

1) Multiple choice. Circle the letter corresponding to the single, most correct answer for each of the following. [2 points each]

The correct units for expressing quantities of photosynthetic irradiance are:

- a) watts  $s^{-1}$
- b) joules  $gram^{-1}$
- c) watts  $m^{-2}s^{-1}$
- b) joules  $m^{-2} s^{-1}$
- e) None of the above are correct

The correct units for expressing quantum yield of photosynthesis are:

- a) watts  $m^{-2}$
- b) mols  $CO_2$  gained / mols photons absorbed
- c)  $\mu mol$   $CO_2$  gained  $m^{-2} s^{-1}$
- b) joules  $m^{-2} s^{-1}$
- e) mols photons absorbed / mols  $CO_2$  gained

To convert photosynthetic photon flux density (PPFD) to photosynthetic irradiance, the following is needed for the calculation:

- a) Atmospheric pressure
- b) Leibig's law
- c) Planck's constant
- b) Atmospheric  $CO_2$  concentration
- e) Beer's law

The correct expression of Fick's Law applied to transpiration rate of leaves in plants is:

(where E = transpiration rate;  $e_i$  = leaf internal water vapor concentration ;  $e_a$  = ambient air water vapor concentration; r = resistance; g = conductance)

- a)  $E = (e_i - e_a) / g$
- b)  $E = (e_i - e_a) \times r$
- c)  $E = (e_a - e_i) / r$
- d)  $E = (e_i - e_a) / r$
- e)  $E = (e_a - e_i) / g$
- f) none of the above are correct

**The field of plant physiological ecology greatly expanded in North America after World War II because:**

- a) the National Science Foundation was formed in the late 1940's to support scientific research
- b) the enhancement of the nation's transportation systems (highways) provided access to remote areas for study
- c) technological advancements in electronics, computing, etc. stemming from WWII provided new ways of conducting ecophysiological measurements
- d) returning veterans had the technical skills necessary to pursue scientific careers
- e) all of the above

**This individual is considered one of the founders of the field of Rangeland Management and Ecology in North America:**

- a) Joseph Priestly
- b) Jan Ingenhausz
- c) Frederic Clementz
- d) Alexander von Humbolt
- e) John Babtista von Helmont
- f) none of the above are correct

**The principal "products" derived from photochemical conversion, the so called "light reactions," that are then used in photosynthetic carbon reduction are:**

- a) ATP and NADPH
- b) RuBP and OAA
- c) Rubisco and H<sub>2</sub>O
- d) PGA and PEP
- e) PEP and PEP carboxylase

**The following is used to evaluate the decay of photosynthetic photon flux density through the canopy of vegetation due to leaf absorption of photons:**

- a) Leibig's law
- b) law of the minimum
- c) Planck's constant
- b) Beer's law
- e) the speed of light
- f) none of the above are correct

**The term adaptation within the context of responses to stress refers to:**

- a) morphological or physiological adjustments by an individual plant to compensate for effects of stress
- b) morphological or physiological differences between individuals in a population due to differences in microenvironmental conditions
- c) evolutionary response resulting from genetic changes in populations leading to compensation for effects of stress
- d) random genetic alterations in a plant induced by a stress
- e) none of the above are correct

**In early research on photosynthesis this individual verified that uptake of minerals from soil was not responsible for the majority of plant mass gain during growth:**

- a) Joseph Priestly
- b) Jan Ingenhousz
- c) Frederic Clementz
- d) Alexander von Humbolt
- e) John Babtista von Helmont

**The most correct definition of water-use efficiency in plants is:**

- a) CO<sub>2</sub> gain by photosynthesis per unit temperature increases
- b) CO<sub>2</sub> gain by photosynthesis per unit water loss by transpiration
- c) water loss by transpiration per unit CO<sub>2</sub> gain by photosynthesis
- d) water loss by transpiration per number photons absorbed
- e) CO<sub>2</sub> gain by photosynthesis per number photons absorbed

**Photosynthetically active radiation (PAR) refers to:**

- a) light within the 400-700 nm waveband
- b) light within the green portion of the visible spectrum only
- c) light within the blue portion of the visible spectrum only
- d) light within the red portion of the visible spectrum only
- e) light within the 300-600 nm waveband
- f) none of the above are correct

