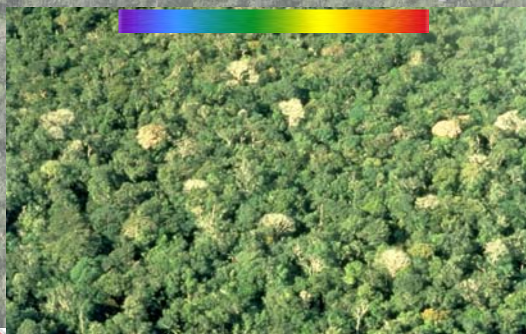
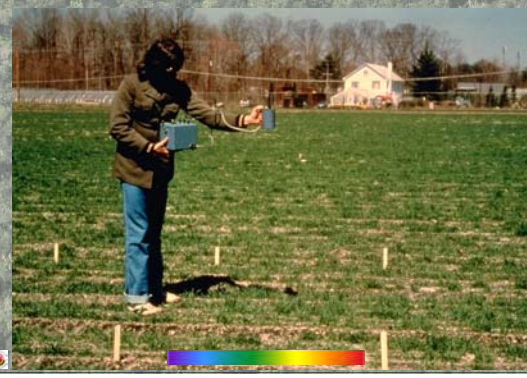
Leaf Reflectance & Absorption

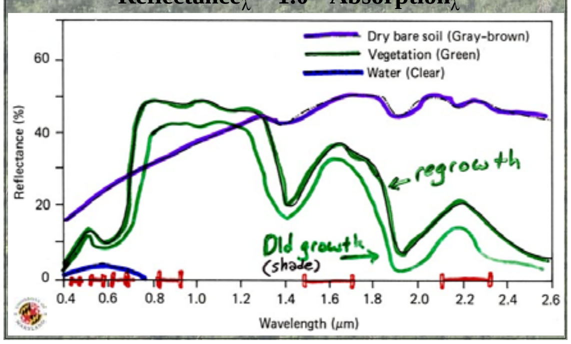


Beltsville winter wheat



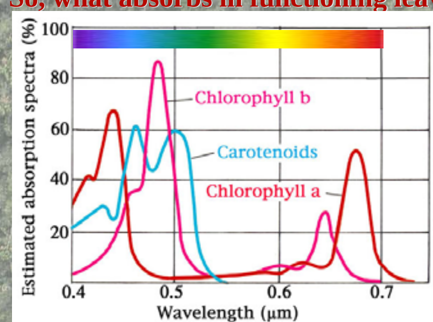
Leaf Spectral Reflectance

Reflectance$_\lambda$ = 1.0 - Absorption$_\lambda$



Plant Pigments

So, what absorbs in functioning leaves?

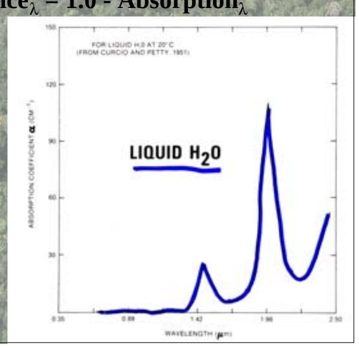


(Reflectance$_\lambda$ = 1.0 - Absorption$_\lambda$)

Liquid Water Absorption$_\lambda$

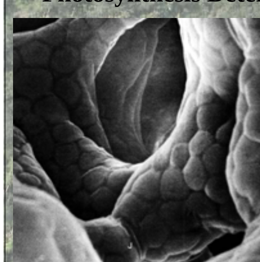
Reflectance$_\lambda$ = 1.0 - Absorption$_\lambda$

Liquid water in plant leaves completes the absorption picture: leaves must be hydrated for photosynthesis



