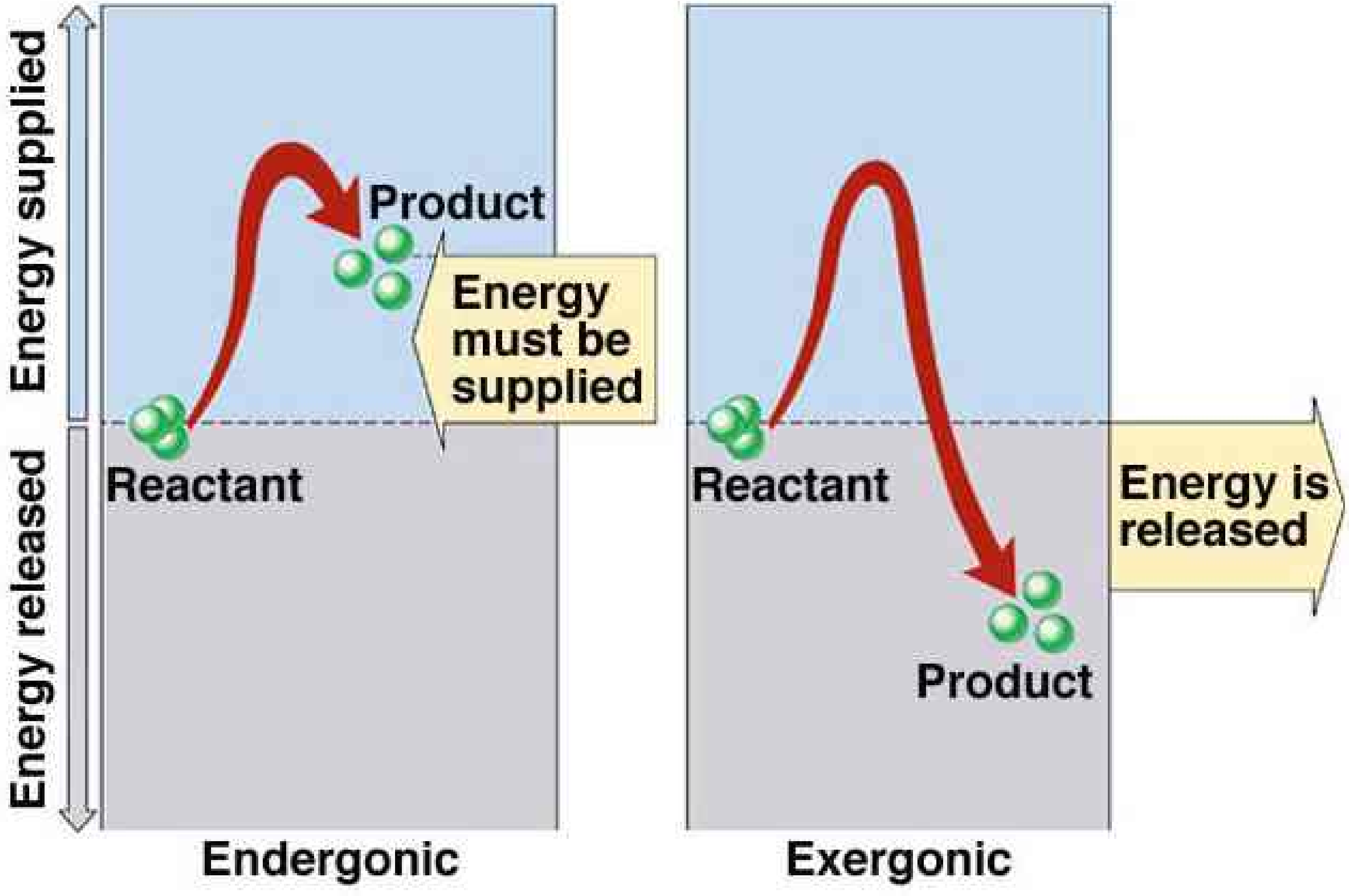
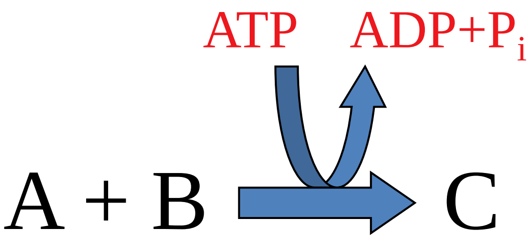
Energetics, Metabolic Biochemistry

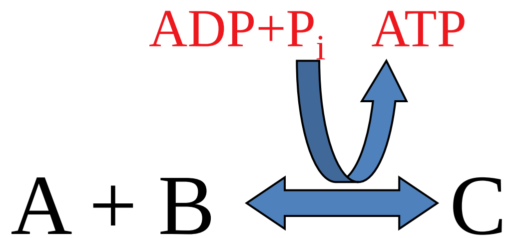
- What is it?
- Why do we care?
- Enzymatic reactions offer a proxy to metabolic capacity.

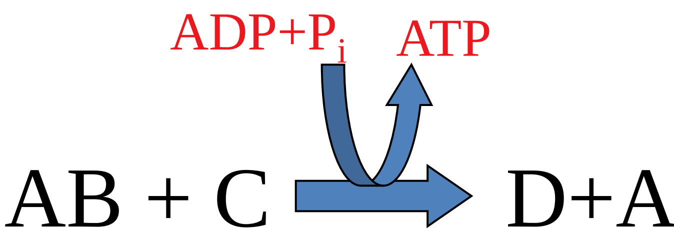
Energetic reactions

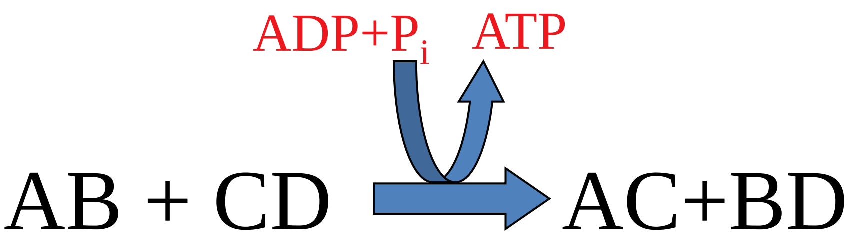
Endergonic - require energy to happen
Exergonic - liberate (release) energy when occurring, they are spontaneous

