PUPIL RESEARCHER INITIATIVE

Bioengineers and incubators

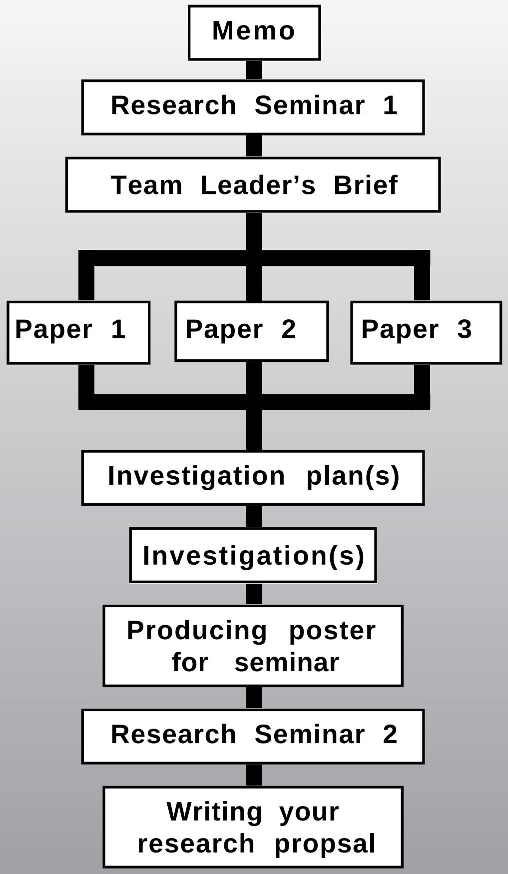
Pupil Research Brief

Teachers' Notes

Syllabus Coverage *Subject Knowledge and Understanding*

- ❑ the thermoregulatory centre of the brain monitors and controls body temperature
- ❑ this centre has receptors sensitive to the temperature of the blood flowing through the brain
- ❑ temperature sensors in the skin send impulses to the centre
- ❑ if the body temperature is too high, blood vessels in the skin dilate so that more blood flows near to the surface and more heat is lost
- ❑ sweat glands release sweat which evaporates to cool the body
- ❑ if the body temperature is too low blood vessels supplying the skin constrict to move blood flow deeper into the skin
- ❑ when muscles 'shiver', the extra respiration releases some energy as heat

Route through the Brief



Introduction

This Brief takes its inspiration from work being carried out by researchers at the Royal Maternity Hospital, Belfast. Advances in medicine have enabled pre-term babies at earlier and earlier stages in their development to be saved. These babies' homeostatic processes, such as temperature control, are not fully developed. Bioengineers are continually striving to develop incubator technology that has the sensitivity and speed of response to cope with the constantly changing individual needs of these babies. Some of the research carried out on pre-term babies which has informed bioengineers is referred to in the papers in the Brief.

The pupils and teacher take the roles of research scientists or engineers in a bioengineering department: the pupils are new **research students** and the teacher is their supervisor, the **Research Director**. The department is seeking funding for a new research project to develop a new incubator to address the needs of very early pre-term babies, i.e. those that are more than 12 weeks premature. The pupils are asked to research one aspect of the issue. They use the results of their work to write an investigation report and make a poster presentation at a research seminar. At the seminar, they will hear about the work of other research groups. They will then use the results of their own investigations, and the work of others, to write a research proposal. This will go to the Research Council (i.e. it is handed in to the teacher), who will decide whether the project deserves support. The teacher may then wish to award the 'grant' to the most promising suggestion.

Pupil Research Brief

Teachers' Notes continued

A theme of this Brief is how researchers communicate with each other. Sometimes science or engineering research projects are too broad for one team to provide all the necessary expertise. To reflect this fact pupils are divided into teams which will specialise in one aspect of the overall problem - designing an incubator for premature babies. Each team will carry out one or two investigations, and then present their findings at a research seminar. Their work will be presented orally (perhaps using visual aids such as OHTs and handouts), but also 'published', in the form of posters which can be displayed around the room. Although poster sessions are common at research seminars and conferences, in this case the posters could be seen to represent papers in a 'proceedings' journal. Using information from their own work, and that of other research teams working on related but different issues, the pupils will then write a research proposal. Pupils will be introduced to the way that researchers use and refer to the work of others. This should emphasise the collaborative and interdependent nature of research.