Leaf Photosynthesis

Photosynthesis Determines Optical Properties



Bean leaf x4200

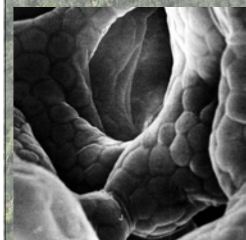
PHOTOSYNTHESIS

Solar Energy

$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

Leaf Photosynthesis

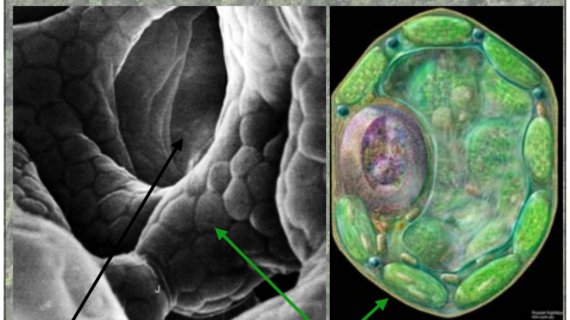
Photosynthesis Determines Optical Properties



PHOTOSYNTHESIS

- Must capture photons to drive chemical reactions (energy input)
- Must be in presence of H2O
- Must be in presence of CO2
- Must get rid of O2 (poisonous)
- Must live in hostile setting…

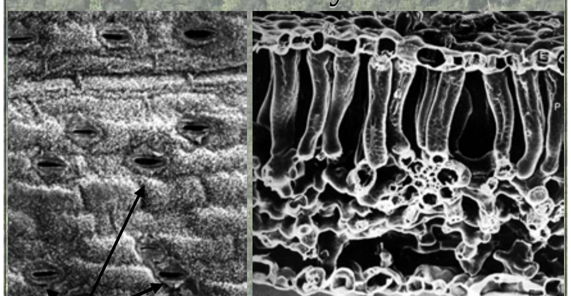
Internal Leaf Structure



Intercellular air labyrinth
CO_2 in & O_2 out

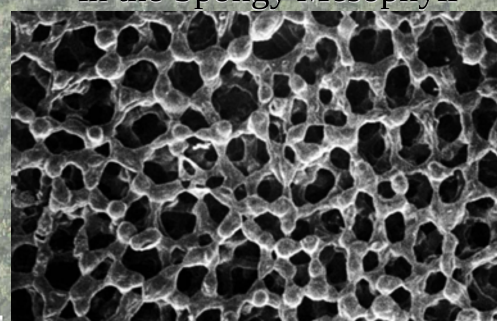
Chloroplasts

Leaf Photosynthesis

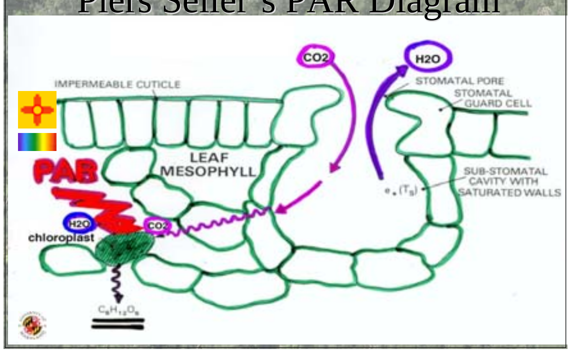


Stomata regulate gas exchange and water loss
CO_2 in/O_2 out

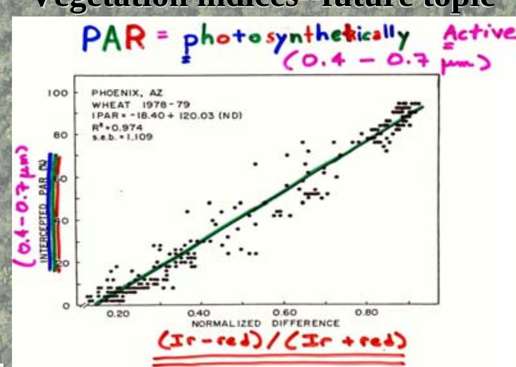
Leaf Reflectance & Absorption in the Spongy Mesophyll