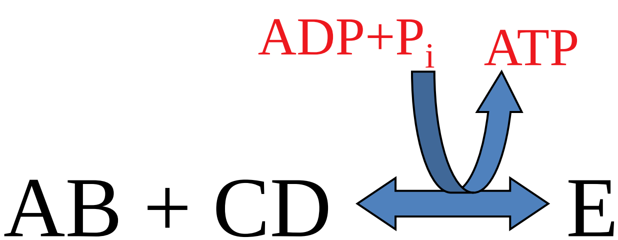


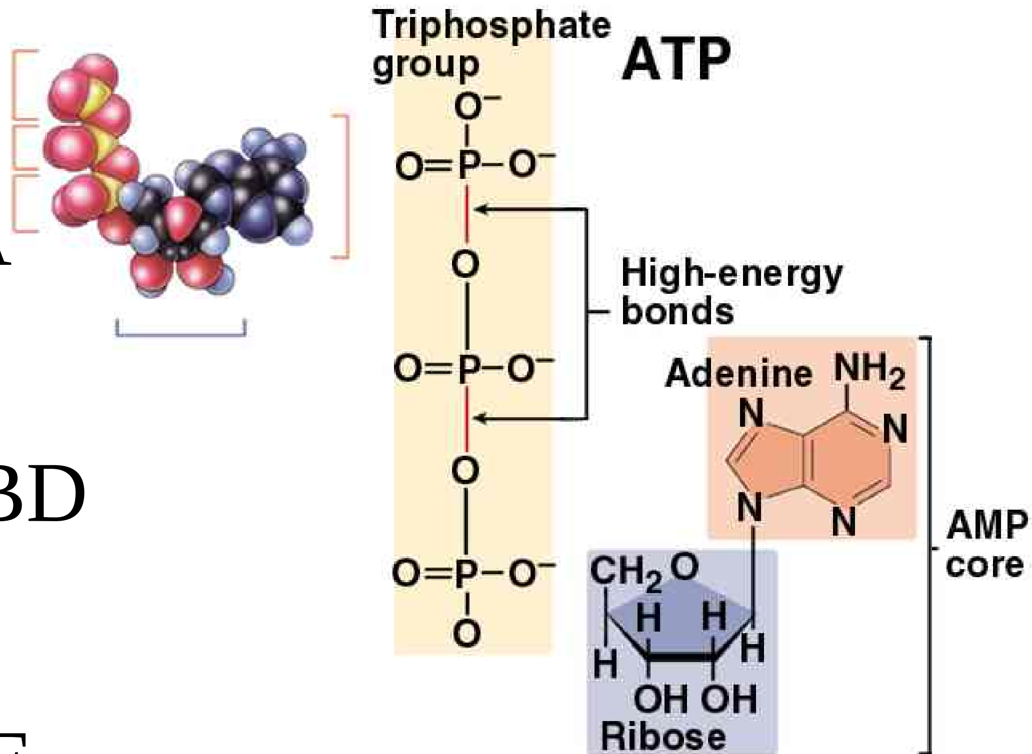

ATP
ADP+Pi
A + B
C

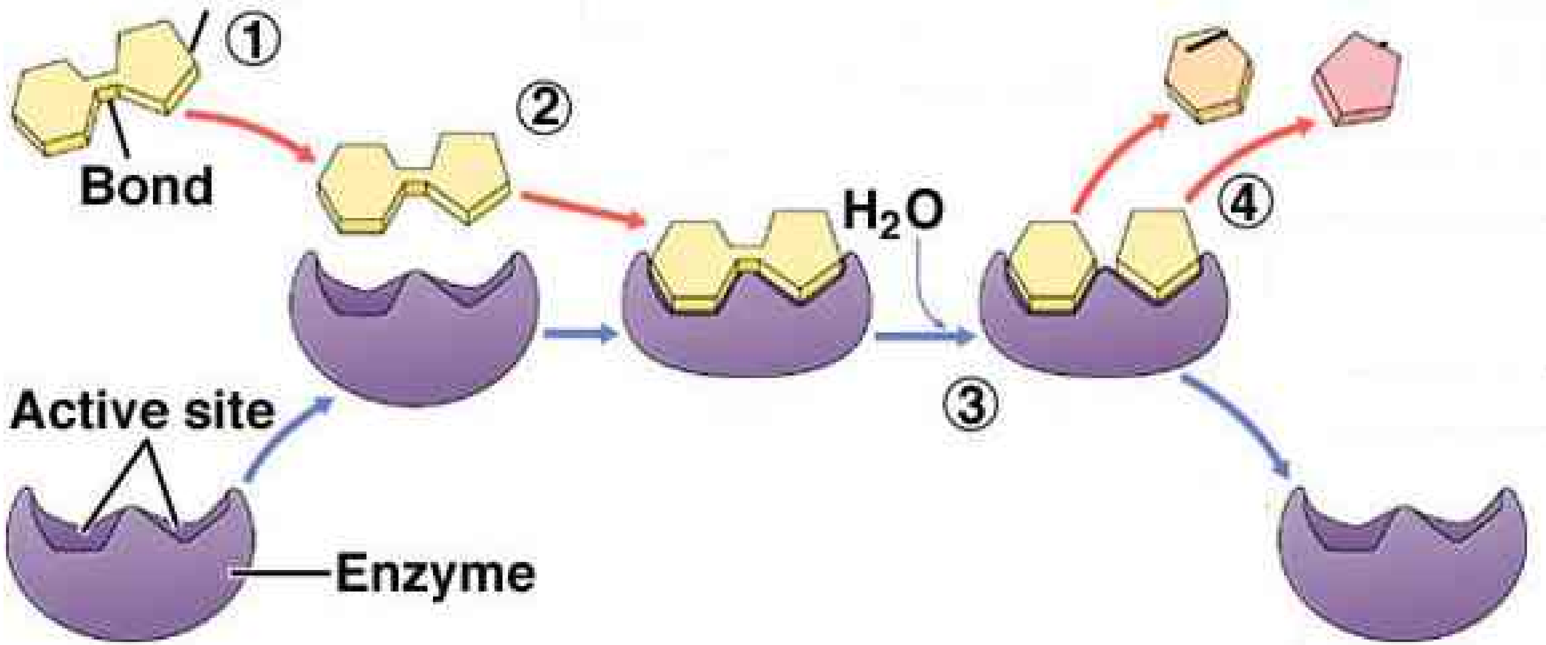

ADP+Pi
ATP
A + B
C


ADP+Pi
ATP
AB + C
D+A

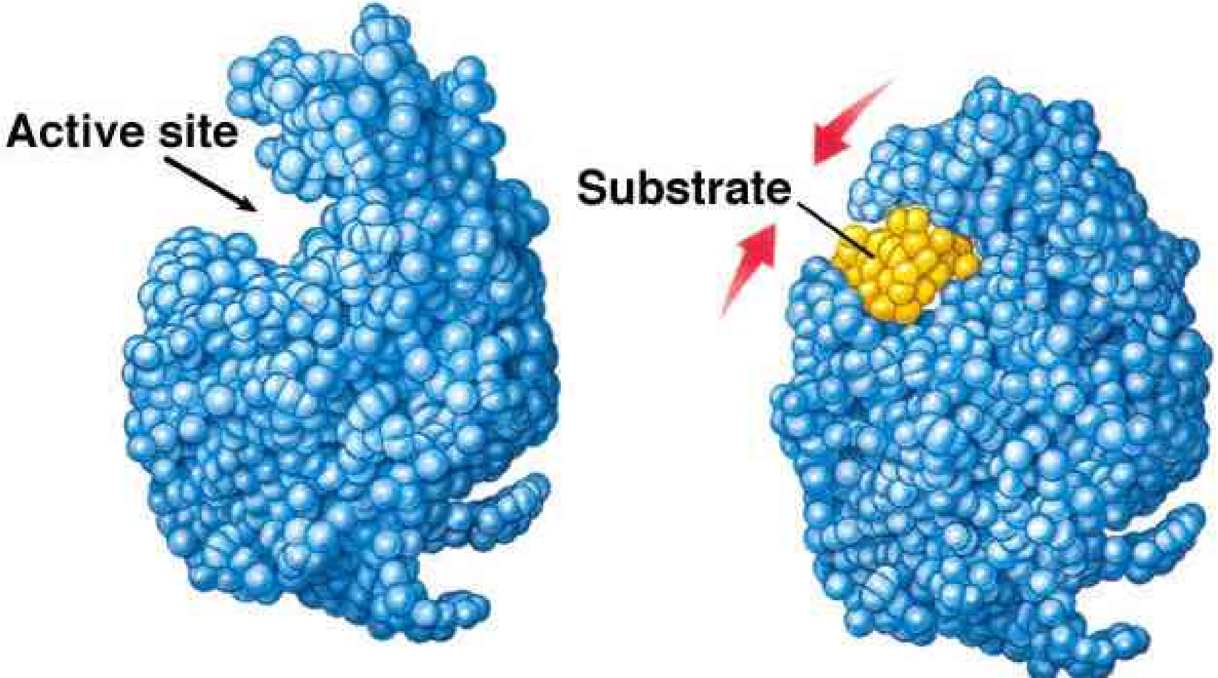

ADP+Pi
ATP
AB + CD
AC+BD


ADP+Pi
ATP
AB + CD
E

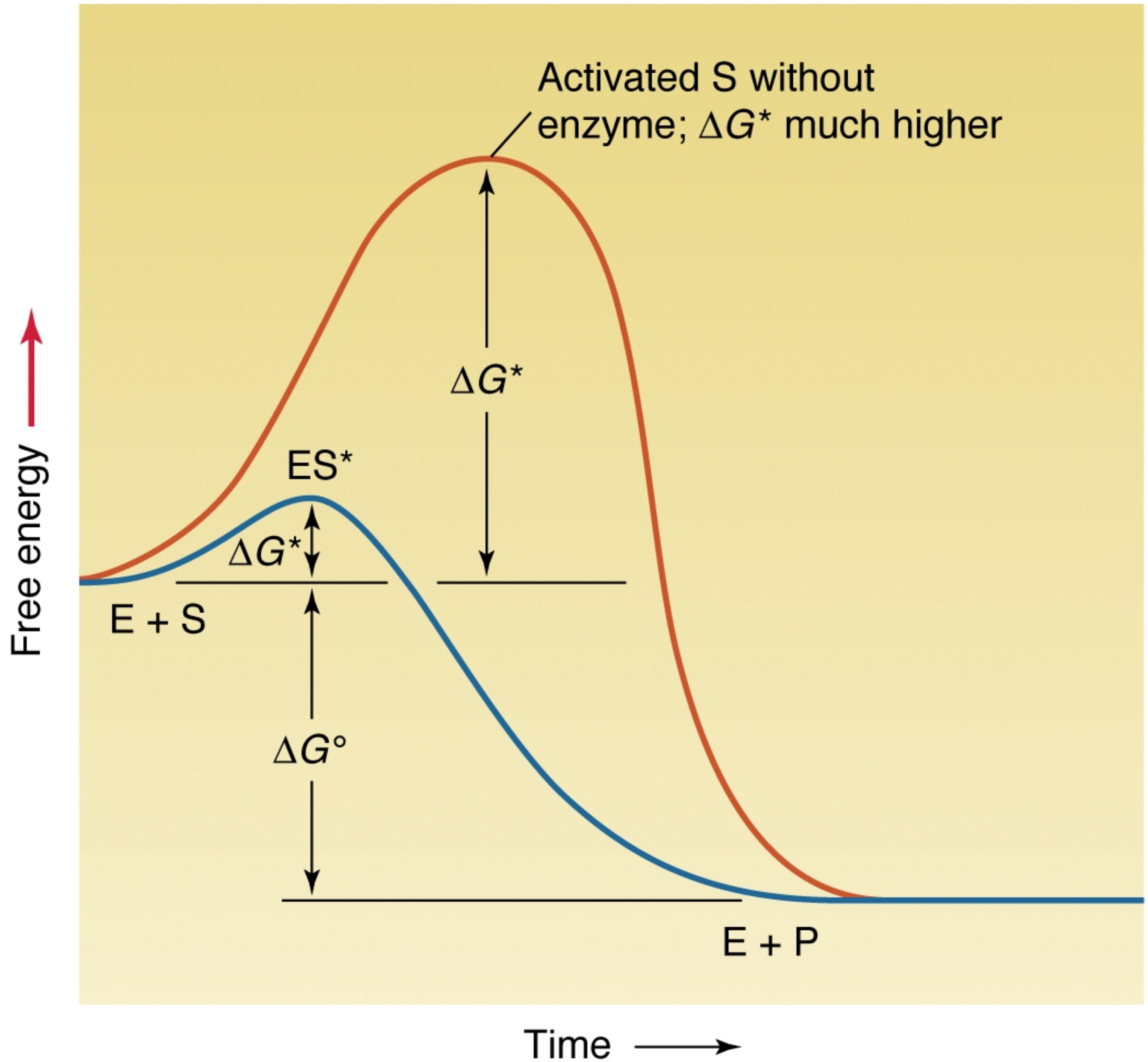

Triphosphate group
ATP
High-energy bonds
Adenine
AMP core
Ribose


①
Bond
②
H_2O
④
③
Active site
Enzyme

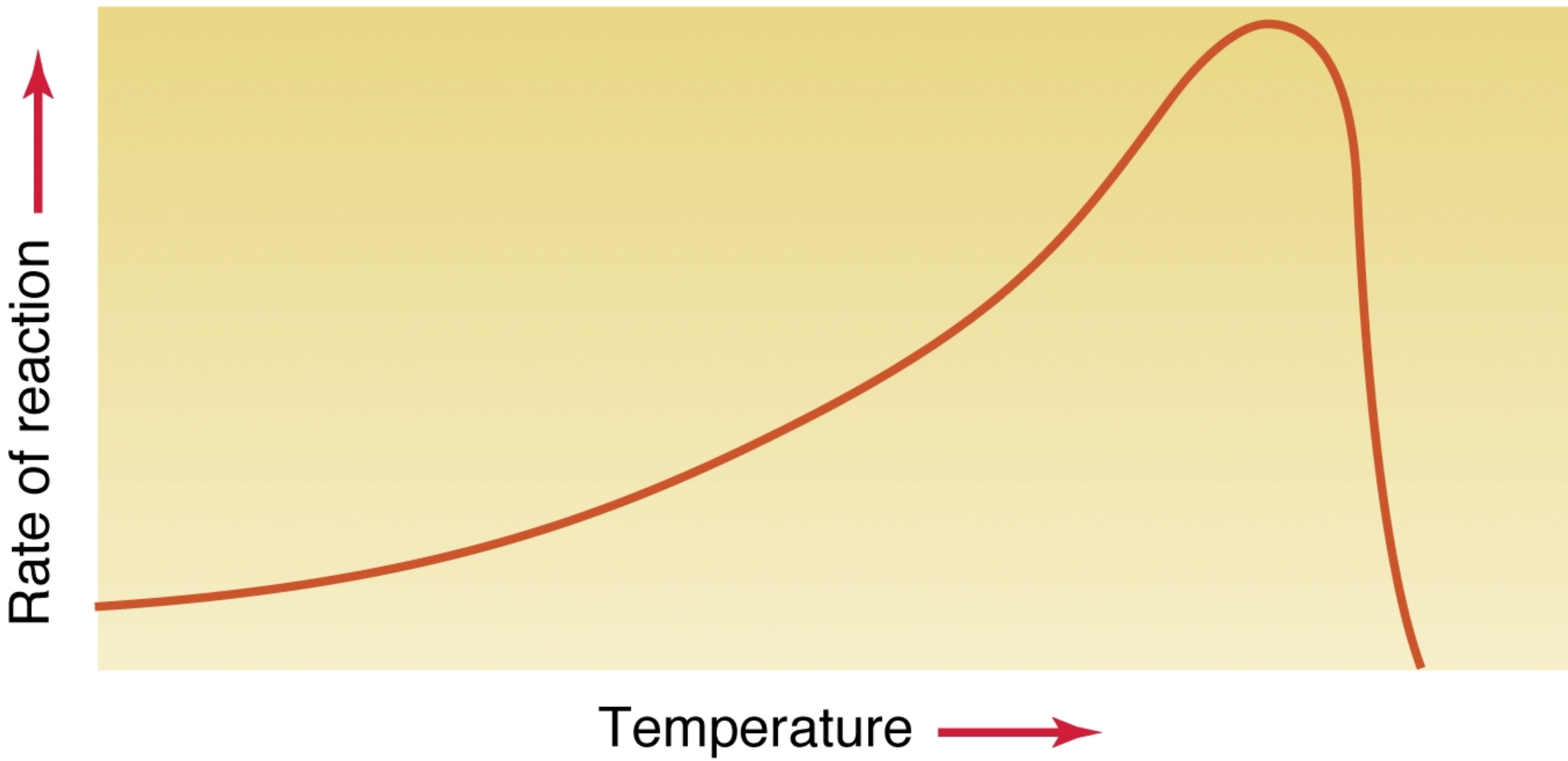
What does an enzyme really look like



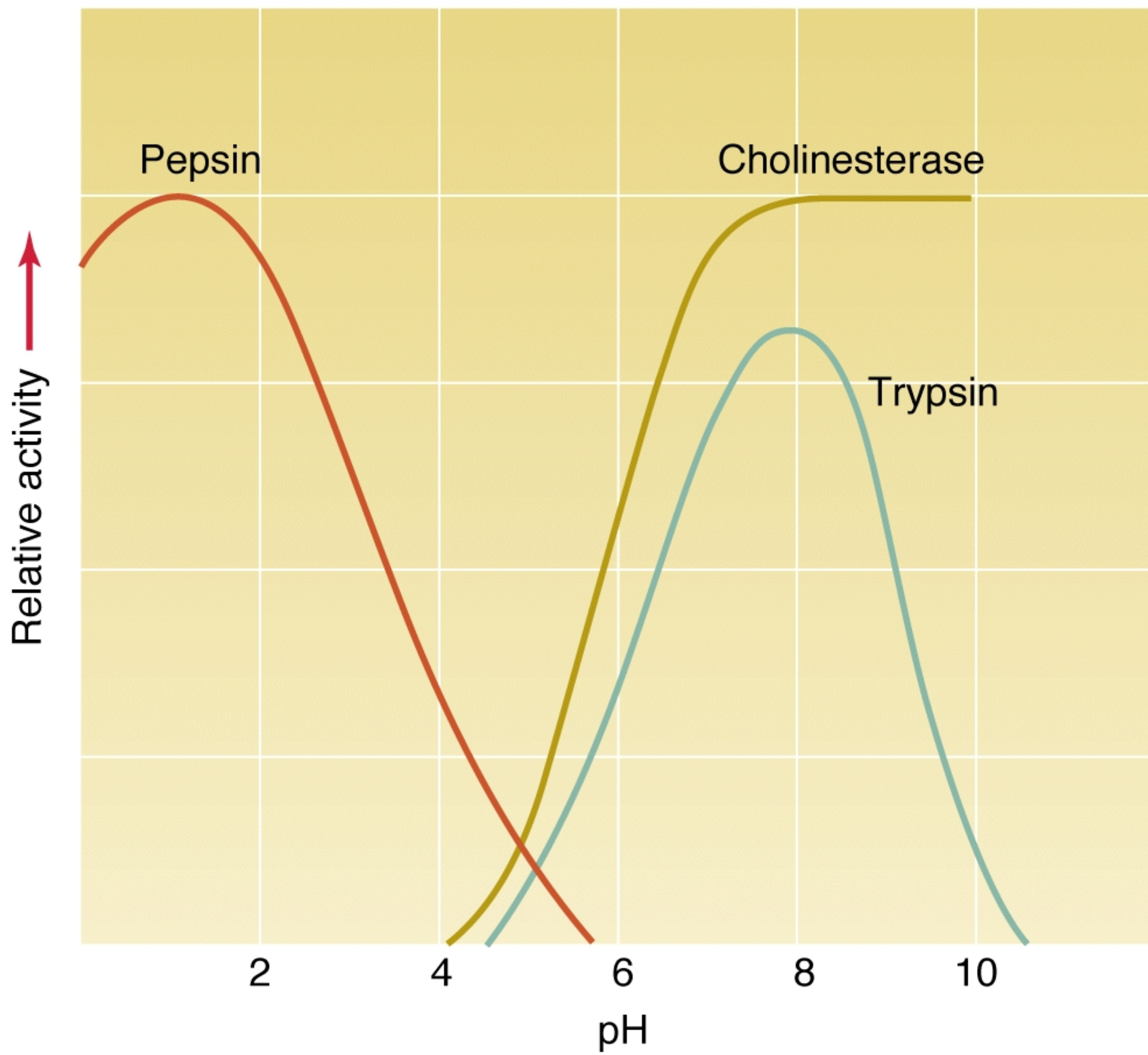
Conformational change


Activated S without enzyme; ΔG* much higher
ΔG*
ES*
ΔG*
E + S
ΔG°
E + P
Free energy
Time

