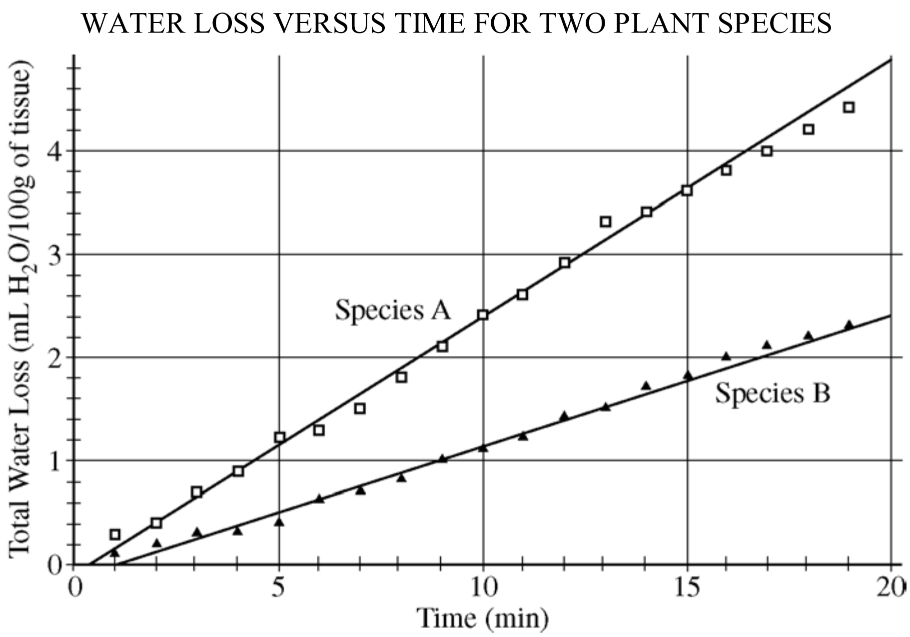
Question 4

The regulation of transpiration is an important homeostatic mechanism in plants.

(a) Under controlled conditions, a transpiration experiment was conducted using two plant species. The data collected are shown in the figure below. Using the data from the experiment, **calculate** the rate of transpiration for species A and species B between the times of 5 and 15 minutes (show your work). **Summarize** the difference between the two transpiration rates. *(3 points maximum)*



- Calculate transpiration rates, with units *(1 point each; 2 points maximum)*.
- Correct setups with incorrect results *(1 point maximum)*.

Species A
(1 point)

$$\frac{3.6 \text{ mL } H_2O - 1.2 \text{ mL } H_2O}{15 \text{ minutes} - 5 \text{ minutes}} = 0.24 \text{ mL } H_2O/100\text{g/min } (\pm 0.02)$$

OR

$$\frac{3.6 - 1.2}{15 - 5} = 0.24 \text{ mL } H_2O/100\text{g/min } (\pm 0.02)$$

OR equivalent

Question 4 (continued)

Species B
(1 point)

$$\frac{1.8 \text{ mL } H_2O - 0.4 \text{ mL } H_2O}{15 \text{ minutes} - 5 \text{ minutes}} = 0.14 \text{ mL } H_2O/100\text{g/min } (\pm 0.02)$$

OR

$$\frac{1.8 - 0.4}{15 - 5} = 0.14 \text{ mL } H_2O/100\text{g/min } (\pm 0.02)$$

OR equivalent

Summarize the difference between the rates *(1 point).*

- Species A is losing water or transpiring faster than species B.

(b) **Identify** and **explain** THREE different structural or physiological adaptations that could account for the different transpiration rates of species A and B.
(6 points maximum)

Identify adaptation (1 point each; 3 points maximum)	**Explain effect and specify directionality (1 point each; 3 points maximum)**
Cuticle	Thicker cuticle decreases transpiration.
Stomata number	Increased number increases transpiration.
Stomata location	Underside location decreases transpiration.
Stomata size	Larger stomata increase transpiration.
Surface area of leaves	Increased surface area increases transpiration.
Root size or structure	Affects rate of water absorption, amount of water lost.
Root hairs	Increased number increases transpiration.
Leaf hairs	Presence decreases transpiration.
Stomatal crypts or recessed pits	Presence decreases transpiration.
C_3 photosynthesis	Requires more water than C_4.
C_4 photosynthesis: CO_2 concentrated as 4-carbon acid	Requires less water than C_3.
CAM photosynthesis: stomata open at night	Reduced water loss during day.
Abscissic acid	Closes the stomata, slows transpiration.
Guard cell regulation	Turgidity opens stomata, increasing transpiration.

