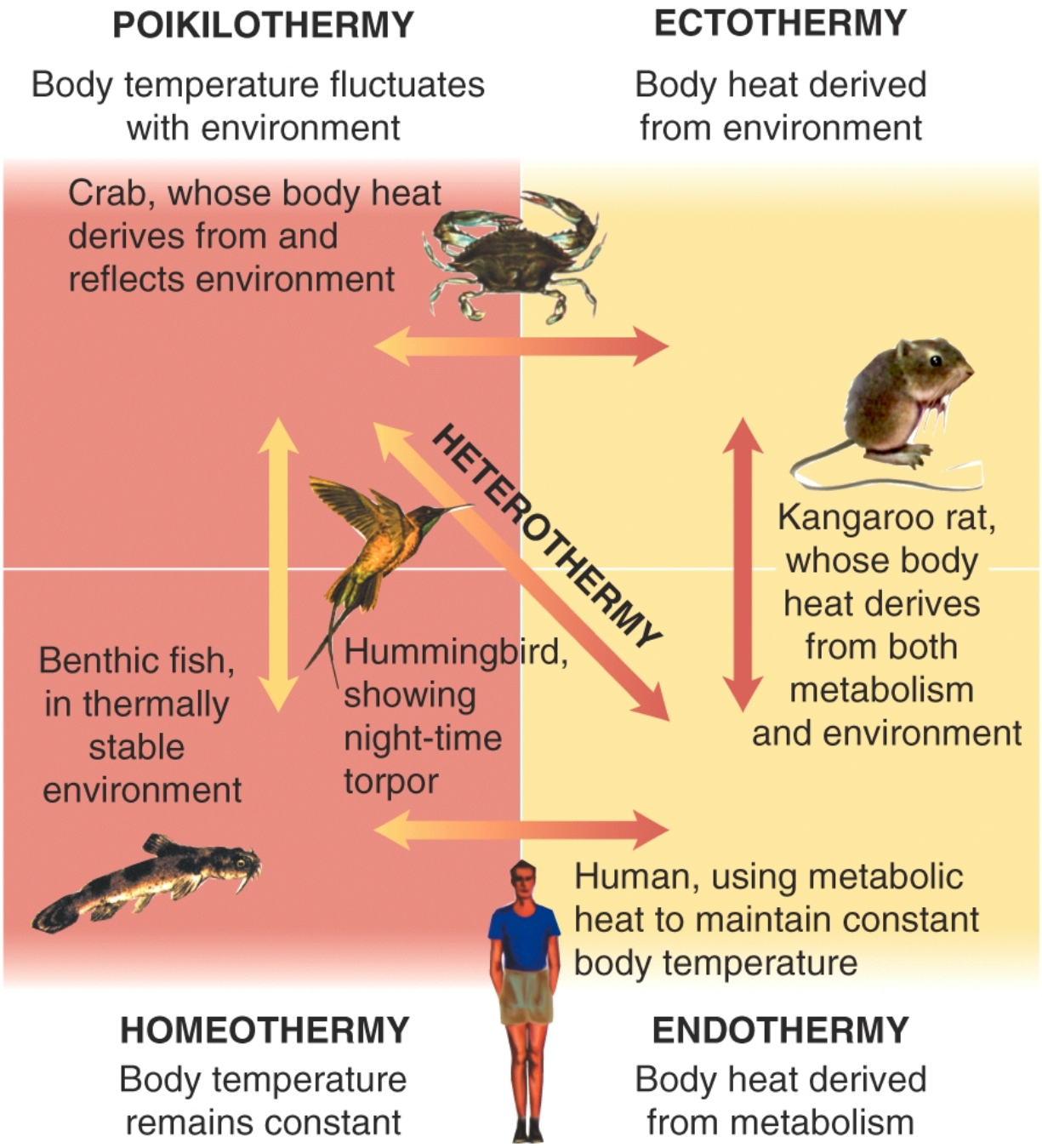
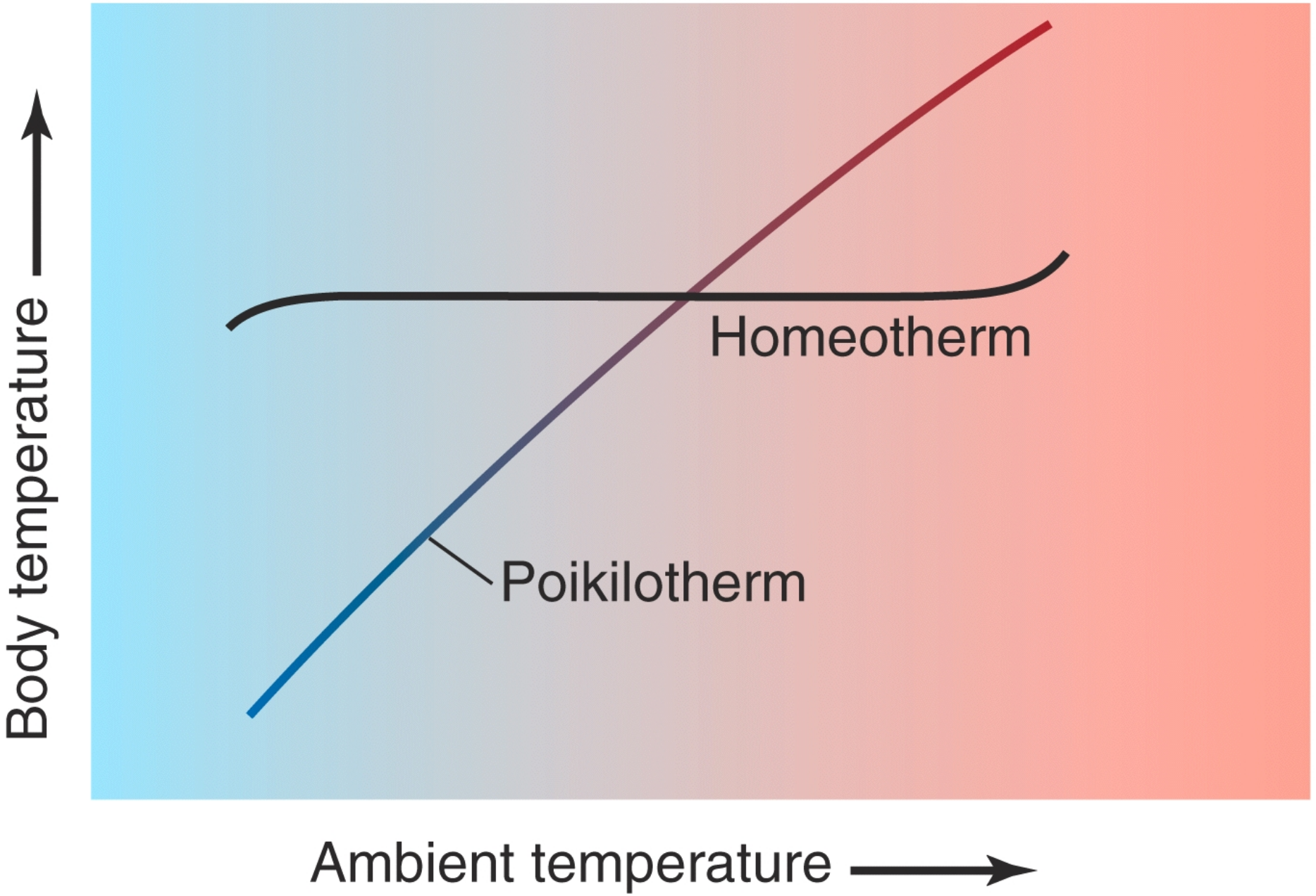
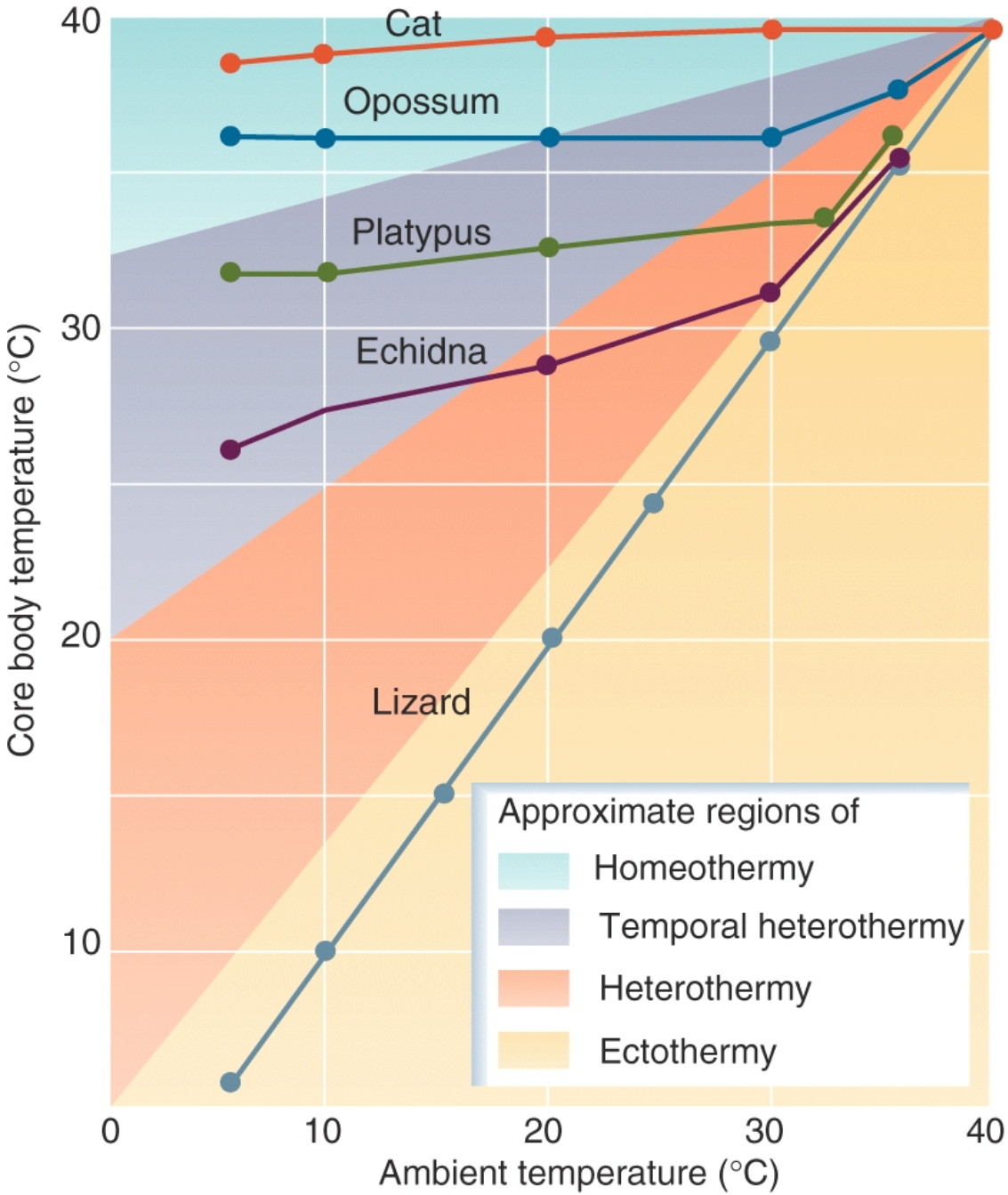
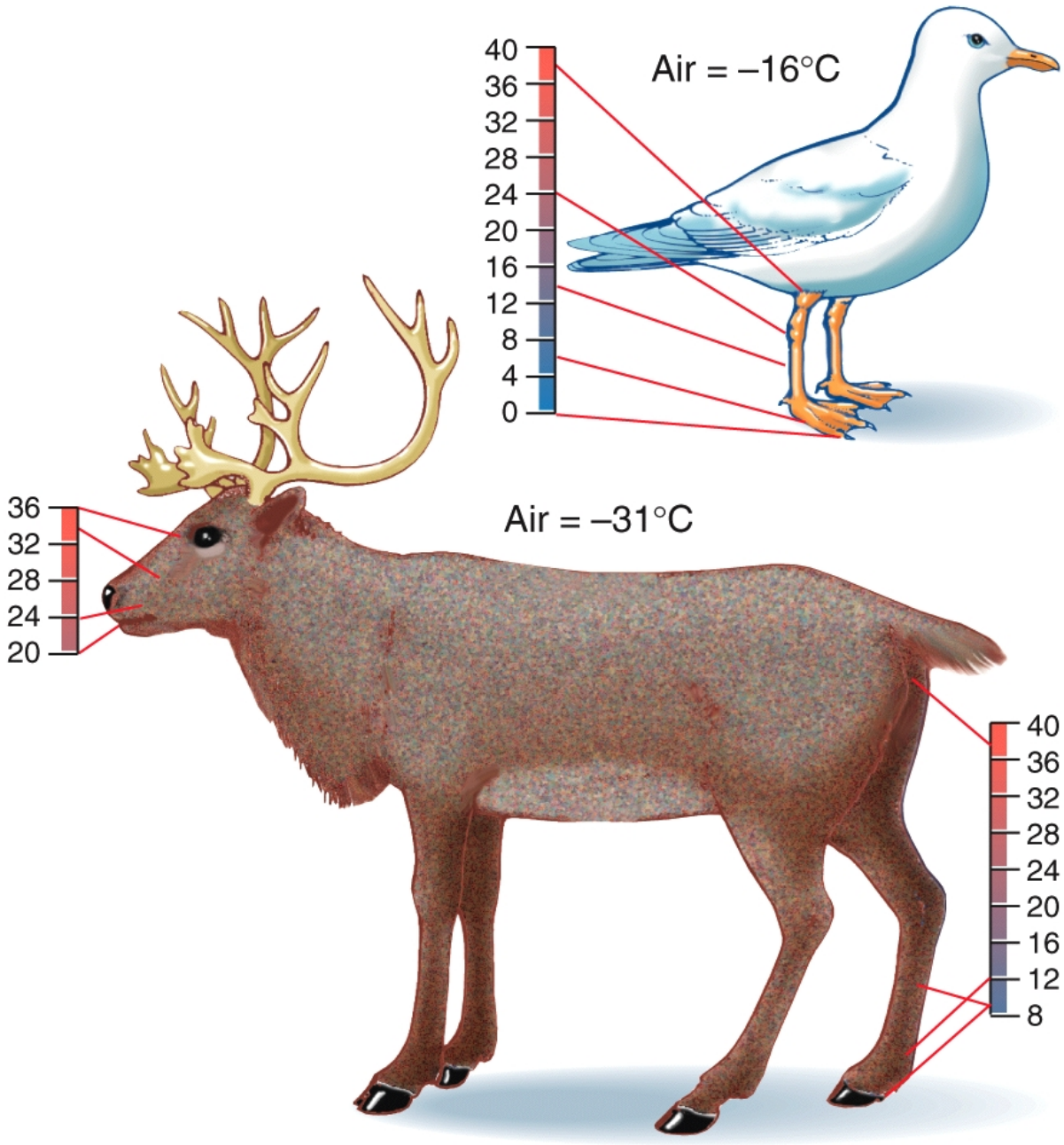
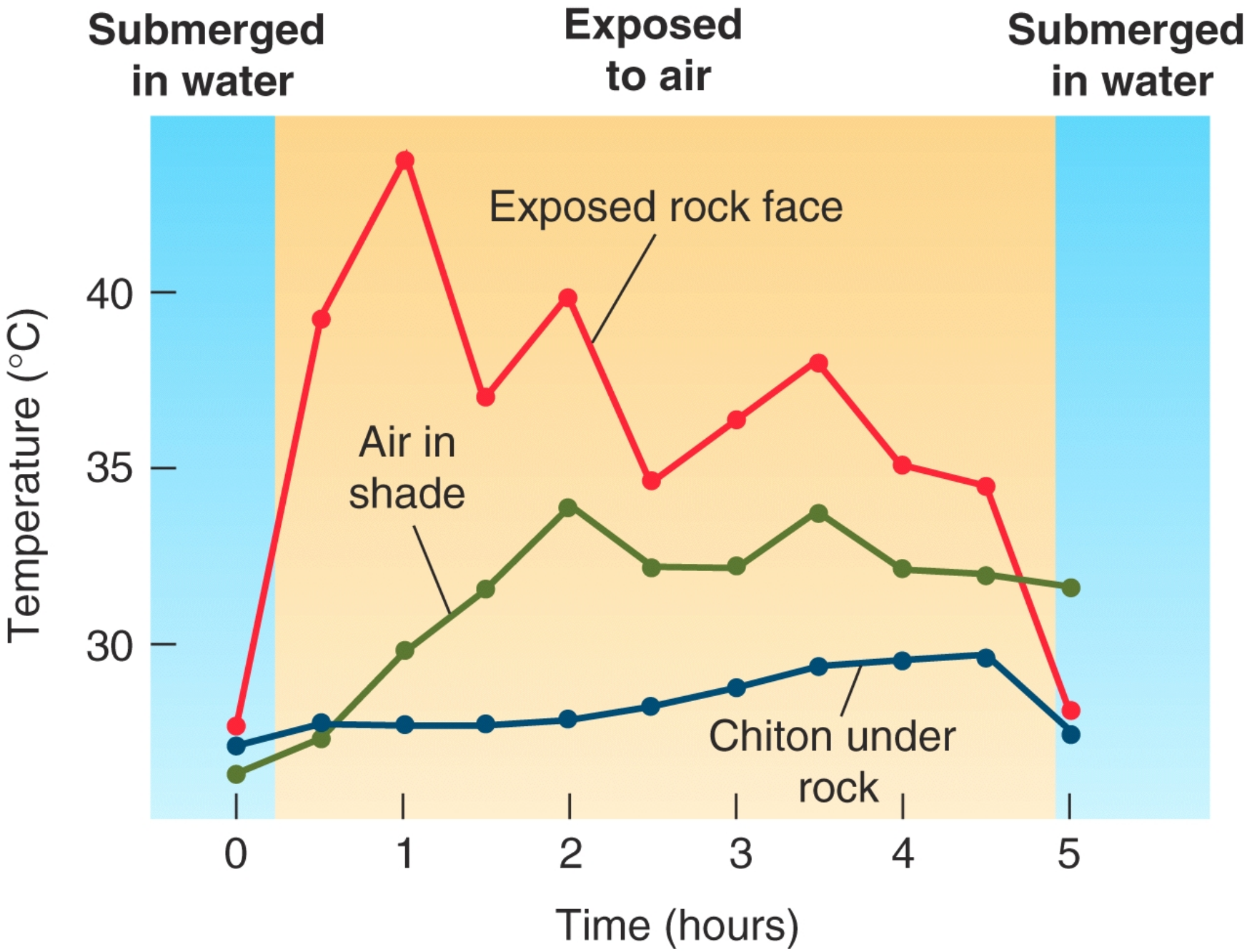
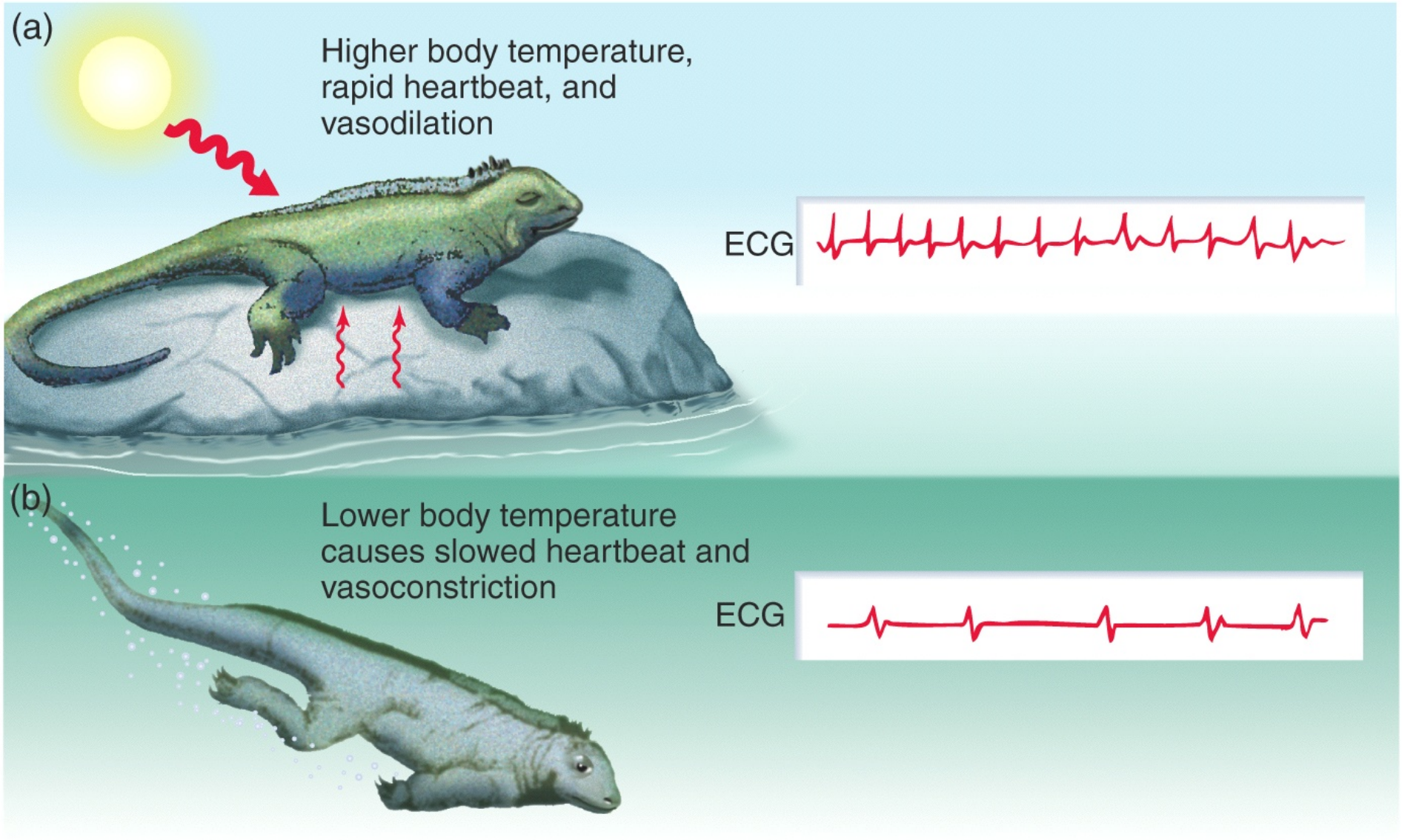

