1)
- volume of water / dampness of the cotton wool (1)
- temperature (1)
- time left / length of time of the investigation (1)
- number of seedlings in each dish / distance of the lamp (1)
- Max 3

3. [2]

- so that light does not affect the direction of growth / so that light is not a variable (1)
- so that any bending is caused only by gravity (1)

4. [2]

- $(52 + 48 + 56 + 44 + 60) \div 5 = 260 \div 5$ (1)
- 52° (1)
- correct answer with no working scores 2

5. [3]

- roots grow away from light / show negative phototropism (dish A) (1)
- roots grow towards gravity / downwards / show positive gravitropism (dish C) (1)
- roots grow straight down in the controls (B and D) when there is no stimulus from one side, so the bending in A and C is caused by light and by gravity (1)
- do not accept 'roots grow towards water'

6. [2]

- dish A: phototropism (1)
- dish C: gravitropism (1)

7. [2]

- it is a control / shows how seedlings grow with no stimulus from one direction (1)
- so that the bending in dish C can be shown to be caused by gravity / to compare with dish C (1)

8. [3]

- shoots grow towards light so leaves receive more light for photosynthesis (1)
- roots grow downwards to reach water / mineral ions in the soil (1)
- and to anchor the plant (1)

9. [2]

- use more seedlings in each dish (1)
- repeat the investigation and calculate a mean (1)
- ignore any anomalous results when calculating the mean (1)
- Max 2

10. [4]

- use several different distances of the lamp from the dish, for example 10, 20, 30 and 40 cm (1)
- keep the number and age of seedlings, temperature, water and time the same (1)
- measure the angle of bend of the shoots with a protractor after the same time (1)
- repeat for several seedlings / repeat the investigation and calculate a mean for each distance (1)
- use the same type of lamp / use a light-proof box so that the only light is from the lamp (1)
- Max 4

Exam tips

- Use the exact words: shoots grow towards light and away from gravity; roots grow away from light and towards gravity. Say 'towards gravity', not just 'downwards', if the question asks for the response.
- A control dish shows what happens when the stimulus does not come from one side. Say what it is compared with, and what it shows.
- To test gravitropism keep the seedlings in the dark, and to test phototropism the light must come from one side only. Change one factor at a time.
- When measuring angles, say from what line you measure them (for example from the vertical) and give the angle in degrees.
- In a bar chart for dishes A to D, draw bars of equal width that do not touch, and label the y-axis 'mean angle of bend / °'.