Investigation to demonstrate how the surface area and volume affects the heat loss in animals

Planning

Aim: To investigate how surface area and volume of an animal affects the amount of heat lost.

Planning a simple procedure

One standard test tube, one boiling test tube, and one centrifuge test tube will be filled with water at 40°C. A thermometer will be placed in each tube to measure the decrease in temperature of the water. This will be timed for 300 seconds using a stopwatch. The temperature of the water will be recorded every 30 seconds.

Preliminary Work

A prior experiment similar to the one outlined above, was carried out to determine the sizes of the test tubes. The surface area and volume for each tube used were

- Standard Test tube Surface area = 2.69 cm^2
  Volume = 18 cm^3
- Boiling Test tube Surface area = 5.73 cm^2
  Volume = 44.66 cm^3
- Centrifuge Test tube Surface area = 2.26 cm^2
  Volume = 14.58 cm^3

The surface areas to volume ratio are as follows:

- Standard test tube 1:6.69
- Boiling test tube 1:7.79
- Centrifuge test tube 1:6.45

The experiment determined which tubes should be used, and the amount of water to be used.

Equipment

Standard Test tube
Boiling test tube
Centrifuge test tube
Test tube rack
Stopwatch
Thermometers x 3
Measuring cylinder
Kettle containing water

Diagram

Method

1. 8.9 cm^3 of water will be measured using a measuring cylinder.

2. The water will be heated to 40°C using a kettle.

3. When the water reaches 40°C it will be poured into a test tube.

4. A thermometer will be placed in the test tube to measure the amount of heat lost.

5. A stopwatch will be used. The temperature of the water will be recorded every 30 seconds, hence there will be 20 readings.

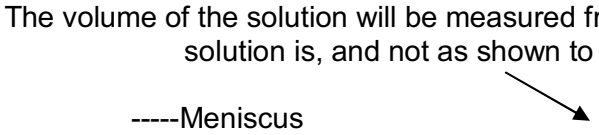
6. The temperature of the water will be recorded in a table of results.

7. Steps 1-6 will be repeated for a boiling test tube and a centrifuge test tube. The amount of water poured into the boiling test tube will be 24.9 cm^3. The amount of water poured into the centrifuge test tube will be 6.6cm^3.

Fair Test

In this experiment there should be only one variable, which is altered. In this investigation it is the size of the test tube that will be altered. Three different sized test tubes will be used to represent three different sized animals. A boiling test tube, standard test tube and centrifuge test tube will be used. In order to keep the other variables constant and to ensure the experiment as precise and reliable as possible the following will be done:

1. Measuring cylinders will be used to measure the exact amount of water. When measuring out the water the readings will be taken from the meniscus as shown below



2. The same observer will observe the amount of heat loss, by reading the values off the thermometer.

3. A stopwatch will be used to time the investigation.

4. The temperature of the surrounding environment is a factor, which may affect the experiment. The tubes must be placed in the same environment.

5. The volume of water will be constant in proportion to the volume and surface area.

6. The whole experiment will be repeated and the results will be recorded into a table. From the two recordings of the amount of heat loss measured in 300 seconds for the reaction to occur, an average will be calculated.

Safety

Whilst heating the water, care has to be taken to when handling the kettle and pouring the water into the tubes as the water will be extremely hot and may cause burns/scorns to the skin.

Prediction

Heat can be transferred in three ways

- Conduction
- Convection
- Radiation

Conduction is the transfer of heat energy from a source to a substance without the substance itself moving. It occurs mainly in solids. Metals are good conductors of heat, as the electrons are very loosely attached to atoms and are easily removed from them. When a metal is heated the 'free electrons' gain kinetic energy. They drift towards the cooler parts of the metal thus spreading the energy to those regions. In substances where no free electrons are present, the heat energy is transferred from one place to another by collisions. Hence the substance becomes warmer.

Convection is the transfer of heat energy from a source to a substance by the movement of the substance itself, which occurs in fluids. Heat is carried from one place to another, by the movement of the molecules.

Radiation is the transfer of heat energy from one place to another by means of electromagnet waves. Radiation does not need a material in order for it to take place. Radiation can travel through a vacuum as in the case of heat from the sun reaching the Earth and warming it enabling life to exist. The rate at which an object radiates heat depends on a number of factors. These factors include

1. The temperature of an object being heated
2. The type of surface of those objects
3. The temperature of the surrounding environment

The sun transfers heat energy to animals by the third method of heat transfer as described above. Large animals have the ability to retain heat more easily than smaller animals. This is because as an animal increases in size, there is proportionately less skin area exposed relative to their total body mass and therefore, less heat loss through the skin (via pores) to the environment. This is called surface area to volume ratio. Smaller animals have a larger surface area to volume ratio.

