The following series of questions relate to the energy balance of a sorghum leaf.

1L. (4) Measurements at solar noon show that the net radiation of the leaf is 700 W m\(^{-2}\) and the sensible heat flux is -100 W m\(^{-2}\). What is the value of latent heat flux? Show how you arrived at your answer. 
\[ Q_E = -(Q* + Q_H) = -(700 \text{ W m}^{-2} - 100 \text{ W m}^{-2}) = -600 \text{ W m}^{-2} \]

2L. (2) Where does evaporation occur in the leaf? cell-air interface in the sub-stomatal cavity

3L. (2) What is the driving force for diffusion of water vapor from the leaf to the air? difference in water vapor concentration between the leaf interior and the air surrounding the leaf

4L. (3) If the leaf temperature is 32° C, what is the value of the vapor density in the leaf interior? How did you arrive at your answer? From the chart, the saturation vapor density at 32° C is 33.85 g m\(^{-3}\).

5L. (3) If the temperature and relative humidity of the air surrounding the leaf are 30° C and 0.5, respectively, what is the ambient vapor density? Show your calculations. 
\[ h_r = \rho_{va} / \rho_{vs} \text{ so that } \rho_{va} = h_r \times \rho_{vs}. \text{ From the table, } \rho_{vs} \text{ at 30° C is 30.4 g m}^{-3}. \text{ Therefore, the ambient vapor density is } 0.5 \times 30.4 \text{ g m}^{-3} = 15.2 \text{ g m}^{-3}. \]

6L. (2) At solar noon, what is the numerical value of the driving force for diffusion of water vapor from the leaf to the air? driving force is 33.85 – 15.2 = 18.65 g m\(^{-3}\)

7L. (2) What two resistances must be overcome for water vapor to diffuse from the leaf interior to the bulk air? stomatal and boundary layer resistances
8L. (4) Will the latent heat flux from a large sorghum leaf be higher or lower than that of a small sorghum leaf, assuming temperatures of the leaves are the same? Why? \( Q_E \) will be higher for the small leaf because the small leaf has a thinner laminar boundary layer.

The following series of questions related the energy balance of a wet, bare soil.

1S. (4) Write the energy balance of a bare soil, and identify each component.
\[
Q^* \text{ (net radiation)} + Q_G \text{ (soil heat flux)} + Q_H \text{ (sensible heat flux)} + Q_E \text{ (latent heat flux)} = 0
\]

2S. (4) Which components of the energy balance of the wet soil are most likely to be positive during the daytime, and which are most likely to be negative? Explain your reasoning.
\( Q^* \) will be positive because more radiation is coming in than leaving. \( Q_G \) will be negative because the surface will be warmer than the soil beneath. \( Q_H \) will be negative because the surface will be warmer than the air. \( Q_E \) will be negative because of evaporation (the vapor density of the surface will be greater than the vapor density of the air).

3S. (4) The following radiation balance measurements were collected for the bare soil at 2 p.m.:
- Shortwave radiation from sun and sky absorbed by the soil = 800 W m\(^{-2}\)
- Longwave sky radiation absorbed by the soil = 200 W m\(^{-2}\)
- Longwave radiation emitted by the soil = 400 W m\(^{-2}\)

What is the value of the net radiation? Show your calculations.
\[
Q^* = \text{absorbed short and longwave radiation minus emitted radiation} = 800 \text{ W m}^{-2} + 200 \text{ W m}^{-2} - 400 \text{ W m}^{-2} = 600 \text{ W m}^{-2}
\]

4S. (4) For the conditions described in the previous question, measurements showed that \( Q_G \) was -100 W m\(^{-2}\) and \( Q_H \) was +100 W m\(^{-2}\). What was the value of \( Q_E \)? Show how you arrived at your answer.
\[
Q^* + Q_G + Q_E + Q_H = 0
\]
\[
Q_E = -(Q^* + Q_G + Q_H)
\]
\[
= -(600 \text{ W m}^{-2} -100 \text{ W m}^{-2} + 100 \text{ W m}^{-2}) = -600 \text{ W m}^{-2}
\]
5S. (2) Based on the previous question, if each gram of water evaporating from the contains 2400 J of energy, how many grams of water vapor per second are being transported away from the soil surface by convection? Show your calculations.
grams of water vapor = \( \frac{600 \text{ J} \text{ s}^{-1} \text{ m}^{-2}}{2400 \text{ J} \text{ g}^{-1}} = 0.25 \text{ g m}^{-2} \text{ s}^{-1} \)

6S. (2) Based on the energy balance measurements, is the soil surface warmer or cooler than the air? How do you know? Sensible heat flux is positive, which means that the surface is cooler than the air.

