Huddle investigation

PLANNING A

Aim: to investigate the effect of huddling on heat loss

Hypotheses:

1. That the larger the huddle, the smaller the amount of heat lost. That is, an organism (test tube) on its own will lose more heat than if it were huddled in a group. In an experiment using test tubes, this will be supported by data which shows that a test tube by itself will lose more heat in the same amount of time than if it were in a huddle.
2. The temperature loss should decrease proportionally as the size of the huddle grows.
3. Also, the organism (test tube) in the centre of the huddle will lose less heat than an organism or test tube on the outside of the huddle.

The reasoning behind this hypothesis is that as the huddle group grows in size, the amount of exposed 'surface area' will be reduced per test tube. Although in practice not every test tube is exposed, theoretically, this is a way of comparing huddles.

Also, in a huddle of many organisms, or test tubes, if there is a centre test tube which is not 'exposed', it will be warmer than those on the periphery of the huddle. This hypothesis can be supported by data collected in the experiment by measuring the temperature of the centre of the huddle and the periphery of the huddle. The centre will be warmer because it has no surface area exposed to the outside.

Huddling is a behavioural adaptation to the cold climate. 'Huddling' (in the case of penguins) is when a group of penguins stand closely together, nestling, in an attempt to reduce heat loss collectively as a group. This idea is effective because as a group, the penguins have lesser surface area exposed to the cold per penguin. Thousands of penguins have been seen in the Antarctic nestling together. It is can be said that huddling together is the most vital adaptation of penguins to survive the breeding season, when the males are incubating the eggs and do not go out to find food, a source of energy.

PLANNING B

Independent variable: the size of the huddle
Dependent variable: the amount of heat lost as a huddle
Controlled variables:

- the type of test tubes
- thickness of the test tube glass
- size of test tubes
- the same test tubes were used
- source of hot water
- use of hot water, not any other substance
- amount of hot water in each test tube
- same thermometer
- controlled environment thus the room temperature should be the same
- the experiment was conducted away from windows, to minimise chance of sunlight adding heat to the huddle
- amount of time allowed for each experiment

Apparatus:
10 identical test tubes
2 rubber bands

2 thermometers
A stopwatch
A test tube rack
Hot water (from a tap)
Materials to record data

Method:
In this experiment the temperatures of different huddles were measured. A test tube is used to represent one penguin.
For means of comparison, an experiment was conducted where single test tube stood alone. Then we also used groups of 7 and 10 test tubes, to represent the increasing size of the huddle.

Safety note: be mindful of the hot water.

Measurements of the circumference of the huddle were also taken, to measure the surface area exposed.

The 1-test tube (solo penguin) experiment

Apparatus:
1 test tube
1 thermometer
A stopwatch
A test tube rack
Hot water
Materials to record data

Method

1. We filled the test tube so that it has 22 mls of hot water. We did not use boiling water because the glass of the test tube may break.
2. We placed the test tube in the rack, so that we were not holding it and transferring heat.
3. We measured the initial starting temperature, and took measurements every minute for 6 minutes. The thermometer was held so that it was not touching the bottom of the test tube, to avoid measuring the temperature of the test tube rather than the water. The water temperature is wanted, because we are measuring the heat loss from the water, which would be the 'body' of the organism. The 'test tube' perhaps can be seen as the skin or fur of the organism. Also, glass retains heat.
4. Repeat this experiment to obtain a more accurate overall result. We repeated this experiment 4 times. In consideration of time restraints, there can be 2 of these experiments conducted simultaneously if there are 2 people involved.
5. The circumference and length of the test tube was measured, so that a rough estimate of the surface area exposed can be measured.

The 7-test tube huddle experiment

Apparatus:

7 identical test tubes
2 rubber bands
2 thermometers
A stopwatch
Hot water
Materials to record data

Method:

1. We first bound the 7 test tubes together, to form a huddle. Identical test tubes are used so that a direct comparison can be made between the inside and the outside of the huddle with regard to heat loss. A test tube made of a thinner glass would lose heat more rapidly than a thick test tube.
2. With 7 test tubes, a 'flower pattern' was formed. The two rubber bands held the test tubes together. In this experiment, there was no props needed to keep the huddle standing, the huddle was self-standing. We also did not want to introduce a beaker to hold the huddle together, because this could act as insulation against heat loss.

