Biology Coursework :
Investigating Heat Loss in Model Animals

PLANNING

Intentions

This experiment is being conducted to investigate the relationship between insulation (e.g. an animal's fat and fur), and (body) temperature using water, test tubes and foam insulation.

Variables

There are various variables that need to be taken into account during the experiment:

Water volume;
External factors, e.g. room temperature, wind strength.
Type of insulation;
Number of layers of insulation;
Different test tube sizes, e.g. Width;
Height;
Glass thickness;
(all affect surface area or insulation).

Scientific Background

We know that in the natural world, body temperature is a very important factor in the ability to survive. This is demonstrated throughout the world in a variety of different climates.
For example, to survive the severe cold, animals in the Arctic generally have more body fat and thicker, longer fur than those of a hotter climate such as Africa. This is a demonstration of Bergman's Rule, which states that animals tend to be larger in colder regions for reasons of thermoregulation. The larger an animal is, the greater its volume, thus the lower its surface area to volume ratio and hence the lower its heat loss.
The two factors that most affect an animal's body heat retention or loss are its volume to surface area ratio as mentioned above(the ratio of the volume of the animal compared to its surface area), and the amount of insulation it carries around with it. This insulation is in the form of fat, feathers or fur (e.g. hairs in humans). The extra bulk greatly reduces heat loss and can make the difference between survival and extinction.

Heat insulation works by slowing down the rate at which energy moves from a warm thing to its cooler surroundings. A good heat insulator will:

- stop the flow of air which allows convection to happen

- be made of a material which is a bad conductor of heat
- reflect heat radiation back where it is wanted.

Heat loss is a result of energy transfer by heat where the moving molecules of one material increase the energy of the molecules in another. This occurs in three different ways:

Conduction
Conduction is when heat energy is passed from one particle to another, close by particle. It is most effective if the particles are close together which is why most good conductors are solids. Conduction is also improved if the molecules have free electrons, which is why metals are such good conductors.
Insulation reduces conduction because it is a bad conductor of heat itself, and it traps layers of still air. Stationary air is a bad conductor of heat because air has particles that are spread out and have very few free electrons, meaning that heat can only travel through it very slowly.

Convection
Convection is when heat is transferred in a liquid or gas due to the particles moving. As the particles warm up, the spaces between them expand, making them less dense and thus making them rise. The cooler particles are more dense and sink, replacing the warmer particles. This is known as a convection current.
Insulation reduces convection because the air cannot pass through the layers to convect.

Radiation
Radiation is when a warm object emits infrared electromagnetic radiation, which can be absorbed by other objects, heating them up.
Radiation is usually reduced by the colour of insulation (eg. fur colour), and so is not very relative to this experiment.

My Experiment
In this experiment will be replacing the animals of the natural world with test tubes of water, whilst their natural insulation of fat and fur will be replaced with one millimetre foam insulation.

The Preliminary Experiment
A preliminary test was carried out using a provisional method which formed the basis for the full experiment.

Five test tubes are taken and labelled A-E, they are then prepared as follows:

- **A** (CONTROL) has no insulation;
- **B** is wrapped in two layers of insulation;
- **C** is wrapped in four layers of insulation;
- **D** is wrapped in six layers of insulation;
- **E** is wrapped in eight layers of insulation.

The test tubes are then carefully filled with 20 cm^3 of water at (or as near as possible to) 100°C and a bung of cotton wool placed in the top. The test tubes are then stood in a test tube rack, with those that do not fit placed in a beaker. The starting temperature of the water is noted and then the water temperature of each test tube is measured using a thermometer every five minutes and the results noted, each time going through the test tubes in the same order. The process is continued until each test tube reaches a steady temperature (room temperature).

There were various problems with this method which prompted me to make changes for the full experiment. These were often due to a lack of either equipment or accuracy.

1. I discovered that it was very difficult to obtain any water that was actually at 100 ºC, and then to fill all the test tubes separately without there being a large drop in water temperature whilst waiting for water to re-boil. In the full experiment the water will just be at a high temperature and all the test tubes filled at the same time, then the starting temperature noted.
2. As it is not possible to have a stopwatch running for each test tube, the test tubes will all have to be filled at the same time to make it easier to keep track of them. When the temperature of each test tube is checked for the first time, the length of time taken to check that test tube will be noted so that it will get checked at intervals of exactly five minutes (after the first check, at least).
3. I have discovered that a lot of the heat is lost through the top of the test tube, so in the full experiment I will use bungs to prevent this thus making the experiment more accurately centred round my investigation.
4. It is also not possible to have a thermometer for each test tube, so I will be using just the one. This will be inserted into the test tubes through cotton wool bungs so as to prevent heat loss.

