Personal engagement

mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1	**The evidence of personal engagement with the exploration is limited with little independent thinking, initiative or insight.** The justification given for choosing the research question and/or the topic under investigation does not demonstrate **personal significance, interest or curiosity.** There is little evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation.
2	**The evidence of personal engagement with the exploration is clear with significant independent thinking, initiative or insight.** The justification given for choosing the research question and/or the topic under investigation demonstrates **personal significance, interest or curiosity.** There is evidence of **personal input and initiative** in the designing, implementation or presentation of the investigation.

Exploration

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1-2	The topic of the investigation is identified and a research question of some relevance is **stated but it is not focused**. The background information provided for the investigation is **superficial** or of limited relevance and does not aid the understanding of the context of the investigation. The methodology of the investigation is only appropriate to address the research question to a very limited extent since it takes into consideration few of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of limited awareness of the significant **safety,** ethical or environmental issues that are **relevant to the methodology of the investigation***.
3-4	The topic of the investigation is identified and a relevant but not fully focused research question is described. The background information provided for the investigation is mainly appropriate and relevant and aids the understanding of the context of the investigation. The methodology of the investigation is mainly appropriate to address the research question but has limitations since it takes into consideration only some of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of some awareness of the significant **safety,** ethical or environmental issues that are **relevant to the methodology of the investigation***.
5-6	The topic of the investigation is identified and a relevant and fully focused research question is clearly described. The background information provided for the investigation is entirely appropriate and relevant and enhances the understanding of the context of the investigation. The methodology of the investigation is highly appropriate to address the research question because it takes into consideration all, or nearly all, of the significant factors that may influence the relevance, reliability and sufficiency of the collected data. The report shows evidence of full awareness of the significant **safety,** ethical or environmental issues that are **relevant to the methodology of the investigation***.

Analysis

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1-2	The report includes **insufficient relevant** raw data to support a valid conclusion to the research question. Some **basic** data processing is carried out but is either too **inaccurate or too insufficient to lead to a valid** conclusion. The report shows evidence of little consideration of the impact of measurement uncertainty on the analysis. The processed data is incorrectly or insufficiently interpreted so that the conclusion is invalid or very incomplete.
3-4	The report includes relevant but incomplete quantitative and qualitative raw data that could support a simple or partially valid conclusion to the research question. Appropriate and sufficient data processing is carried out that could lead to a broadly valid conclusion but there are significant inaccuracies and inconsistencies in the processing. The report shows evidence of some consideration of the impact of measurement uncertainty on the analysis. The processed data is interpreted so that a broadly valid but incomplete or limited conclusion to the research question can be deduced.
5-6	The report includes sufficient relevant quantitative and qualitative raw data that could support a detailed and valid conclusion to the research question. Appropriate and sufficient data processing is carried out with **the accuracy** required to enable a conclusion to the research question to be drawn that is fully **consistent** with the experimental data. The report shows evidence of full and appropriate consideration of the impact of measurement uncertainty on the analysis. The processed data is correctly interpreted so that a completely valid and detailed conclusion to the research question can be deduced.

Evaluation

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1-2	A conclusion is **outlined** which is not relevant to the research question or is not supported by the data presented. The conclusion makes superficial comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **outlined** but are restricted to an **account** of **the practical** or **procedural issues** faced. The student has **outlined** very few realistic and relevant suggestions for the improvement and extension of the investigation.
3-4	A conclusion is **described** which is relevant to the research question and supported by the data presented. A conclusion is described which makes some relevant comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **described** and provide evidence of some awareness of the **methodological issues*** involved in establishing the conclusion. The student has **described** some realistic and relevant suggestions for the improvement and extension of the investigation.
5-6	A detailed conclusion is **described and justified** which is entirely relevant to the research question and fully supported by the data presented. A conclusion is correctly **described and justified** through relevant comparison to the accepted scientific context. Strengths and weaknesses of the investigation, such as limitations of the data and sources of error, are **discussed** and provide evidence of a clear understanding of the **methodological issues*** involved in establishing the conclusion. The student has **discussed** realistic and relevant suggestions for the improvement and extension of the investigation.

Communication

Mark	Descriptor
0	The student's report does not reach a standard described by the descriptors below.
1-2	**The presentation of the investigation is unclear, making it difficult to understand the focus, process and outcomes.** The report is not well structured and is unclear: the necessary information on focus, process and outcomes is missing or is presented in an incoherent or disorganized way. The understanding of the focus, process and outcomes of the investigation is obscured by the presence of inappropriate or irrelevant information. There are many errors in the use of subject-specific terminology and conventions*.
3-4	**The presentation of the investigation is clear. Any errors do not hamper understanding of the focus, process and outcomes**. The report is well structured and clear: the necessary information on focus, process and outcomes is present and presented in a coherent way. The report is relevant and concise thereby facilitating a ready understanding of the focus, process and outcomes of the investigation. The use of subject-specific terminology and conventions is appropriate and correct. Any errors do not hamper understanding.

*For example, incorrect/missing labelling of graphs, tables, images; use of units, decimal places. For issues of referencing and citations refer to the "Academic honesty" section.

Biology IA

Research question:
Is there a significant difference in the claw and carapace lengths of male porcelain fiddler crabs (*Uca annulipes*) at the fore mangrove compared with the back mangrove?

The "fore mangrove" is considered as the area directly adjacent to the low waterline of the river in the mangrove forest, whilst the "Back mangrove" is an area further in towards the land in the mangrove forest. This location was approximately 35m inland from the waterline for this experiment.

Background information:
Pulau Tioman is a Malaysian island in the South China Sea, with a latitude of only 2.8 degrees north[1]. With it being so close to the equator, it has a tropical rainforest climate with lush mangrove forests as well as coral reefs. I have carried out this experiment in the mangrove forests of this island studying male *Uca annulipes*, which are also known as porcelain fiddler crabs. These crabs are detritivores that sift through sand in order to find sedimental detritus, left behind by the receding tides[2]. The males of this species have one enlarged claw that is used to attract females of its species, where larger claws are considered to be more attractive. These fiddler crabs can be found in the mangrove both next to the river and away from it, and I have decided to look for differences in claw and carapace size depending on the distance from the river. Distance from the river is an abiotic factor that could potentially affect the claw and carapace sizes of these crabs, which is the independent variable of this experiment.

Hypothesis:
The location that is further away from the river (Back mangrove) will have male porcelain fiddler crabs that are larger in both carapace size and claw size compared with the location that is adjacent to the river at low tide (Fore mangrove). Since it takes some time for the rising tide to reach the back of the mangrove, and the back gets uncovered first by the receding tide, crabs at the back mangrove will be spending a larger proportion of their time on the surface compared to crabs at the fore mangrove. This might allow them to look for food for a longer time, resulting in larger claw and carapace sizes.

Personal engagement:
When we were given a tour of the mangrove on the day we arrived on Tioman, I saw a large number of fiddler crabs by the first river we crossed. However, these crabs were also present a good distance into the mangrove forest, far away from the river. This made me wonder if these crabs located so far away from the river got the same amount of resources available to them, such as food and area for habitat. I thought that a good way to look at these factors was its carapace size, as organisms tend to be larger the more food and space they have available to them. However, I thought that looking at just its carapace size would not be sufficient, so I have decided to limit the crabs I measure to males, and also measure the length of their iconic giant claw, which they wave around to attract females and intimidate other males. Since this claw is only useful for attracting females, only crabs that have access to extra food and space on top of the amount they need for survival will be able to spend their resources growing it. By

[1]"Pulau Tioman, Malaysia." Geographical Names.
[2]"Fiddler Crab." Wikipedia.

measuring claw sizes in conjunction with carapace sizes, I will be able to have a better idea of the amount of resources these crabs have available to them. During the actual data collection, I have encountered many difficulties due to the crabs being harder to catch than expected, but I have managed to collect all the required data despite staying at the location for longer than expected.

Independent variable:
Distance from the river at low tide in the mangrove (Front & Back mangrove)

Dependent variable:
Length of the larger claw on male porcelain fiddler crabs (mm), length of its carapace (mm)

Controlled variables:
-Gender of the crab
Only male fiddler crabs are captured and measured

-The claw that is measured
The larger, enlarged claw is measured

Variables that could not be controlled, but were monitored:
-Vegetation in the area
Plants such as mangroves or seaweed that could be present in the area

-Other animals in the area
Organisms such as other species of crab, or animals that prey on the fiddler crab

-Temperature of the area

Equipment:
-Vernier caliper x1
-25m measuring tape x2
-1m x 1m quadrat x1
-Random number table for 0-25 x1

The uncertainty on the caliper is considered as ±0.10mm, as although it is able to measure to the nearest 0.02mm, the claws of the caliper may not have been aligned exactly with the claw due to difficulty in accurate measurement of the claw.

Method:
1. Set up a 25m x 25m sampling grid at a location adjacent to a river at low tide with fiddler crabs present with two tape measures. This location is the "Fore mangrove", which is the side of the mangrove that is adjacent to the river. Record any qualitative data observed.
2. Using a 0-25 random number table, find a coordinate within the sampling grid and place the bottom left hand corner of a 1m x 1m quadrat at that location.

3. Pick up and measure the length of the claw and the length of the carapace (does not include legs) of any male porcelain fiddler crabs (*Uca annulipes*) present within the quadrat using the Vernier caliper. Only males have an enlarged claw, so this feature can be used to distinguish males from females. There may be species of orange fiddler crabs (*Uca vocans*) in the area as well, which have orange pimply claws, so make sure not to measure these. The features of the porcelain fiddlers that are being investigated include: a square-like body, white or pink pincers, and a dark body with white stripes[3]. Record your data.
4. If there are any crab holes with small balls of sand around it within the quadrat, there is a possibility that there is a crab inside the hole. Dig in your finger next to this hole and gently push up the crab from underneath with your finger. Measure its claw and carapace length using a caliper if it is a male. Record your data. Take care not to harm the crab whilst doing this.
5. Repeat steps two and three until a minimum of 10 male porcelain fiddler crabs have been measured at the location.
6. Repeat steps one to five at a location further in towards the land from the river, approximately 30m away. This location will be the "Back mangrove", which is the side of the mangrove that is further away from the river. Record any qualitative data observed at the new location as well.

The data for the claw and carapace lengths obtained at these two locations will be analyzed using the student's t-test to see if there is a significant statistical difference. If there were a significant statistical difference, it would mean that there is a high possibility that the differences are not due to chance, allowing me to conclude that the differences in biotic/abiotic factors at the two locations may have an effect on the sizes of porcelain fiddler crabs. Random sampling in a 25m x 25m sampling grid is used at the two locations in order to prevent human bias, and a minimum of 15 values should be collected for both claw and carapace length at each location in order to have a reliable set of data for the student's t-test. Random sampling at two locations was chosen over the transect method for testing the relationship between distance from the waterline and the size of crabs, as the distribution of crabs in the area was rather uneven, so there would have been many quadrats with no crabs present if the transect method was used, resulting in a data set that is hard to work with.

