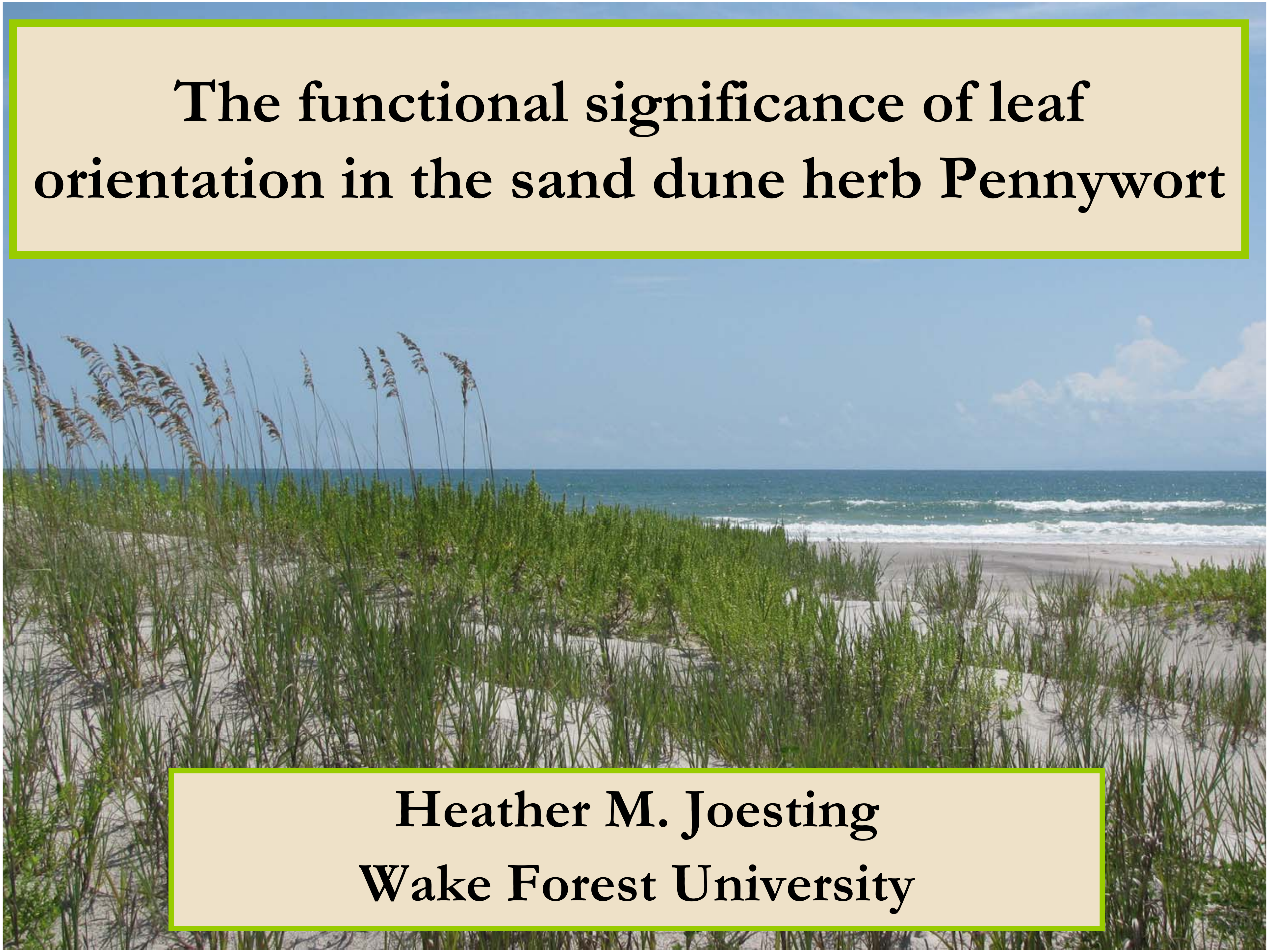
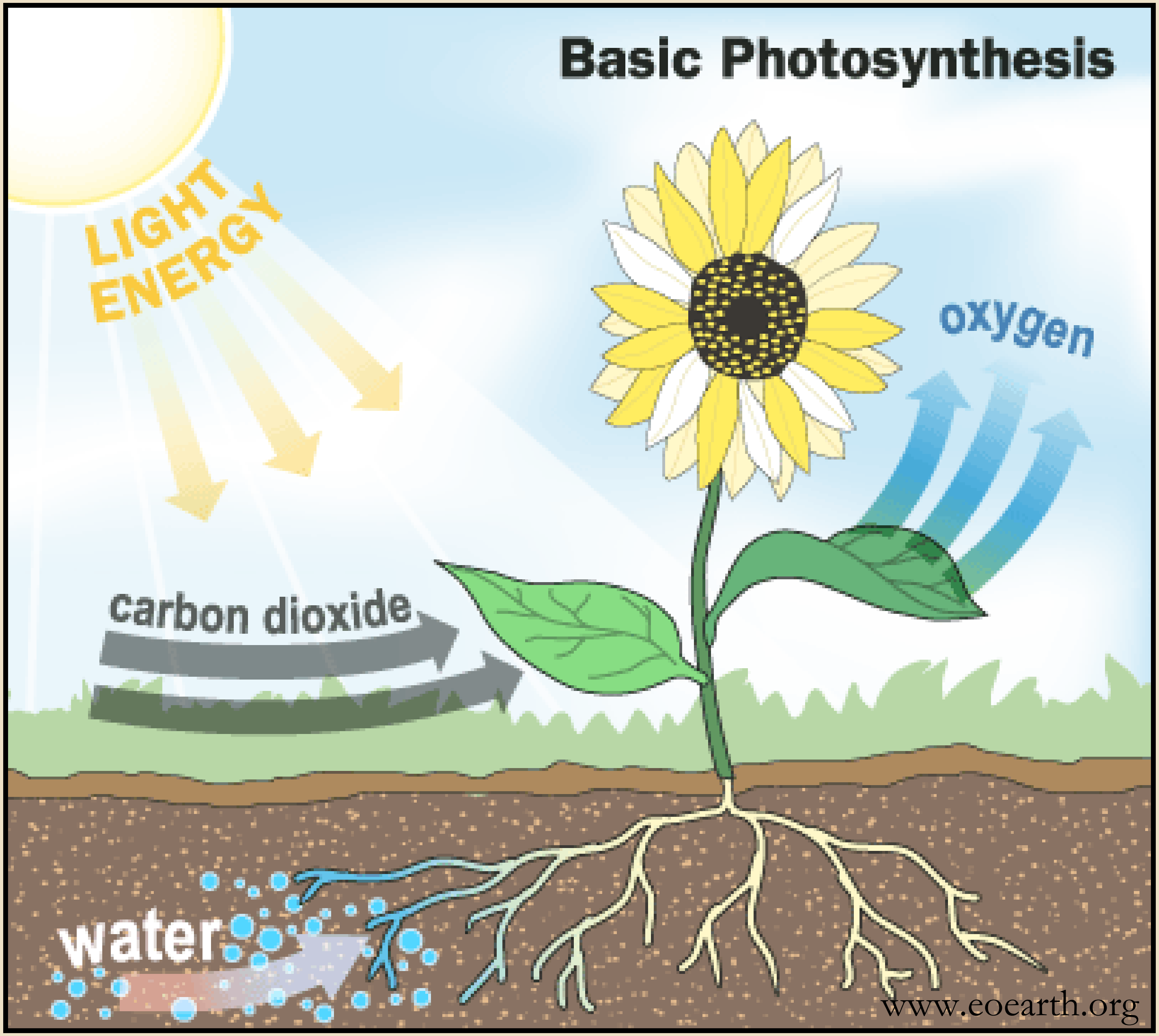
The functional significance of leaf orientation in the sand dune herb Pennywort