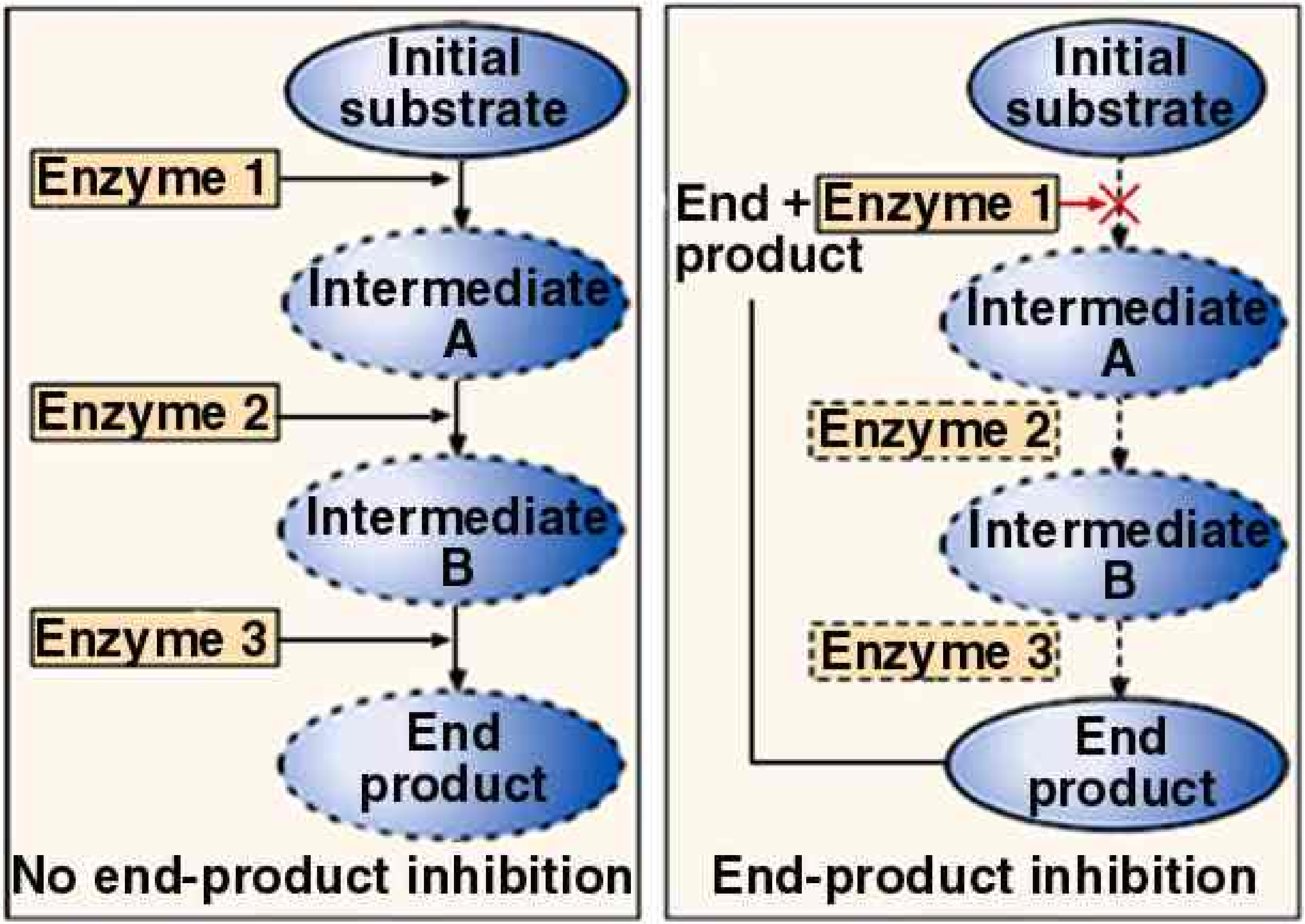
(a) Enzyme activity versus temperature



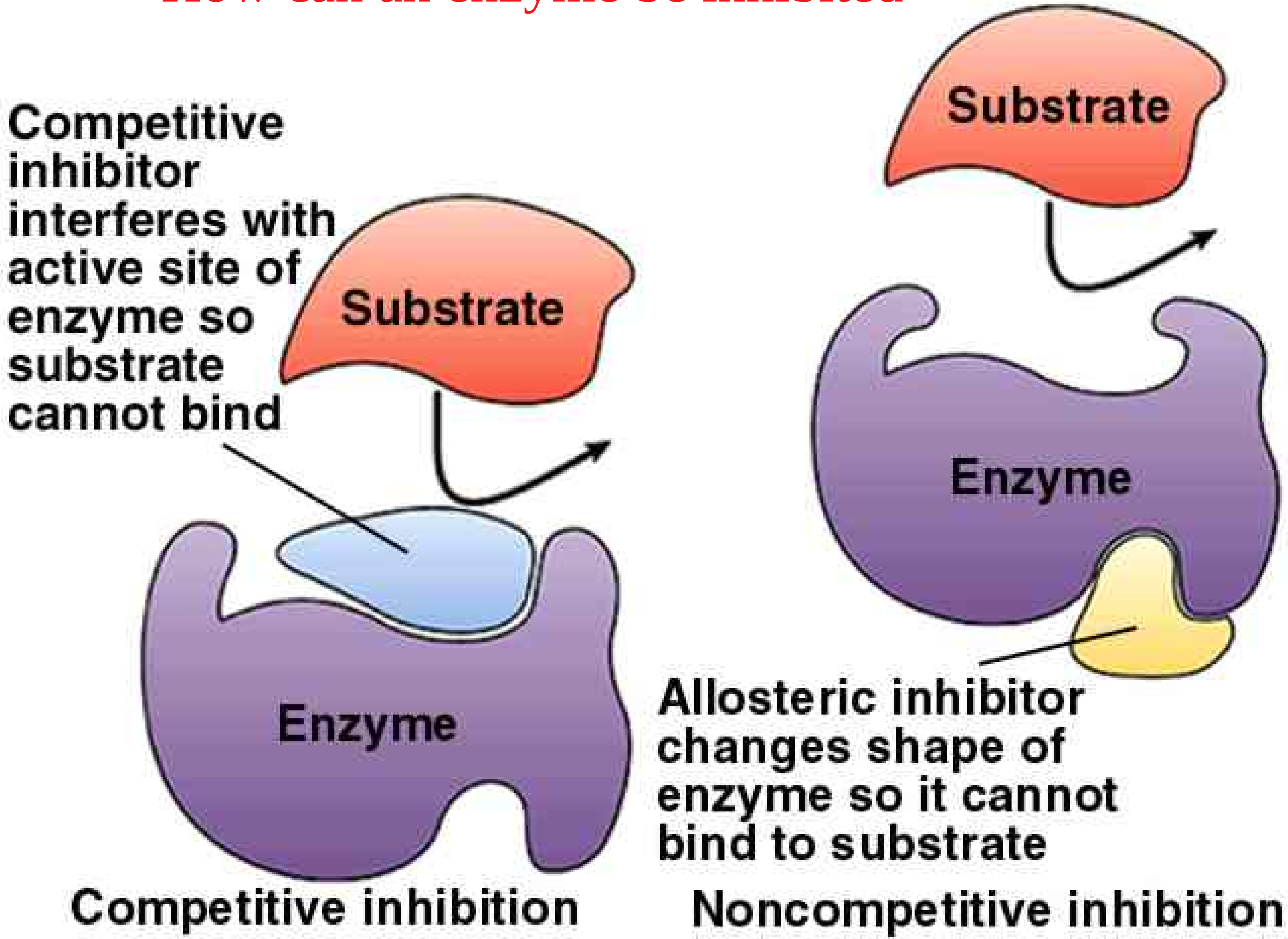
(b) Enzyme activity versus pH

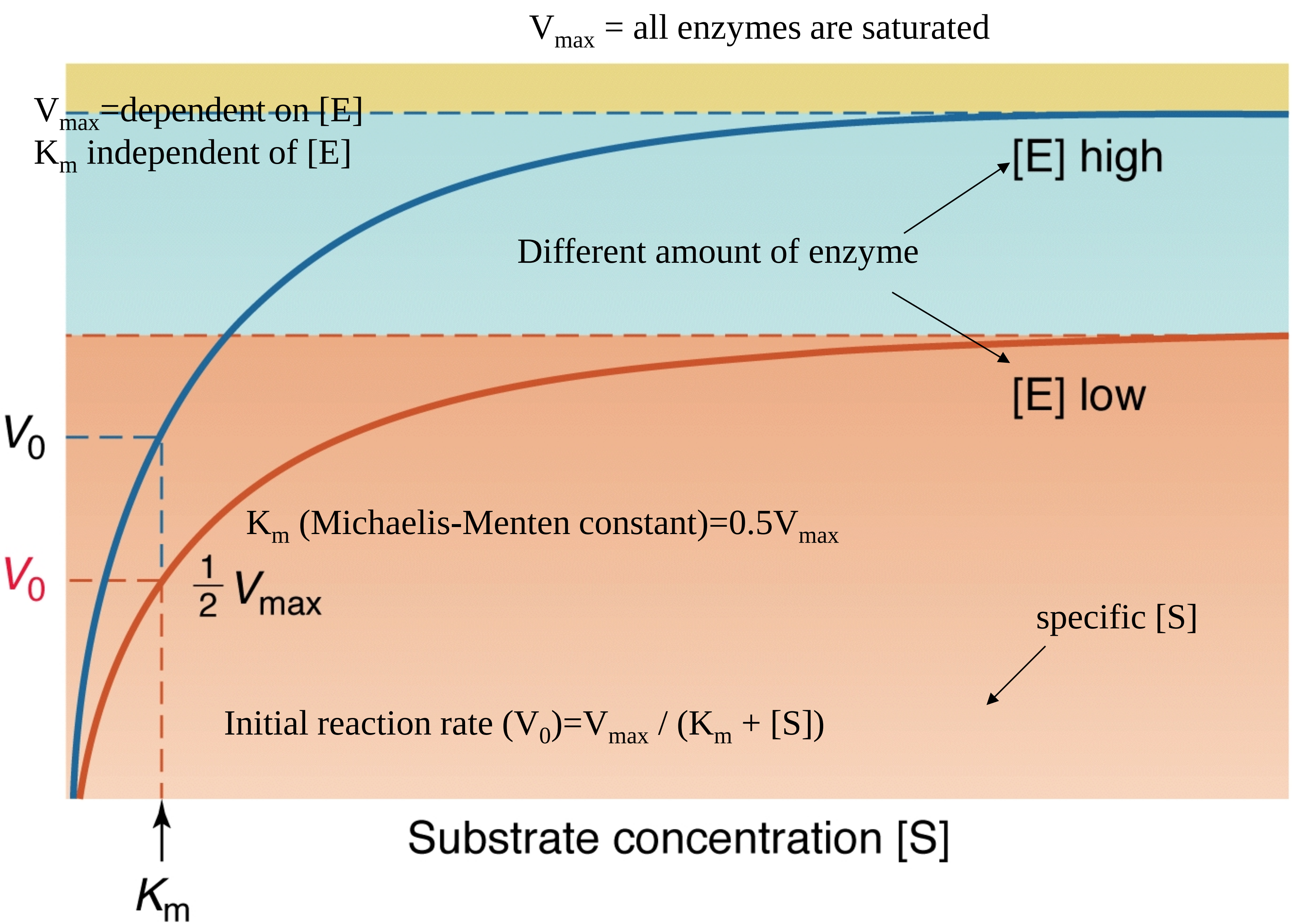


Control of enzymatic reactions



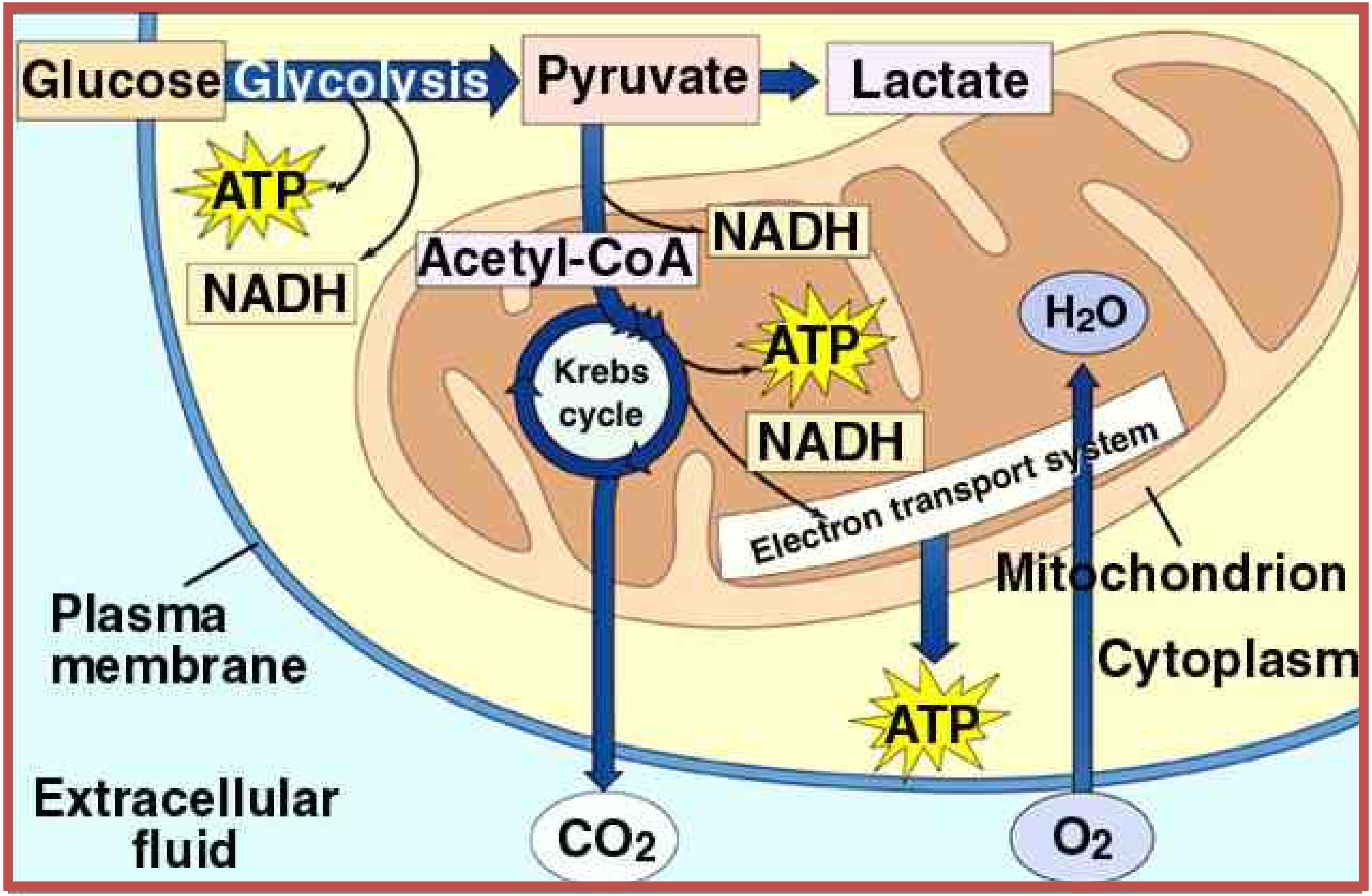
How can an enzyme be inhibited



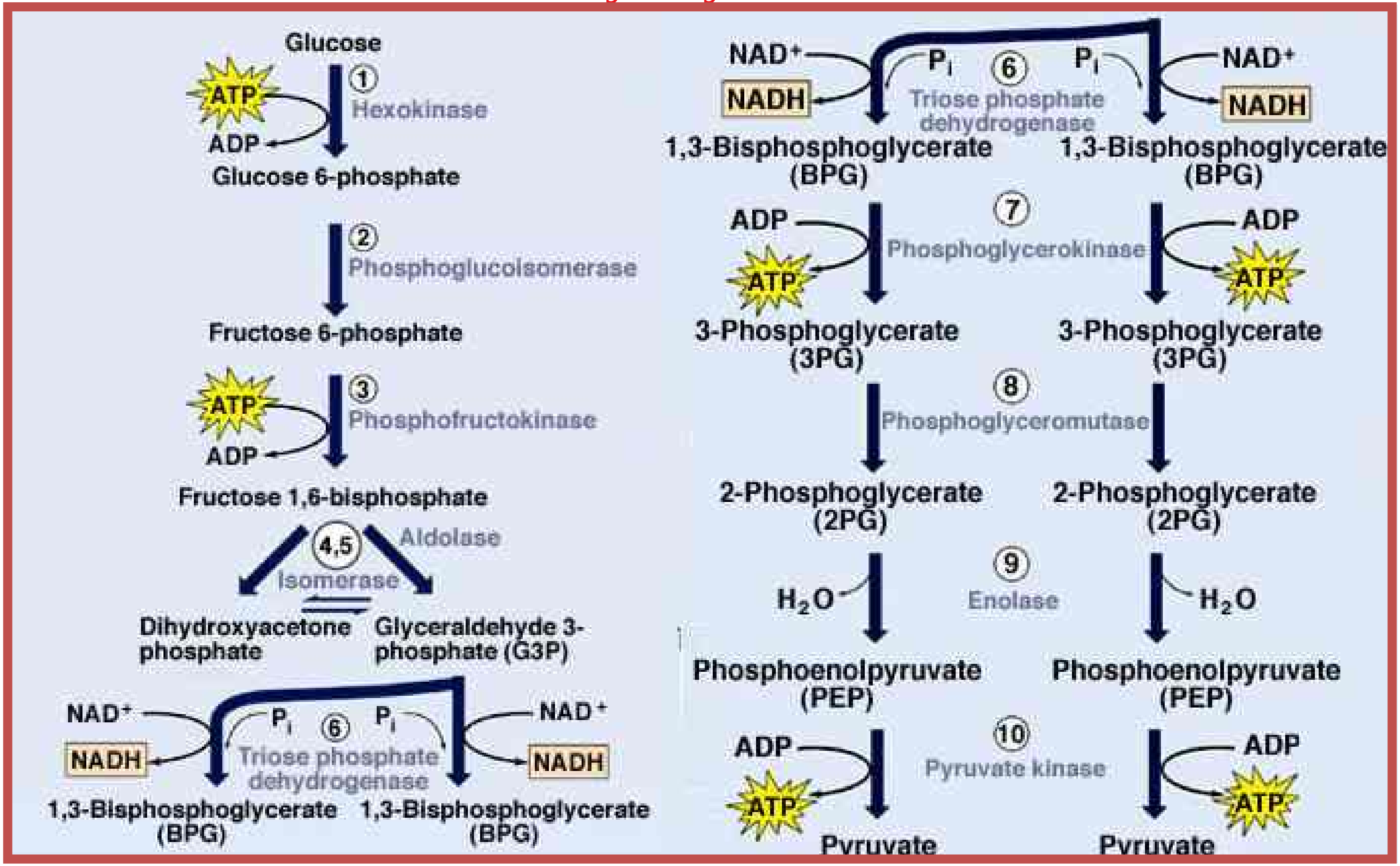


V_{max} = all enzymes are saturated
V_{max} =dependent on [E]
K_m independent of [E]
[E] high
Different amount of enzyme
[E] low
V_0
V_0
K_m (Michaelis-Menten constant)=0.5V_{max}
$\frac{1}{2} V_{max}$
specific [S]
Initial reaction rate (V_0)=V_{max} / (K_m + [S])
Substrate concentration [S]
K_m

