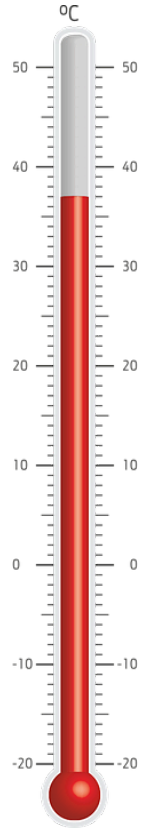
Plant responses to temperature over space and time

February 16, 2021

Class questions

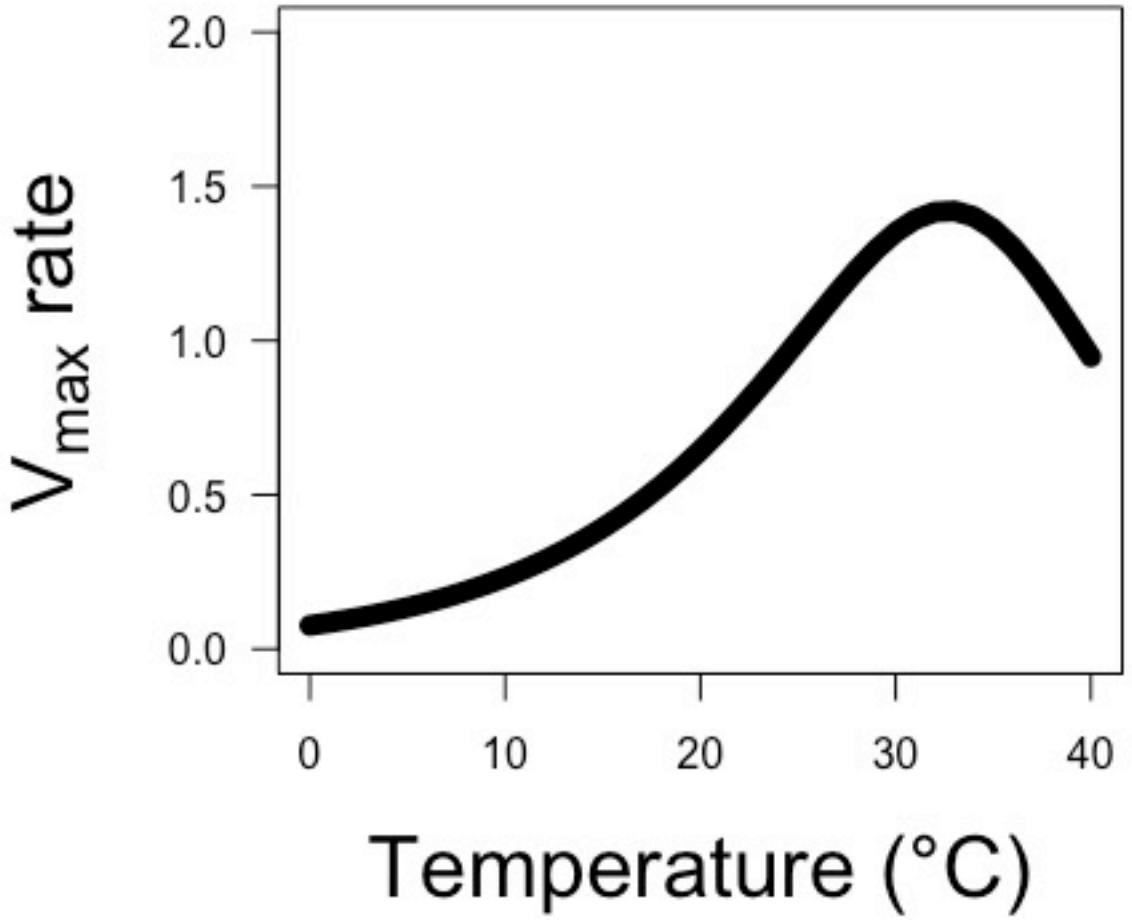
1. How does temperature vary over space and time?



Class questions

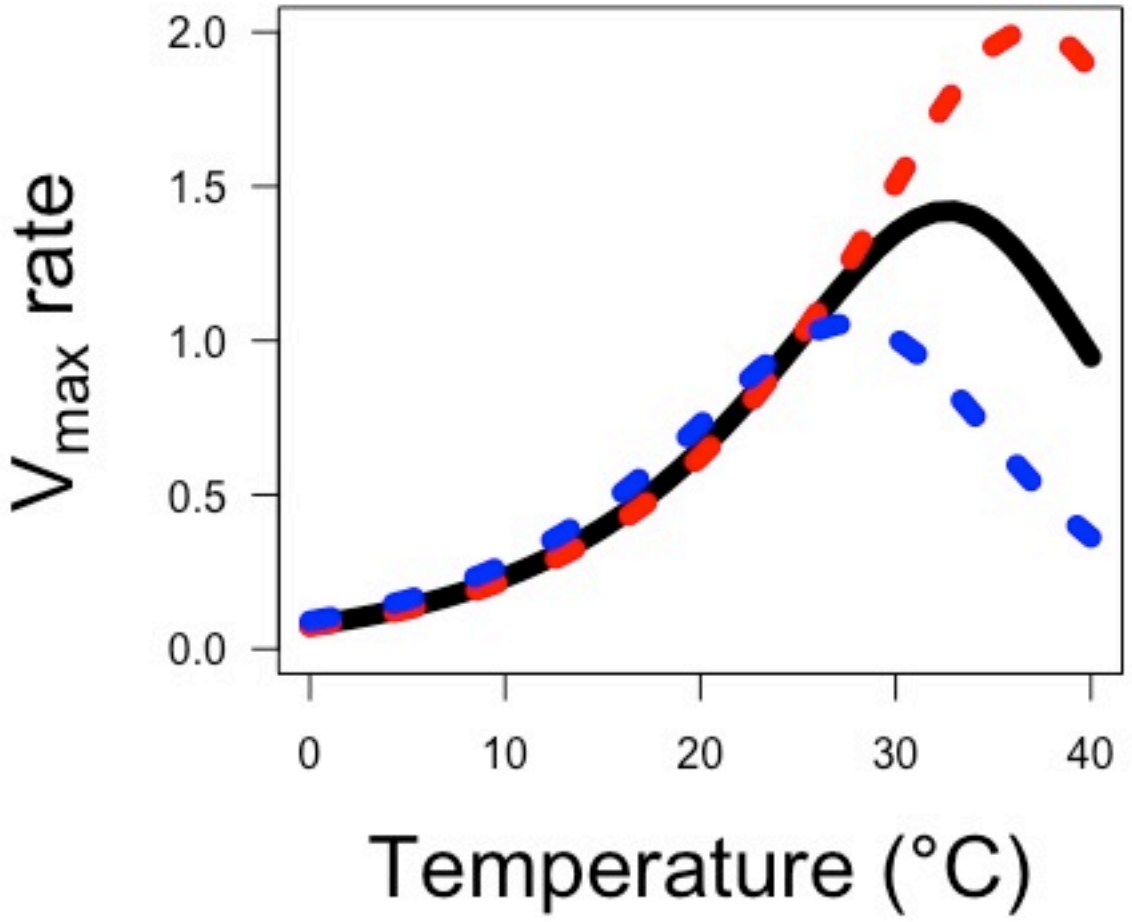
1. How does temperature change in natural environments?
2. Why does temperature variation matter for plants?