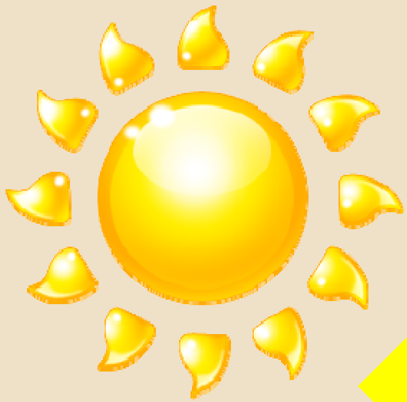
Heather M. Joesting

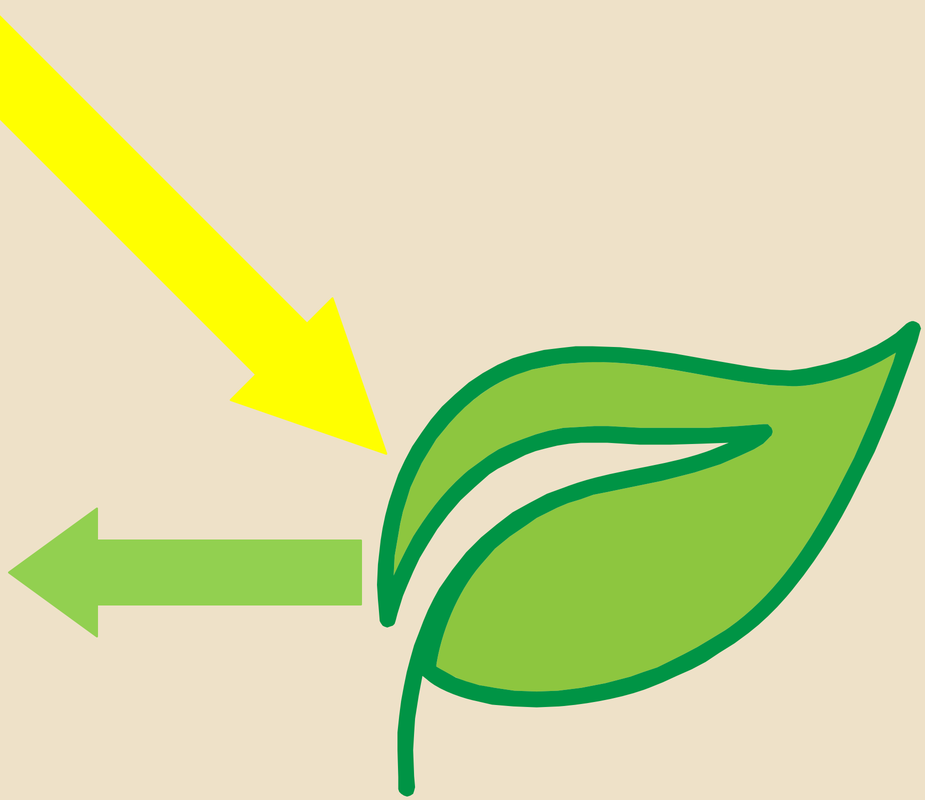
Wake Forest University



Light + CO_2 + H_2O → Sucrose ($C_6H_{12}O_6$) + O_2

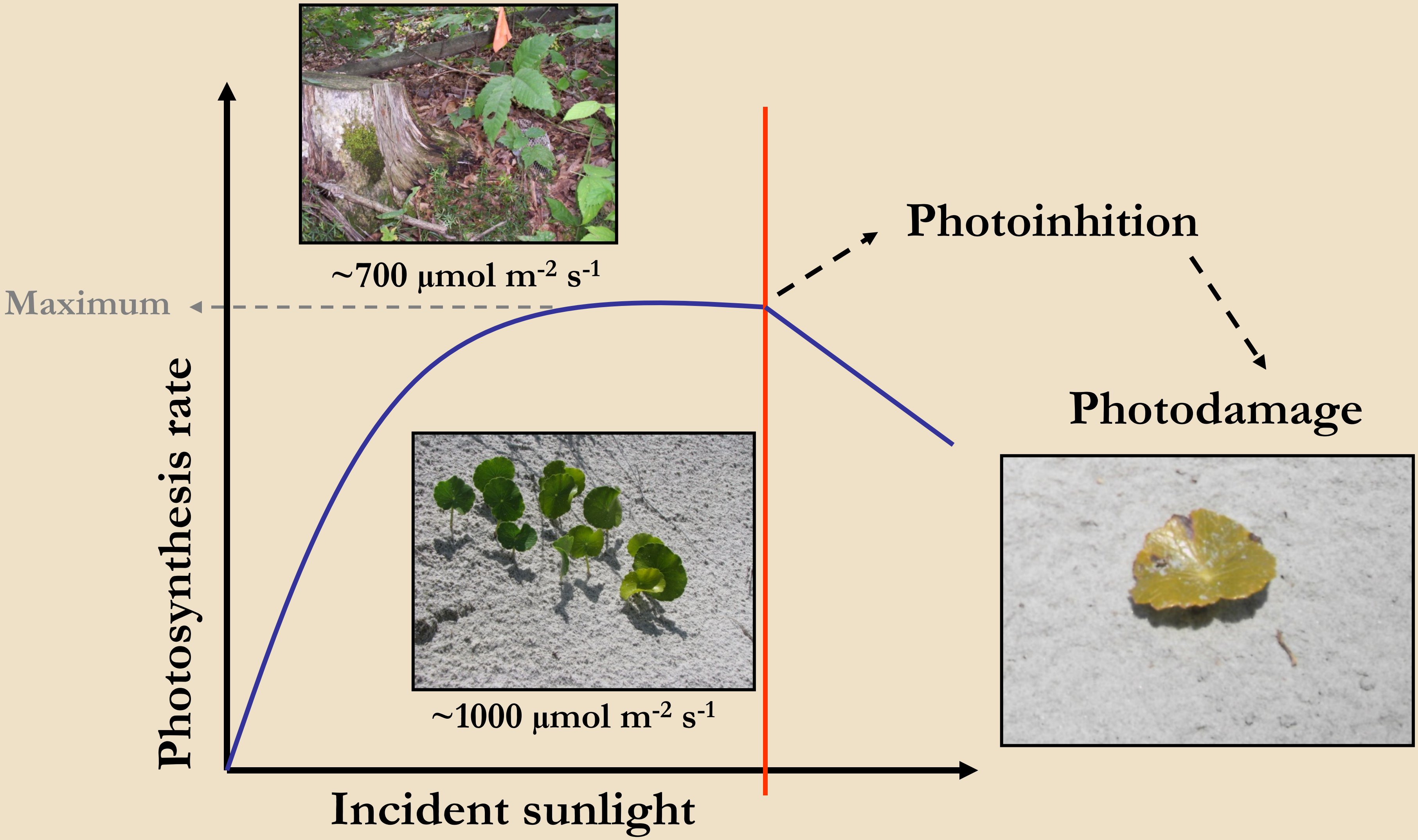
Sunlight and Photosynthesis



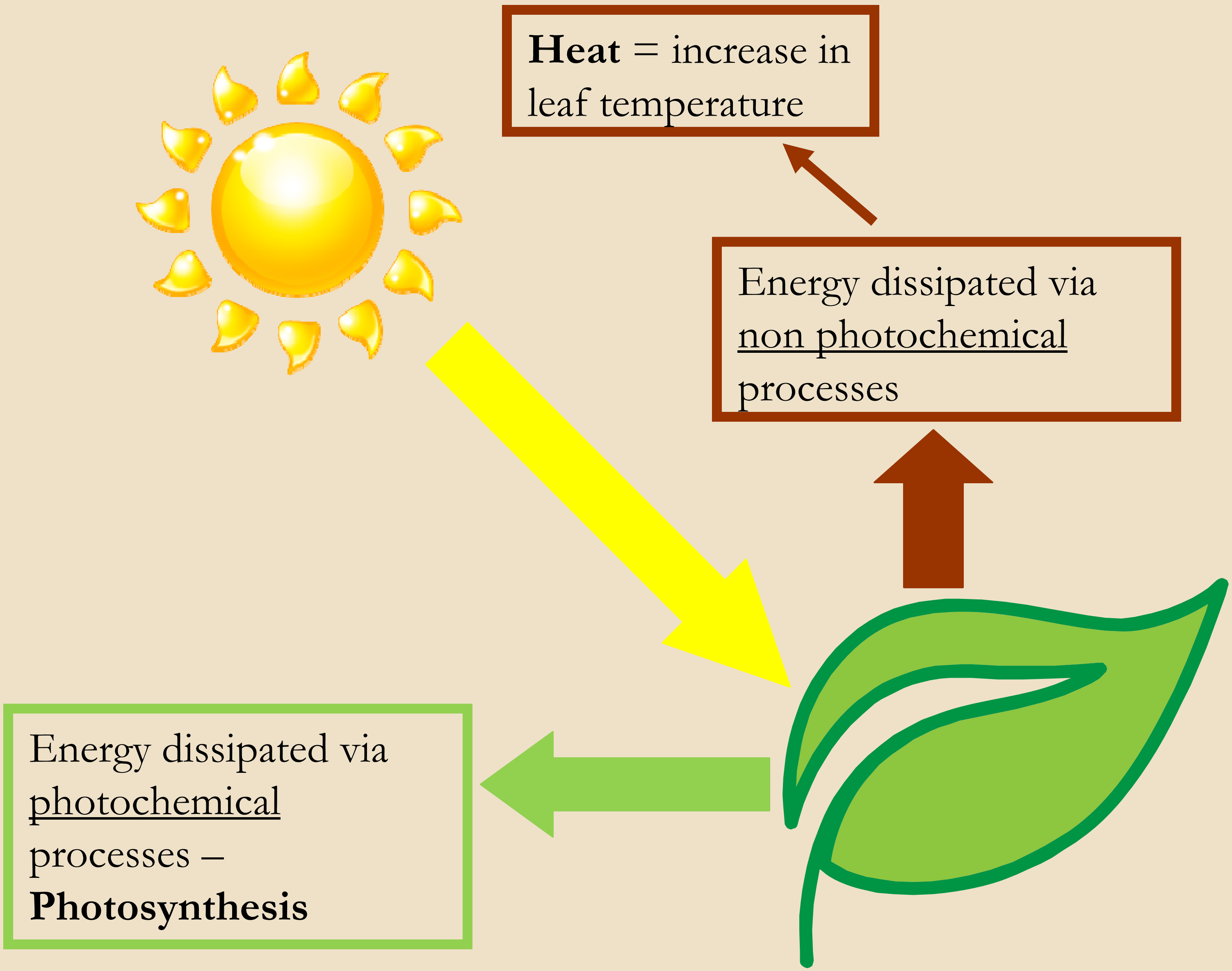


