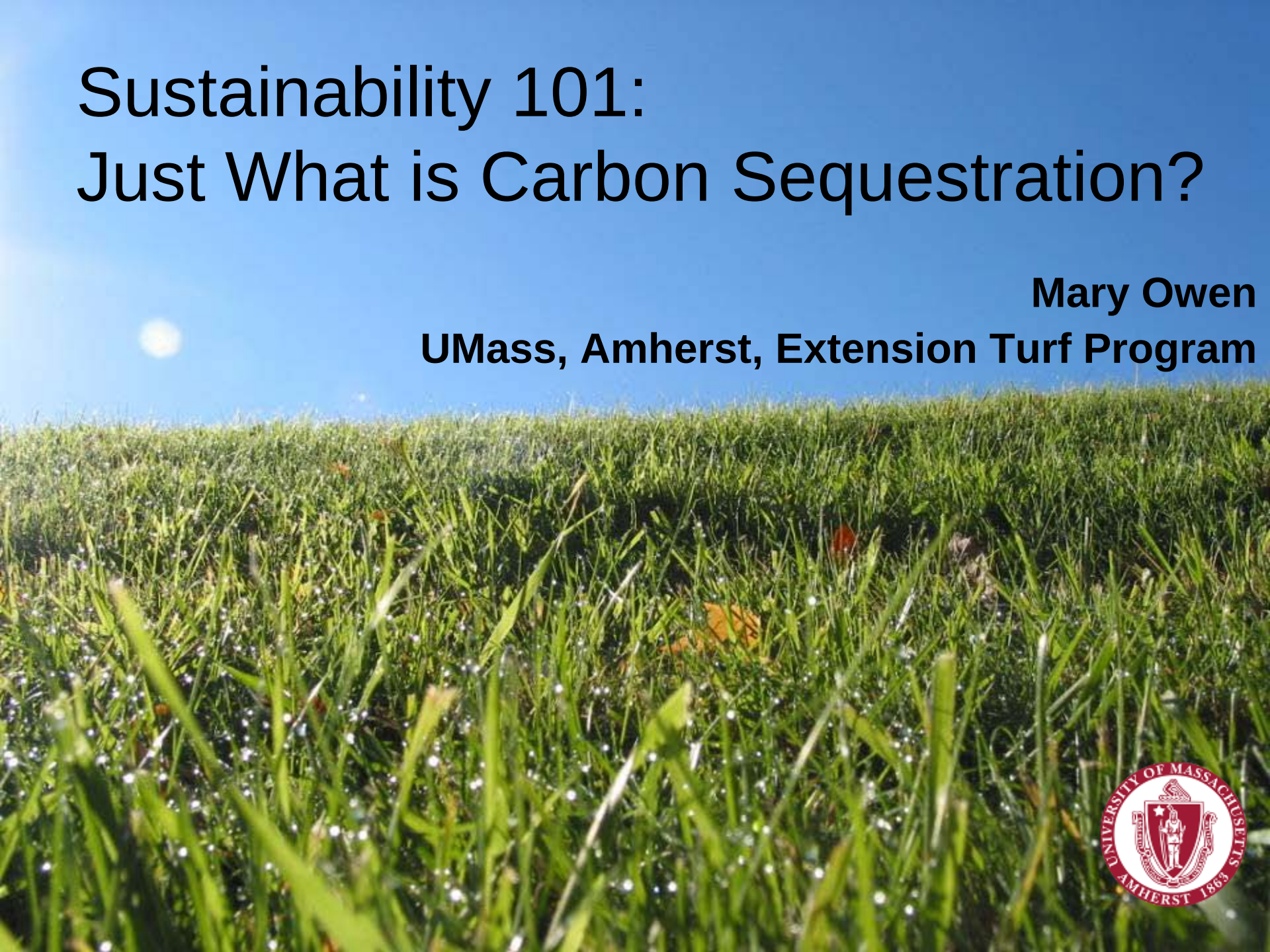
Sustainability 101:
Just What is Carbon Sequestration?