Experimental and investigative skills

- planning experimental procedures
- obtaining evidence
- analysing evidence and drawing conclusions
- evaluating evidence

Prior knowledge

Pupils should be familiar with respiration and the blood system. They should have a basic understanding of the transfer of energy by conduction, convection, radiation and evaporation. Knowledge of the homeostatic temperature control in humans should be covered by the teacher in the first research seminar.

Running the Brief

Pupil grouping

Pupils could work in a number of groupings during this Brief. Suggestions are:

Memo	-	individuals
Research seminar 1	-	whole class; teacher-led seminar
Team leader's brief	-	class in sub-groups of three pupils until research seminar 2
Respective background papers allocated to sub-groups for analysis		
Investigation(s)		
Writing investigation report		
Preparing for presentation at research seminar		
Research seminar 2	-	whole class; pupil presentations
Writing investigation report	-	individuals or sub-groups of three

Timing

The Brief should take between 4-5 hours of classroom time. Extra time may be needed to write up individual investigation reports if these are to be used for examination assessment purposes. Some of the work could be done as homework.

Activities

In this Brief, the teacher and pupils take on the role of research scientists in a bioengineering department. The pupils are new **research students**, whilst the teacher is their supervisor, the **Research Director**.

The teacher (Research Director) should give all pupils (research students) a copy of the **Study Guide**, and the **memo** at the end of the lesson preceding the start of the Brief. The Study Guide provides pupils with a summary of what they should produce as they work through the Brief. It can also act as a checklist for pupils to monitor their own progress. The memo sets the context for the Brief, and invites the students to a **research seminar** on *Temperature control in humans* in order to cover the background science, and provide a further briefing for the research team.

The research seminar is in fact the first lesson of the Brief. It provides an opportunity to cover some of the essential syllabus content whilst remaining in the roles defined within the simulation scenario of the Brief. The main points to cover are:

- homeostasis and homeostatic mechanisms
- the structure of the skin
- parts of the body involved in temperature control
- the four ways that heat energy can be transferred from the body to the external environment
- changes that occur in the body, particularly the skin, to prevent over heating
- changes that occur in the body, particularly the skin, to prevent over cooling.

Pupil Research Brief

Teachers' Notes continued

Teachers will have their own approach to this. If the roles within the simulation are maintained, the pupils could be asked to do some background reading in preparation for the seminar so that they can make contributions to the discussions. Some useful stimulus and background reading can be found on this topic in the article *Bioengineers and Incubators* in the first issue of *PRISM* (September 1996), the PRI pupil journal.

Following the first seminar the class should be split into three large groups. Each group should be allocated one of the three **research papers**. The large groups should be subdivided to give **sub-groups** of three pupils. This should help to ensure active participation of all pupils in the Brief. A **team leade**r for each sub-group should be selected. When organising groups and allocating research papers, it should be noted that Papers 1, 2 and 3 make progressively more difficult demands on the pupils, with Paper 3 being the most demanding.

Team leaders should be given copies of the **team leader's brief**, and their group's allocated research paper. The team leader's brief outlines the tasks to be carried out by the group, including analysis of the research paper, planning and carrying out one or more investigations, writing the investigation report and the poster design and oral presentation to be made at the second research seminar.

The overall aim of the work is to produce a research proposal for the development of a new incubator. The proposal should include reference to why the research is necessary, a report of current relevant research (based on the presentations at the second seminar and their own findings), and a summary of their recommendations for the design of the incubator.

Each of the research papers has been annotated by the Research Director, making suggestions for activities and investigations to be carried out by the research teams.

