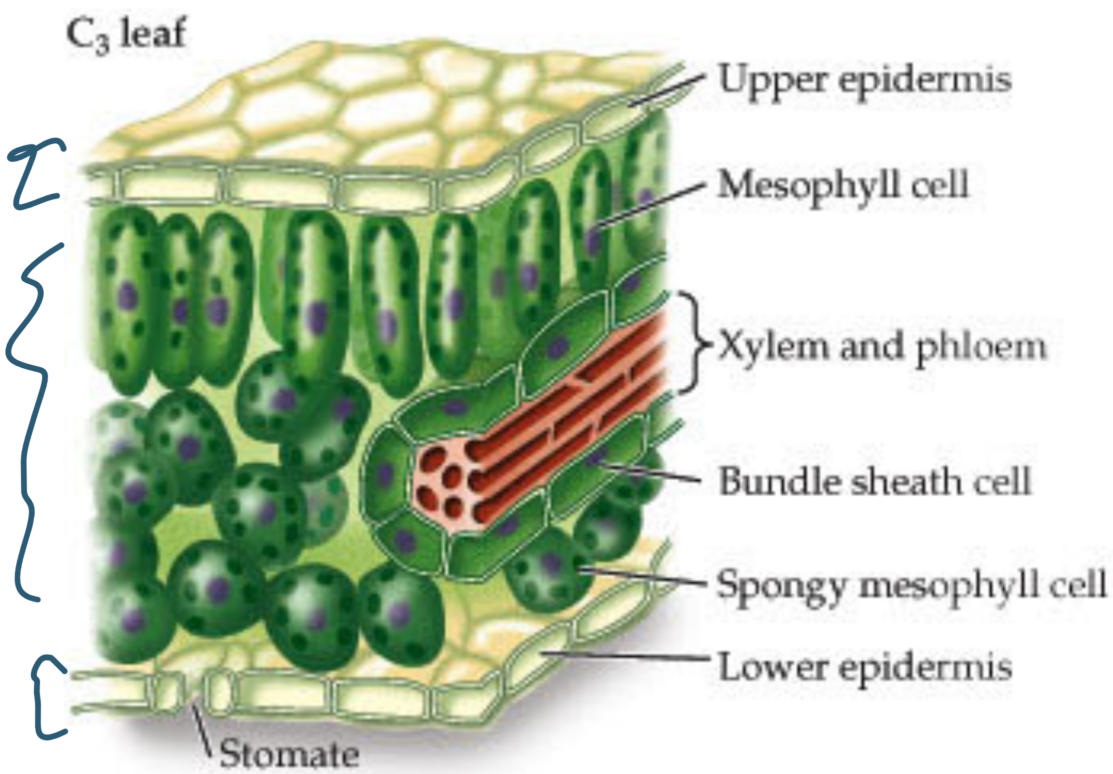
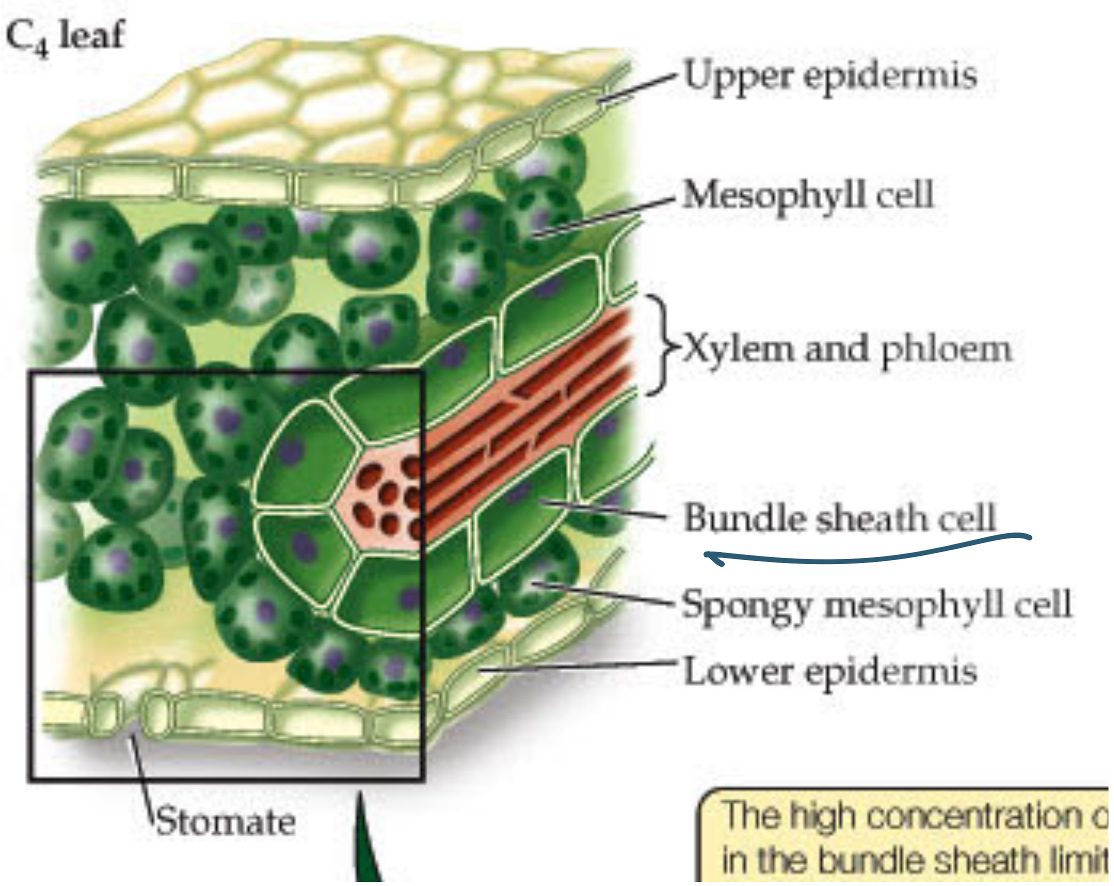
