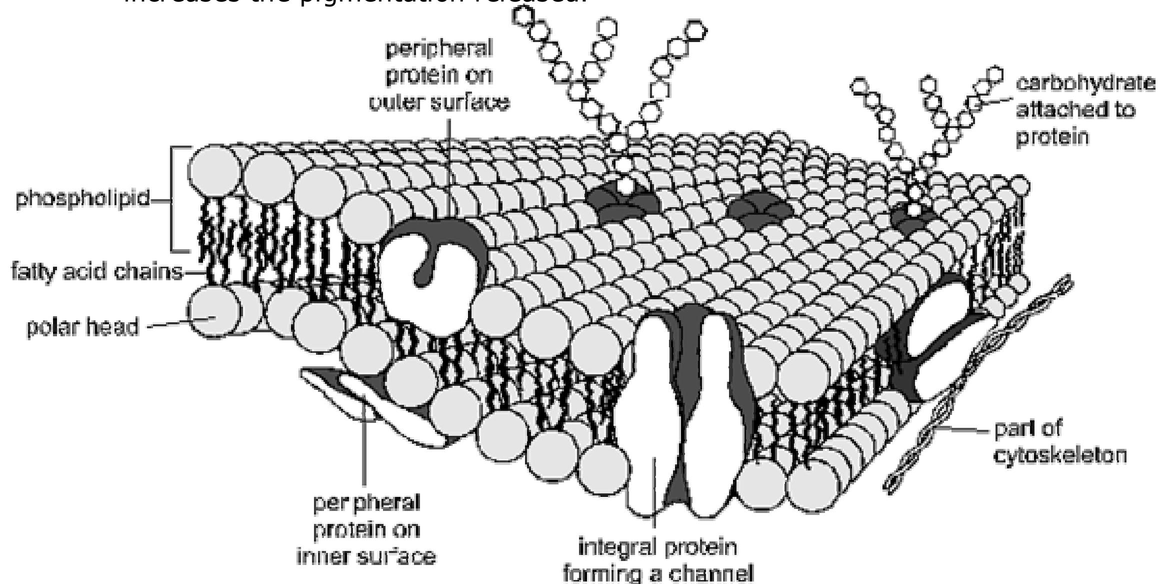
INVESTIGATING HOW TEMPERATURE AFFECTS THE PERMEABILITY OF CELL MEMBRANE

Aim -The purpose of the experiment is to test the effect of increased temperature on the permeability of beetroot cell membrane.

Background information- The cell membrane surrounds all living things and is partially permeable so as to serve as a boundary between cell and environment and control substances that are allowed in and out of the cell. Cell membranes are made up of phospholipids, carbohydrates and proteins.

The phospholipids are arranged in a way that their polar hydrophilic (water attracting) phosphate heads face outwards and their non-polar (hydrophobic) fatty acid tails face inwards. The phospholipids are arranged in a bi-layer. The hydrophobic layers act as a barrier to some molecules.

There are also other molecules which are indented into the phospholipids such as Proteins. Proteins are tertiary structures made up of coiled and folded strings of amino acids which are very strong and held in place by peptide bonds. Proteins are responsible for most of the cells properties and some proteins are involved in transporting substances across the membrane while others are involved in maintaining the cells shape. However at very high temperatures the binds holding the ……. break and thus the proteins lose their structure and stability. This increases the pigmentation released.



In the cells of a beetroot plant, a substance called betalins is found in the membrane vacuoles, which gives beetroot its red colour. Normally the pigments cannot pass through the membranes but at higher temperatures the cell becomes damaged and the betalins will 'bleed' from the cells. I am going to investigate the pigment lost at different temperatures.

Hypothesis- an increase in temperature will lead to more damage to the cell membranes, which will increase their permeability, and therefore allow more of the pigment to be released.

Expected result- the following temperatures will be used to measure the absorbency, 0C, 10C, 20C, 30C, 40C, 50C, 60C, 70C. as using any higher or lower may take up to much time in getting to the required temperature. expect the graph for the results to look as follows::

increasing the temperature will cause the partially permeable membrane of the Beetroot to become damaged and so it will be less rigid. Also I predict that after 40C the proteins in the cell membrane will start to denature as they will reach the optimum temperature. This will increase the permeability allowing more colour to be released. I predict that when I test a small amount of the water which contained the beetroot in the colorimeter, the higher the temperature of the water the higher the reading will be on the colorimeter as less light will pass through.