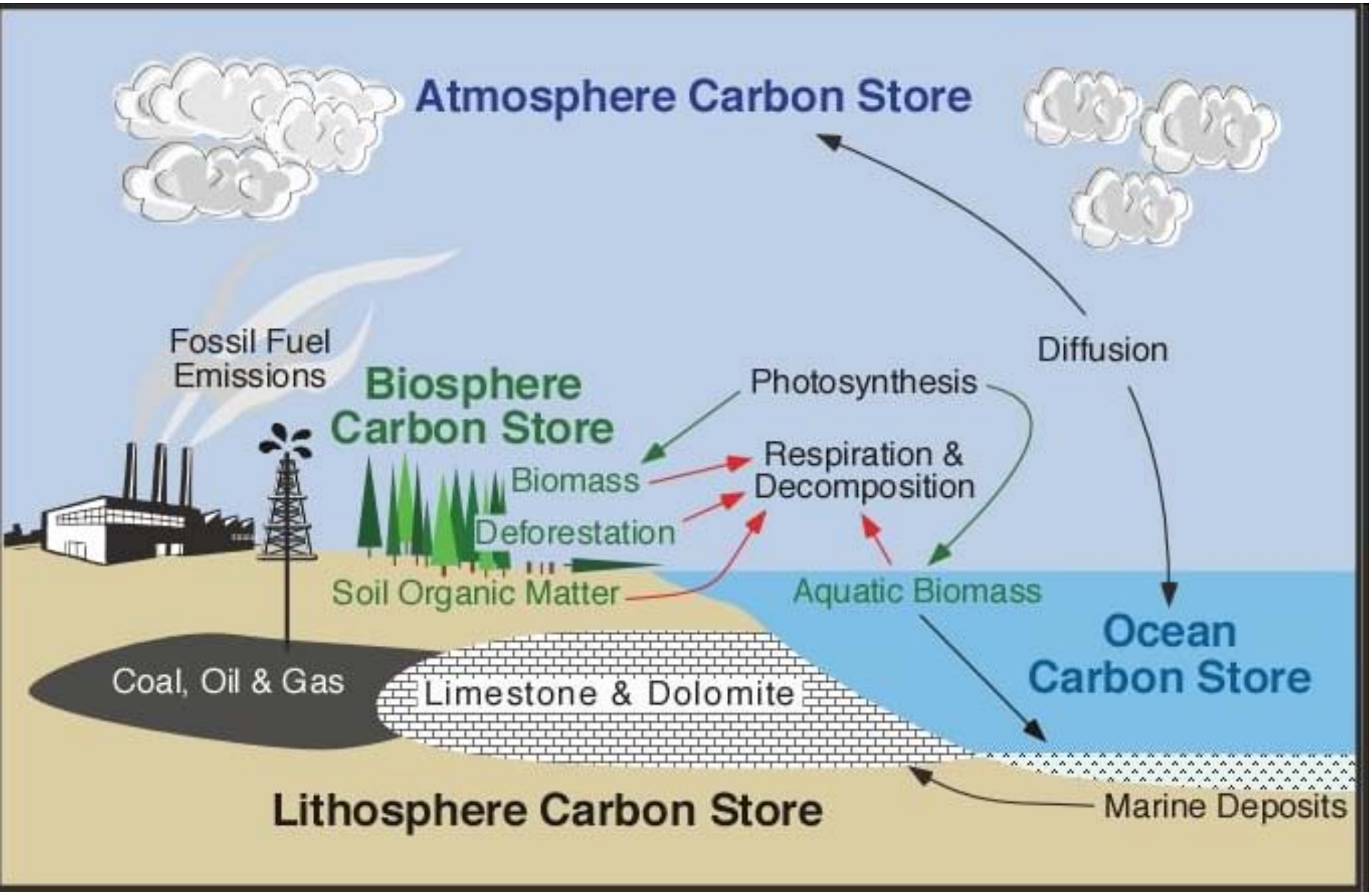
Mary Owen

UMass, Amherst, Extension Turf Program

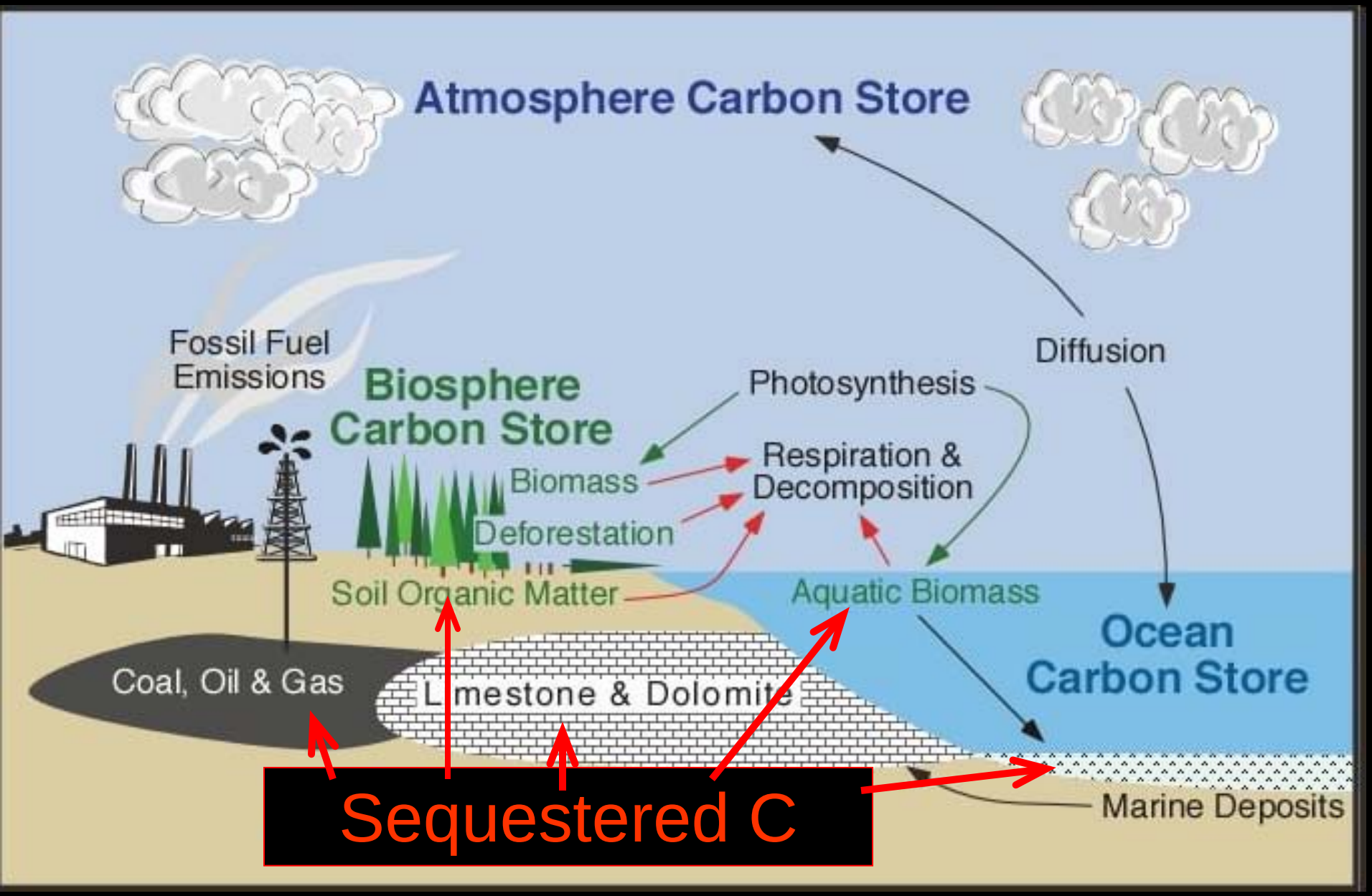


Carbon Sequestration……

- Capture and storage of carbon
  - ocean, soil, biomass
  - injection of CO_2 from power plant emissions into geologic formations (e.g. oil and gas reservoirs and unmineable coal seams) (DOE)
  - fixation of carbon through the process of photosynthesis



http://www.physicalgeography.net


Atmosphere Carbon Store
Fossil Fuel Emissions
Biosphere Carbon Store
Photosynthesis
Diffusion
Biomass
Respiration & Decomposition
Deforestation
Soil Organic Matter
Aquatic Biomass
Ocean Carbon Store
Coal, Oil & Gas
Limestone & Dolomite
Marine Deposits
Sequestered C

C fixation in turfgrasses

Photosynthesis is the process by which chlorophyll containing plants combine carbon dioxide and water, in the presence of light energy (sunlight), into simple sugars and carbohydrates

$$6CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

Photosynthesis

Energy

$$6CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

(chlorophyll)

Carbohydrates in turfgrasses

Non-structural CHO

Energy
(sink priority)

Storage
(CHO reserves)

Structural CHO

Large molecules

Provide architecture of the plant

Respiration is the process by which energy is released from carbohydrates for plant growth & development

$$C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12\ H_2O$$

Respiration

$$C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12\ H_2O$$

Energy

Photosynthesis

Energy

$$6CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

(chlorophyll)

Respiration

Energy

$$C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12\ H_2O$$

Respiration

- Provides energy for metabolism, cell maintenance, growth, and nutrient uptake and transport
- C_3 and C_4 use the same pathway
- Happens in all living plant parts

Cool season, C_3 turfgrasses

Bluegrasses,

Poa spp.

