

A-Level Biology Bridging Work

Session 3- Development of Practical Skills in Biology

1.1.1 - Planning:

- Experimental design, including to solve problems set in a practical context including selection of suitable apparatus, equipment and techniques for the proposed experiment
- Identification of variables that must be controlled, where appropriate
- Evaluation that an experimental method is appropriate to meet the expected outcomes

1.1.2 - Implementing:

- How to use a wide range of practical apparatus and techniques correctly
- Appropriate units for measurements
- Presenting observations and data in an appropriate format

1.1.3 - Recording:

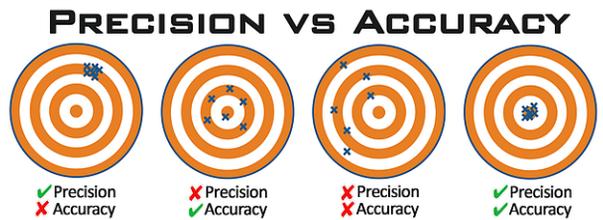
- Processing, analysing and interpreting qualitative and quantitative experimental results; including reaching valid conclusions, where appropriate
- Use of appropriate mathematical skills for analysis of quantitative data
- Appropriate use of significant figures
- Plotting and interpreting suitable graphs from experimental results, including:
 - (i) selection and labelling of axes with appropriate scales, quantities and units
 - (ii) measurement of gradients and intercepts

1.1.4 - Evaluating:

- How to evaluate results and draw conclusions
- The identification of anomalies in experimental measurements
- The limitations in experimental procedures
- Precision and accuracy of measurements and data, including margins of error, percentage errors and uncertainties in apparatus
- The refining of experimental design by suggestion of improvements to the procedures and apparatus

Planning an experiment

A well-designed experiment should give results that are:



- _____ - precise results don't vary much from the mean. Precision is reduced by random error
- _____ **and reproducible** - repeatable means that if the same person completes the experiment again using the same method and apparatus, they will get the same results. Reproducible means that if someone else does the experiment, using a slightly different method or apparatus, the results will still be the same or very similar
- _____ - valid results answer the original question. In a valid experiment all of the variables have been controlled to ensure that only the independent variable has affected the results
- _____ - accurate results are very close to the true answer
- _____ - reliable data is trustworthy - there are no anomalous values

Never use the word "amount" Better terms include mass, number, volume, concentration, length

Variables

- **Independent** - what is being changed
- **Dependent** - what is being measured
- **Control** - what must be kept constant to ensure a valid test

TASK: Identify the variables for an investigation into how temperature affects enzyme activity. Name as many control variables as you can

Good experimental design

Controls:

- **Negative controls** are included in experiments to check that only the _____ is affecting the DV. They should not have any effect
- E.g. a tube of water and substrate is used instead of enzyme and substrate (all other variables like volume and pH remain the same)
- Controls can also allow a _____ to be made
- E.g. When investigating the effect of a new drug you would have two experimental groups - one that is given the drug and one that is not (given a placebo instead)

Good experimental design

Sample size:

The larger the sample size, the less likely it is that results are due to chance and the more _____ the results will be _____

Repeats/replicates:

Taking several repeat measurements (at least _____) allows any anomalies to be identified and ignored/discarded. The _____ can be calculated, reducing the impact of _____ error

NOTE: Repeating an experiment doesn't make results reliable. Discarding anomalies or repeating tests giving anomalous results does. Also, always be specific and say "mean" (or mode/ median) instead of "average"

Taking accurate measurements:

The apparatus you choose has to be _____ enough (e.g. a gas collection tube can measure to 0.1cm³ but a 100cm³ measuring cylinder cannot. The scale on the measuring apparatus must be to small enough divisions (e.g. mm rather than cm on a ruler)

To increase accuracy you need to increase the independent variable by smaller _____ (e.g. every 5°C rather than every 10°C or every minute rather than every 5 minutes)

Writing a plan for an experiment

You should include the following in a plan:

Recording results

Features of a good results table:

- _____ variable on the left
- _____ variable on the right, with space to record replicates and a mean
- Units in the _____ row only (where appropriate), NOT by every value in the body of the table
- All data should be recorded to a consistent number of _____
- Ruled lines using a pencil (table should be boxed in)