Energy dissipated via photochemical processes – **Photosynthesis**

Sunlight and Photosynthesis



Sunlight and Leaf Temperature



Sunlight and Leaf Temperature

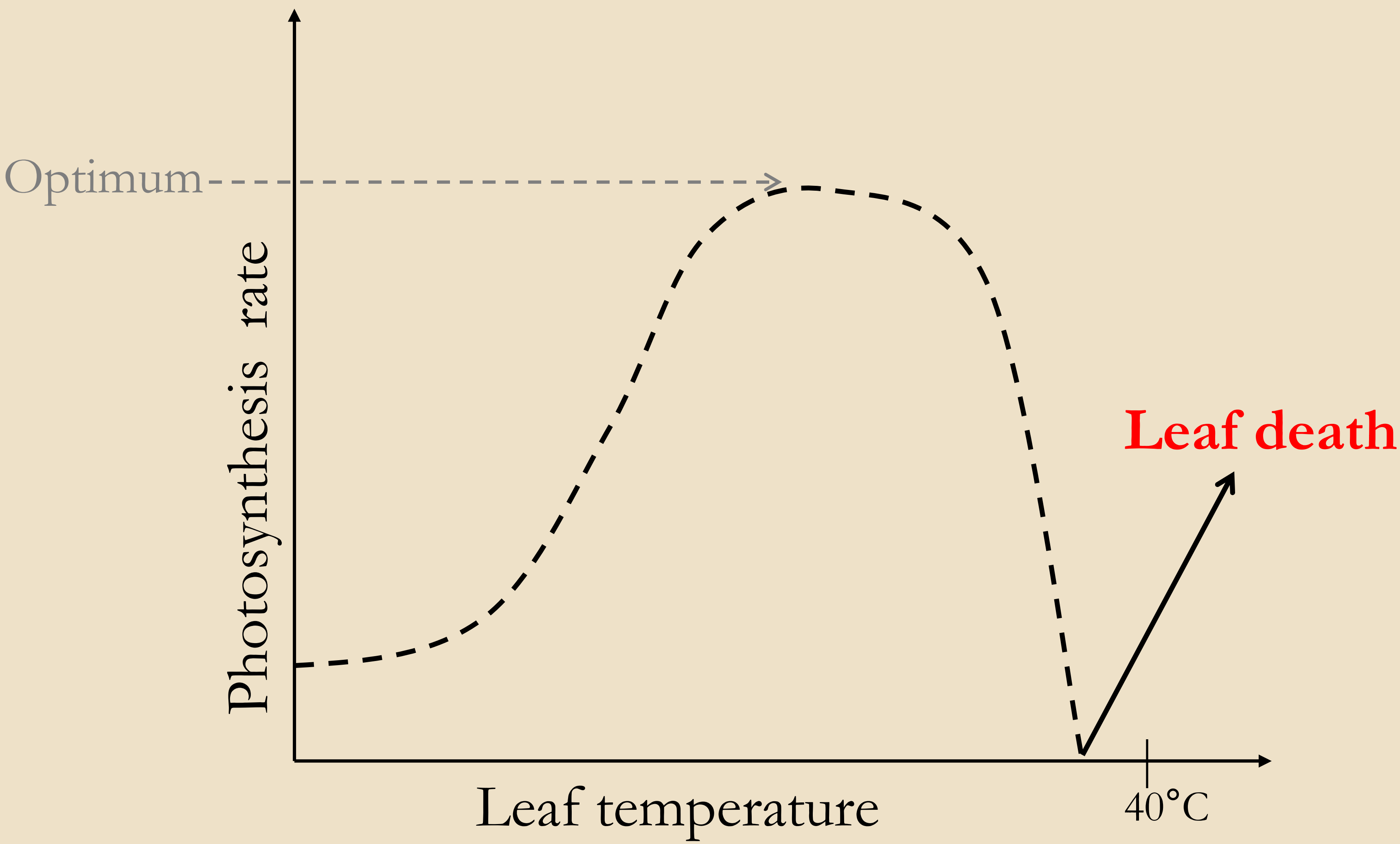
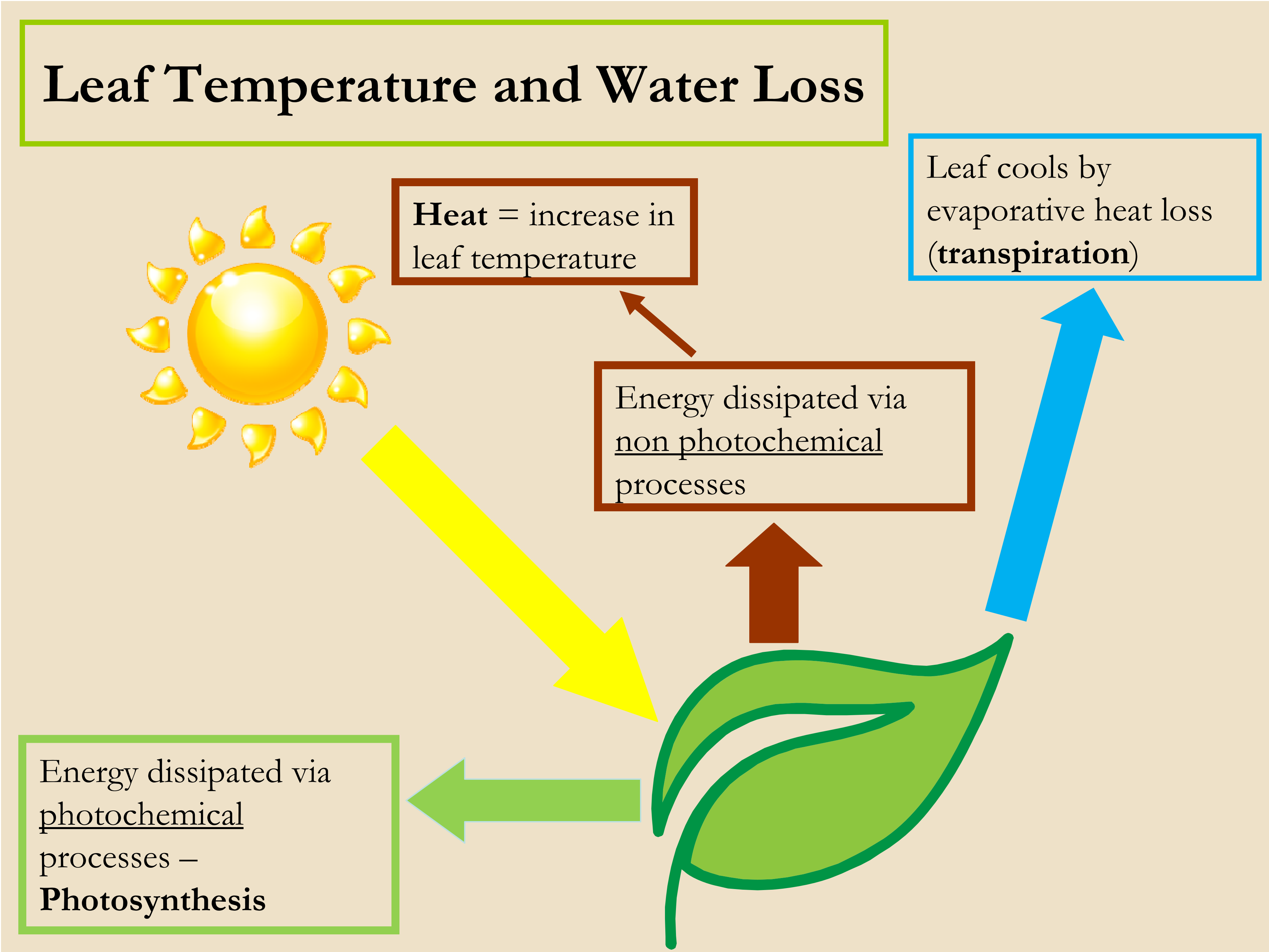
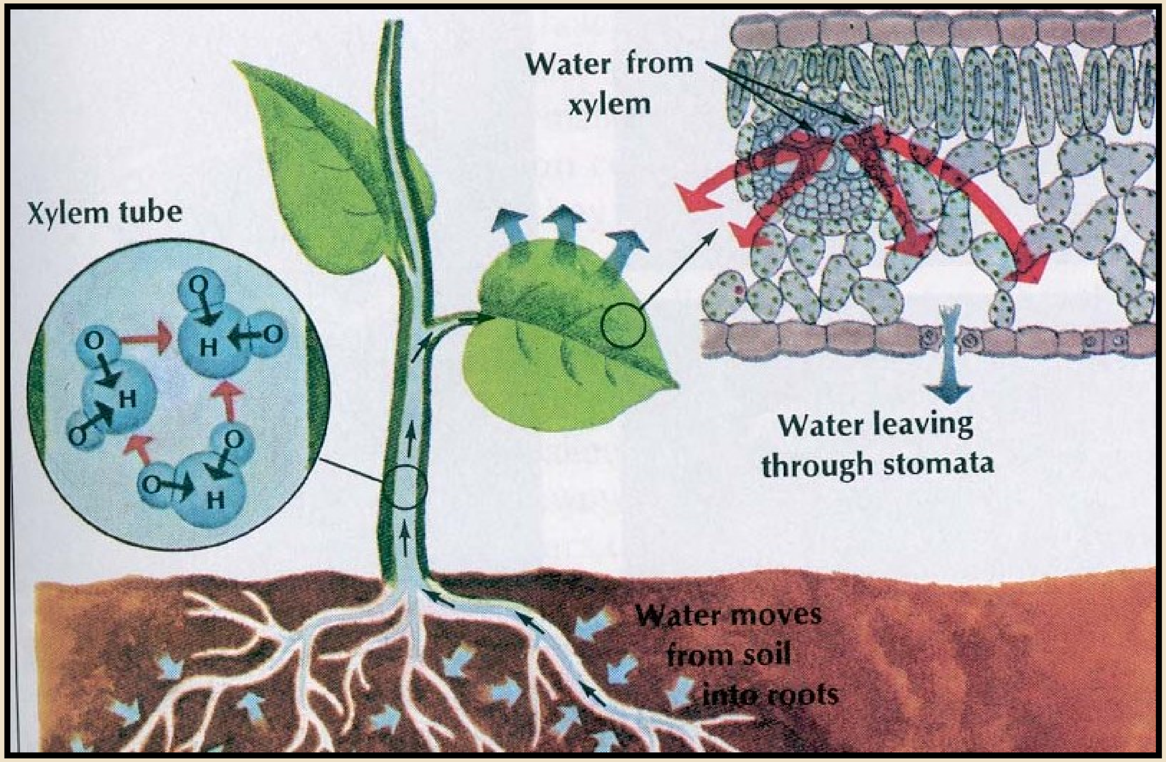