Kentucky

annual

Bentgrasses,

Agrostis spp.

creeping

velvet

colonial

Fine fescues,

Festuca spp.

creeping red

Chewings

hard

Tall fescue,

Festuca arundinacea or Schedonorus pheonix

Ryegrasses,

Lolium spp.

perennial

annual

intermediate

Warm season, C_4 turfgrasses

Bermudagrass,

***Cynodon* spp.**

Buffalograss

Bouteloua dactyloides

Kikuyugrass

Pennisetum clandestinum

Seashore paspalum

Paspalum vaginatum

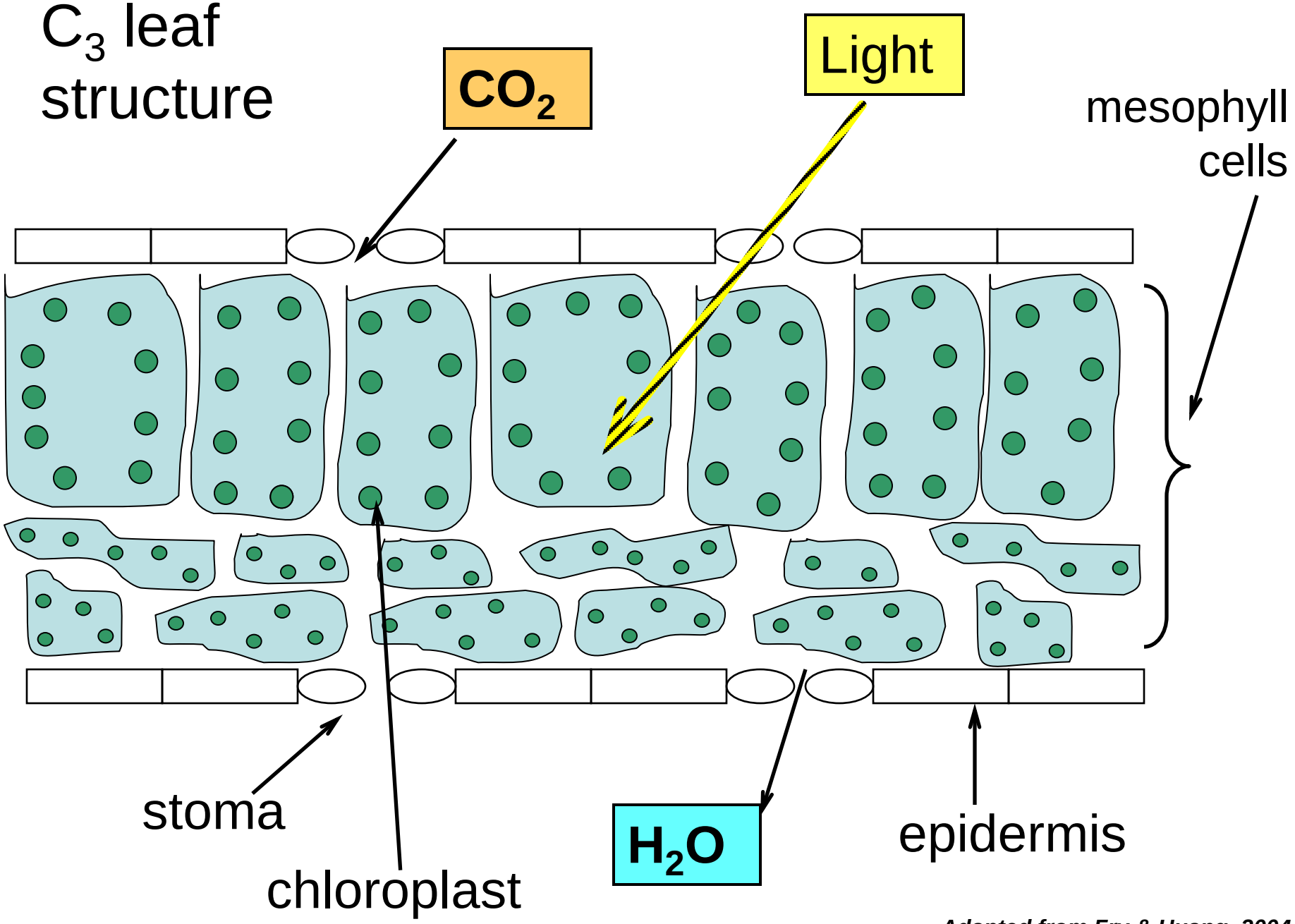