Research paper 1 *Determining the normal temperature range in humans*. This paper discusses the need to maintain a constant body temperature, how to measure body temperature and how to use group measurements to produce a tally chart and then a normal distribution curve for body temperature. The research team should first investigate the body temperatures of a group of people - the larger the better. (This is referred to as *Investigation 1*.) This will allow them to determine the normal body temperature range. They should then investigate where a sensor could be semi-permanently attached to a baby's body to accurately reflect changes in core temperature (*Investigation 2*). They could, for example, compare changes in skin temperature on the forehead, arm, armpit, neck, leg, and abdomen with core temperature (under the tongue). Temperature probes could be used to carry out this part of the Brief (see later section *Investigation details*). The students should use their investigation results to make recommendations on the design of the new incubator for presentation at the second research seminar.

Research paper 2 *The need for a mechanical device to control temperature*. This paper outlines some of the causes of heat loss in pre-term babies (i.e. the transfer of energy to the environment) and why incubators are needed. The research team is encouraged to carry out two investigations. The first looks at the effects of body size and surface area to volume ratios on the rate of heat loss, by using different sized flasks or beakers of hot water, and recording the temperature of the water over a period of time (*Investigation 3*). This could be carried out using temperature probes and spreadsheets (see *Investigation details - Model on*e). As a follow up to this investigation pupils are asked to use a spreadsheet to model the effect of changes in surface area to volume ratios on energy transfer (heat loss) between the baby and the environment. The model can be used to explore how surface area to volume ratios, which change as a baby grows, affect the rate of energy transfer between the baby and the environment (see *Investigation details - Model Two*). The second investigation looks at the effect of evaporation of water from a baby's skin on its body temperature, using two thermometers or temperature probes covered with moist (not drenched) cotton wool. Pupils can explore the effect of air movement on evaporation using a fan, or by blowing. However, pupils may see the fan, mistakenly, as a device which makes the air cold. To try to address this misconception the teacher could demonstrate a similar cooling effect on moist cotton wool if a hair drier (set to warm/hot) is used. The research team should use their investigation results to make recommendations for the design of the incubator to overcome the problems faced by premature babies at the second research seminar.

Research paper 3 *Keeping babies warm*. This paper outlines the background science and application of a neutral thermal environment in baby care, and heat energy transfer in incubators. The research team is encouraged to investigate heat energy transfer and methods of reducing it using a simple model. This could involve using a 50cm^3 beaker of water to represent the baby, and an inverted 400cm^3 beaker or cling film covered box as the incubator. Thermometers or temperature probes could be placed in the 'baby', the 'incubator' and in the

Teachers' Notes continued

environment immediately outside the incubator, to monitor changes in temperature. When attempting to reduce energy transfer to the environment (*heat loss*) the research team must remember that the baby will need to be observed whilst in the incubator. They must make recommendations for the design of a new incubator based on their investigation for presentation at the second research seminar.

All the groups will present their findings, using posters (and OHP slides if necessary) at the second **research seminar**. Instructions for preparing their presentations are given in the team leader's brief. Each group should be given a maximum of five minutes to make their presentation. The posters should be displayed around the room so that pupils can refer to them. Each poster should have a title, a date (year only) and the names of all the contributing authors (surname followed by initials). Pupils will use their notes made during the seminar, backed up by references taken from the poster display to help them write their research proposal. In the proposal, the pupils should make reference to other groups' posters as if they were research papers. This means that they would need to cite author and year date where relevant in the text of their report, and to list all such references in surname order at the end of their report. The list of references should include authors' names (surname followed by initials, title of 'article' and year produced). This will introduce pupils to the way that research papers are based on a combination of the author's own original work and that of others working in related fields. It would reinforce the point that communication is important in helping researchers develop their ideas.

Following the handing in of research proposals, the teacher may wish to 'award' the research grant to the most promising proposal.

Investigation details

The following investigations are prompted by the research papers. Pupils would normally only carry out the investigation(s) associated with one of the three papers.

The investigations are:

1 The normal temperature range in humans
2 Finding the best place to attach a temperature sensor to a baby's body
3 The effect of size and surface area to volume ratios on energy transfer
4 The effect of evaporation on energy transfer
5 Using a model incubator to investigate energy transfer.