Question 4 (continued)

(c) Water potential (Ψ) is described by the following formulas.

$$\Psi = \Psi_p + \Psi_s$$

$$\Psi = -iCRT$$

Discuss the variables in both formulas and how they affect water potential.
(4 points maximum)

Variables in $\Psi = \Psi_p + \Psi_s$		**Discussion of effect on water potential (1 point each; 2 points maximum)**
Ψ_p	Pressure potential	Water will move from the area of high pressure to the area of low pressure.
Ψ_s	Solute potential	Water will move from the area of high solute potential (low solute concentration) to the area of lower solute potential (higher solute concentration).

	Variables in $\Psi = -iCRT$	**Discussion of effect on water potential (1 point each; 2 points maximum)**
i	Ionization constant	Greater ionization decreases water potential/increases water movement, OR Decrease in ionization increases water potential/decreases water movement.
C	Concentration	Increase in concentration decreases water potential/increases water movement, OR Decrease in concentration increases water potential/decreases water movement.
R	Pressure constant	No change in water potential/movement.
T	Temperature	Increase in temperature decreases water potential/increases water movement, OR Decrease in temperature increases water potential/decreases water movement.

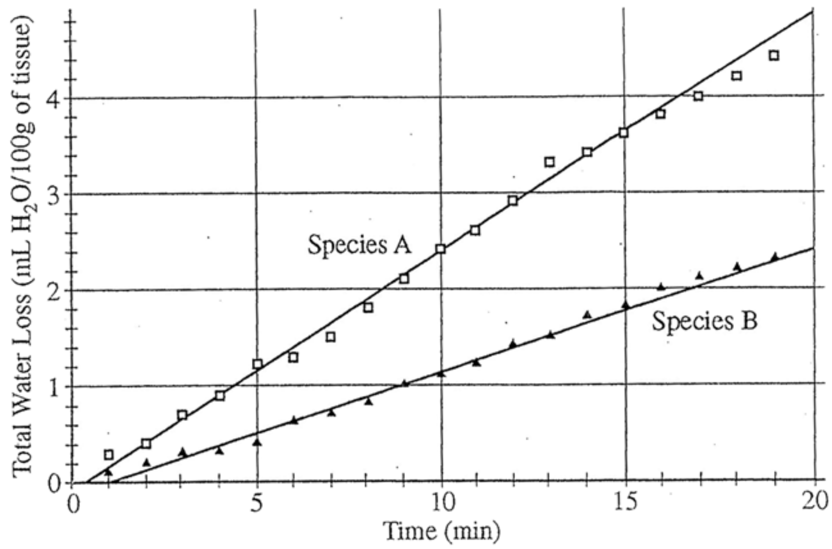
- Discussion stating that the formula allows osmotic potential or water movement to be calculated or predicted *(1 point).*

4A1

4. The regulation of transpiration is an important homeostatic mechanism in plants.

(a) Under controlled conditions, a transpiration experiment was conducted using two plant species. The data collected are shown in the figure below. Using the data from the experiment, **calculate** the rate of transpiration for species A and species B between the times of 5 and 15 minutes (show your work). **Summarize** the difference between the two transpiration rates.

WATER LOSS VERSUS TIME FOR TWO PLANT SPECIES



(b) **Identify** and **explain** THREE different structural or physiological adaptations that could account for the different transpiration rates of species A and B.

(c) Water potential (Ψ) is described by the following formulas.

$$\Psi = \Psi_p + \Psi_s$$

$$\Psi = -iCRT$$

Discuss the variables in both formulas and how they affect water potential.

a) Species A: $\frac{3.6 \text{ mL } H_2O/100g \text{ tissue} - 1.2 \text{ mL } H_2O/100g \text{ tissue}}{15 \text{ min} - 5 \text{ min}}$