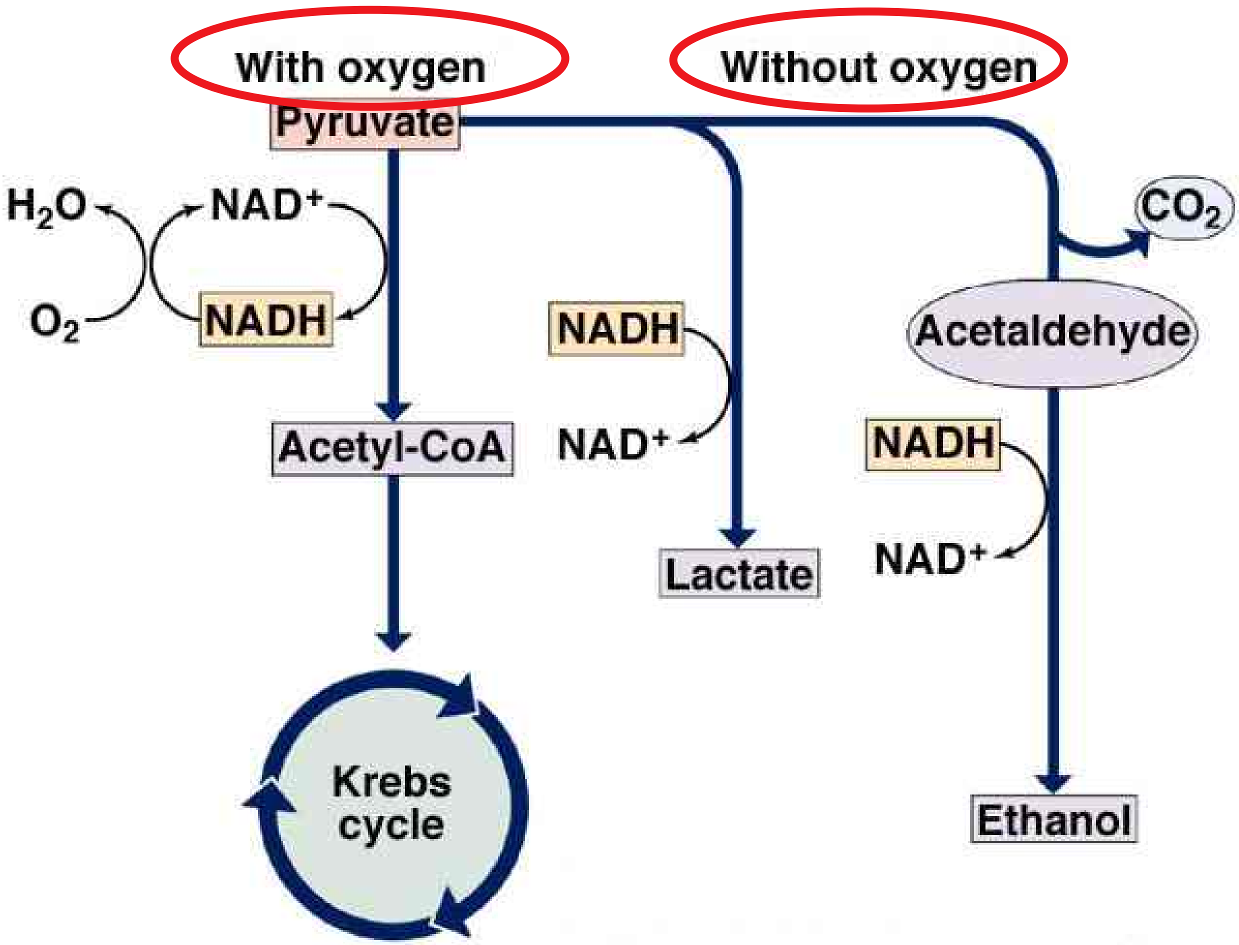
Cellular energy production from glucose



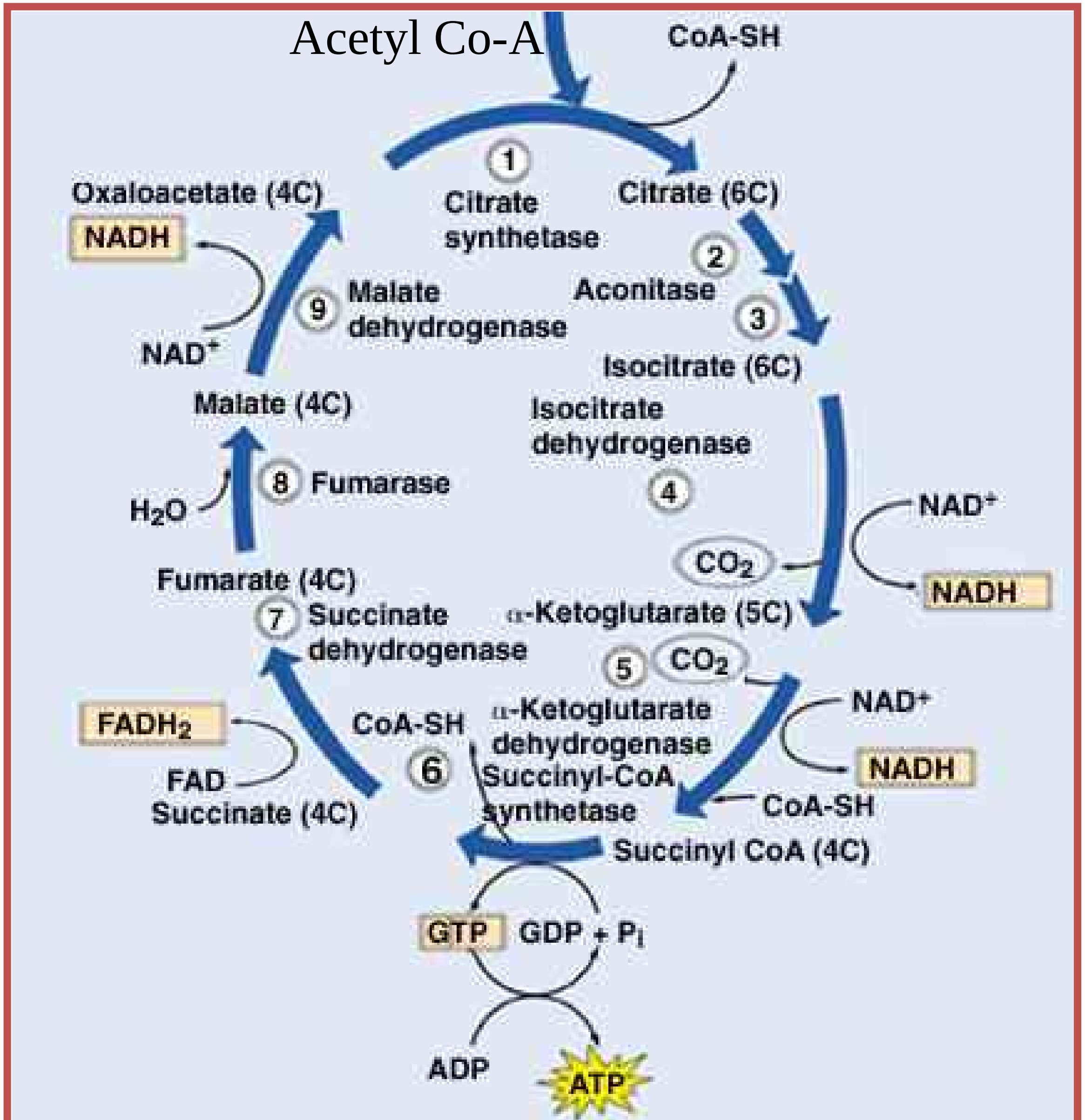
Cellular energy production from glucose
Glycolysis

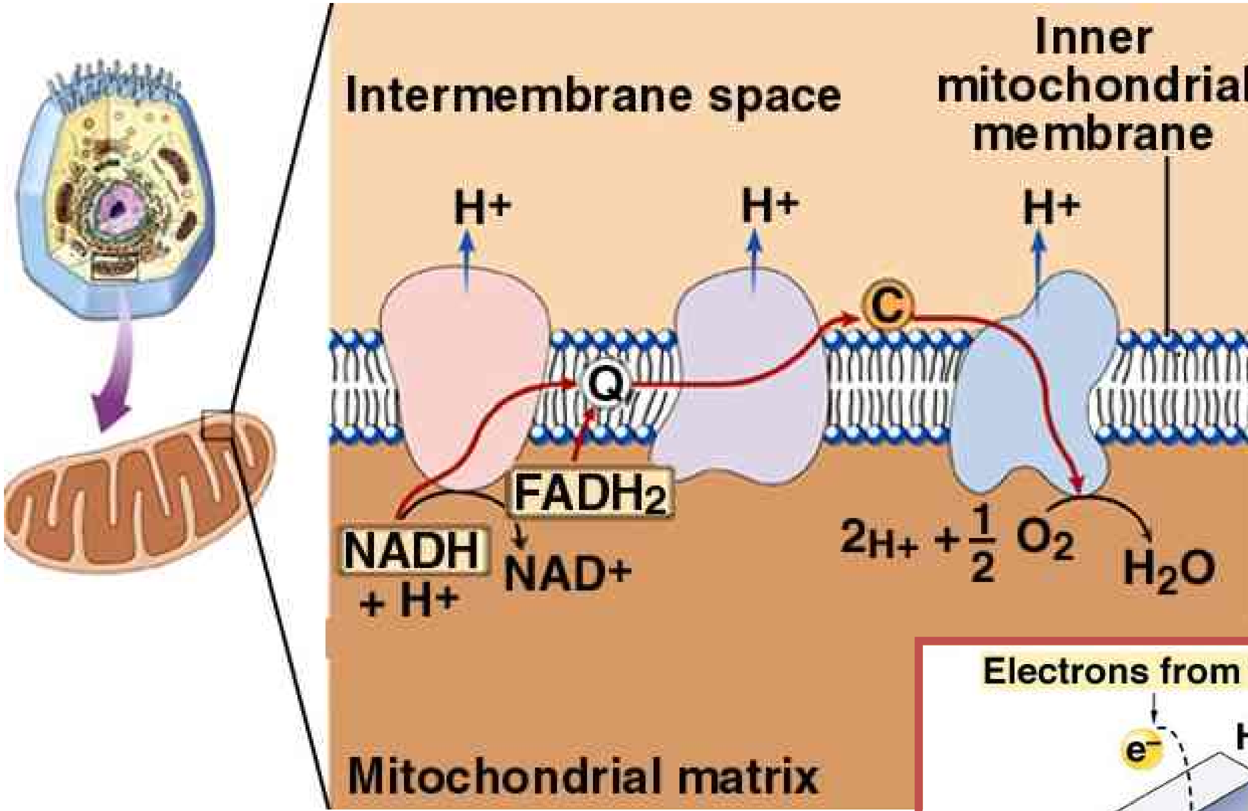


The fate of pyruvate



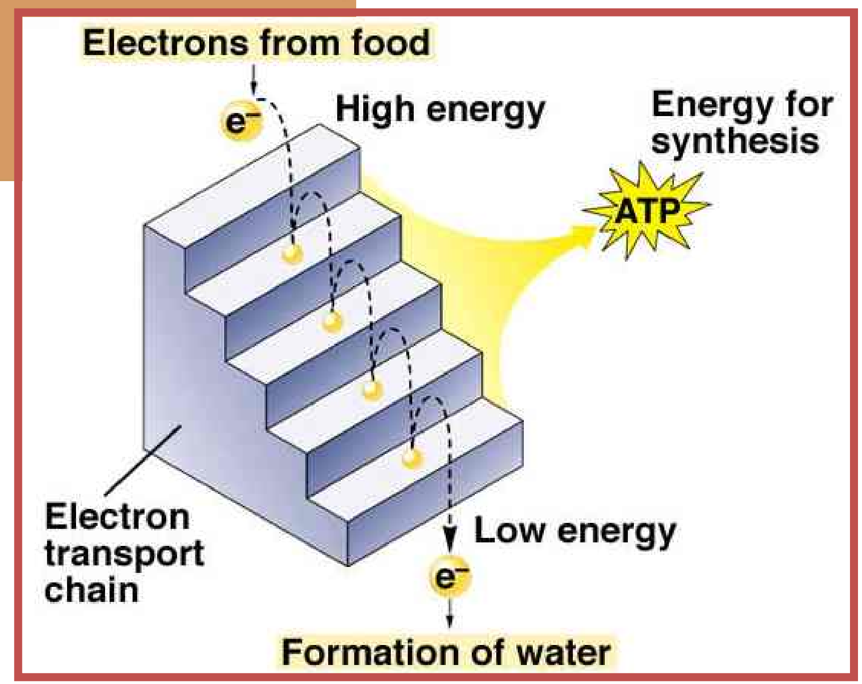
Cellular energy production from glucose
Krebs cycle, TCA cycle, oxidative phosphorylation