Safety

When working with the fiddler crabs, uttermost care is taken in order to minimize the harm done to them. Their sizes should be measured while they are on the ground when possible, and they are picked up only when necessary. When attempting to dig one up, dig next to its hole and slowly lift it out. Try to repair its hole if possible, and release the crab right where you found them after measuring them.

[3]"Porcelain Fiddler Crabs (Uca Annulipes) on the Shores of Singapore." Wildfactsheets.

As for the safety of the person carrying out the research, there is the possibility of cuts caused by marine debris such as glass, metal or sharp plastics that often get trapped in the roots of mangroves. Fiddler crabs can also pinch rather strongly with their claws when agitated, resulting in injury. Both of these hazards can be avoided by wearing protective clothing (Long sleeves, trousers and proper shoes) and gloves when carrying out this experiment. You may also encounter animals such as monitor lizards and macaques in the mangrove, which are usually not aggressive, but it is best not to agitate them for your safety.

Raw data

Figure 1: Table showing claw length and carapace length of male porcelain fiddler crabs at the fore mangrove

Crab number	Length of claw (mm) (±0.10mm)	Length of carapace (mm) (±0.10mm)
1	30.52	17.36
2	28.24	15.10
3	27.24	15.58
4	33.82	23.04
5	29.14	16.52
6	31.88	17.00
7	30.42	21.96
8	38.64	25.02
9	45.26	27.80
10	33.12	18.04
11	25.98	17.24
12	23.50	18.12
13	26.42	16.72
14	31.74	17.88
15	28.68	16.60

Qualitative observations:
-Location is right next to a river that is connected to the sea, at low tide
-Not many plants in the area
-No canopy cover, bright sunlight
-Sand contains dead organic matter such as branches and leaves
-Sand is clay like and moist
-Other species of crab not observed
-Fiddler crabs are rather aggressive, trying to pinch your finger and escape

Figure 2: Table showing the claw length and carapace length of male porcelain fiddler crabs at the back mangrove

Crab number	Length of claw (mm) (± 0.10mm)	Length of carapace (mm) (±0.10mm)
1	15.68	15.02
2	18.24	16.40
3	22.52	18.96
4	16.72	14.04
5	20.22	16.42
6	18.04	19.32
7	27.54	19.86
8	27.82	18.50
9	32.76	26.12
10	26.44	18.04
11	15.52	12.28
12	22.50	17.84
13	18.56	15.20
14	33.26	17.22
15	19.82	17.38

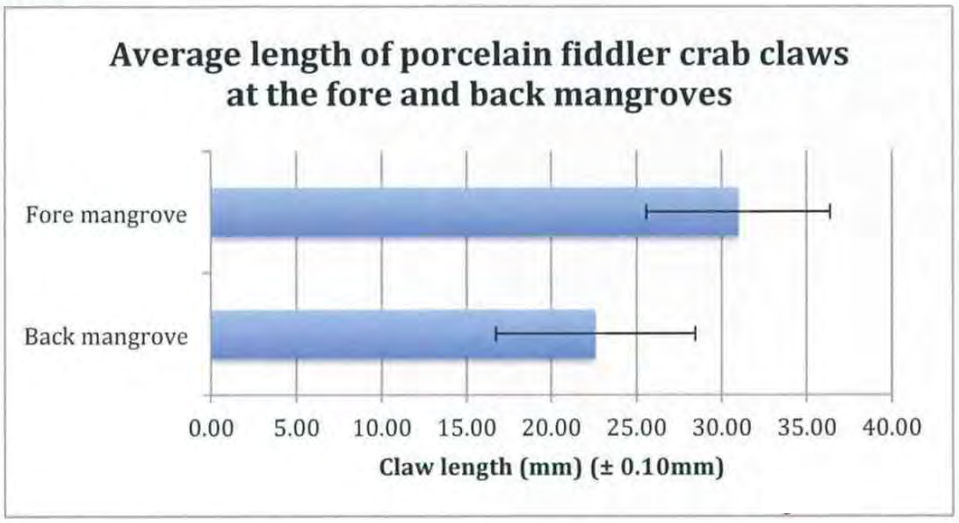
Qualitative observations:
-Location has a small stream of salt water running through it
-Lots of vegetation in and around the location
-Mangrove trees with pencil roots present
-Some canopy coverage of the sky resulting in shades
-Sand is very watery
-Other species of crab present as well (orange fiddler (*Uca vocans*), Large black crab with light blue underside)
-Crabs are less aggressive when picked up compared to ones at the fore mangrove

Processed data

Figure 3: Table showing average and standard deviation of claw and carapace lengths at the fore mangrove and the back mangrove

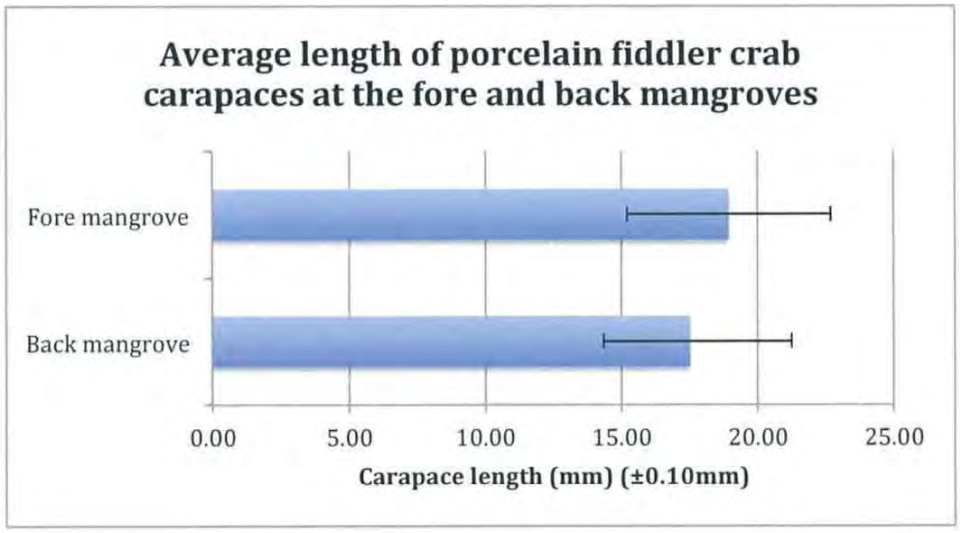
	Claw lengths		Carapace lengths	
	Fore mangrove	Back mangrove	Fore mangrove	Back mangrove
Average (mm) (± 0.10mm)	30.97	22.59	18.93	18.05
Standard deviation (mm)	5.41	5.86	3.74	3.35

Figure 4:



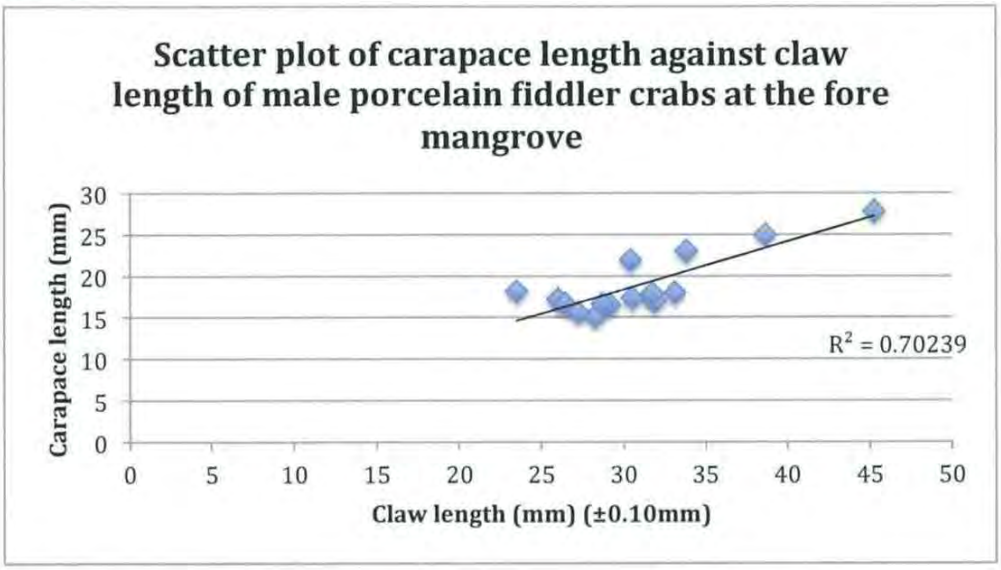
The average claw length of male fiddler crabs is much higher in the fore mangrove compared to the back mangrove. There is a slight overlap in the error bars due to the standard deviation being quite high for lengths at both locations, but a clear difference can be seen.

Figure 5:



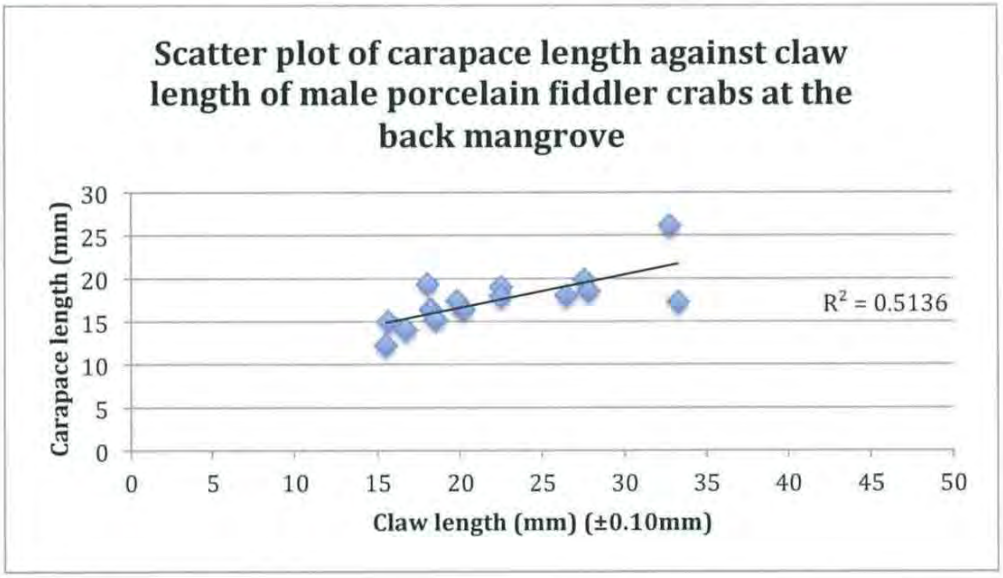
The average carapace length of the fiddler crabs is longer in the fore mangrove compared to the back mangrove, but only but a small amount. There is also a major overlap in the error bars, meaning that there may be very little actual difference in the lengths at the two areas.