3. Then we filled the test tubes with hot water from the tap, minimising the time taken. Each test tube was filled to approximately the same level. It would have taken too long to measure out 22 mls for each test tube – the water in the first test tube would have lost a significant amount of heat by the time the 7^{th} test tube was filled.
4. As soon as all test tubes were filled, the initial temperature of the inner test tube and an outer test tube was taken (it does not matter *which* outer test tube is measured). Again, care was taken so that the water temperature was measured, not the test tube glass temperature.

5. Measurements of temperature (of both the inner and an outer test tube) were taken every minute, for 6 minutes.
6. This experiment was repeated 4 times.
7. Again, with time restraints, 2 of these experiments can be conducted simultaneously, simply by doubling the apparatus needed.
8. The circumference of the huddle and the length of a test tube was measured, so that later calculations of the surface area could be worked out.

The 10-test tube huddle experiment

Apparatus:

10 identical test tubes
2 rubber bands
2 thermometers
A stopwatch
Hot water
Materials to record data

Method:

1. The 10 identical test tubes were bound together by the two rubber bands. Again, identical test tubes are used so that direct comparisons of between test tubes within the huddle can be made.
2. In the experiment of the 10 test tubes, the formation illustrated below was formed.

3. In this case, the test tubes were also self-standing, so no other apparatus was needed to prop the huddle.
4. Steps 3 to 8 of the 7-test tube huddle experiment can be applied in the same way for this 10-test tube huddle experiment.

To measure the circumference of a huddle

1. To measure the circumference of a huddle, to place a string around the entire huddle and measure the string would be inaccurate. To gain a more accurate measurement, the string should trace the test tubes on the periphery, as shown below.

2. The string is then marked, and measured against a ruler.

RESULTS

Results from the 1-test tube experiment (solo penguin)

	Temperature (˚C) of the 1 Test Tube Huddle			
Time (mins)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**
0	40.0	40.0	43.0	45.0
1	39.0	39.0	42.0	43.0
2	37.5	38.5	40.5	42.0
3	36.0	38.0	39.5	40.0
4	35.0	36.5	38.5	39.0
5	34.75	35.5	38.0	38.0
6	34.0	34.5	37.0	37.0

Results from the 7-test tube huddle experiment

	Temperature (˚C) of the 7 Test Tube Huddle							
	Trial 1		**Trial 2**		**Trial 3**		**Trial 4**	
Time (mins)	Inner Test Tube	Outer Test Tube	Inner Test Tube	Outer Test Tube	Inner Test Tube	Outer Test Tube	Inner Test Tube	Outer Test Tube
0	43.0	42.0	42.0	42.0	44.0	44.0	48.0	46.0
1	42.0	41.0	41.0	41.0	54.0	44.0	48.0	45.0
2	43.0	41.0	42.5	40.5	44.5	43.0	48.0	45.0
3	43.0	41.0	42.0	40.0	44.0	42.0	47.0	44.0
4	42.0	40.5	42.0	39.0	43.0	41.0	46.0	43.0
5	41.0	40.0	41.0	39.0	43.0	41.0	45.5	41.5
6	40.5	39.0	40.5	38.5	42.0	40.0	45.0	41.0

Results from the 10-test tube experiment

	Temperature (˚C) of the 10 Test Tube Huddle							
	Trial 1		**Trial 2**		**Trial 3**		**Trial 4**	
Time (mins)	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer

	TT	TT	TT	TT	TT	TT	TT	TT
0	46.0	44.0	46.0	44.0	49.0	48.0	48.0	46.0
1	45.5	43.0	45.0	44.0	49.0	47.0	48.0	45.0
2	45.0	43.0	45.0	44.0	48.0	46.0	47.0	44.0
3	45.0	42.0	44.0	42.0	47.5	45.5	46.5	43.0
4	44.0	41.0	44.0	42.0	47.0	45.0	46.5	42.5
5	43.0	40.5	44.0	41.5	46.0	44.0	46.0	41.5
6	42.0	39.5	43.0	40.5	45.5	43.0	46.0	41.0

Physical Measurements of the huddle

Table showing the physical measurements of the huddle and the test tubes			
	1-test tube	**7-test tube huddle**	**10-test tube huddle**
Circumference (cm)	6.9	24.5	31.6
Length of test tube (cm)	15.0		