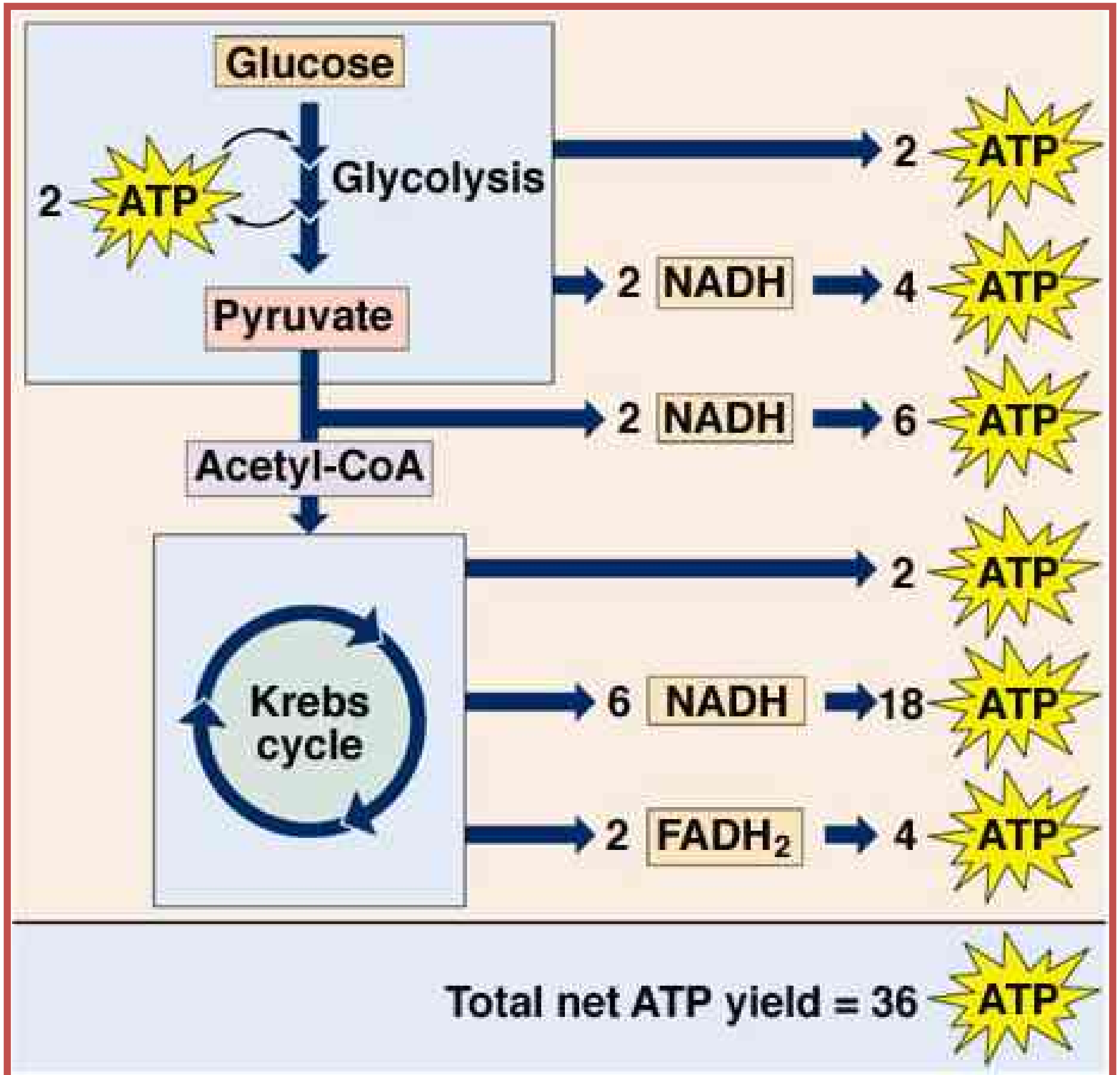


The final step in cellular energy production

The electron transport chain



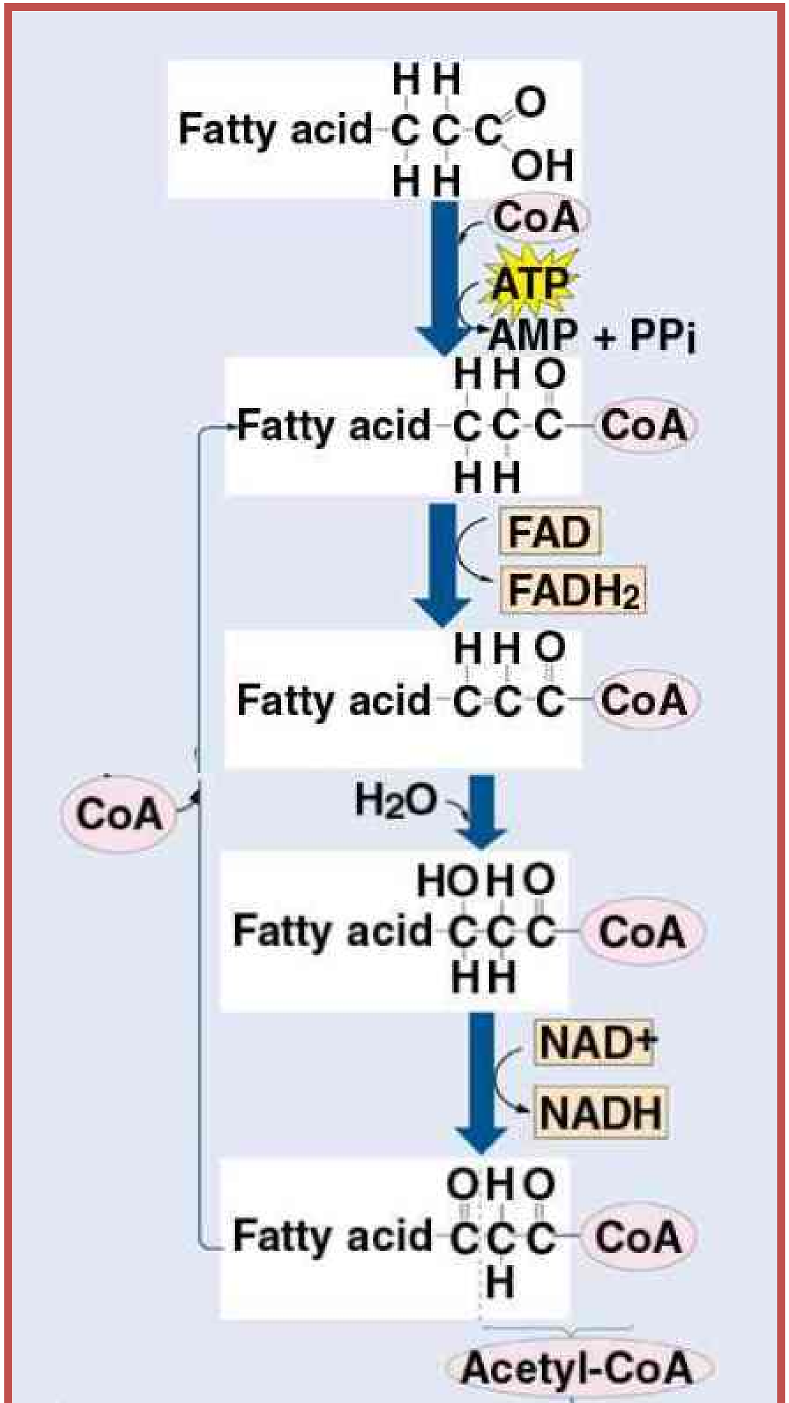
How much ATP is synthesized from 1 molecule of glucose (6 carbons)?



In reality:
NADH =2.5 ATP
$FADH_2$ =1.5 ATP
leaky membranes

10 NADH =25
2 $FADH_2$ = 3
ATP invested =-2
Direct ATP =4

Total 30 ATP



Beta oxidation of fatty acids, much more efficient !

Every round results in:
removal of 2 carbons
investment of 1 ATP

1 $FADH_2$ → 1.5 ATP
NADH → 2.5 ATP
1 Acetyl Co-A Invested → -1 ATP

3 NADH (2.5x3) =7.5 ATP
1 $FADH_2$ (1.5) =1.5 ATP
1 direct ATP = 1 ATP

Total ATP per 2 carbons = 13 ATP

30 ATP from glucose (6 carbon)
36 ATP from fatty acid (6 carbon)

20% more ATP

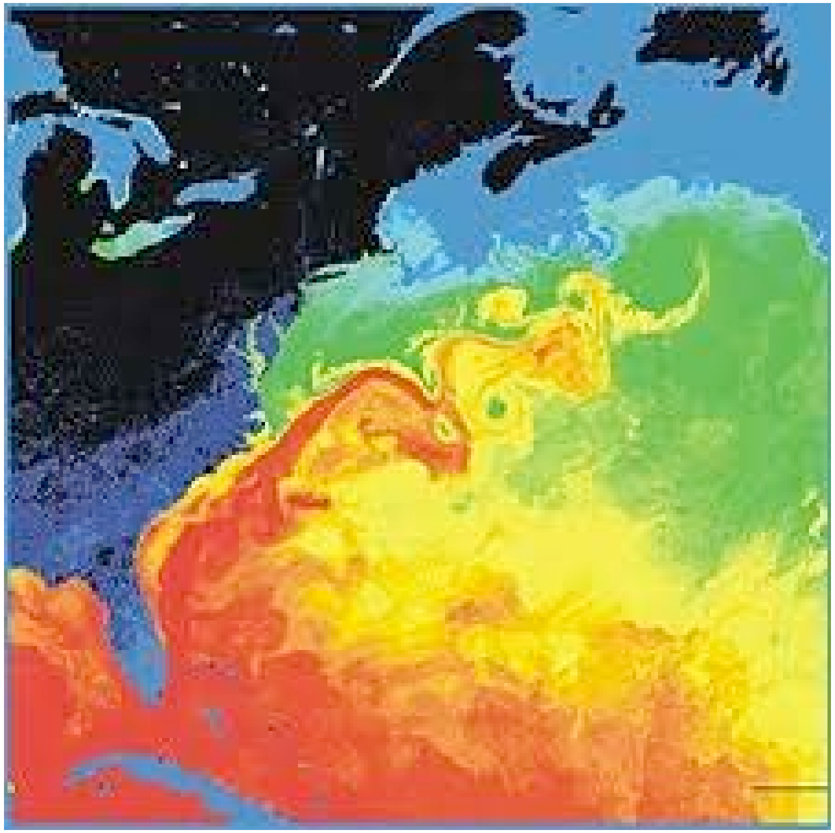
fatty acids have 16-120 carbons

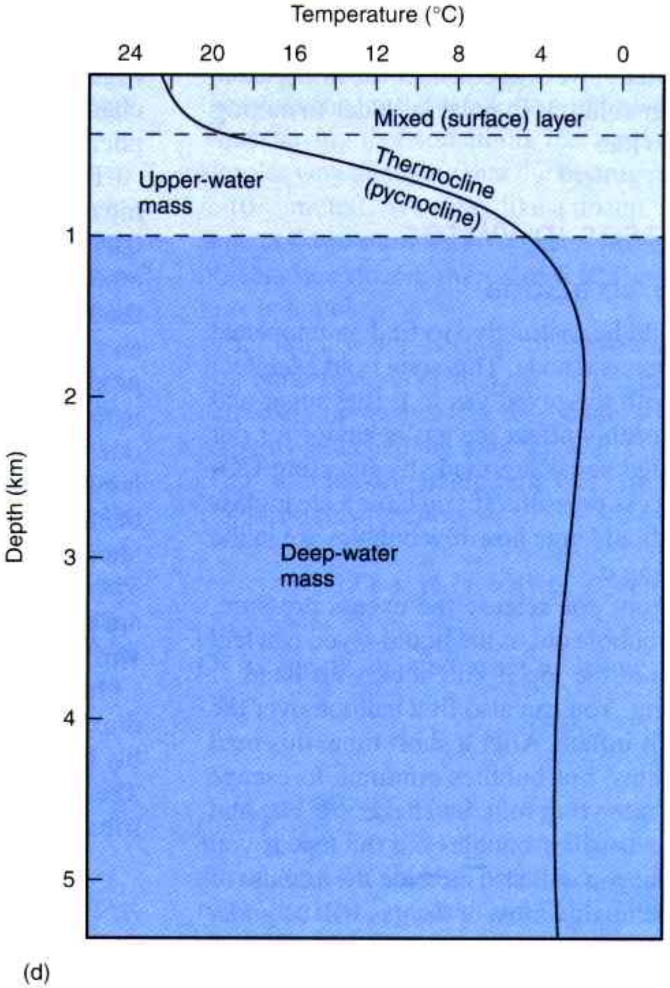
720 ATP

What is the swimming capacity in sharks?

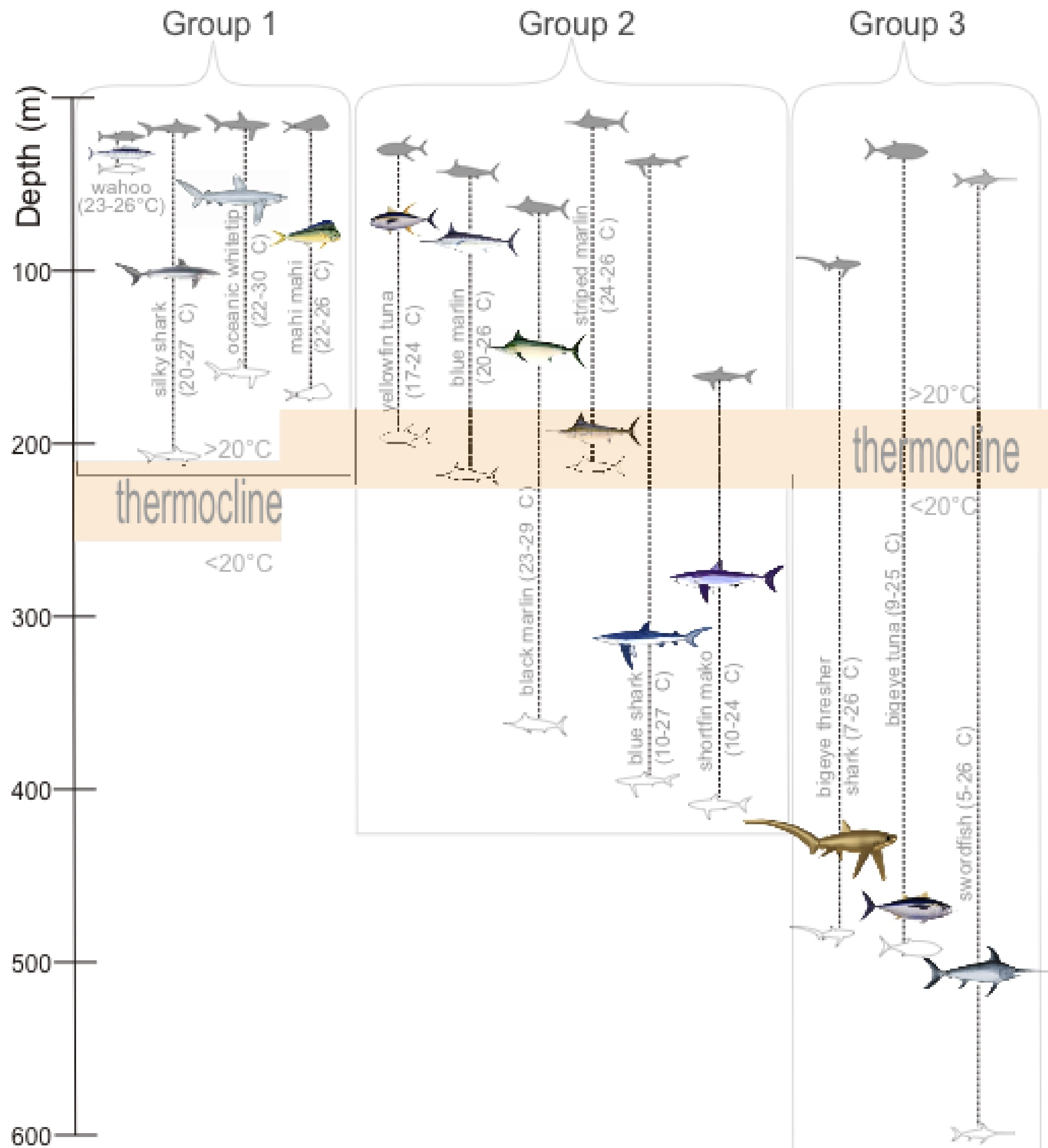
What type of swimming: aerobic (sustained, continuous)
anaerobic (burst)

At what temperature?



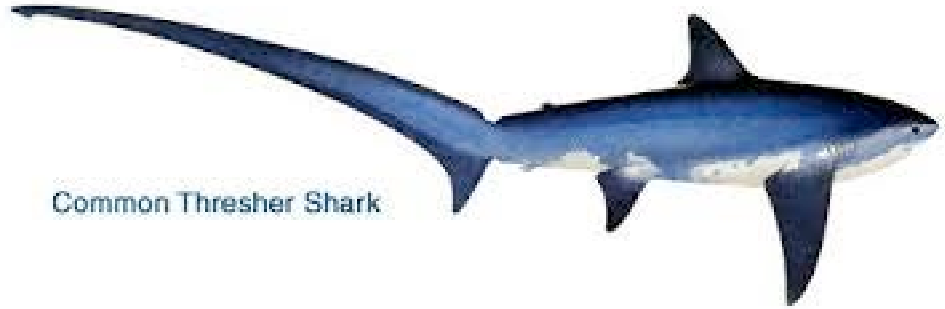


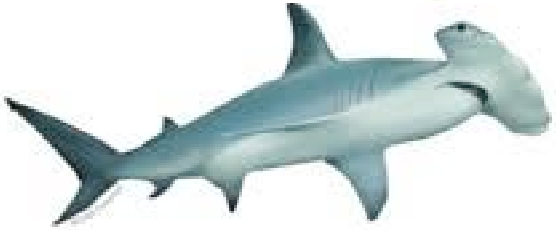
At what time?

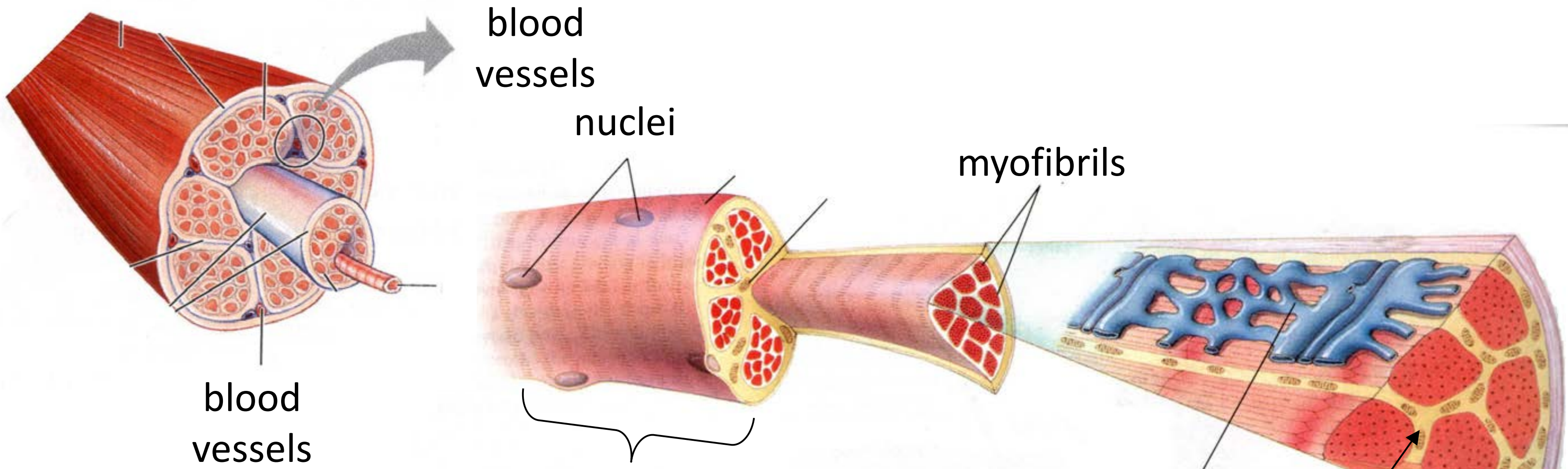

Group 1
Group 2
Group 3
Depth (m)
100
200
300
400
500
600
wahoo (23-26°C)
silky shark (20-27 C)
oceanic whitetip (22-30 C)
mahi mahi (22-26 C)
>20°C
thermocline
<20°C
yellowfin tuna (17-24 C)
blue marlin (20-26 C)
striped marlin (24-26 C)
black marlin (23-29 C)
blue shark (10-27 C)
shortfin mako (10-24 C)
bigeye thresher shark (7-26 C)
bigeye tuna (9-25 C)
swordfish (5-26 C)

What is the swimming capacity in sharks?