Anomalous results do not fit the general pattern or trend. In results tables we circle anomalies to identify them and we ignore them when calculating the mean

Independent variable (units)	Dependent variable (units)			
	Test 1	Test 2	Test 3	Mean

Species	Tally	Frequency
Sparrow		7
Blue tit		4
Goldfinch		2
Blackbird		10

Frequency tables - often used in sampling

Processing data

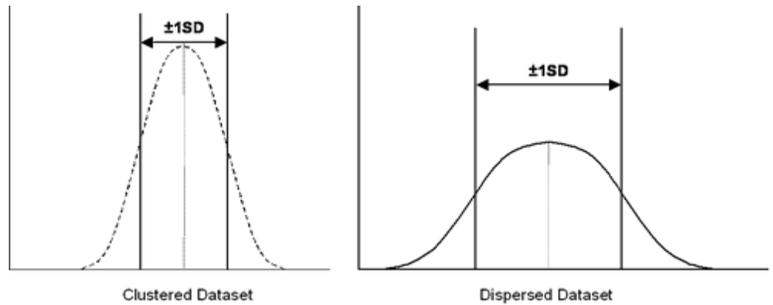
- **Mean** - _____
- **Median** - _____

- **Mode** - _____
- **Range** - _____
- **Standard deviation (SD)** - _____

Calculating mean rate: divide the change in the dependent variable by the difference in time

Both range and SD are measures of dispersion of data (how spread out it is)

SD is more useful because it takes into account ALL the values in a sample, whereas range only considers two values. This means that SD is less likely to be affected by anomalous results or outliers



Statistical tests

Statistical tests give us more confidence in our conclusions

- _____ - tests the degree to which two sets of data are correlated. A value of +1 indicates a strong positive correlation, a value of -1 indicates a strong negative correlation and a value of 0 indicates no correlation
- _____ - tests if there is significance in the difference of two means for two data sets. Comes in two forms - paired (when using the same test subjects under different conditions e.g. pulse rate of the same participants before and after exercise) or unpaired (comparing different subjects e.g. people taking a trial drug compared to different people who are taking a placebo)
- _____ - for categorical (qualitative) data. Tests whether or not the observed values differ significantly from expected values

Calculated values can be compared to a table of _____ values to see if we accept or reject the null hypothesis and to confirm whether results are statistically _____ or likely due to chance

Significant figures

The first significant figure of a number is the first digit that isn't a zero

The second, third and fourth significant figures follow on immediately after the first (even if they are zeros)

