

GRAPHICAL TECHNIQUES

What is a graph?

A graph is basically an illustration of how two variables relate to one another – it is basically a ‘picture’ of the results.

Types of graphs

There are a number of types of graphical techniques depending on whether or not the variables are quantitative (numerical) and on the relationship between the variables.

These include line graphs, scatter diagrams, histograms, bar charts, kite diagrams and pie charts.

Line graphs

A line graph is used in the situation where both variables are quantitative (numerical) and continuous (any numerical value is possible, not just whole numbers); and to determine the nature of a causal link between an independent variable and a dependent variable. The independent variable is that factor which is being manipulated or changed during the practical; the factor that is consequently measured is the dependent variable. The independent variable is that which causes a change in the dependent variable.

A General Construction

- (i) The graph should have a caption (title) which summarises the relationship which is being illustrated. The caption must include the independent variable (the variable that is manipulated by the experimenter), the dependent variable (the variable that is being measured) and the biological material being investigated.
- (ii) The independent variable is placed on the x-axis, while the dependent variable is placed on the y-axis.
- (iii) Appropriate scales should be devised for the axis so making the most effective use of the graph paper. Scales involving three units of the variables to one unit on the axes should be avoided. The data should be critically examined to establish whether it is necessary to start the scale(s) at zero.
- (iv) Axes should be clearly and appropriately labelled with the name of the variable (e.g. time) followed by a solidus (/) and the unit of measurement (e.g. minutes). Thus, the label might be “time/minutes” which reads “time in minutes”. (Care should be taken not to use a solidus in the unit of measurement itself, e.g. “rate of movement in millimetres per second” should be written “rate of movement/mm s⁻¹” and **not** “rate of movement/mm/s”.)

- (v) Points should be notated with a saltire cross (⊗) or an encircled dot (⊙) (though it is possible to place any symbol round the dot, e.g. Δ or □, and this is particularly useful when there are two or more sets of data to be plotted on the same graph).

B Why join up the points?

The points only show the measurements that have been taken. It is not actually known what is happening between the points, so why join them up?

There are basically two reasons for joining the points:

- (i) it makes it easier to see the trend or relationship between two variables;
- (ii) it may be important to calculate what is happening between points – a process known as interpolation – or beyond the points plotted – a process known as extrapolation.

C How to join up the points

Once the points are plotted a decision must be made as to whether to join them up with short straight lines or draw a line of best fit through the points. In making this decision, it is important that the quality of the data is understood in any given situation.

In most cases, *it is better to join the points with straight lines because you do not know how the values between the recorded points may vary*. Conventions have been established by the Society of Biology (formerly the Institute of Biology) who have provided the following guidance: “*A smooth curve should only be drawn if there is good reason to believe that the intermediate values fall on the curve, otherwise, straight lines joining the points should be drawn, thus indicating uncertainty about the intermediate values*”.

(a) Short, straight lines directly between points

If it is not known what is happening between the points then linearity is assumed. This is particularly the case in Biology where other unmeasured variables are influencing the points or where experimental error produces points which are not reliable. In these cases the points are joined directly by short, straight lines.

Figure 1 shows a line graph of data for the production of gas by Elodea (an aquatic plant) at different relative light intensities (calculated as the inverse of the distance of a light source from the plant). Short straight lines are the preferred method of joining the points since:

- while the experimenter attempts to control conditions, this is not easy to achieve as
 - carbon dioxide levels may vary in the immediate vicinity of the plant;
 - temperature may fluctuate during the course of the experiment; and
- there is no necessity to make a calculation from the graph.

Note that the line is not extrapolated to the 0, 0 coordinates.

Figure 2 shows the results for sampling beetles with pit fall traps, laid along a transect line extending outwards from the centre of a hedge. Drawing a smooth curve would be totally inappropriate. The data is prone to experimental error and so there is uncertainty about the results.

(b) Line of best fit

A line of best fit (straight line or smooth curve) will be drawn if:

- there are sufficient data points to be confident in the relationship or because theoretical considerations predict that there is good reason to believe that the intermediate values fall on the line, e.g. the course of a starch-amylase reaction (see Figure 3); or
- the line is to be used to make calculations by interpolation or extrapolation. If interpolation between two points is required, accuracy is improved by drawing a line of best fit so that all points are considered and not just the two points between which interpolation is to occur. If extrapolation beyond the points is required, accuracy is improved by extending a line of best fit so that all points are considered and not just the end two.