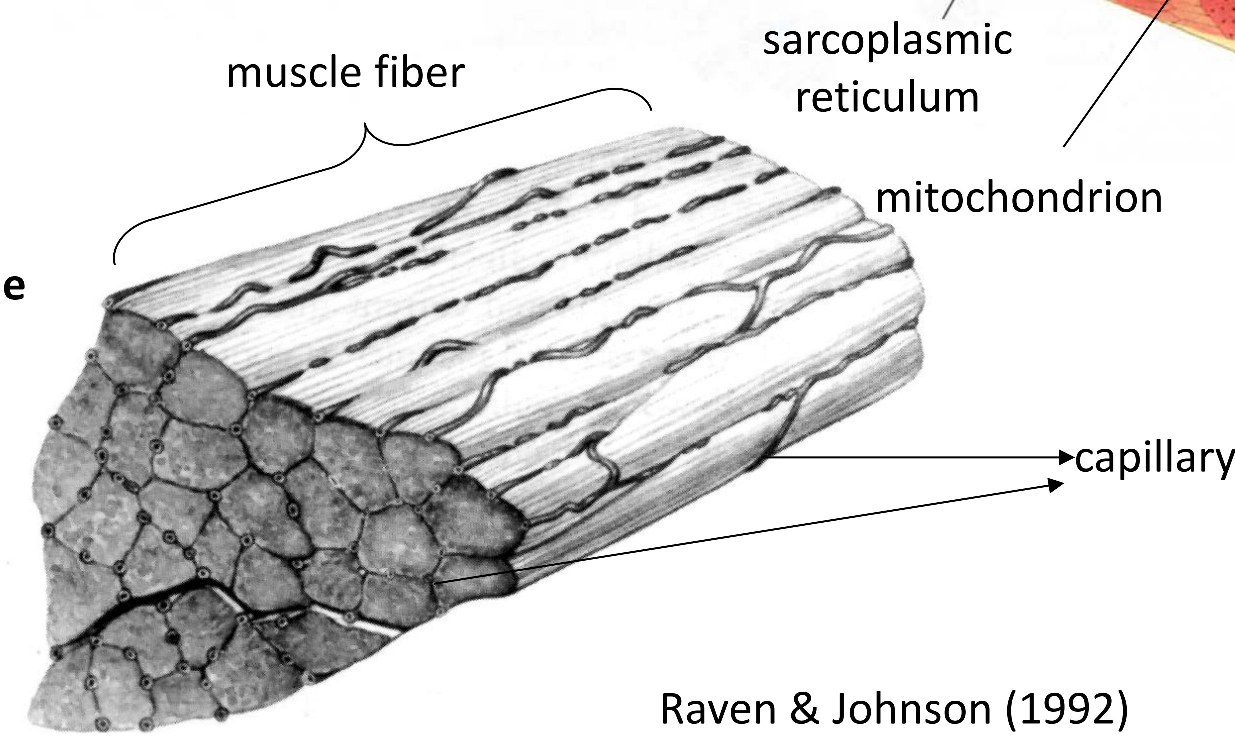
What species are being compared and why?







- **muscle amount**
- **capillary density**
- **fiber size**
- **muscle myoglobin**
- **mitochondria volume**
- **enzyme activities**
- **thermal effects**

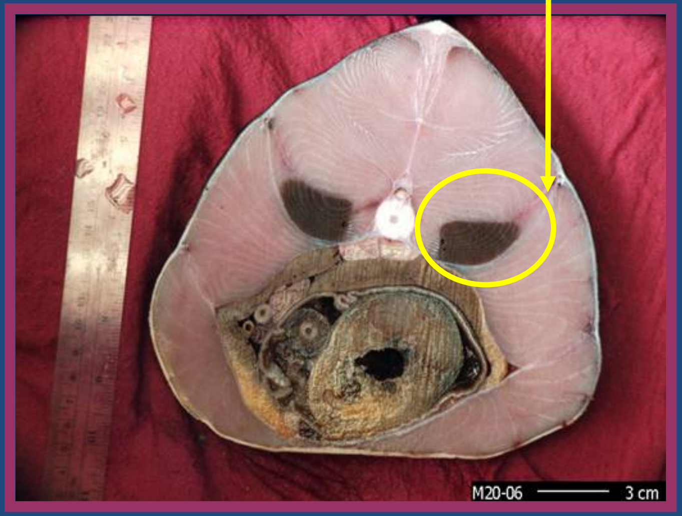


Raven & Johnson (1992)
Mathieu-Costello & Hepple (2002)

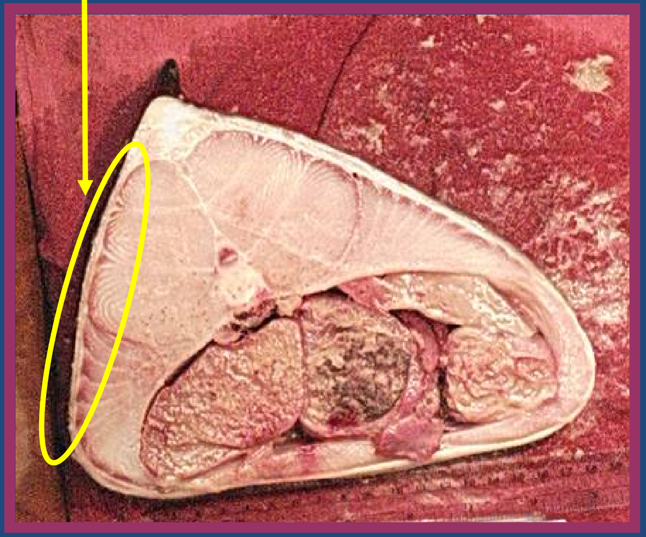
Different red muscle positions

Internal External

mako shark



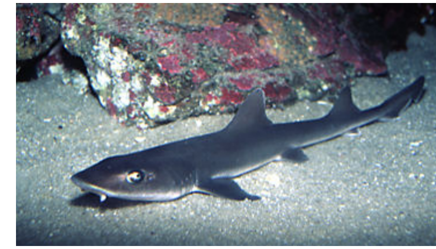
blue shark



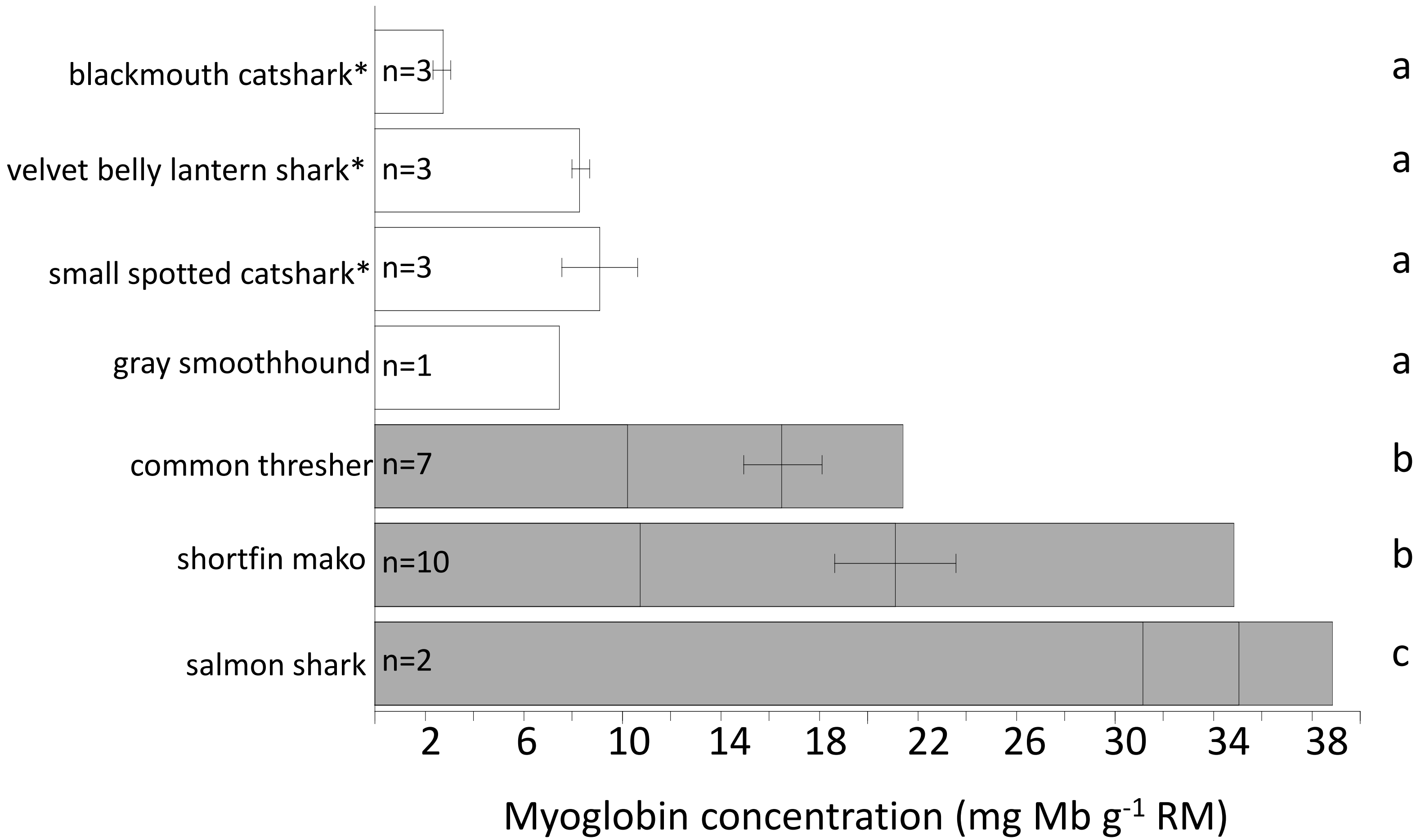
blackmouth catshark

velvet belly lantern shark

small spotted catshark



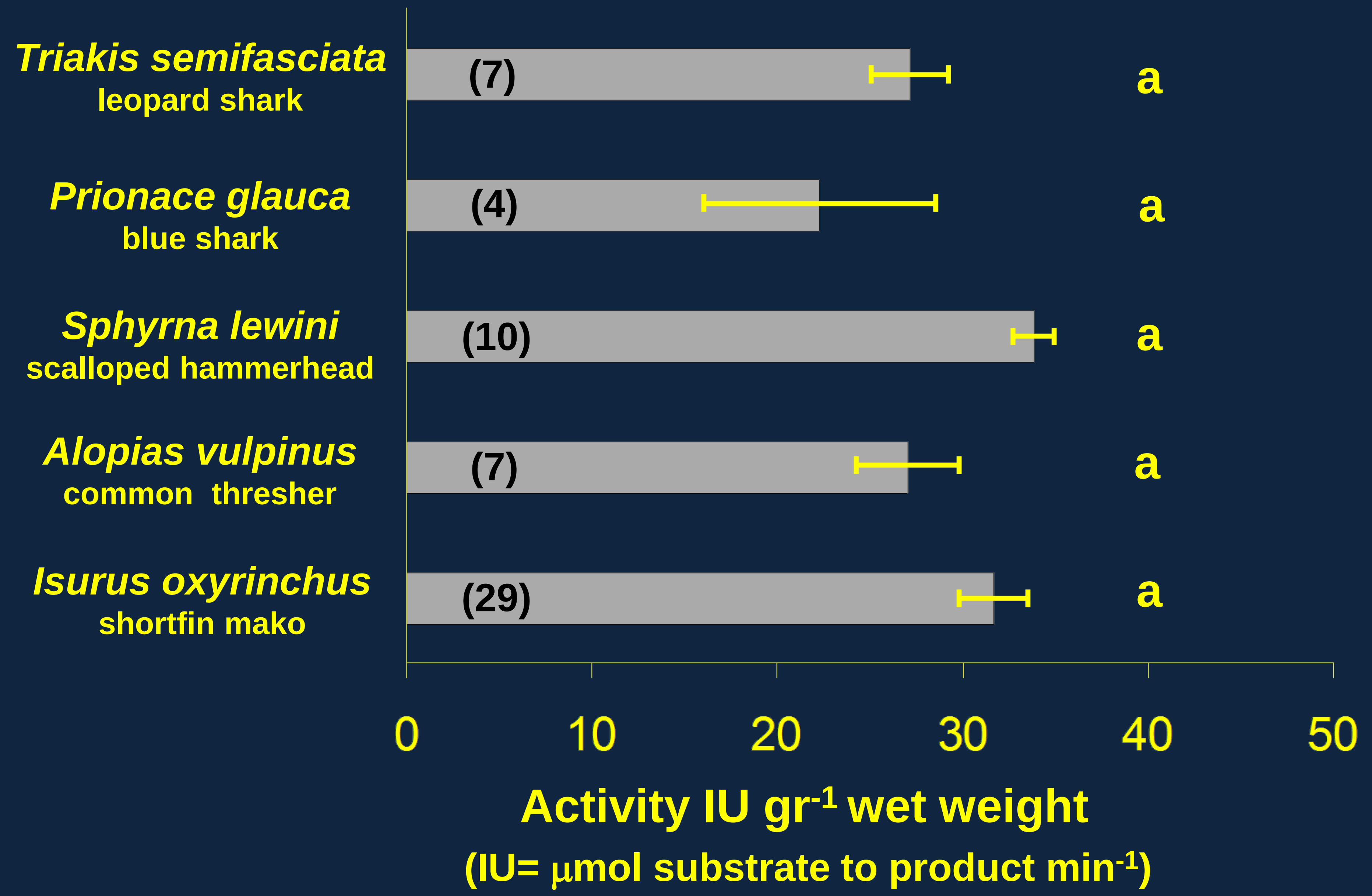
gray smoothhound

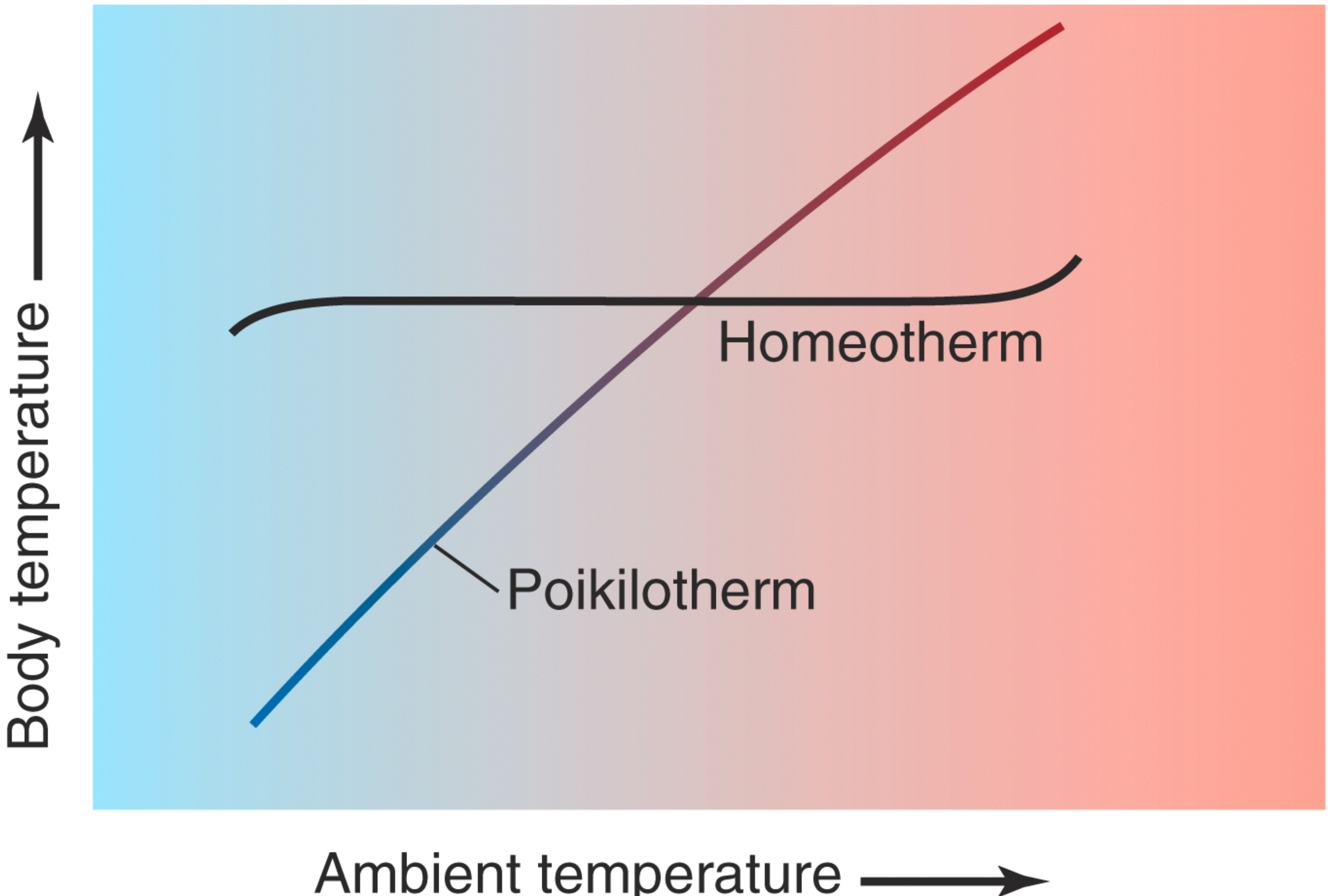


*Kryvi *et al*. (1981)