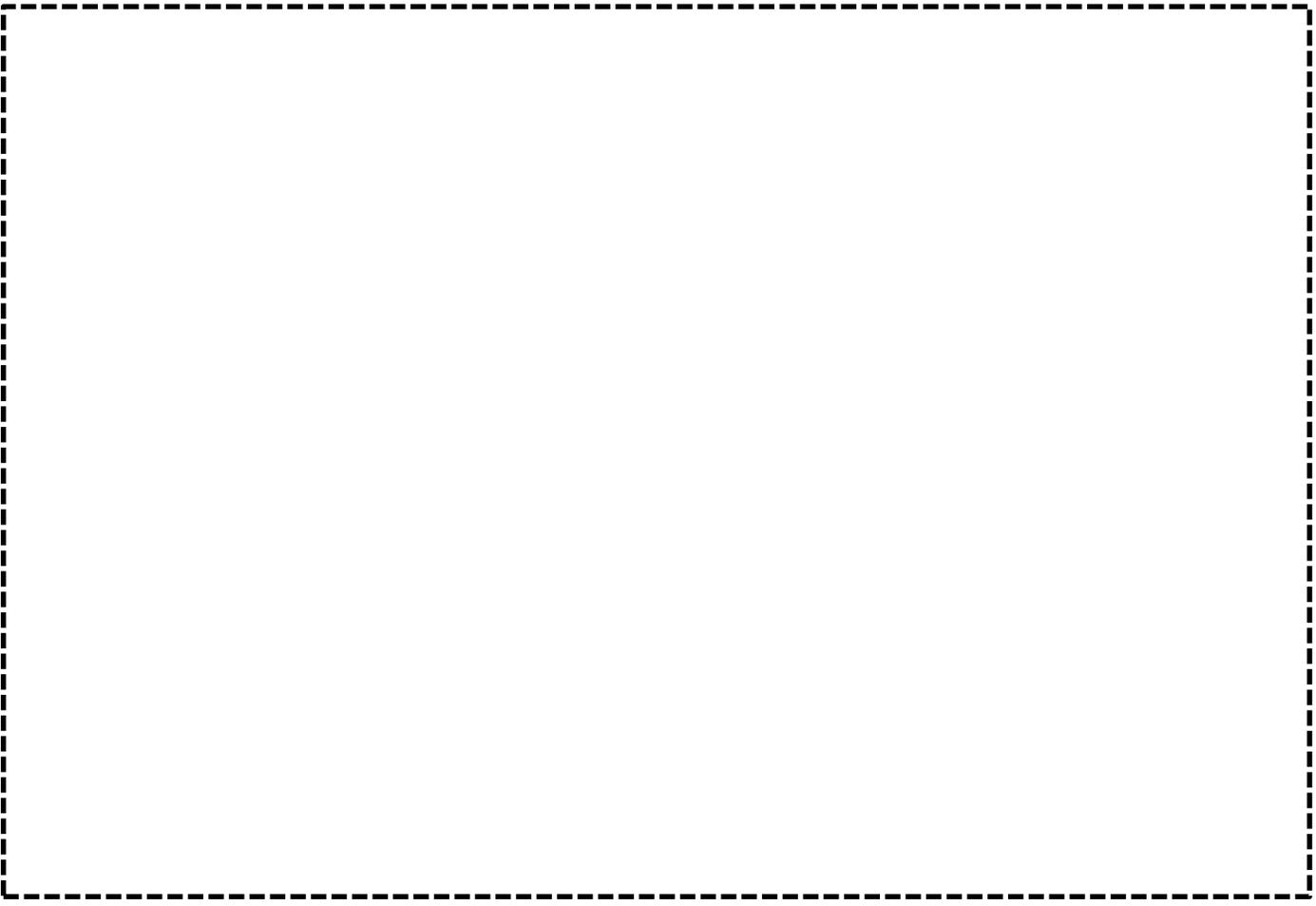
- E.g. 0.6874976 rounds to 0.69 to 2 s.f. and to 0.687 to 3 s.f.
- E.g. 0.05638 rounds to 0.056 to 2 s.f. and to 0.0564 to 3 s.f.

Exam questions often ask for data to be given to **3 s.f.**

You should always give your answer to the lowest number of significant figures used in a table or calculation if the desired number of s.f. is not stated

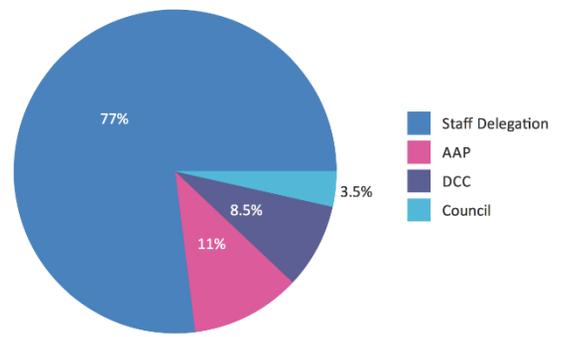
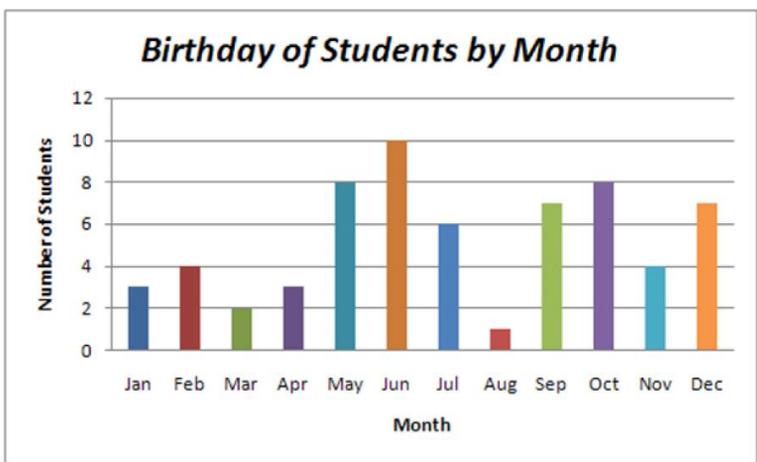
Rounding - if you need to round a number with a recurring decimal (dot above) always round up or down rather than giving the value with a dot above e.g. 6.66[•] becomes 6.67