POIKILOTHERMY
Body temperature fluctuates with environment
ECTOTHERMY
Body heat derived from environment
Crab, whose body heat derives from and reflects environment
HETEROTHERMY
Kangaroo rat, whose body heat derives from both metabolism and environment
Benthic fish, in thermally stable environment
Hummingbird, showing night-time torpor
Human, using metabolic heat to maintain constant body temperature
HOMEOTHERMY
Body temperature remains constant
ENDOTHERMY
Body heat derived from metabolism

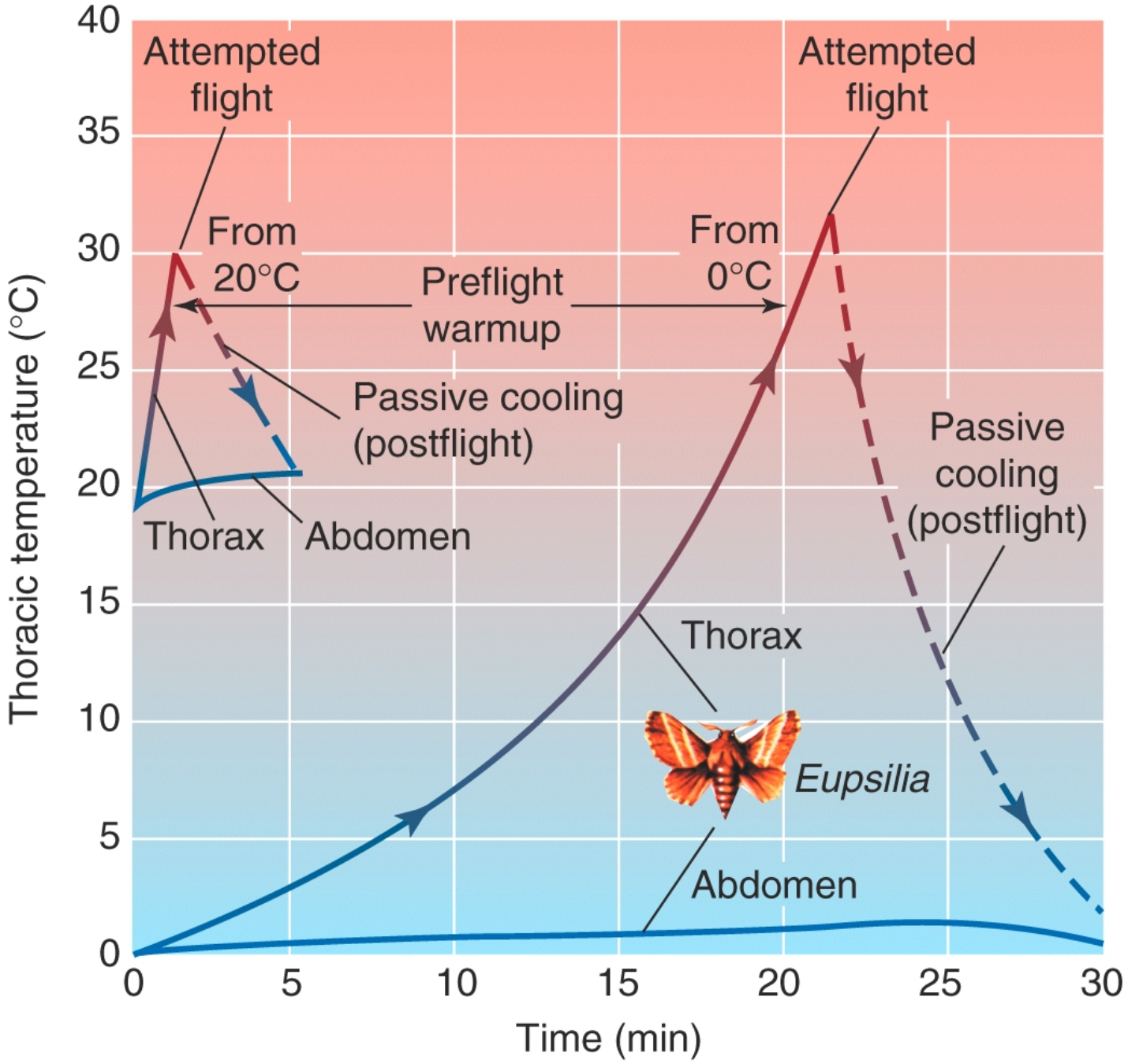

Body temperature
Homeotherm
Poikilotherm
Ambient temperature


Cat
Opossum
Platypus
Echidna
Lizard
Approximate regions of
Homeothermy
Temporal heterothermy
Heterothermy
Ectothermy
Core body temperature (°C)
Ambient temperature (°C)
0
10
20
30
40
10
20
30
40