**The most accurate definition of an isotope is:**

- a) atoms that radioactively decay
- b) atoms that radioactively decay
- c) atoms with the same number of neutrons, but different numbers of protons
- d) all atoms with an even number of protons and neutrons
- e) atoms with the same number of protons, but different numbers of neutrons
- f) none of the above are correct

**The definition of a plant's carbon balance is simply:**

- a) net photosynthesis per unit transpiration
- b) transpiration per unit energy absorbed
- c) transpiration per number photons absorbed
- d) carbon gained per unit transpiration loss
- e) transpiration per unit carbon gained
- f) none of the above are correct

**A photoautotroph is an organism that:**

- a) obtains energy through the uptake and chemical oxidation of organic compounds present in its surrounding environment
- b) obtains energy through the uptake and chemical oxidation of inorganic compounds present in its surrounding environment
- c) obtains energy through the photochemical conversion of light energy
- d) obtains energy through the conversion of heat to organic compounds
- e) none of the above are correct

**Stress response in a plant, as defined in lecture, refers to:**

- a) the reduction in the rate of an essential process due to the imposition of a stress factor
- b) the ability to adjust to stress through morphological changes
- c) the ability to adjust to stress through physiological changes
- d) the increase in the rate of an essential process due to physiological or morphological changes
- e) none of the above are correct

**Stress resistance refers to:**

- a) the capacity to endure and maintain the rate of an essential process in the face of stress
- b) the capacity to escape in space or time the stress factor
- c) the inability to adjust morphologically to a stress factor
- d) the capacity to either avoid or tolerate a stress factor
- e) none of the above are correct

**Relative growth rate is best defined as:**

- a) the dry weight increase of a plant per unit time
- b) the fresh (wet) weight increase of a plant per unit time
- c) the fresh weight increase of a plant per unit dry weight
- d) the dry weight increase of a plant per unit fresh weight
- e) none of the above are correct

2) Contrast **holism** and **reductionism** in ecology. Which of the two perspectives is embraced by plant physiological ecologists? **[8 points]**

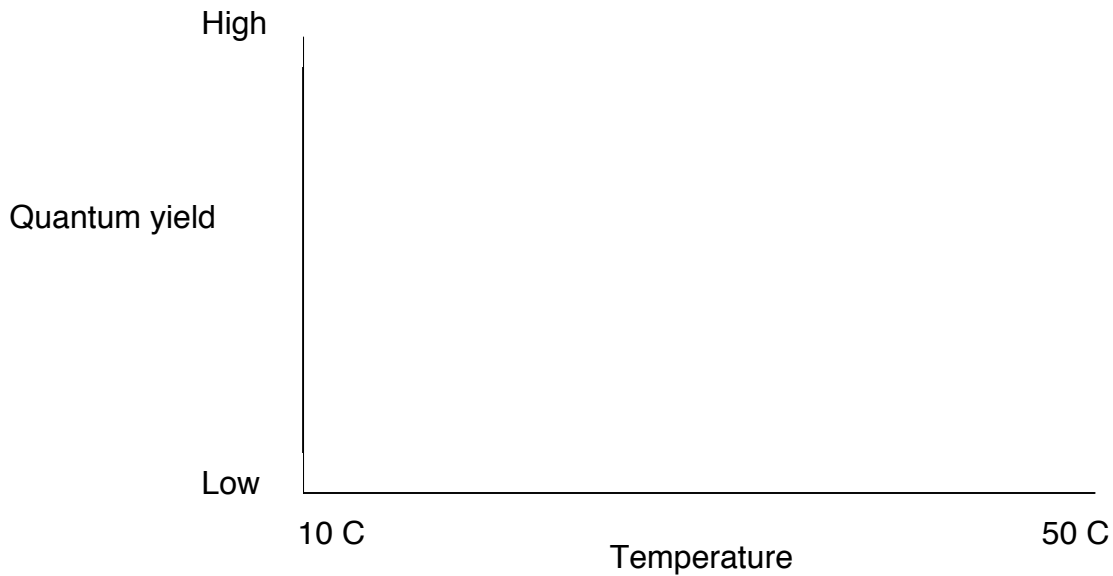
3) Using the conceptual analogy of “filters” that was discussed in class, explain why only a small proportion of the world’s 270,000 vascular plant species occur within a particular region. **[8 points]**