What makes a good graph?



Presenting data

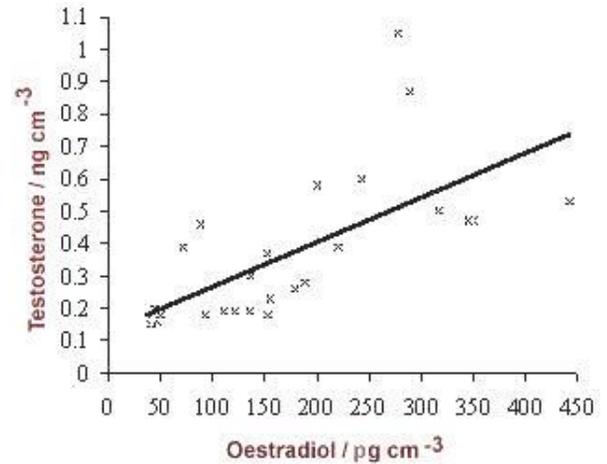
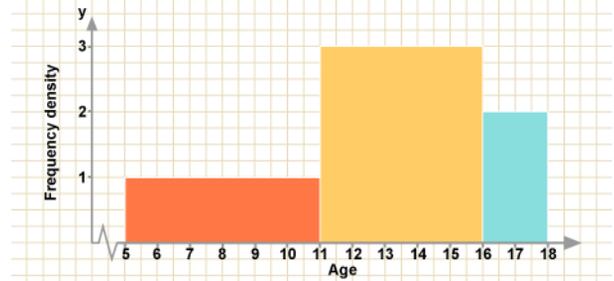
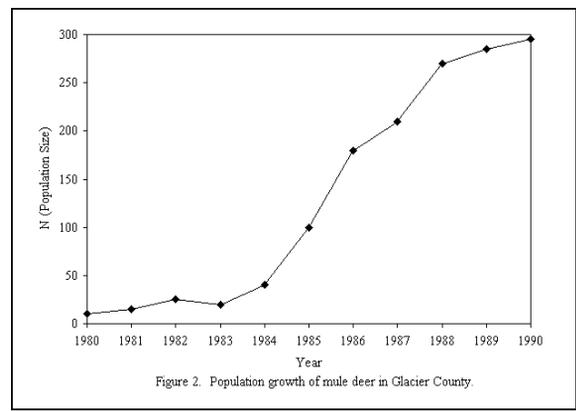
- Qualitative data - descriptive and categorical (non-numerical) e.g. blood group, hair colour
- Discrete data - numerical data that can only take certain values in a range with no overlap e.g. number of rabbits
- Qualitative and/or discrete data are displayed using a **bar chart** or **pie chart**



Presenting data

Continuous data is numerical data that can fall anywhere within a range e.g. height, mass, length of stem

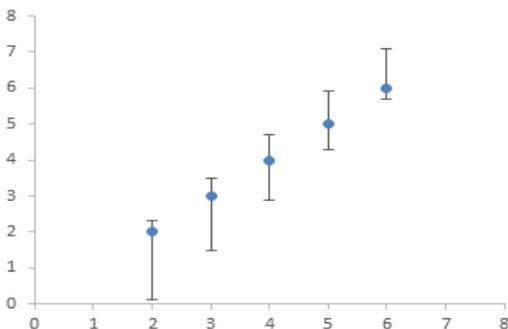
- **Line graphs** - Data on both axes is _____ and the points are joined together
- **Histograms** - display frequency data when the IV is continuous. They look like bar charts but the _____ of the bars represents the frequency rather than height of the bars
- **Scattergraphs** - show how two variables are _____. Both variables must be numerical (continuous data). A line of best fit may or may not be included to show the trend of the data