Apparatus- The following apparatus will be needed in the investigation;

Raw beetroot Preferably the same type and size of beetroot will be needed to make the investigation fair and more reliable
Size 4 cork borer to obtain the beetroot pieces as it will enable me to have pieces and radius of the same size and ensure that the dependant variables are kept the same.
White tile cut down on to this with the knife so that I do not damage the desk or risk hurting my hand
Knife to measure cut the beetroot into 1cm length slices.
Ruler to measure and the beetroot into 1cm length slices.
Water baths I will also need a bunsen burner to heat the water. I feel a bunsen burner is a better option to use than a kettle as I can get it to the required temperature more easily and also because the kettle would have more impurities, whereas I can wash the beaker before hand.
Plastic beaker. A beaker will then be needed to place the water when it is being heated. I will use a 250ml beaker as I can get all the water in instead of having to add more each time.
2 boiling tube racks2 test tube racks which I can place the tubes in.
Crushed ice I will need ice for temperatures below the room temperature.
Boiling tubes I will then need to get 8 test tubes and instead of small beaker as I can place the tubes in a rack so there are more stable and also so that less space is taken up in the desk as the beaker is wider
Thermometer I will also have to use a 0-90 thermometer to take readings of the temperature. I will use a 0-90 C thermometer as the temperatures I need are below this and so there is no point using a larger one. Also it will be easier to read with a smaller scale. Ice will also be needed to get the temperatures lower than room temperature
Colorimeter Colorimeters are very useful tools for obtaining quantitative data by following reactions that involve a change in colour or opacity. They take the guesswork out of matching colours or end points in experiments. Attaching the colorimeter to a datalogger allows you to see the progress of the reaction, and to create a permanent record of the whole experiment. •Datalogging is an extension of normal scientific enquiry techniques. **1 Datalogging improves the validity of the data2 Datalogging removes the need for long periods of repetitive**

data-recording Transmission is not a linear scale, and is normally used when you are:
•following a trend in the reaction
•following a reaction where the concentrations of the products creating the colour change are unknown.
As the transmission scale is not linear, it is not directly related to the concentration of the
chemicals in a solution that create a colour change.

Absorbance is a linear scale. It can be used when you are:
•calibrating the colour change to a known concentration value, for example finding the
concentration of sugar in a sample.

Cuvettes I will use a curvette to put the solutions in; I will place 2cm in each curvette using a 2cm pipette so that each has the same volume and so it is far more reliable to compare the results. When using the colour meter I will measure the absorbency of the distilled water and then compare this to the different beetroot concentrations. I will then need to measure the solutions against a colorimeter I will use a colorimeter rather than a chart as the sensor is sensitive to light and is in the same position all the time which will give far more accurate measurements of absorbency than interpreting using a scale. Cuvettes are designed to be optically identical to each other. Many have a small mark on them so you can make sure the same faces are always lined up with the light source and sensor. If there is no markalready present, you can add a small mark at the very top of the cuvette, where it does
not interfere with the passage of light through the test solution.
Stopclock A stopwatch will also be required to measure the time for each experiment, so that I get a fair and more precise time for each, instead of relying on a watch or clock.
Distilled water I will use distilled Water, as this will ensure a more accurate result as normal tap water has chemicals added which can affect the experiment.
Pipette For transferring the water in to a measuring cylinder a 5cm pipette will be used as the beaker could be very hot to hold and transfer the water. Also I can get more accurate measurements with the pipette. I will transfer the water into a 50ml measuring cylinder as I may not get exactly 5cm each time in the pipette and so measuring it before would be more accurate.
Small measuring cylinders
forceps whilst transferring the beetroot in to the water so the beetroot does not come into contact with the skin and so that I do not involuntarily affect the permeability of the cell membrane.
500ml beaker so that the beaker with the distilled water can be placed in this.
tripod and a **gauge** to place the beaker on whilst it is getting heated, so direct heat does not come in contact with the glass, as it could get very hot.
heatproof mat will need to be placed under all this to keep the Bunsen burner on something safe and also so that it remains stable and there is less risk of it falling over.**goggles** and a **laboratory coat** at all times to ensure safety and reduce the risk of any accidents. Also to reduce staining as the beetroot juice

