Name/Student ID:_____ SC/BPHS2090 Final Exam (Lew)

Be sure to write your name and ID above. Read the two sub-questions carefully, think, then write your answers in the lined space (front and back of this page). When finished, please hand your answer in, separate from your exam booklet. **Be Sure to Show Units!**

QUESTION: Using microcalorimetry, Lamprecht[1] recently refined measurements of the *energetics of small insects*, and provides summary values of 10–100 mW g^{-1} for insects weighing 0.1–1 g (W = J s^{-1}). For a xylem-sucking insect, xylem sap provides carbohydrate concentrations of about 0.66 mM (mMoles/liter in glucose equivalents)[2].

• Glucose is a common energy source for a bacteria and the Gibbs free energy change for conversion to H_2O and CO_2 is 2870 kJ $mole^{-1}$. If glucose is the only energy source available, what is the required flux (liters s^{-1}) of xylem sap through the xylem-sucking insect? How often must the insect drink it's own body weight (s)? For simplicity's sake, use 50 mW g^{-1} metabolic rate and 0.5 g insect weight.

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[1] Lamprecht I (1998) Monitoring metabolic activities of small animals by means of microcalorimetry. Pure and Applied Chemistry. 70:695–700.
[2] Campbell JA and S Strother (1996) Seasonal variation in pH, carbohydrate and nitrogen of xylem exudation of *Vitis vinifera*. Australian Journal of Plant Physiology. 23:115–118.

• Novotny and Wilson (1997)[3] note that insects that feed on plant phloem cells (which contain about 1 M glucose equivalents) are, on average, smaller than xylem-sucking insects (xylem contains less than 0.001 M glucose equivalents). Based on your knowledge of biological pumps, why would this be true? Explain so that a non-physicist like Dr. Lew can understand, providing an equation-based rationale.

(End)

[3] Novotny V and MR Wilson (1997) Why are there no small species among xylem-sucking insects? Evolutionary Ecology 11:419–437.

Part One

Here are the constants and other values we require

> $metabolic := 5\,\frac{[\![J]\!]}{[\![kg]\!][\![s]\!]} : weight := 0.0005[\![kg]\!] : glucose := 0.00066\,\frac{[\![mol]\!]}{[\![liter]\!]} : Gibbs := 2870 \cdot 10^3\,\frac{[\![J]\!]}{[\![mol]\!]} :$

Now we can solve for the liters of xylem sap required per second

> $\frac{metabolic \cdot weight}{glucose \cdot Gibbs}$

$$\frac{1.32 \times 10^{-6}\,[\![L]\!]}{[\![s]\!]} \tag{1}$$

To determine the time required for the insect to 'drink' its body weight, divide weight (as volume) by the xylem consumption rate.

> $\frac{0.0005\,[\![L]\!]}{\frac{1.32 \times 10^{-6}\,[\![L]\!]}{[\![s]\!]}}$

$$378.7878788\,[\![s]\!] \tag{2}$$

Thus, the insect must drink its body weight every 6.3 minutes!
Scoring: equation set-up (6/10); correct answers (2/10 and 2/10)

Part Two

Here are the constants and values we require (T = 293 K)

> $RT := 2.437\,\frac{[\![liter]\!][\![MPa]\!]}{[\![mol]\!]} :$

For phloem cells, the internal pressure can be estimated to be

> $solve\left(P = RT \cdot 1\,\frac{[\![mol]\!]}{[\![liter]\!]}, P\right)$

$$2.44 \times 10^{0}\,[\![MPa]\!] \tag{3}$$

For xylem cells, the internal pressure can be estimated to be

> $solve\left(P = RT \cdot 0.001\,\frac{[\![mol]\!]}{[\![liter]\!]}, P\right)$

$$2.44 \times 10^{-3}\,[\![MPa]\!] \tag{4}$$

>

Thus, a phloem-feeding insect doesn't have to pump, because the internal pressure is so high (2.44 MPa).
By contrast, a xylem-feeding insect does.... The cell osmotic pressure is low, and the xylem is normally under suction (about 2000 kPa).
To do so, it has to have a pump strong enough to 'suck' the solution.
This in turn means the insect has to be large enough to provide for the pump muscles (Cibarial dilator muscles).
This is why xylem-feeding insects are larger than their phloem-feeding counterparts.
Scoring: equation set-up and/or correct analysis (10/10). The constants provided were incorrect. This is accounted for in scoring.