DATA PROCESSING AND PRESENTATION

Change in temperature in the experiments

Table showing the change in temperature (Initial temperature – Final temperature)					
	Temperature (˚C)				
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Average**
1-test tube huddle	6.0	5.5	6.0	8.0	**6.375**
7 test-tube huddle – **INNER test tube**	2.5	1.5	2.0	3.0	**2.250**
7 test tube huddle – **OUTER test tube**	3.0	3.5	4.0	5.0	**3.875**
10 test-tube huddle – **INNER test tube**	4.0	3.0	3.5	2.0	**3.125**
10 test tube huddle – **OUTER test tube**	4.5	3.5	5.0	5.0	**4.500**

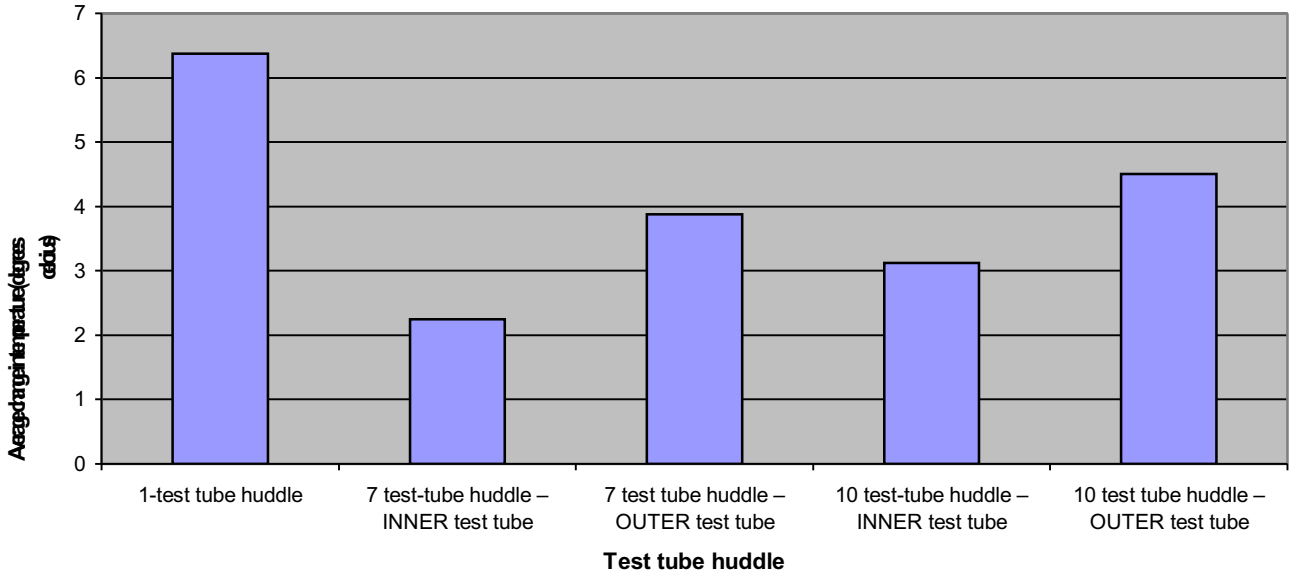
The variations in starting temperature in this case were ignored, as it was the initial temperature minus the final temperature calculated, thus the *change* was measured.

It can be seen that the average change in the 1-test tube experiments were vastly different to those obtained in the other experiments. However this figure may be distorted by the result of Trial 4. If we look at the individual results from Trials 1 to 3, they are comparable with the

results from the outer test tubes of the 10-test tube huddle. In this way, they do not look so atypical. The result obtained from Trial 4 must be an anomaly in the results.

To more easily interpret the averages as shown in **bold type** in the table above, a bar chart can be drawn.

Bar chart showing the average overall heat loss (initial temperature - final temperature) in the experiments



From the chart, the distinct differences in heat loss can be seen, and two hypotheses are supported: the single test tube alone lost the most heat on average, and the inner test tubes lost less heat than the outer test tubes. However as shown by the overall taller columns for the 10-huddle, the increasing size of the huddle does not necessarily mean the lower the heat loss.

The amount of heat lost by the single test tube (6.375°C) was almost 3 times as great as the amount lost by the test tube at the centre of the 7-huddle (2.250°C). The average amount of heat lost by an outer test tube of the 10-huddle was still significantly lower than that of the single test tube. Even if the anomaly of Trial 4 is taken out, the average is 5.833°C, which is still considerably lower than 6.375°C.