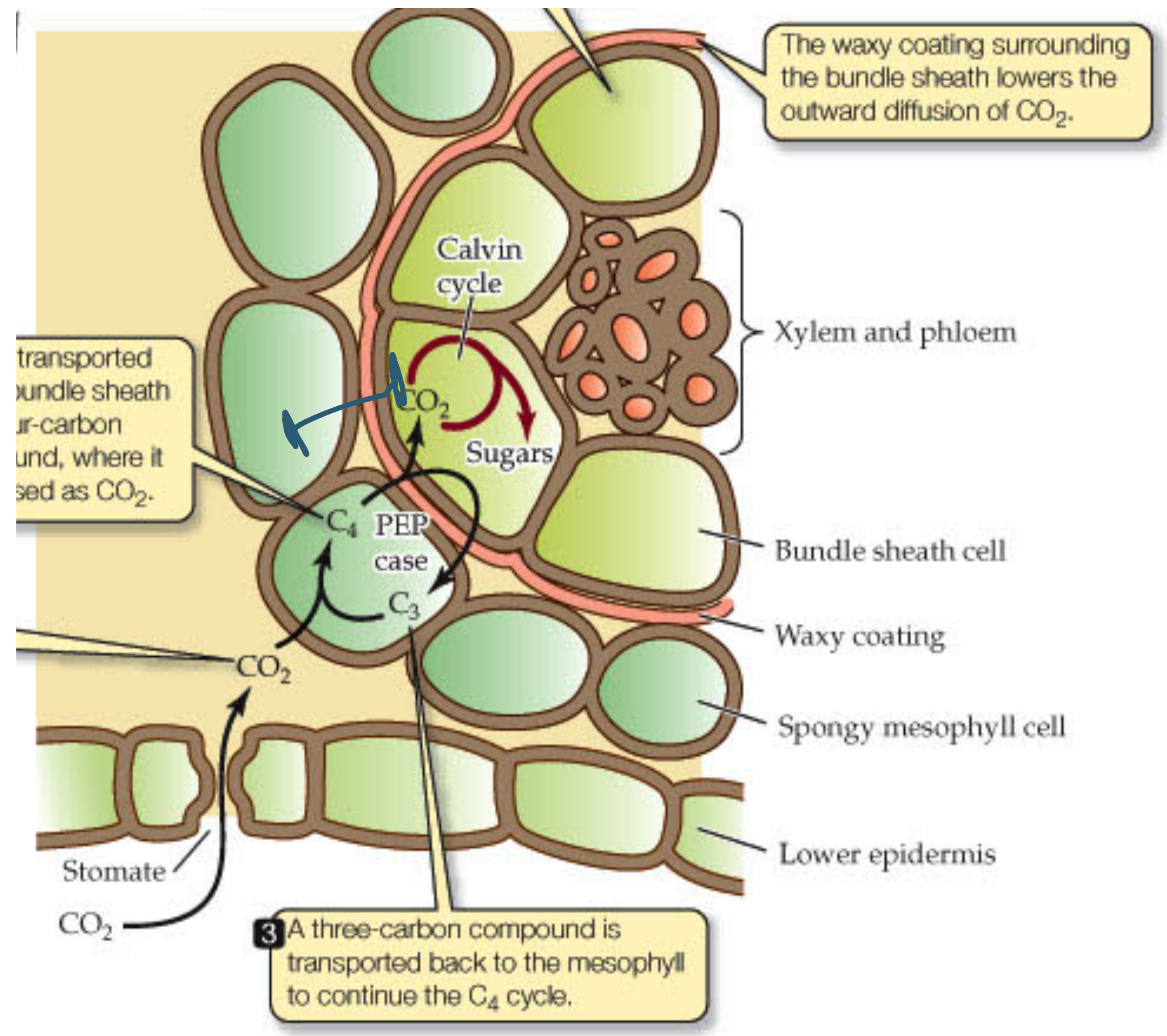
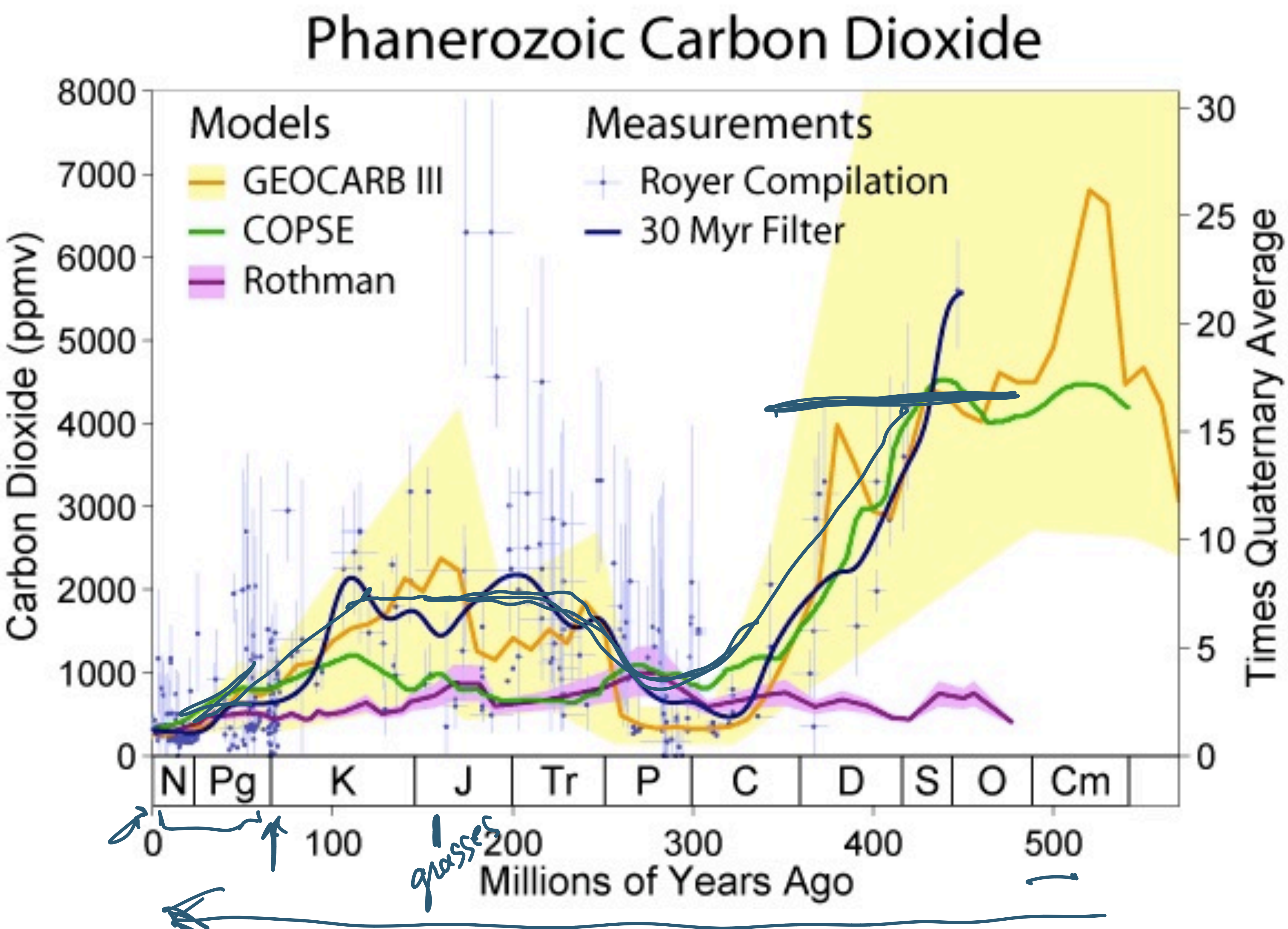
C_4 plants create a miniature atmosphere inside their bundle sheath cells to increase photosynthetic efficiency in low CO_2 environments