Photo from georgeweigel.net



Leaf Temperature and Water Loss
Heat = increase in leaf temperature
Leaf cools by evaporative heat loss (transpiration)
Energy dissipated via non photochemical processes
Energy dissipated via photochemical processes – Photosynthesis

Transpiration



Increased sunlight exposure

Increased leaf temperature

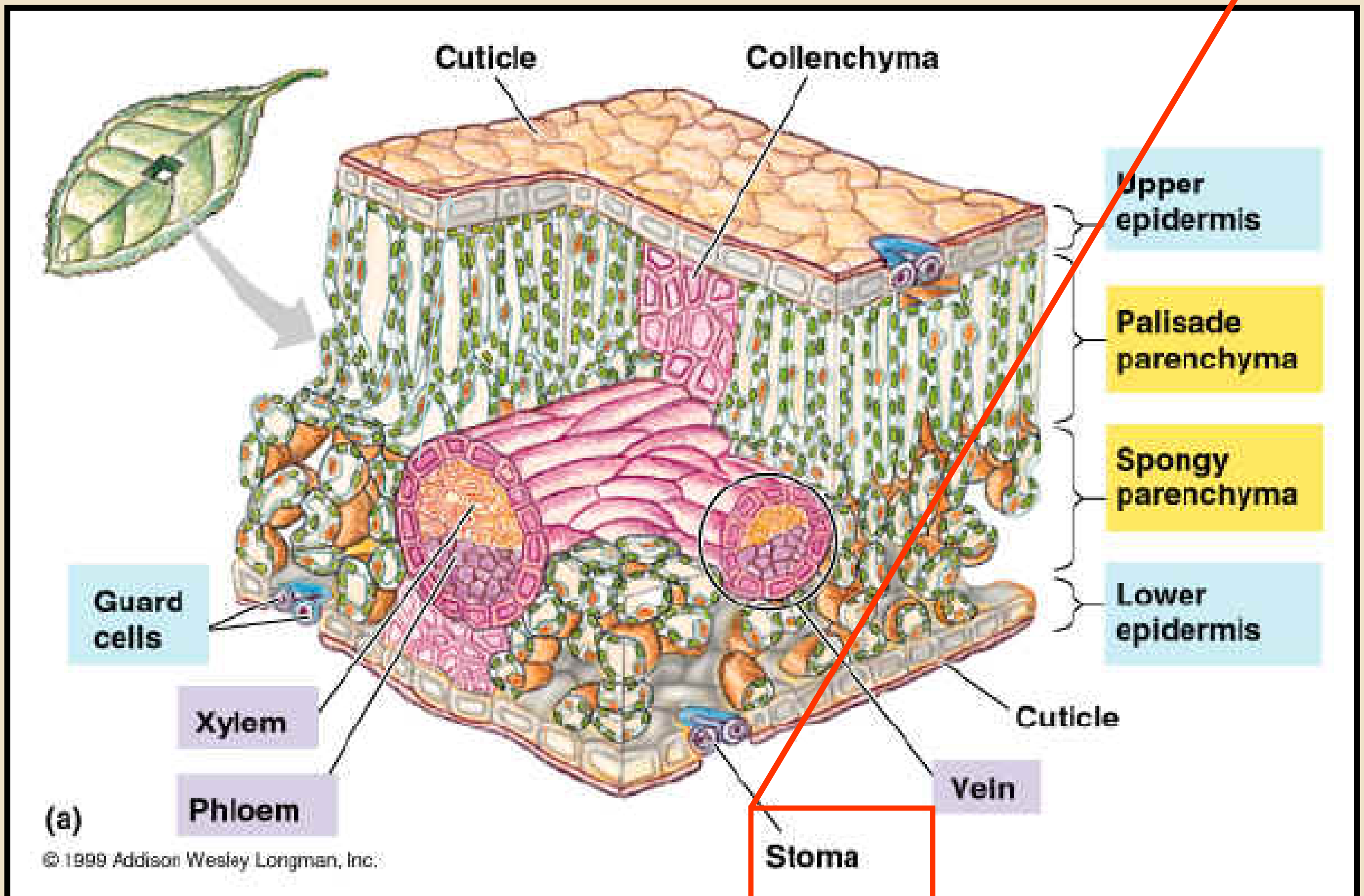
Increased transpiration rate

Increased water loss

Wilting

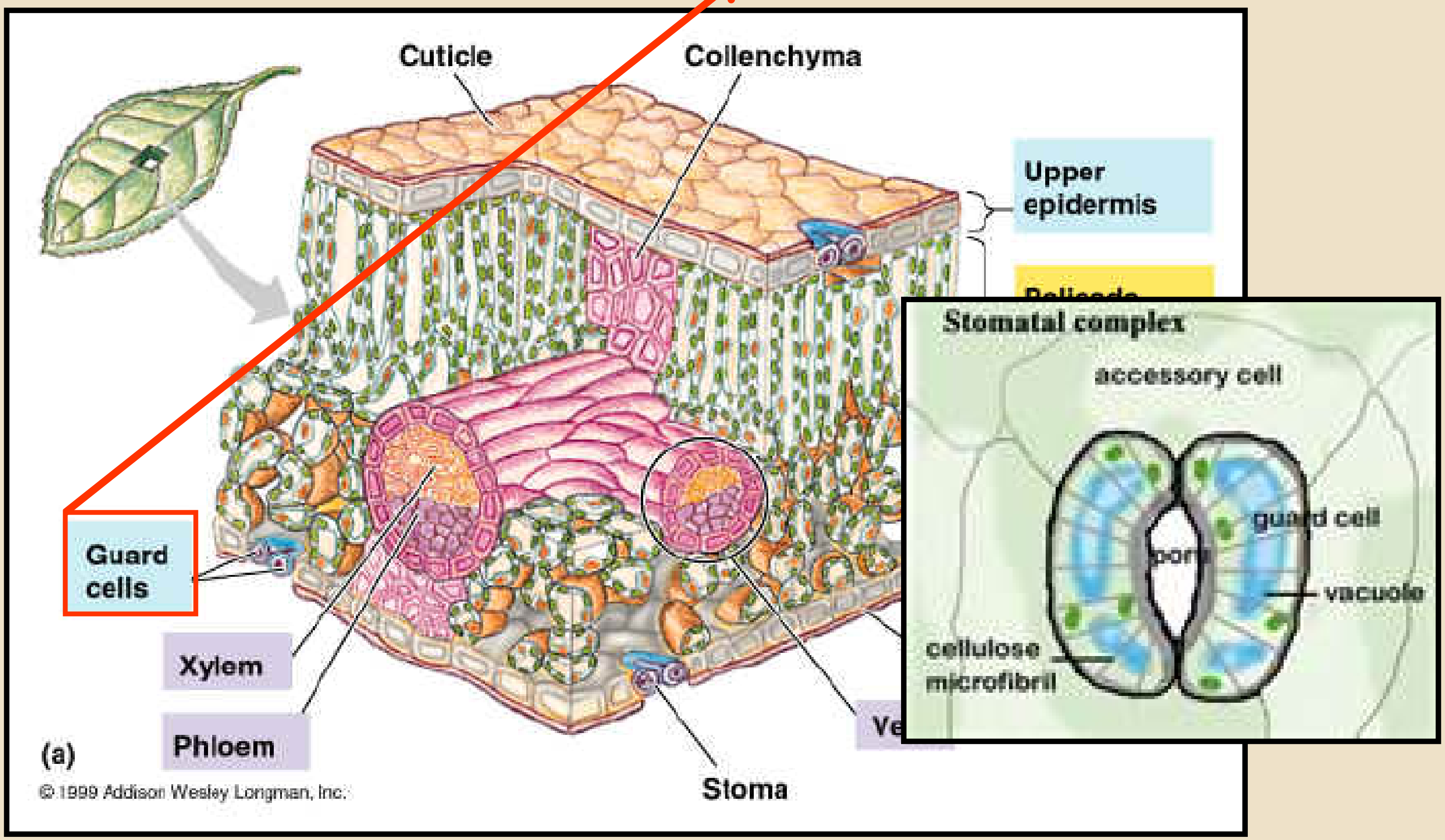
Light Processing in Leaves

Functions for gas exchange, primarily takes up CO_2 and loses water vapor

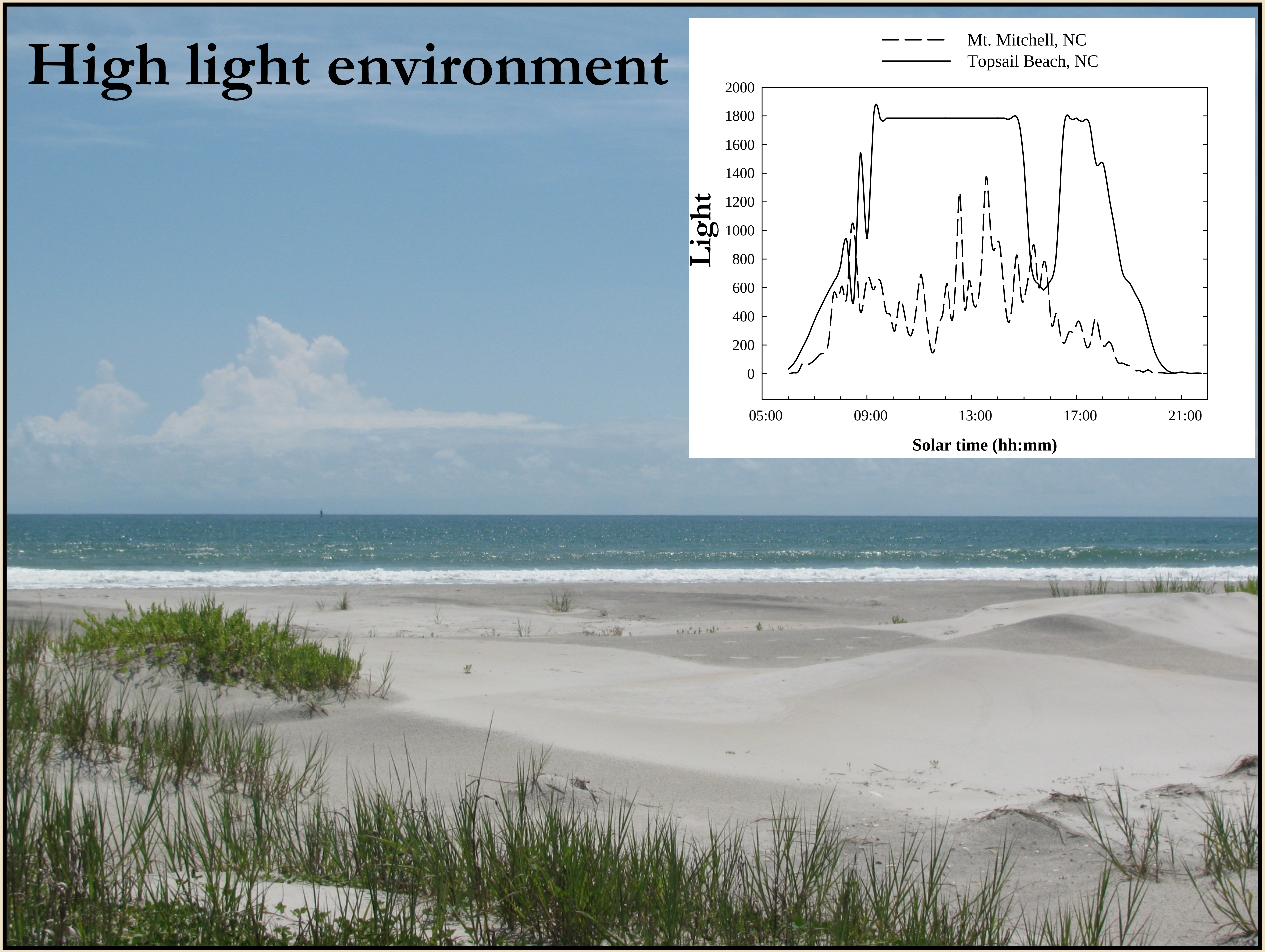


Light Processing in Leaves

Controls opening of stomata, opens by filling with water



High light environment



Adaptations to High Light Stress

- Anthocyanin production
- Small leaf size
- Hairs and wax to make surface more reflective
- Leaf succulence
- CAM photosynthesis
- **Leaf orientation**

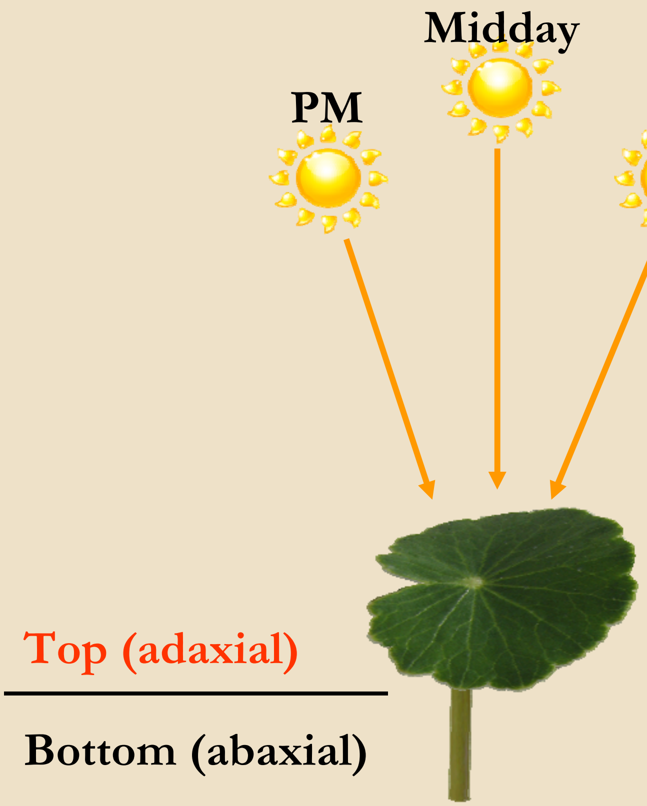
Leaf Orientation

Rumex densiflorus in alpine tree-line, Wyoming
Geller and Smith, 1982

Perezia nana in Sonoran Desert
Sylvertsen and Cunningham, 1979

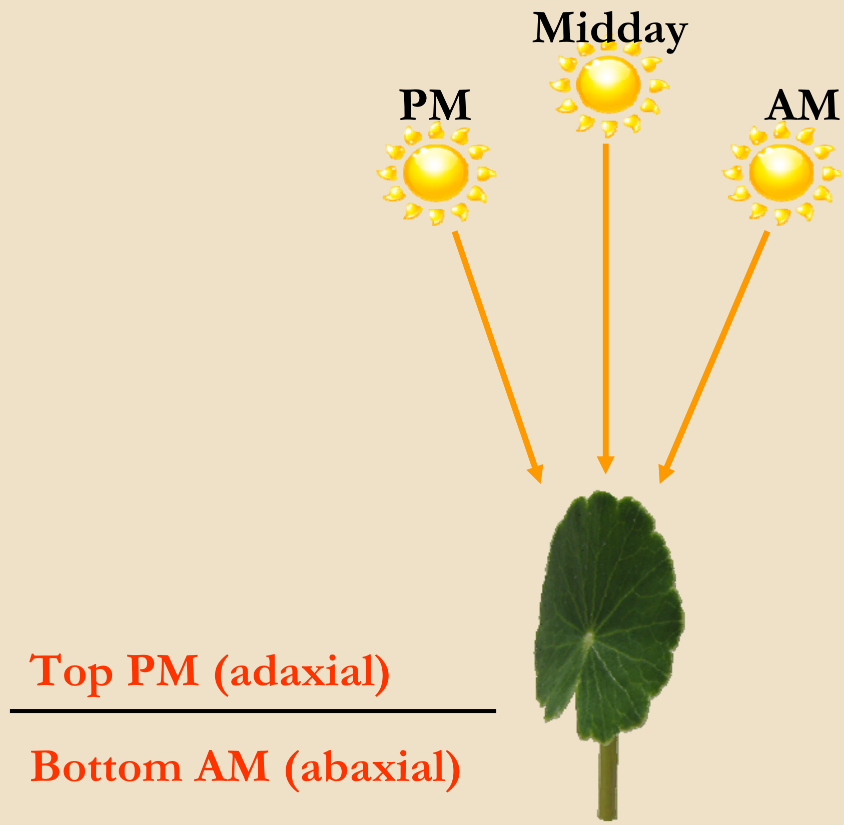
Leaf orientation reduces midday light exposure and decreases leaf temperature and transpiration rate
Werk and Ehleringer, 1984; Smith and Ullberg, 1989; James and Bell, 2000

Leaf Orientation – Angle



Top/bottom = high

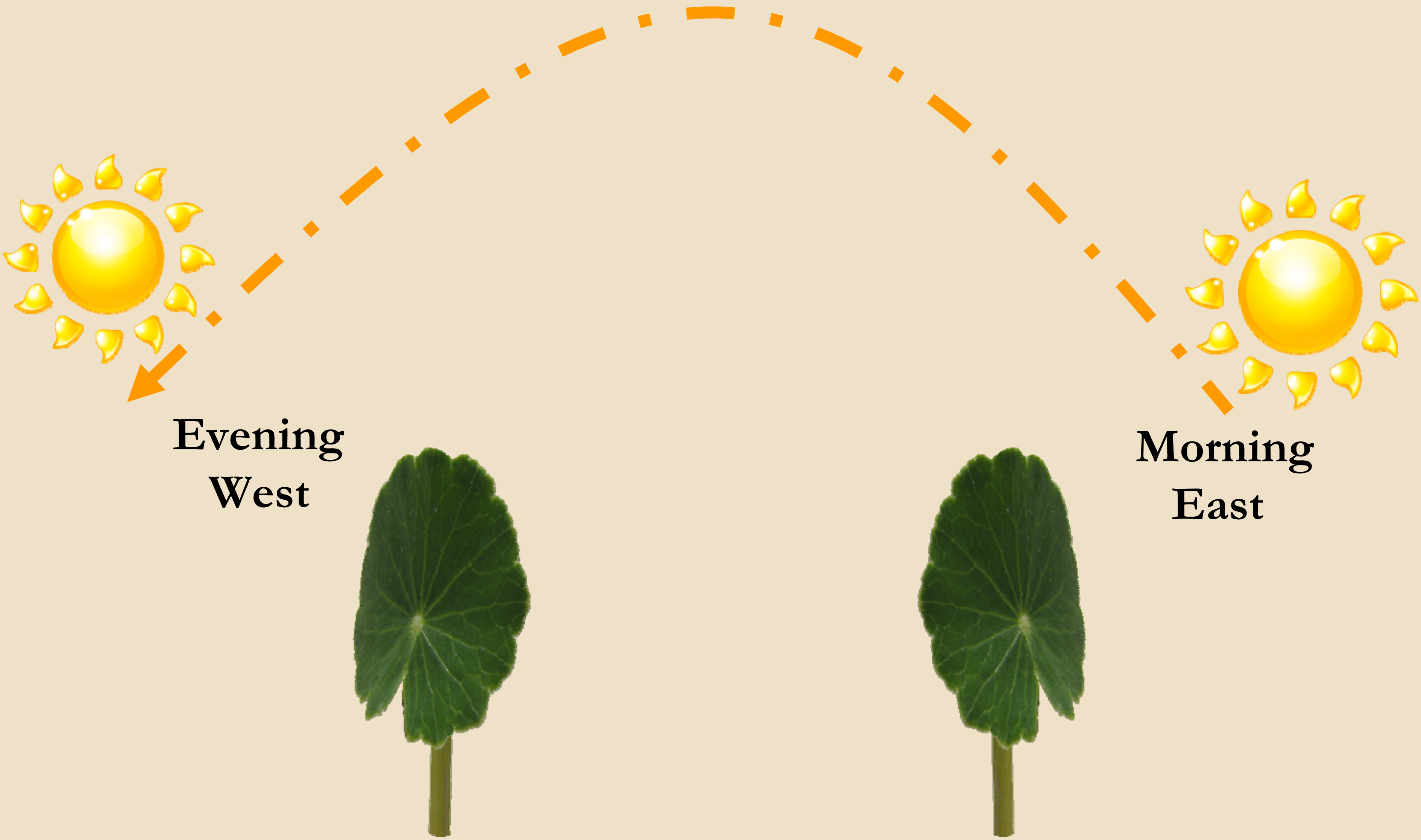
<u>Increased</u> leaf temperature, potential water loss, and risk of photoinhibition