Processes that respond to temperature: Enzymatic potential



Enzyme rate (Vmax) is the result of both the activation rate and deactivation rate

Leads to a peaked exponential response

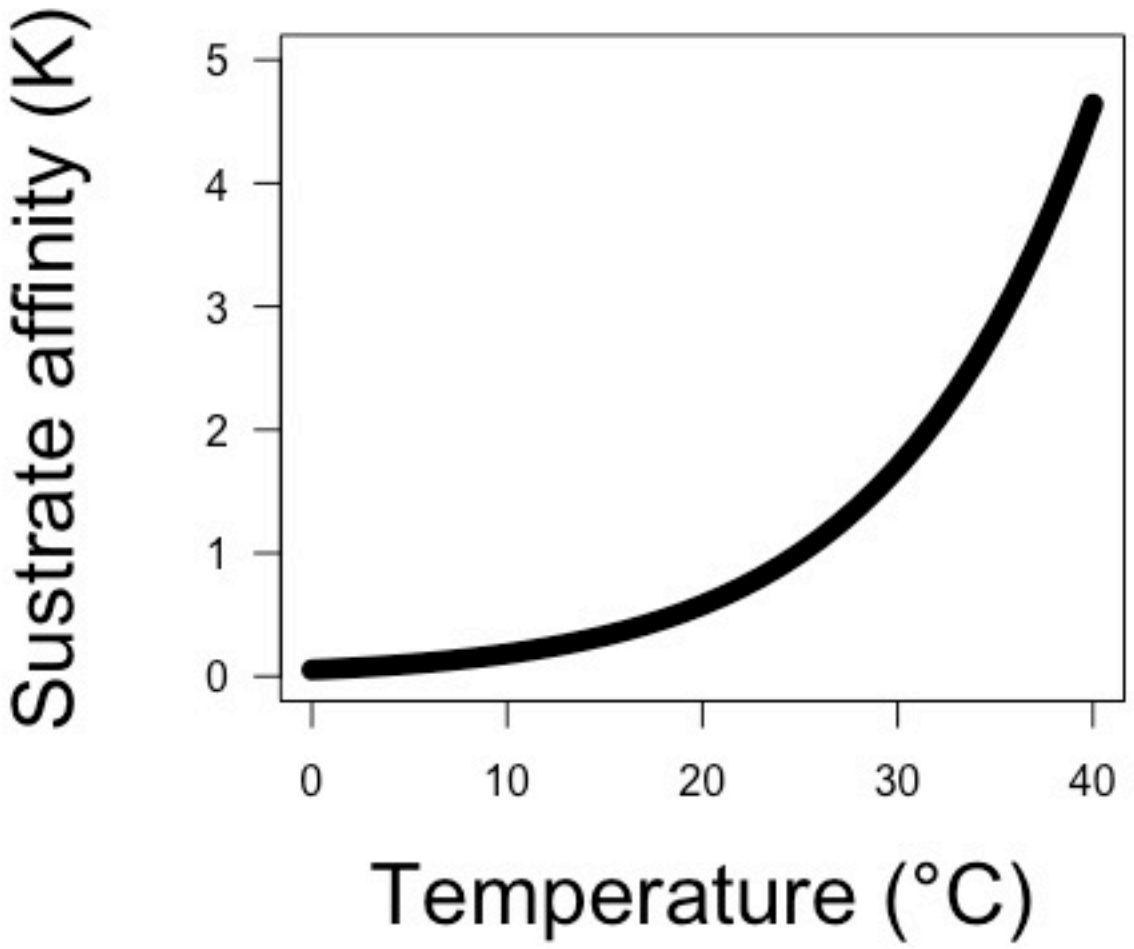


This peak may change based on acclimation

Red = warm acclimated

Blue = cold acclimated

Processes that respond to temperature: Substrate affinity

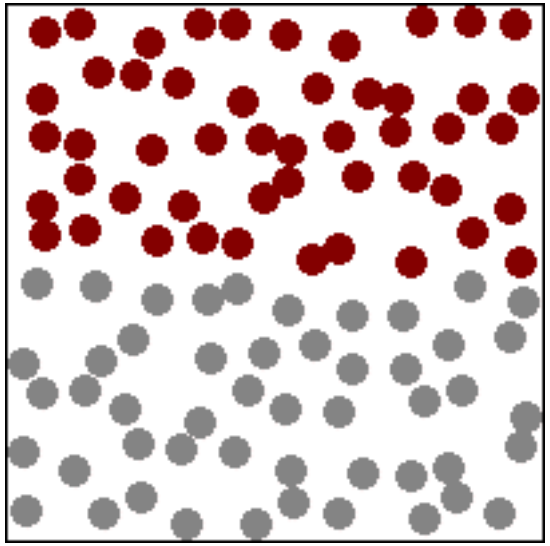


Substrate affinity increases with temperature

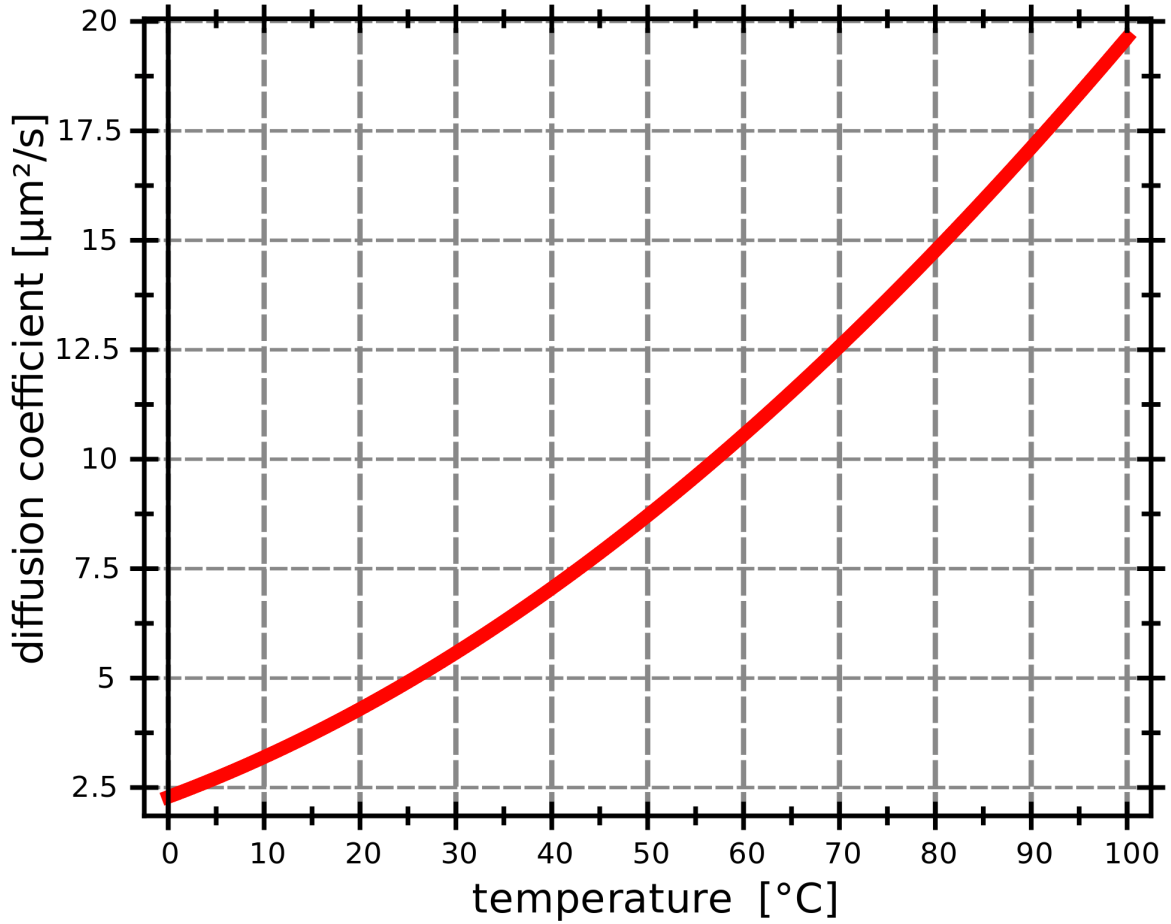
The change is dependent on the substrate and enzyme

Processes that respond to temperature: Diffusion

Diffusion: movement from area of low concentration to high concentration



Diffusion rates increase with temperature (Fick's law coefficient increases)



Class questions

1. How does temperature change in natural environments?
2. Why does temperature variation matter for plants?

Respiration and temperature

Respiration and temperature

1. Enzymatic rates increase with T
2. Substrate affinity increases with T

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What should the response look like?