40
36
32
28
24
20
16
12
8
4
0
Air = –16°C
36
32
28
24
20
Air = –31°C
40
36
32
28
24
20
16
12
8

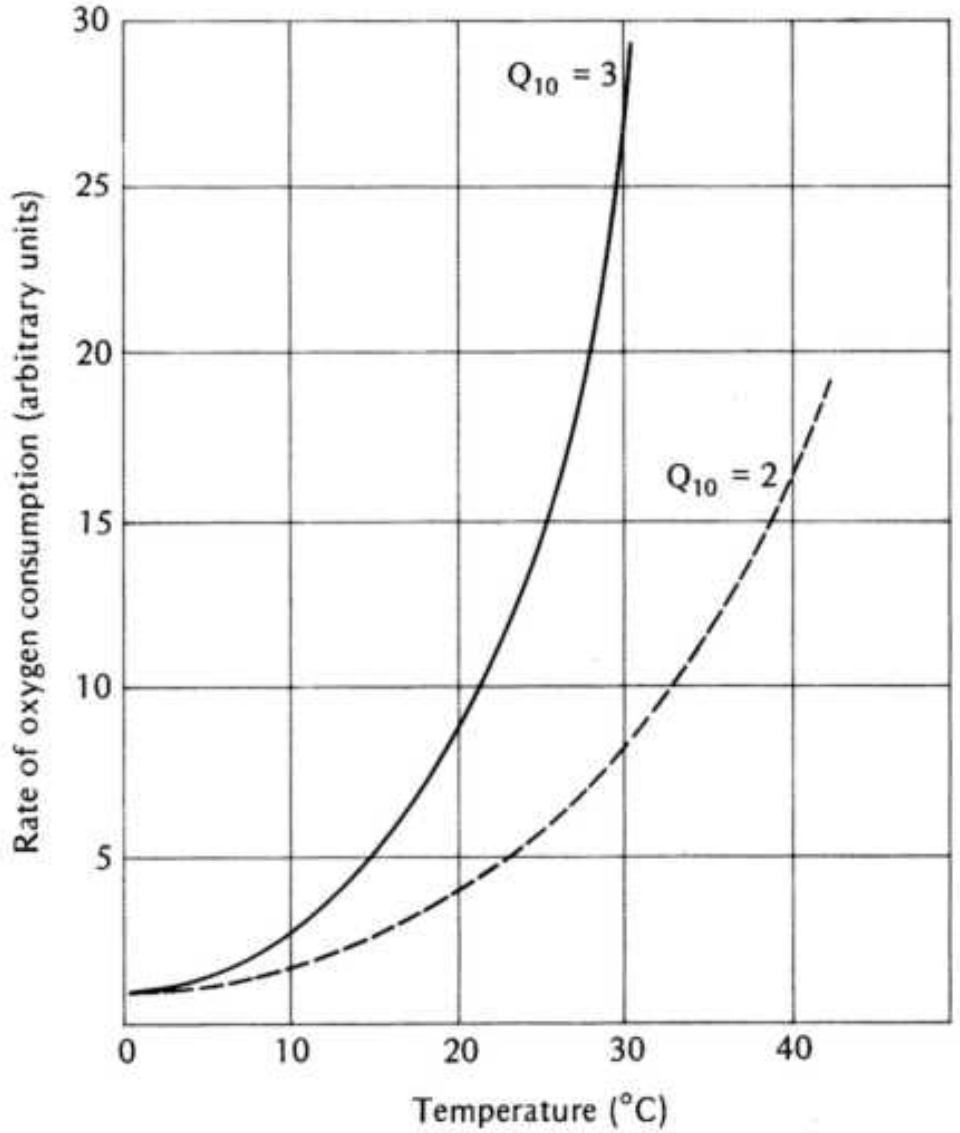

Submerged in water
Exposed to air
Submerged in water
Exposed rock face
Air in shade
Chiton under rock
Temperature (°C)
40
35
30
0
1
2
3
4
5
Time (hours)

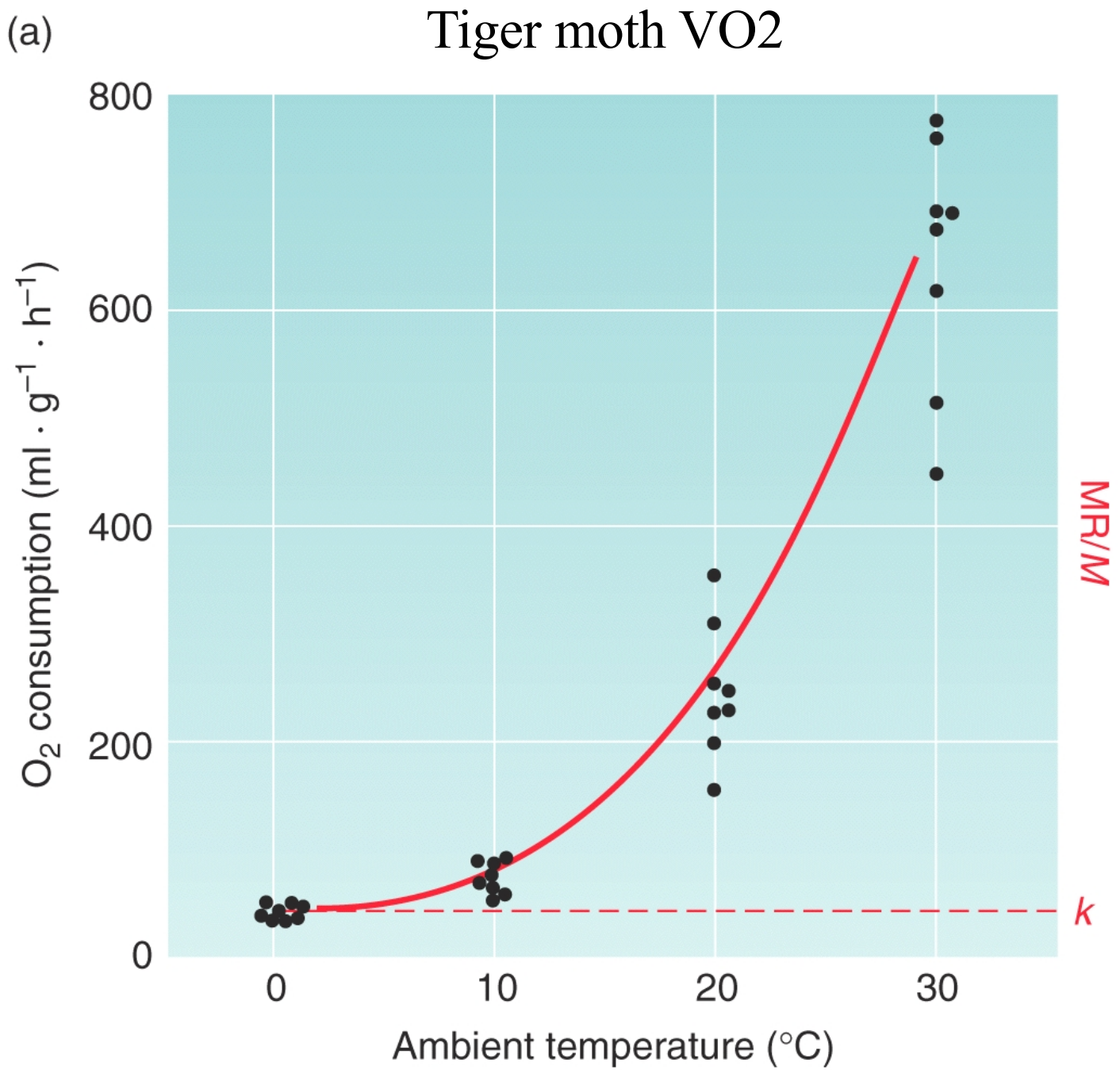

(a)
Higher body temperature, rapid heartbeat, and vasodilation
ECG
(b)
Lower body temperature causes slowed heartbeat and vasoconstriction
ECG


Attempted flight
Attempted flight
From 20°C
From 0°C
Preflight warmup
Passive cooling (postflight)
Passive cooling (postflight)
Thorax
Abdomen
Thorax
Eupsilia
Abdomen
Thoracic temperature (°C)
Time (min)
0
5
10
15
20
25
30
35
40

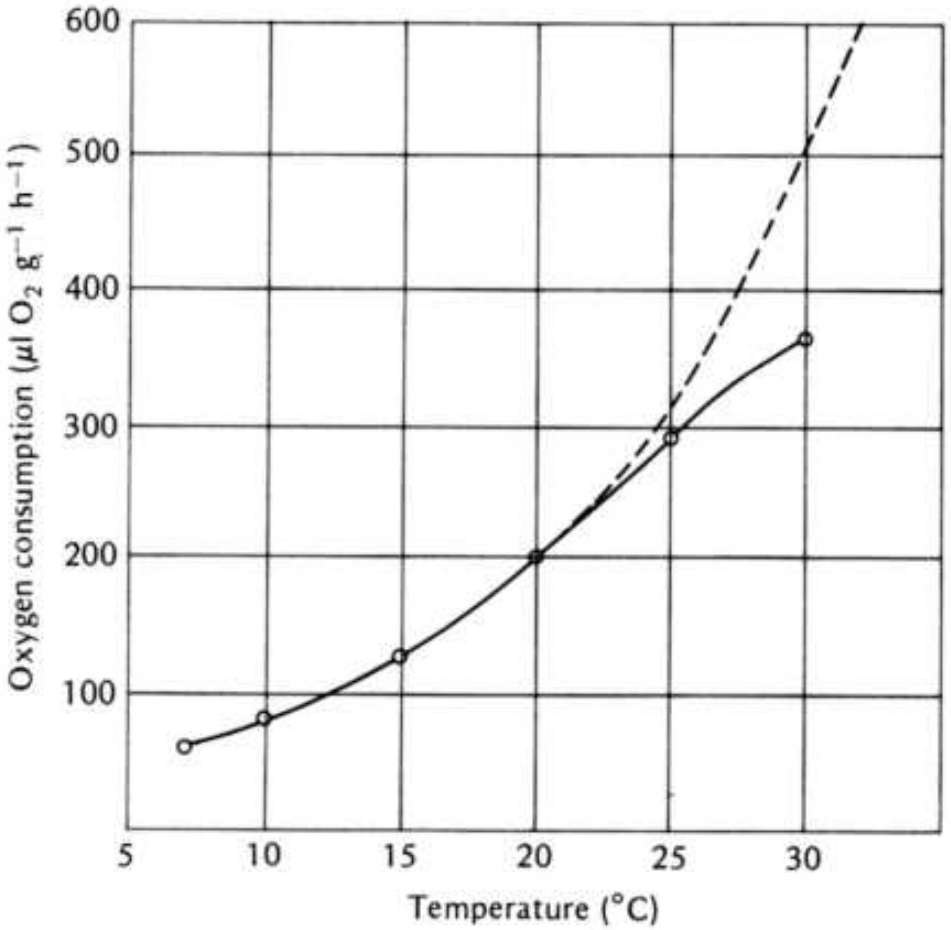
$$Q_{10}=(R_2/R_1)^{10/(T_2-T_1)}$$

$$R_2=R_1\,Q_{10}^{(T_2-T_1)/10}$$

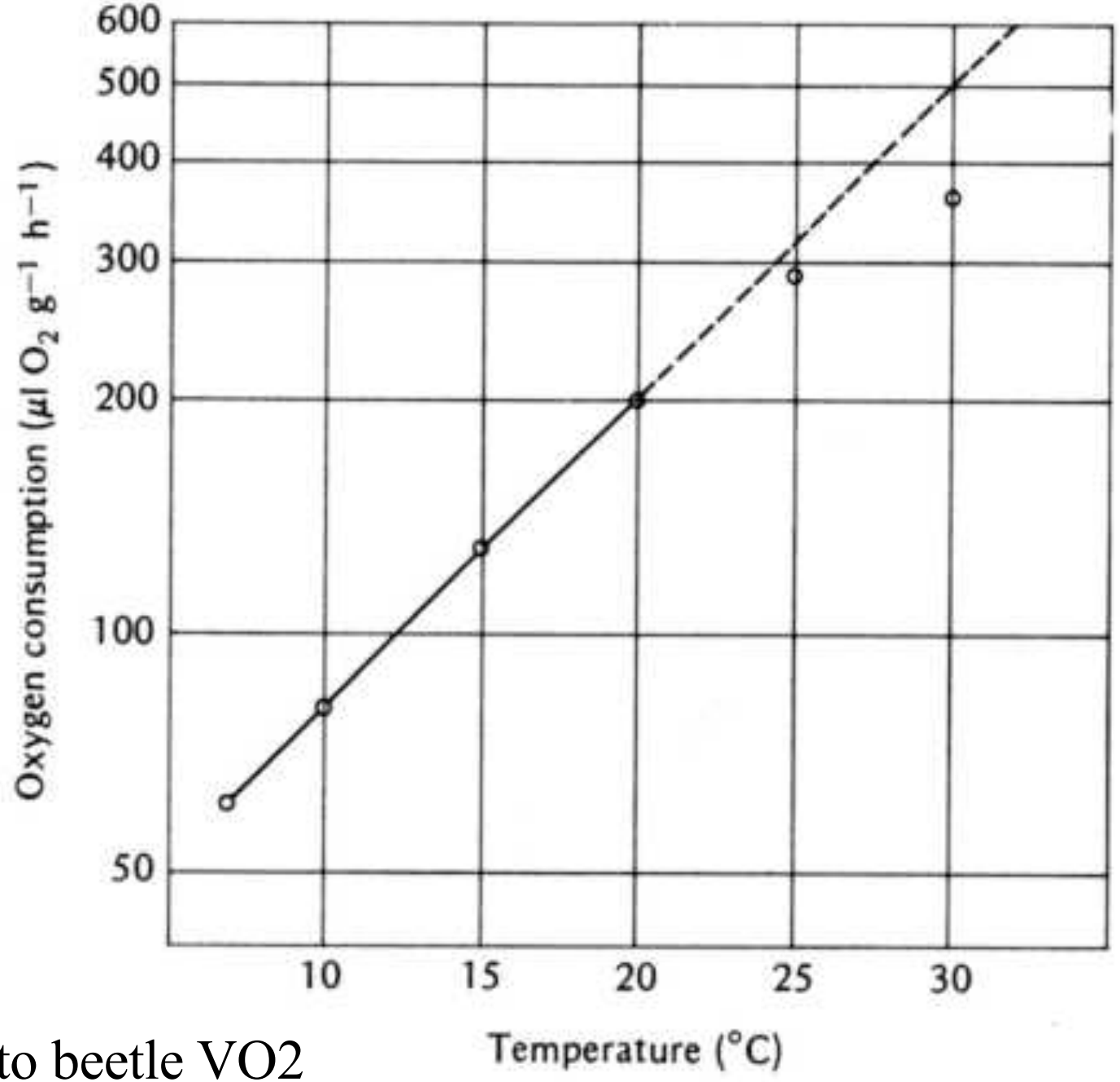



(a)
Tiger moth VO2
800
600
400
200
0
O_2 consumption (ml · g^{-1} · h^{-1})
0
10
20
30
Ambient temperature (°C)
MR/M
k