Top/bottom ≈ 1

<u>Lower</u> leaf temperature, potential water loss, and risk of photoinhibtion

Leaf Orientation – Azimuth



Pennywort – *Hydrocotyle bonariensis*

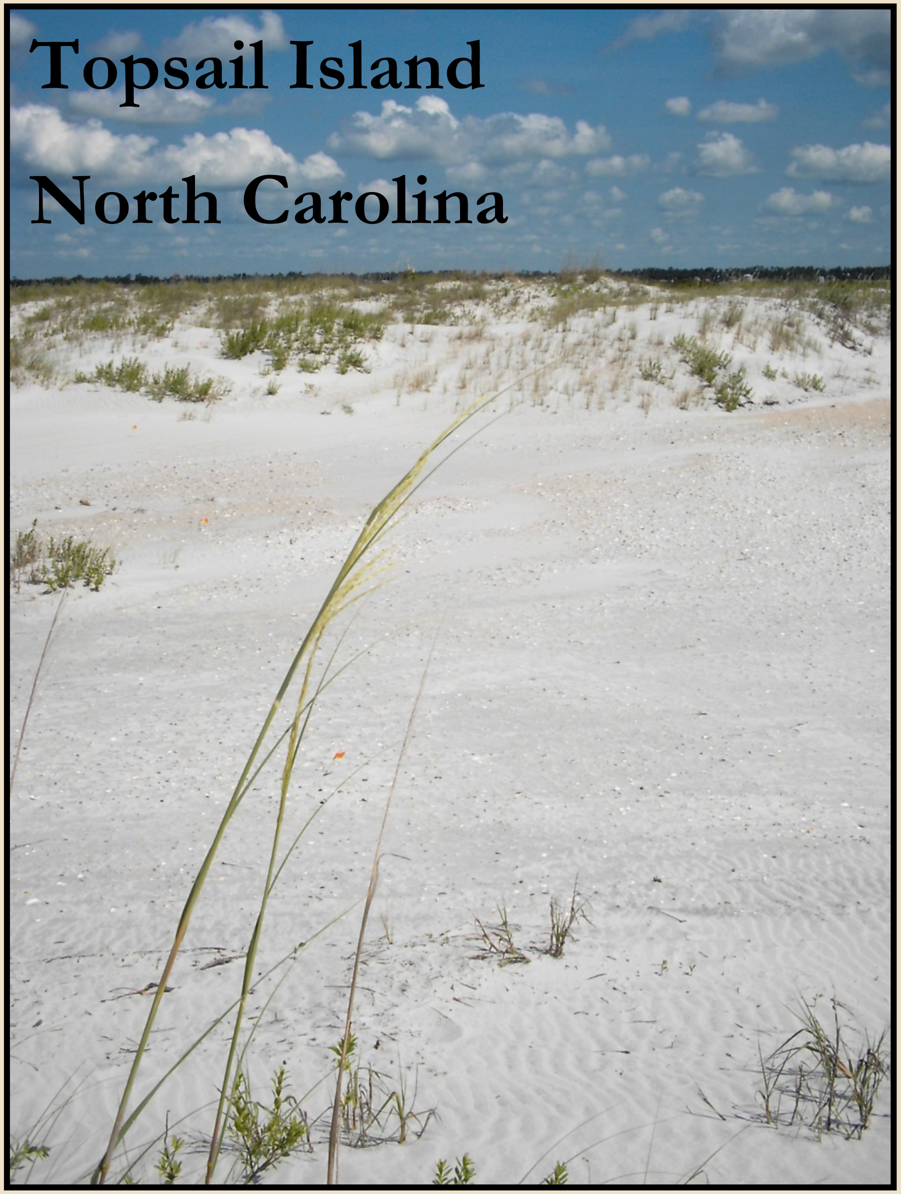
Pennywort – *Hydrocotyle bonariensis*

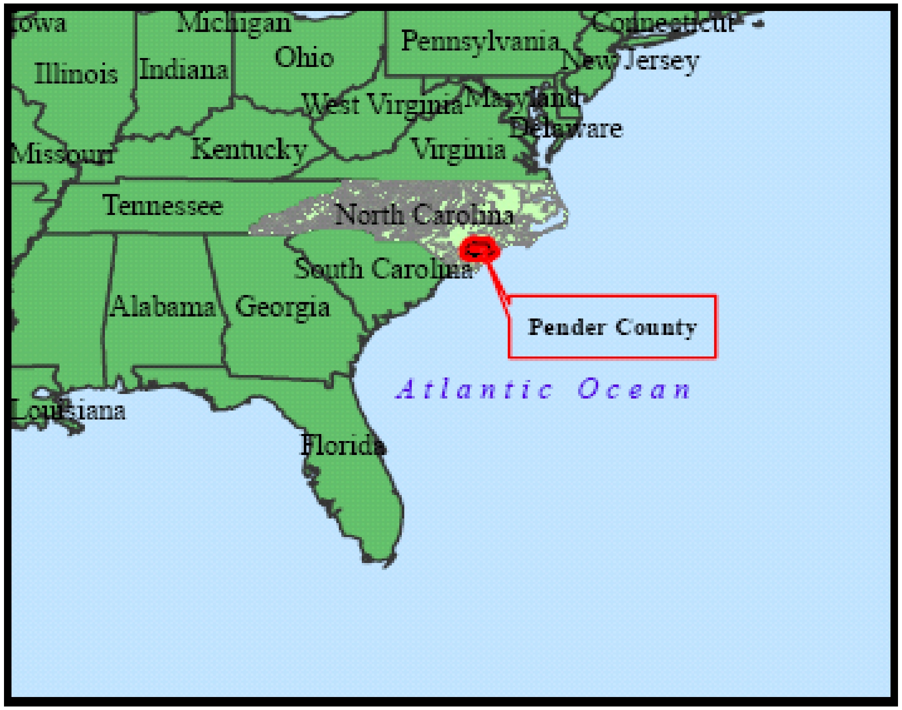
Questions

What is the function of observed leaf orientation in Pennywort (*Hydrocotyle bonariensis*)?

1. Is there daily and/or seasonal leaf orientation, and what is the effect on sunlight exposure?
2. What is the effect of leaf orientation on leaf temperature, photosynthetic gas exchange, and water loss?

Study Site


Topsail Island
North Carolina


Iowa
Michigan
Pennsylvania
Connecticut
Illinois
Indiana
Ohio
New Jersey
West Virginia
Maryland
Delaware
Missouri
Kentucky
Virginia
Tennessee
North Carolina
South Carolina
Alabama
Georgia
Pender County
Atlantic Ocean
Louisiana
Florida


N
W
E
S

Questions

What is the function of observed leaf

orientation in Pennywort (*Hydrocotyle bonariensis*)?

1. **Is there daily and/or seasonal leaf orientation, and what is the effect on sunlight exposure?**
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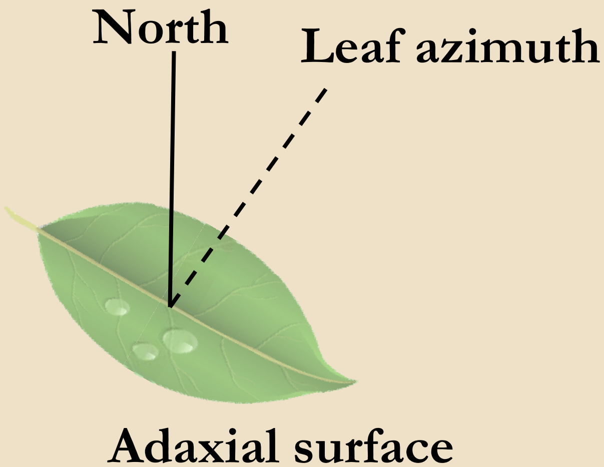
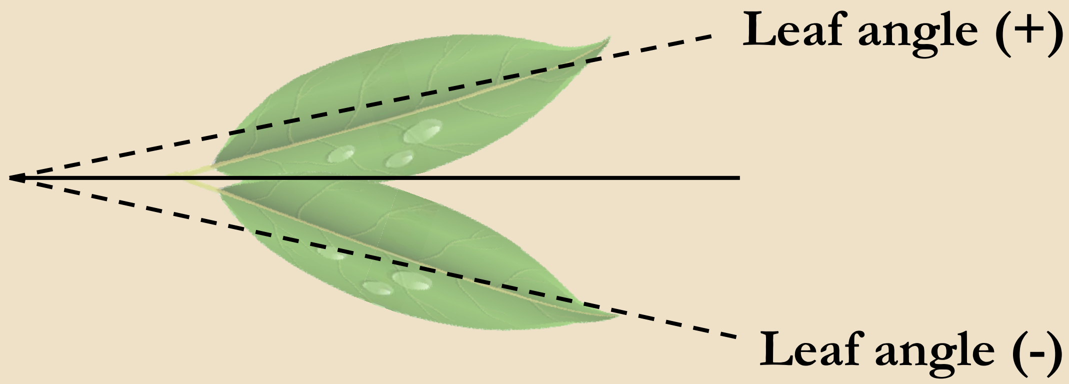
Q1 – Methods

– Measured leaf angle every two hours from 08:00 h to 18:00 h on single mature leaves

– Early season (May), mid-season (June and August), and late season (September)