Photosynthesis and temperature

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Photosynthesis and temperature

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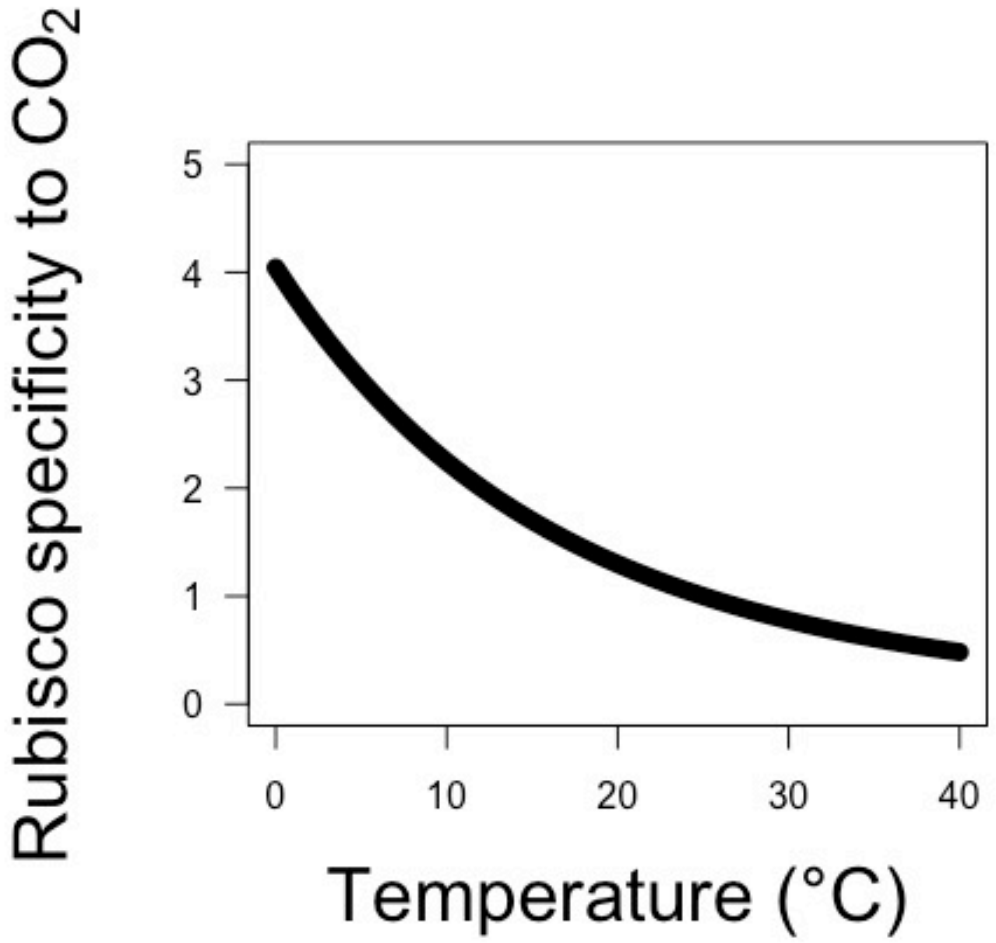
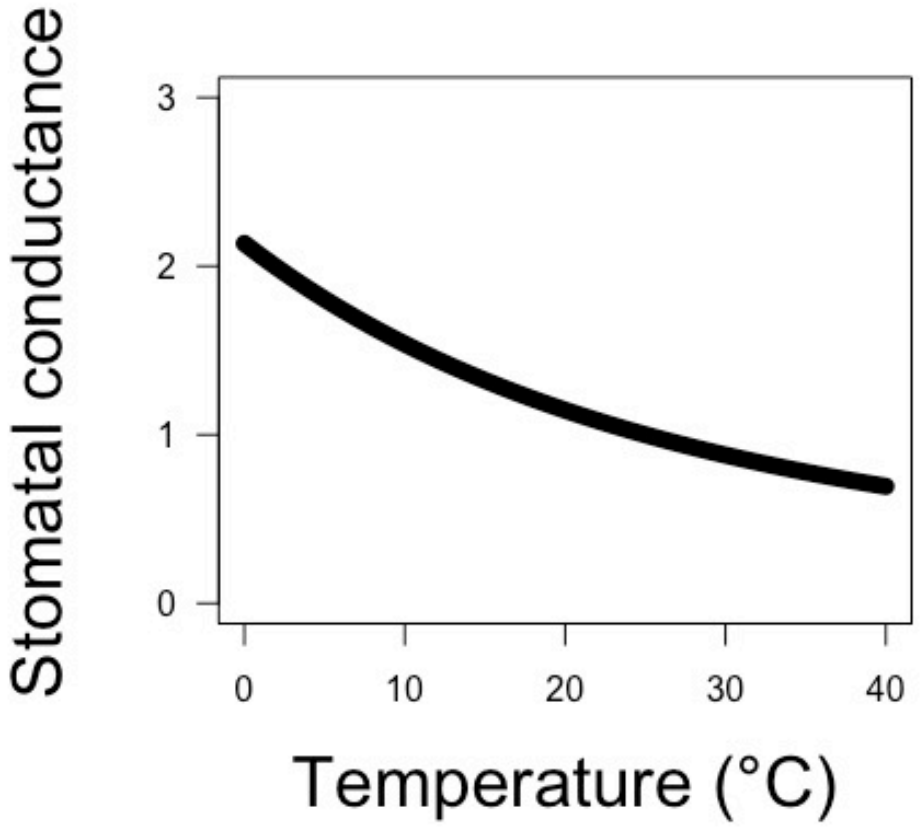
2. Substrate affinity increases with T
3. Rubisco likes O2 more at higher T!



Photosynthesis and temperature

1. Enzymatic rates increase with T
2. Substrate affinity increases with T
3. Rubisco likes O2 more at higher T!
4. Stomata close at higher T!



Photosynthesis and temperature

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What should the response look like?

Photosynthesis and temperature

1. Enzymatic rates increase with T
2. Substrate affinity increases with T
3. Rubisco likes O2 more at higher T!
4. Stomata close at higher T!

Would this differ for C4 species?

Transpiration and temperature

Transpiration and temperature

1. Diffusion rates increase with T

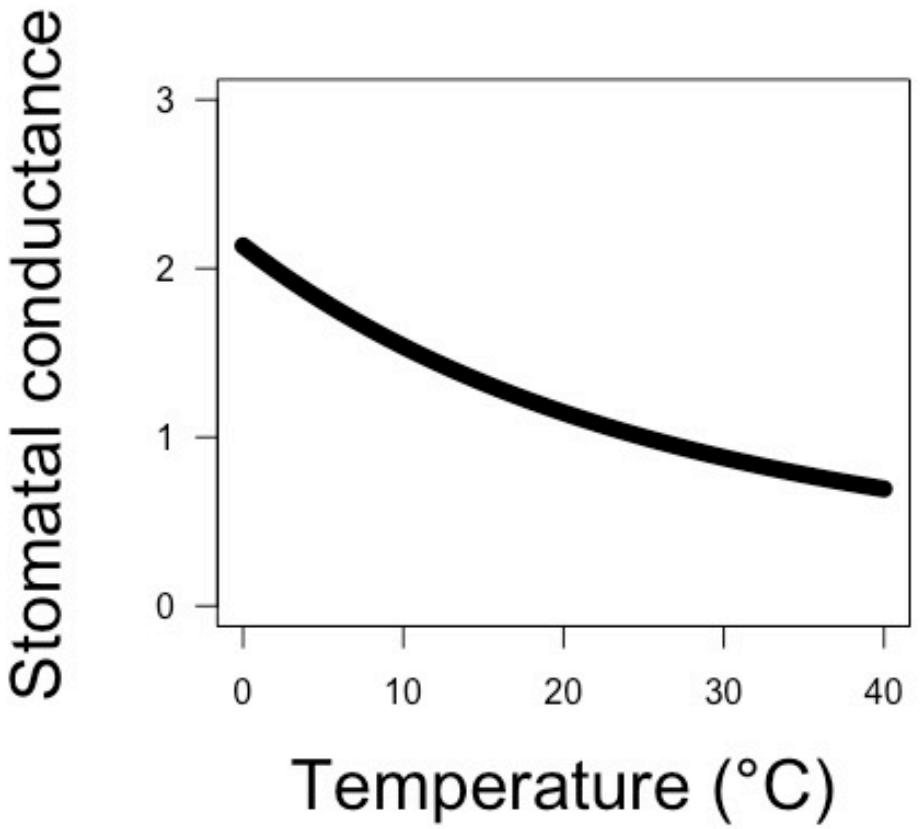
Transpiration and temperature

1. Diffusion rates increase with T

What should the response look like?