- lowers the rate of O_2 uptake during photorespiration
- C_4 plants have advantage in low $[CO_2]$


C3 leaf
Upper epidermis
Mesophyll cell
Xylem and phloem
Bundle sheath cell
Spongy mesophyll cell
Lower epidermis
Stomate


C4 leaf
Upper epidermis
Mesophyll cell
Xylem and phloem
Bundle sheath cell
Spongy mesophyll cell
Lower epidermis
Stomate
The high concentration o
in the bundle sheath limit

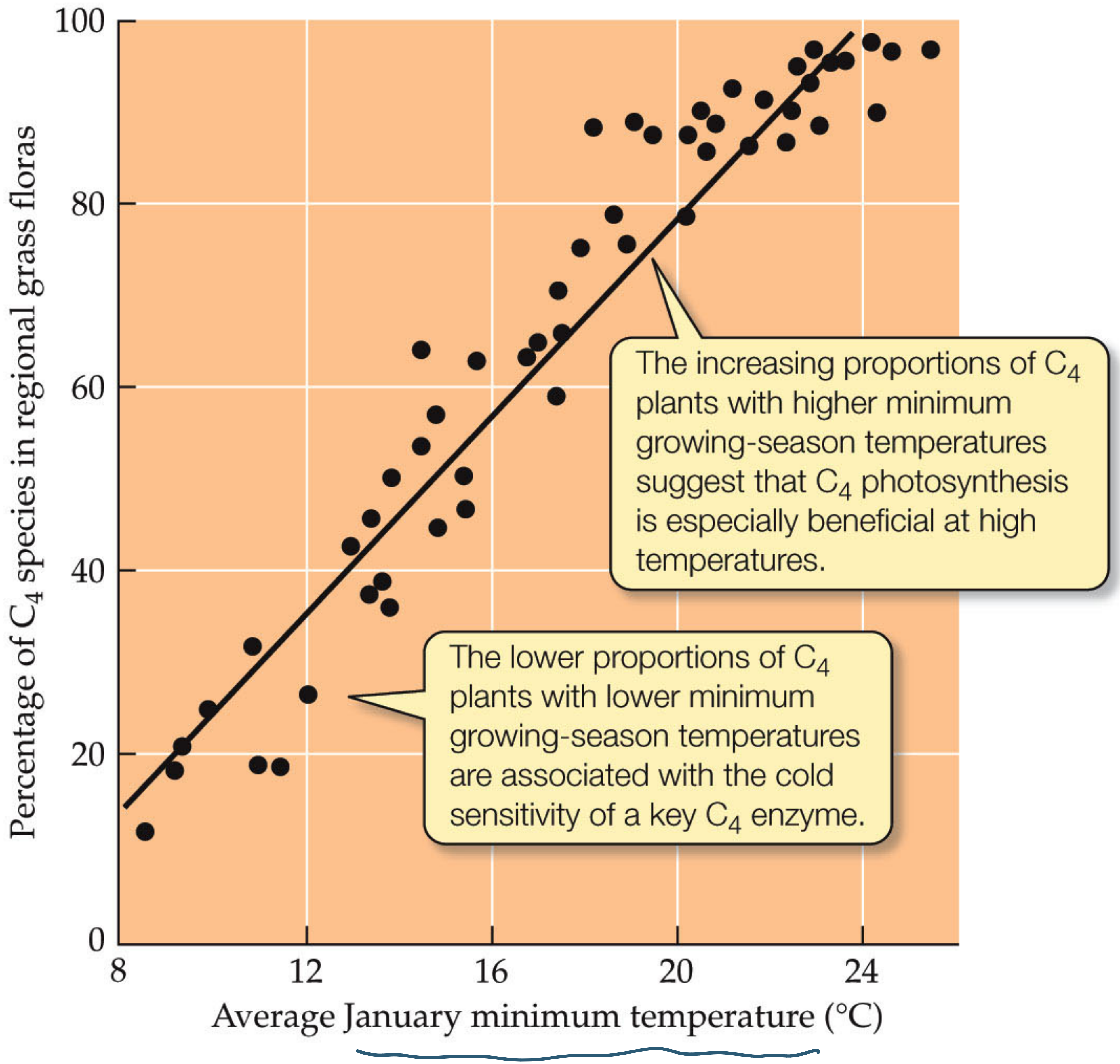

The waxy coating surrounding the bundle sheath lowers the outward diffusion of CO2.
Calvin cycle
CO2
Sugars
Xylem and phloem
transported
undle sheath
r-carbon
und, where it
sed as CO2.
C4
PEP case
C3
CO2
Bundle sheath cell
Waxy coating
Spongy mesophyll cell
Lower epidermis
Stomate
CO2
3 A three-carbon compound is transported back to the mesophyll to continue the C4 cycle.