<u>Method-</u> start by wearing a laboratory coat and goggles at all times to ensure safety to the eye body. then wash my hands so that if they have any substances they do not affect my experiment by coming into contact with the beetroot or water. then obtain all the equipment needed for the investigation so that the

procedure is orderly and I do not have to look for things in between the experiment.

using a cork borer and pushing down onto a white tile cut out 8 cylindrical discs of beetroot. Next I will measure 1cm length of beetroots and cut out 8 pieces using the knife and cutting down onto a white tile. I will then get 8 test tubes for all the different temperatures and wash and dry the tubes so that no substance remains as this could affect the results. Then I will place the tubes in a test tube rack so they are on a flat surface and so it is easy to transfer the right amount of liquid. Using a size 4 cork borer and a knife, ruler and white tile to aide me I will cut 8 identical pieces of beetroot which are 1cm in length. I will use the same diameter corer and cut all the beetroots to the same length so that the surface area of each beetroot is similar and that the dependant variable is kept the same. I will then using tongs to place the beetroot pieces in a beaker of distilled water and leave overnight so that excess dye is washed away. Because the beetroot has been cut part of the cell membranes will be broken and therefore the excess dyewill leak out. By leaving them overnight it will ensure that the results are reliable.

I will get the normal distilled water which will be at room temperature at about 34C and place it in a beaker. I will then add ice to a larger beaker and place the water beaker in this. I will work by starting with the 30C and then working down to 0C, adding more ice if needed. I have decided to carry out the investigation this way so that I can get the required temperature the most quickly (from room temp) so I do not have to wait too long. For the temperatures above room temperature i.e. 40-70C I will start with 70C degrees and work my way down. This is so that after I have heated the water, I will not have to heat it again as it will cool so I will have the required temperature. This way I can make full use of the time.

I will then get the 5cm pipette and use it to transfer water into a measuring cylinder. I will measure 20cm of water I have decide to use 20cm because I feel that it is enough to cover the beetroot and a suitable volume to measure for just 20 minutes.

Next I will get forceps to transfer the beetroot into the test tube and start timing as soon as it is dropped in. I will time for 20 minutes to allow time to carry out each experiment in the time available and also that I carry the experiment out for a reliable amount of time. I feel that any time less than 20 minutes would not be sufficient. I will then stop the experiment after 20 minutes and use a 2cm pipette and place the solution in to a curvette to measure the absorbency. I will first measure the absorbency of distilled water by placing it into the slot. Test the logger before use with a simple sensor (e.g. temperature) that does not require any special set-up procedure. This can confirm that the equipment is working,and helps you check that you understand how to use the equipment before you collect your real data.I expect the reading to be 0. Then I will press r on the colorimeter and place the solution in to compare it. I will repeat this experimental procedure for all the temerparures below room temperature adding more ice when required.

For temperatures above the room temperature i.e. 40C, 50C, 60C, 70C I will need to heat the distilled water. I will heat the water above 70C work my way down the measurements. I have decided to this as I can the next temperature as it is cooling from the previous one instead of re-heating. Thus I will place the beaker on the tripod, making sure that there is gauze below it and a heatproof mat under

all this. When lighting the bunsen burner with a matchstick I will make sure that the hole is on so that the flame is visible, thus reduce the risk of an accident. I will use a thermometer to measure the temperature and once the solution is heated I will once again use a pipette to transfer the water in to a measuring cylinder. I will start transferring the water slightly above the required temperature so that by the time I have transferred it all, it will have fell to the required temperature. After measuring 20cmand checking that the water has fallen to the required temperature I will transfer it into the test tube. I will again use forceps to drop the beetroot into water and start timing as soon as the beetroot is in. I will measure the absorbency as before. I will then reduce the heat of the burner and measure each of the remaining temperatures following the same method. I will then wash my hands at the end of the experiment just to make sure that if any particles got to my hand they are removed.

I am going to use a 10C space for the temperature as I think that using five would be too small to distinguish trends, and more than that would also prove to be difficult.