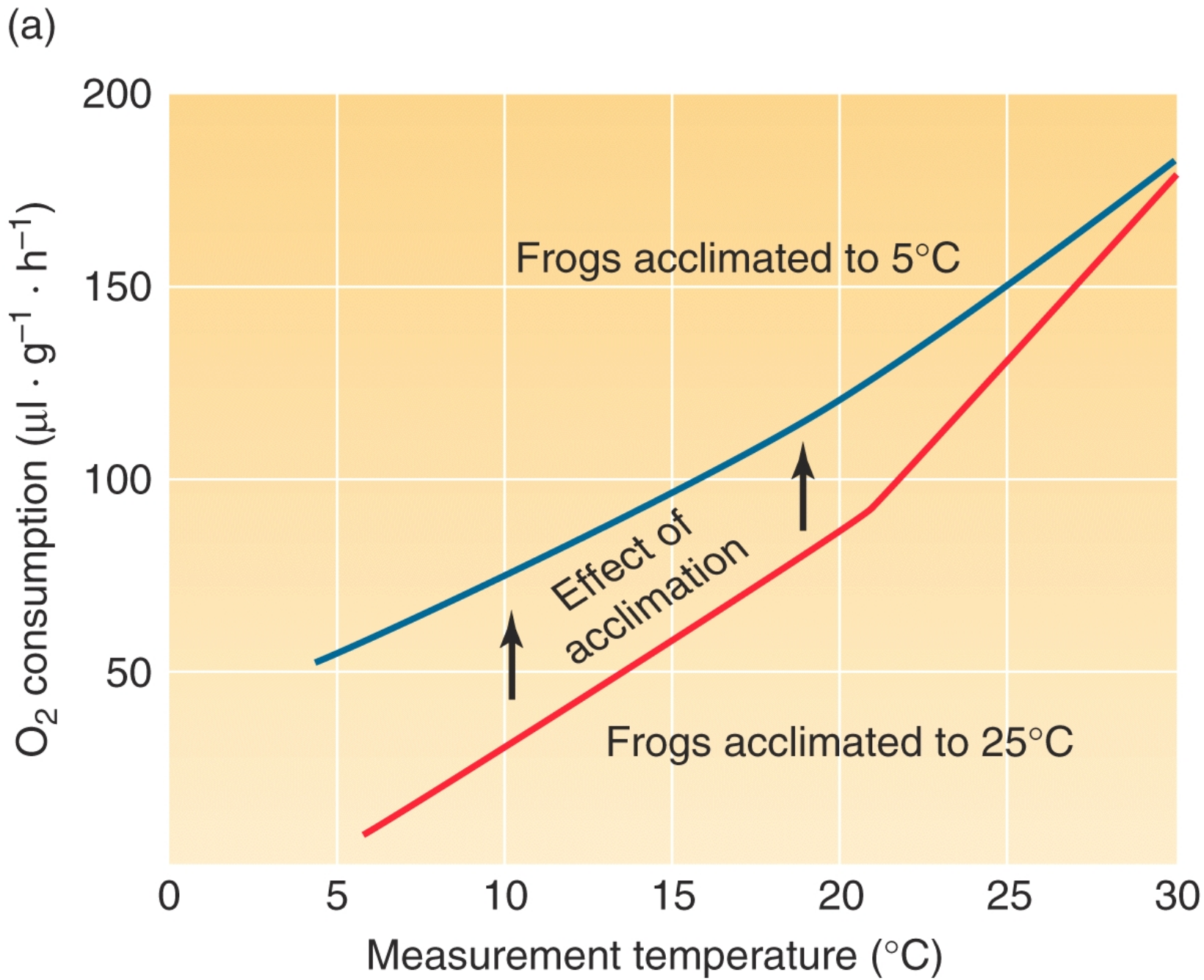
Temperature (°C)	O_2 consumed ($\mu l\ g^{-1}\ h^{-1}$)	Temperature interval (°C)	Q_{10}
7	61		
10	81	7–10	2.57
15	126	10–15	2.41
20	200	15–20	2.52
25	290	20–25	2.10
30	362	25–30	1.56

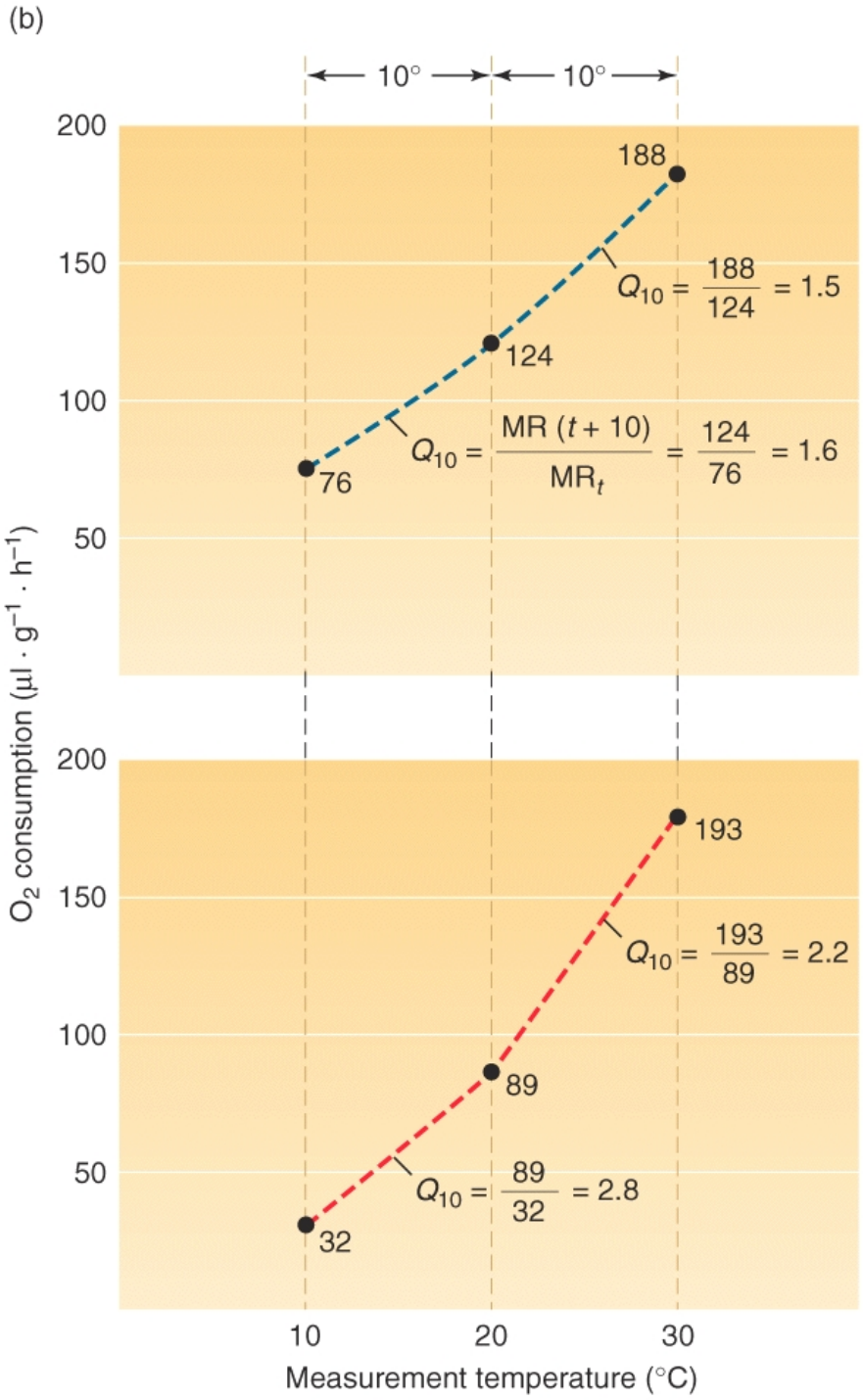


Potato beetle VO2



Potato beetle VO2

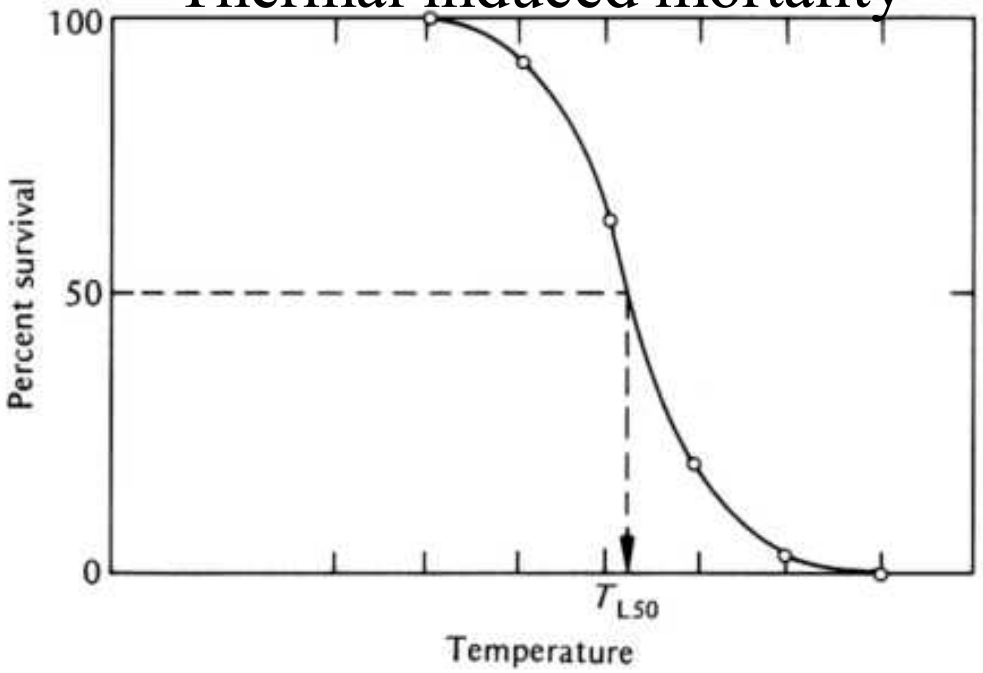

(a)
200
150
100
50
O_2 consumption ($\mu l \cdot g^{-1} \cdot h^{-1}$)
Frogs acclimated to 5°C
Effect of acclimation
Frogs acclimated to 25°C
0
5
10
15
20
25
30
Measurement temperature (°C)


(b)
10°
10°
200
150
100
50
188
124
76
$Q_{10} = \frac{188}{124} = 1.5$
$Q_{10} = \frac{MR\ (t + 10)}{MR_t} = \frac{124}{76} = 1.6$
200
150
100
50
193
89
32
$Q_{10} = \frac{193}{89} = 2.2$
$Q_{10} = \frac{89}{32} = 2.8$
O_2 consumption ($\mu l \cdot g^{-1} \cdot h^{-1}$)
10
20
30
Measurement temperature (°C)