Lines of best fit are generally used in Chemistry and Physics, but only sometimes in Biology.

There are a number of situations in which you have to make calculations from a graph. These include:

- constructing a calibration curve for colorimeter reading (% transmission) to percentage starch (using iodine to produce a blue-black solution) – a smooth curve is required;
- plotting percentage change in mass of potato tuber against water potential of the bathing sucrose solution (or its molarity) and determining the water potential of the potato tuber where the line of best fit (a straight line) intersects the x-axis with no net change in mass – see Figure 4;
- plotting percentage plasmolysis against water potential of the bathing sucrose solution (or its molarity) and determining the average solute potential of the epidermal tissue from the line of best fit (most likely a sigmoidal or S-shaped curve) at 50% plasmolysis.

A line of best fit is added by eye. You should use a transparent plastic ruler or a flexible curve to aid you. When judging the position of the line *the following rules should be applied:*

1. There should be approximately the same number of data points on each side of the line.
2. The points should be evenly distributed, either side of the line, both at the top and the bottom of the line.
3. The line should be near as many points as possible.

It should be emphasised that it is not necessary to connect any points when you are constructing a line of best fit. Furthermore, resist the temptation to simply connect the first and last points.

D Assessment of graphical construction

You may be assessed on your construction of a graph in both written AS papers and in AS and A2 coursework. You are advised to adopt the following guidance:

1. You must draw a line of best fit if you are going to calculate from the graph. Indeed, in written AS papers, you will be directed to draw a line of best fit when a calculation is required.
2. If a line of best fit is appropriate then you must follow the rules provided previously.
3. Otherwise joining points with straight lines is both easier and preferable.

Figure 1 The production of gas (oxygen) by Elodea at different relative light intensities.

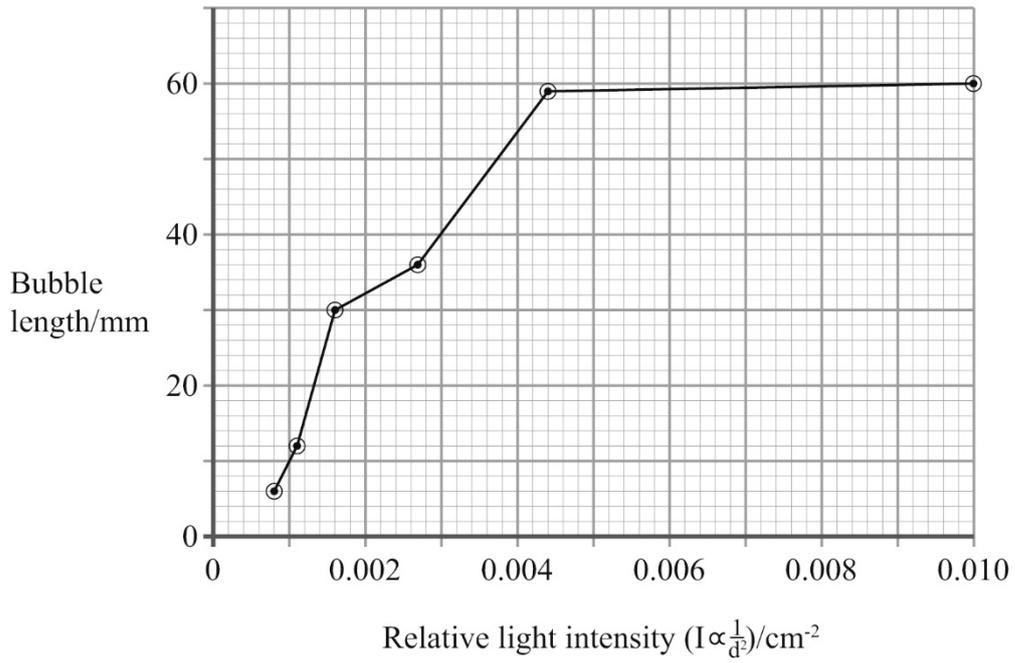


Figure 2 The number of beetles caught at different distances from the centre of a hedge.