Temperature measurement (applicable to all investigations)
Temperature measurement can be carried out with a range of different devices from mercury-in-glass thermometers to computer interfaced sensors. The choice of device will be made according to the task, considering factors such as range, sensitivity, accuracy and safety.

Sensors and dataloggers are most appropriate for measuring and recording changes in temperature, as opposed to determining absolute or fixed values of temperature. These changes may be small, occurring in short or very long time intervals, or difficult to measure because of location.

Most temperature sensors use a temperature dependent component such as a thermistor. The resistance of the thermistor changes as the temperature changes. This can be detected as a varying voltage and translated into a digital signal by the datalogger. This signal can then be displayed by appropriate datalogging software. The user will only see the end product of this - the data on the computer screen. The analysis and interpretation of the data is where the science begins.

Skin temperature
The datalogger may be appropriate for this measurement particularly when looking at the effect of exercise on temperature. Ideally the sensor would be attached to the skin using medical tape and logging started before exercise. This would allow any changes to be monitored and recorded as the exercise took place.

Most temperature sensors used in schools are designed for use in liquids and are mounted in a stainless steel case. This does not make them very suitable for attaching to the skin, though the standard temperature sensor for the LogIT datalogger and the *Philip Harris* First Sense temperature sensor are both flexibly mounted and will work reasonably well.

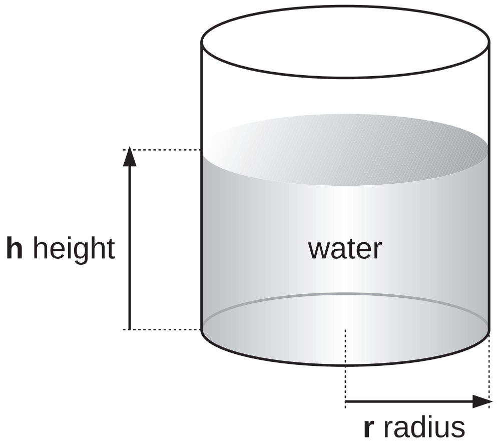
Interesting results can be obtained from investigations into variation in skin temperature in areas over muscles when exercising. A sensor taped to the biceps shows surprising results particularly at the beginning of the activity.

Modelling heat loss in small babies
The relationship between heat loss and surface area can be explored by simple investigations into cooling-rate of different sized containers of hot water. This effect can also be simply modelled using a

Teachers' Notes continued

spreadsheet. This would be a good way of both introducing the concept of modelling and introducing pupils to the use of IT to support this technique.

The spreadsheet models illustrated are used simply in the analysis of the problem. They are provided as examples and guidelines, teachers or pupils will probably develop their own files. The spreadsheet could be given to the class to input data or the pupils could be encouraged to develop their own model with some guidance and support from the teacher. This would be beneficial both for developing scientific understanding and in their development of IT capability. Spreadsheets are a generic tool. Examples commonly used in schools, such as Microsoft Excel (PC, Mac), Claris Works (PC, Mac) and Eureka (Acorn), could all be used for this activity.



surface area $= 2\pi \mathbf{r}^2 + 2\pi \mathbf{rh}$
$= 2\pi \mathbf{r}(\mathbf{r}+\mathbf{h})$

volume $= \pi \mathbf{r}^2 \mathbf{h}$

	B	C	D	E	F	G	H	I	J	K	L
	container	volume of water (cm^3)	radius **r** (cm)	height **h** (cm)	surface area (cm^2)	*ratio*	start temp. (°C)	finish temp. (°C)	change (°C)	time (min)	*cooling rate* (°C/min)
14	beaker	90	2.5	5	118.02	1.31	67	23	44	18	2.4
15					0.0	0.00			0		0.0
16					0.0	0.00			0		0.0
17					0.0	0.00			0		0.0
18					0.0	0.00			0		0.0
19					0.0	0.00			0		0.0

enter formula: =2*PI()*D14*(D14+E14) here, and fill down the column

enter formula: =F14/C14 here, and fill down the column

enter formula: =J14/K14 here, and fill down the column

Fig. 1 Spreadsheet template model 1

The standard experiment is carried out here. Different sized beakers are used to model different sized babies. The cooling-rate of hot water in the containers is found by measuring the change in temperature over a known period of time.

