THERMAL BALANCE OF REPTILES

Rationale

This practical is a Windows-based computer simulation of the thermo-physiology of reptiles. It replaces an experiment using live lizards (blue tongue skinks) that we ran previously.

Computer simulation exercises are being introduced as an important part of teaching large practical classes in Second Year level. We have done this for several reasons - primarily in relation to the ethical issues arising from the use of live animals in teaching. These include (i) large class sizes requiring large numbers of animals, (ii) long experiment times which compromise an animal's behavioural responses (iii) use of live animals minimises student input to experimental design because procedures have had to be approved by an Ethics Committee in advance and (iv) the unwillingness of some students to do live animal experiments.

This is the second version of this programme but incorporates some new features including a screen where you can move the animal into several different microclimates. Most of the bugs should have been eliminated but we are particularly interested in your opinions and responses. If you discover bugs or conflicts please notify us by email or a note giving as much detail as possible. We can't fix bugs during the semester without a major effort but you should be able to work around any minor problems. The model is not a perfect representation of the physiological processes but it is more than adequate for our purposes.

The programme

(1) Access the programme by selecting the menu Item from the Biology Group on any of the PCs in Copland G029 and Copland G022.

(2) Bring a empty formatted 1.44 Mb PC (not Mac) disk to a lecture or prac session and we will give you a copy of the programme to install on your own PC. The programme will not run on a Mac unless that Mac runs some sort of PC Emulation Package like Soft PC.

The programme can be run in two modes:

Static Mode – allows you to change aspects of the environment and animals and run the simulation over several hours.

Mobile Mode – allows you to move the reptile that you have specified between three different microenvironments – the top of a rock, the shade of a rock and underneath the rock over a 24 h period. The environmental conditions prevailing during that 24 h period can be specified but you cannot change behaviour, skin colour or conditions. These blank out from the screen and are automatically be set as behaviour: yes; and conditions: outside.

Getting started - What some of the switches mean

(i) **Animal variables**

Weight (kg)

The programme will accept body weights between 10 g and 1000 kg. You must enter the values in kilograms. Therefore the limits are 0.01 and 1000. I suggest that you focus your investigations on say three body masses. I suggest a typical value for common blue tongues is about 1kg; a small blue tongue is about 150 g. You may also wish to see what happens to animals of 0.02 kg and a very large animal (obviously not a blue-tongue!) of 20 kg. While you will not be able to play Jurassic Park, you will certainly gain an idea of the thermal inertia of large reptiles that may give you some insights into the debate about "hot-blooded dinosaurs".

Body temperature

The body temperature range is 2^{o}C to 50^{o}C. The programme will accept higher temperatures but performance maybe erotic outside this range. The typical range that a lizard might experience is between about 10^{o}C and 40^{o}C. I know of one species in the Middle-East that has a preferred maximum of 42^{o}C.

Eccritic temperature

Selection of the correct eccritic temperature is very important. The major weakness of the model is that it relies too much on the selected eccritic temperature. The eccritic temperature is the preferred or selected body temperature of an animal and will generally be between 32 and 40^{o}C. You should use a lower eccritic temperature for smaller animals - for example a 20g animal may have an eccritic temperature of say 30^{o}C whereas large animals will have eccritic temperatures of 38^{o}C to 40^{o}C. The programme will accept a greater range but again the further you go from the ranges seen in the real world, the less reliable will be the simulations.

(ii) Environmental variables

Julian day

The Julian Day is simply the number of the particular day of the year. For example, January 1 is "1"; July 1 is "181" and December 31 is "365". Variations in this setting serve to vary the angle of the sun above the horizon and so vary the intensity and duration of solar radiation. It should have no effect if you move the animal into the shade. Note the comment under latitude if you find you are getting more rapid heating in summer than in winter.

Air temperature

The range of air (or ambient) temperatures accepted by the programme is between 0 and 100^{o}C but 50^{o}C is about the upper ambient temperature measured on earth. I suggest that you go no higher than this. Most previous experiments have been performed at air temperatures between 20^{o}C and 40^{o}C.

Latitude

We did the programming for this in Scotland and used Northern Hemisphere equations for the angle of the sun. For the Southern Hemisphere you need to enter the value as a negative. You will only notice this difference if you are changing the Julian day as well. i.e. animals may heat more quickly in winter than in summer!

Hobart 49^{o}S Brisbane 27^{o}S

Melbourne 37^{o}S Townsville 19^{o}S

Sydney 33^{o}S Cape York 12^{o}S

Time past Midnight

This should be self-explanatory and serves to allow variations in solar load.

(iii) Options

Behaviour

The behaviour switch allows the animal to defend or reach an eccritic temperature by behavioural means (as well as any physiological means). For example if radiant heat load is too high, typical behaviours might be to move to a shaded area. Alternatively, an animal might bask in sunlight to allow its body temperature to increase more rapidly. It is a very simple simulation of “behaviour” but running the programme in “mobile” mode allows you to have greater control over behaviour.

Skin colour

The skin colour of many lizards changes as their body temperature change. Although this is not very noticeable in animals such as blue-tongues, other species such as the Spiny tailed Lizard of the Middle-East goes from dark brown to almost pure white as body temperature approaches 42^{o}C.

Conditions

The Shade/Exposed switch allows you to remove the input of solar radiation. In effect at the same air temperature you should see a much more rapid rate of heat transfer and hence body temperature change when solar radiation is allowed. In the absence of solar radiation heat transfer will mainly be effected by convection. An interesting "experiment" might be to allow behaviour and move the animal into shade and then into exposed conditions.