<u>Method (Full Experiment)</u>

Five test tubes of the same size (A,B,C,D,E) are taken and wrapped in 1mm insulation as follows:

- **A** (CONTROL) has no insulation;
- **B** is wrapped in two layers of the insulation;
- **C** is wrapped in four layers of the insulation;
- **D** is wrapped in six layers of the insulation;
- **E** is wrapped in eight layers of the insulation.

The test tubes are then carefully filled with $20cm^3$ of hot water of the same temperature and placed in a rack or in beakers to prevent any spillages. Bungs of cotton wool are placed in the test tubes, then the temperatures of the test tubes checked with a thermometer to make sure that each test tube is at the same temperature. This starting temperature is noted. A stopwatch is then started and every five minutes the temperature of each test tube of water is measured with a thermometer and noted. This is continued until each test tube of water reaches a constant temperature (room temperature). The whole experiment is then repeated to ensure accuracy.

Control of Variables & Measurements to be made

All the aforementioned variables will be controlled as best they can, although there may be some problems with the starting water temperature and the room temperature will have to be ignored as it cannot be controlled. The independent variable will be the amount of insulation. This will be 1.0mm thick insulation which will cover the whole test tube and wrapped around in layers; it will increase in increments of two layers. The dependent variable is the temperature of the water as it cools which will be measured accurately with a thermometer every five minutes. The control in the experiment will be test tube A which has no insulation (though it still has a cotton wool bung).

Prediction

I predict that the more insulated the test tubes are, the longer it will take for the water inside them to reach room temperature, e.g. the rate of heat loss to slow down as more insulation is added. This will show that more insulation results in less heat loss.

OBTAINING RESULTS

Table of Results:
1st Experiment

TIME (minutes)	TEMPERATURE (ºC) A	B	C	D	E
0	55	54	54	55	54
5	47	47	49	50	49
10	36	40	43	47	45
15	30	38	40	43	42
20	27	34	38	39	40
25	25	31	34	37	38
30	24	29	32	34	35
35	23	27	30	31	32
40	22	25	28	29	30
45	21	23	27	28	29
50	20.5	22	25	27	28
55	20	21.5	24.5	25	27
60	20	21.5	24	25	26.5
65	20	21	23.5	24	26
70	19.5	21	23	23	25.5
75	19	20	22	23	24.5
80	19	20	21.5	22	24
85	19	19.5	21	21	23.5
90	19	19.5	20	21	23
95	19	19	20	21	22
100	19	19	19.5	20.5	22
105	19	19	19.5	20.5	21
110	19	19	19	20	21
115	19	19	19	19.5	20
120	19	19	19	19	20
125	19	19	19	19	19.5
130	19	19	19	19	19

Table of Results:
2nd Experiment

TIME (minutes)	TEMPERATURE (ºC)				
	A	B	C	D	E
0	58	58	58	58	58
5	36	49	50	52.5	53
10	33	42	45	48	48
15	30	38	40	44	45
20	27	35	37	40	41.5
25	26.5	32	35	38	39
30	25.5	29	32.5	36	37
35	24	28	31	33	34.5
40	23.5	27	29	32	33
45	23.5	27	28.5	31	32.5
50	23	26	28	30	31.5
55	22.5	25.5	26.5	28.5	30
60	22	24.5	25.5	27.5	29
65	21.5	24	25	26.5	28
70	21	23.5	24.5	26	27.5
75	21	22	23	25.5	26.5
80	20	21	22	24.5	25
85	19.5	20	22	24	25
90	19	20	21	23	24.5
95	19	19.5	20.5	22.5	24
100	19	19	19.5	22	23
105	19	19	19	21	22
110	19	19	19	21	21.5
115	19	19	19	20	21
120	19	19	19	19.5	20.5
125	19	19	19	19	20
130	19	19	19	19	19

Table of Results:

Mean averages of results for both experiments

TIME (minutes)	**MEAN TEMPERATURE(ºC)**				
	A	**B**	**C**	**D**	**E**
0	56.5	56	56	56.5	56
5	41.5	48	49.5	51.25	51
10	34.5	41	44	47.5	46.5
15	30	38	40	43.5	43.5
20	27	34.5	37.5	39.5	40.75
25	25.75	31.5	34.5	37.5	38.5
30	24.75	29	32.25	35	36
35	23.5	27.5	30.5	32	33.25
40	22.75	26	28.5	30.5	31.5
45	22.25	25	27.75	29.5	30.75
50	21.75	24	26.5	28.5	29.75
55	21.25	23.5	25.5	26.75	28.5
60	21	23	24.75	26.25	27.75
65	20.75	22.5	24.25	25.25	27
70	20.25	22.25	23.75	24.5	26.5
75	20	21	22.5	24.25	25.5
80	19.5	20.5	21.75	23.25	24.5
85	19.25	19.75	21.5	22.5	24.25
90	19	19.75	20.5	22	23.75
95	19	19.25	20.25	21.75	23
100	19	19	19.5	21.25	22.5
105	19	19	19.25	20.75	21.5
110	19	19	19	20.5	21.25
115	19	19	19	19.75	20.5
120	19	19	19	19.25	20.25
125	19	19	19	19	19.75
130	19	19	19	19	19