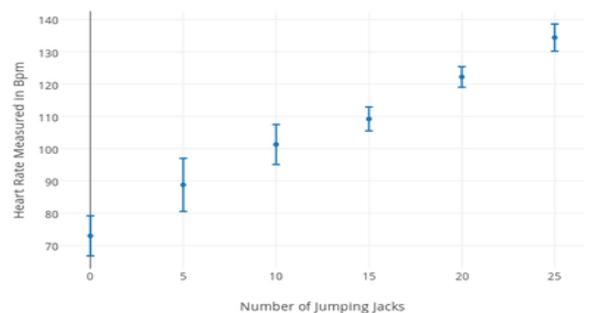
Range bars and error bars

When plotting the mean values on a graph, range bars or error bars may be added to show the variance of the data

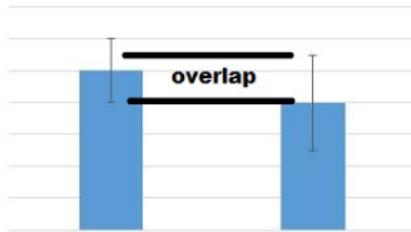
- _____ bars show the smallest and greatest values in the data set and may not be of equal length either side of the mean
- _____ bars are usually plotted using the standard deviation - they are always equal in length both above and below the mean



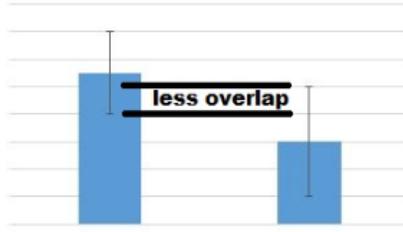
Mean Heart Rate of Participants With Standard Deviation Error Bars



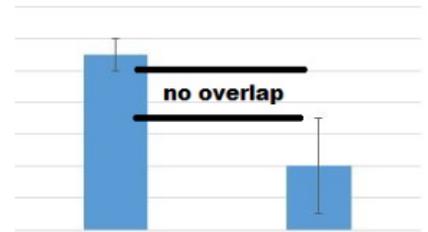
Overlap in error bars



When standard deviation errors bars overlap quite a bit, it's a clue that the difference is not statistically significant. You must actually perform a statistical test to draw a conclusion.



When standard deviation errors bars overlap even less, it's a clue that the difference is probably not statistically significant. You must actually perform a statistical test to draw a conclusion.

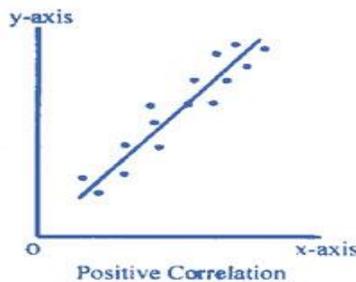


When standard deviation error bars do not overlap, it's a clue that the difference may be significant, but you cannot be sure. You must actually perform a statistical test to draw a conclusion.

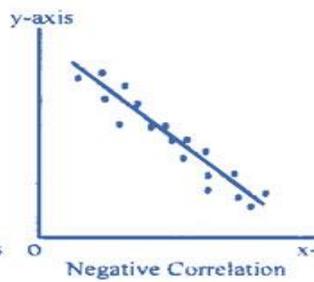
Drawing conclusions from data

Conclusions must be _____ - they must answer the original question

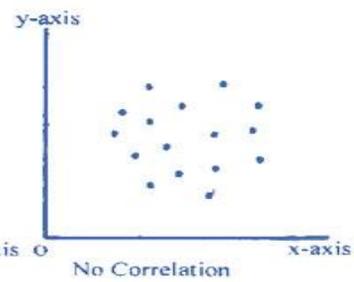
We can often draw conclusions by looking at the correlation between two variables:



As one variable increases, so does the other variable



As one variable increases, the other variable decreases



There is no clear relationship between the two variables

We must be careful not to confuse correlation and causation!