values = mean ± SEM

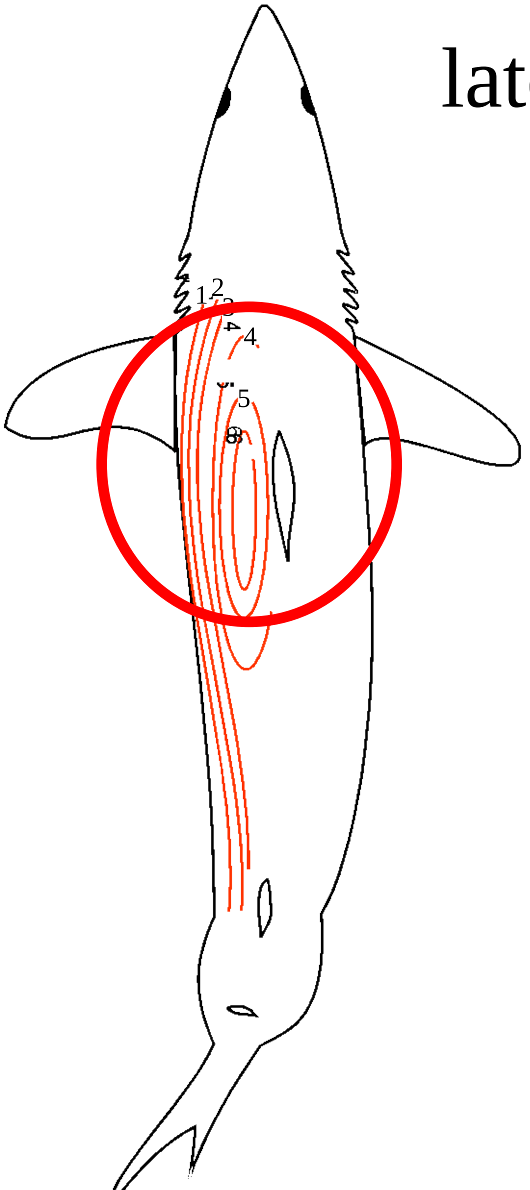
CS in RM at 20ºC

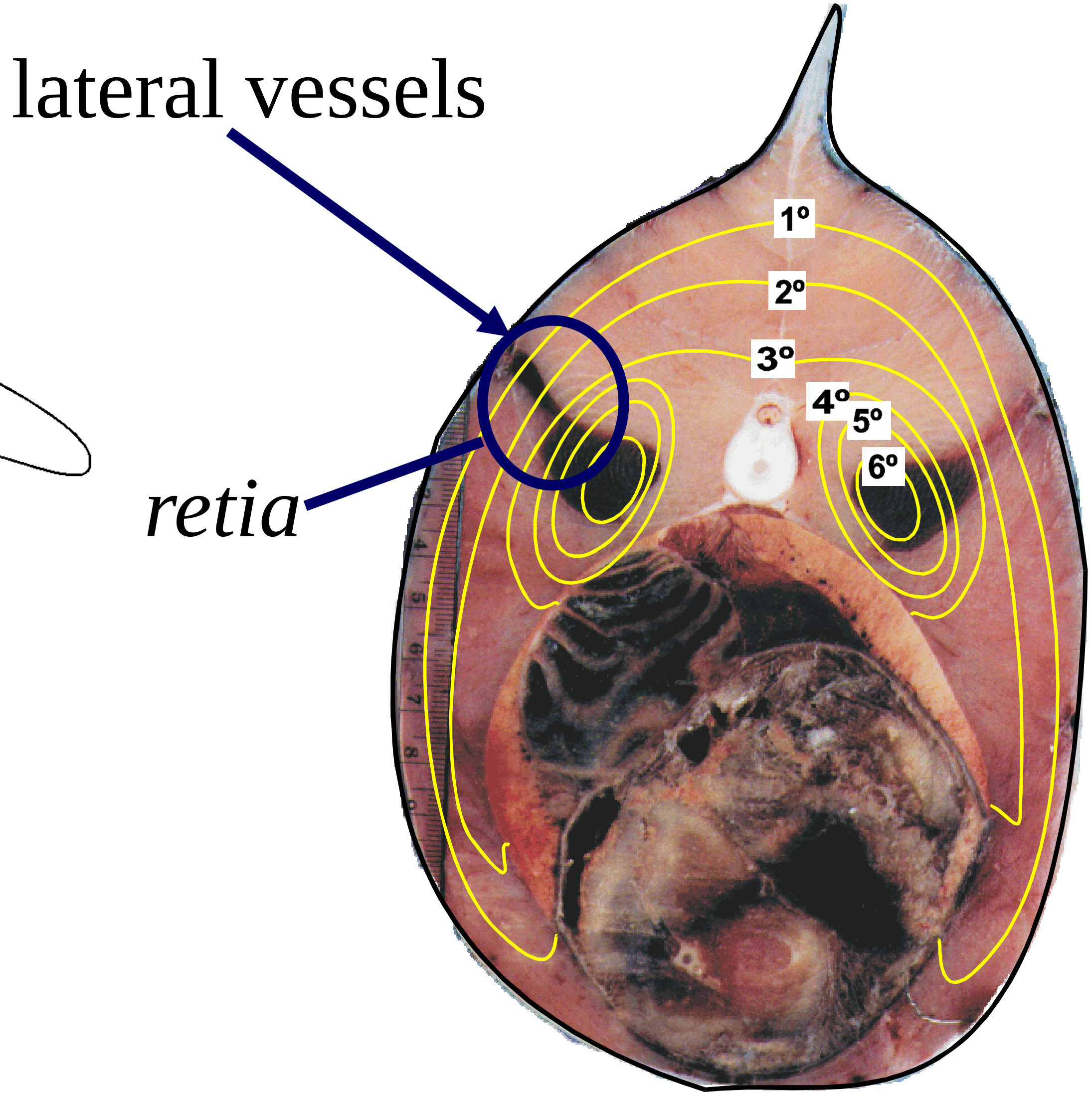



Body temperature
Homeotherm
Poikilotherm
Ambient temperature

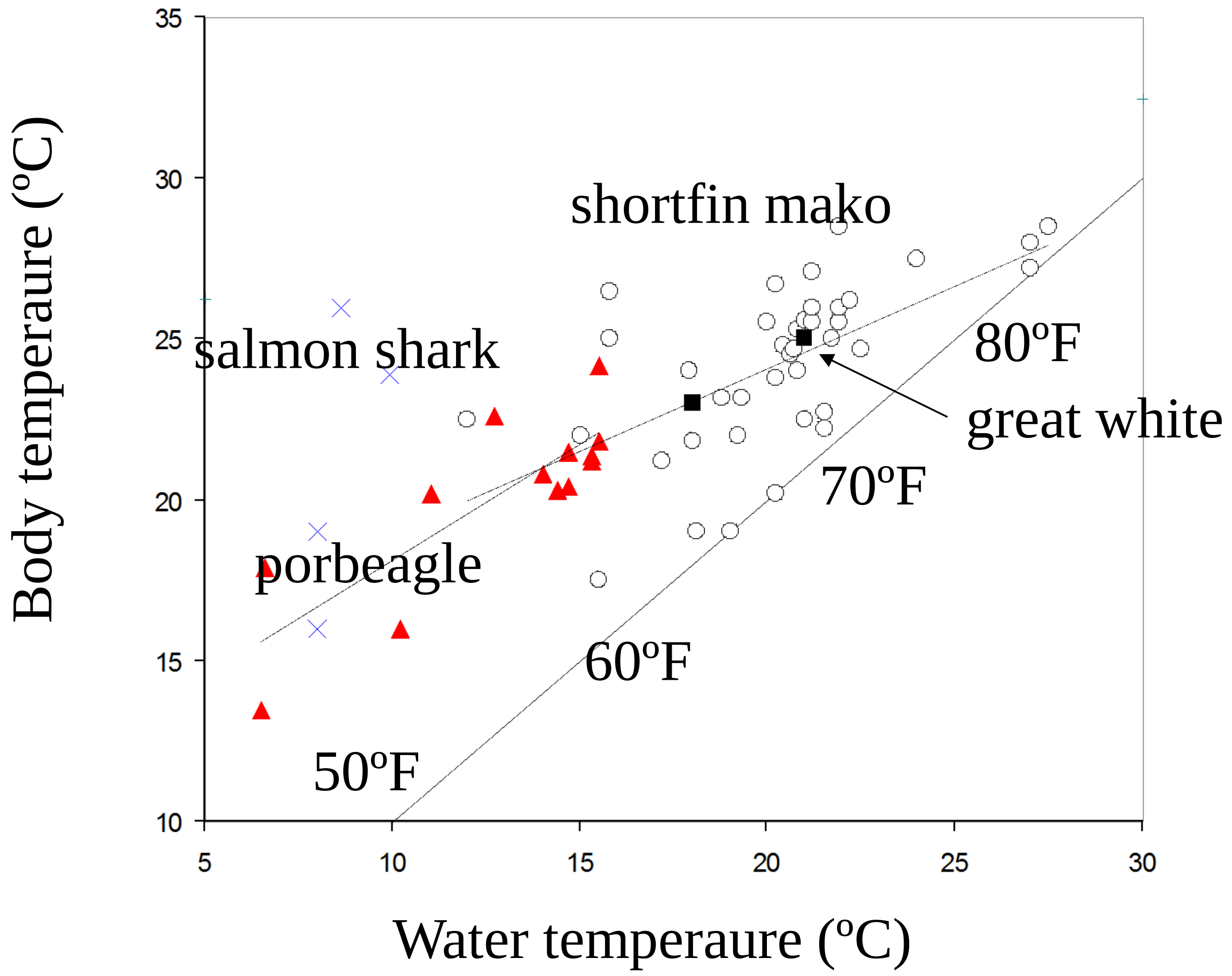
Warm Fish?