Before I test the samples of water I will first test the distilled water and use it as a control to see the difference in water colour. Using a pipette I will transfer 2cm of water from the tubes into the cuvettes. I will set the colorimeter to 0% which will give a blue/green colour. I will then take a reading of the colour absorbency in the order that I started. I will keep the colorimeter on 0% absorbance and repeat for the rest of the temperatures.

I will draw up a graph of the results so that I can clearly distinguish the trends and that accurate conclusions can be made.

Plotting a calibration curve
To relate readings of absorbance to actual concentrations, you need to make a calibration curve. Make up a series of solutions of known concentration, and take readings of the absorbance values of these solutions. Plot absorbance values against the concentrations of these standard solutions. You can then use this calibration curve to convert absorbance values from your experiment to concentrations. If you are doing a rate experiment, then the absorbance is directly related to concentration, so a graph showing the change in absorbance over time is a genuine rate graph.

Fair testing- To ensure that the test is fair so reliable and accurate results are obtained I will make sure the following is done:

I have considered how to keep factors that affect the rate of movement across membrane constant and only change the independent variable. The independent variable in my investigation will be the temperature, as this will be constantly getting higher each time. Thus the dependant variable will be the pigmentation released. All the other variables will be kept constant as otherwise it could affect the results. For example the type of the beetroot should be the same; if not then

this could affect what temperatures the membrane denatures because of the different prior environments of the beetroot.

I will make sure that I wipe the test tubes after rinsing them so any excess water is removed.
I must also ensure that the same volume of water is placed in each of the tubes as a higher volume in one tube could affect the diffusion. Thus I will measure the required volume after heating the water. This is because if I measured it first then a lot would evaporate with the heat and the investigation would not be fair.

I will try to move the test tubes as least as possible in between the experiments so I do not speed up any reaction involuntary. Furthermore I will work on a flat surface, so as to make sure there is the right amount of volume and when transferring the water from the pipette to the test tube, I will try not to spill any.

I will use the same beetroot for the whole experiment as using a different beetroot may affect the results. This is because a particular beetroot may contain more betalins which could result in a faster rate at which the dye is released. This would not make the experiment a fair test.

ame sized cork borer (number 4) to ensure that all the beetroot pieces are the same width in diameter. A larger surface area will cause faster diffusion as more of the membrane will be exposed. (Ficks law)

volume of water in each experiment must be consistent as more or less water could affect the rate of movement across the cell membrane.

time the beetroot are left in the water. If they were all kept to different times then the results would not be reliable enough to draw up a conclusion and say if the results agree with the hypothesis.

The independent variable will be the temperature of the water the beetroot pieces will be placed in. These temperatures will vary from 7°C to 73c.

I will make sure before using the boiling tubes that they are clean and if not they are properly cleaned and dried so as not to contaminate the water with anything that is left behind in the tubes. This is because if the water got dirty this could possibly affect the results.

I will make sure than once the beetroots are in the boiling tubes I do not keep taking them out again or that I do not shake the tubes but leave them in the racks. This is because by extracting the beetroot or shaking the tubes it may speed up or slow don't the amount of dye that is released.

Finally when using the calorimeter I must make sure that each sample is compared against the distilled water, and not another sample.

Safety- Safety is very important in any scientific experiment. Before I start the experiment I will wear goggles and a laboratory coat so any risk of accidents is reduced. Also I will tie back any lose clothing and hair as they could come in the way of the experiment and cause an accident. I must make sure that I do not eat/drink/chew during the experiment as the products could be contaminated.

Also I will wash my hands before and after the experiment so any substances are removed, and do not affect the investigation or cause harm to me.

Whilst using the cork borer and knife I will make sure that I always cut down onto a tile so that I reduce the risk of an accident to my hand.

When heating the eater with the Bunsen burner I will have to be very careful with the fire and make sure that nothing is in the way. Also I will keep the flame visible so that I can see and be aware of the flame. After boiling the water in a kettle I will make sure that I pick the kettle up by the handle and I do not touch the outercase as it will be very hot.

I will take extra caution whilst handling glassware as it could easily be smashed. Because the beaker could be very hot at times I will use a pipette to transfer the liquid so that I do not have to lift the beaker.