The surface area to volume ratio of an object is its surface area relative to its volume. The larger an animal, the smaller its surface area to volume ratio. Small animals have a

large surface area to volume ratio lose and gain heat more quickly than a larger animal with a small surface area to volume ratio. This is important in temperature regulation.

I predict from the above scientific knowledge that the centrifuge test tube will loose the most heat and the boiling test tube will loose the least heat in a given time. This is because the centrifuge test tube is the smallest and has the largest surface area to volume ratio it will loose heat more quickly compared to the boiling test tube. This is because the boiling test tube has the largest test tube and has a smaller surface area to volume ratio, so it will loose the least amount of heat as there is less surface area exposed relative to the total volume.

Obtaining Evidence

Results table:

The table shows the decrease in temperature of heated water contained in different sized test tubes in 300 seconds

Time/seconds	Boiling test tube /°C (largest)	Standard Test tube/°C	Centrifuge test tube/°C (smallest)
0	40.0	40.0	40.0
30	39.5	39.0	39.0
60	38.5	38.0	38.0
90	38.0	37.5	37.5
120	37.5	36.5	37.0
150	37.0	36.0	36.0
180	37.0	35.0	35.0
210	36.5	34.0	34.5
240	36.0	34.0	33.0
270	36.0	33.0	32.0
300	35.0	32.0	30.0

Analysing and Considering Evidence

From the results table and graph the following trends and pattern can be identified: the temperature of the water dropped by 1°C or 1.5°C every 30 seconds. It can be seen that at around 60°C all the test tubes were approximately at the same temperature, which was 38-38.5°C.

The graph showed a gradual decrease in temperature of the water contained in all of the tubes. The water contained in the boiling test tube demonstrated a decrease of 5°C in temperature, the standard test tube demonstrated a decrease of 8°C in temperature, and the centrifuge test tube demonstrated a decrease in 10°C. Hence the centrifuge test tube demonstrated the largest decrease in temperature where as the boiling test tube demonstrated the smallest decrease.

In conclusion the test tube with the greatest surface area to volume ratio (centrifuge test tube) lost the most heat. It was predicted that the centrifuge test tube, which has the

largest surface area to volume ratio, will loose the most heat and the boiling test tube, which has the smallest surface area to volume ratio, will loose the least amount of heat.

From the results obtained in the investigation it can be seen that the prediction was proven correct. The centrifuge test tube lost the most heat (shown by a greater decrease in temperature of the water) because it had the largest surface area to volume ratio. The centrifuge test tube has a larger surface area in relation to its volume through which the heat of the water contained could escape. Therefore the water cooled down the most as the heat was radiated to the surroundings. The boiling test tube has a smaller surface area in relation to its volume through which little heat of the water contained could escape. Therefore it took longer for the water to cool down and less heat was radiated to the surroundings. These findings can be applied to animals and the amount of heat lost by them relative to their surface area and volume. A camel has a small surface area in relation to the volume and therefore has the ability to retain heat more easily than smaller animals. As the camel looses less heat it can tolerate changes in temperature and cope in the cold temperature at night. A mouse has a large surface area in relation to the volume and therefore can loose more heat in order to keep cool. The heat is then radiated to the surroundings. From the two examples given it can be seen that the surface area and volume of an animal plays an important part in temperature regulation.

Evaluation

The experiment was successful, the method used and the measurements obtained were accurate and reliable as the prediction was proven correct. A second reading was not taken as the results obtained were accurate and followed a pattern. There were no anomalous results. The method was suitable but to further improve the results of the experiment a number of steps could have been taken

1. A digital thermometer could be used as it would reduce human error and give more accurate results.

2. Using a digital stopwatch to time the investigation, as this would give a more accurate time and results

3. Cling film could be placed over the test tube to reduce the amount of heat loss and make it all more applicable to animals as animals are closed systems as opposed to having extremely large openings.

The results were reliable, as the prediction was proven correct and it was fair test by using the same observer to observe the amount of heat lost, using a stopwatch, and measuring the amount of water accurately and placing the test tubes in the same environment, however the steps above (1-3) could have produced an even more accurate result.

Further study, which would help support the conclusion, could involve investigating how the size and shape of an animal affects the amount of heat loss. It could also be investigated whether the sizes or shape of an animal was the most important factor in determining the amount of heat lost.