7S. (3) Measurements showed that the soil heat flux for this wet soil was greater than that of an adjacent dry soil, even though textures and temperature gradients were the same. What accounts for this difference? Wet soil has a higher thermal conductivity.

The following series of questions relate to the energy balance of animals.

1A. (4) Analysis of the energy balance of a grizzly bear shows that very little latent and sensible heat loss occurs from the skin. Why? The fur imposes a high resistance to diffusion of heat and water vapor.

2A. (5) Below is a picture of a black-collared lizard perched on a rock during the middle of the day. Based on the following measurements, diagram the lizard’s energy balance using arrows to show the direction of each energy balance component. Assume the lizard’s belly is in contact with the rock. Be sure to label your arrows.

absorbed short and longwave radiation from sun and sky and rock = 1000 W m\(^{-2}\)
longwave radiation emitted by lizard = 500 W m\(^{-2}\)
air temperature = 35°C
surface temperature of lizard = 30°C
surface temperature of rock = 25° C
latent heat flux = -100 W m⁻²

3A. (5) Below is a picture of the lizard sitting on a the rock during the middle of the night. Based on the following measurements, diagram the lizard’s energy balance using arrows to show the direction of each energy balance component. Again, assume the lizard’s belly is in contact with the rock.

absorbed longwave radiation from sky and rock = 400 W m⁻²
longwave radiation emitted by lizard = 500 W m⁻²
air temperature = 15° C
surface temperature of lizard = 20° C
surface temperature of rock = 25° C
latent heat flux = -100 W m⁻²
General Questions

1G. (2) What are upslope winds caused by surface heating called?
   Anabatic winds

2G. (2) Is the class gerbil an endotherm or a poikilotherm?
   Endotherm

3G. (4) Net radiation is the fundamental quantity of energy which is available at the surface
to drive nearly all of the environmental processes involved in organism-environment
interaction. What is the definition of net radiation?
   Net radiation is absorbed short and longwave radiation minus emitted radiation.

4G. (4) Air temperatures in Houston tend to be higher than those in surrounding rural areas.
What accounts for this? Be specific in your answer.
   Building materials store large amounts of heat during the daytime because of their high
heat capacity, and release heat slowly at night. Evaporative cooling is low because the
amount of vegetation is limited. Thus, more net radiation is available to heat the air.
The radiation load is higher because the artificial surfaces reflect and emit large flux
densities of radiant energy, and urban areas produce heat from combustion. Wind speeds
are lower in cities, so that convective heat loss of heat is less.

5G. (3) Humidity inside a corn canopy tends to be quite high. Why is that the case?
   Wind speeds and convection in the canopy are low, so that much of the water vapor
remains in the canopy.

6G. (4) The light environment at the bottom of a forest is generally not very suitable for
growing plants. Why? There is less light, and the spectral composition of the light
changes as specific wavelengths are filtered out by the trees. Blue light is removed by
the leaves, while amounts of red and infrared radiation are increased.

7G. (4) Measurements at the global CO₂ monitoring facility in Mauna Loa, Hawaii, show that
CO₂ concentration in the atmosphere is at its minimum in the northern hemisphere
summer and at its maximum in the northern hemisphere winter. Why?
   CO₂ concentrations are at their minimum in the northern hemisphere summer because of
CO₂ uptake for photosynthesis. Most of the earth’s land mass and plants are in the
northern hemisphere.
8G. (5) What gases in the atmosphere are primarily responsible for the greenhouse effect? 
water vapor, CO₂, methane, halocarbons, nitrous oxide

9G. (4) Describe the mechanism by which these gases contribute to global warming.
Greenhouse gases absorb longwave radiation emitted from the surface of the earth, which 
increases the kinetic energy of the gas molecules. This increases the amount of longwave 
radiation emitted back toward the surface of the earth by the atmosphere.

10G. (2) Based on the Hadley general circulation model, how much is the average air 
temperature in the U.S. expected to rise over the next 100 years? 5° F

11G. (2) Based on this model, which region of the country will experience the largest 
percentage increase in rainfall over the next 100 years? southwestern U.S.

12G. (4) Is the increasing concentration of atmospheric CO₂ expected to have a positive or 
negative impact on U.S. agriculture? Why? The impact will be mostly positive because 
most agricultural crops benefit from increased concentration of atmospheric CO₂.

Bonus question (3 points)

How many inches are there in a yard?
## Saturation vapor density as a function of temperature

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