Zoysiagrass

***Zoysia* spp.**

St. Augustinegrass

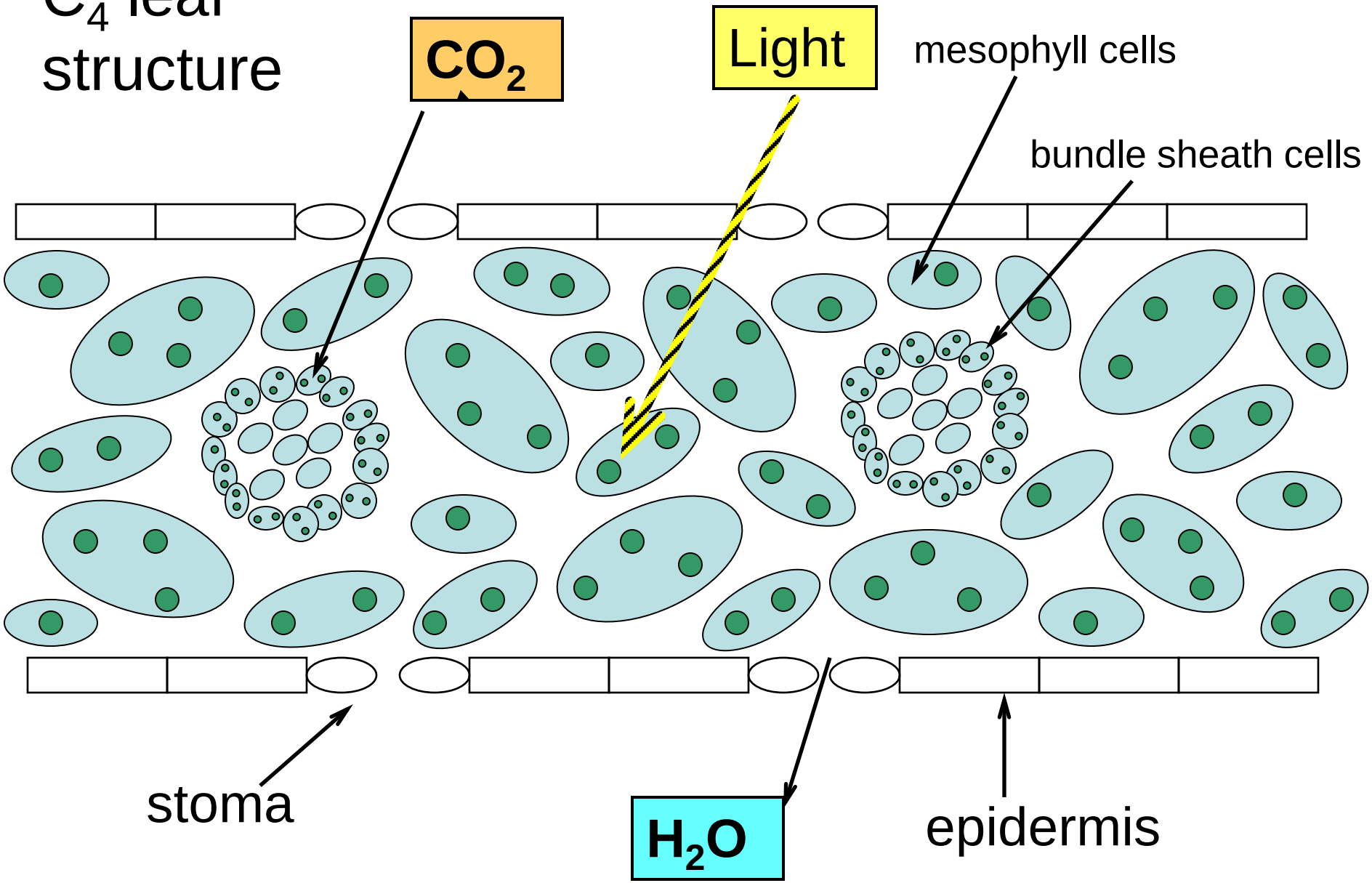
Stenotaphrum secundatum

C_3 leaf structure



Adapted from Fry & Huang, 2004

C_4 leaf structure



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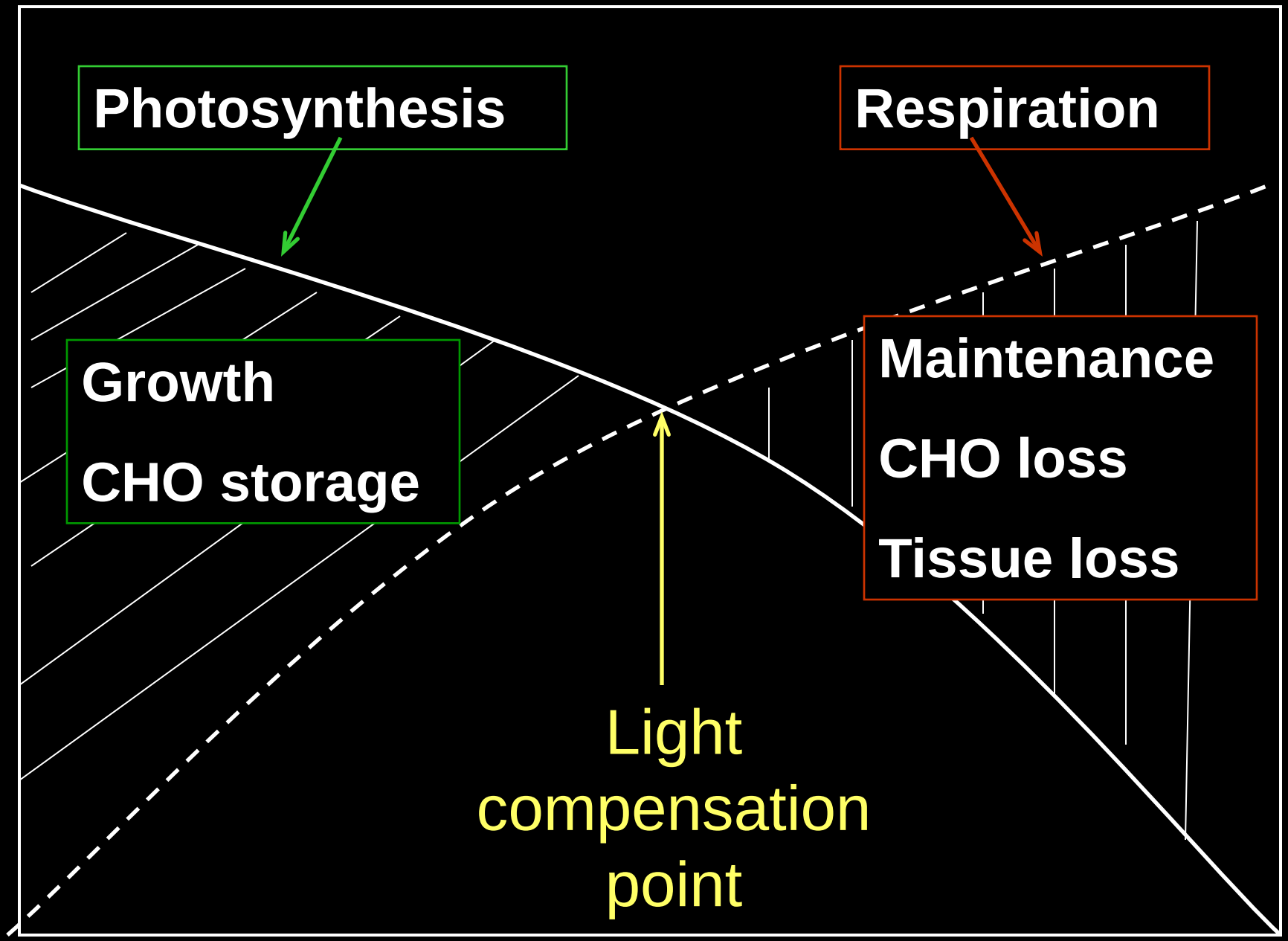


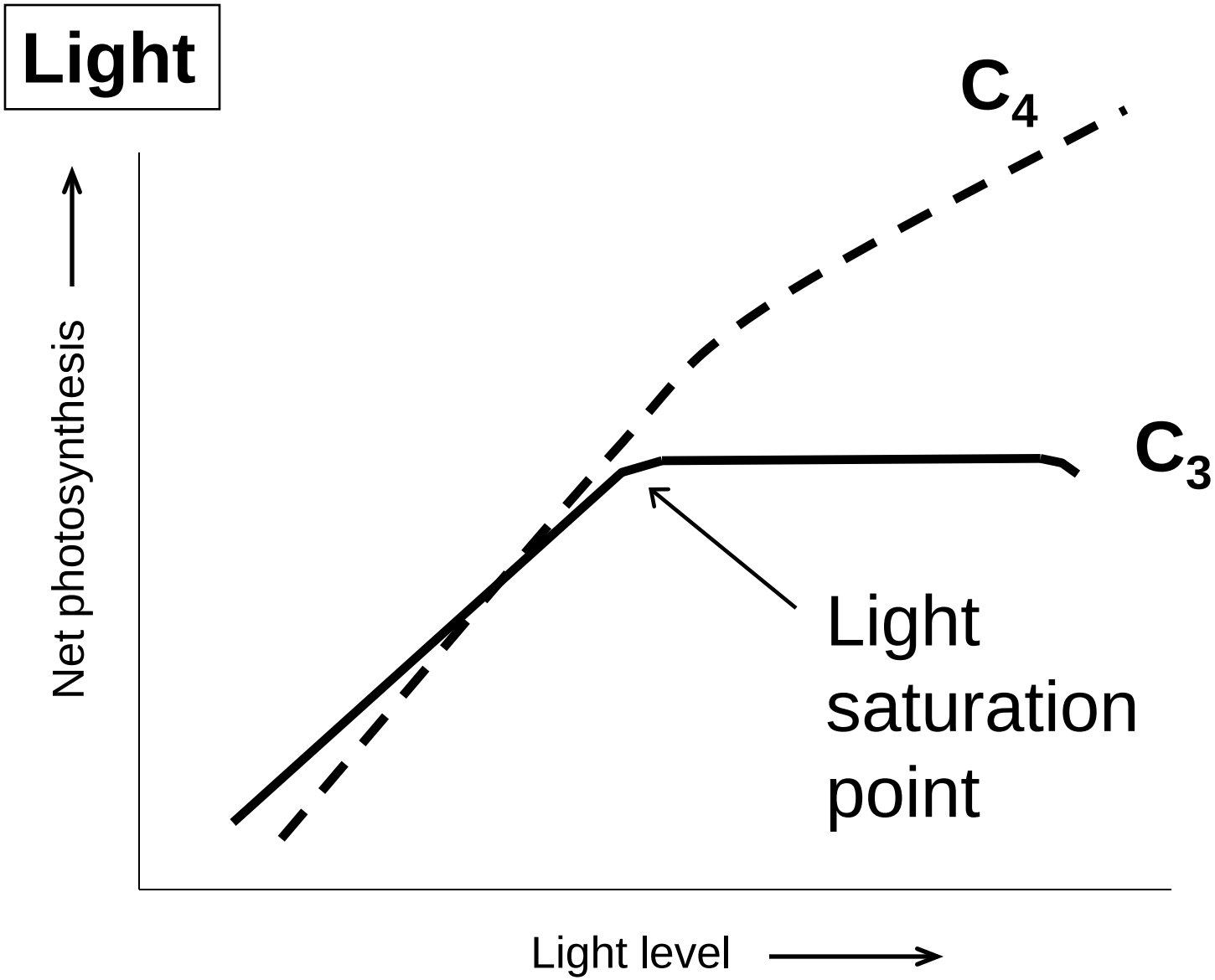
Adapted from Fry & Huang, 2004

Factors Affecting PHS

- **Light**
- **Temperature**
- **Water**
- **Nutrient Availability**
- **Leaf Characteristics**