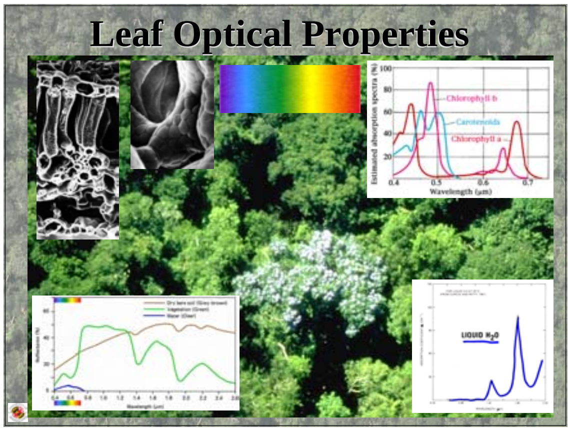


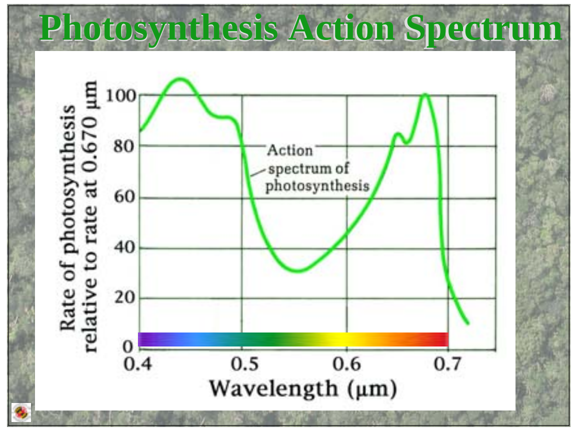
Leaf Photosynthesis
Piers Seller's PAR Diagram