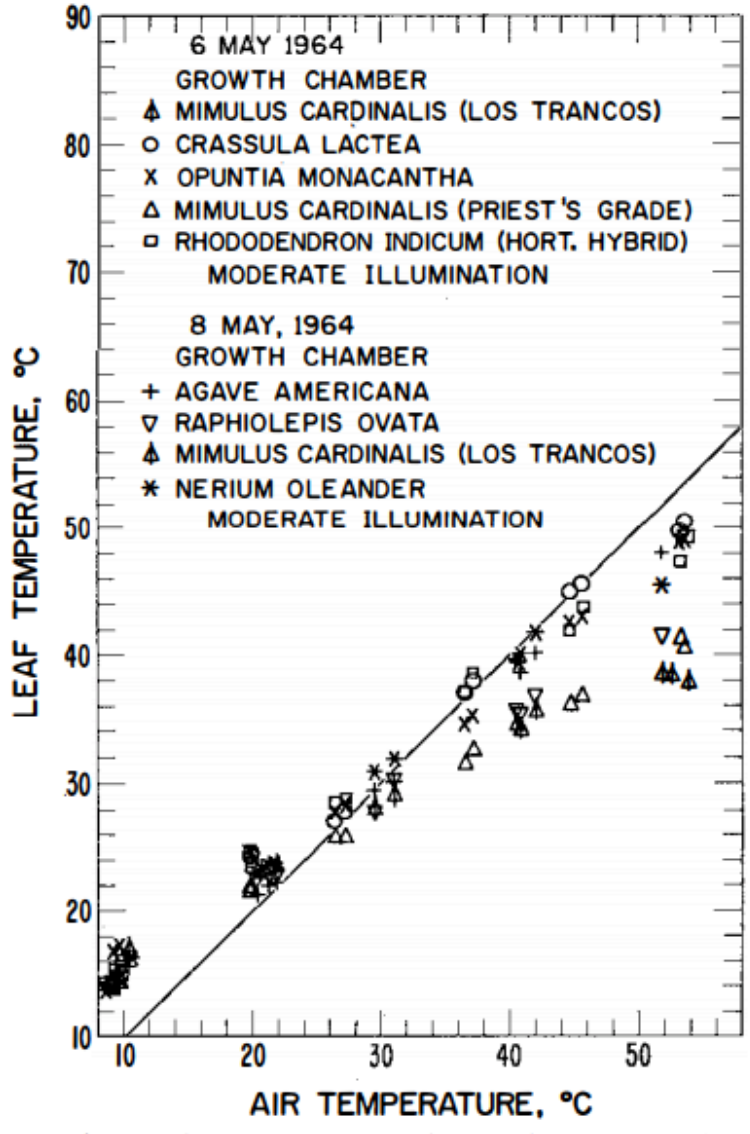
Transpiration and temperature

1. Diffusion rates increase with T
2. Stomata close with increased T!



Transpiration and temperature

1. Diffusion rates increase with T
2. Stomata close with increased T!
3. Leaves cool with increased T!



Gates (1968)

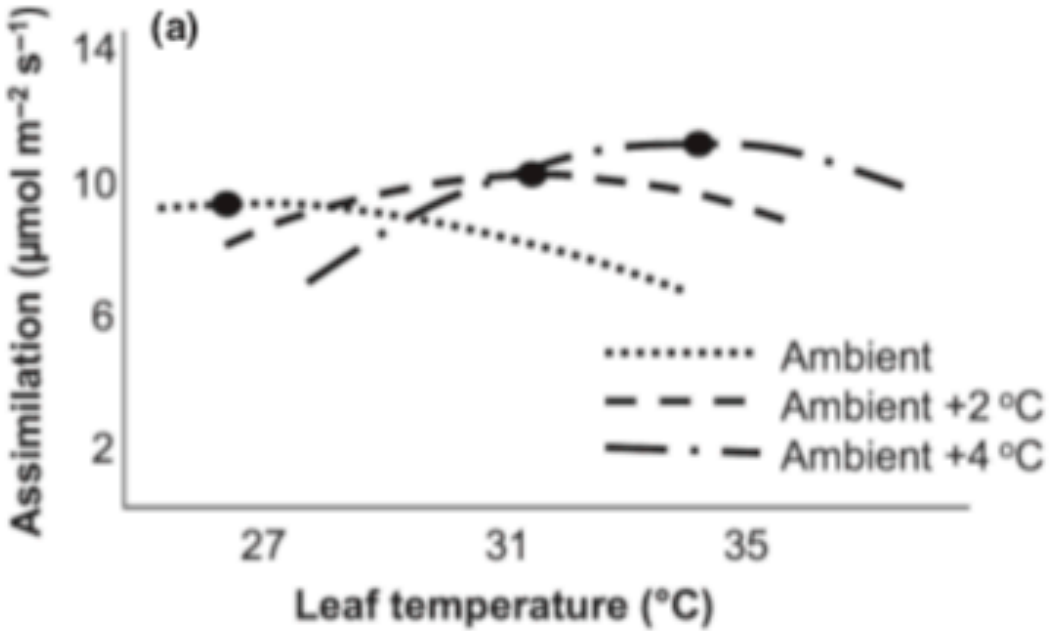
Transpiration and temperature

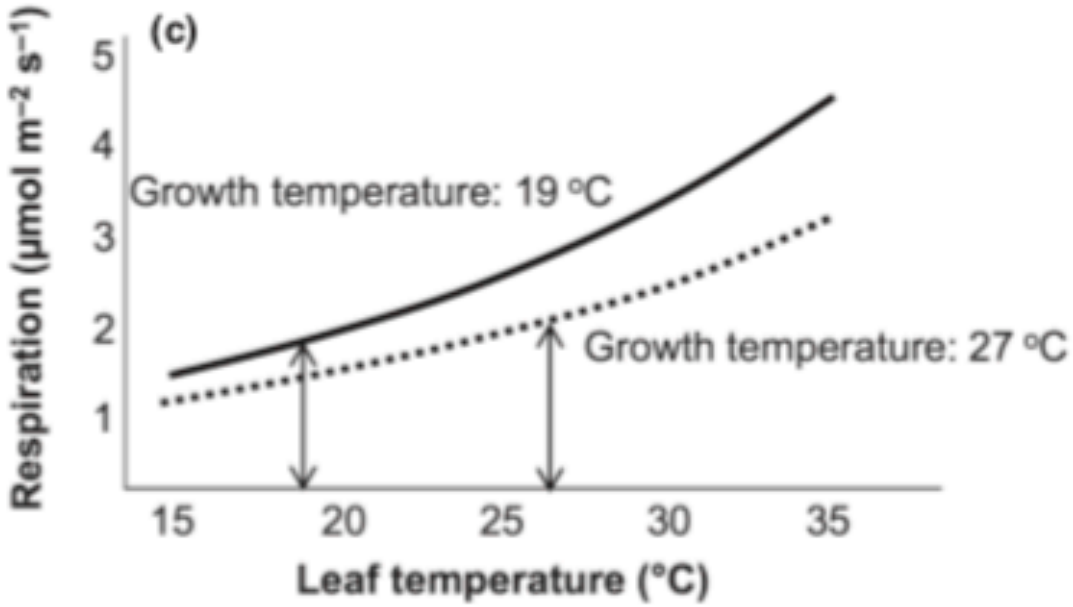
1. Diffusion rates increase with T
2. Stomata close with increased T!
3. Leaves cool with increased T!