I will make sure that the desktop I am working on is clean and has no obstructions, all stools, books and belongings and unwanted equipments I will put away as they could cause accidents. I will work on a flat surface to minimise the occurrence of an accident, if there are any spillages/ accidents I will clean/report them immediately.

I know how to use equip

Ethical issues- In this experiment an edible ingredient is going to be used. However I must make sure that because it is being used for the investigation that it is not consumed prior or after the investigation. Consuming it after the experiment could cause harm to the body.

Results- I have recorded the results in a table as it is more systematic and so easier for me to interpret and distinguish any trends. Also it will be easier for me to identify any errors or anomalies. **What makes a good table?**
A good **table** of results should have:

Temperature C	% Absorbency
0C	0.00
10C	0.00
20C	0.10
30C	0.17
40C	0.19
50C	0.23
60C	0.30
70C	0.34

•an informative title
•units in headings, not next to the numerical data.

A **graph** is a visual representation of data. Numerical data should be presented in a way that helps in the identification of any trends or patterns in the data.
more easily seen in a graph than in a table, and anomalies more easily identified.

Line graphs
A **line graph** can be used to show relationships in data which are not immediately obvious from tables (Figure 4).
When drawing any type of graph with axes, remember always to include:
•an informative title
•sensible scales on each axis, if appropriate
•labels on both axes
•units on both axes, if appropriate
•a key.

The general trend of the results is obvious, as the temperature is increased the beetroot let out more color, thus the water was darker. This backs up my hypothesis in which I stated that the more heat added, the more dye will be released as more damage is done to membranes within the cell. And so the permeability of the cell membrane is directly proportional to the temperature. This is because as temperature rises the movement of the phospholipids increases allowing more of the dye to move across the membrane.

I can identify that the results overall follow a pattern and that as the temperature increases so does the absorbency. The biggest difference in absorbency was between 20 and 30C from 0.10 to 0.17 and 50C to 60C, from 0.23 to 0.30.

From 0ºC to 20ºC, there's a slight increase in the average percentage of absorbeny. This is because when water freezes, it expands and this makes the cell membrane burst. The bursting results in more pigments leaking.

In general between 20ºC and 60ºC, as the temerature increases more pigments are leaking out thus the darker the colour. This is because the cell becomes less permeable.

Spearman's rank correlation
A Spearman's rank correlation test will tell you whether two variables are correlated, i.e. whether a change in one variable is accompanied by a change in the other variable. It will tell you whether the relationship is a positive correlation (both go up together) or a negative correlation (one goes up as the other goes down) and the strength of any correlation.
For any Spearman's rank correlation you do, the null hypothesis will be:
There is no correlation between the two variables.
You can use this test on interval or ordinal data and the data will always be in matched pairs. This means that one piece of data is associated with one other piece of data only, for example, if you were measuring temperature and water depth, each temperature measurement would belong with only one specific depth measurement (both taken atthe same place). If you mixed the matched pairs up the data would be meaningless.
Examples of where you might use Spearman's rank correlation:
•Is there a correlation between temperature and height up a mountain?
•Is there a correlation between mouse density and proximity to a cheese factory?
•Is there a correlation between current speed and mayfly nymph abundance?
•Is there a correlation between cigarette smoking and low intelligence?

•Is there a correlation between species diversity and height on the seashore?

Using Spearman’s rank correlation
Use a Spearman’s rank correlation test when you’ve got two variables and you want to see if they are correlated. Your calculated Spearman’s rank correlation coefficient (rs) lets you test to see if you’ve got a correlation between two variables, i.e. if a change in one variable is accompanied by a change in the other variable. It also measures the strength
of any correlation. You need at least eight pairs of data in matched pairs. Being in matched pairs means that one piece of data is associated with only one other piece of data. For example, if you were measuring speed of hair growth at different ages, each hair growth measurement would belong with only one age measurement. If you mixed the matched pairs up the data would be meaningless.
Types of correlation
Positive correlations
Figure 1 shows the (fictional) relationship between amount of beer drunk and temperature. It seems that the hotter it gets, the more beer is
drunk. As one variable goes up so does the other. This is an example of a perfect **positive correlation**. If you calculated rs for these data you would get a value of _1 (plus one). Rarely will you get exactly _1 but strongly positively correlated variables will usually give you a value approaching
_1.
Negative correlations
Figure 2 shows students’ happiness quotient plotted against the number of hours spent doing statistics. Extraordinary as it may seem, it would appear that the longer you spend doing statistics the more unhappy you become. As one variable (time spent doing stats) goes up, the other (happiness quotient) goes down. This is
a perfect **negative correlation**. If you calculated rs for these data you would get a value of −1 (minus one). Rarely will you get exactly −1. Strongly negatively correlated variables will usually give you a value approaching