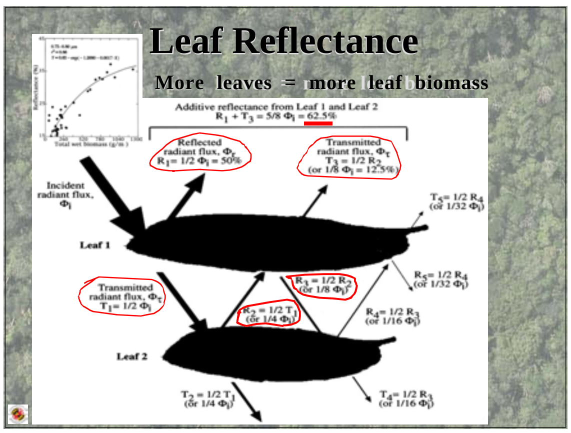


Vegetation indices--future topic

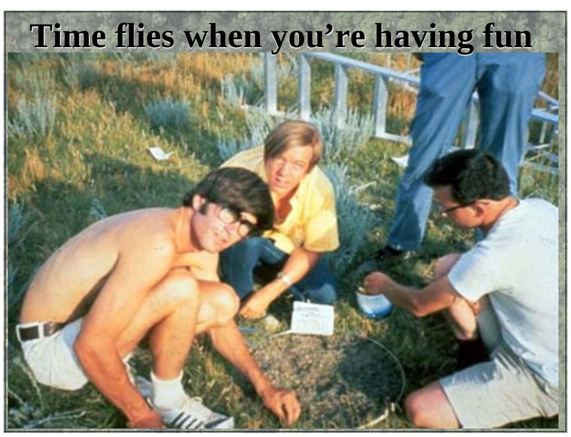


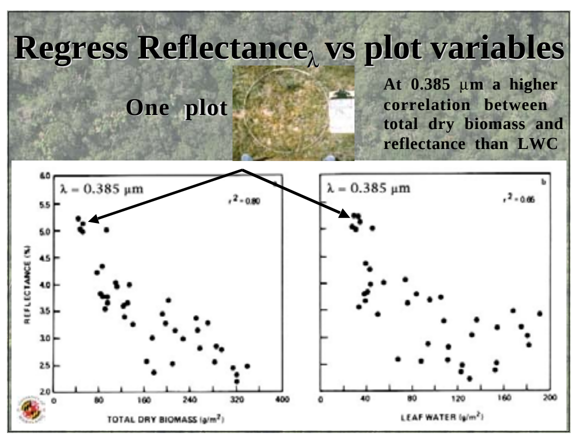

Leaf Optical Properties
Chlorophyll b
Carotenoids
Chlorophyll a
Wavelength (µm)
LIQUID H2O

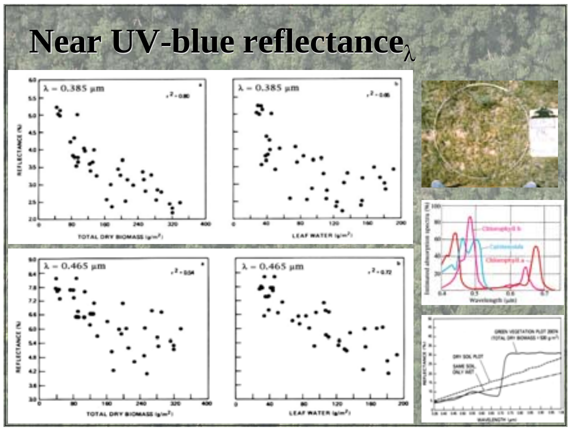

Photosynthesis Action Spectrum
Rate of photosynthesis relative to rate at 0.670 µm
Action spectrum of photosynthesis
Wavelength (µm)
0.4
0.5
0.6
0.7
100
80
60
40
20
0

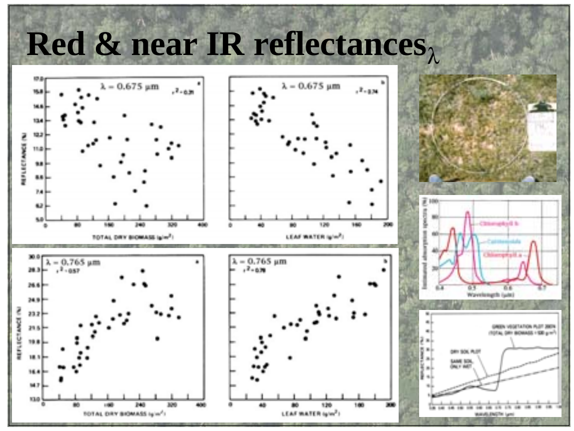

Leaf Reflectance
More leaves = more leaf biomass
Additive reflectance from Leaf 1 and Leaf 2
R1 + T3 = 5/8 Φi = 62.5%
Incident radiant flux, Φi
Reflected radiant flux, Φr
R1 = 1/2 Φi = 50%
Transmitted radiant flux, Φt
T3 = 1/2 R2
(or 1/8 Φi = 12.5%)
T5 = 1/2 R4
(or 1/32 Φi)
Leaf 1
Transmitted radiant flux, Φt
T1 = 1/2 Φi
R3 = 1/2 R2
(or 1/8 Φi)
R2 = 1/2 T1
(or 1/4 Φi)
R5 = 1/2 R4
(or 1/32 Φi)
R4 = 1/2 R3
(or 1/16 Φi)
Leaf 2
T2 = 1/2 T1
(or 1/4 Φi)
T4 = 1/2 R3
(or 1/16 Φi)
Total wet biomass (g/m²)