Figure 6:



There is a strong positive correlation between carapace lengths and claw lengths at the fore mangrove: the larger the carapace, the larger the claw. This can also be seen from the Pearson's correlation coefficient of 0.84 (square root of R^2), which indicates a very strong positive relationship. There is a high concentration of crabs with a 15-20mm carapace and a 25-35mm claw.

Figure 7:



There is a positive correlation between carapace and claw lengths at the back mangrove as well, although the correlation is not as strong as it was in the fore mangrove. The Pearson's correlation coefficient (square root of R^2) is 0.72, which is still considered a strong positive relationship. The points are quite evenly spread out, and it can be seen that the claw lengths at the back mangrove are smaller in general when compared with the plots on figure 6.

Student's t-test:
As mentioned before, the student's t-test will be used in order to test if there is a significant statistical difference between the claw and carapace lengths of male porcelain fiddler crabs at the fore and back mangrove.
The null hypothesis for this test is "There is no significant statistical difference between the claw lengths of the porcelain fiddler crabs at these two locations" and "There is no significant statistical difference between the carapace lengths of the porcelain fiddler crabs at these two locations". Putting the set of claw length and carapace length data (figures 1 and 2) at the two locations through the t-test allows us to see whether the respective hypothesis still stands.

Figure 8: Table showing the p values as the result of a t-test for both the claw length and carapace length of male porcelain fiddler crabs at the fore and back mangrove

	Claw length	Carapace length
P value	0.000319	0.503

Data sets with a p value of below 0.05 is considered to have a significant statistical difference between them, as there is at least a 95% possibility that these differences are not due to pure chance.

From these p values obtained through the t-test, the null hypothesis can be rejected for the claw lengths, as it is well below the critical value of 0.05, at 0.000319. The p value it too high for the null hypothesis for the carapace lengths to be rejected, at 0.503, so this one will still stand.
From these results, these two statements can be made:
-"There is a very highly significant statistical difference between the claw lengths of male porcelain fiddler crabs at the fore mangrove and the back mangrove"
-"There is no significant statistical difference between the carapace lengths of male porcelain fiddler crab s at the fore mangrove and the back mangrove"

Conclusion
The aim of this experiment was to investigate how distance from the low water line affects the growth of porcelain fiddler crabs, by testing if there was a significant statistical difference in the claw and carapace lengths of male crabs at a location adjacent to the river at low tide (fore mangrove) and a location further in towards the land (back mangrove). Based on my biological knowledge on these fiddler crabs and some deduction, I have hypothesized that porcelain fiddler crabs near the back of the mangroves would be larger in both claw and carapace size due to it having more time to feed.
From the data that has been obtained (Figure 8), it can be said that there is a very highly significant statistical difference in the claw lengths of male porcelain fiddler crabs at a location that is adjacent to the river and a location that is further away from the river, with the location that is nearer to the river having porcelain fiddler crabs with larger claws. No major difference in carapace size can be observed. This is not what I have expected in my hypothesis, as I thought crabs would be generally larger at the back mangrove. However, the data that

supports this conclusion is pretty strong. A p value of only 0.000319 (Figure 8) means that there is just a 0.0319% possibility of the claw sizes being different due to chance, which is very unlikely. This difference was also very apparent when the actual measurements were being done at the locations in the mangrove, as the crabs at the fore mangrove had obviously larger claws than those at the back mangrove, which can also be seen from the average claw length of 3.08cm at the fore mangrove compared to 2.24cm at the back mangrove (Figure 3). There is also not too much overlap in the range of data collected for the claw lengths, as seen from the error bars on figure 4. As for the carapace lengths, both the p value of well over 0.05 and the overlap of the error bars on figure 5 suggest strongly that there is no significant statistical difference between the two locations.

The relatively strong positive correlations between claw and carapace lengths of male porcelain fiddler crabs at both locations suggest how crabs with a bigger carapace tend to have bigger claws. This is seen from the Pearson's correlation coefficients of 0.84 (Very strong correlation) and 0.72 (Strong correlation) (Figures 6 and 7) for the fore and back mangroves respectively. All the points lie close to the trend line, meaning that there weren't any male crabs measured that had a unusually big claw with a small carapace, or vice versa. From this, it can be inferred that these crabs don't "bluff" their claw sizes, where they spend all their resources such as nutrients in order to grow their claw to attract females, whilst actually being small in body size. Although I have used a random sampling grid when collecting data in order to reduce human bias, I may have unintentionally collected larger crabs due to them being easier to notice within the random quadrat.

Since we know that the difference for claw size was probably not due to chance from the p values obtained from the t-test, it would mean that it could be due to the environment they live in. One major reason that the porcelain fiddler crabs at the fore mangrove had much larger claws than the ones at the back mangrove could be due to interspecific competition in the back mangrove. As far as I have observed, there were no other crab species at the fore mangrove other than the porcelain fiddler crabs (*Uca annulipes*), but there were other, much larger crabs present at the back mangrove such as orange fiddler crabs (*Uca vocans*)(Figure 1). Competition with these larger species of crab could have made it much more difficult for the crabs at the back mangrove to obtain food or enough space for their hole in order to grow a large claw. The fiddler crabs found at the fore mangrove were also more aggressive compared to the ones found at the back mangrove, as they tend to pinch your finger and stab with the nails on their feet in an attempt to escape. The fiddler crabs at the back mangrove did not do much of this, which could mean that they are more passive and thus can not get as much food or space for habitat as the ones found at the fore mangrove.

The general area of the mangrove that I have surveyed was rather flat, with not much inclination of the ground. This would mean that the back and the front would get flooded with the rising waters of the tide, and would resurface again with the receding tide, at around the same time. Therefore, it would mean that the time the fiddler crabs get in order to look for food would be around the same, which would explain why my hypothesis was incorrect.

Evaluation

Having sampling grids in two distinct locations, one that is right next to the river, and one that is as far away from the river as possible, was well suited for this experiment. Since a lot of data can be collected at each location compared to the transect method, it allowed me to get a solid set of data on the sizes of the crabs in the area, and also use the student's t-test to check if the difference is statistically significant. Although the gradual change in claw and carapace sizes can not be seen with increasing distance from the river, taking two locations at the extremes should give me a good idea of how size changes. The use of the random sampling grid also helps reduce human bias, as I may only pick and measure crabs that match the size that I am expecting if this was not used. Measuring both the claw and carapace length has allowed me to plot these two values against each other in order to look for correlations between them, which would not have been possible of only the claw length was measured. Just the carapace length does not define everything about the crab, but it gives us a general idea of how big that individual crab was.

As with many investigations in the ecological field, there were many causes for error in the experiment. Although the data I have collected suggests that there is a significant difference in claw size and no significant difference in carapace size at the two locations, there were many flaws in the experiment that may have affected these results.

Error/limitation	Significance of error	Improvements
1m x 1m quadrat is not placed exactly at the coordinates, since the coordinates are found within the grid by having people walk from the x and y axes and marking where they meet	The coordinates could be off by as much as a few meters due to people not walking straight. This random error is not that significant in this case, since you are looking for a random location anyways. However, this could potentially result in the same location being sampled twice, which could result in incorrect data.	All the grid lines for the random sampling grid at both locations can be drawn out on the sand beforehand in order to ensure the grid with the correct coordinates is sampled.
Abiotic factors such as pH of the sand, temperature, sunlight, and nutrient levels in the soil could not be controlled	This is not significant as the aim of this experiment was to see the change in size of these crabs with varying distances from the river. Although these factors are not directly relevant to the aim of this experiment, it is normal for them to change as you move away from the	All of these abiotic factors could be monitored at both locations with pH probes, thermometers and soil test kits and recorded in order to be able to relate any trends in the results to these values.

	river, so it is naturally a part of the experiment.	
Only 15 porcelain fiddler crabs were measured at each location	This is very significant, as it is recommended to have a minimum of 20 samples at each location when carrying out a student's t-test to get a reliable p value. 15 values is enough to get a general idea of the differences in the claw and carapace lengths, but it may not be an accurate representation of what is actually there.	More samples of male porcelain fiddler crabs could be measured at both locations in order to get a more reliable p value. This was not possible in this experiment due to time constraints, but it the results obtained would be significantly more reliable the more measurements are made at each location.
Limited porcelain fiddler crabs measured to only males	This is significant as in that it does not give me a complete view of the change in carapace size of porcelain fiddler crabs with varying distance, since females are not measured. However, it is insignificant when measuring claw sizes as well as the carapace size, since females do not have an enlarged claw that can be measured.	No modification has to be made in this case, as I am looking at both the claw and carapace sizes, which can only be measured on males. If looking at only carapace size, a greater number of samples from both genders would be required.
Not all male porcelain fiddler crabs found within the random quadrat were measured due to crabs escaping	This is rather significant as it means that I was unable to measure crabs that were fast at reacting or had a very cautious nature, which could potentially be a factor that would affect claw and carapace size. For example, crabs that are very cautious may not spend as much time as the other crabs on the surface to feed, resulting in smaller carapace and claw sizes.	I could try to dig up the crabs that have burrowed deep into their holes with a shovel, in order to make sure I measure every single male crab in the quadrat. However, this may not be the most ethical thing to do, as it would result in the destruction of the crab hole.
Species other than porcelain fiddler crabs (*Uca annulipes*) may have	This would have a very significant effect if other species were measured	A dichotomous identification key can be used on every fiddler

been measured as well, as I am not experienced with identifying crab species	as well, since crabs of different species naturally grow to different sizes independent of distance from the river.	crab sample in order to ensure that it is in fact *Uca annulipes* that is being measured, to prevent accidental measurement of other species.

Whilst carrying out this investigation, a few new questions came to my mind relating to these fiddler crabs. The first one is the possible factors that could affect the size of their carapace, if there are any at all. In my investigation, I could not see any significant statistical difference in the carapace size at the two locations, and their averages were very close to each other. I could carry out an investigation where I run a line transect from the river towards the inner mangrove, to see if there is any gradual change in carapace size with increasing distance from the low water mark of the river. This would allow me to have a larger sample size, as I can measure both males and females, and will also give me a better idea of the change in carapace size with distance from the river. Another possible investigation would be to look at the species distribution of crabs in an area and the effect it has on the claw and carapace sizes of porcelain fiddler crabs (*Uca annulipes*). In my investigation, the area that had many different species of crabs, as well as some plants, had porcelain fiddler crabs that were smaller than the areas that didn't have these. I have concluded that these differences could possibly be due to interspecific competition. In order to further clarify this, I can carry out an investigation looking at the correlation between the species distribution of crabs of a particular area of the mangrove and the claw and carapace lengths of porcelain fiddler crabs there. If my conclusion is correct, I would probably see that areas with a greater number of competitor species such as *Uca vocans* would have porcelain fiddler crabs with smaller claw and carapace sizes.