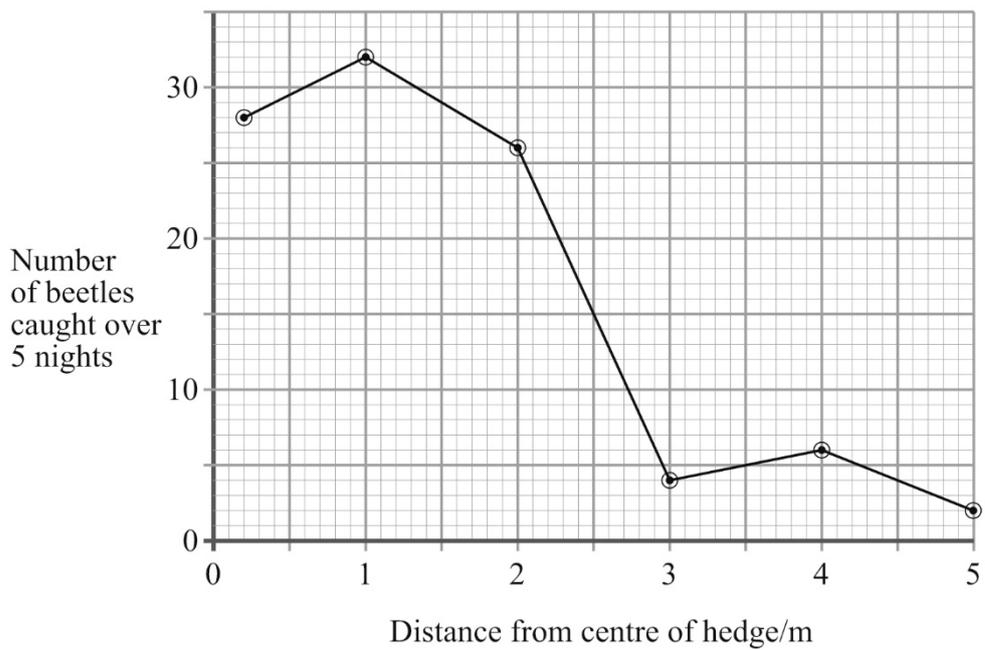


Figure 3 The course of a starch-amylase reaction.

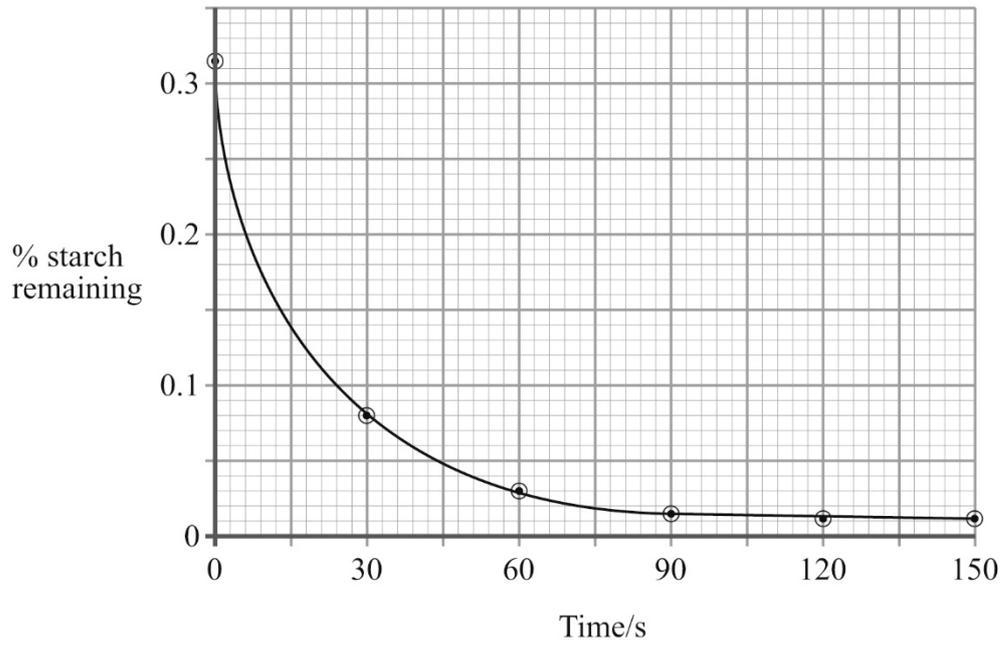


Figure 4 Percentage change in mass of potato tuber plotted against the molarity of the bathing sucrose solution for the determination of the water potential of potato tuber tissue.