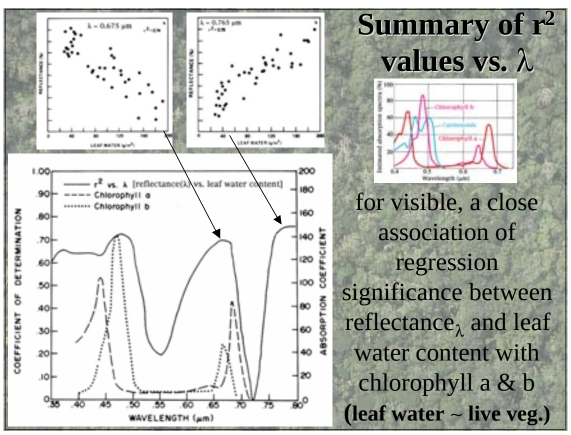

Nondestructive Biological Mass
(or biomass) Objective
Grassland system -- very simple
Plant biomass is source of energy for system
Anything is better than clipping!!!
Clipping is limited for time & space extrapolations

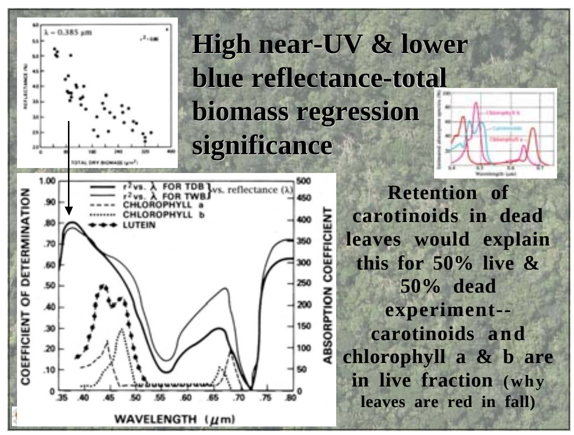

Time flies when you're having fun

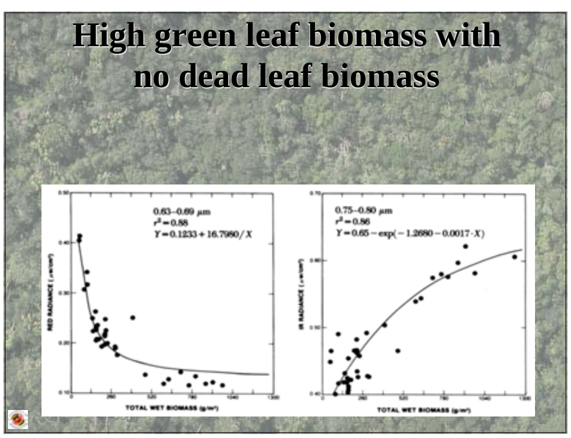

Regress Reflectanceλ vs plot variables
One plot
At 0.385 µm a higher correlation between total dry biomass and reflectance than LWC
λ = 0.385 µm
λ = 0.385 µm
REFLECTANCE (%)
TOTAL DRY BIOMASS (g/m²)
LEAF WATER (g/m²)

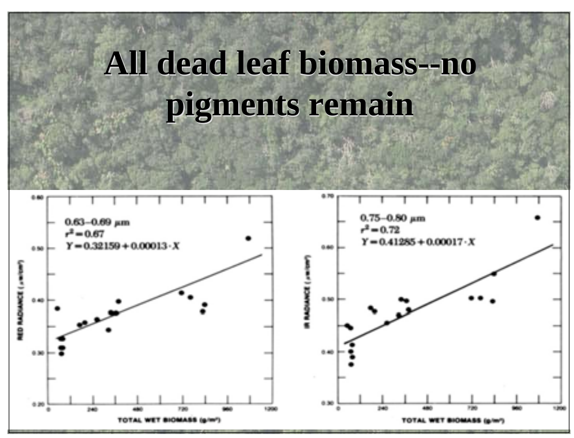

Near UV-blue reflectance$_\lambda$
λ = 0.385 μm
λ = 0.465 μm
TOTAL DRY BIOMASS (g/m²)
LEAF WATER (g/m²)
REFLECTANCE (%)