- **Correlation** - _____

- E.g. there are many risk factors linked to coronary heart disease, like stress, age, family history and high cholesterol levels, but no one of these factors alone can be said to cause CHD
- **Causation** (causal relationship) - _____

When drawing a conclusion avoid broad generalisations - be specific. You can only conclude what is shown by the data so don't embellish

Uncertainty in data

Uncertainty is _____.

The results from an experiment won't ever be perfect - there will always be a degree of uncertainty due to limitations in the sensitivity of the apparatus you are using

A _____ sign tells you the range in which the true value lies - we call this the _____ of error

E.g. a 10cm^3 pipette has gradations (divisions) to mark every 0.1cm^3 . If you measure a volume using this pipette you are measuring to the nearest 0.1cm^3 - the real volume could be up to 0.05cm^3 less or 0.05cm^3 more. The uncertainty value of the pipette is $\pm 0.05\text{cm}^3$ and the margin of error is 0.1cm^3

If you are combining measurements from two or more different pieces of apparatus in an experiment then you need to combine their uncertainties

E.g. Measuring 5cm^3 glucose solution with a 10cm^3 pipette = $\pm 0.05\text{cm}^3$

Then measuring 10cm^3 distilled water using a measuring cylinder with 1cm^3 gradations = $\pm 0.5\text{cm}^3$.
Total uncertainty = $\pm 0.55\text{cm}^3$

Errors can be minimised by:

Types of error

- **Random error** - mistakes made whilst taking measurements using low-resolution apparatus (limitations to precision)
 - E.g. You measure the mass of a ring three times using the same balance and get slightly different values: 17.46g, 17.42g, 17.44g
 - How to minimise random error: Take more _____. Random errors can be evaluated through statistical analysis and can be reduced by calculating the _____ of a large number of observations
- _____ **error** - repeated and reproducible inaccurate measurements in the same direction caused by problems with apparatus
 - E.g. The cloth tape measure that you use to measure the length of an object had been stretched out from years of use. As a result, all of your length measurements were too small
 - E.g. The electronic scale you use reads 0.05g too high for all your mass measurements because it is improperly zeroed (calibrated) throughout your experiment
 - How to minimise systematic error: Systematic errors are difficult to detect and cannot be analysed statistically, because all of the data is off in the same direction (either too high or too low)

Evaluating results and methods:

Confidence in conclusions

Deciding on how much confidence you have in a conclusion, statement or claim can only be done after you have _____ the results and method

If the results/data are repeatable, _____ and valid and they back up the conclusion or claim then you can have a high degree of confidence. This can also be supported with the results of a _____ test

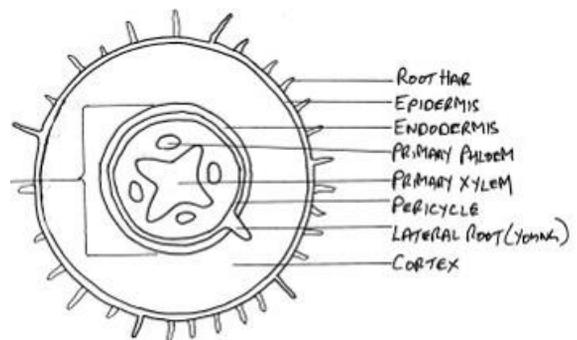
If asked to evaluate a conclusion or claim, or to explain how far data supports a conclusion, make sure you give reasons for both why it is valid **and** why it may not be valid

What makes a good biological drawing?

- Use a **sharp pencil** only. Don't use pens or coloured pencils.
- Use **clear, continuous lines**. A line which encloses a shape, such as a circle, should join up neatly without obvious overlap.
- **Don't use any form of shading**. This includes stippling, cross-hatching and shading.
- Accuracy is paramount. It shows good observation. Pay particular attention to the outlines of structures and to the **relative proportions** of different parts of the specimen. Don't draw what you think you *should see*, for example *text book style drawings*. Draw what you observe.
- Make the drawing **large enough**. If the specimen is a relatively large structure such as a plant or a section of an organ, it should normally occupy more than half the available space on the page. In microscopy, individual cells drawn at high power should be about one to several centimetres in diameter.
- Include a **title** stating what the specimen is.
- Include a **scale** if relevant. If you are drawing from a microscope, it is also useful to state the **combined magnification** of the eyepiece plus objective lenses used when making the drawing, e.g. x100 (low power) or x400 (high power).