$= \frac{2.4 \text{ mL } H_2O/100g \text{ tissue}}{10 \text{ minutes}} = \frac{0.24 \text{mL } H_2O/100g \text{ tissue}}{\text{min}}$

transpiration rate is about 0.24 mL H_2O/100g tissue per minute

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4A₂

Species B: $\frac{1.8 \text{ mL } H_2O/100g \text{ tissue} - 0.4 \text{ mL } H_2O/100g \text{ tissue}}{15 \text{ min} - 5 \text{ min}}$

$= \frac{1.4 \text{ mL } H_2O/100g \text{ tissue}}{10 \text{ minutes}} = \frac{0.14 \text{ mL } H_2O/100g \text{ tissue}}{\text{min}}$

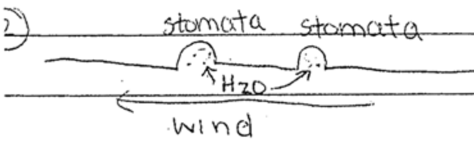
transpiration rate is about 0.14 mL H_2O/100g tissue per minute

Species A had a higher transpiration rate than B meaning that more water was lost from A in the same amout of time.

2) Species B may have had a thicker, waxy cuticle than A which would protect from excess water loss and prevent desiccation.

Species B may have their stomates located in depressions which would maintain water potential, decreasing transpiration. (see diagram ②) Having the stomates in depressions would

2)



prevent air movement from blowing evaporated water from transpiration away too quickly, which would decrease water potential outside and increase transpiration.

Species B may be a CAM plant that have their stomates open during the cooler nights and stores CO_2 for use in daytime when it gets hot so the stomates close to prevent excess water loss and desiccation.

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Water moves from high water potential to low.

4A3

c) Water potential is determined by pressure potential and solute potential. If there is positive pressure (push), this increases pressure potential and water potential. If there is negative pressure (pull), this decreases pressure potential and decreases water potential. Pressure potential is Ψ_P

If there is high solute concentration, this decreases solute potential and water potential (hypertonic solutions have high solute concentration). If there is low solute concentration, this increases solute potential and increases water potential (hypotonic solutions have low solute concentration)

Solute potential is Ψ_S

Water potential is also determined by molarity, atmospheric pressure, and temperature.

High molarity (high solute concentration) decreases water potential and vice versa (low molarity, high water potential)

High atmospheric pressure decreases water potential and vice versa (low pressure, high water potential).

High temperature also decreases water potential and vice versa (low temp, high water potential)

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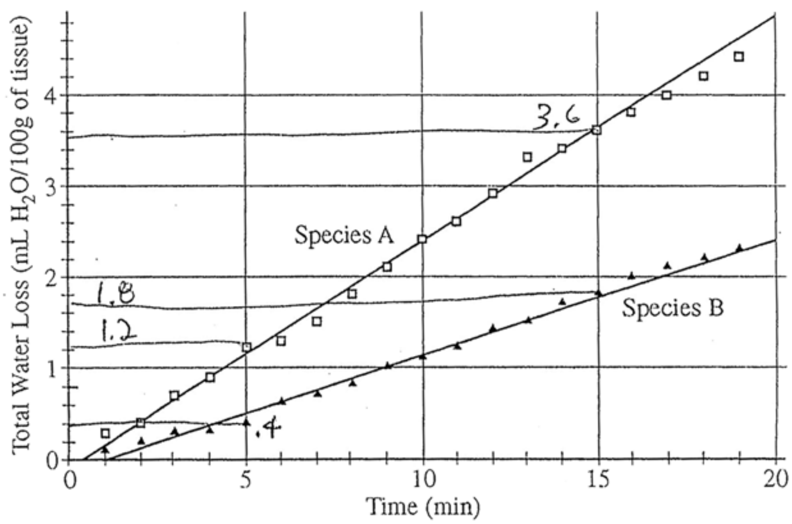
4B1

4. The regulation of transpiration is an important homeostatic mechanism in plants.

   (a) Under controlled conditions, a transpiration experiment was conducted using two plant species. The data collected are shown in the figure below. Using the data from the experiment, **calculate** the rate of transpiration for species A and species B between the times of 5 and 15 minutes (show your work). **Summarize** the difference between the two transpiration rates.

WATER LOSS VERSUS TIME FOR TWO PLANT SPECIES



   (b) **Identify** and **explain** THREE different structural or physiological adaptations that could account for the different transpiration rates of species A and B.