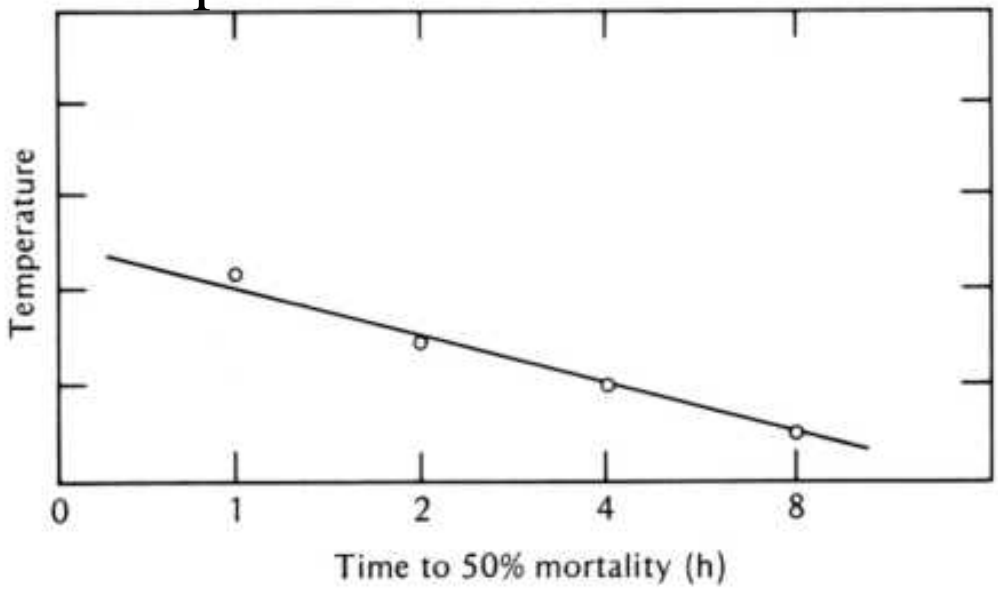
Snail heat resistance

Occurrence	Snail	Temperature (°C)
Spray zone, upper part of intertidal zone	*Tectarius vilis*	48.5
	Planaxis sulcatus	48
	Nodilittorina granularis	47
	Littorina brevicola	47
Shallow splash pools	*Paesiella raepstorttiana*	47
Middle part of intertidal zone	*Nerita japonica*	46
	Nerita albicilla	44
Lower part of intertidal zone in sheltered or shadowy places or under stones	*Lunella coronata*	43
	Drupa granulatus	42
	Purpura clavigerus	42
	Monodonta labis	42
Lower part of intertidal zone at water's edge	*Tegula lischkei*	39