What should the response look like?

But now what about acclimation!

Acclimation leads to a roughly homeostatic response!





Gunderson et al. (2010)

Silim et al. (2010)

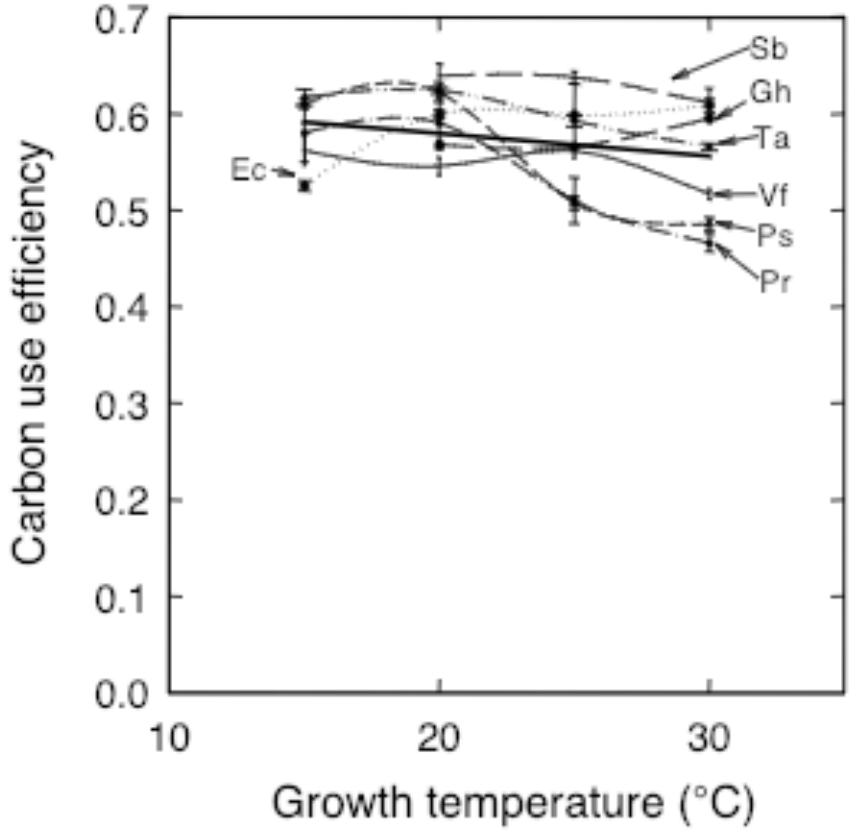


Fig. 3. The carbon use efficiency of whole plants (including roots in inert potting medium) for a range of plant species grown continuously at various temperatures between 15 and 30°C. Ec, *Eucalyptus camaldulensis*; Pr, *Pinus radiata*; Ps, *Pisum sativum*; Vf, *Vicia faba*; Ta, *Triticum aestivum*; Gh, *Gosypium hirsutum*; Sb, *Sorghum bicolour*. Data are derived from Gifford *et al.* (1996*b*) and Gifford (1992). Error bars are standard errors of the mean. The bold straight line is the linear regression through all the data.

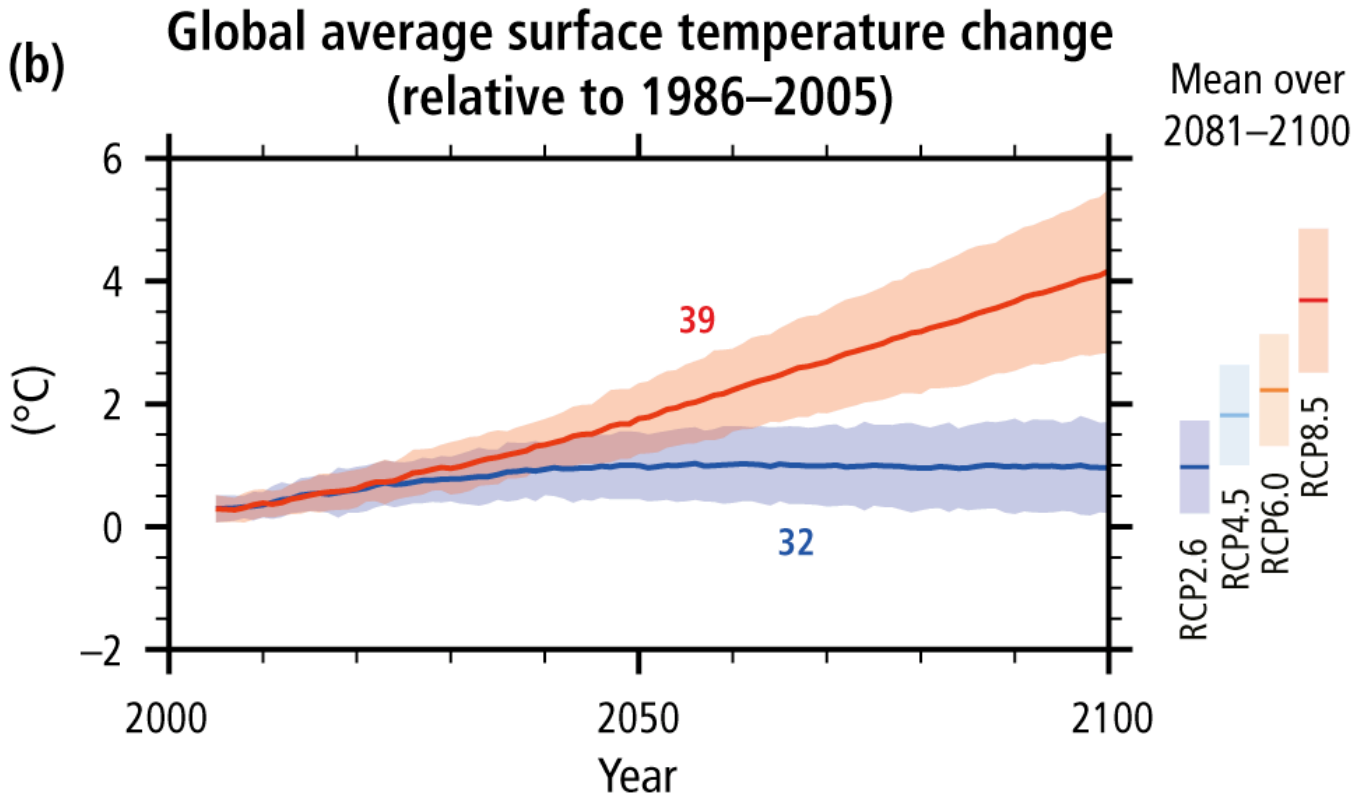
CUE = photosynthesis / respiration

Gifford (2003)

Class questions

1. How does temperature change in natural environments?
2. Why does temperature variation matter for plants?
3. Does any of this even matter?

Will a 3-5°C increase in temperature matter? Why or why not?



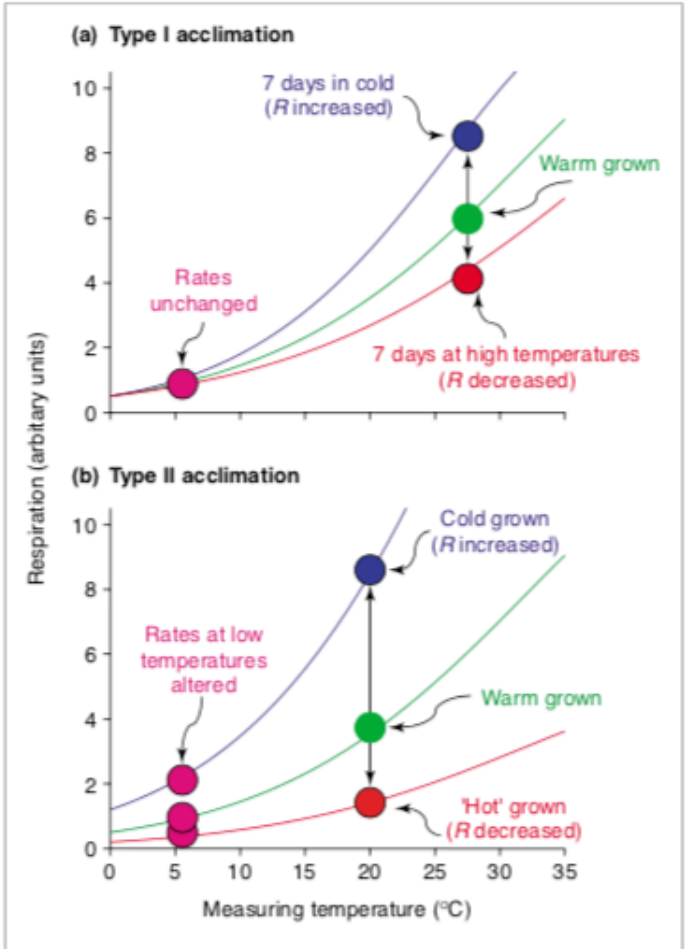
IPCC (2013)