Bibliography

"Fiddler Crab." Wikipedia. Wikimedia Foundation. Web. 23 May 2015.

"Porcelain Fiddler Crabs (Uca annulipes) on the Shores of Singapore." Wildfactsheets. Web. 23 May 2015.

"Pulau Tioman, Malaysia." Geographical Names. Web. 23 May 2015.

International Baccalaureate
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For first use in 2016 assessment

4/ICCS

Group 4: Individual candidate cover sheet (biology, chemistry and physics)

Arrival date: Session:

School number: School name:

- Complete this form in the working language of your school (English, French, Spanish).
- The form must be completed by the teacher and candidate.
- A completed copy should be retained by the school.

Subject: Biology Level: HL

Candidate name: Session number:

Candidate section:
To be completed by the candidate.

Title of the group 4 project: The ethics behind the theraputic use of embryonic stem cells

Write a reflective statement of about 50 words outlining your involvement in the group 4 project:

I have contributed to the Chemistry part of the practical by setting up the micro burette from the appartus provided, and carried out a number of the titrations myself.
For the video, I have written up the script from the research done by others in the group, and provided vocal narrattion for the video.
As a group, we had difficulties coming to an agreement on how we were going to approach our topic due to differing opinions on the topic, but once we got started on the actual project, we worked very well as a team.

Title of individual investigation: Is there a significant difference in the claw and carapace lengths of male porcelain fiddler crabs (Uca annulipes) at the fore mangrove compared with the back mangrove?

IB Biology

Cow Milk Spoilage in Five Different Temperatures

Purpose:
Investigation of the rate of cow pasteurized milk as measured by the pH spoilage in different temperatures of 1˚C, 5˚C, 7˚C, outside temperature (average 10 ˚C) and room temperature (20˚C). And determining the best temperature for storing milk.

Research Question:
How does the temperature in which milk is stored affect its pH?

Hypothesis:
The milk stored in the temperature of 1˚C is expected to have slower rate of the spoilage than other milk due to the low rate of lactobacilli reproduction. That means that the milk stored in the temperature of 1˚C is expected to have slower decrease in its pH.

Background Information

Knowing the best temperature for milk storage is important since it can either cause milk spoilage or extend it freshness. At home, my grandmother tends to store milk outdoors while the temperature outside is not high. She lives in a countryside and during colder parts of a year the electricity does not usually work. So she is left with no choice but to store milk outdoors. Moreover, my grandmother refuses to keep milk that tastes or smells 'strange' while the smell and taste of the milk might not be necessarily indicates of milk being expired. Expired milk is bad for the health because of increased number of bacteria in it while it is wasteful to throw away milk that might be still safe to drink. Therefore, I would like to investigate how long she could keep milk in different low temperatures so that I could tell her my results.

Cow milk comes to grocery stores either after being "prepared" by pasteurization, sterilization or UHT.

- Pasteurization involves milk being heated to 72˚C for 15 seconds, which kills most of the bacteria save for lactobacilli. That process eliminates many fermentative bacteria as well as pathogenic ones.
- Sterilization has milk heated to 105˚C for 15 seconds, which kills all bacteria, however, milk changes its tastes to "cooked".

- UHT milk is heated to 130°C for 2 seconds. That is enough to kill all bacteria without changing the milk flavor.

Hence, pasteurized milk can be kept in the fridge for about 10 days until it goes bad. Sterilized and UHT milk, on the other hand, do not need to stay in a fridge as long as it stays unopened inside its container. When the container is unsealed microbes can get inside the milk, which requires the milk to be stored inside a fridge. Raw milk even if kept refrigerated will go bad quickly (sooner that any of "prepared" milk) because of the presence of psychrophilic bacteria that is cold-tolerant ("Microbes and Food. We Are What We Eat. Milk." *Microbes and Food. We Are What We Eat. Milk*).

Lactose (disaccharide) is an integral part of the milk and other diary products. Milk also contains lactic acid bacteria (*lactobacillus* genus) that converts lactose into glucose and then lactic acid. Therefore, the pH of the milk is a good indicator of determining the milk quality. Milk pH stands between 6.8 and 6.5. When milk becomes spoiled the pH goes down thus increasing the acidity of the milk due to the bacteria activity. When milk pH goes below 6.5 it starts getting spoiled ("Measuring the Ph of Milk." *SlideShare*). Lactobacilli continues producing lactic acid until milk pH reached 4.6 since after that point bacteria die out.

Growth/reproduction of bacteria is controlled by cooling the milk; it will not kill bacteria but slow the reproduction rate down greatly ("Bacteria." *Microbiology*). There is an optimum temperature at which bacteria grows the most. Temperatures below the optimum one slow down bacterial growth or stop it whatsoever without killing bacteria. However, if temperatures are above optimum it starts killing bacteria.

The pH is measured using a pH sensor or a traditional pH meter ("Measuring the Ph of Milk." *SlideShare*).

Design

Variables & Controls

Independent variables: Temperature of milk storage

Dependent variable: change in pH of milk

Factors to be controlled	Impact on data if not controlled	How it will be controlled
Same brand of milk	Different brands of milk might have different composition of milk with different amount of lacto bacteria	I will buy the same kind of milk
All of milk pasteurized	This process kills most of the bacteria save for lactobacilli	Look at the milk description

Same amount of milk in beakers	Different amount of milk might affect the rate at which milk will go bad	I will put 60 ml of milk in each beaker using a measuring cylinder
Time period on which pH sensor is placed inside a cup.	It takes time for pH sensor to reach the value of pH so that it does not fluctuate	Let the pH sensor be inside a cup for a minute

Materials

Paper cups (25)
Plastic lids (25)
Measuring cylinder (100 ml)
pH Meter (*Science Workshop*™ 500 Interface)
Laptop with PASCO Capstone app
Buffer Solution pH 10
Buffer Solution pH 4
Buffer Solution pH 7
Beaker (100 ml)
Distilled water
Fridge at 1˚C
Fridge at 5˚C
Fridge at 7˚C

Procedure

1. Pour 60 ml of milk in a paper cup using measuring cylinder
2. Set the pH meter
3. Plug it in the laptop
4. Open PASCO Capstone app
5. Go to "Hardware Setup"
6. Choose a yellow circle which the wire is plugged to
7. Add pH sensor
8. Go to calibration
9. Choose pH as a type of measurement to calibrate
10. Go to "next"
11. Choose "Two Standards" as a type of calibration you would like to perform
12. Press "next"
13. For the first point "Standard Value" put "4.00"
14. Put pH sensor into the Buffer Solution with pH of 4
15. When the value gets still press "Set Current Value to Standard Value"

16. For the second point "Standard Value" put 10.0
17. Rinse the pH sensor with distilled water
18. Put pH sensor into the Buffer Solution with pH of 10
19. When the value gets still press "Set Current Value to Standard Value"
20. Rinse the pH sensor with distilled water
21. Choose "Digits" on the right side of the page to display data
22. Press on "select measurement" and choose "pH"
23. Press "Record"
24. Put pH sensor into the Buffer Solution with pH of 7 to check the calibration
25. If the digits show 7.0 rinse the pH sensor with distilled water
26. Pour 60 ml of milk in each of 25 cups and label them
27. Put the pH sensor into the milk
28. Measure pH of milk in each cup
29. Record the data
30. Pour the rest of the milk (60 ml) into 20 paper cups
31. Close them with lids
32. Place the first 5 cups in a fridge with temperature of 1°C
33. Place the second 5 cups in a fridge with temperature of 5°C
34. Place the third 5 cups in a fridge with temperature of 7°C
35. Place the fourth 5 cups in an area at 10°C
36. Place the fifth 5 cups in a room temperature as a control.
37. Leave all 25 cups for 11 days overall for each cup
38. Take the pH on the 3rd day
39. Record the data
40. Check on milk pH on the 5th day
41. Record the data
42. Check on milk pH on the 7th day
43. Record the data
44. Check on milk pH on the 9th day
45. Record the data
46. Check on milk pH on the 11th day
47. Record the data
48. Plot graphs
49. Compare the data
50. Draw a conclusion

Safety: beware Buffer solutions with pH of 4 and 10. If some got on the hands rinse them with distilled water. Wear safety googles.

Data Collection and Processing

Milk Spoilage Experiment Data Table 1 (Change in pH of milk stored at different temperatures)

1st Day pH (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial	Average
1	7.0	7.0	6.9	7.0	7.0	7.0
5	6.9	7.0	7.0	7.0	7.0	7.0
7	6.9	6.9	7.0	7.0	7.0	7.0
10	7.0	7.0	7.0	7.0	7.0	7.0
20	7.0	6.9	7.0	7.1	7.0	7.0

3rd Day pH (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial	Average
1	6.9	7.0	7.0	7.0	7.0	7.0
5	7.0	7.0	6.9	7.0	7.0	7.0
7	6.9	6.9	7.0	7.0	7.0	7.0
10	7.0	7.0	7.0	7.0	7.0	7.0
20	7.0	6.9	7.0	7.0	7.0	7.0

5th Day (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial	Avarage
1	6.9	7.0	7.0	7.0	7.0	7.0
5	7.0	7.0	6.9	7.0	7.0	7.0
7	6.9	6.9	7.0	7.0	7.0	7.0
10	7.0	6.9	7.0	7.0	7.0	7.0
20	6.3	6.1	6.2	5.7	5.8	5.9

7th Day pH (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial	Average
1	6.9	7.0	7.0	7.0	7.0	7.0
5	7.0	7.0	6.9	7.0	7.0	7.0
7	6.9	6.8	7.0	7.0	7.0	7.0
10	6.8	6.8	6.7	6.8	6.8	6.8
20	6.0	5.9	6.1	5.5	5.6	5.8

9th Day (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial	Average
1	6.9	7.0	7.0	7.0	7.0	7.0
5	6.9	7.0	6.9	6.9	6.9	6.9
7	6.8	6.8	6.8	6.8	6.9	6.8
10	6.4	6.5	6.4	6.3	6.4	6.4
20	6.0	5.9	5.8	5.5	5.4	5.7

11th Day (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial	Average
1	6.9	7.0	7.0	7.0	7.0	7.0
5	6.9	7.0	6.9	6.9	6.9	6.9
7	6.8	6.7	6.8	6.8	6.9	6.8
10	6.3	6.2	6.2	6.2	6.0	6.2
20	5.9	5.8	5.6	5.5	6.0	5.6

Average Change of Milk pH after 11 days Data Table 2

Temperature (˚C)	Average Change of Milk pH (1 dp) (±0.1)
1	0.0
5	0.1
7	0.2
10	0.8
20	1.4