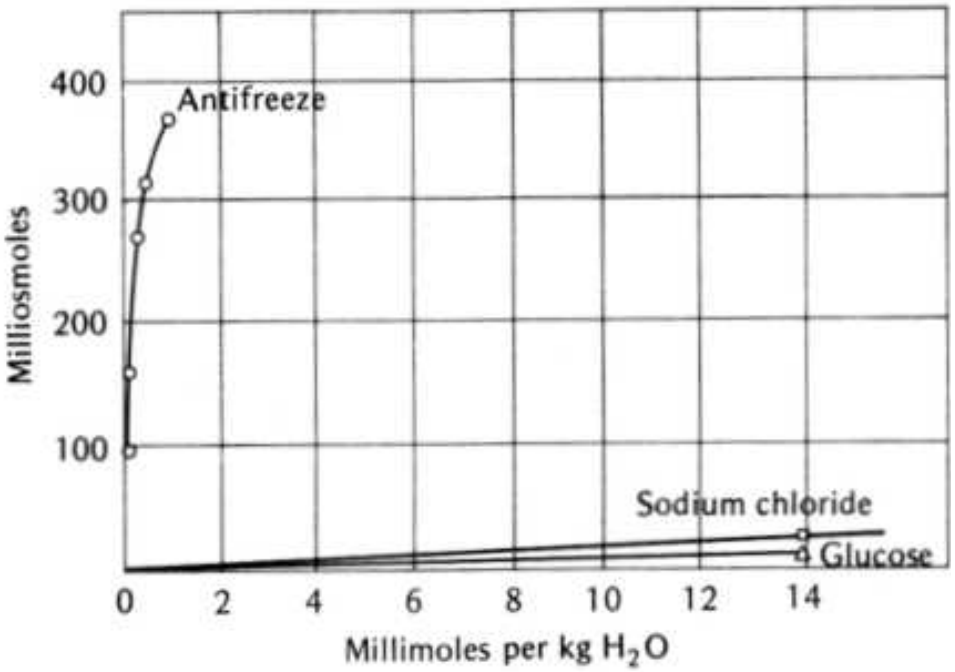
Thermal induced mortality

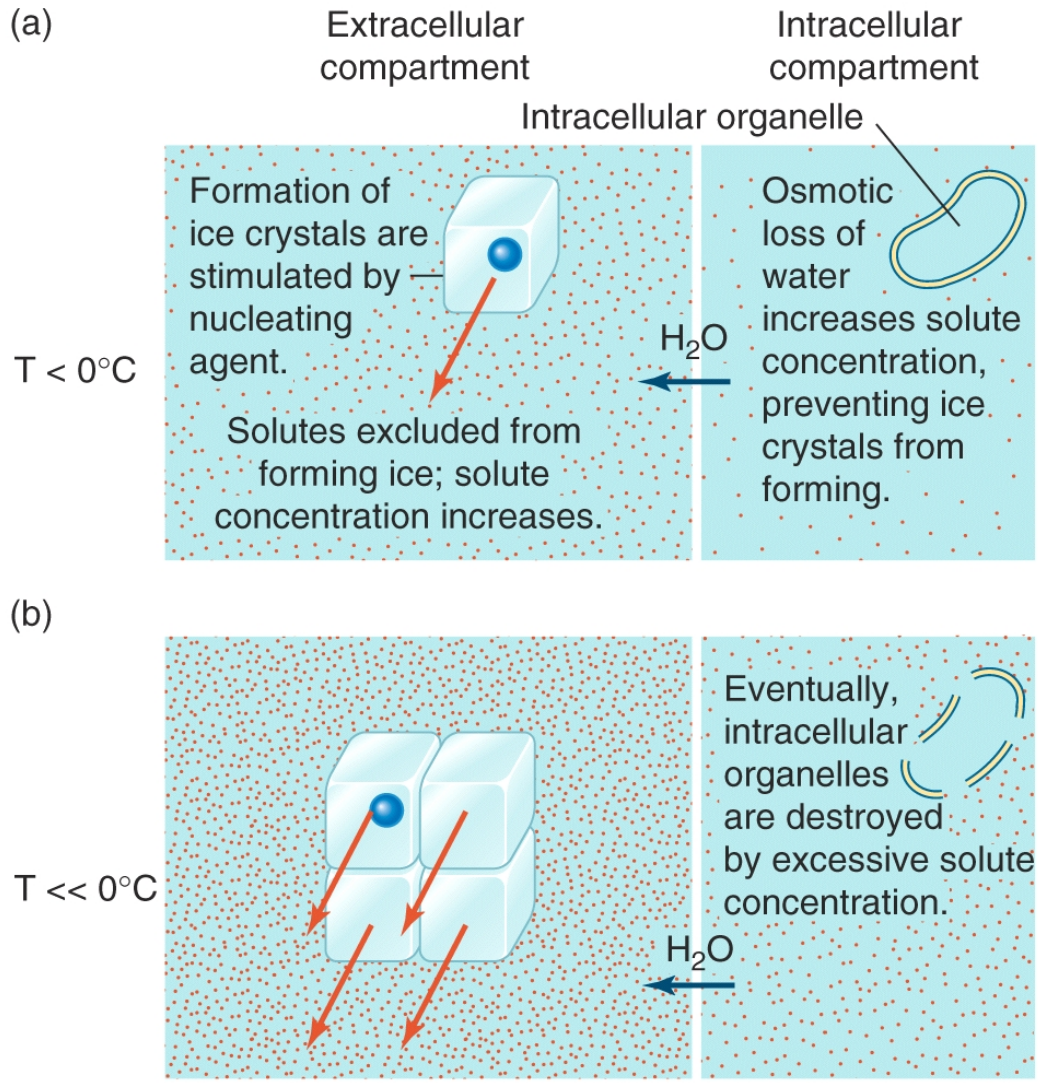


Time dependant thermal induced mortality



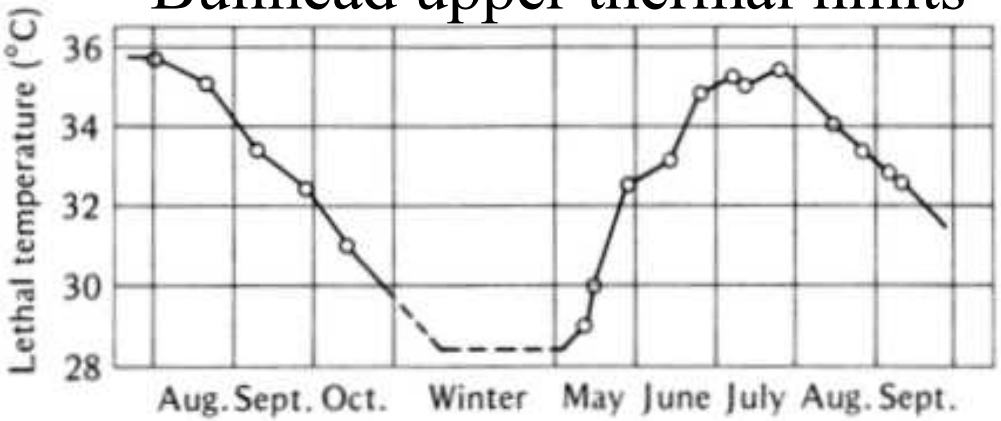
Antifreeze in Antarctic fish

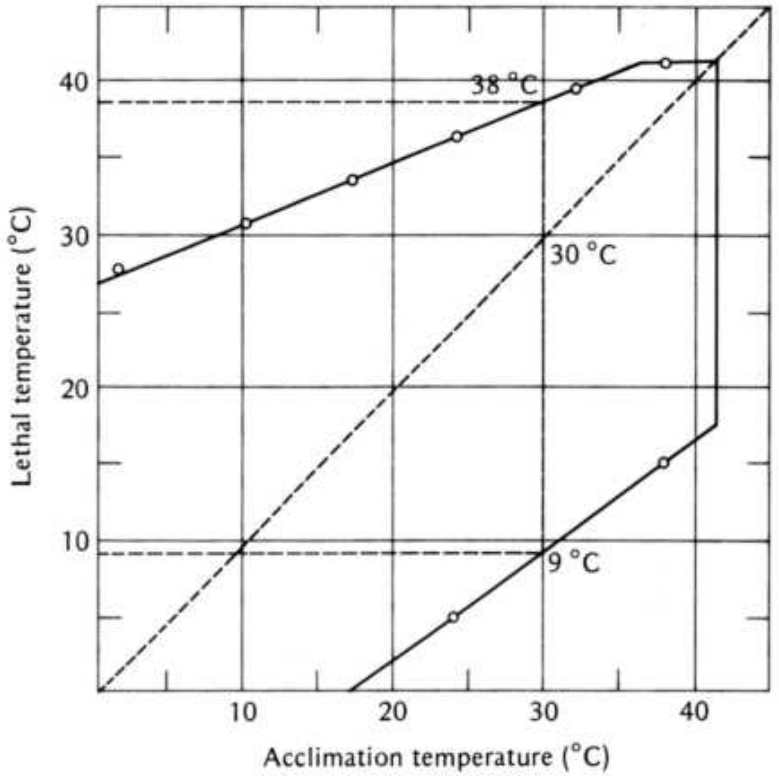




Ice crystal induction

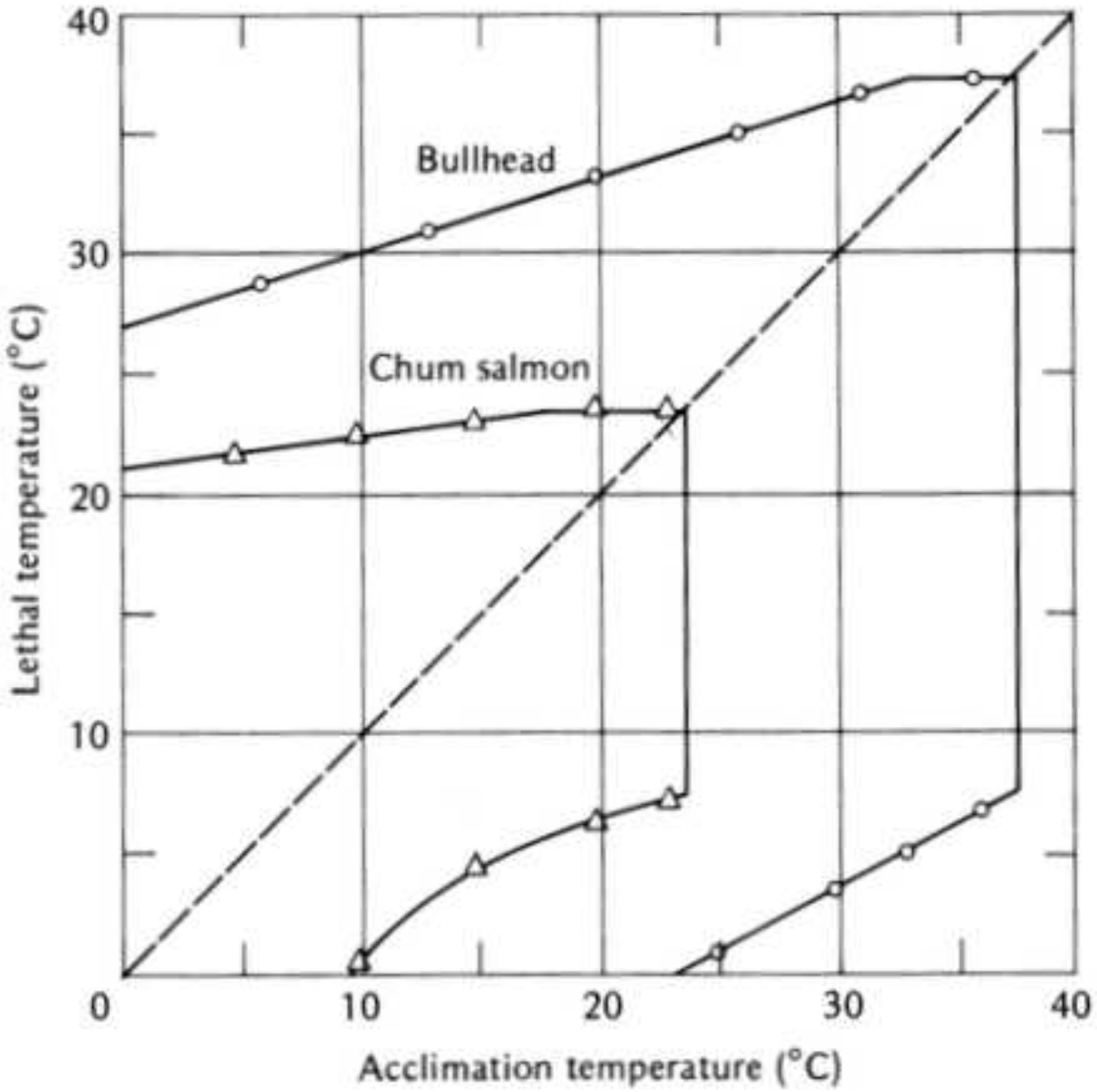
Bullhead upper thermal limits



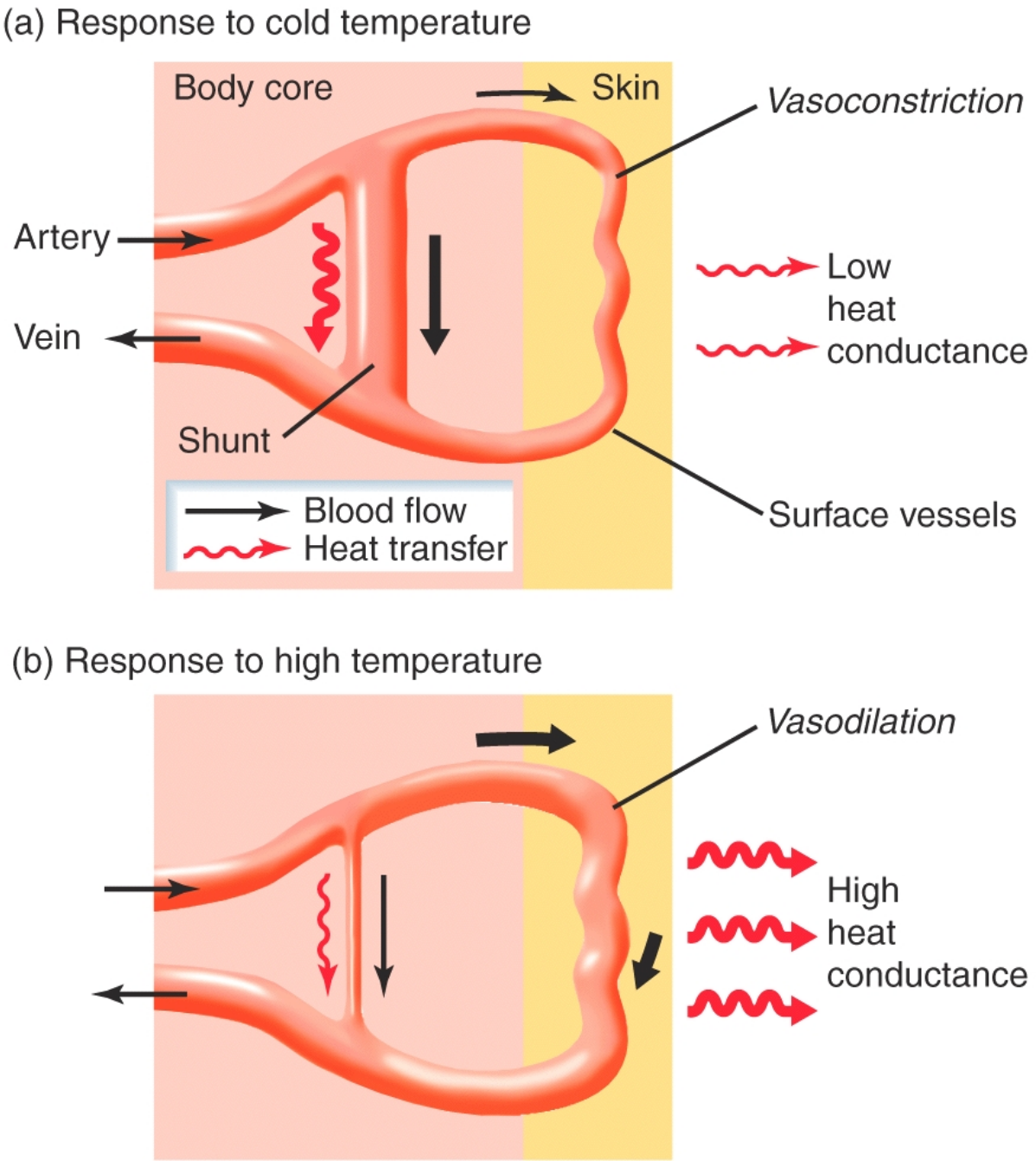


Thermal tolerance loop for goldfish

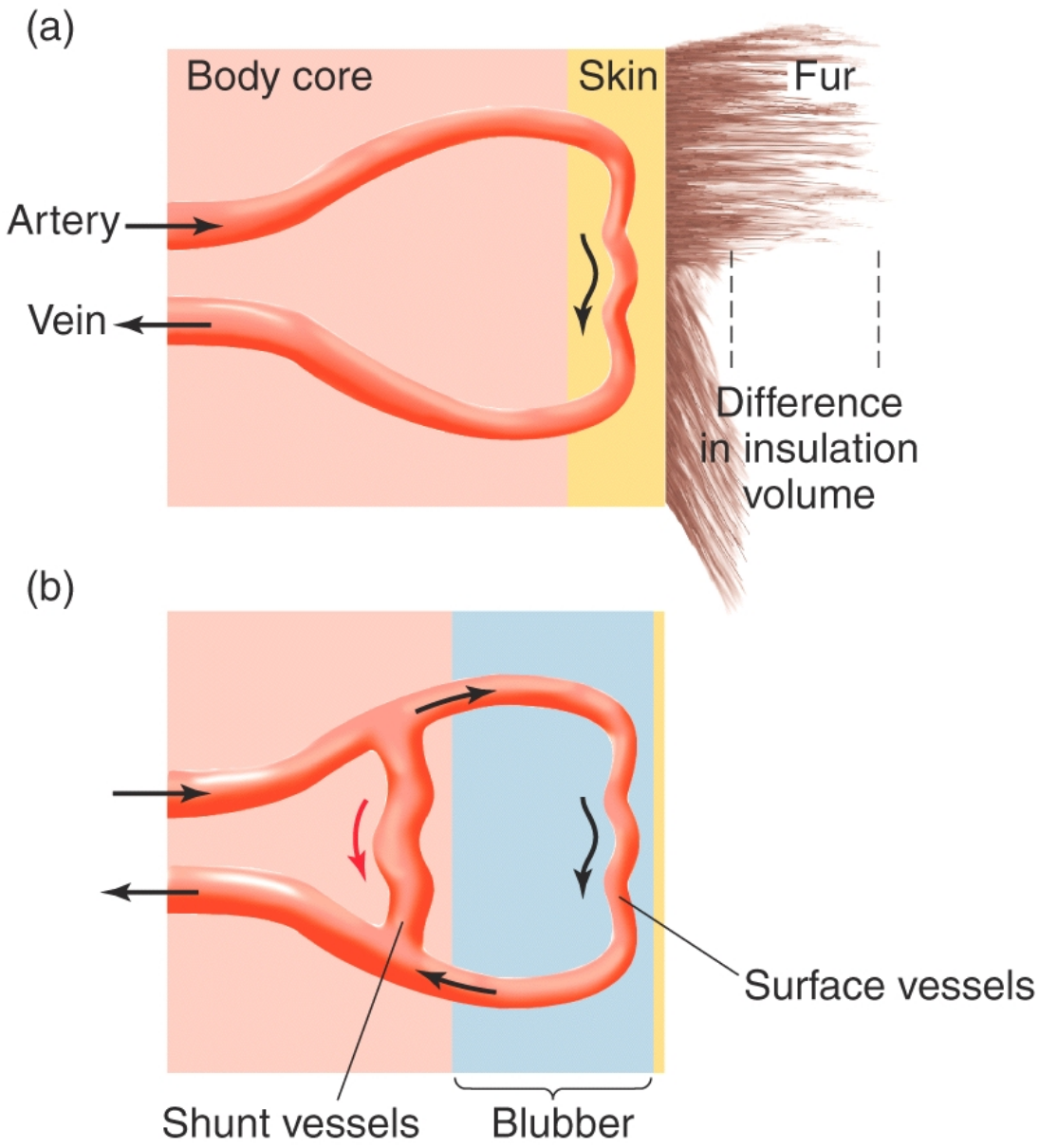
Thermal tolerance loop for bullhead and salmon



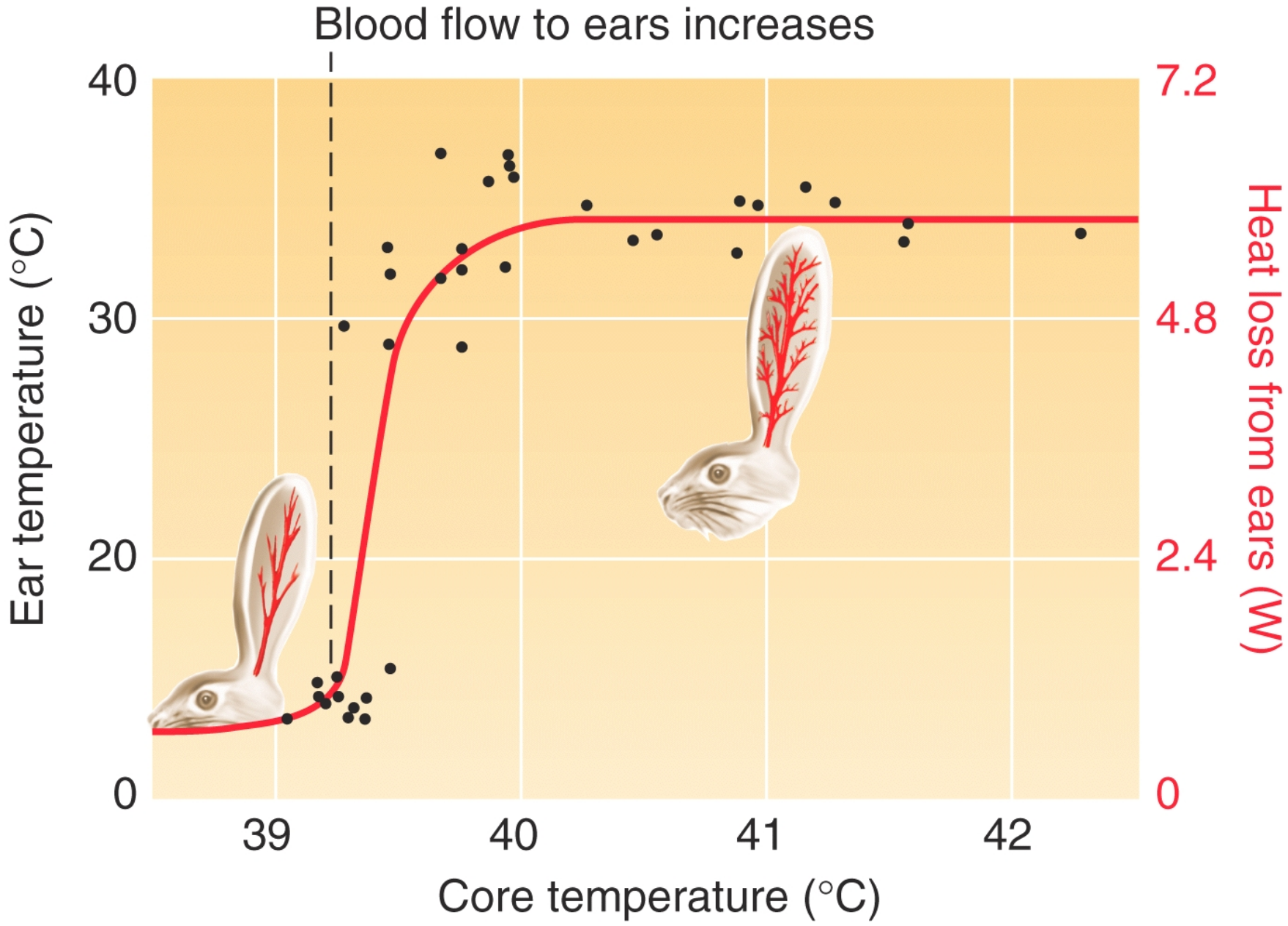
Cardiovascular control in thermoregulation