Thermal acclimation and the dynamic response of plant respiration to temperature

Atkin and Tjoelker (2003). Trends in Plant Science

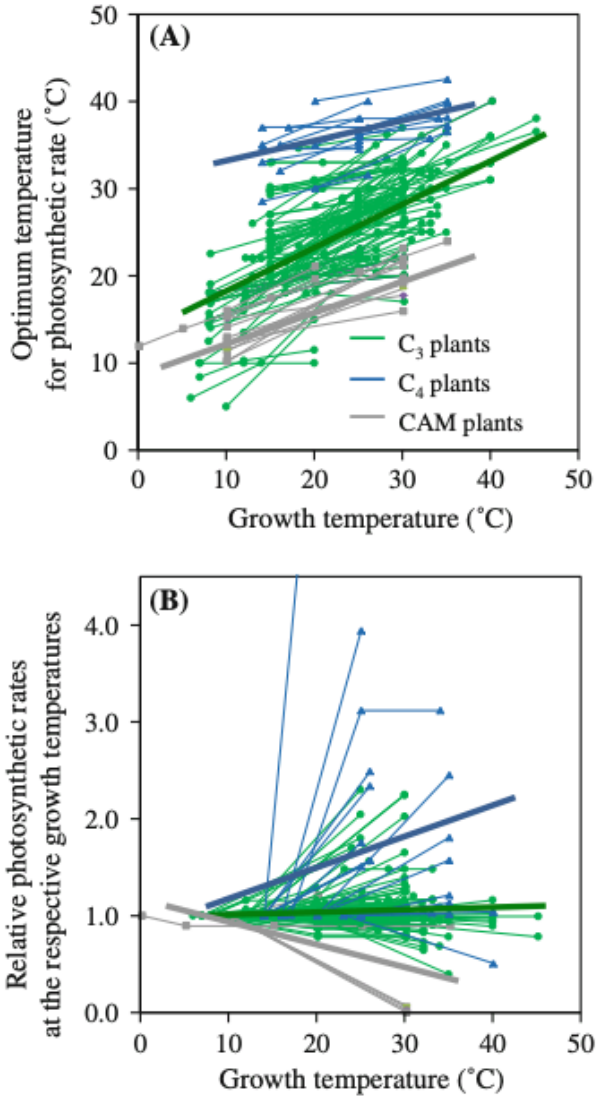
Let’s talk about acclimation

Seems pretty cut and dry!



Atkin & Tjoelker (2003)

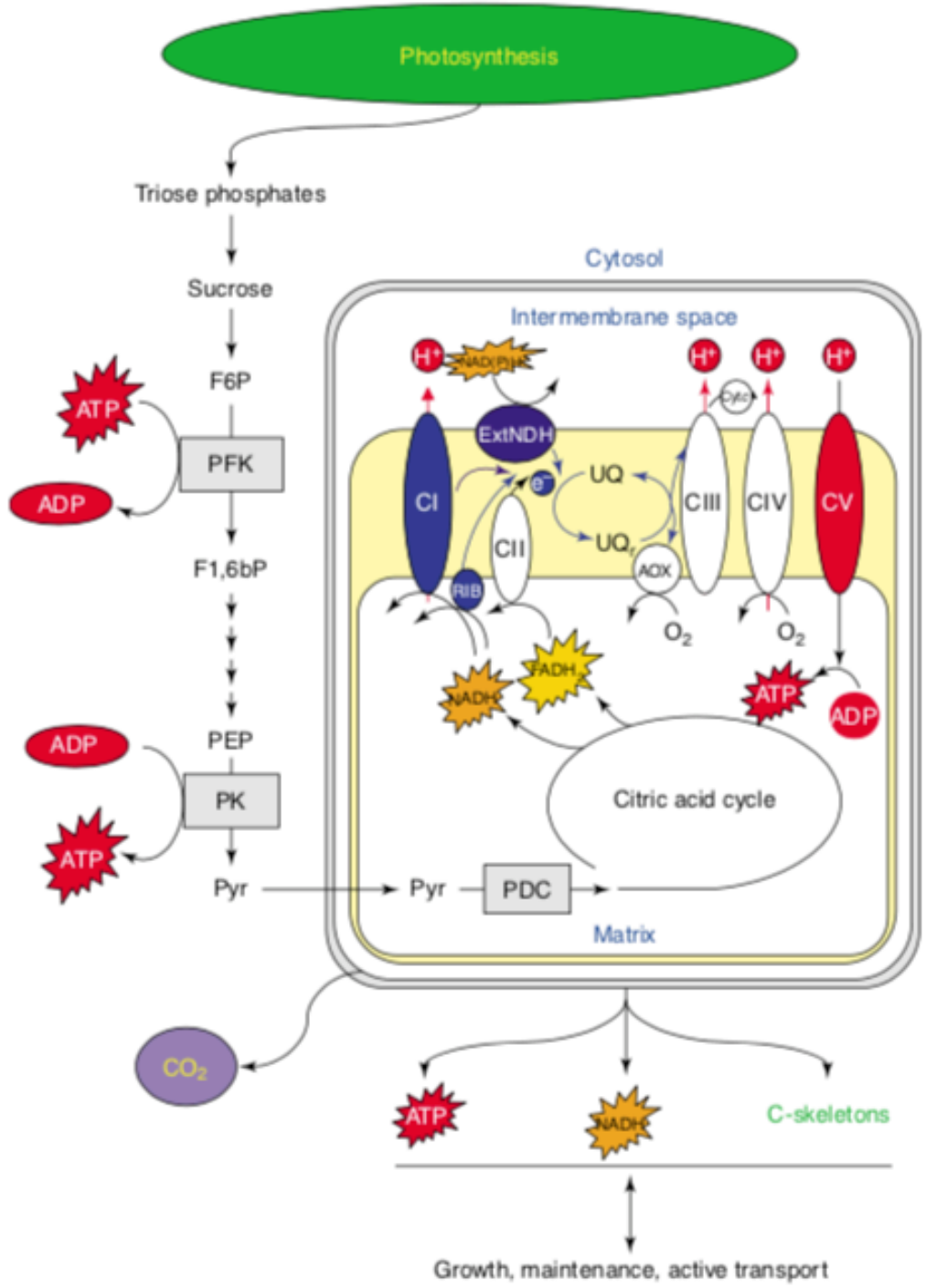
It turns out acclimation can be quite variable