Red & near IR reflectances$_\lambda$
λ = 0.675 μm
λ = 0.765 μm
TOTAL DRY BIOMASS (g/m²)
LEAF WATER (g/m²)
REFLECTANCE (%)

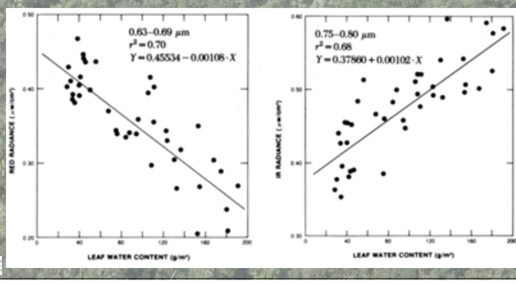

Summary of r² values vs. λ
for visible, a close association of regression significance between reflectance$_\lambda$ and leaf water content with chlorophyll a & b
(leaf water ~ live veg.)
r² vs. λ [reflectance(λ) vs. leaf water content]
Chlorophyll a
Chlorophyll b
COEFFICIENT OF DETERMINATION
ABSORPTION COEFFICIENT
WAVELENGTH (μm)

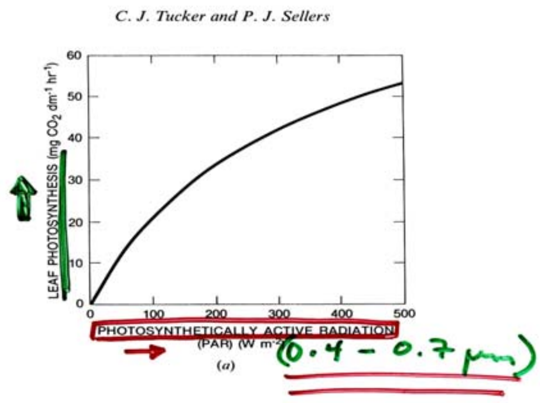

High near-UV & lower blue reflectance-total biomass regression significance
Retention of carotinoids in dead leaves would explain this for 50% live & 50% dead experiment--carotinoids and chlorophyll a & b are in live fraction (why leaves are red in fall)
λ = 0.385 μm
r² vs. λ FOR TDB
r² vs. λ FOR TWB
vs. reflectance (λ)
CHLOROPHYLL a
CHLOROPHYLL b
LUTEIN
COEFFICIENT OF DETERMINATION
ABSORPTION COEFFICIENT
WAVELENGTH (μm)


High green leaf biomass with no dead leaf biomass
0.63–0.69 μm
r² = 0.88
Y = 0.1233 + 16.7980 / X
0.75–0.80 μm
r² = 0.86
Y = 0.65 − exp(−1.2680 − 0.0017·X)
TOTAL WET BIOMASS (g/m²)


All dead leaf biomass--no pigments remain
0.63–0.69 μm
r² = 0.67
Y = 0.32159 + 0.00013·X
0.75–0.80 μm
r² = 0.72
Y = 0.41285 + 0.00017·X
TOTAL WET BIOMASS (g/m²)

50% live & 50% dead

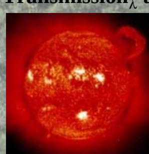




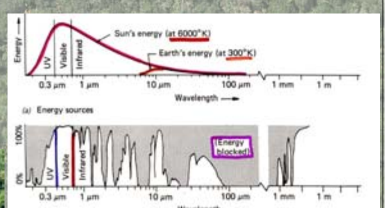
Leaf Reflectance & Absorption

Reflectance$_\lambda$ = 1.0 - Absorption$_\lambda$

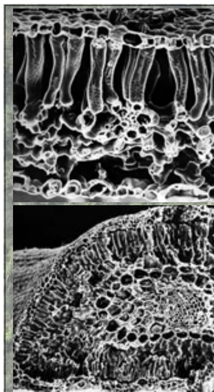
Transmission$_\lambda$ transient--if not absorbed$_\lambda$ then reflected$_\lambda$