Light

- Light Saturation Point – level at which PHS reaches maximum
- Light Compensation Point – level at which PHS and RESP reach equilibrium
  - zero net carbon gain
  - no plant growth will occur
- Both LSP and LCP are higher in C_4 than in C_3



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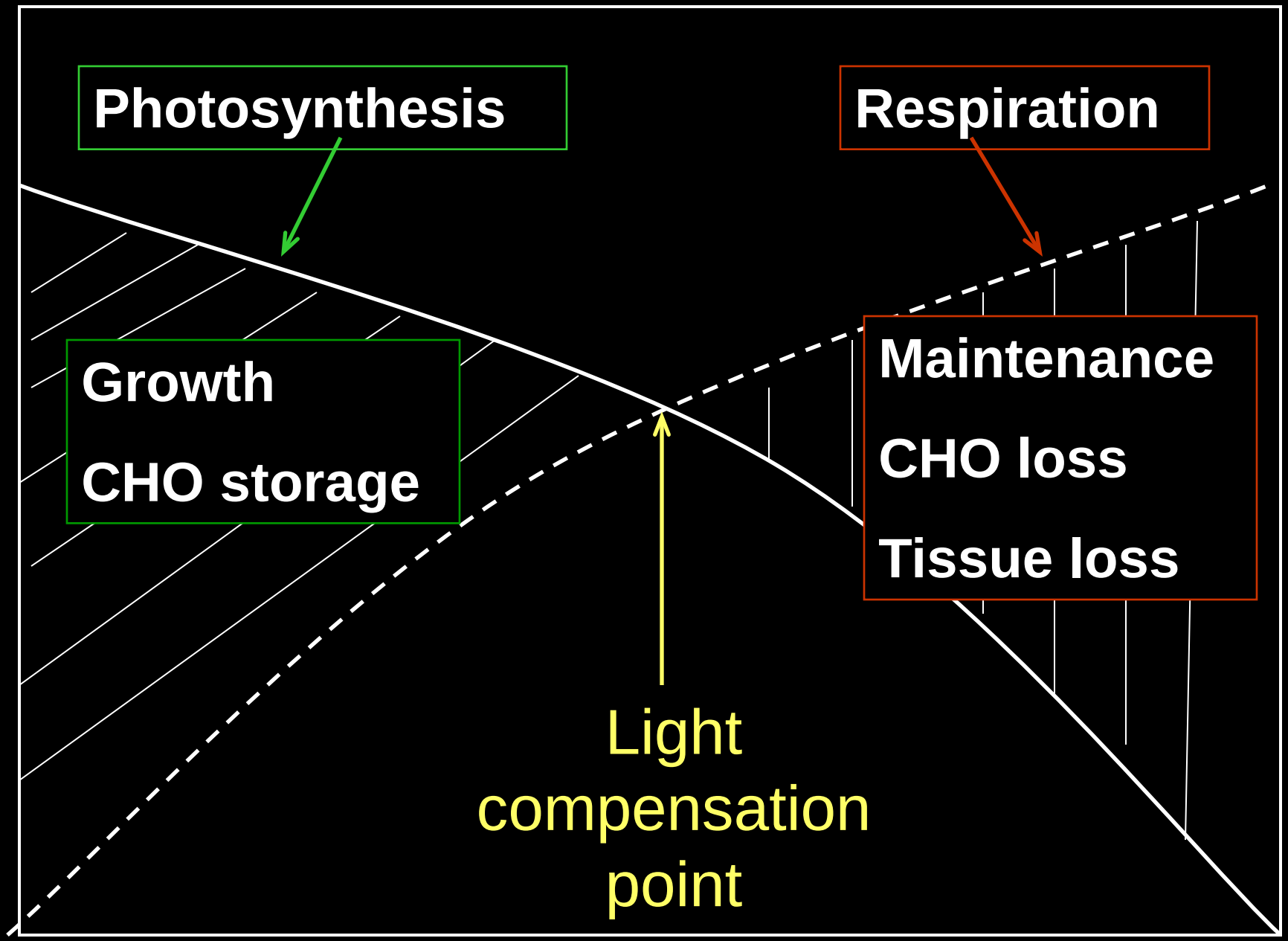
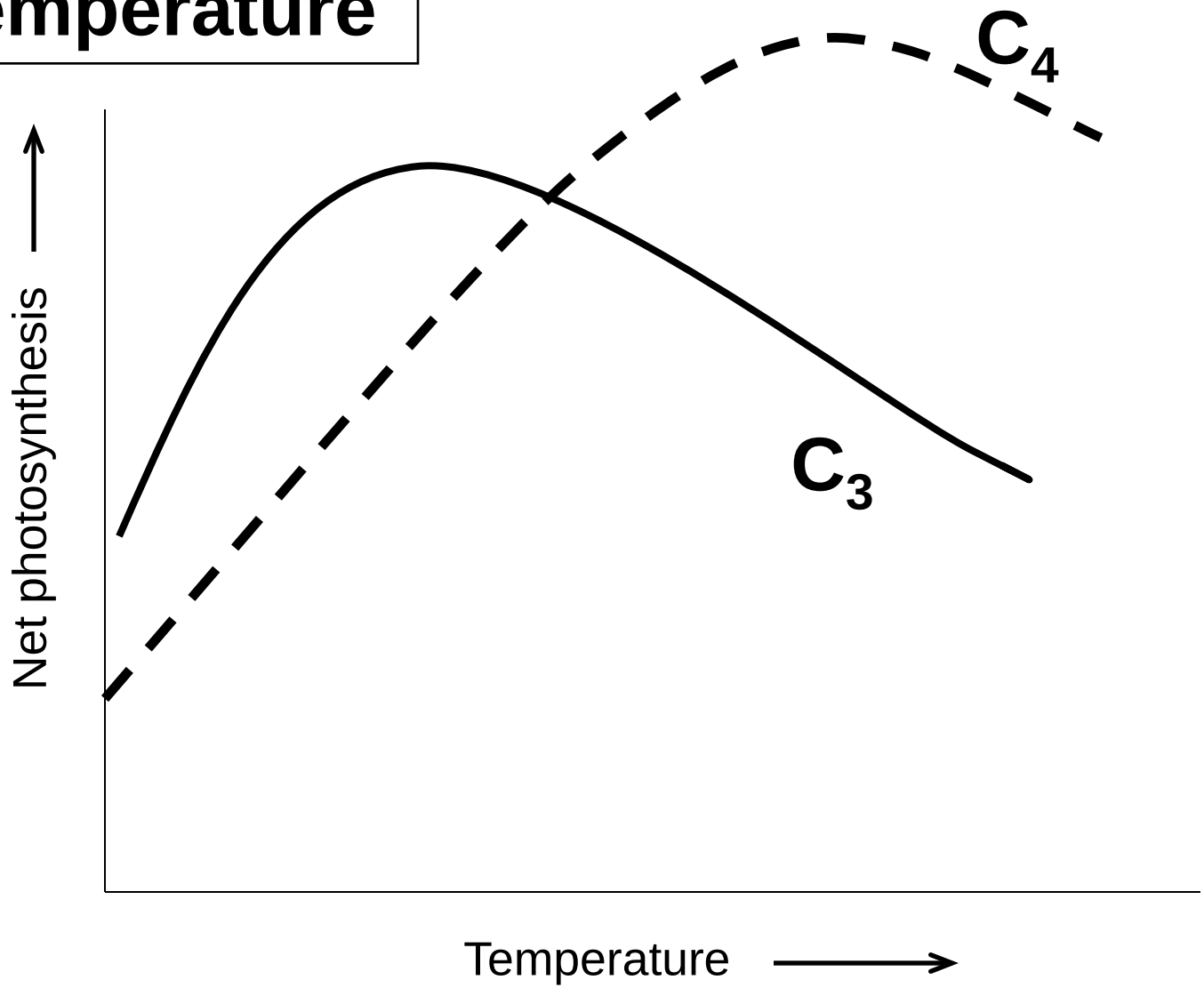