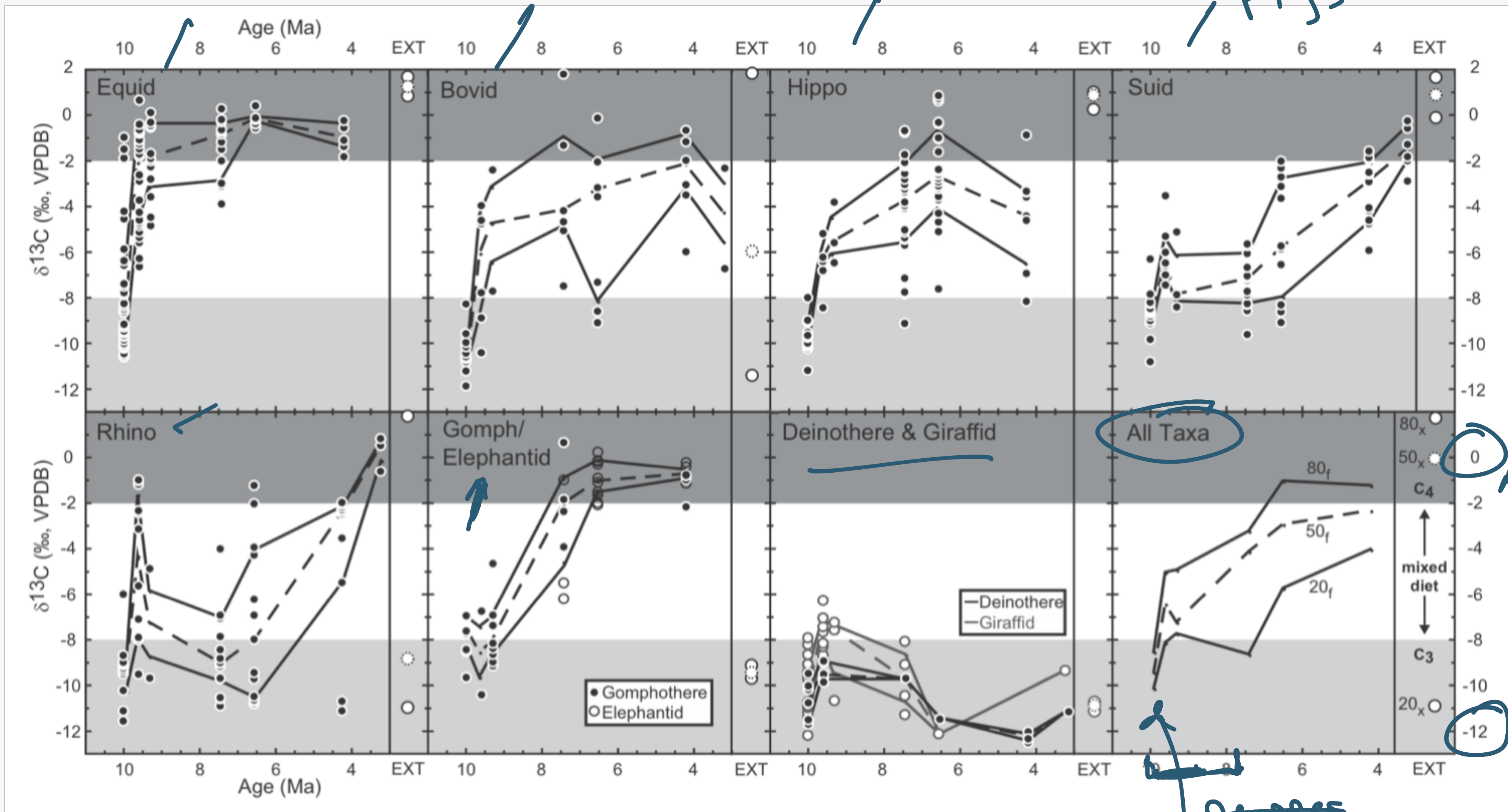
C4 photosynthesis becomes abundant

10-7 Myrs ago

C3 photosynthesis (way back)



Percentage of C_4 species in regional grass floras
Average January minimum temperature (°C)
0
20
40
60
80
100
8
12
16
20
24
The increasing proportions of C_4 plants with higher minimum growing-season temperatures suggest that C_4 photosynthesis is especially beneficial at high temperatures.
The lower proportions of C_4 plants with lower minimum growing-season temperatures are associated with the cold sensitivity of a key C_4 enzyme.