Conclusion-I found out that overall as the temperature increased the colour released was darker, i.e. more pigmentation was released. This agrees with my prediction and shows that at lower temperatures the colour did not leak as much but at higher temperatures the cell loses its permeability. This is because by increasing the temperature the structure of the membrane changes as the proteins loses their tertiary structure and begins to denature. This is because the interactions of the bonds that hold the protein in its structure are weak and easily altered by physical changes. This tertiary structure will begin to breakdown the proteins and lose the ability to control what passes through and so more betalins will pass through and so there will be a greater pigment loss. As a result the lipid biayer may also be begin to break and larger gaps start to form between the phospholipids molecules and more pigments (betalins) can move into and out of the cell.

The line of best fit on the graph is shows that the temperature is proportional to the light absorbency. However it is not a strong positive correlation. For temperatures below 45C there was little difference between the temperatures. However after 45C there is a huge difference between. The temperatures. I think this is because….

The results in the graph indicate that overall as the temperature increases the permeability of the cell membrane decreases. The graph has produced a curve rather than the expected straight line. I think that this could have been because many of the experiments had to be reheated and so it affected the membrane.

I feel that the graph can support a valid conclusion as it agrees with my prediction. The absorbency figure goes up steadily and this shows that there was a relationship between the temperature and the membrane permeability. I did not also have anomalies, which I think make the results more reliable.

Although my results seem valid I acknowlede that they are not very relaible as I only have one set of resullts. Consequentrly I cannot check the precision of the results or the degree of accuracy I do not have other set of results to compare with. However the above results on their own do look precise with a positive correaltion.

Although the results are good enough I understand that they are not completely accurate. Most importantly I know that because we did not have the availability of water baths it was very difficult to maintain the right temperature. Consequently although I heated the temperature slightly above what was needed to allow time for it to cool the temperature fell very quickly. As a result I had to (re)heat the solutions, including the ones with ice. Also as a result of this I may have moved some test-tubes more than others which could have affected the permeability of the membrane.

Another error could have been my visibility. I understand that because I was wearing goggles it could have slightly obscured my view. Consequently when checking the temperature with the thermometer, whilst measuring the volume and when stopping the clock after 20 minutes I could have misread the measurements/temperature/time. Thus my reaction time when stopping and even starting the clock each time could have been faster or slower giving unequal times. Another possibility could be that because I used the same thermometer in between the experiments it could have transferred some particles from one to another and so affect the reliability. Furthermore when placing the curvettes in the colorimeter the time it took to collect the solutions and place them in the slot could have varied, which in turn could have affected the results.

Evaluation- Overall the procedure used was suitable, however to obtain more reliable and valid results changes/improvements could be made.

If a trail run was carried out, it could have been used to recognise weaknesses in the procedure so that the actual experiment gave more reliable results and fewer errors.

Each temperature was only carried out once, to get more reliable and accurate and valid results could have carried it out at least 1 more time, or get another students set of results and combine them to get an average. could have obtained an average

When using the cork borer to obtain the beetroot pieces the samples were not obtained from the same area. It is important to take the pieces from a similar region of the beetroot as each type of tissue will have a different water potential and so it is important to use the same.. This could affect the results as different parts of the beetroot could contain more betalin than others, which would mean that that the more diffusion would happen in the beetroot pieces which contained more betalin when heated. By making sure that each beetroot was cut out of the same place in the beetroot it would ensure a more accurate set of results as all the pieces would contain the same amount of dye.