Photosynthesis
Respiration
Growth
CHO storage
Maintenance
CHO loss
Tissue loss
Light compensation point

Photorespiration

- In C_3 grasses, seldom in C_4
  - O_2 is consumed
  - CO_2 is released
- Can result in a net reduction in photosynthesis especially during high temperatures

Temperature



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Temperature

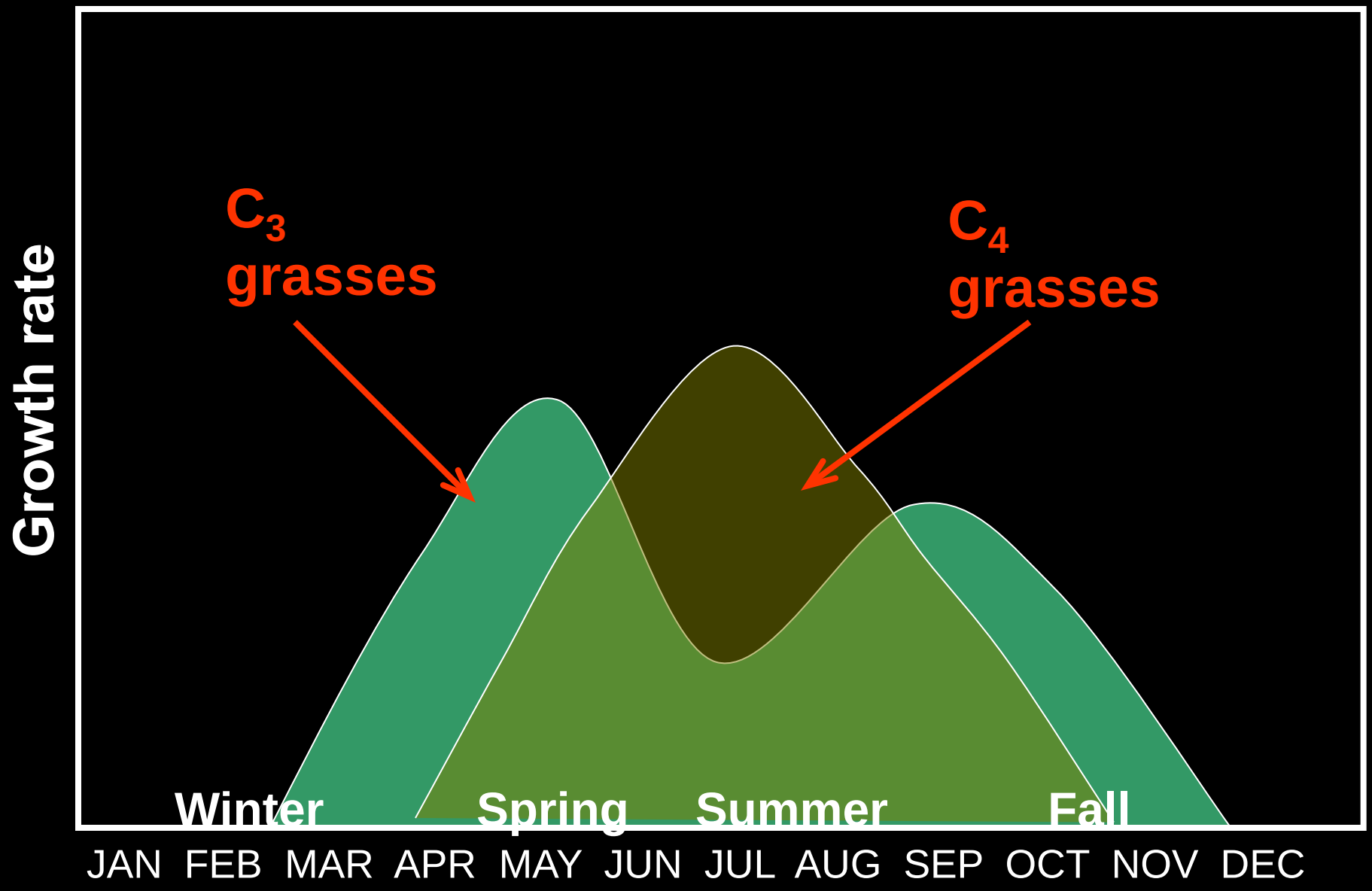
Optimum temperature for photosynthesis

C_3: 68-77°F (20-25°C)

C_4: 86-95°F (30-35°C)

When exposed to full sunlight and high temperatures C_4 grasses can produce 2X the dry matter that C_3 can produce

Seasonal growth patterns: C_3 and C_4 Grasses



Adapted from J.S. Ebdon

Some other C_4 plants……..

crabgrass

yellow nutsedge

nimblewill

Water

- Necessary for PHS
- Affects open/close of stomates
  - too little or too much can lead to stomatal closure (reduced CO_2)
- Water deficit → synthesis of abscisic acid in roots → stomatal closure
- C_4 grasses are more efficient at water use

Leaf Characteristics

- Greater leaf area = more PHS
- As leaf angle increases, canopy shade increases and PHS is reduced
- Pubescent leaves reflect more light and are less efficient at PHS

Role of Nutrients in PHS

Nutrient(s)	Role
N & Mg	Essential parts of chlorophyll
Fe	Activates enzymes involved in chlorophyll production
S	Involved in electron transport in PHS (chemical movement of energy)