   (c) Water potential (Ψ) is described by the following formulas.

$$\Psi = \Psi_p + \Psi_s$$

$$\Psi = -iCRT$$

Discuss the variables in both formulas and how they affect water potential.

a) Species A : 2.4/10 = 0.24 mL H_2O/100 g of tissue per minute
3.6 − 1.2 = 2.4 15 − 5 = 10
Species B : 1.4/10 = 0.14 mL H_2O/100 g of tissue per minute
1.8 − 0.4 = 1.4 15 − 5 = 10
The transpiration rate of Species A, 0.24 mL of water loss per 100 grams of tissue per minute, is greater than the transpiration rate of Species B, 0.14 mL of water loss per 100 grams of tissue

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ADDITIONAL PAGE FOR ANSWERING QUESTION 4

a minute. ~~$~~ The transpiration rate of Species A is greater than the transpiration rate of Species B by 0.10 mL of water loss per 100 grams of tissue a minute.

b) One physiological adaptation that could account for the different transpiration rates of Species A and species B is the closing and opening of the stomata. Species A may be more adept ~~at~~ at gauging when to close ~~the stomata~~ or open its stomata. Plants open the stomata to increase the rate of transpiration and close the stomata to conserve water and decrease the rate of transpiration. A structural adaptation that ~~sp~~ could account for the different transpiration rates of species A and ~~spec~~ B is a cuticle, or waxy covering, over the leaves. A waxy covering over the leaves of a plant would ~~re~~ increase the conservation of water thus reducing the rate of transpiration. So species B could have cuticles on its leaves. Another structural adaptation is guard cells. ~~G~~ Guard cells ~~enables~~ regulate the opening and closing of the stomata. Without guard cells, a plant cannot open and close its stomata thus affecting its rate of transpiration. Having the stomata closed reduces transpiration while opening the stomata increases transpiration.

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4B3

Transpiration is the process by which water from the leaves evaporates into the air ~~and then~~ which creates a low concentration of water in the leaves. ~~so that~~ This causes water to move up from the stem into the leaves. Cohesion and adhesion assist in this process. The water leaving the stem creates a low water potential in the stem ~~also the roots~~ so water in the roots enters the stem. And water obtains its water from the soil. Water evaporates from the leaves because the water potential in the air is lower than that of the leaves.

c) In the equation $\Psi = \Psi_p + \Psi_s$, Ψ_p is the water potential of the plant and Ψ_s is the water potential of the soil. So the ~~water~~ total water potential is the water potential of the plant plus the water potential of the soil. In the equation $\Psi = -iCRT$, i is the imaginary number $\sqrt{-1}$, C is the heat/humidity, R is a constant and T is the temperature. So water potential is dependent upon temperature and humidity based on this equation. ~~In the that~~ Water potential is also dependent on the water potential of the soil and plant.

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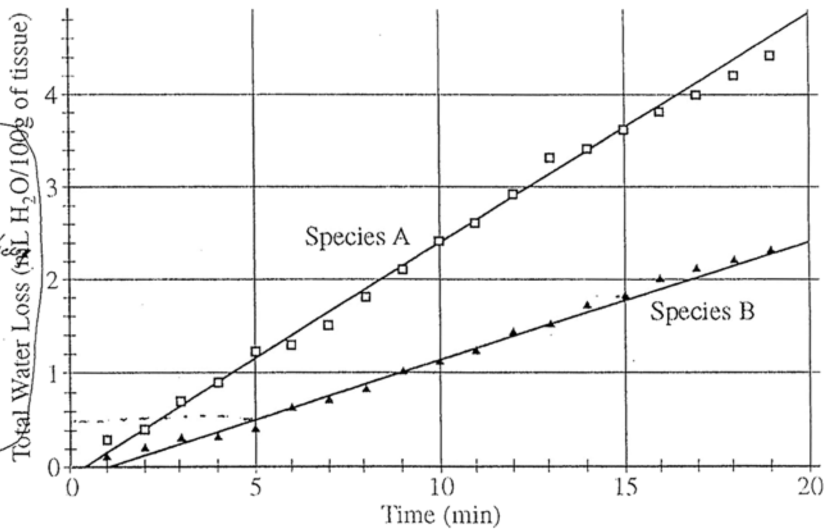
4C

4. The regulation of transpiration is an important homeostatic mechanism in plants.

(a) Under controlled conditions, a transpiration experiment was conducted using two plant species. The data collected are shown in the figure below. Using the data from the experiment, **calculate** the rate of transpiration for species A and species B between the times of 5 and 15 minutes (show your work). **Summarize** the difference between the two transpiration rates.

