Equations for Exam 1, Biology 641

SI Units:

Temperature in units of Kelvin (= T (°C) +273)
Distance in units of m; area in units of m^2; volume in units of m^3
Mass in units of kg
Time in units of seconds (s)
Heat in units of Joules (J)
Heat flux (Q) in units of Watts (W; 1 W = 1 J/s)

Constants:

specific heat capacity (c_p) of water (and tissue) = 4180 J/(kg K)
$\sigma = 5.67\ 10^{-8}\ W\ m^{-2}\ K^{-4}$
k_b of tissue (water) = 0.6 W/mK
λ = latent heat of vaporization = 2.5×10^6 J/Kg
μ_{air} = dynamic viscosity of air (assume the same for all temps) = $18\ 10^{-6}$ Kg/(m s)
ρ_{air} = density of air at 20°C = 1.205 kg/m^3
$\mu_{water,10}$ = dynamic viscosity of seawater at 10°C= $1.39\ 10^{-3}$ Kg/(m s)
$\mu_{water,30}$ = dynamic viscosity of seawater at 30°C= $0.868\ 10^{-3}$ Kg/(m s)
$\rho_{water,10}$ = density of seawater at 10°C = 1023.45 Kg/m^3
$\rho_{water,30}$ = density of seawater at 30°C= 1021.18 Kg/m^3

Equations:

$R2 = R1\ Q_{10}^{\ (T2-T1)/10}$
$Q_{10} = (R2/R1)^{\ 10/(T2-T1)}$
$Re = \rho\ U\ L / \mu$
$\delta = 5\ \mathrm{Sqrt}[\ (x\ \mu)/(\rho\ U_\infty)]$
$\Delta\text{heat stored} = \Delta T\ (m\ c_p)$
$\Delta T_1\ (m_1\ c_{p1}) = \Delta T_2\ (m_2\ c_{p2})$
Q_{solar} = short-wave solar heat flux = $\alpha\ A_s S$
Q_{IR} = long-wave (infrared) heat flux to surroundings = $A_{IR}\ \sigma\ (\varepsilon_{surr} T_{surr}^4 - \varepsilon_{org} T_b^4)$
$Q_{cond} = K_b\ A_{cond}\ (T_1 - T_2)/d$
$Q_{conv} = h_c\ A_{conv}\ (T_b - T_f)$
$Q_{evap} = \lambda\ h_m\ A_{evap}\ (C_s - C_f)$

Name:

Exam 1

Biol 641, September 13, 2005
(160 points total)

Read each question carefully; ***some questions have multiple parts. Please confine your responses to the space allocated for each question.*** Please show all work- this will help me to assign partial credit. However, I reserve the right to take off points for incorrect parts of answers (i.e., no "shotgunning.")

1. Define and distinguish the terms *temperature* and *heat*. Explain why a physiological ecologist cares about the distinction between these two terms, and why they cannot be used interchangeably (10 pts).

2. Define *thermal inertia*. What factors determine an organism's thermal inertia, and give two examples of why this concept is important to an organism's physiology. (10 pts). Explain how this concept might impact how you conduct temperature measurements in the lab or field? (5 points)

3. Explain how the no-slip condition, fluid velocity and fluid viscosity all interact to create a boundary layer (15 points).

4a. A snail, with a mass of 10g and an initial temperature of 40°C, is placed into a sealed water bath with initial temperature of 15°C and mass 10g. The system is allowed to come to equilibrium, until both snail and water are at 22.5°C. What is the (average) specific heat capacity of the snail? (show all work, including units; 15 pts.)

4b. Suppose the same experiment described above was conducted in a cup that was open to the air at the top (as in lab). Would the estimate of specific heat capacity likely be higher or lower than that calculated above? Explain why (10 pts)

5. Using an oxygen probe, you measure the respiration rates of three species of fish over a range of temperatures, and your data are as follows:

Table 1. Respiration rates (μg O_2/minute) of three species of fish over a range of temperatures.

Temperature (°C)	Sp. A	Sp. B	Sp. C
5.5	2.1	2.6	2.0
11.6	4.1	4.9	3.3
21.4	12.0	13.7	7.5
29.2	28.4	31.1	14.4
34.2	49.2	48.2	21.8
42.5	105.3	75.2	43.6

a. What are the Q10s for each species? Show all work. (20 pts).

b. Calculate the respiration rate for species A at 40°C. Show all work (10 pts.)

c. Rank the tolerance to high temperatures by each species, and *justify your answer using the data in Table 1*. Which species is *least* likely to be found in a hot tidepool in Baja, Mexico? (10 points).

6. Suppose you want to model flow around a tropical coral with length 15cm in a wind tunnel. The gorgonian normally lives in water with a flow speed of 30 cm/s. Your wind tunnel, however, has a fixed wind speed of 4 m/s. What size do we need to make our model of the gorgonian in order to make sure the fluid flow characteristics remain the same when we do our trials? Show all work. (15 points).

7. Two benthic sponges are sitting on the bottom of the ocean, in a well-developed boundary layer (one that has been growing for 100m since the nearest "leading edge"). One is 15 cm tall, the other 1 m tall. The ambient water flow (several m above the bottom) is 10 cm/s. Is the smallest coral big enough to escape the effects of the boundary layer? Justify your answer quantitatively (15 points).

8. What physiological function does a heat shock protein (hsp) serve (5 pts)?

9. A small snake crawls out from under a thick rock and on to the top of the rock to sun itself. The initial temperature of the snake is 20°C and that of the rock is 35°C. The intensity of the sun is 800 W/m^2. The snake has a projected area of 12 cm^2 and mass 15g. The short-wave absorptivity of the snake is 0.9, and the area of conduction is the same as that of the projected area. The radius of the snake's body is 1 cm. Assuming that short-wave solar radiation and conduction to the rock are the only sources of heat input to the snake, what is the rate of heat flux to the snake? (10 points). Given this rate of heat input, what is the increase in body temperature of the snake over the first three minutes? (5 pts). If the snake had eaten a large meal, effectively increasing its mass by 50%, what effect would this have on the rate of temperature increase, assuming that factors such as surface area were only minimally affected. (5 pts.)