The spreadsheet template can be used to record the results of heat loss over time for different containers. The template also includes cells for calculating the surface area and volume of the containers and subsequently the ratio of surface area to volume. When the results have been completed a graph of cooling-rate against this ratio can be drawn (using the spreadsheet graphing tool), showing the effect of size on cooling and heat loss.

Teachers' Notes continued

Modelling heat loss in babies
- how does the surface area/volume ration change as size increases?

	Given Data				Calculated Data				
	density (g/cm^3) = 1								
	gestation (wks)	head circumference (cm)	mass (g)	length (cm)	volume (cm^3)	surface area (cm^2) head	surface area (cm^2) body	surface area (cm^2) total	*ratio*
10	28	26	1100	36	1100	215	3797.8	4013	3.45
11	32	29	1800	41	1800	268	5414.1	5682	3.01
12	36	32	2500	45	2500	326	7224.1	7550	2.89
13	40	35	3500	51	3500	390	9894.5	10284	2.83
	B	C	D	E	F	G	H	I	J

density assumed to be $1 g/cm^3$ but can be altered in this cell.

estimate from mass using density formula: =D10/D6

assume the head is a sphere and use the formula: =C10^2/PI()

assume the body is a rectangular cube use the formula: =(E10-(C10/PI()))*2*(C10^2)/(PI()^2)

formula: =H10/F10

Fig. 2 Spreadsheet template model 2

In the second model the spreadsheet is used to extend the ideas from the previous experiment. The table of data for variation of size of baby according to gestation is provided for the pupils to develop a model of volume and surface area of the baby.

weeks of gestation	Mass (g)	Length (cm)	Head circumference (cm)
28	1100	36	26
32	1800	41	29
36	2500	45	32
40	3500	51	35

Fig. 3 Average dimensions at different periods of gestation

The shape of the baby must be approximated for pupils to be able to calculate surface area. In the example shown the head is treated as a sphere and the body as a rectangular cuboid. This could be further refined depending on the ability of the pupils.

The approximation shows that as the weeks of gestation increase, the surface area to volume ratio decreases. Pupils should be able to use the information from the first model and investigation to comment on the heat loss as the term of the baby increases.

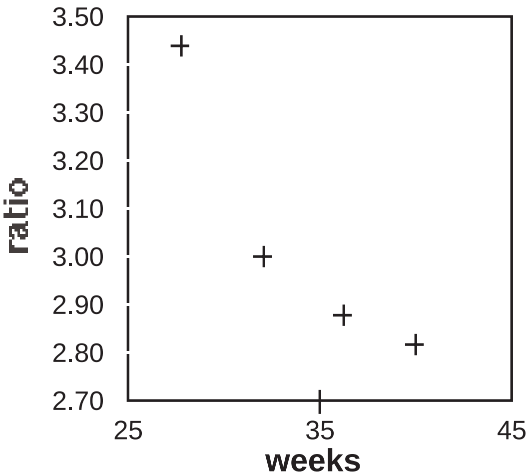


Fig. 4 Graph showing change in ratio as baby develops

Even with a limited amount of data the trend is clearly seen in the sample results shown. Pupils could be encouraged to expand the data in the model by further research.

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Technical details

Investigations based on Paper 1
Clinical thermometer
cotton wool
disinfectant eg *Millons*
Four -10 to 110°C thermometers
temperature sensors
datalogging software
computer
interface box

Investigations based on Paper 2
Four beakers (various sizes)
Four -10 to 110°C thermometers
warm water
card and scissors
retort stands, bosses and clamps
cotton wool
elastic bands
computer with spreadsheet software

Investigations based on Paper 3
50 cm^3 beaker
Three -10 - 110°C thermometers
warm water
400ml beaker or box and clingfilm (to make model incubator)

For each of the three sets of investigations, pupils may decide to use other apparatus not listed above.