Average = Sum of values/ Number of values

E.g. Average = (6.0 + 5.9 + 5.8 + 5.5 + 5.4)/5 = 6.7 (1 dp)

Change of Milk pH = 1st day pH – 11th day pH

E.g. Change of 20˚C Milk pH = 7.0 – 5.6 = 1.4

Milk Spoilage Experiment Data Table 2 (Qualitative Data)

1st Day pH (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial
1	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
5	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
7	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
10	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
20	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell

3rd Day pH (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial
1	Half frozen, no smell	White, no smell	Half frozen, no smell	White, no smell	White, no smell
5	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
7	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
10	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
20	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell

5th Day (±0.1)

Temperature (˚C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial
1	Half frozen, no smell	Half frozen, no smell	Half frozen, no smell	White, no smell	White, no smell
5	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
7	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
10	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
20	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell

7th Day pH (±0.1)

Temperature (°C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial
1	Half frozen, no smell	Half frozen, no smell	Half frozen, no smell	White, no smell	White, no smell
5	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
7	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
10	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
20	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell

9th Day

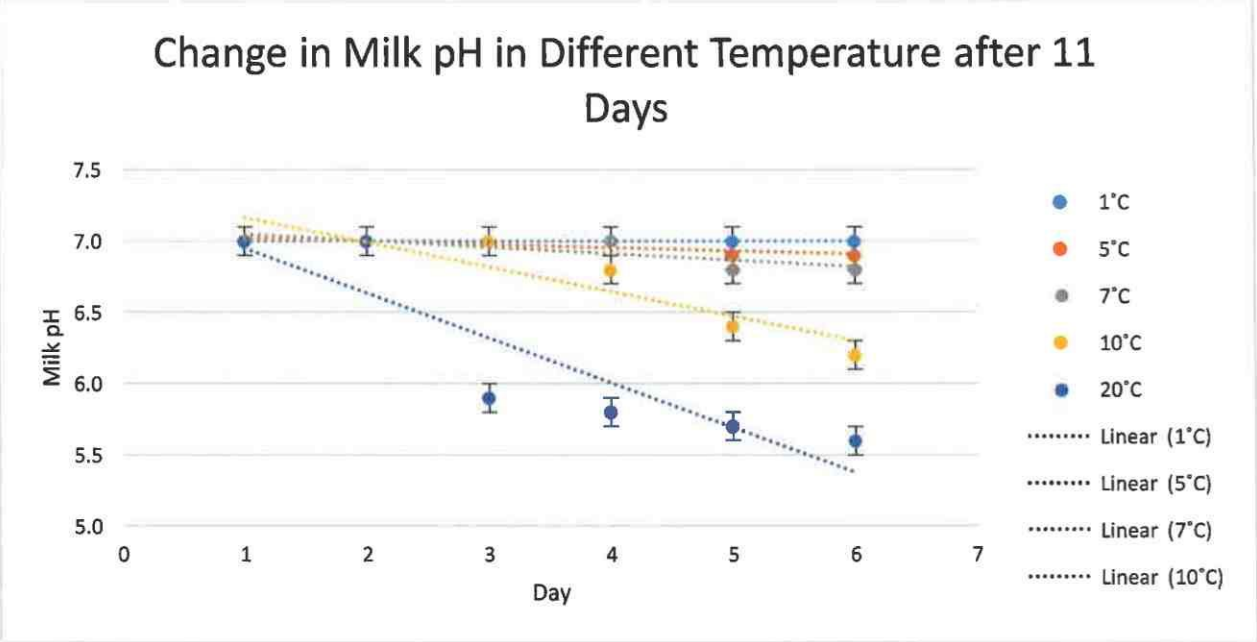
Temperature (°C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial
1	Half frozen, no smell	Half frozen, no smell	White, no smell	White, no smell	White, no smell
5	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
7	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
10	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell	White, unpleasant/sour smell
20	Milk curdles, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell

11th Day (±0.1)

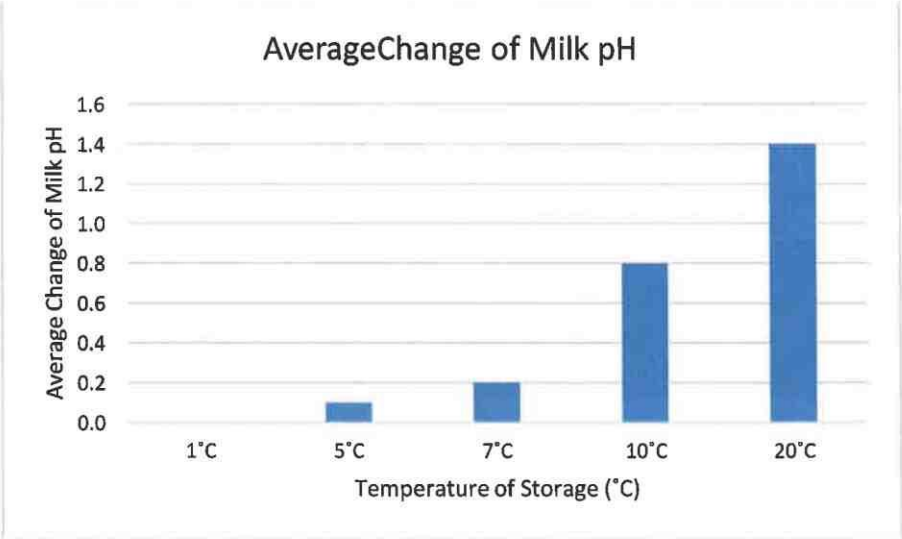
Temperature (°C)	1st Trial	2nd Trial	3rd Trial	4th Trial	5th Trial
1	Half frozen, no smell	Half frozen, no smell	Half frozen, no smell	White, no smell	White, no smell
5	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
7	White, no smell	White, no smell	White, no smell	White, no smell	White, no smell
10	Milk curdles, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell
20	Milk curdles, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell	Milk curdled, pale-yellow fluid, unpleasant/sour smell

Data Analysis

Graph 1



Graph 2



The graphs and average data tables show that pH of milk stored in the room temperature gradually decreased by 1.4 during 11 days after measuring the initial pH. The error bar is set on ± 0.1 since it was the value on which the values on pH sensor were fluctuating. The pH of milk kept at 10˚C gradually decreased by 0.8. The line of best fit shows the downward trend. Moreover, the pH of milk placed in the fridge at 7˚C gradually decreased by 0.2. The line of best fit shows the downward trend as well. As for pH of milk store at 5˚C, it gradually decreased by 0.1. In addition, pH of milk stored in 1˚C has not changed. The line of best fit is parallel to the x-axis. The overall decrease in pH of milk placed in 1˚C, 5˚C and 7˚C is not significant since the values 6.9 and 6.8 are close to the neutral point (Image 1: pH scale below), which indicates that the activity of lactobacilli was insignificant compared to the change in 10˚C and 20˚C where milk became more significantly acidic. Also pH of 6.9 and 6.8 are larger than 6.5, which is considered to be point when milk expires ("Measuring the Ph of Milk." *SlideShare*). Also by looking at the Milk Spoilage Experiment Data Table 1 it is evident that the initial pH of the milk was above predicted 6.7, and so another brand of milk pH was checked, which turned out to be 7.0 as well, which indicates that pH of 7.0 is a normal pH of distilled milk sold in grocery stores.

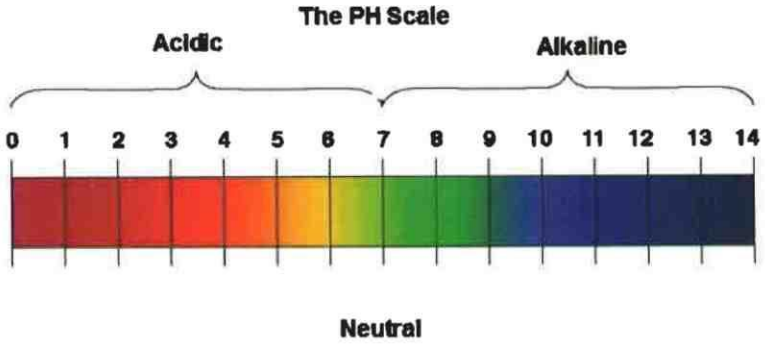


Image 1 ("Alkaline Without Alkalinity." *Dr. Sircus.* 17 Sept. 2014. Web. 24 Oct. 2015.)

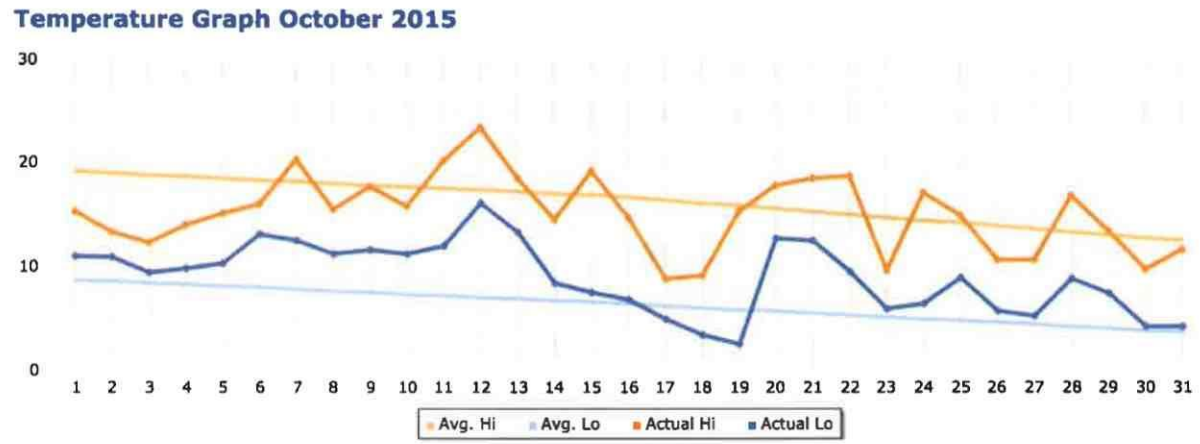
Conclusion and Evaluation

Conclusion

The hypothesis stated that the milk stored in the temperature of 1˚C is expected to have slower decrease in its pH due to the lower rate of lactobacilli reproduction. The processed data and the graph helped support and prove it since the pH of milk stored in 1˚C has not changed in 11 days the experiment has been conducted. However, the qualitative data table showed that some of milk stored in 1˚C got half frozen, which makes this temperature not very suitable for storing milk since some time will be needed for milk to turn back to liquid. The data and the graph displayed that the milk spoilage did not occur in temperatures 5˚C and 7˚C either since the change in pH were 0.1 and 0.2 respectively.