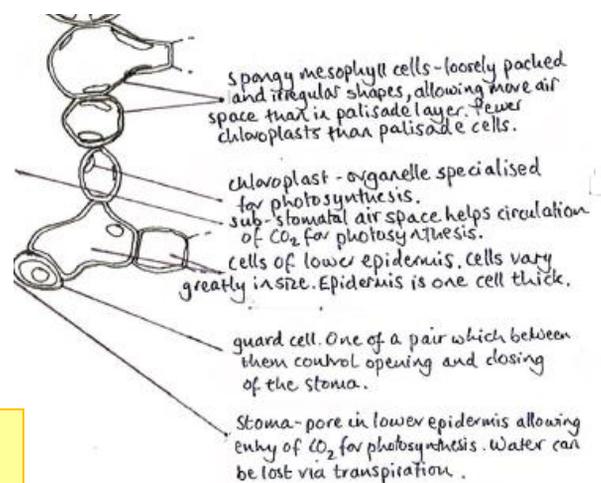
Labelling

- Use a **sharp pencil and a ruler** for label lines and scale bars.
- Label all relevant structures/all tissues
- Label lines should start exactly at the structure being labelled; **don't use arrowheads**.
- Labels should be written **horizontally**, as in a textbook, not written at the same angle as the label line.
- Arrange label lines neatly and make sure they **don't cross over** each other.
- It is visually attractive (though not essential) if the length of the label lines is adjusted so that the actual labels are right or left justified, i.e. line up vertically above each other on either side of the drawing.
- Add a scale bar immediately below the drawing if necessary



Annotating

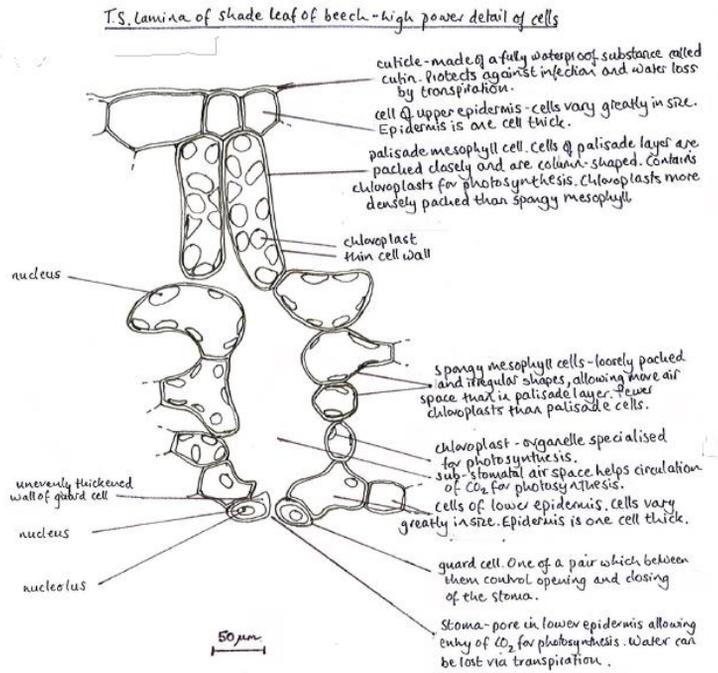
Annotation adds concise **descriptive notes** about the structures labelled on a biological drawing. It is used to draw attention to features of particular biological interest, either **structural** (such as *shape, size, colour, cell contents*) or **functional**



Remember that annotations are different to labels, which only provide **names**

High-power drawings

- The purpose of high power drawings is to show as much **accurate** _____ as microscopy will allow
- Draw only a **few** representative adjacent cells
- **Don't** _____ in nuclei or nucleoli - just draw the outline



What has been done badly/incorrectly in the left half of the diagram? What has been done well/correctly on the right half of the diagram?