Pigs

eating more C4

eating more C3

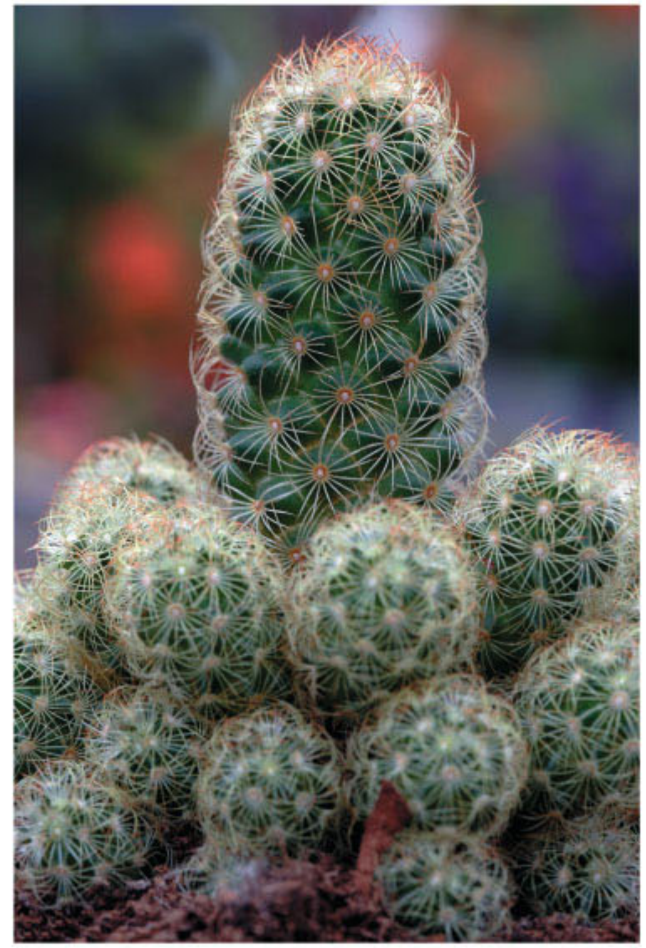
grasslands evolve

10 Myrs ago

3 Myrs ago

- Evolve larger body sizes in response to consuming more grasses in diet

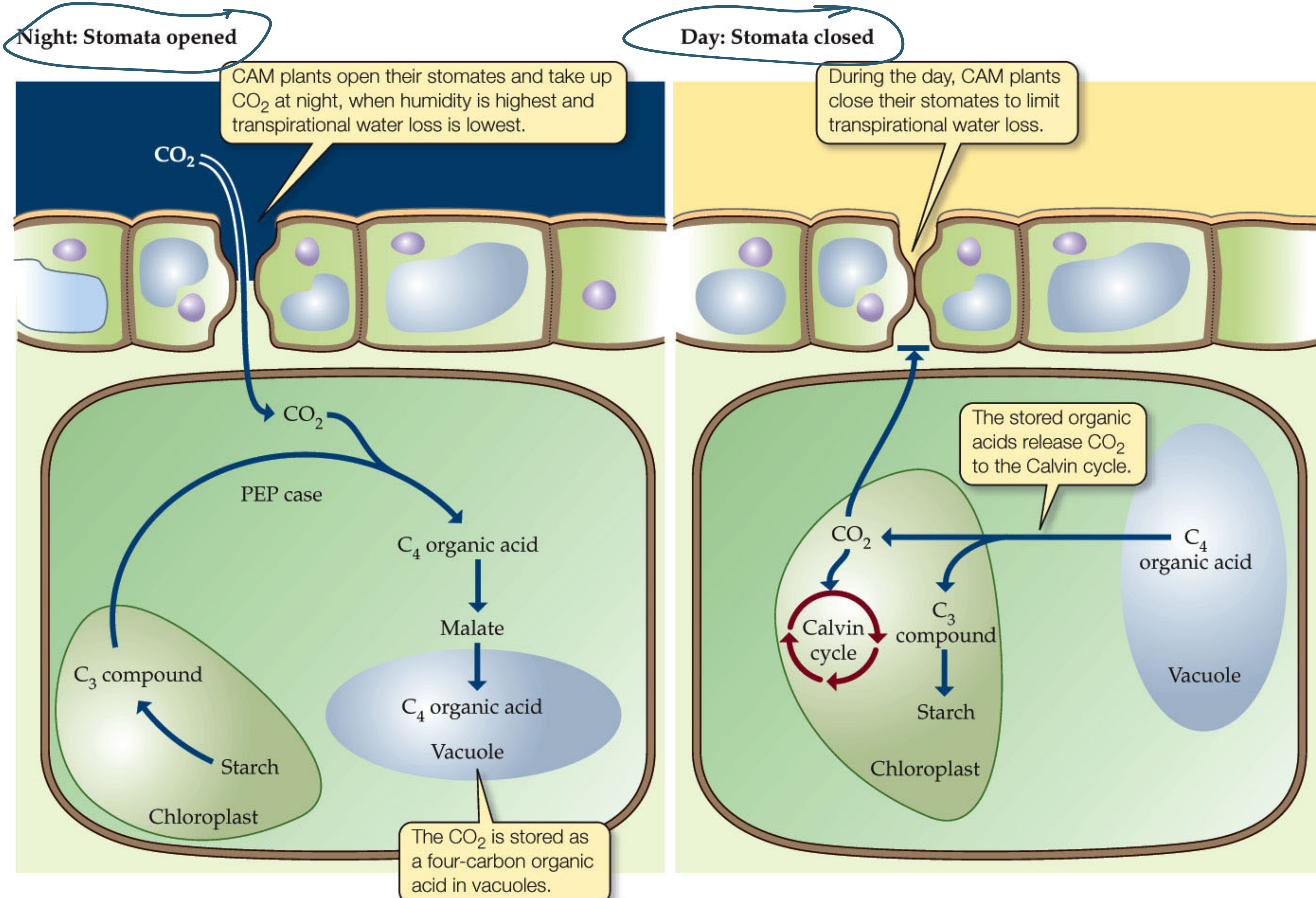
Crassula tabularis, a stem succulent plant native to the desert of Namibia



Golden star cactus (*Mammillaria elongata*), native to Mexico

Pineapple (*Anana comosus*), a bromeliad native to Central and South American tropical forests

CAM : 10000 spp.
in 33 families
~ temporal seperation of photosynthetic pathway
- open stomata at night to take up CO_2
close during the day



Night: Stomata opened
CAM plants open their stomates and take up CO_2 at night, when humidity is highest and transpirational water loss is lowest.
CO_2
CO_2
PEP case
C_4 organic acid
Malate
C_4 organic acid
Vacuole
C_3 compound
Starch
Chloroplast
The CO_2 is stored as a four-carbon organic acid in vacuoles.
Day: Stomata closed
During the day, CAM plants close their stomates to limit transpirational water loss.
The stored organic acids release CO_2 to the Calvin cycle.
CO_2
C_4 organic acid
Calvin cycle
C_3 compound
Starch
Vacuole
Chloroplast

Chemosynthesis

- Use energy from inorganic compounds to produce carbohydrates
- Earliest autotrophs were likely ~~chemo~~ chemosynthetic bacteria/archea
- Early Earth atm. low in O_2, rich in H_2, CH_4, CO_2

Heterotrophs

- obtain energy by consuming energy-rich organic compounds from other organisms
- Detritovores
- Herbivores, ~~p~~ parasites, predators

Herbivores, parasites: Don't ~~s~~ kill their ~~resources~~ resources, but lower their fitness