That suggests that the lactobacilli reproduction is greatly hindered by the range of temperature from 1˚C to 7˚C. That means that milk can be stored in either of those temperatures. In addition, the milk stored outdoors has undergone later and lesser decrease in pH than the milk stored in room temperature, which implies that milk can be also stored outside for no more than 7 days if the temperatures are similar to ones during the experiment (chart 1 below; days experiment was conducted: from 17th October to 27th October(inclusively)). The data related to the room temperature showed that milk cannot be stored in that condition for longer than 3 days since the pH starts decreasing significantly to 5.6 after 3 days, which indicates the milk spoilage. Also the line of best fit suggests that milk pH goes below 6.5 on 2.5 day. To sum up, the temperature in which milk is stored does affect the rate of pH decrease.

Chart 1 ("St. Catharines, CA." *AccuWeather.*)



Evaluation and Improvement Methods:

The weaknesses and limitations:

Weaknesses & Strengths	How weaknesses/strengths impacted the data	Suggestions for improvement
Milk pH was not measured daily during 11 days.	The changes in pH have been rather abrupt and gradual change was not fully shown. The need of calibration for each day might have cause errors in measuring pH of milk.	Measure milk pH everyday or even twice or three times per day.

Work Cited

"Bacteria." *Microbiology*. Web. 25 Oct. 2015.

"Consequences of Drinking Expired Milk." *LIVESTRONG.COM*. LIVESTRONG.COM, 13 Apr. 2015. Web. 7 Nov. 2015.

Lu, Michael, Yvonne Shiau, Jacklyn Wong, Raishay Lin, Hannah Kravis, Thomas Blackmon, Tanya Pakzad, Tiffany Jen, Amy Cheng, Jonathan Chang, Erin Ong, Nima Sarfaraz, and Nam Sun Wang. "Milk Spoilage: Methods and Practices of Detecting Milk Quality." FNS Food and Nutrition Sciences 04.07 (2013): 113-23. Web. 28 Sept. 2015.

"Measuring the Ph of Milk." *SlideShare*. N.p., n.d. Web. 28 Sept. 2015. <http://www.slideshare.net/farhana25/measuring-the-ph-of-milk>.

"Microbes and Food. We Are What We Eat. Milk." *Microbes and Food. We Are What We Eat. Milk*. N.p., n.d. Web. 28 Sept. 2015. <http://resources.schoolscience.co.uk/SGM/sgmfoods12.html>.

"St. Catharines, CA." *AccuWeather*. Web. 8 Nov. 2015.

The experiment was conducted only for 11 days while not reaching the expiry date of the milk (October 30th, 2015) due to restricted amount of time available.	Unable to observe which of milk stored in 1˚C, 5˚C and 7˚C would expire first. That hindered determining which of temperatures is best for milk storage.	Milk pH should have been continued being measured even after expiry date to observe which of temperatures would keep milk fresh for longer
Only one package of milk was tested which limits the reliability of the experiment.	Best storage temperature might be different for each brand of milk. While it is safe to keep milk outside for 7 days for one kind of brand it might be different for another.	More trials could have been done with different brands or packages of milk so that the trend was applicable to wider range of milk. Also the use of different types of milk such as soy milk, goat milk, rice milk, almond milk and cow milk would have enriched the experiment. In addition, Use of pasteurized, sterilized and UHT milk would have shown the difference in spoilage of those kinds of milk.
Some cups in room temperature might have been placed closer to some sort of heat; some cups in outdoors temperature might have been exposed to the sun, which would have affected the temperature of milk.	Cups placed in the same place might have had different temperatures thus different rate of bacteria growth.	Make sure that cups are placed on the same distance from the source of either cold or heat.

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For first use in 2016 examinations

4/ICCS

Group 4: Individual candidate cover sheet (Biology, Chemistry and Physics)

Arrival date: Session:

School number: School name:

- Complete this form in the working language of your school (English, French, Spanish).
- The form must be completed by the teacher and candidate.
- A completed copy should be retained by the school.

Subject: Biology Level: HL

Candidate name: Session number:

Candidate section:
To be completed by the candidate.

Title of the group 4 project: Building a Rube Goldberg Machine

Write a reflective statement of about 50 words outlining your involvement in the group 4 project:

During this Science Project, I worked with my friends, which made it quite enjoyable for me. Even though we faced many problems during the creation of our mechanism I think this was a great experience for all of us. Our mechanism represented a blood circulation in human body, precisely, a gas exchange from CO2 to O2. My part represented how carbon dioxide (a tennis ball) is replaced by oxygen in lungs (bags). My part depended on whether the fan will be switched on by another ball before, which was quite tricky and we also needed enough energy to enable the tennis ball hit a heavier ball, which required all of us think over my part. Overall, I feel that we all worked hard and I really appreciate the effort everyone put in our project.

Title of individual investigation: Cow Milk Spoilage in Five Different temperatures

Candidate declaration: I confirm that this investigation is my own work and is the final version. I have acknowledged each use of words or ideas of another person, whether written, oral or visual.

Candidate's signature: Date:

Turn over

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Diploma Programme answer cover sheet

BIOLOGY

SL
PAPER TWO

04 May 2016 (morning)

Invigilator only: Candidate absent (insert x if applicable) ☐

Candidate

Section or option	Question
B	5

General instructions

- Write in **blue** or **black** ink, and use soft pencil for graphs and diagrams. The use of colour is only permitted in geography examinations.
- Do not write on any QR code on this cover sheet.

When using 4 page answer booklets

- Write your session number and name in the appropriate boxes on the front page of the answer booklet.
- At the start of each answer to a question, write the question number in the box. If you make a mistake, fill in the box completely and use the next available box to write the question number.
- Parts of an answer, for example (a), (b), (c), must be written on the lines provided.
- Leave at least one line space between each part of an answer.

At the end of the examination

- Complete the candidate boxes (on the left) with the section(s)/option(s) and question(s) answered. If all questions have been answered, write ALL.
- Attach this cover sheet to your work using the string tag provided.
- In the box below, write the number of 4 page answer booklets attached to this cover sheet.

Number of 4 page answer booklets attached ☐

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International Baccalaureate
Peterson House, Malthouse Avenue,
Cardiff CF23 8GL, UNITED KINGDOM

Diploma Programme
Programme du diplôme
Programa del Diploma

Biology
Standard level
Paper 2

Wednesday 4 May 2016 (morning)

1 hour 15 minutes

Instructions to candidates

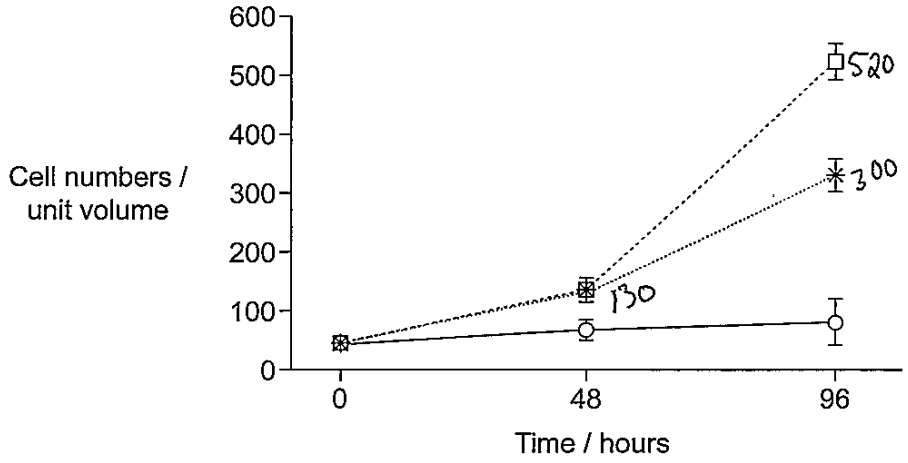
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer one question.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

2216–6005

Section A

Answer **all** questions. Write your answers in the boxes provided.

1. During the development of multicellular organisms, cells differentiate into specific cell lines. A study was carried out on the early stages of differentiation in cells from mouse embryos that were grown in cultures. Two differentiated cell lines were studied, one of inner embryonic tissue (endodermal cells) and the other of external embryonic tissue (nerve cells) after 48 and 96 hours of incubation in cell cultures. A culture of undifferentiated cells was used as a control group. Cell population growth was measured by changes in cell density in all three cell lines.



Key: ··□·· control cells (undifferentiated) ···✳··· endodermal cells —○— nerve cells

[Source: adapted from V Bryja, *et al.*, (2008), *Cell Proliferation*, **41**, pages 875–893]

(a) Distinguish between the changes in cell numbers in the three cell lines that occur during the 96 hour period. [2]

The nerve cells multiply slowly and steadily through the 96 hours. The control cells and endodermal cells multiply much more readily than the nerve cells through the whole experiment. The control cells and endodermal cells grow almost identically in the first 48 hours, but in the last 48 hours, the control cells multiply by 400%, but the endodermal only multiply by about 230%

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(Question 1 continued)

(b) Using the data in the graph, deduce the relationship between cell differentiation and population growth. [1]

The more differentiated the cell, the less it grows.

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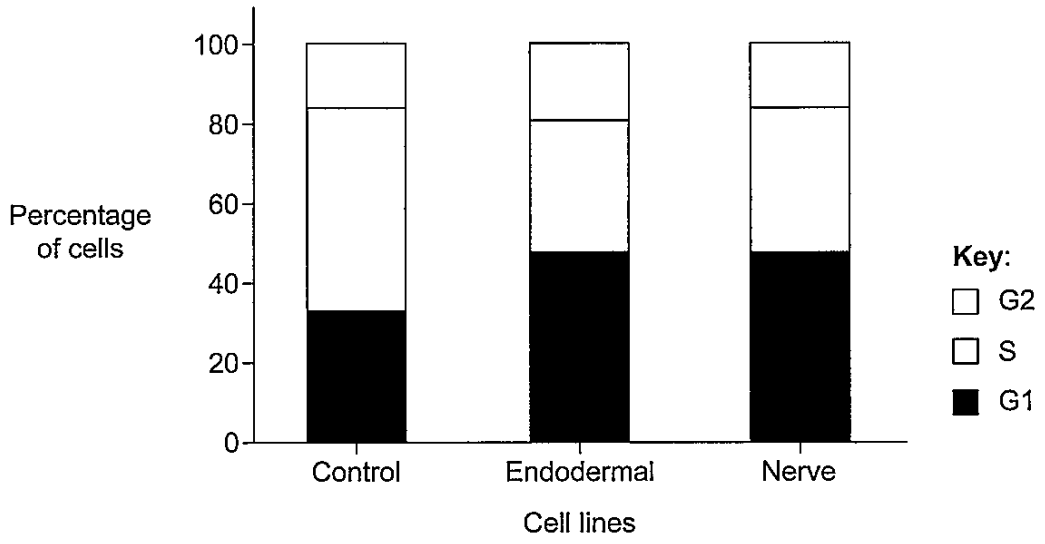
(Question 1 continued)

There are three phases of interphase in the cell cycle:
- the growth phase with the synthesis of RNA and proteins (G1)
- the phase of DNA replication (S)
- and the pre-mitotic phase of rapid growth (G2).