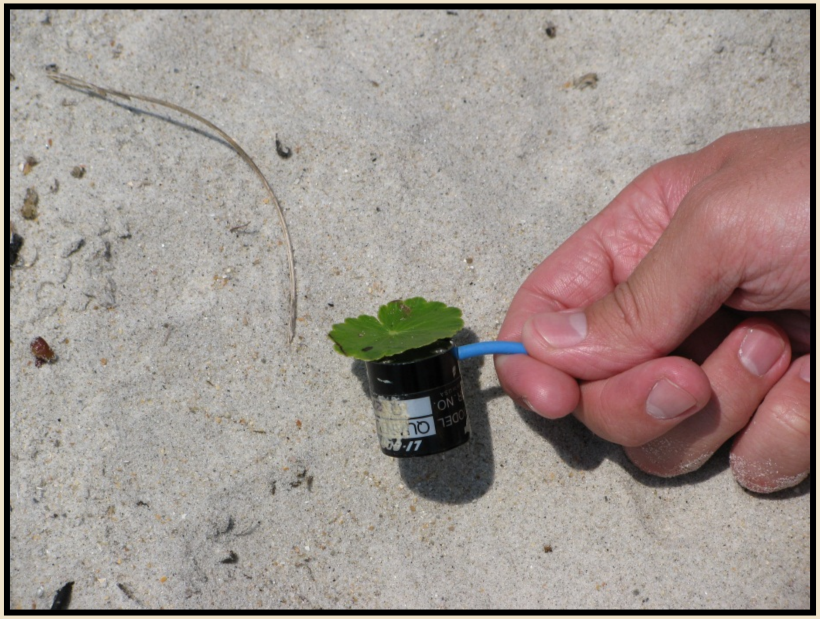




Q1 – Methods

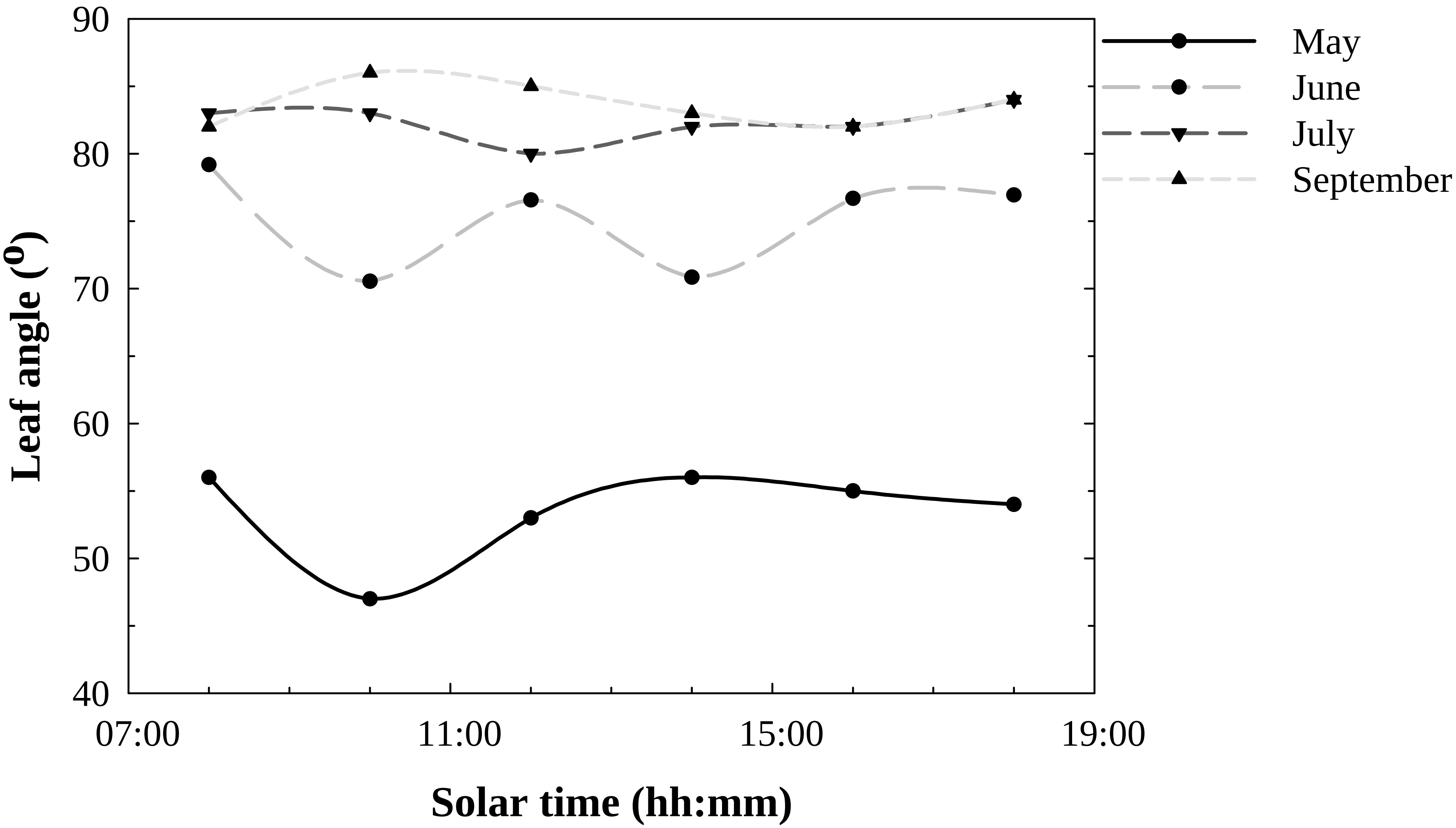
- Light measured as Photosynthetically active radiation (PAR; describes amount of incident light seen by leaf)

- Measured for top of leaf and bottom of leaf every 2 hours from 08:00 h to 18:00 h in May, June, August, and September

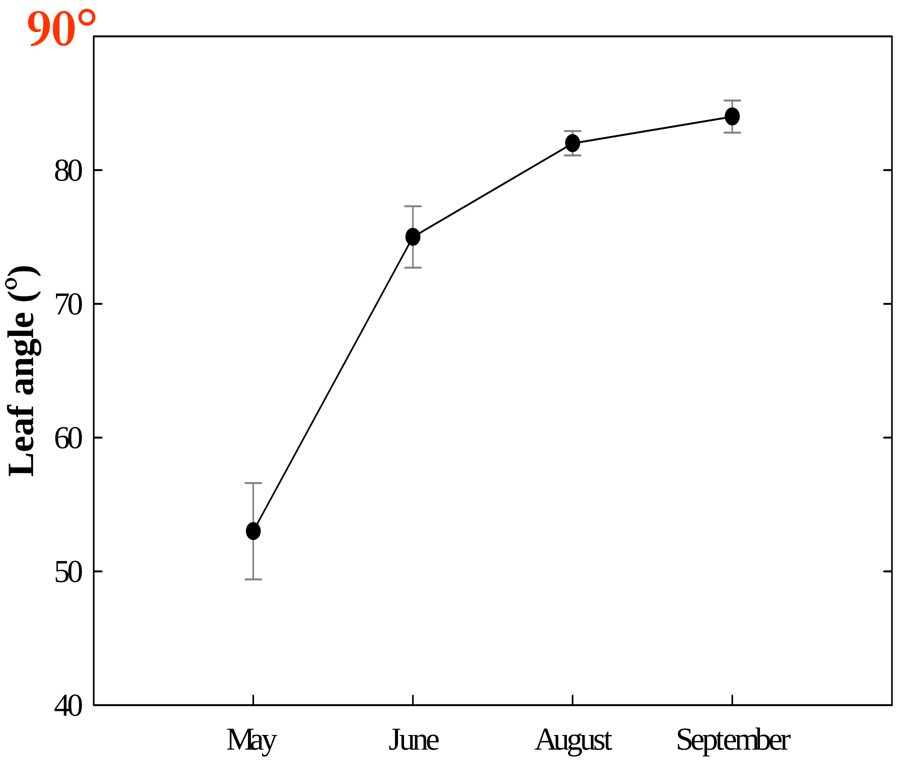


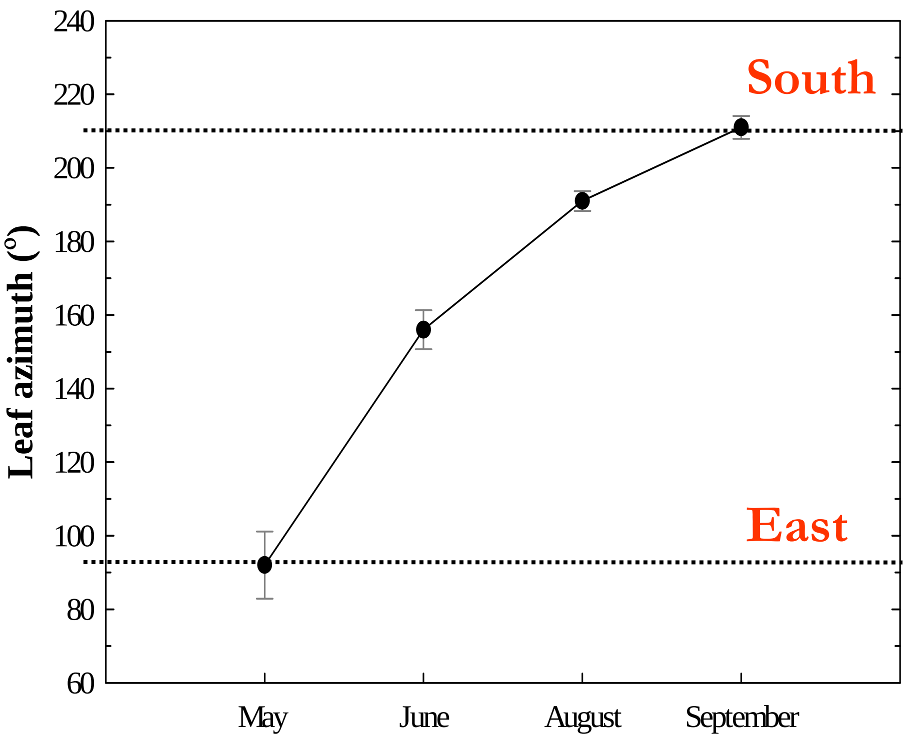
Daily Leaf Orientaiton

Same general trend for leaf azimuth



Seasonal Leaf Orientation



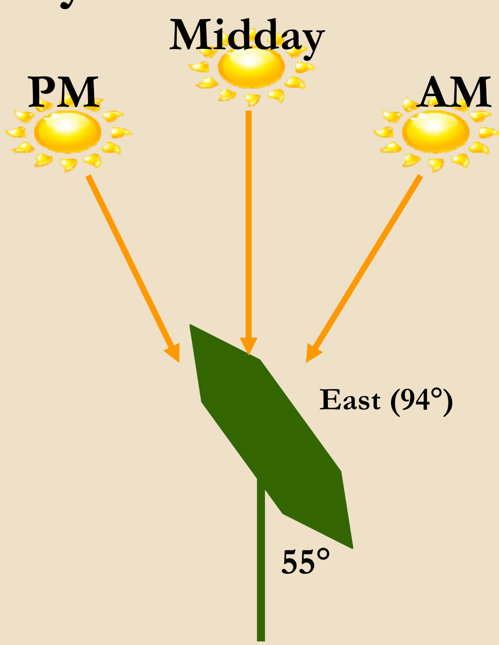


Increase in mean leaf angle over the growing season, from 55° to 82°

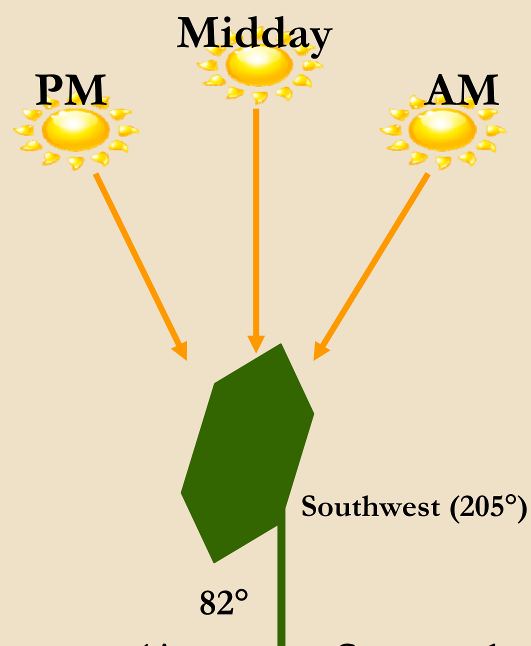
Increase in mean leaf azimuth over growing season, from 94° to 205°

Seasonal but Not Daily Orientation

- **Daily orientation:**
  - There was **little to no variation** daily in mean leaf angle and mean leaf azimuth
- **Seasonal orientation:**
  - **Increase** in mean leaf angle and mean leaf azimuth over growing season
- **First study to show seasonal but not diurnal orientation**



Early season (May)



Late season (August - September)

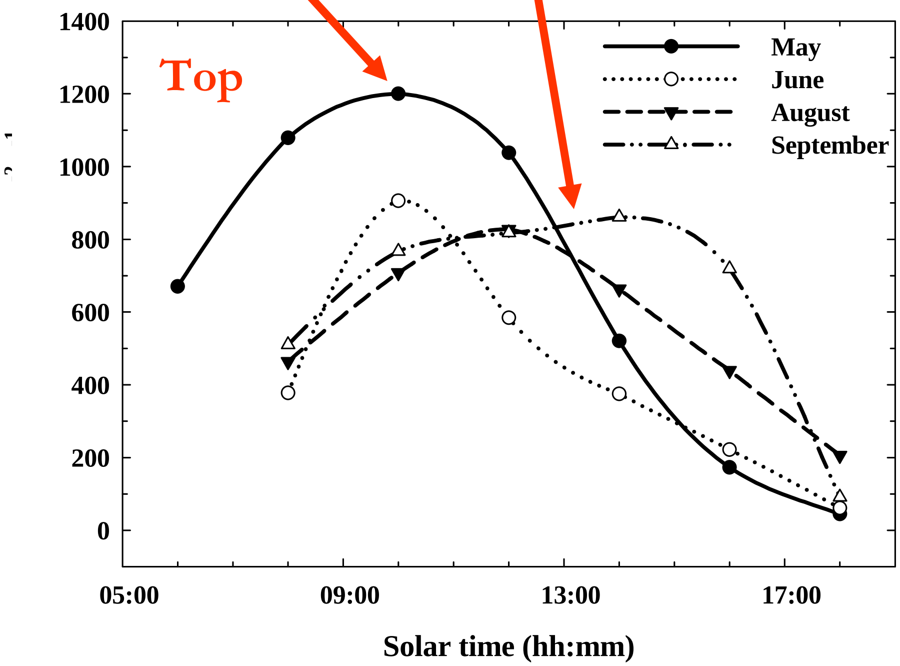
Daily Light on Top and Bottom Leaf Surface