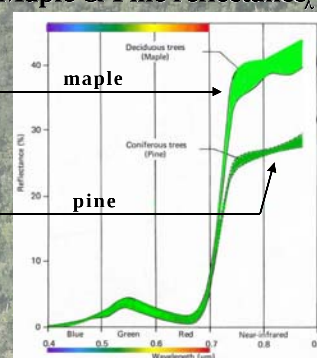


5880 K

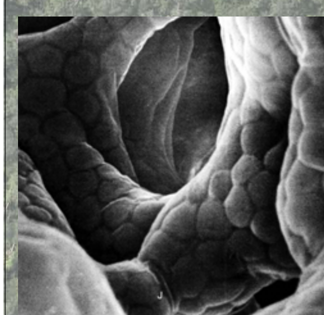


Maple & Pine reflectance$_\lambda$



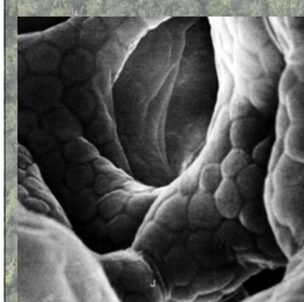


Leaf Reflectance & Absorption



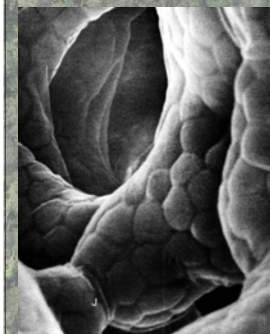
If no absorption, then the photons can be reflected or transmitted; transmitted photons are ultimately absorbed or reflected

Leaf Reflectance & Absorption



Photosynthesis requires CO_2 from atmosphere to be in contact with the plant cell surfaces. The intercellular labyrinth allows movement of CO_2 into leaves and O_2 out. Part of the "deal" is H_2O is lost

Leaf Reflectance & Absorption



Bean spongy mesophyll x4200

Beer-Lambert Law

$Out_\lambda = In_\lambda * e^{(-abs_\lambda * x)}$

Out_λ = $Flux_\lambda$ out

In_λ = $Flux_\lambda$ before "x"

abs_λ = absorption $coef_\lambda$

X = thickness of medium

How can a small concentration of absorbers (plant pigments) maximize $absorption_\lambda$?—<u>increase X</u>

Air-Cell Refraction of Light

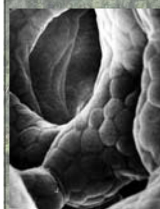
Index of refraction (n): $n = c/c_n$

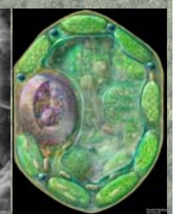
Where c = speed of light in vacuum

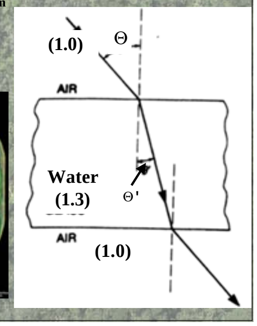
c_n = speed of light in $medium_n$

Snell's Law: $n \sin\Theta = n' \sin\Theta'$

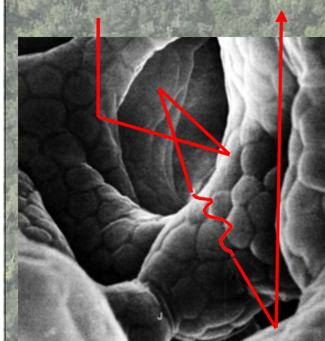
$n \sin\Theta = n' \sin\Theta'$







Leaf Reflectance & Absorption



If no absorption, photons can be reflected internally &/or refracted between air (1.0) & hydrated cells (1.33)