The graph shows the percentage distribution of the three cell lines in the different stages of interphase after 96 hours of incubation.



[Source: adapted from V Bryja, *et al.*, (2008), *Cell Proliferation*, 41, pages 875–893]

(c) Compare and contrast the percentage of control and nerve cells in each of the three phases after 96 hours of incubation. [2]

The control has about 35% in G1, 15% in G2 and 50% in S; the nerve cells have 50% in G1, 15% in G2, and 35% in S. There are similar percentages of G2 cells in both populations, but the control spends proportionally similar amounts of time in S as nerve cells do in G1 and similar proportional times in G1 as the nerves do in S.

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(Question 1 continued)

(d) Using the data of both graphs, deduce the relationship between the percentage of cells in each cell cycle phase and the population growth. [2]

There is little to no relationship between the percentage of cells in each cell cycle and population growth. The Endodermal cells and nerve cells have nearly identical percentages, but their growth is very different.

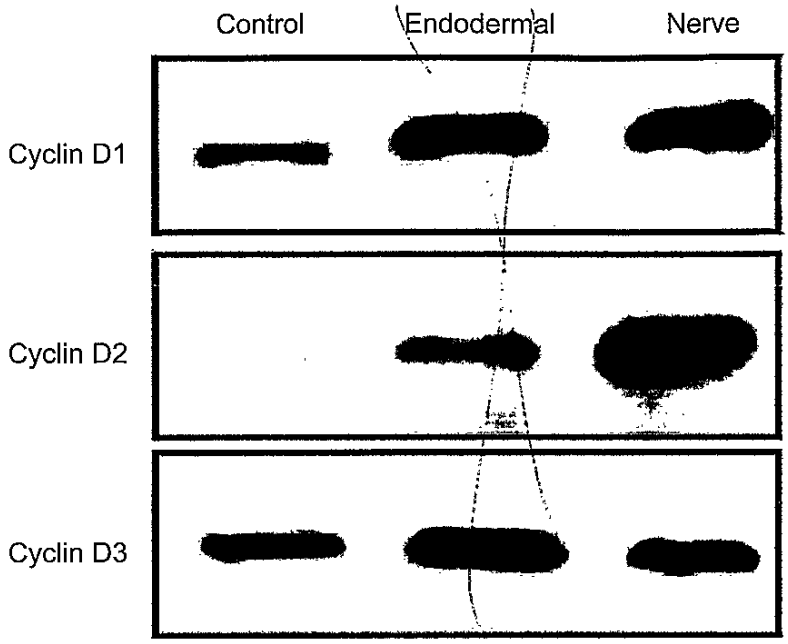
(e) Interphase is followed by mitosis. State the final product of the mitotic cell cycle. [1]

two identical nuclei, which should divide into 2 cells.

(This question continues on the following page)

(Question 1 continued)

The role of regulators in the different stages of differentiation was also studied. After 96 hours of incubation a sample was taken of each cell line and the cyclins separated by gel electrophoresis. The presence of different cyclins D1, D2 and D3 was analysed in the three cell lines. The image shows the results. The size and the intensity of the band is an indicator of the quantity of cyclins.



[Source: adapted from V Bryja, *et al.*, (2008), *Cell Proliferation*, 41, pages 875–893]

(f) Compare and contrast the amounts of the different cyclins in nerve cells and control cells. [2]

The control has much less of these cyclins than does the nerve cell line. The nerve cells have about twice as much D1 than the controls, slightly more D3, and the nerve cell has its biggest segment in D2 cyclins, a band that is nearly nonexistent in the control. The D3 cyclins are available in fairly similar amounts though.

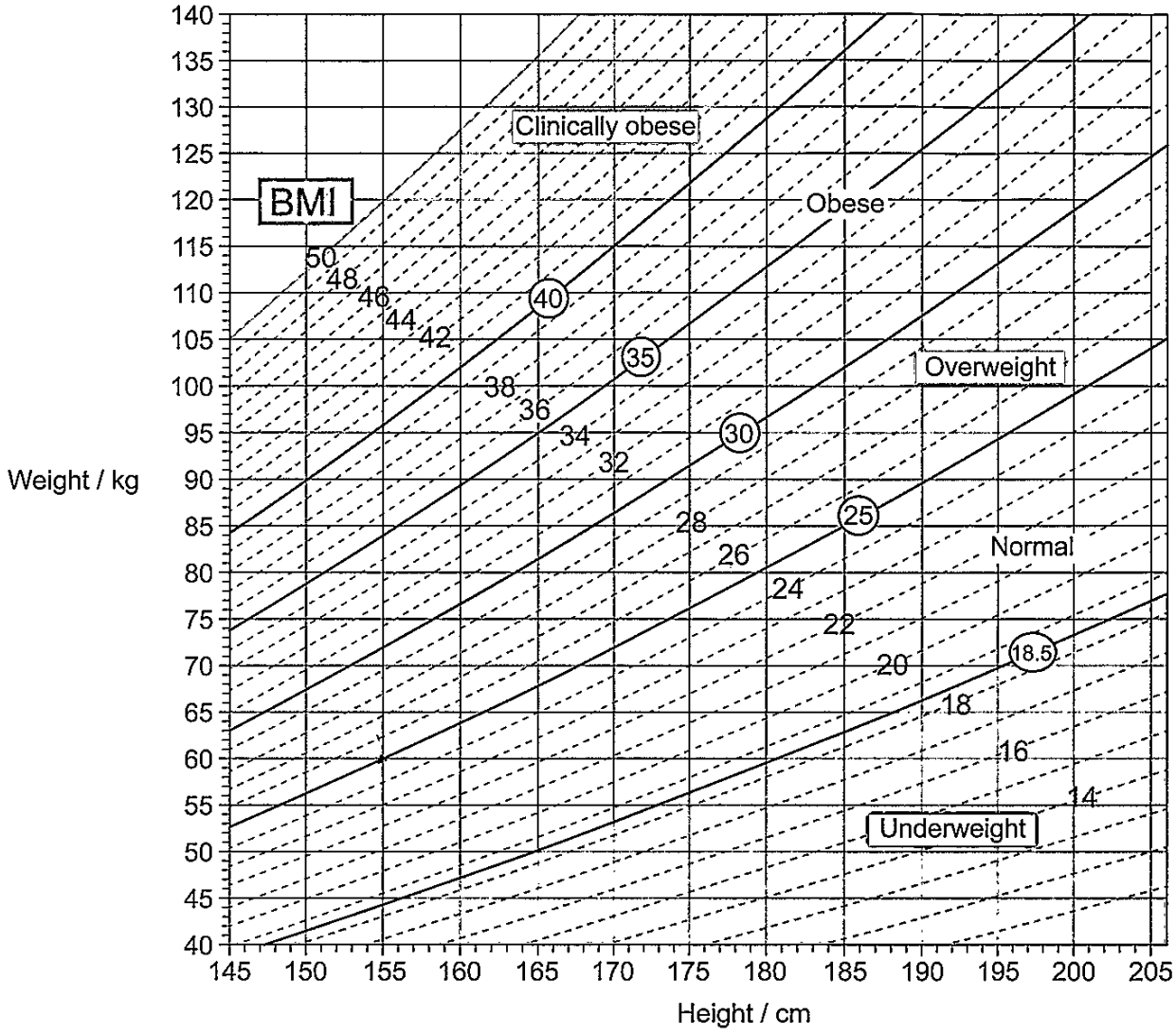
(This question continues on the following page)

(Question 1 continued)

(g) Using the data, discuss the possible roles of the three cyclins in the differentiation of nerve and endodermal cell lines. [3]

the D2 cyclin probably triggers the S phase to terminate or happen faster. This would explain why the S phase encompasses more percentage in the control than in nerve cells. Cyclin D3 probably has to do with phase G_2 because all 3 cell types have similar percentages in G_2 and amounts of cyclin D3. Cyclin D_1 likely has to do with slowing down G_1 because the nerve cells and Endodermal cells have more cells in G_1 proportionally than does the control.

2. The image shows a nomogram.



(a) (i) Using the nomogram, state the lower weight limit for a woman with the height of 155 cm who is classified as overweight, giving the units. [1]

Lower weight limit: 60 Kg

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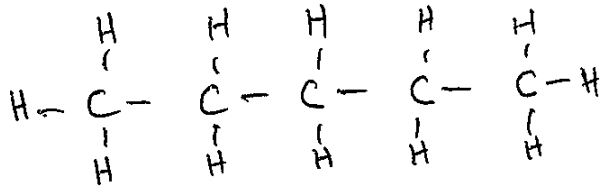
(Question 2 continued)

(ii) State a major health problem of the circulatory system that is correlated with obesity. [1]

type 2 diabetes

(b) Draw the structure of a saturated fatty acid. [2]



(c) Describe how the hormone leptin helps to prevent obesity. [3]

Leptin is an appetite inhibitor which is released by the adipose tissue. The more adipose (fat) the more leptin is released. When the leptin reaches the brain, the nerves are triggered to carry the signal of non-appetite to the body

3. (a) (i) Distinguish between the thermal properties of water and methane. [2]

Methan has a much lower latent heat of vaporization and also a much lower specific heat capacity and is a gas at a much lower temperature.