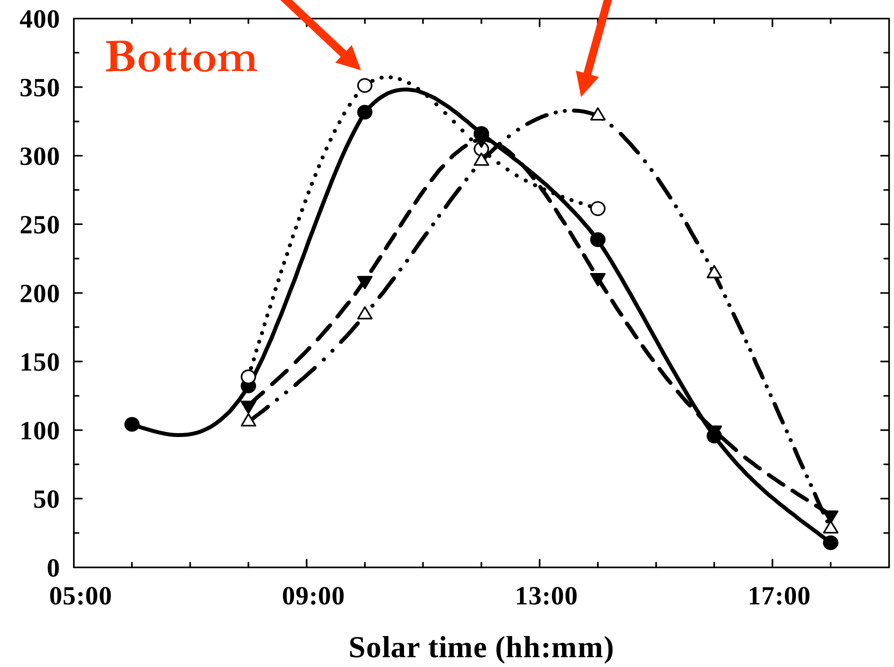
Leaf angle 50 – 70°

Leaf angle 80 - 85°

Leaf azimuth East

Leaf azimuth Southwest

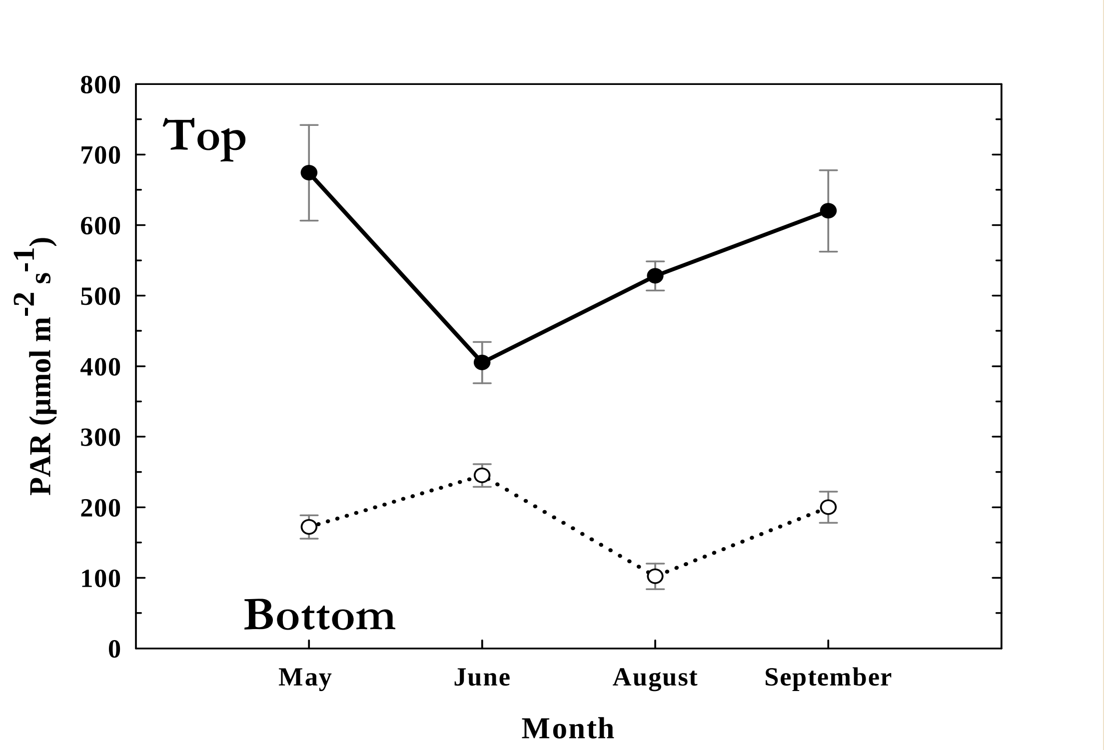




Reduction in midday light on top leaf surface with more inclined leaf in late season

Shift in peak (09:00 – 10:00 h early season, 12:00 – 14:00 h late season) on both top and bottom leaf

Seasonal Ratio of Top: Bottom Light Exposure



	May	June	August	September
Top PPFD	674 ± 67.8	406 ± 29.2	528 ± 20.6	620 ± 57.7
Bottom PPFD	172 ± 16.5	245 ± 16.1	162 ± 18.1	200 ± 22.1
Top/Bot	**3.92**	**1.66**	**3.26**	**2.07**

Q1 – Conclusion

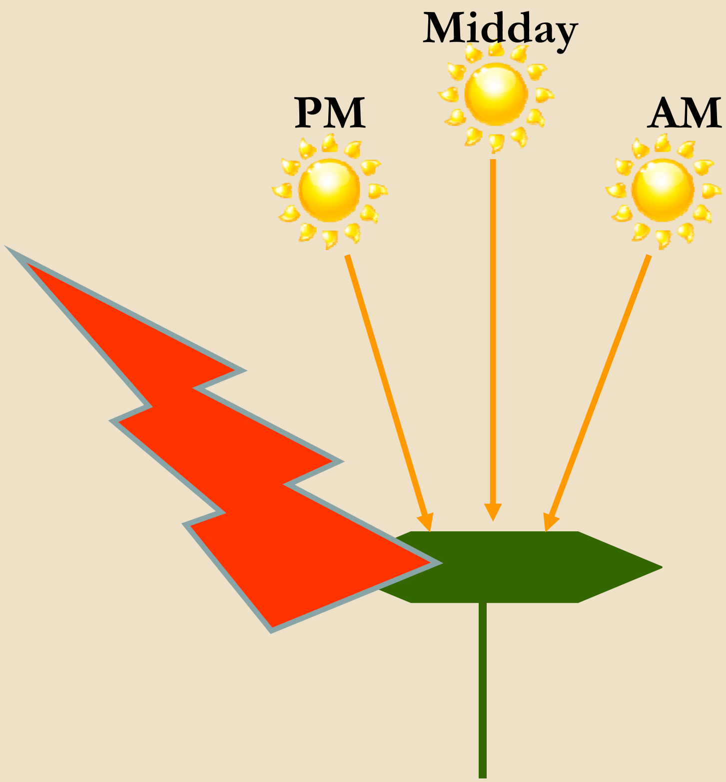
- Seasonal increase in leaf angle (more vertical) and leaf azimuth (seasonally tracks the sun)

- <u>Daily light regulation:</u>
  - ↑ a.m., **peak** midday, ↓ p.m.

- <u>Seasonal light regulation:</u>
  - ↓ in top light exposure, **shift in peak** in bottom light exposure

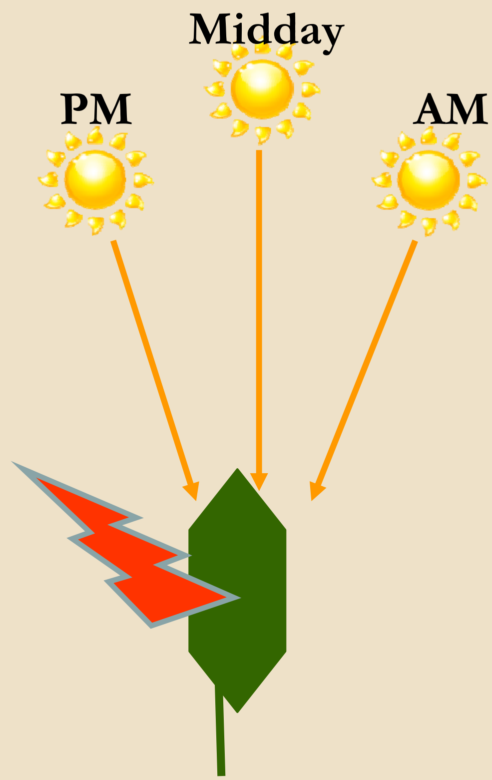
May: ~4x more light on top leaf surface (mean leaf angle = 54°)
June: ~1.5 x more light on top leaf surface (75°)
August: ~3x more light on top leaf surface (82°)
September: ~2x more light on top leaf surface (82°)

Q2 – Expectations



↑ leaf temperature and transpiration (E)

↓ photosynthesis (A)



↓ leaf temperature and transpiration (E)

↑ photosynthesis (A)

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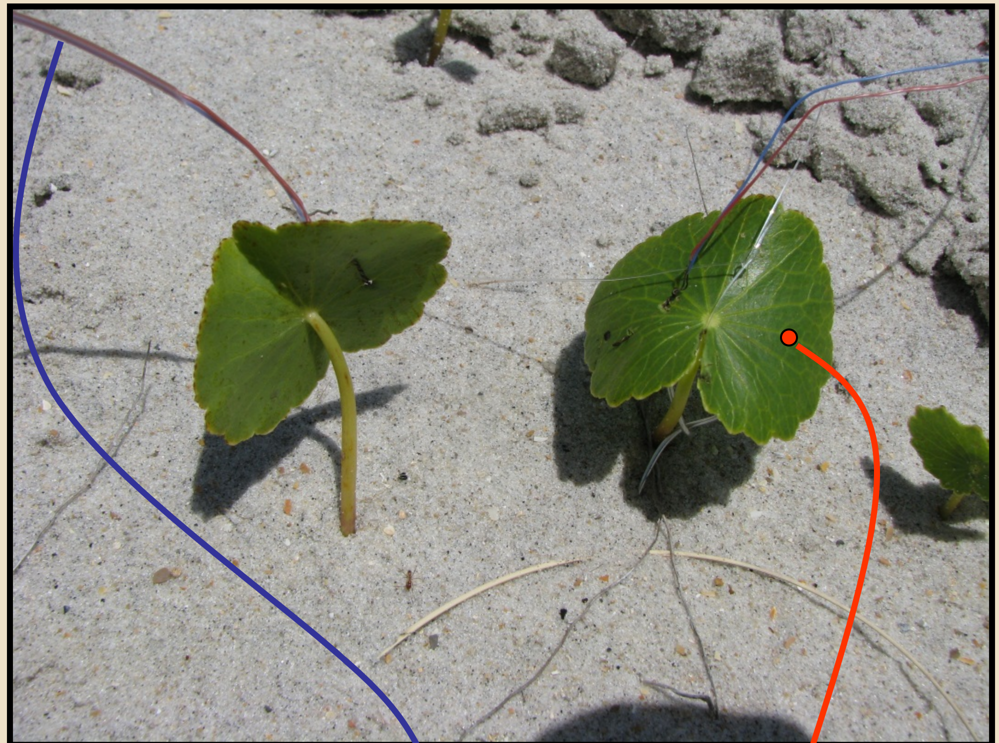
Q2 – Methods