WATER LOSS VERSUS TIME FOR TWO PLANT SPECIES



Species B:

$\frac{1.9 \text{ mL } H_2O/100g - .3 \text{ mL } H_2O/100g}{15 \text{ min} - 5 \text{ min}}$

$\frac{1.6 \text{ mL } H_2O/100g}{10 \text{ minutes}}$

(b) **Identify** and **explain** THREE different structural or physiological adaptations that could account for the different transpiration rates of species A and B.

(c) Water potential (Ψ) is described by the following formulas.

Species A: $\frac{3.3 \text{ mL } H_2O/100g - 1.1 \text{ mL } H_2O/100g}{15 \text{ minutes} - 5 \text{ minutes}}$

$\Psi = \Psi_p + \Psi_s$

$\Psi = -iCRT$

10 minutes

2.2/10

.22/min

Discuss the variables in both formulas and how they affect water potential.

Species A has ~~a~~ higher rate of transpiration than ~~p~~ species B as ~~it as~~ species A is losing more water per minute than species B. Species A loses nearly twice as much water as species B does per minute.

Species A: .22 ~~mg~~ mL H_2O/100g of tissue/min.

Species B. .16 mL H_2O/100g of tissue/minute

One species may have a waxy cuticle which would help prevent water loss via transpiration. ~~The The~~ Plants' ability to close their stomata is another important factor in transpiration.

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Question 4

Overview

This question presented an opportunity to demonstrate knowledge of transpiration and water potential in plants. In part (a) a graph of transpiration data for two populations of plants was provided and was intended to be used to calculate the rates of transpiration. In part (b) there was a request to identify and explain the structural or physiological adaptations that could account for the differences in transpiration rates in two populations. Part (c) provided two formulas for water potential and requested a discussion of the component factors in those equations.

Sample: 4A
Score: 10

The response earned the maximum of 3 points in part (a). Two calculation points were earned for showing the setup of the calculations and final values with full units. The statement that "Species A had a higher transpiration rate than B" earned 1 point for the summary.

The response earned the maximum of 6 points in part (b). It earned 3 points for correctly identifying three adaptations that could account for the different transpiration rates: cuticle, stomata in depressions, and CAM photosynthesis. The correct explanations that the cuticle "would protect from excess water loss," "stomates in depressions would prevent air movement from blowing evaporated water from transpiration away too quickly," and that CAM plants "have their stomates open during the cooler nights" earned the other 3 points.

In part (c) 1 point was earned for correctly observing that an increase in positive pressure increases water potential. This gave the response the maximum final score of 10 points. This response would have received an additional point for the statement that a low solute concentration increases the solute potential and increases water potential, but it had already earned the maximum number of points. It also correctly identifies the role of high molarity and temperature effects on water potential; however, because the response fails to link the discussion to the symbols in the equation (C and T), no point would have been awarded for that statement.

Sample: 4B
Score: 8

The response earned the maximum of 3 points in part (a). Two points were earned for showing the calculation setup, with the final value and units shown later in the response. The statement that "[t]he transpiration rate of species A … is greater than the transpiration rate of species B" earned 1 point for the summary.

In part (b) the discussion of the opening and closing of stomata, regulated by guard cells, earned 1 identification point. Another point was earned for the related explanation: "opening the stomata increases transpiration." One more identification point was earned for mentioning the "cuticle, or waxy covering, over the leaves," and 1 point was earned for the explanation that the cuticle "would increase the conservation of water."

In part (c) 1 point was earned for stating that "R is a constant."

Question 4 (continued)

Sample: 4C
Score: 6

The response earned the maximum of 3 points in part (a). Two points were earned for the calculations; the setup and calculations are shown in the margins, and the final results, with units, are in the discussion. The statement that "species A has a higher rate of transpiration than species B" earned 1 point for the summary.

In part (b) 2 identification points were earned: 1 for the mention of "a waxy cuticle" and 1 for citing the ability of plants to close their stomata. One explanation point was earned for the reference to "a waxy cuticle which would help prevent water loss via transpiration."

The response does not attempt part (c).