4) For each of the following processes in plant photosynthesis, note whether the process is associated with **carbon reduction** reactions or **photochemical conversion** reactions by *circling* the appropriate answer. **[1 point each]**

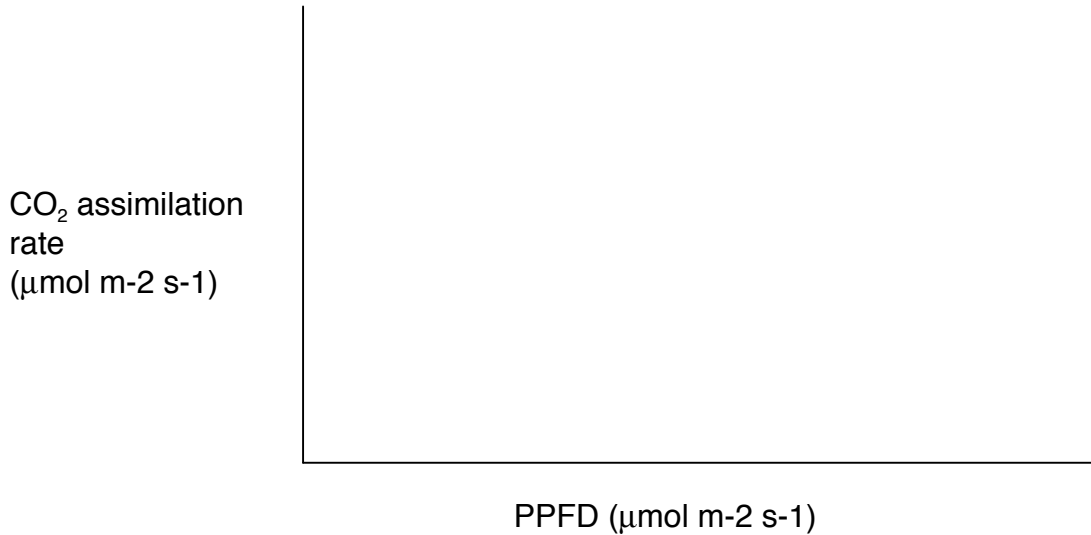
- |  |                  |                          |
|--|------------------|--------------------------|
| a) CO <sub>2</sub> binds to RuBP                                 | carbon reduction | photochemical conversion |
| b) O <sub>2</sub> binds to RuBP                                  | carbon reduction | photochemical conversion |
| c) O <sub>2</sub> is released from splitting of H <sub>2</sub> O | carbon reduction | photochemical conversion |
| d) Zeaxanthin is activated                                       | carbon reduction | photochemical conversion |
| e) photons absorbed by chlorophyll                               | carbon reduction | photochemical conversion |
| f) ATP is produced   | carbon reduction | photochemical conversion |
| g) NADPH is produced   | carbon reduction | photochemical conversion |
| h) RuBP is recycled  | carbon reduction | photochemical conversion |

5) Draw three lines on the graph below representing the **quantum yield** responses of hypothetical **C3** and **C4** plants in relation to **temperature**. One line should represent the response curve for a C3 plant in today's atmosphere (380 ppm CO<sub>2</sub>; 21% O<sub>2</sub>). Label this line "C3 today." Another line should represent the response curve for a C4 plant in today's atmosphere (380 ppm CO<sub>2</sub>; 21% O<sub>2</sub>). Label this line "C4 today." Finally, draw a line representing the likely response of a C3 plant in air with elevated levels of CO<sub>2</sub> concentration (700 ppm CO<sub>2</sub>; 21% O<sub>2</sub>). Label this line "C3 future."