Predators: kill resources

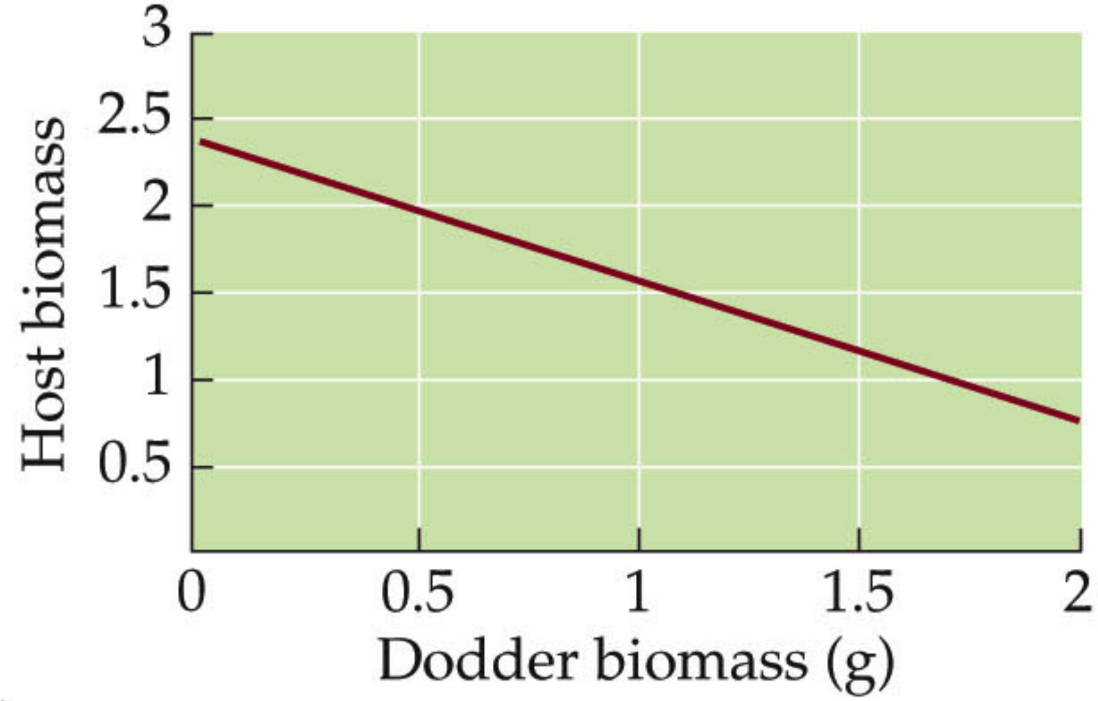
- Holoparasites: plants w/o photosynthetic pigments that consume other plants e.g. Dodder

- Hemiparasite: both photosynthetic and parasitic (mistletoe)

- Effort invested in finding/obtaining food influences how much benefit is gained
  Micro-organisms invest little energy in consuming detritus
  ~ detritus has ↓ energy content
  Profitability: weigh the cost and benefits of different foraging strategies
- Stoichiometry: [C, N, O, P]
  plants → animals ↑ E cost
  animals → animals ↓ E cost

(A)

(B)



(C)


FreeBigPictures.com

Body Size & Allometry

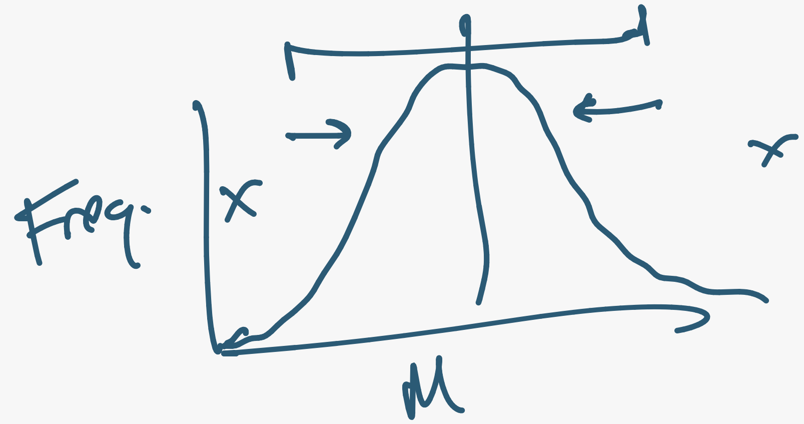
1) Size varies

Largest: Blue Whale @ 10^8 grams
Smallest: Mycoplasma @ 10^{-13} grams } 21 fold variation

Humans @ 10^5 grams

What is body size?

1) Structural size ~ morphology
2) Mass

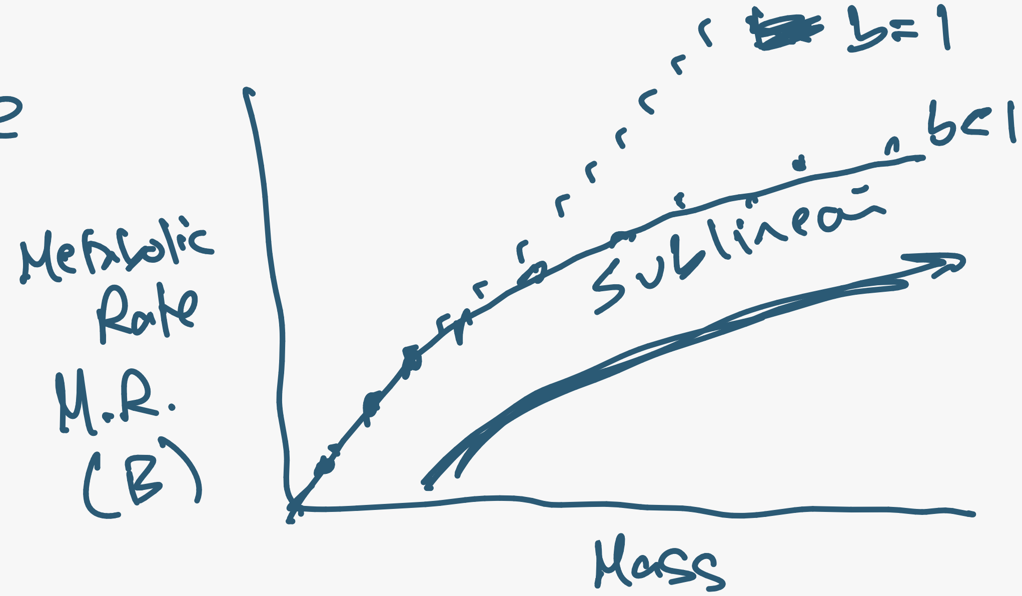


Cope's Rule ~ trend towards larger body size over evolutionary time

Size as Adaptation

↔ Thermoregulation
→ Predation
→ Competition
↔ Sexual Selection
→ Metabolic efficiency