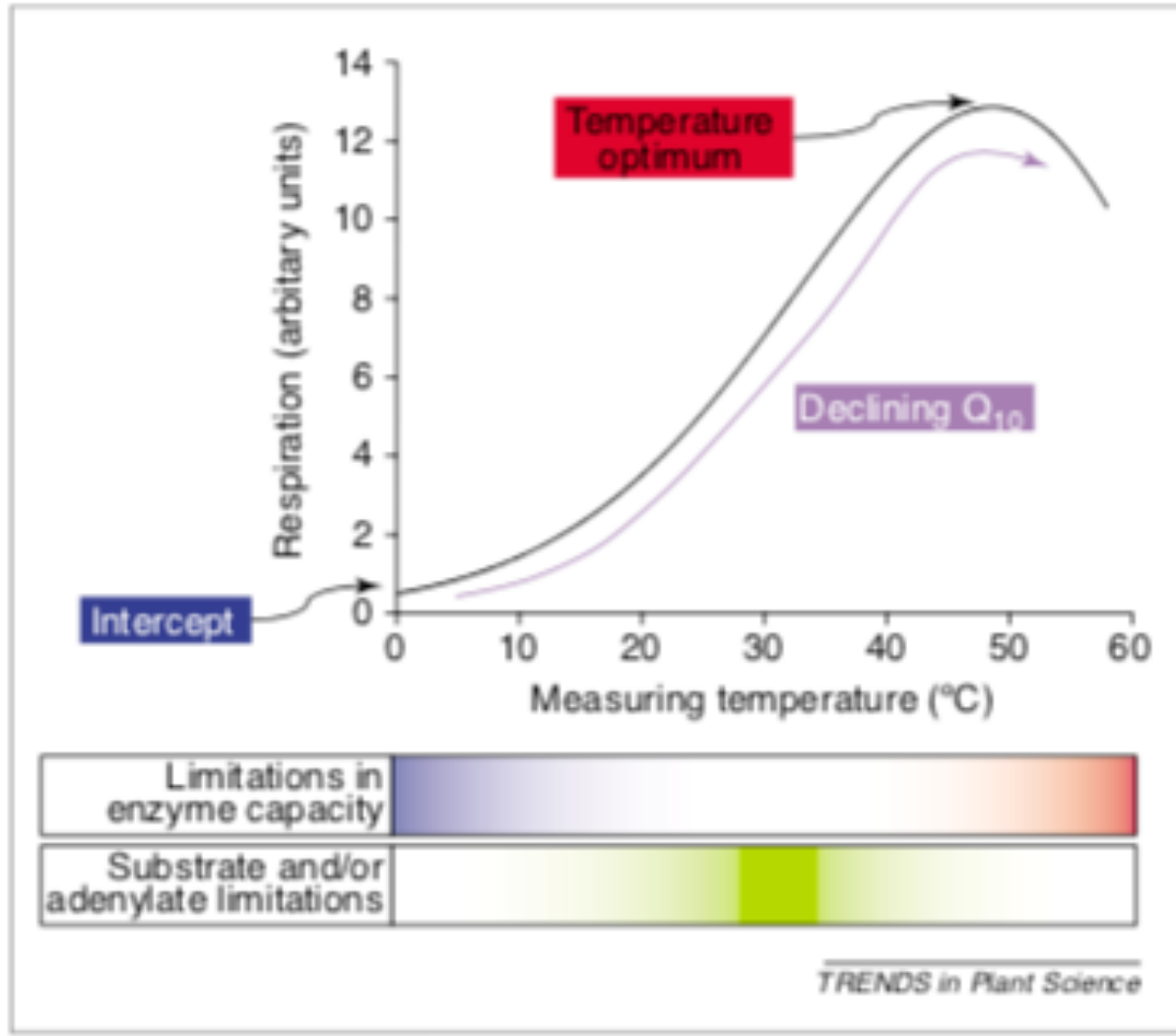


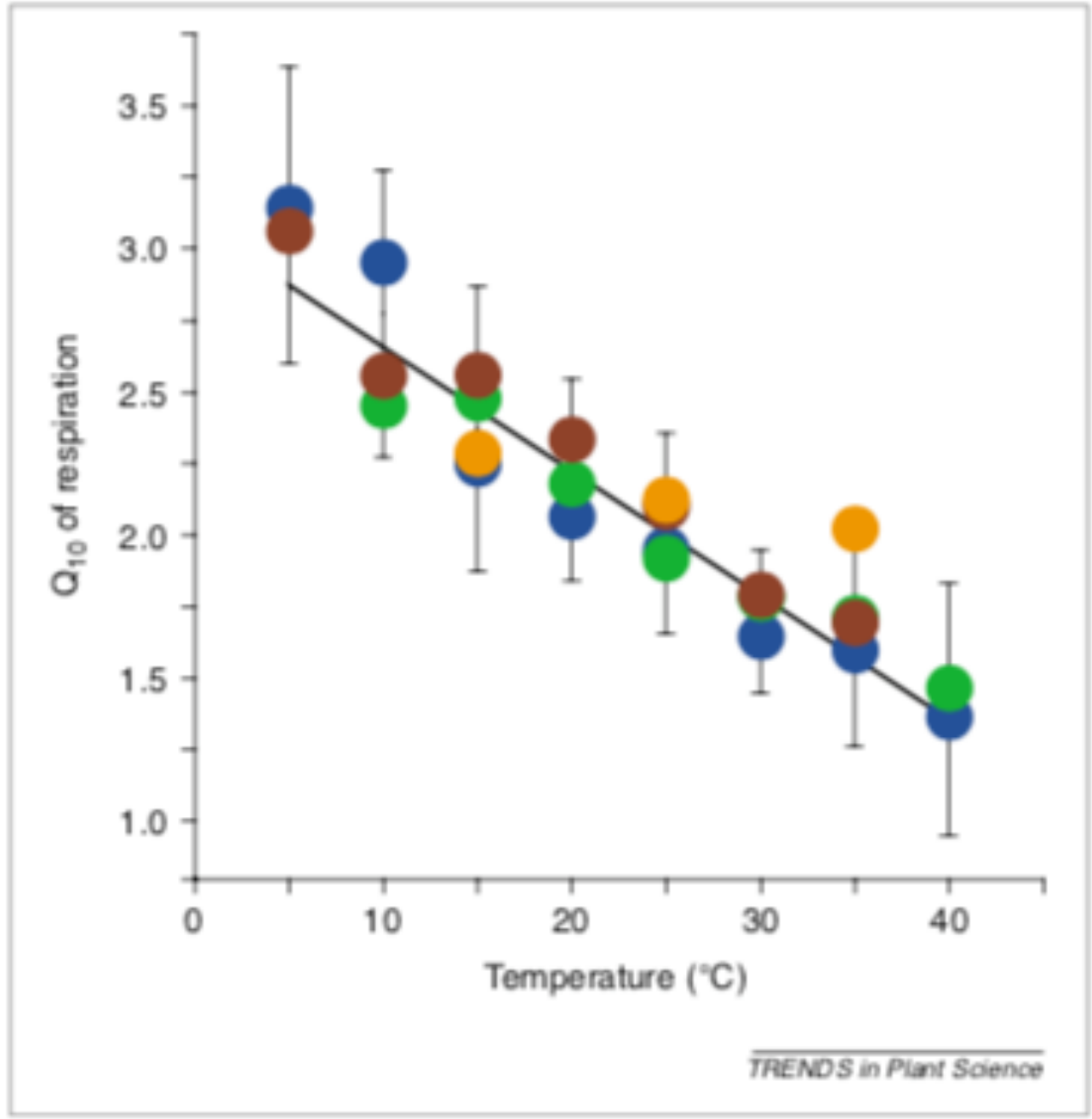
Yamori et al. (2014)