In the space beneath your graph, provide a biochemical explanation for any differences in the three curves drawn. Also, predict how the latitudinal distribution and dominance of C3 and C4 grasses of the North American prairies will shift in response to an increase in atmospheric CO<sub>2</sub> concentration from 380 to 700 ppm. Assume all other aspects of the environment remain unchanged. **[12 points]**



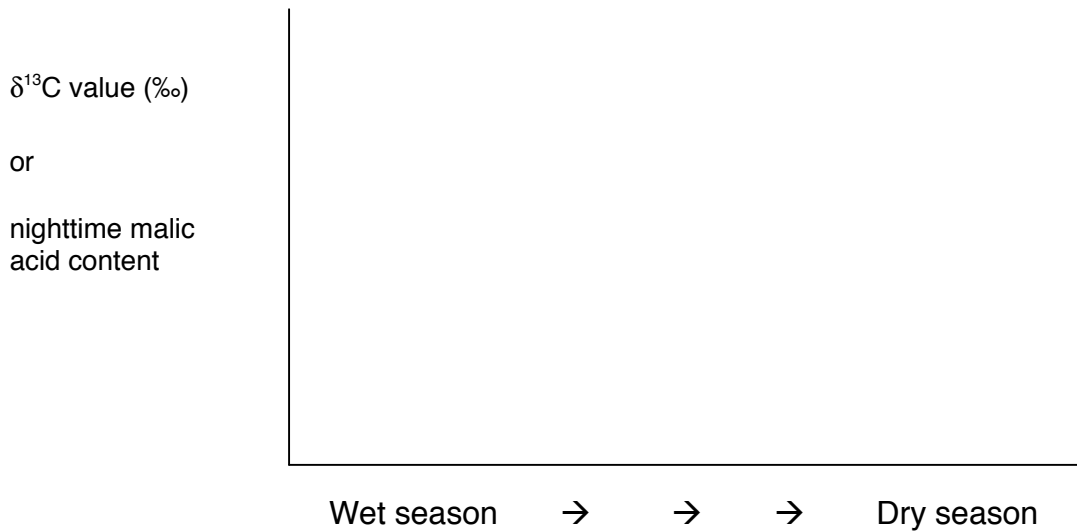
6) Draw two lines on the graph below representing light response curves of photosynthesis. The first line should represent that for a **shade-acclimated leaf**. Use a **solid (—) line** for this shade curve. The second line should represent the light response curve of photosynthesis for a **sun-acclimated leaf** on this tree. Use a **dashed (- - -) line** for the sun curve. On the curve for the sun-acclimated leaf, identify the dark respiration rate ( $R_d$ ), the light compensation point (**LCP**), and the maximum rate of photosynthesis ( $A_{max}$ ). [6 points]



7) For each of the following, note whether the listed trait is associated with **C3**, **C4** and/or **CAM** photosynthesis by *circling* the appropriate answer(s). More than one answer could apply in each case. [1 point each]

- |  |    |    |     |
|--|----|----|-----|
| a) CO <sub>2</sub> binds to RuBP                       | C3 | C4 | CAM |
| b) carboxylation catalyzed by PEP-carboxylase          | C3 | C4 | CAM |
| c) carboxylation catalyzed by Rubisco                  | C3 | C4 | CAM |
| d) high photorespiration                               | C3 | C4 | CAM |
| e) nighttime acidification of tissues                  | C3 | C4 | CAM |
| f) 'Kranz' anatomy                                     | C3 | C4 | CAM |
| g) extremely high WUE                                  | C3 | C4 | CAM |
| h) succulence  | C3 | C4 | CAM |
| i) low quantum yield at high temperature               | C3 | C4 | CAM |
| j) recapturing of nighttime respired CO <sub>2</sub>   | C3 | C4 | CAM |
| k) coordination between photosystems I and II          | C3 | C4 | CAM |
| l) high CO <sub>2</sub> concentration in bundle sheath | C3 | C4 | CAM |

8) Draw two lines on the graph below depicting the predicted response of a **facultative CAM** plant to the seasonal drying of its environment. One line (solid line) should depict the shift in the  $\delta^{13}\text{C}$  value of leaves successively produced from the wet season through the season. The second line (dashed line) should depict the nighttime malic acid concentration in photosynthetic tissues over the same period. In each case on the y-axis, up is a more positive value (for  $\delta^{13}\text{C}$ ) or higher concentration (for malic acid). **[6 points]**



9) List one possible ecological function for the **alternative electron transport pathway** in mitochondrial respiration and give an example of a plant that demonstrates this function. **[4 points]**

**BONUS:** Why does the carbon-13 to carbon-12 isotope ratio of cheap Mexican, American and Canadian beers differ from the more expensive German beers? **[2 points]**