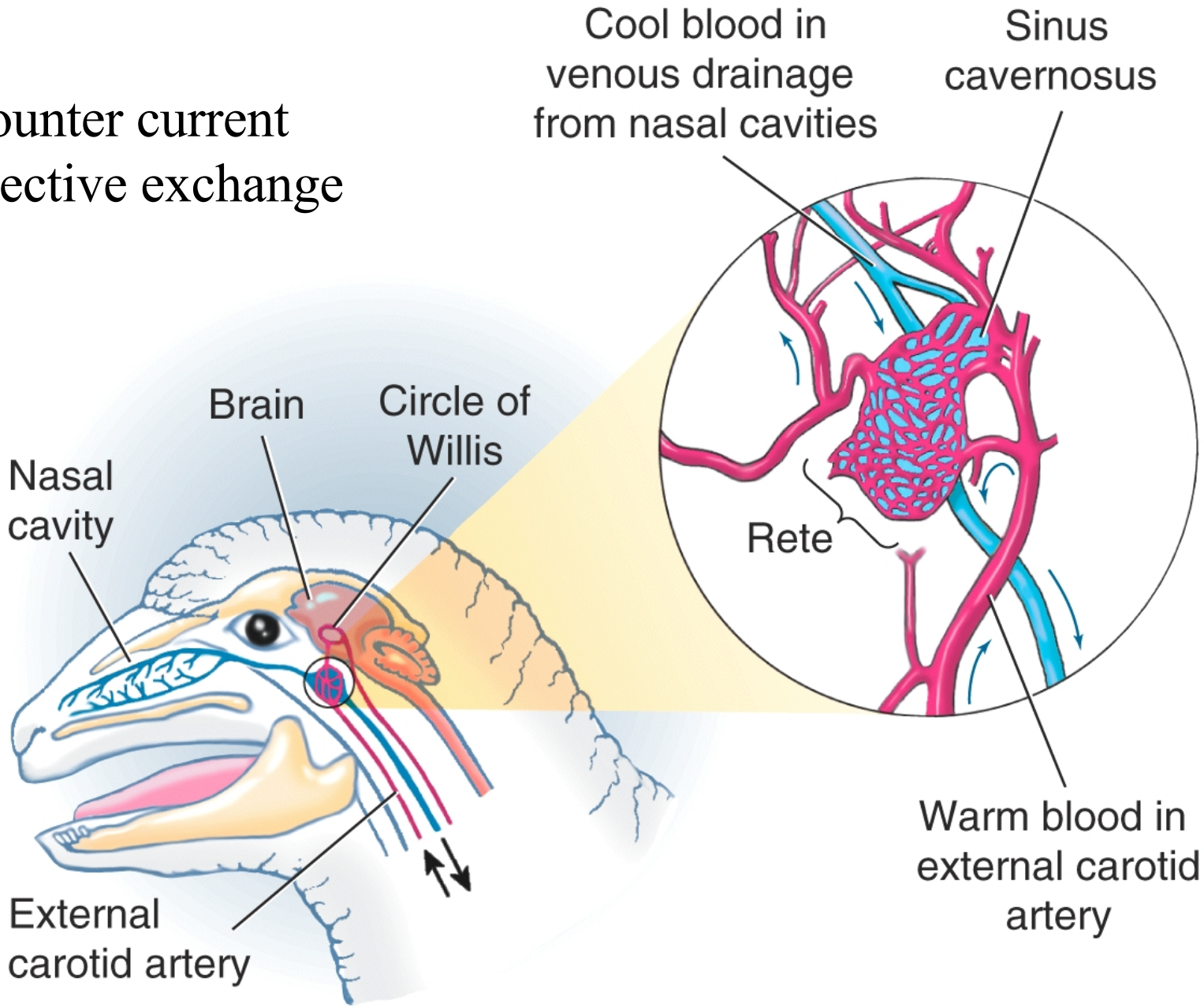
Hair and blubber are and additional control in thermoregulation