Role of Nutrients in PHS

Nutrient(s)	Role
Fe, S, Mn, and CU	Parts of several proteins involved in PHS
Cl	Needed for evolution of O_2 through PHS
K	Promotes maintenance of cell turgor and stomatal opening
Lack of adequate nutrition can result in stomatal closure, leading to reduced PHS	

Factors Affecting Respiration

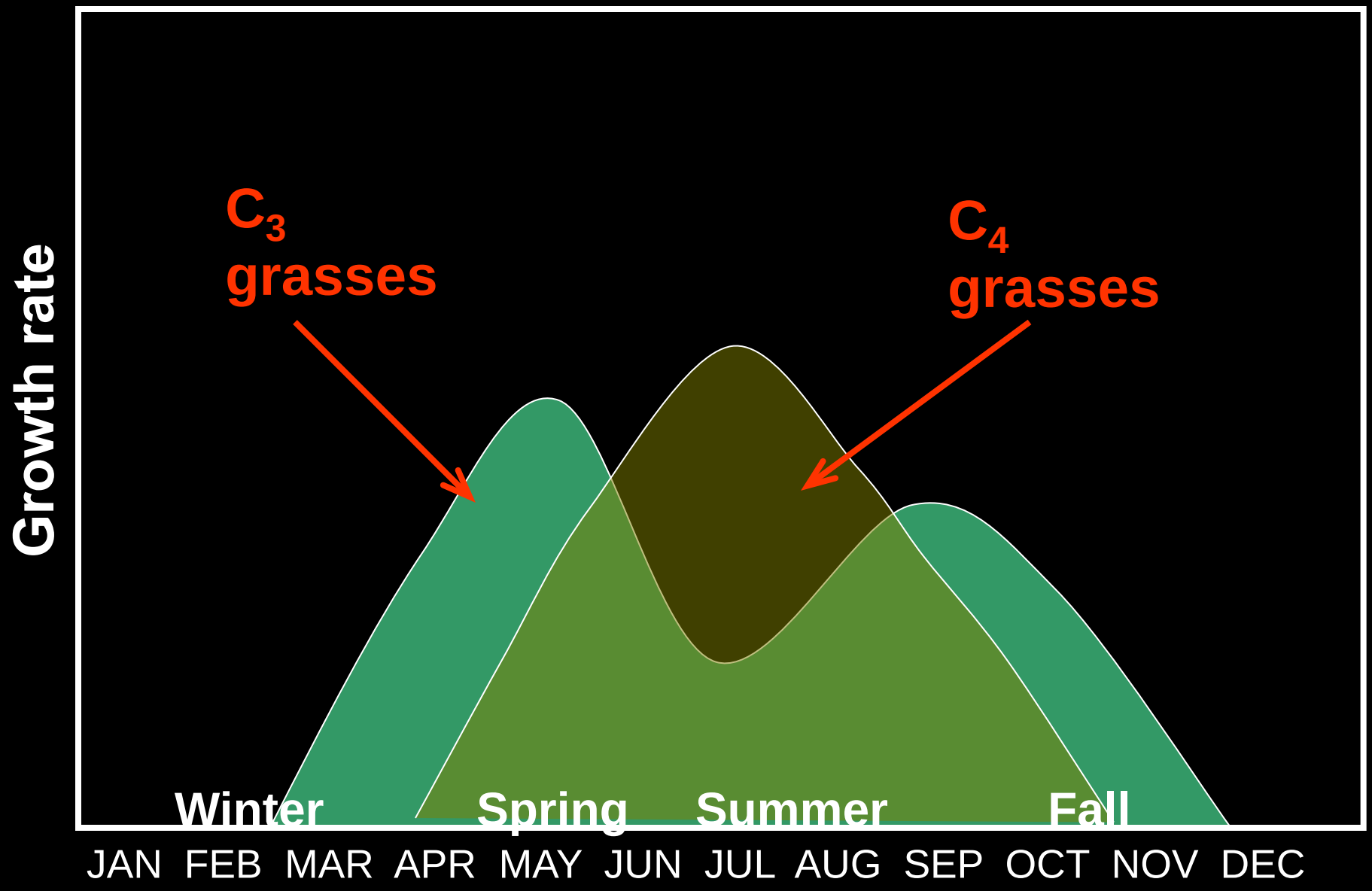
- CHO availability
- O_2 availability
- Temperature
- Water
- Nutrient availability
- Plant physiological condition and age

Not all turf areas can fix CO_2 effectively

All that’s green does not photosynthesize

Carbohydrates in turfgrasses

Seasonal growth patterns: C_3 and C_4 Grasses



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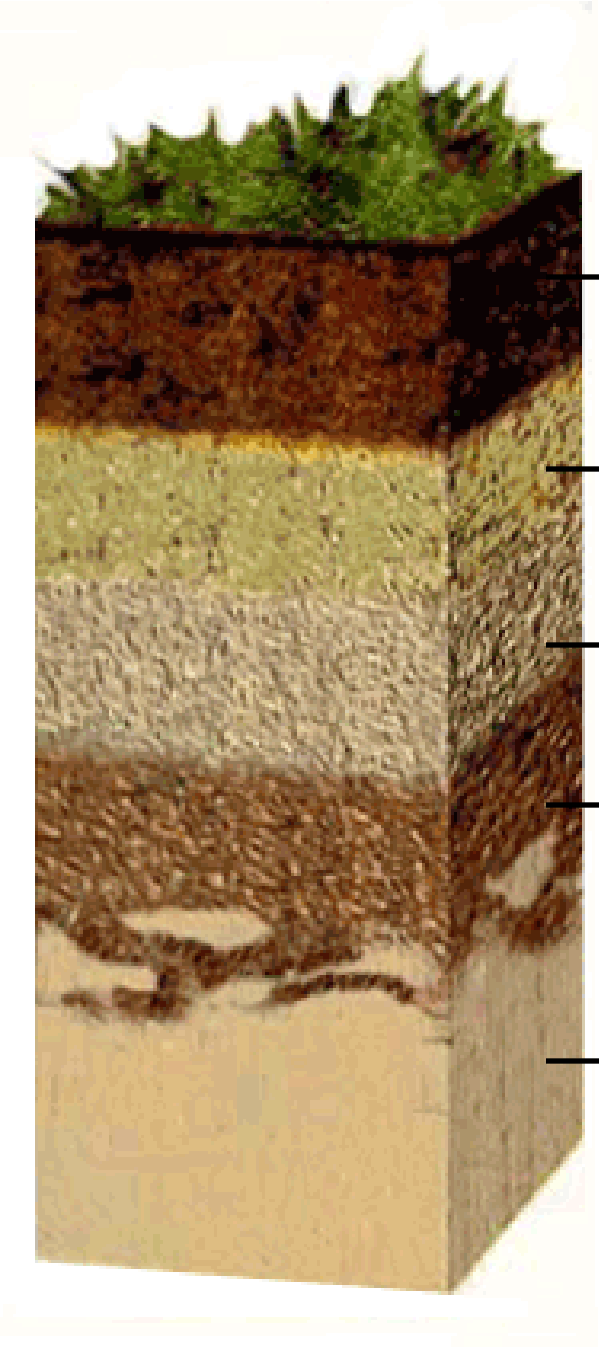
- Carbon stored in plant tissue eventually ends up in the soil as soil organic carbon (SOC) in the soil organic matter (SOM).