ANALYSIS

The graphs all show that the more insulation a test tube had, the slower the water inside it cooled, as was predicted earlier. The graphs from both experiments show this well, with the results for the two experiments relatively close together.

The difference between the temperature loss in test tube A (which had no insulation) and in test tube B (which had two layers of insulation) when shown on the graphs supports the prediction well. There is a large gap between the two lines which, on their own show what a difference the insulation makes.

The better insulated the test tubes were, the slower was the rate of heat loss, and thus the shallower the curves were representing this on the graph.

Initially there is a steep fall in temperature, particularly in the uninsulated tube which decreases and levels out as the temperature becomes lower (i.e. that is the graph starts out as a steep curve which flattens out to a horizontal line). This shows that most heat is lost in the first thirty to forty minutes of the experiment. The better insulated test tubes lose far less heat in this time than those with less insulation. For example, from the averages graph, uninsulated test tube A loses 22ºC in water temperature in the first ten minutes of the experiment whilst the most insulated test tube, test tube E, loses only 9.5ºC in the same time. This is a difference in temperature loss of 12.5ºC. On average, test tube A did 59.5% of its heat loss in the first ten minutes whilst test tube E did less than half that doing only 25.7% of its heat loss in the same time. This is a clear indication that insulation makes a large difference at the time when most heat is lost.

Unlike my prediction graph, the results graphs show that although the best insulated test tube shows the slowest heat loss, the beneficial effect of adding more insulation lessens as the insulation gets thicker. This is shown by the fact that on the graphs the rate of heat loss for the last two test tubes with the thickest insulation, test tubes D and E, are very close together, i.e. their rates of temperature decrease are very similar. This indicates that adding even more insulation would make a very small difference to the effectiveness. This would seem to suggest that there is an optimum level of effectiveness for using insulation. In an animal, this optimum level of insulation means that a compromise would have to be made between insulation for warmth and the bulk and mobility of the animal.

EVALUATION

The experiment went well and the results were of a satisfyingly high degree of accuracy, as the two sets of data were close together, meaning that the mean averages of the results were a very good representation overall. The accuracy of the results was conclusive, and the graphs showed a clear correlation with no obvious anomalous points. This provided reliable and sufficient evidence to firmly support my earlier prediction, showing clearly that the more layers of insulation there are, the less heat loss there is because there are more layers of trapped air, meaning that less heat loss can occur by conduction and convection. The results were also indicative enough to enable me to develop other theories and conclusions concerning the effect of insulation and its use in the natural world.

There were, however, various problems with the experiment. Getting the water temperature for each test tube the same at the beginning of both experiments was very difficult, and so sometimes the closest possible temperature was used instead. This is why the graphs show that test tube D with 6 mm of insulation beginning at a higher temperature than test tube E which had 8 mm of insulation.
There were other factors that may have affected the accuracy of the experiment. These problems include the time it took to fill the test tubes, during which the water cooled rapidly. Also, the time it took to check the temperature of each test tube made the times slightly inexact. Some heat was also lost when the temperatures were checked because of insertion and removal of the thermometer (though the bungs remained in place). These problems could be overcome by finding a way to fill all the test tubes at the same time, and by having a separate thermometer for each test tube through a rubber bung, preventing heat loss.

There are several ways in which this investigation could be furthered. One way is by extending the parameters of this experiment, for example by beginning with the water at a higher temperature, or by taking readings more often, such as every two minutes instead of every five minutes. To further investigate the theory that insulation thickness is not directly proportional to the rate of heat loss, test tubes with even more layers of insulation could be added to the experiment. Another way to continue this investigation would be to involve surface area and volume in an experiment thus relating to how heat loss changes in animals of different sizes. This could be done by looking at heat loss from a larger volume of water in a similar shaped container, for instance a boiling tube instead of a test tube, using the same layers of insulation.

My experiment provided accurate and reliable results to support my conclusion, giving a clearer picture of how animals use insulation to survive the climatic variations of the natural world, whether desert or ice cap.