The difference between the inner and outer test tubes of the 7 and 10-huddles is on average 1.5°C (the difference between the inner and outer test tube of the 7-huddle was 1.625°C, and the difference between the inner and outer test tube of the 10-huddle was 1.375°C). This clearly supports the hypothesis that the inner test tube loses less heat than an outer test tube because of the lack of surface area exposed to the external environment.

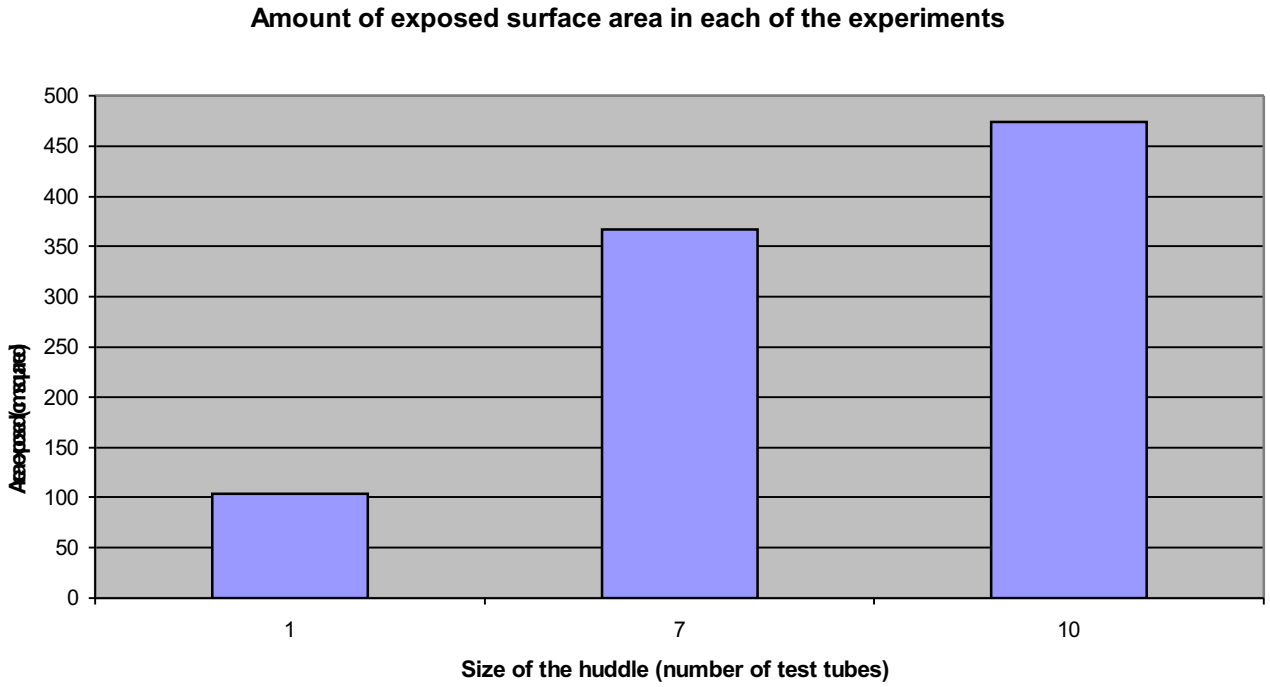
The fact that the 10-huddles overall lost more heat in the same amount of time than the 7-huddles is surprising, because assuming the more test tubes in a huddle, the more heat there is to share between the test tubes. However, if we perhaps look at the theory that radiation is

transferred from hot to cold (so that the colder are warmed by the hotter), the size of the 10-huddle may be hindering its ability to collectively retain heat. Perhaps the overall greater surface area can be seen as the cause of the overall greater heat loss in the 10-huddle than in the 7-huddle.

Below is a table showing the exposed surface area in each of the huddles.

Table comparing the surface area exposed in the different huddles in the experiment			
	1-test tube	**7-test tube huddle**	**10 test tube huddle**
Overall surface area exposed (circumference x length of the test tube) – cm^2	103.5	367.5	474.0
Surface area *per* ?es? ?ube (theoretically) – cm^2	103.5	52.5	47.4

The graph below compares the differences in exposed surface area.



A greater exposed surface area would mean that more heat is being lost at one time from a single source. Perhaps it can be concluded that despite the increased amount of heat contained in the huddle (more test tubes means more hot water thus more energy altogether), the increase in exposed surface area counterbalances this heat, and thus the huddle is losing more heat than it is retaining collectively. The heat from the inner test tubes would be passing out more heat to the outer test tubes, to maintain the same temperature.