Measured monthly from 06:00 – 21:00 h with leaf thermocouple (*N* = 2 – 4 pairs)

Measured monthly from 09:00 to 17:00 h with infrared gun (*N* = 10 pairs)

Q2 – Methods

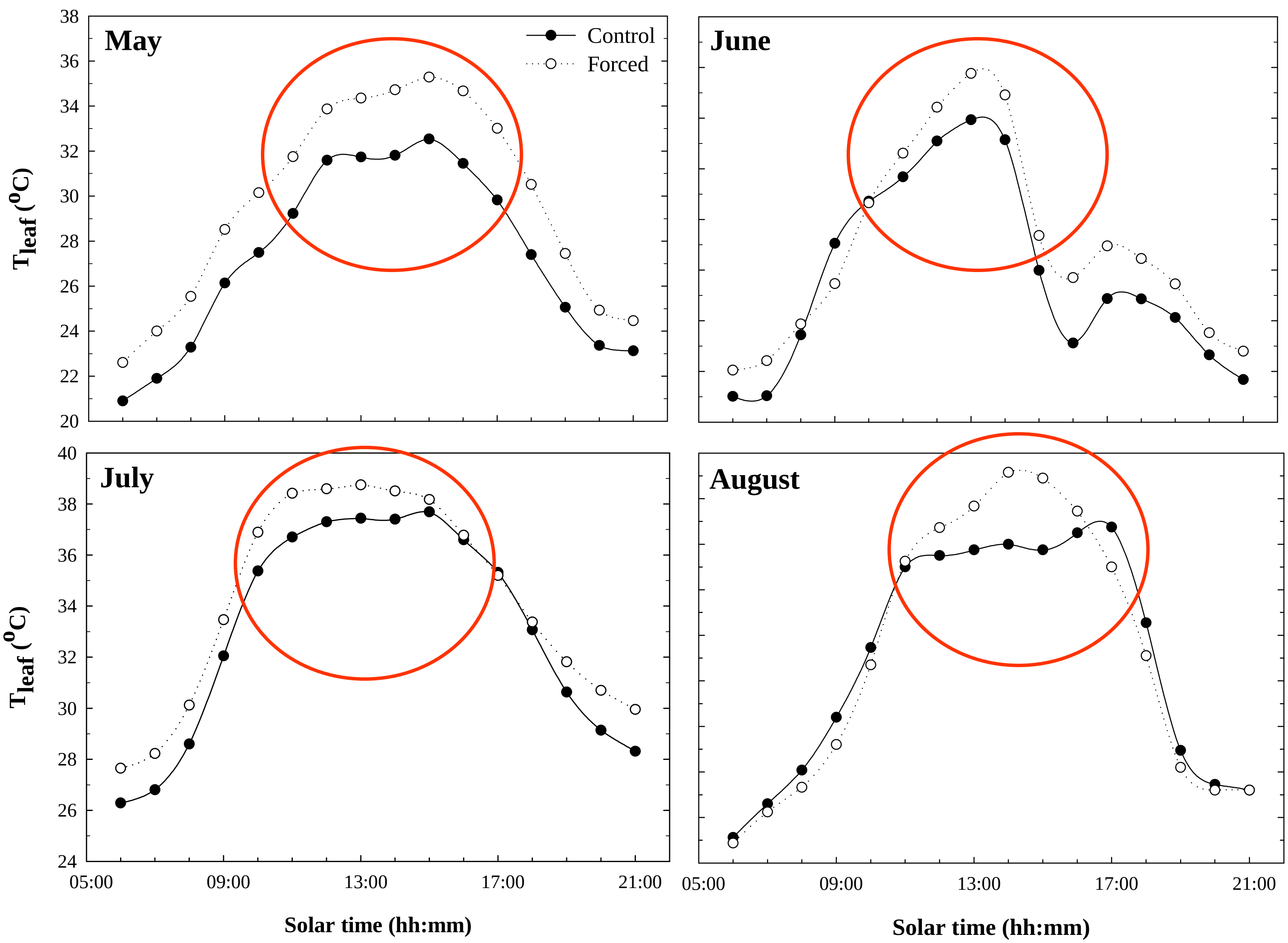
Photosynthetic gas exchange measured on experimental and control leaves in July and August at midday

LICOR LI-6400 portable photosynthesis system

Measures gas exchange in plant leaves

Known amount of CO_2 and water vapor to leaf – Amount of CO_2 and water vapor back to system = Amount of CO_2 taken up by leaf and water vapor released

Daily Leaf Temperature



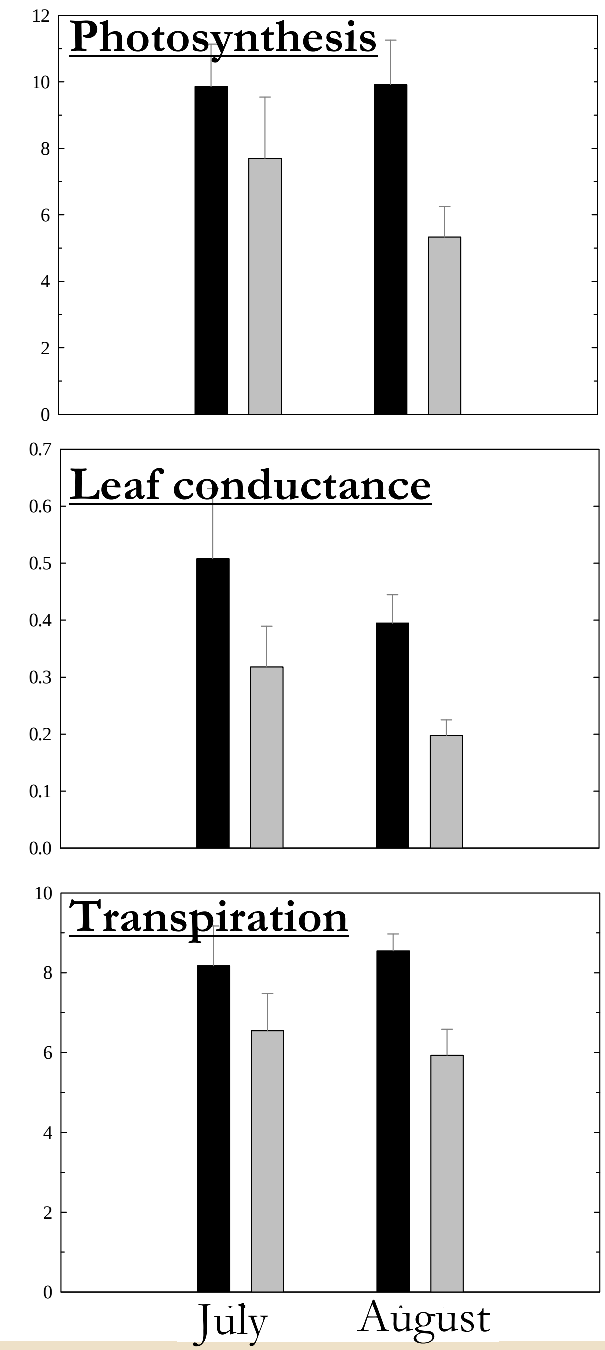
Gas Exchange

Control

Experimental (forced)

Inclined leaves have greater:

- Photosynthesis
  - Leaf converting more light and CO_2 to sucrose
- Leaf conductance
  - Stomata are open and exchanging more CO_2 and water vapor
- Transpiration
  - Leaf is losing more water by evaporative heat loss



Role of Transpiration

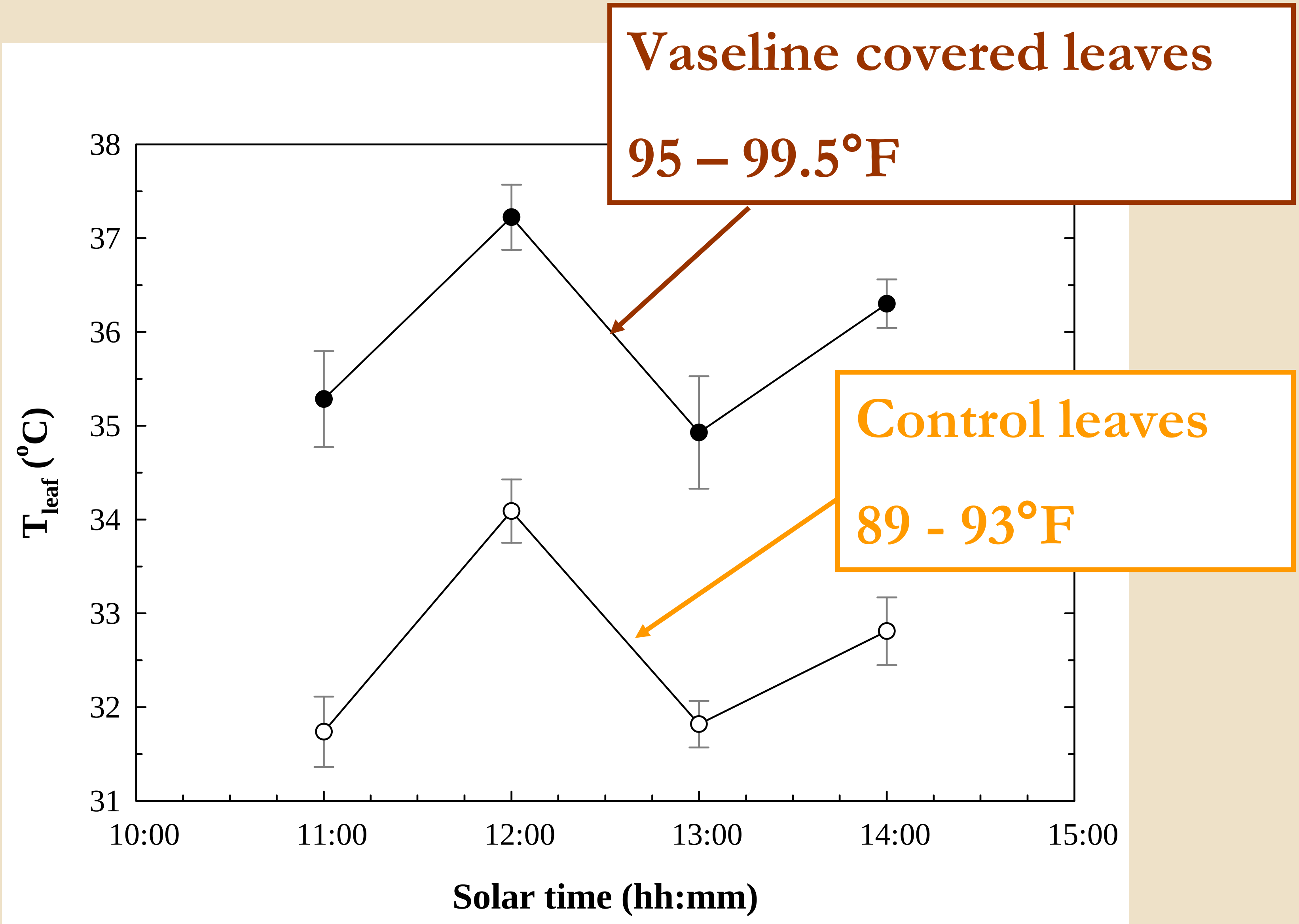
- What is the influence of transpiration in reduced leaf temperature in inclined leaves?

Three groups of six similar sized leaves with similar leaf inclination

3 leaves control, 3 leaves covered in Vaseline (experimental)

Leaf temperature measured every hour from 11:00 – 14:00 h with infrared gun

Midday Leaf Temperatures



Q2 – Conclusions

- Inclined leaves have lower leaf temperatures and greater photosynthetic gas exchange
- There is also an important role of evaporative heat loss via transpiration maintaining leaf temperatures
  - Leaves covered in vaseline could not lose water vapor and had higher leaf temperatures as result

- **Function of leaf orientation in Pennywort**
  - Leaf angle increases over season to reduce midday incident sunlight
  - Increase in leaf azimuth seasonally tracks sun to maximize a.m. and p.m. light capture
  - Inclined leaf orientation reduces leaf temperature and facilitates photosynthetic gas exchange

Acknowledgements

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Department of Biology

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Wreana Ward

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