- Kleiber Curve



$M.R. = aM^b$ } Power relationship

(linear space)

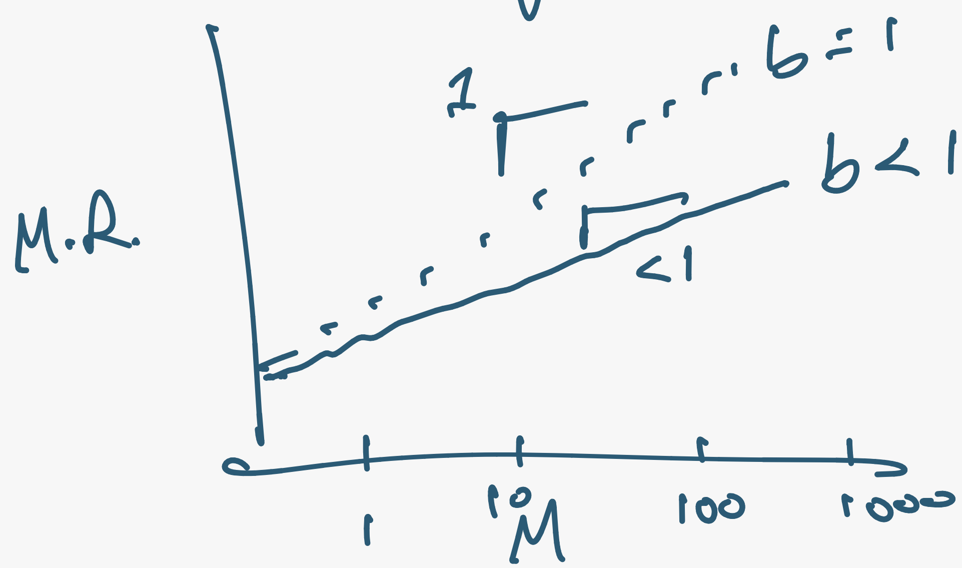
$\log(M.R.) = \log(aM^b)$

$\log(M.R.) = \log(a) + b\log(M)$

$y = mx + b$

- log transforming a power law turns relationship M.R. and M. into straight lines

log-spacing



y-intercept : $\log(a)$

slope : b

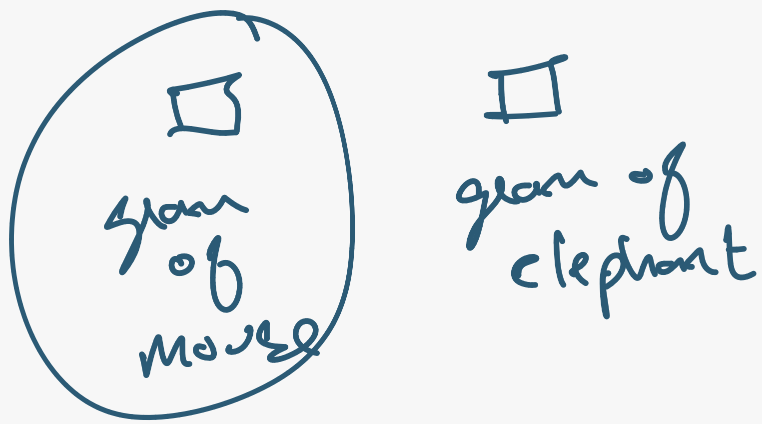
$b<1$, $b>0$ then we have a saturating M.R. w/ increasing mass

if $b=1$ we have isometry ~ a proportional change in M.R. rate with M

$b>1$ exponential increase in M.R. with M

$b>0$, $b<1$ } Bigger organisms are more efficient per unit biomass

- take more calories to run absolutely
- per gram they take fewer calories to run



Bigger organisms have lower metabolic rates per unit biomass

Build intuition for why $b<1$

Smaller

Radius $= r$

$SA = 4\pi r^2$ $\quad SA \propto r^2$

$V = \frac{4}{3}\pi r^3$ $\quad V \propto r^3$

$M \propto r^3$

Larger

Radius $= 2r$

$SA \propto (2r)^2 \propto 4r^2$

$V \propto (2r)^3 \propto 8r^3$

Heat produced by each cell $\propto$ Volume $\propto r^3$

Shed heat through Surface Area $\propto r^2$

- Organisms have to TUNE DOWN their metabolic rate so they can dissipate heat produced by metabolism across surface area

M.R. $\propto V$

M.R. $\propto SA \propto r^2 \propto (r^3)^{2/3} \propto (V)^{2/3}$ WRONG

($(r^3)^{2/3} = r^2$; V → M)