Soil profile with horizons

O organic residue

A topsoil

B subsoil

C substratum

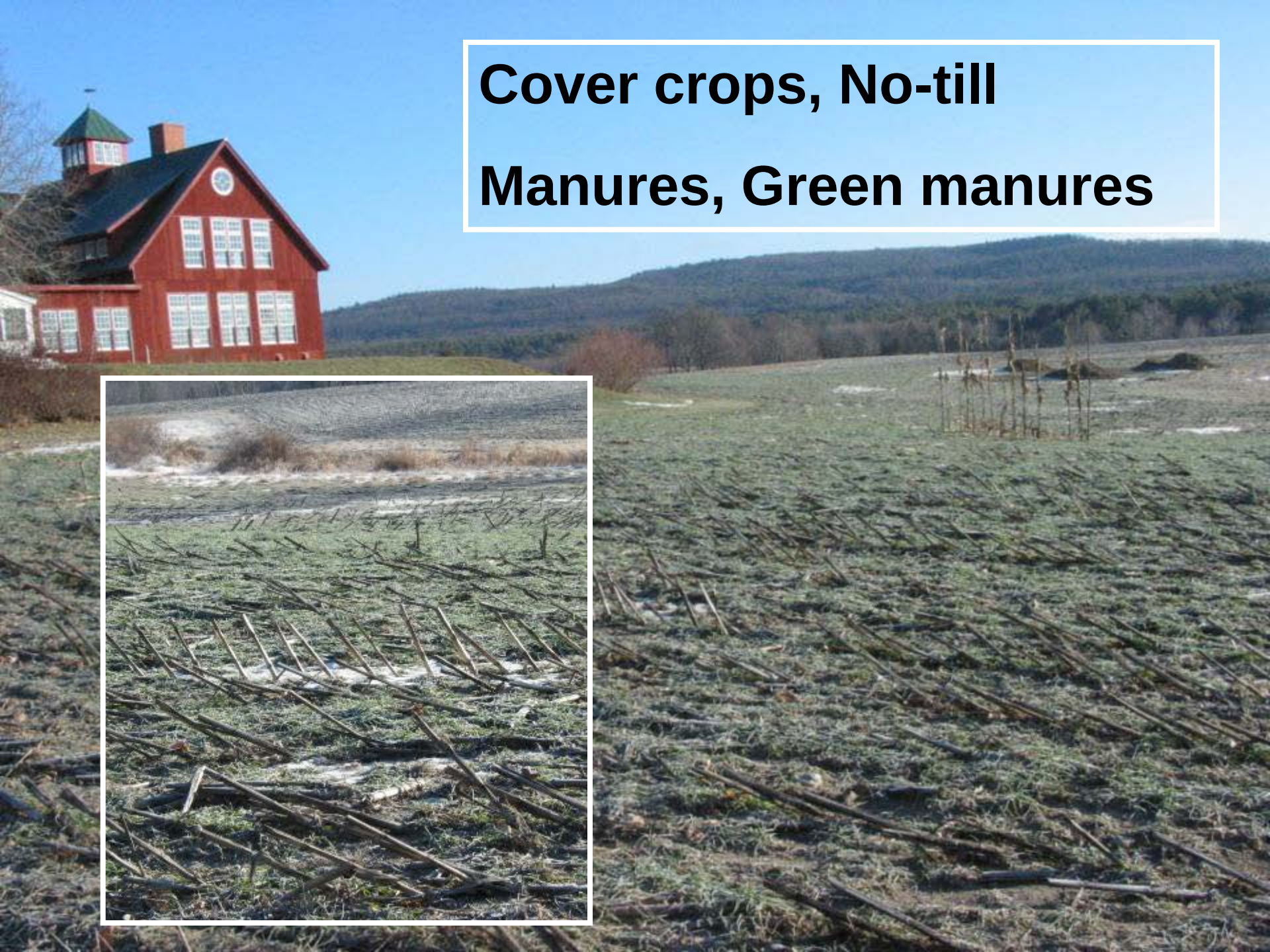
D bedrock (if present)

Humates are a form of sequestered C

photo courtesy Mesa Verde Resources

Soil organic matter can be depleted by:

- extensive cultivation
  - introduction of high levels of O_2 and increase in microorganism activity
- high N fertilizer use



Cover crops, No-till

Manures, Green manures

Turf is a perennial crop…..

…highly trafficked turf poses a challenge

CO_2 and Turf studies:

- Kent et al., 2007. Carbon sequestration in urban turf soils. Agron. Soc. Intern'l Annual Mtg Abst.
- Lopez-Bellido, Lal, Danneberger and Street, 2010. Plant growth regulator and nitrogen fertilizer effects on soil organic carbon sequestration in creeping bentgrass fairway turf. Plant Soil.
- Milesi et al., 2005. Mapping and modeling the biogeochemical cycling of turf grasses in the United States. Env. Mgt.
- Qian et al., 2003. Long term effects of clipping and nitrogen management in turfgrass on soil organic carbon and nitrogen dynamics: the CENTURY model simulation. Journal of Environmental Quality.

CO_2 and Turf studies:

- Qian & Follett, 2002. Assessing soil carbon sequestration in turfgrass systems using long-term soil testing data. Agronomy Journal.
- Qian & Follett, 2008. Soil organic carbon input from turfgrasses. Agronomy Society of America abstract.
- Qian, Follett and Kimble, 2010. Soil organic carbon input from urban turfgrasses. Soil Science Society of America.
- Townsend-Small and Czimczik, 2010. Carbon sequestration and greenhouse gas emissions in urban turf. *and* Corrections to "Carbon sequestration and greenhouse gas emissions in urban turf." Geophysical Research Letters.

Turf and CO_2 studies summary

- Soil organic matter accumulates from root, shoot and litter turnover, especially as turf matures
- Total C sequestered continues to increase as turf matures
- Different grasses may vary in the amount of C they sequester

Turf and CO_2 studies summary

- Well watered, well fertilized turf is a significant carbon sink
- Turf maintained under high and low fertility is a significant sink for both C and N when clippings are returned
- Nutrient needs of some types of turf (e.g. lawns, undisturbed parkland, etc) allowed to mature for a long period of time may have a reduced need for additional nutrient input.

Turf and CO_2 studies summary

- Low fertilization and clipping removal on young stands can result in rapid decline of biomass (SOC).
- Reducing N inputs and returning clippings as a turf stand ages can lead to minimal long term nutrient leaching potential
- Use of PGRs in combination with N fertility may increase C sequestration.

Management strategies to promote carbon sequestration

Select grasses and cultivars best suited to site and use, with emphasis on stress, traffic and pest tolerance.


Maintain turf cover.
Provide adequate and balanced nutrition.

Use excellent establishment practices.

Irrigate to ensure functional quality, with conservation as a priority.

Build roots

Be careful with build-up of organic matter in sand based systems.

Return clippings, either straight away or compost and use as topdressing.

Manage traffic

Consider energy and resource efficiency whenever possible.

- manufacture, transport and application of turf management materials
- water distribution
- equipment operation and maintenance

Consider converting peripheral lawns into *managed* meadows.


Thank you!