Safety issues

PLEASE NOTE: It is also important that you prepare your own risk assessments for the practical work in this Brief in the usual way.

Pupils as experimental subjects: precautions should be taken to prevent emotional stress. No pupil should be pressurised into being a 'subject'

Hot liquids: danger of burns/scalds

If burned/scalded: hold under flowing cold water for at least 10 minutes. If anything other than very minor (shallow, less than 5mm diameter), seek medical attention.

Using Sensors attached to the body: there is a small risk of electrocution from attachment to the sensor if it is directly connected to a mains-supplied computer. This is an extremely small risk. To eliminate this danger the following should be done:

- use the datalogger (powered by battery) in remote mode, and download data to the computer when measurement is completed;
- use the datalogger in real time connected to a portable battery powered computer such as a laptop or a palmtop.

Assessment issues for *Experimental and Investigative Science* (National Curriculum for England and Wales, Northern Ireland Curriculum)

P	Planning	O	Obtaining evidence
A	Analysing evidence	E	Evaluating evidence

There are five possible investigations in this Brief.

Normal temperature range in humans
This investigation provides opportunities to select, use and compare different measuring instruments of differing levels of precision and the selection and use of statistical techniques. High level marks for **Skill Areas P and O** are possible. Use of statistical techniques including working out frequency distributions could also allow high marks for **Skill Area A**. The full range of marks for **Skill Area E** are available if pupils evaluate the techniques and instruments used to gather data.

Placement of sensors to measure skin temperature
Low and middle marks are possible for **Skill Area P**, due to the simple nature of the task (likely to include only categoric variables, although scientific knowledge to underpin this will be important). **Skill Area O** could be extended to higher levels by concentrating on comparative results. **Skill Areas A and E** are likely to be middle range or lower marks unless **O** is extended.

Body proportions and heat loss
This investigation could be carried out at a variety of levels, depending on the availability of suitable glassware. For low marks in **Skill Area P**, pupils will need to plan a fair test involving equipment they have selected. Marks could increase if they select a suitable number and range of measurements, but this could be dependent on the availability of glassware. High marks would require taking reliability and validity into account. **Skill Areas O, A and E** may be limited by their approach in **Skill Area P**, although high marks in **Skill Area E** could result from comments about the reliability of the evidence, and improvements to provide further evidence.

Energy transfer and evaporation
At its simplest this can be a 2-value, categoric investigation (dry and wet), but it could easily be extended by systematically varying the amount of water used, and further by considering the ambient temperature and humidity. Pupils' approaches to this will determine their mark in

Teachers' Notes continued

Skill Area P. For **Skill Area O** middle level mark range would be usual, if pupils produce cooling curves, but higher marks could be achieved if they take into account such factors as ambient humidity. The full range of marks should be available for **Skill Areas A and E**, depending on the approach taken in **Skill Areas P and O**.

Model incubators and energy transfer
Use of scientific knowledge to help design and produce a model is appropriate to the low mark range in **Skill Areas P and O**. Knowledge of ambient conditions and how they interact with the 'model' may move this to higher mark levels. Detailed knowledge of such factors as ambient conditions and their interaction with the incubator 'model' will be needed for these high marks in **Skill Areas A and E**.

Scottish syllabus coverage

Standard Grade Biology - *Body in Action*
Standard Grade Physics - *Electronics; Health Physics*

Further pupil research opportunities

Pupils could find out what the latest developments are in neonatal care. This is an area of lively research activity. They may wish to design an electronic temperature monitor/controller, using equipment such as MFA boards, that will sound an alarm if the temperature gets too low or if the moisture level gets too high (i.e. the baby is sweating).

Note : references cited in Paper 3 of the pupil Brief are all real papers except for Hull, D. (1995) which is simulated (Paper 2 in the Brief).