When using the cork borer although I used the same size ones, it is a possibility that I may not have got the same volume of shape each time. Also when measuring the 1cm pieces and cutting with a knife, there is bound to have been some even slight difference. As an alternative to using a ruler to measure the beetroot pieces I could have used another piece of equipment such as vernier clips to give far more accurate measurements. eyepiece graticule. For small items, a standard ruler will give anaccuracy to 1 mm; vernier callipers will give an accuracy to 0.1 mm. Larger objects or distances may require a tape measure, which will have an accuracy that depends on the scale.

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During the experiment I had goggles on which could have obscured my view. I understand they are needed for safety; nevertheless they could have affected my visibility when measuring the volumes and identifying the temperature as well as stopping the timing. Instead of relying on a stop clock, an automatic clock or timer could be used that would indicate when 20 minutes were over. My eyesight could have contributed to some inaccuracy. Because I did not use an automatic stop clock it could be possible that I stopped the stopclock late. This could mean that the beetroot pieces were in for longer than 30 minutes. To avoid this next time I should use an automatic stopclock.

Also whilst handling the beetroot pieces I did not take great care to ensure that I handle them with care. It could be possible that when placing them in the tubes I just threw them in which could have caused damage to the membrane. This could possibly cause more of the dye to leak out.

Also the experiment was only carried out on a small scale. To obtain better results I think the temperature gap between each tube should have been 10C so that the trend and point where the membrane denatures can be distinguished more easily. However I feel that my results show fairly well how a membrane functions under temperature change.

The other difficultly was getting the right temperature. Because no water baths were available I used a kettle to heat the water. Water baths would have been much more reliable and sensible to use as the bath could heat each water to the required temperature as they are thermostatically controlled. The problem with using the kettle was that it can only heat water till boiling point and so that meant I had to add tap water or ice to get the required temperature. Also the kettle can contain many impurities which I was not aware of. When conducting this experiment next time I will make sure that if water baths are not available I will use a Bunsen burner to heat the water as this way I can get the required temperatures more easily.

I realise that a systematic error in the procedure was that I used the same thermometer for each temperature. This could have transferred some particles. If available, water baths would be a better option to use.
I could have used Electronic balances

I would also use a smaller range of temperatures, starting with 10 to about 50,

Dropping pipettes
Pasteur pipettes (also called dropping pipettes) are designed to give a constant volume in each drop, although they are not very accurate. They should be held upright (rubber bulb at the top) during use. To get a drop to form, squeeze v ery gently on the rubberbulb. If you are too enthusiastic several drops will come out. Be very careful using Pasteur pipettes with hazadous solutions. If you take the end of the pipette out of the solution before you release the bulb you will find that a little bit of air gets drawn intothe end of the pipette. That will help stop the liquid in the pipette leaking out. Do notlay Pasteur pipettes down flat nor tip them upside down, as this lets the solutions runinto the bulb. This can lead to the solution getting contaminated, and to the rubber in
the bulb perishing.

Bibliography-
To ensure results are valid apparus and experimental procedure will be selected and used in a way that will ensure that the reulst measure what hey are meant to. E.g if eausred to earlythe results would not be valid as not measuring exact thing
e.g if stiuff nt controlles or taken into accout not valid
precision-saccuracy of repeated measurements
precison involves choice of apparus and and skill used
but not necessary accurately e.g faulty equp give precise but not accurate e.g dirty curvette appropriate accuracy equip
reliable-repeatable
valid-precise and repeaale
errors-systematic values differing from the true value by the same amount
random-values ying equally above or below true value
systematic-clorometer micrsocpe personal bias
random-not standard procesure increase reliability
not carelesnees
give examples in work
size of errors
depend
indept
control variables
hyp if this is increased (indep) thenthis wil derease (dep)
what will I measure
how controls others
hiw many repeats?
Actually test hyp?
How present and analyse?
Have table ready so easy o reord dats
In method you shouldinclude measurements
How changes/recorded chnges of indep
How made sure only one cond changedand how controlled others
What measured
What done to make sre reulst-valid and reliable
Safety/ethicl u did
Tjis equop over that equp

Improve reliability-large replicates and results that vary consirable should be discounted or repatecalculate the meand
Datlogger-reduce random errors e.g if wanes for long time reduce subjectivity and indiuce bjectivity
Greater the variationof replicates the greater the degree of error error bars
Precision, reliability and validity of a set of results requires apparatus to be chosen and
used appropriately.