Mobile Mode

There are some additional switches when running the animal in “Mobile”mode. Note in particular that you can change the speed of the simulation with the sliding switch and that you also have the option of pausing the simulation by clicking the “Pause” button. You should use slow settings to give you time to observe what is happening to the body temperature and make a decision as to where to move the icon “animal”. You can move the animal by clicking and dragging it to a different location. Note that the graph now covers a 24 h period.

BUG ALERT: There is a possible minor bug in the rock temperature routine: If you abort a simulation before it gets to the end, the rock temperature for the next simulation may not always be initialised correctly. Either allow a simulations to run to the end or re-do that experiment.

(iv) Printing and data output. You can export relevant data for each experiment to a *.txt file. The file will be in a space delimited form (i.e. will have a space between each datum). The first line of this file will be the comment that you enter into the comment box. This file format is easily imported into MS Excel where you can manipulate and plot the data to produce the figures that you need to summarize your findings.

Note that although you can perform a number of experiments on the screen you can only output two simulations at any time – if you output only a single simulation then the data will be mirrored under the first experiment.

Alternatively you can print directly from the screen to any on- line printer. Again the comment that you must enter in the box on screen will appear on the printout. This output option may be helpful in checking particular features of your experiments but should not be submitted as part of your report.

When using the model in the mobile mode, it may be useful to read the paper by Christian and Weavers (1996) which shows an excellent graphical display of the yearly temperature profiles. Note that switches for behaviour, skin colour and shade/exposed are not activated in mobile mode. Note also that if you wish to commence the mobile simulation with the animal either under or in the shade of the rock, then you must wait for the simulation to start and then click and drag the icon.

The programme when run in Static Mode also produces a plot of Heart rate vs Body temperature when running in static mode. However, at this stage the Heart rate graph itself cannot be printed from the screen, but you can output the data as described above.

The Animal and Environment variables can be changed by typing a new value in the box.

Some advice

To answer questions about the degree of physiological control that lizards have over their body temperature, you will need to do some controlled experiments. I suggest that initially you do this in “Static Mode”. This means (i) turning behaviour "off" (ii) removing the effect of solar radiation by putting the animal in shade. This will then be equivalent to many of the experiments reported in the literature. I suggest the following approach

(i) read these notes again!

(ii) spend a short session playing with the programme to see what it can do.

(iii) read some of the references so that you know what experiments will be worthwhile doing. There are far more possible combinations than are either necessary or sensible. Try not to vary too many factors.

(iv) design some useful experiments to answer the questions you have identified from your reading.

(v) Perhaps then ask how modifying one further factor might change your conclusion.

Build up your investigations in this way rather than simply changing a number of factors randomly or simultaneously.

The following questions might help you to get started but they are a guide only. These questions could be answered just by using the model in the static mode. If you answered these and wrote the work up adequately, you could achieve a passing grade. To achieve a higher grade we are looking for evidence that you can make some independent investigations and that you are able to make some intelligent and worthwhile experiments. Those investigations could utilise both the static and mobile modes of the programme

1. Do lizards heat faster than they cool?

2. How does body mass affect these rates?

3. How does skin colour interact with body size to affect heating rates?

4. What mechanisms could account for a difference in the rates of heating and cooling?

5. How does latitude and time of year constrain the distribution and activity patterns of an animal such as a blue tongue skink?

Write-up –

- ***Read the notes at the front of this manual for more details of what is expected in writing a scientific report.***
- ***Read the section above to check what is required for different grades.***

Produce a scientific report that details your investigations.

Introduction should have details of the problems you are investigating and should refer to previous investigations in the laboratory. The Methods should simply describe the different experiments you undertook e.g. “the effect of body mass on heating and cooling rates of reptiles”

The results should summarise in narrative the principal findings and should refer to summaries of your data. Do not include reams of original printouts marked with highlighter pen. You must summarise the findings either in graphs or tables. Use appropriate statistical procedures when necessary

The discussion should emphasise the significance of your results in the context of the problems you set out to address and in the context of previous work.

Conclude with a list of the references you have actually referred to in the text.

References

Bartholomew, G.J. and Tucker, V.A. (1963) Control of changes in body temperature, metabolism and circulation by the agamid lizard *Amphibolurus barbatus*. Physiological Zoology 36: 199-218. (the first classic paper showing differences in heating and cooling rates in lizards)

Bartholomew, G.J. (1982) Physiological control of body temperature. Pages 167-211 in C. Gans (ed) Biology of the Reptilia. Volume 12 (Physiology C). Academic Press: New York. (a major review of body temperature relationships)

Christian, K.A. and Weavers, B.W. (1996) Thermoregulation of monitor lizards in Australia: an evaluation of methods in thermal biology. Ecological Monographs 66:139-157, 1996. (an excellent integration of laboratory, field and modeling studies in reptile thermoecology)

Fraser, S. and Grigg, G.C. (1984) Control of thermal conductance is insignificant to thermoregulation in small reptiles. Physiological Zoology 57:392-400. (how do small and large animals differ in their thermoregulation)

Huey, R.B., Peterson, C.R., Arnold, S.J., and Porter, W.P. (1989) Hot rocks and not-so-hot rocks: retreat-site selection by Garter snakes and its thermal consequences. Ecology 70:931-944. (describes the importance of rock size to theremal ecology of snakes – used to develop our model)

McArthur, A.J. Thermal interaction between animal and microclimate: a comprehensive model. (1987) Journal of Theoretical Biology 126:203-238 (this describes equations that we used in part to construct the model)