- **Elevated tissue temperatures (endothermy)**

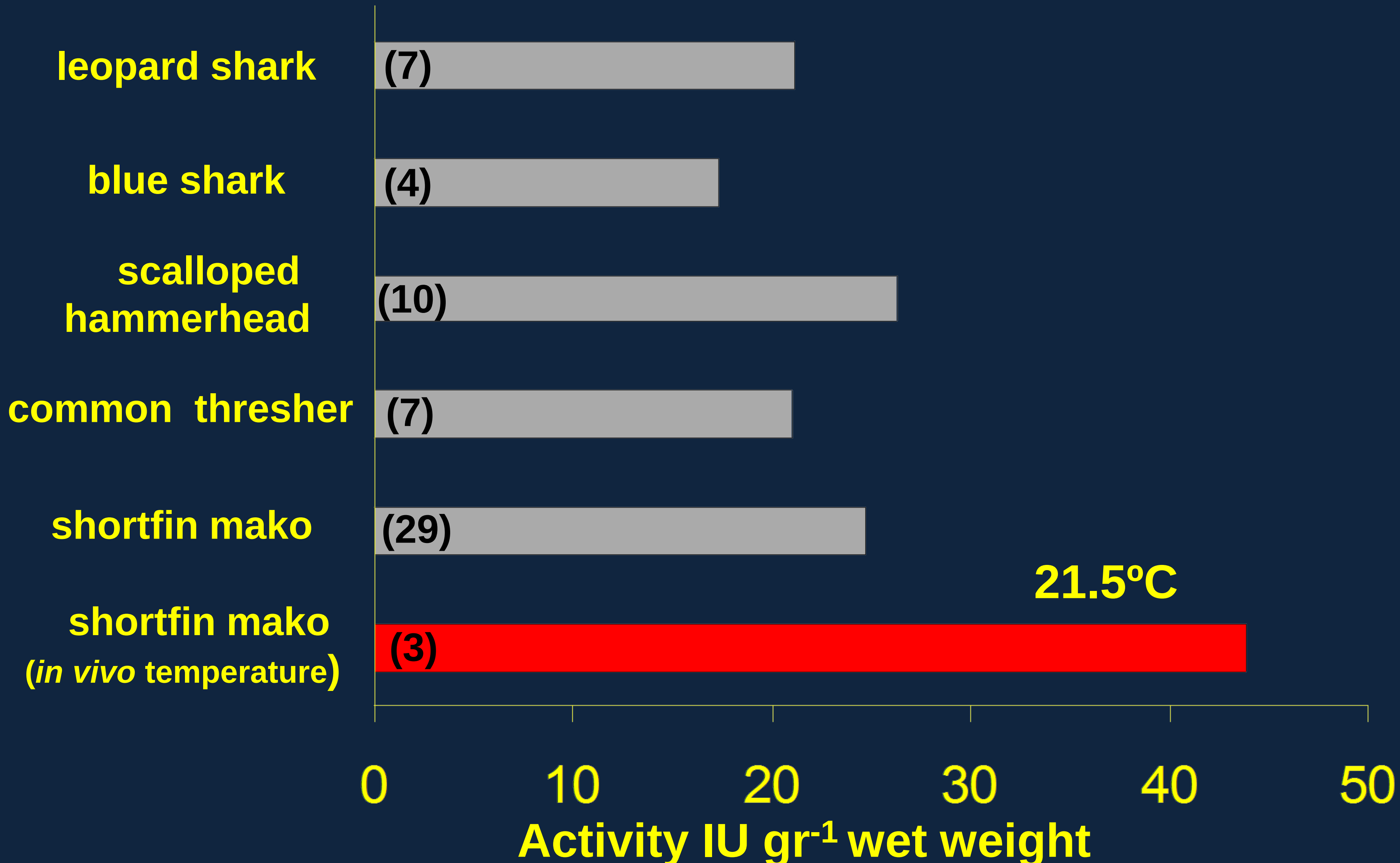




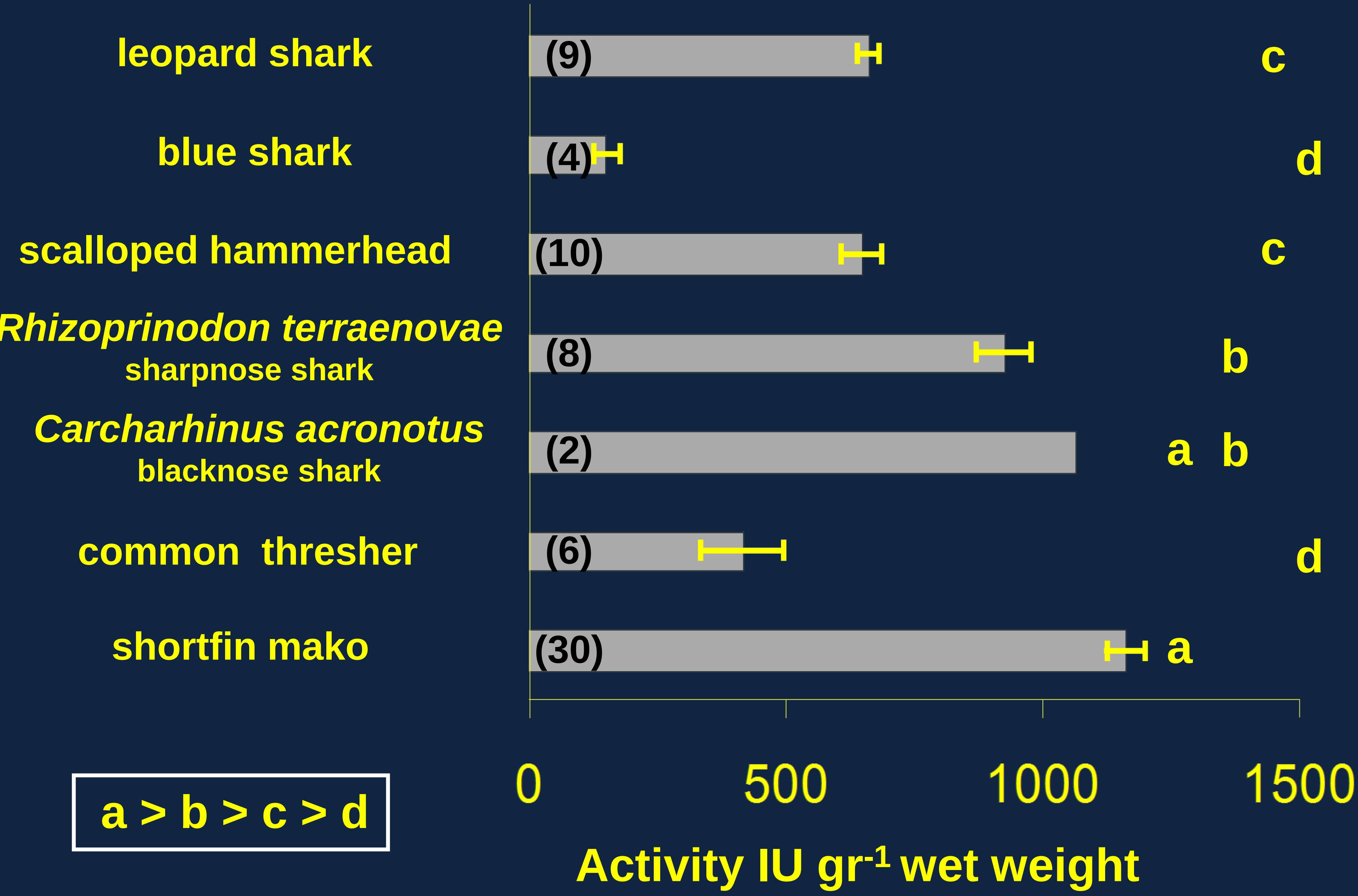
Body temperature of lamnids



CS in RM at 15ºC

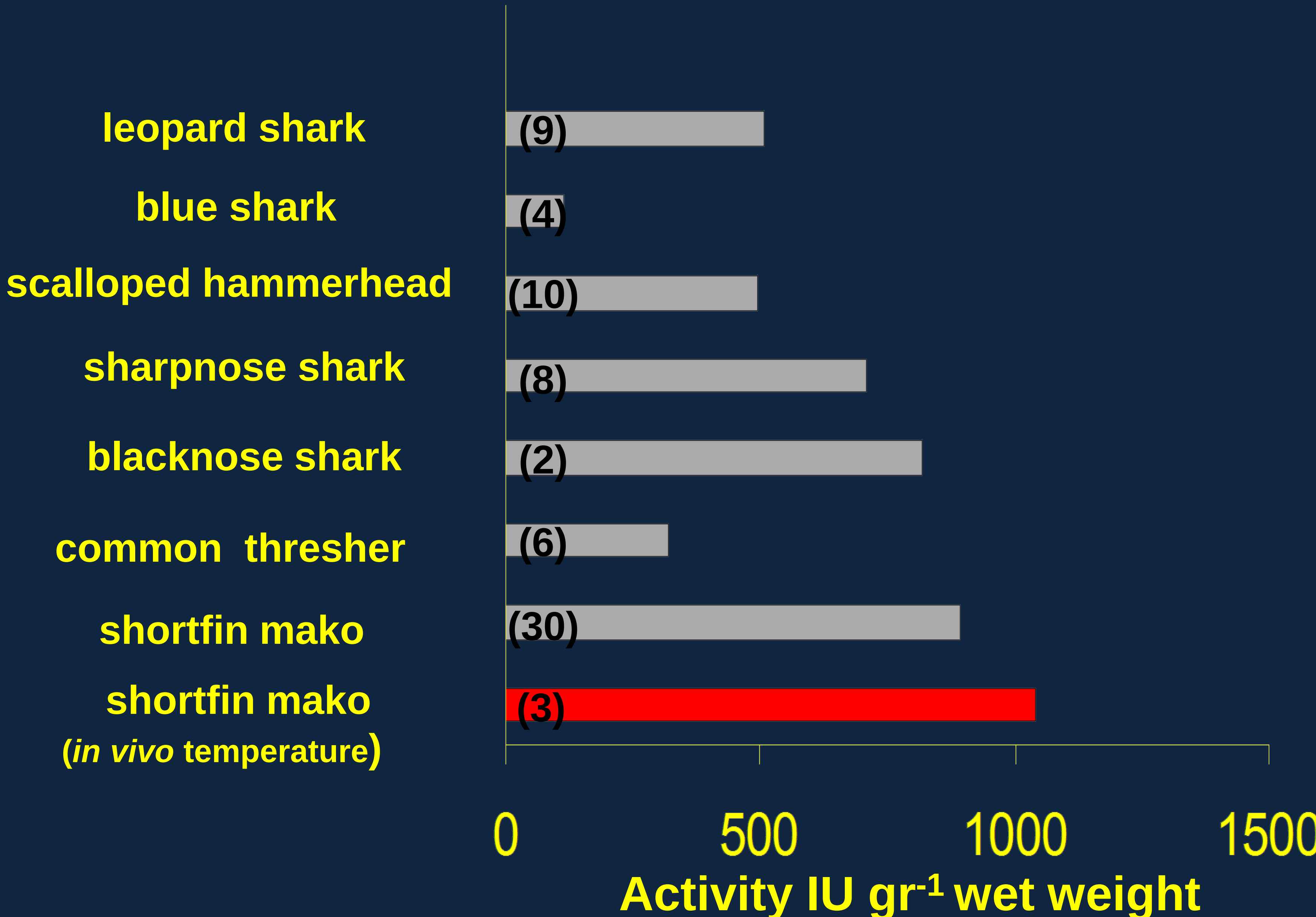


LDH in WM at 20ºC

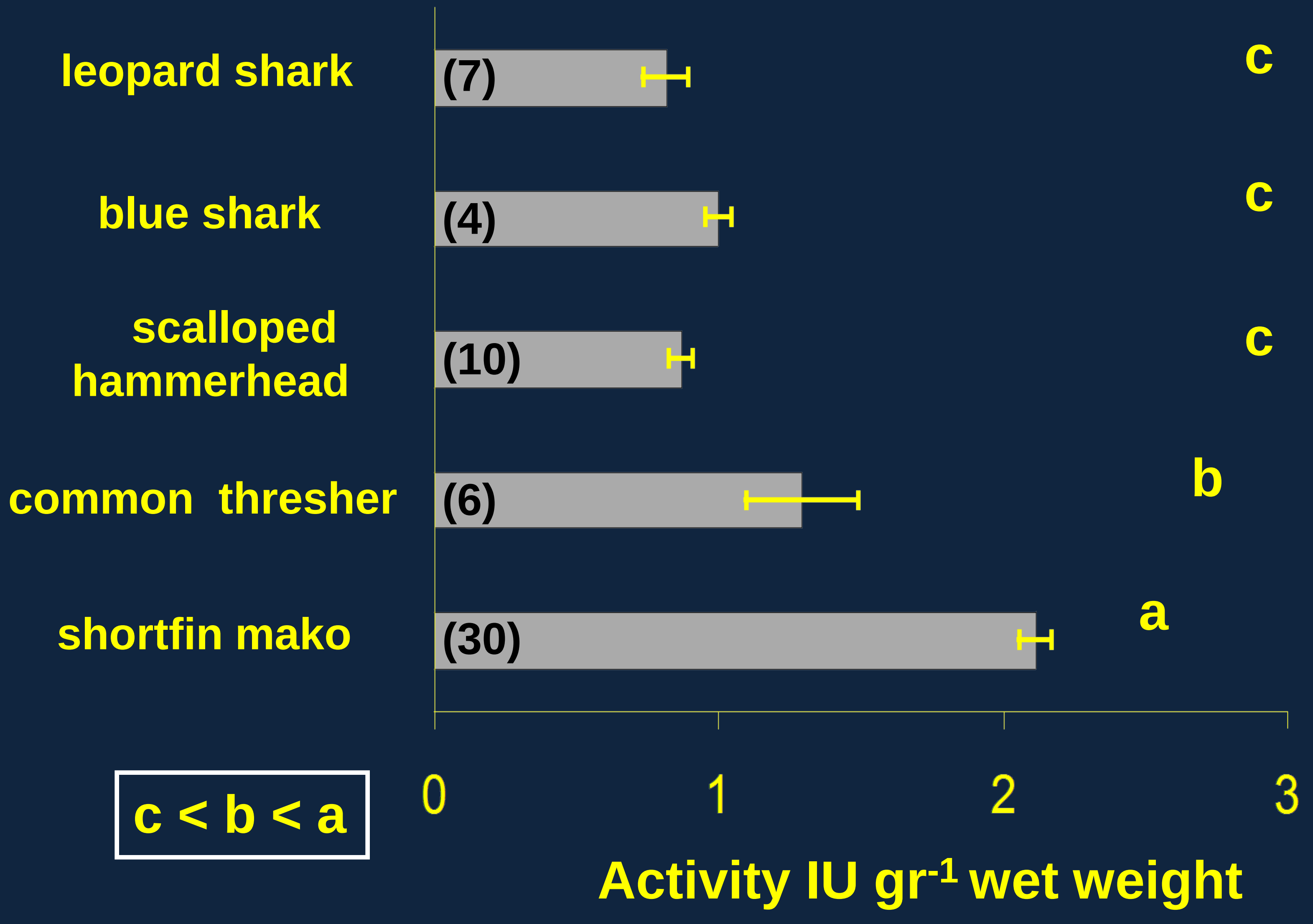


a > b > c > d

LDH in WM at 15ºC

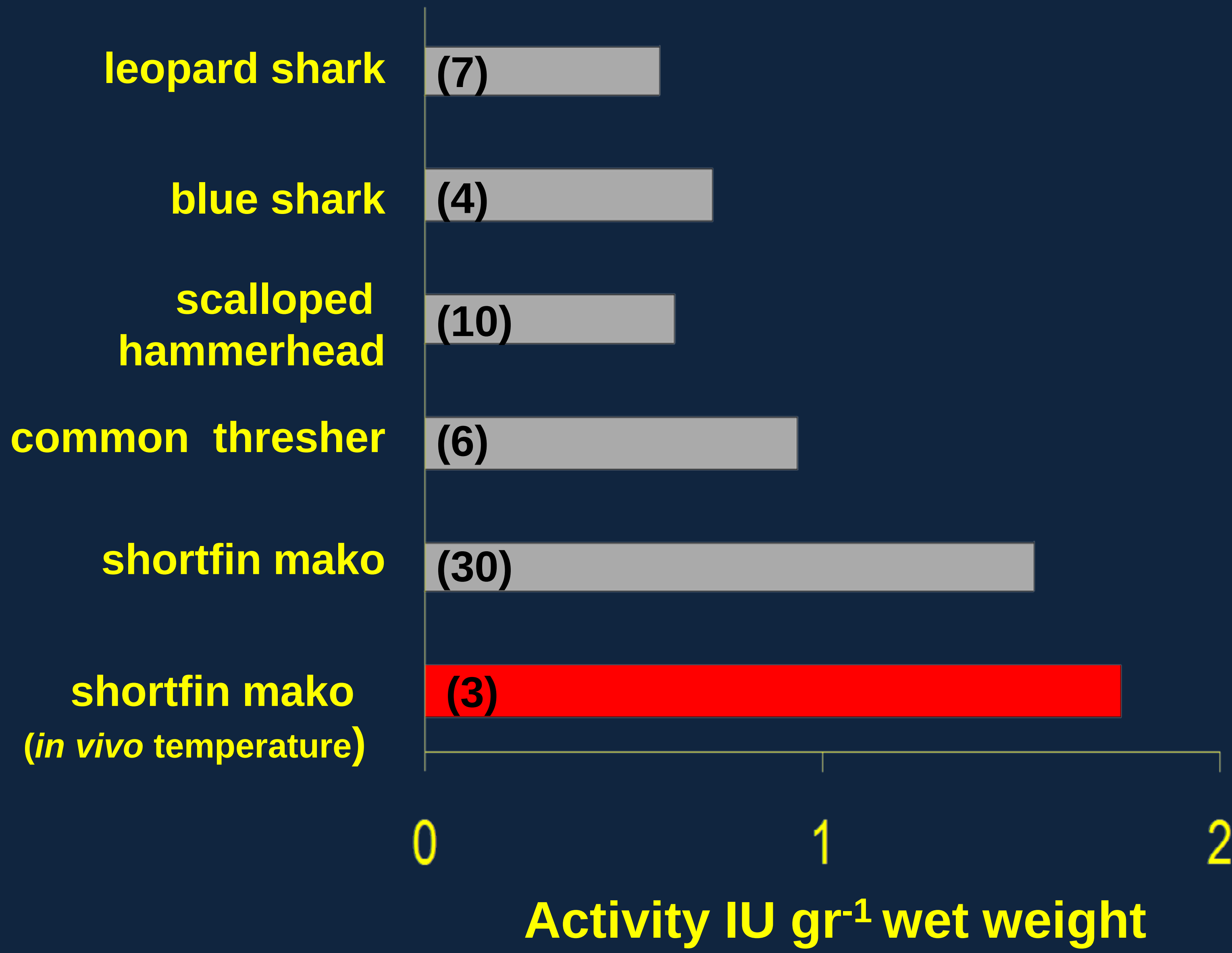


CS in WM at 20ºC



c < b < a

CS in WM at 15ºC



In summary:

Sustained swimming:

- RM has similar aerobic capacity when compared at the same temperature.

- temperature is important

- temperature enhances sustained swimming in some sharks

Enhanced sustained swimming is very energetically demanding

In summary:

Burst swimming:

- WM does not have similar anaerobic capacities when compared at the same temperature.

- temperature is important

- temperature enhances burst swimming in some sharks

- recovery from burst swimming is species-specific

species-specific

Metabolic rate

The rate of energy consumption : Total energy use over time

1. indicates how much food animal needs
2. is a measure of total physiological activity
3. measures demand animals can place on an ecosystem

Ways to measure MR

A. Direct Calorimetry-measure heat output of an animal

calorie = energy needed to elevate 1g water by 1°C

B. Indirect Calorimetry- by way of oxygen consumption or CO_2 production

1 liter of oxygen consumed = 4.83kcal production (depending on diet)

Respiratory exchange ratio, *R:*

R= Moles of CO_2 produced per time / Moles of O_2 consumed per time

Value of 1= pure carbohydrate diet, = 0.7 lipid based diet

Standard Metabolic Rate (SMR) no activity, no digestion assimilation, no stress

Basal Metabolic Rate (BMR) usually applied to endotherms

Routine Metabolic Rate (RMR) averaged for all time

Maximum Metabolic rate (MMR) peak value or mean peak value

What affects MR:

Age
Gender
Body temperature
Environmental temperature
Type amount of food
Activity level
Homeostasis
Time of day
Body size