(ii) Explain the reasons for the unique thermal properties of water. [2]

it has a high specific heat capacity = 1 KC/g.°C

Hydrogen bonding yields high latent heat of vaporization

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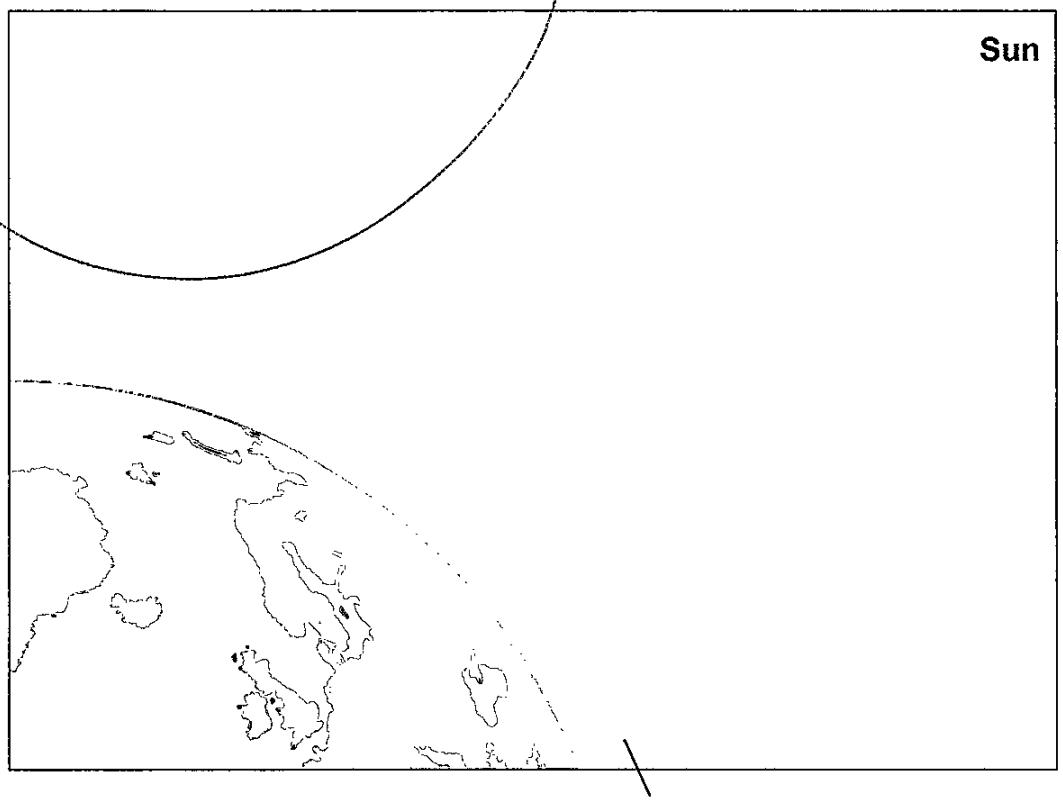
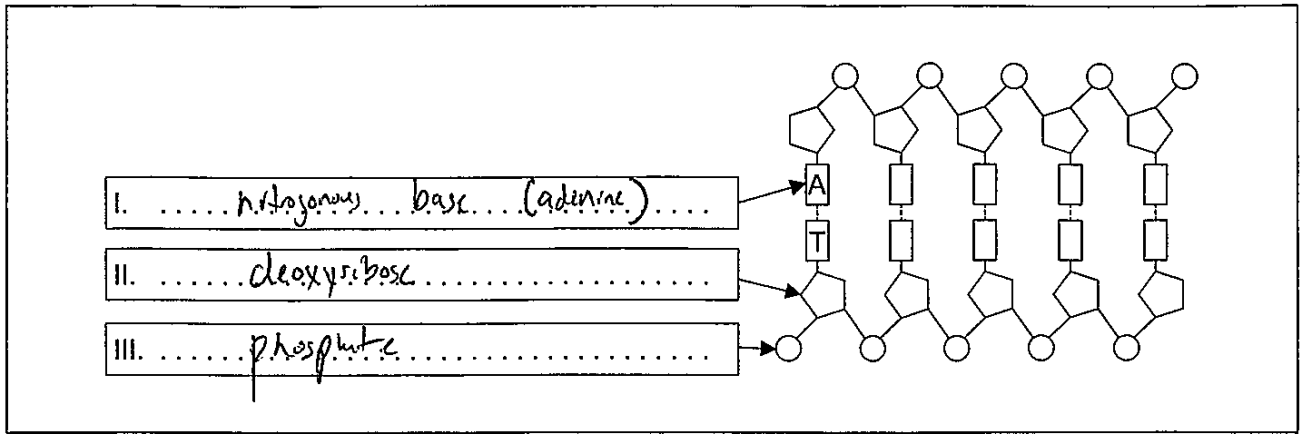
(Question 3 continued)

(b) Using the diagram, explain the interaction of short and long wave radiation with greenhouse gases in the atmosphere. [3]



Short wave radation can often get stuck in the atmosphere and cause an enhanced greenhouse effect (with excess carbon). This leads to heating of the earth too much because they bounce back onto the earth unlike long ones which can leave.

4. (a) Label the parts of two paired nucleotides in the polynucleotide of DNA. [3]



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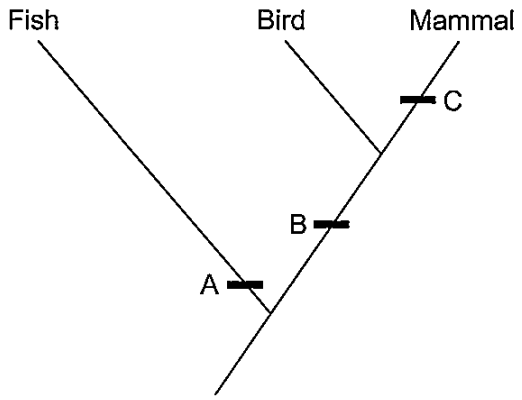
(Question 4 continued)

The image shows part of a cladogram.



(b) Using the cladogram, identify **one** diagnostic feature that characterizes the given groups of vertebrates at A, B and C. [3]

A: no pentadactyl limb

B: body temperature maintained

C: hair

(c) State the name of the domain to which these organisms belong. [1]

eukaryote

Section B

Answer **one** question. Up to one additional mark is available for the construction of your answer. Write your answers in the boxes provided.

5. (a) Outline the action of enzymes. [4]

(b) Many genetic diseases are due to recessive alleles of autosomal genes that code for an enzyme. Using a Punnett grid, explain how parents who do not show signs of such a disease can produce a child with the disease. [4]

(c) Explain the propagation of electrical impulses along a neuron including the role of myelin. [7]

6. (a) Draw a labelled diagram of a eukaryotic plant cell as seen in an electron micrograph. [4]

(b) Outline the process of gas exchange necessary for aerobic respiration in a unicellular eukaryotic organism. [3]

(c) Explain how the process of evolution occurs. [8]

5a Enzymes act as catalists. They bind to a substate in order to perform a task. Enzymes can do many things. Restriction enzymes cut DNA at specific places in order to transfer it (or at least thats what we use it for artificially). Polymerase binds together nitrogenous bases to make DNA or RNA strands. Ligase binds okazaki fragments, amylase breaks down carbohydrates, lactase breaks down lactose. Basically, everything your body does as far as metabolism probably has something to do with our special protein friend the enzyme. They can only act in very specific environments though because outside of their ideal pH and temperature they become denatured and lose their shape.

5b

	Q	q
Q	QQ	Qq
q	Qq	qq

Cystic Fibrosis is a genetic decease that is recessive, which means that it only displays characteristics if someone has 2 recessive alleles of that particular gene. The good and bad of that is that many people can be carriers without knowing it. If two parents who are both carriers have a child there is a 25% chance that that child will not even be a carrier (QQ), a 50% chance that the child will be a carrier (Qq) and a 25% chance that the child will have the genetic disorder (qq).

5c Electrical impulses are carried down a neuron by the use of a sodium – potassium pump. To begin, the neuron establishes a resting potential (-70 mv). It does this by pumping potassium into the cell and sending sodium out (see fig. 1).

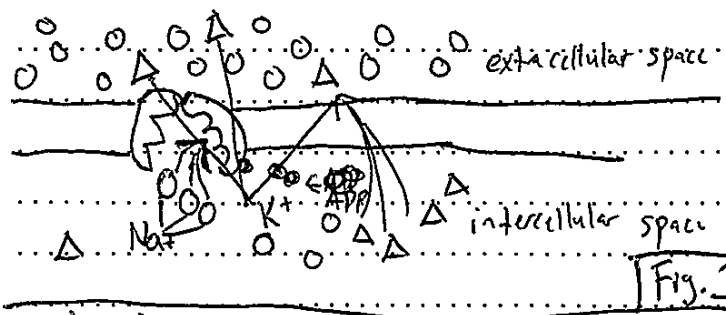


Fig. 1

Because there is more Na^+ outside and more K^+ inside, active transport is required. So ATP gives its phosphate to the pump to allow 3 Na^+ into the protein. once the slot is full the protein changes shape and pushes the Na^+ out and accepts K^+ (fig 2). It then changes shape again, spits out the K^+ and also releases the phosphate and the cycle begins again.

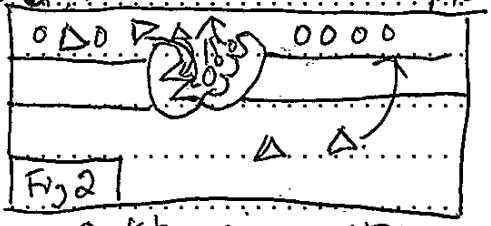
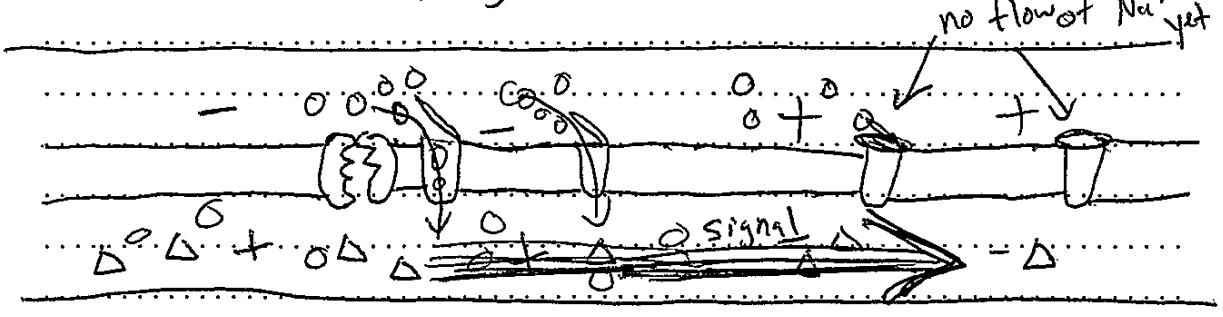


Fig 2

It is important to note that K^+ can diffuse out the membrane without the help of any thing, which further increases the polarization of the cell to be more positive on the outside. Once this is established, the cell is at its resting potential.

When the neuron needs to transport a signal it is triggered by an electrical current. If this current meets the treshold (-50mv) then voltage-gated sodium channels open allowing a rush of Sodium to enter the cell, depolarizing it. This triggers the next section and the signal travels down the neuron (see fig 3).



Once it is depolarized, it has reached the action potential (25 mv). This triggers the signal down the neuron. To reestablish the resting potential K^+ channels open allowing it to release and the Na^+ K^+ starts again. (this reverse polarization prevents backflow). Once the signal has gone all the way down the neuron it reaches the end or the synapse. When the synapse is depolarized it triggers calcium to flow in, which causes vesicles to form around neurotransmitters which are ejected via exocytosis and received by special receivers on the other end of the Synapse. (Neonicotine can block these receivers.) One of these neurotransmitters is acetylcoline which when it is received breaks down into acetate and choline. The coline is then received back into the cell to be recycled.

Myelin Shieths (composed of lipoproteins) wind around a neuron and can speed up the transport of a signal by Saltination. The signal is able to jump segments that are covered in the Shieth and thereby speed up the process.