Perhaps in theory, the 10-huddle should lose less heat because of the lower surface area per test tube figure (the surface area exposed per test tube for the 7-huddle is 52.5 cm^2; 10-huddle, 47.4 cm^2). However the discussion in the paragraph above gives a reason why this figure is misleading if one is to use this to judge the efficiency of a huddle in retaining heat.

In real life, it would be difficult to say that the greater the huddle, the greater the surface area, thus the greater the inefficiency in heat retention. Penguins prove this – there huddles of thousands of penguins seen in the Antarctic region during breeding season. If smaller groups are more efficient, then surely the penguins would break up into smaller huddles as a survival mechanism.

CONCLUSION

The results from this series of experiments supports two hypotheses: that a single test tube will lose more heat per test tube than a test tube in a huddle, and that in a huddle, the inner test tube will lose less heat than an outer test tube. The single test tube on average lost 6.375°C, whereas the other test tubes only lost 2.250-4.500°C. The differences between the inner and outer test tubes within the huddles was at least 1.375°C, as in the case of the 10-huddle. The difference between the inner and outer test tube of the 7-huddle was 1.625°C.

The hypothesis that the greater the size of the huddle, the lower the heat loss per test tube is not supported by the data collected. The validity of heat loss 'per test tube' comparison is maintained by the measuring of temperatures of the individual test tubes, not by measuring the overall temperature of the huddle. The data showed that the 10-huddle per test tube lost overall more heat than the 7-huddle, both in the cases of the inner (the inner 10-huddle test tube lost 0.875°C more heat than the inner 7-huddle test tube) and outer test tubes (the outer 10-huddle test tube lost 0.625°C more heat than the outer 7-huddle test tube).

It can be concluded 'huddling' has an effect on heat loss, in that a huddle will lose less heat than a single test tube (or organism, as applied in real life). However, according to the experiment, it seems that the greater the size of the huddle, the greater the heat loss, although it is not as great as the heat loss experienced by the single test tube. This is odd, because in real-life, experiences of penguins would tells us that the greater the size of the huddle, the lower the loss of heat per penguin (test tube). It can also be concluded that huddling is most beneficial to the animal in the centre, as they experience less heat loss than an animal on the periphery of the huddle. Thus, huddling has a significant effect on heat loss.

EVALUATION

Evaluation of method:

A weakness in the method is that the volume of water for the 7-huddle and 10-huddle experiments differed every time it was performed. As mentioned in the Method, it would have been impractical to measure out exactly 22 mls for each test tube, because by the time the 7^{th} or 10^{th} test tube was filled, the first test tube would have lost a considerable amount of heat while standing. The volume of water for each experiment was measured, and between the 7-huddles, there was only a difference of 4 mls, and between the 10-huddles, there was a difference of 5 mls.

We have to take note of the fact that glass absorbs and retains heat, and so the 'heat loss' we are attempting to measure may not be completely accurate. However, if we draw parallels between the test tube and skin of the animal, this may be accurate because the animal would retain the heat in its fur/feathers, thus not all the heat would be lost to the external environment. The heat loss in the water can be paralleled with the core temperature of the animal.

I did not take into account the area exposed at the top of the test tubes, or at the bottom of the test tube because these would have been too difficult to measure. The meniscus of the water would prove difficult to measure, as would the curve of the bottom of the test tube. Furthermore, heat lost from the top would not be through glass (there is on glass at the top of the test tube). The bottom of the test tube is also thicker than the sides. Thus, heat lost from both these gaps would not be the same as heat lost from the sides. In order to keep the experiment consistent, these were ignored as part of the calculation for 'surface area'.

Time restrictions must also be considered. Although the time the temperatures were measured over was fairly small (6 minutes), there were still palpable differences between the experiments, and the hypotheses could be supported with the data collected. The differences were not so small it was difficult to establish whether or not there was a pattern. However if the experiment was conducted over an even longer period of time (perhaps 10 minutes), the patterns may be even more distinct. Perhaps in the long run the 10-huddle may have performed better than the 7-huddle in heat loss.

The temperature could also only be measured to 1 decimal place, but my partner and I decided to round up to the nearest half or whole number. This way, interpretation is clearer and reading the thermometer can be done with ease.