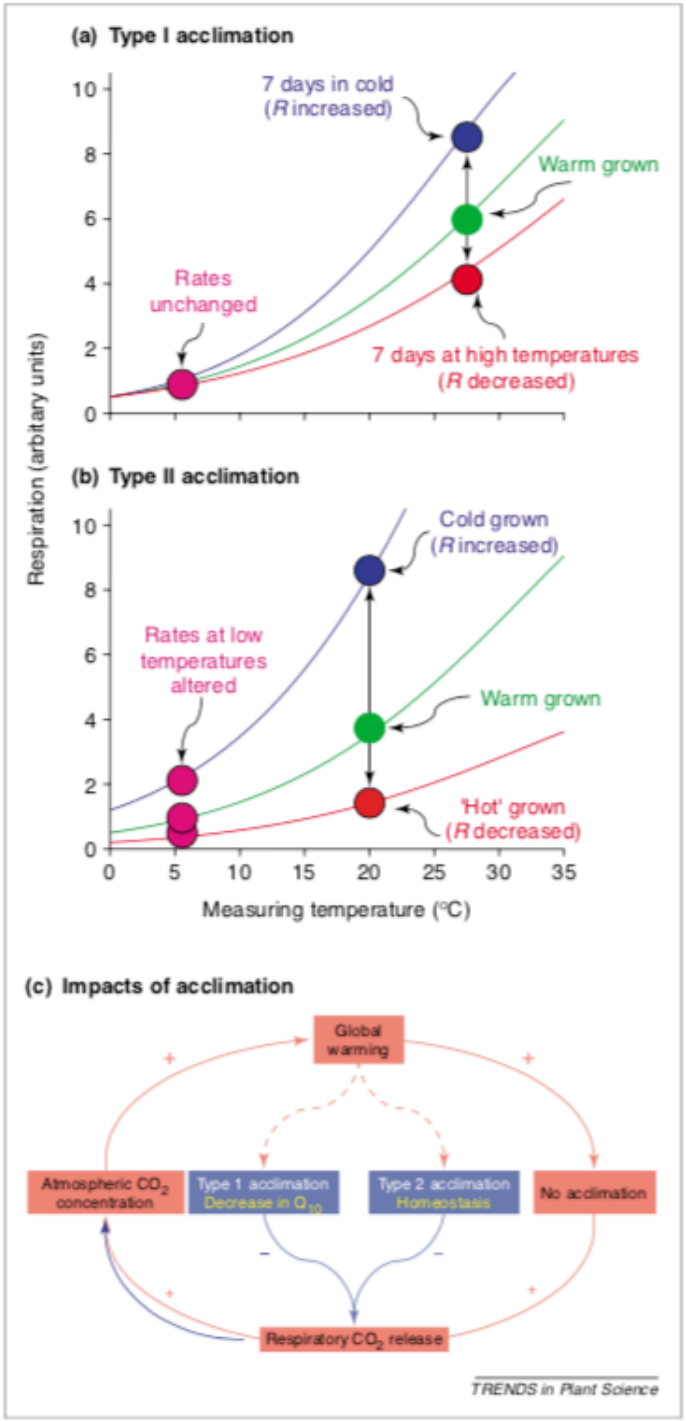
Given what you know about temperature responses: Why would plants acclimate?

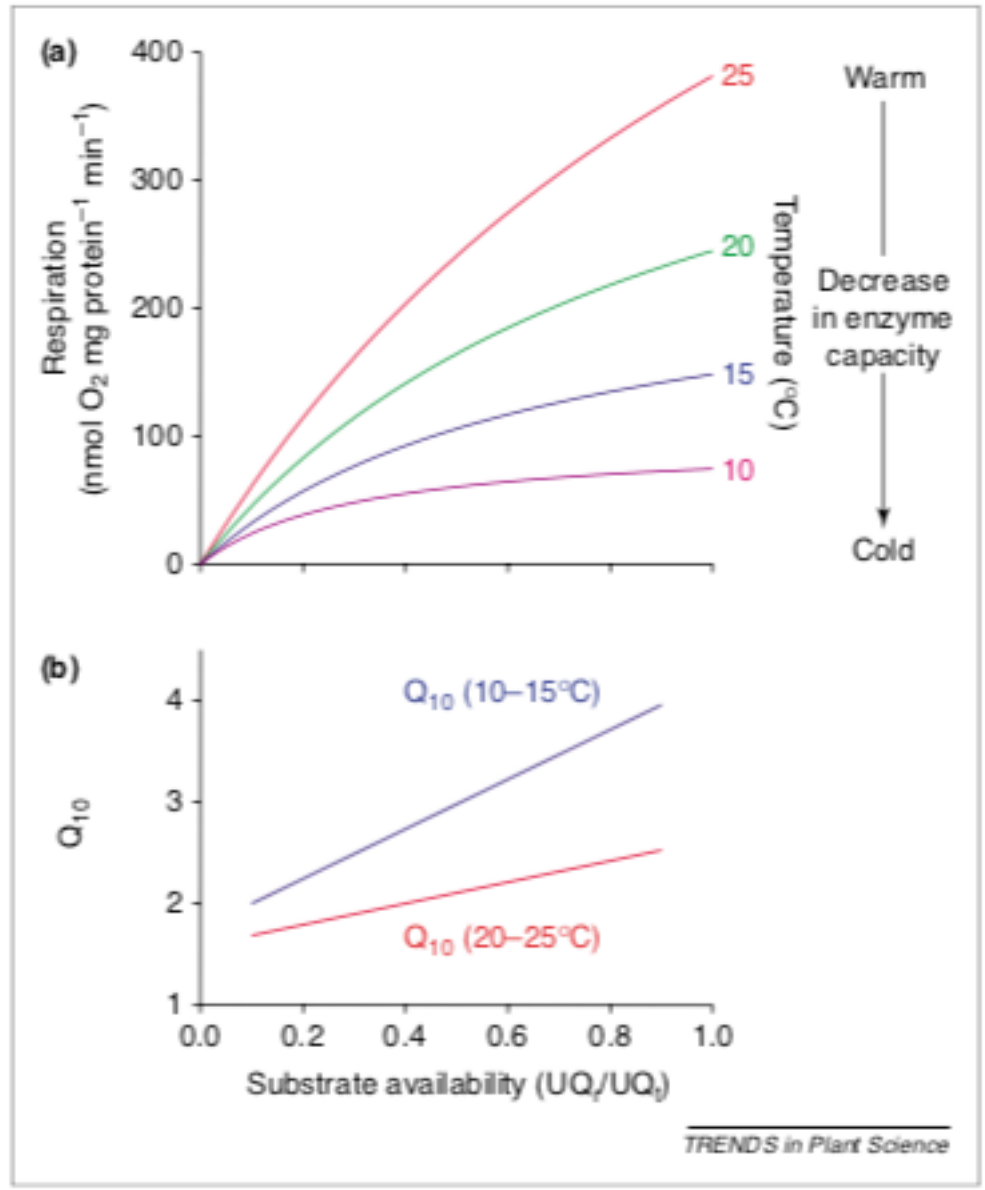
Figures for ease of viewing


Photosynthesis
Triose phosphates
Sucrose
F6P
ATP
PFK
ADP
F1,6bP
PEP
ADP
PK
ATP
Pyr
Cytosol
Intermembrane space
H+
NAD(P)H
ExtNDH
CI
CII
UQ
UQr
CIII
CIV
CV
Cyc
AOX
RIB
O2
O2
FADH2
NADH
ATP
ADP
Citric acid cycle
Pyr
PDC
Matrix
CO2
ATP
NADH
C-skeletons
Growth, maintenance, active transport


Respiration (arbitary units)
14
12
10
8
6
4
2
0
Temperature optimum
Declining Q_{10}
Intercept
0
10
20
30
40
50
60
Measuring temperature (°C)
Limitations in enzyme capacity
Substrate and/or adenylate limitations
TRENDS in Plant Science


3.5
3.0
2.5
2.0
1.5
1.0
Q_{10} of respiration
0
10
20
30
40
Temperature (°C)
TRENDS in Plant Science


(a) Type I acclimation
7 days in cold
(R increased)
Warm grown
Rates
unchanged
7 days at high temperatures
(R decreased)
Respiration (arbitary units)
(b) Type II acclimation
Cold grown
(R increased)
Rates at low
temperatures
altered
Warm grown
'Hot' grown
(R decreased)
Measuring temperature (°C)
(c) Impacts of acclimation
Global
warming
Atmospheric CO2
concentration
Type 1 acclimation
Decrease in Q10
Type 2 acclimation
Homeostasis
No acclimation
Respiratory CO2 release
TRENDS in Plant Science


(a)
400
300
200
100
0
Respiration (nmol O_2 mg protein^{-1} min^{-1})
25
20
15
10
Temperature (°C)
Warm
Decrease in enzyme capacity
Cold
(b)
4
3
2
1
Q_{10}
Q_{10} (10–15°C)
Q_{10} (20–25°C)
0.0
0.2
0.4
0.6
0.8
1.0
Substrate availability (UQ_r/UQ_t)
TRENDS in Plant Science