Convective heat loss

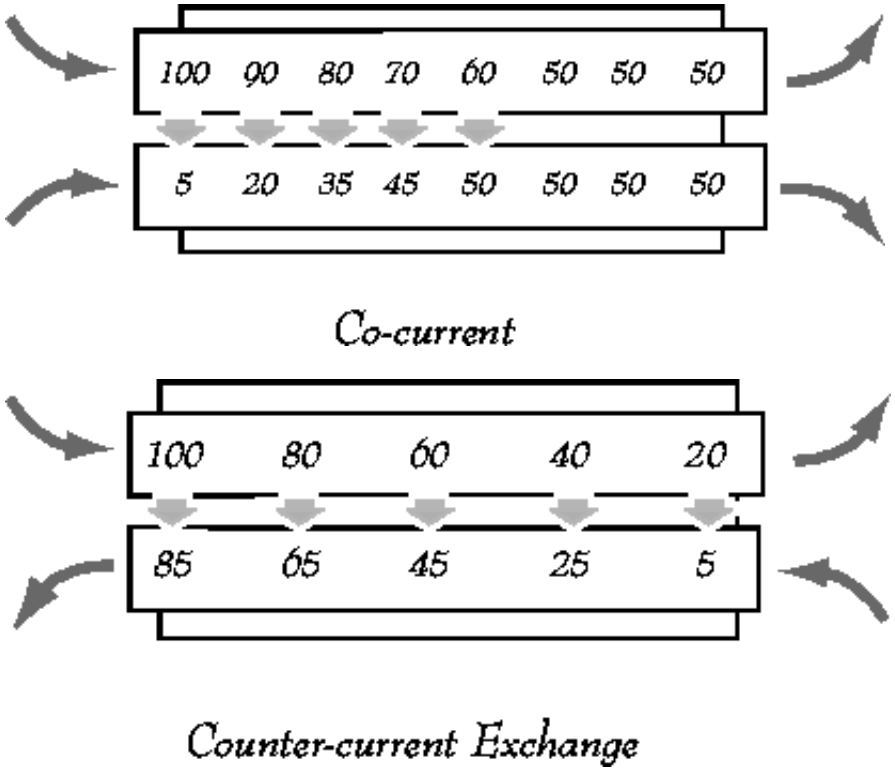


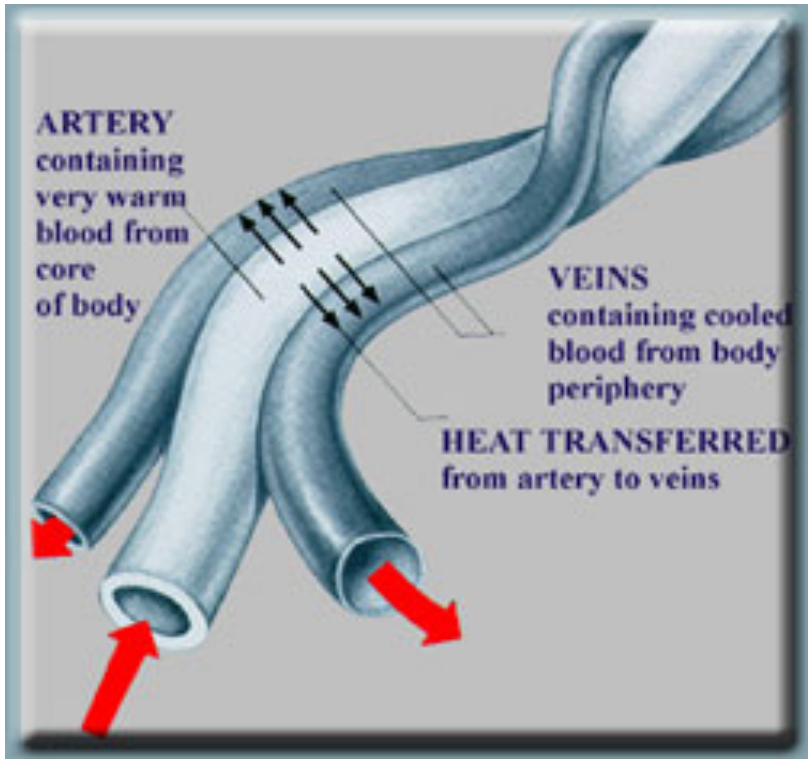
Counter current convective exchange



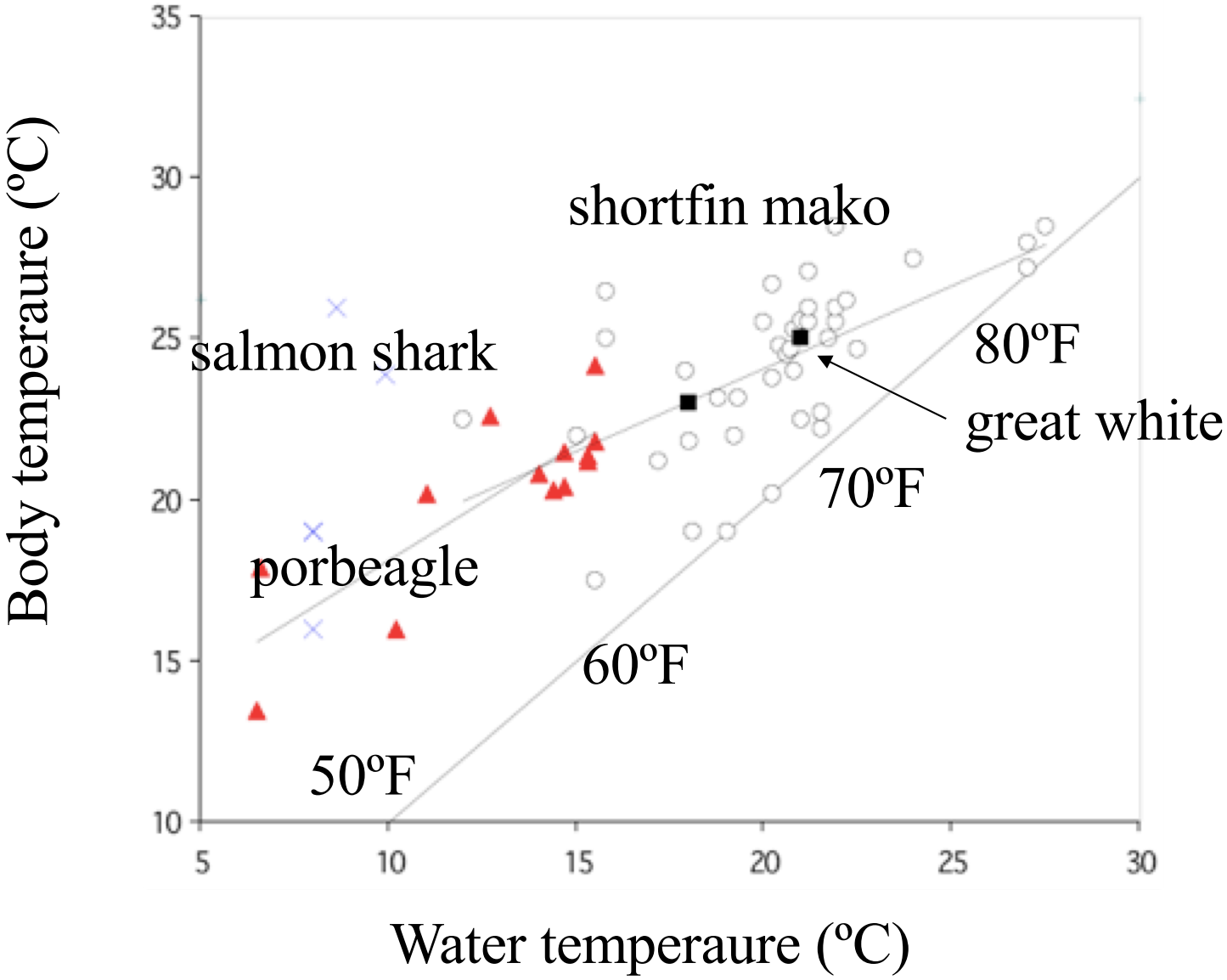
Countercurrent Exchange

- Works by diffusion
- Much more efficient than Co-current

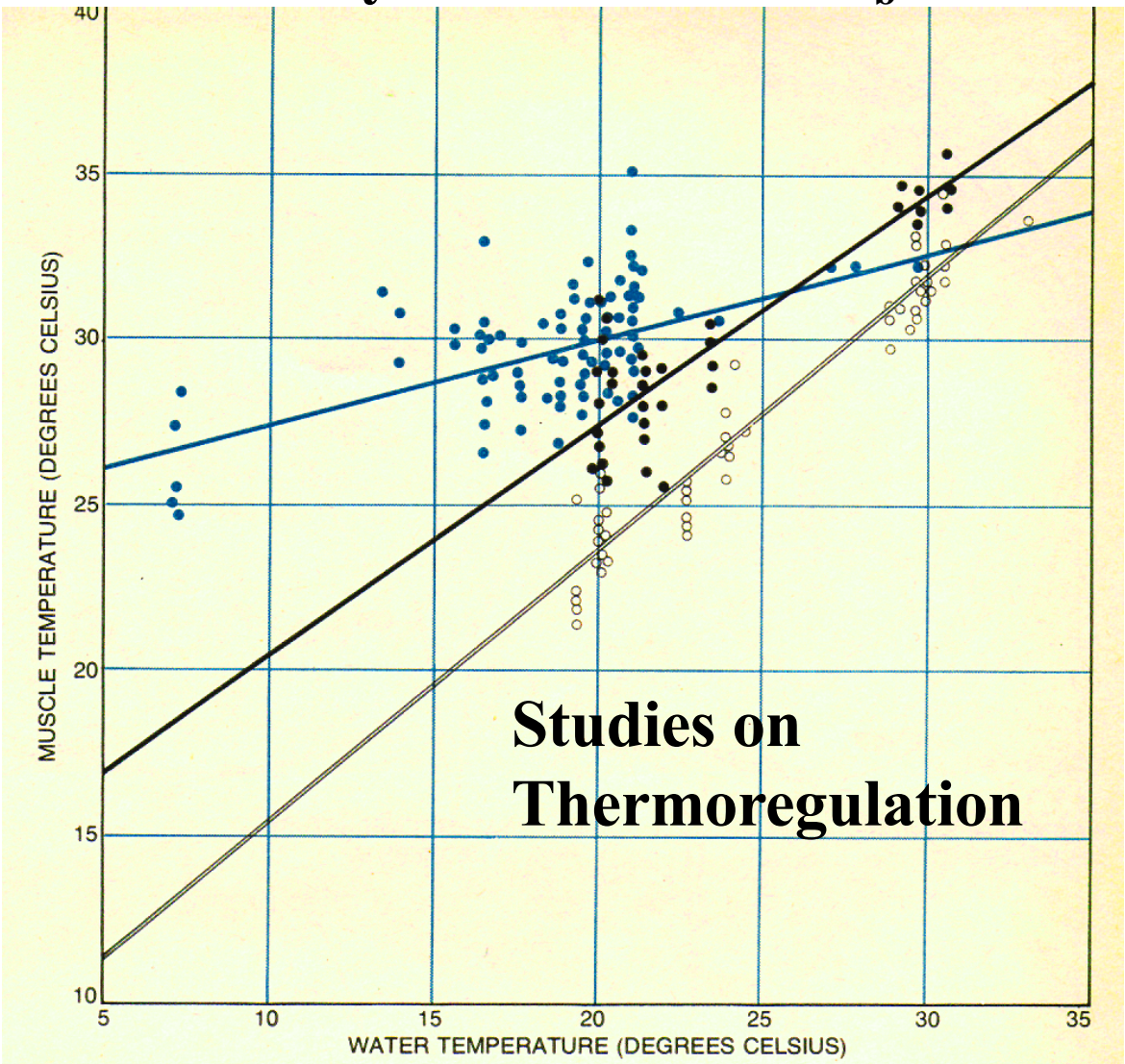




Body temperature of lamnids

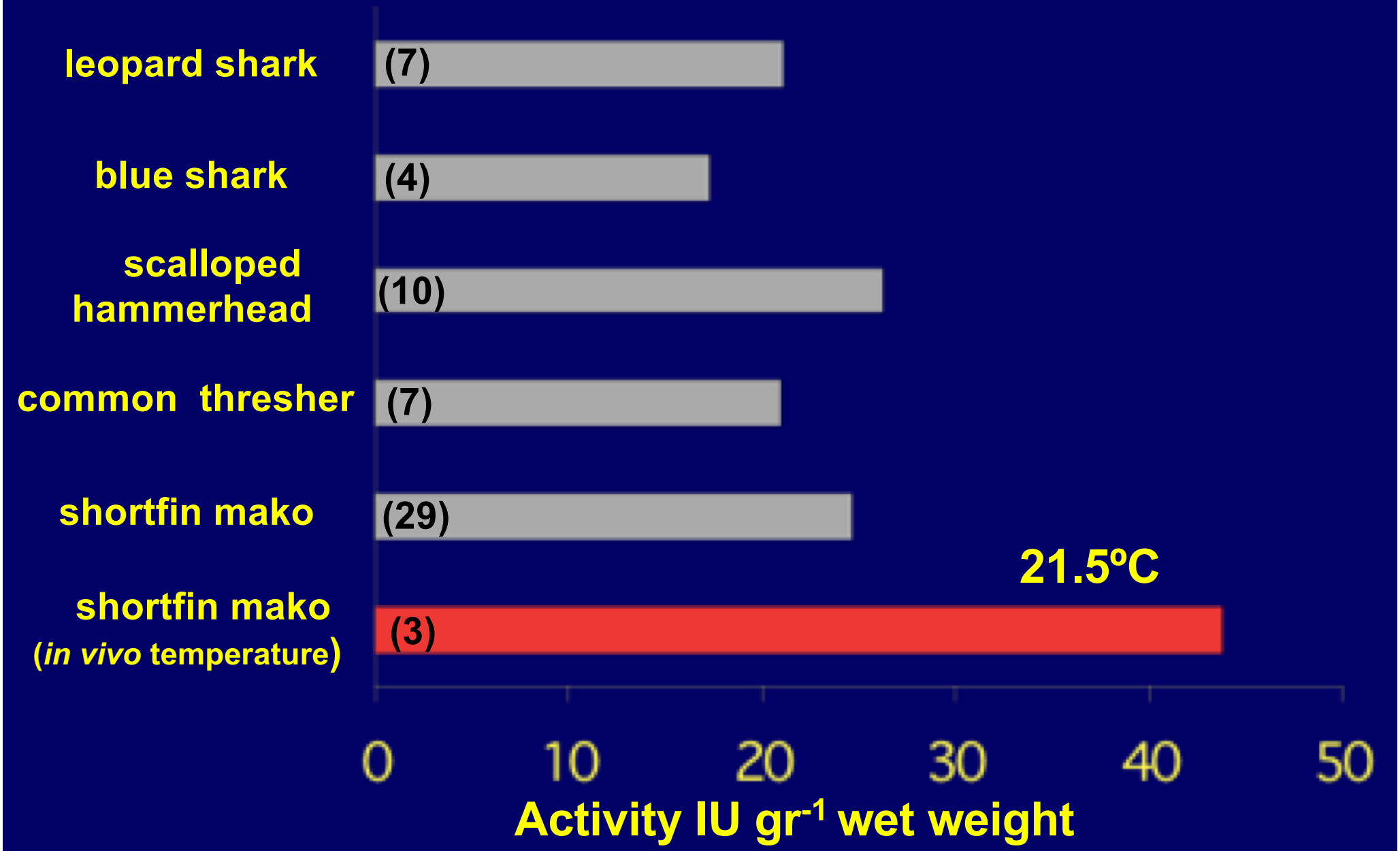


Carey's data on tuna T_b

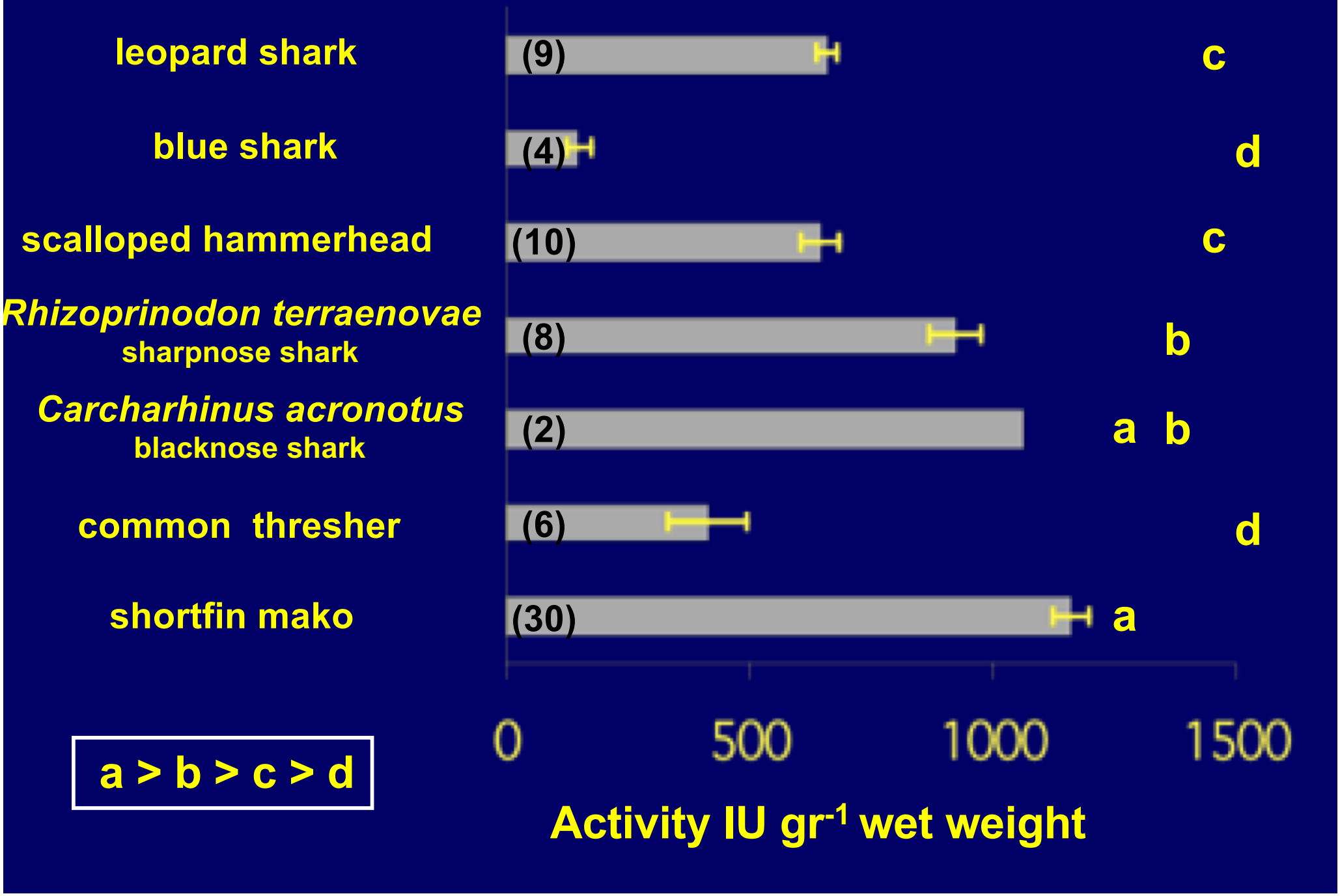


MAXIMUM MUSCLE TEMPERATURES are plotted against water temperature for bluefin (*color*), skipjack (*solid black*) and yellowfin (*open black*). The bluefin regulates its temperature almost independently of water temperature. The skipjack is warmer than the yellowfin but both tend to maintain a fixed temperature difference above water temperature.

CS in RM at 15ºC

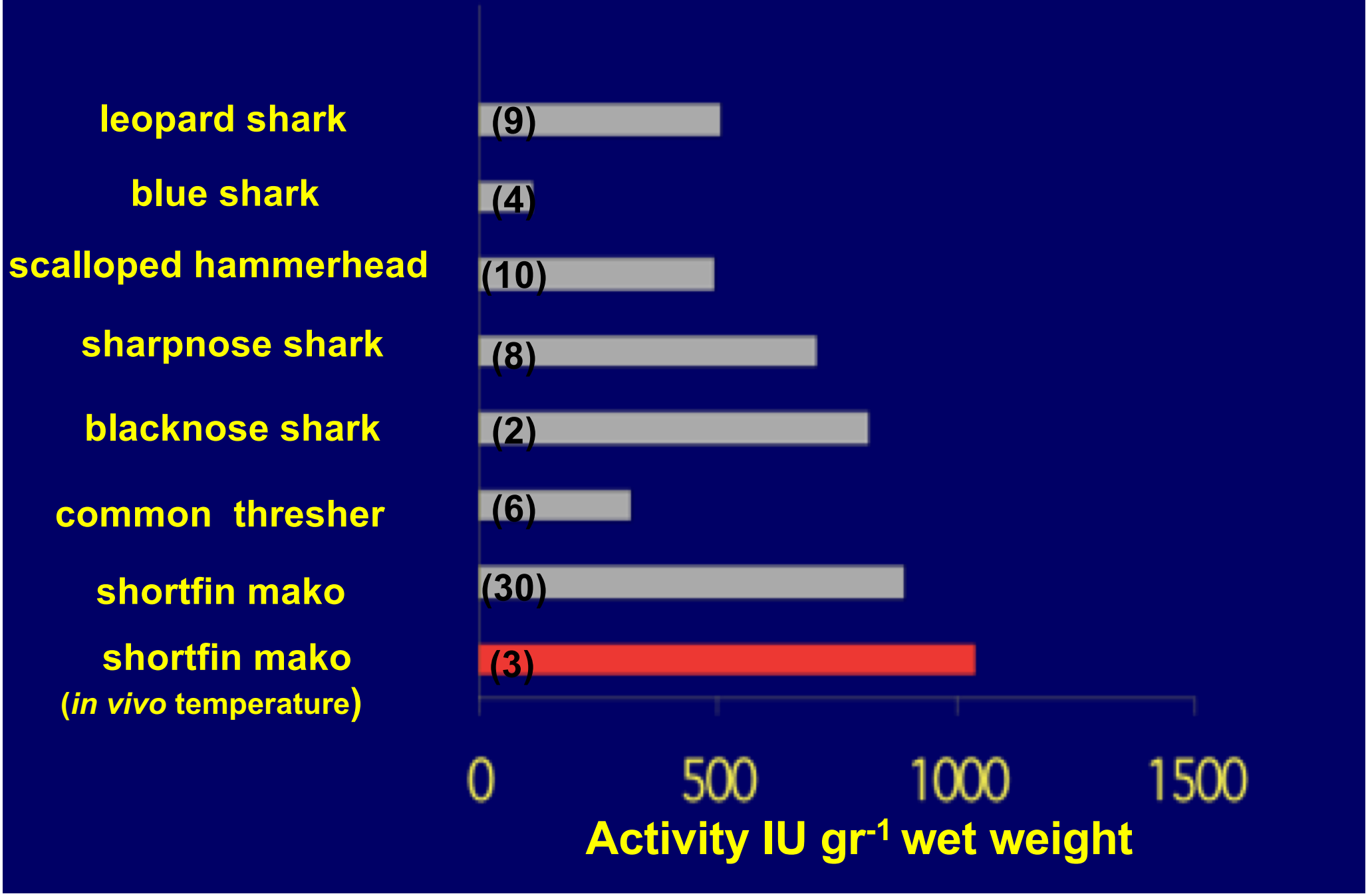


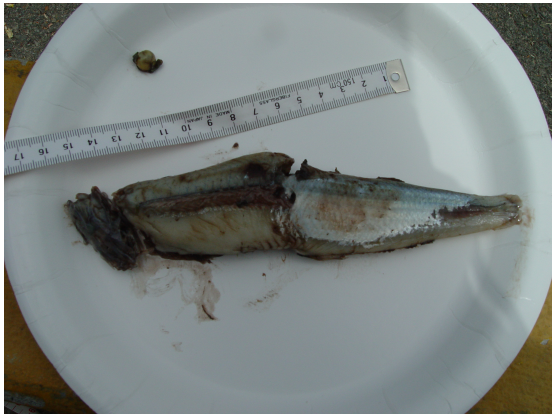
LDH in WM at 20ºC



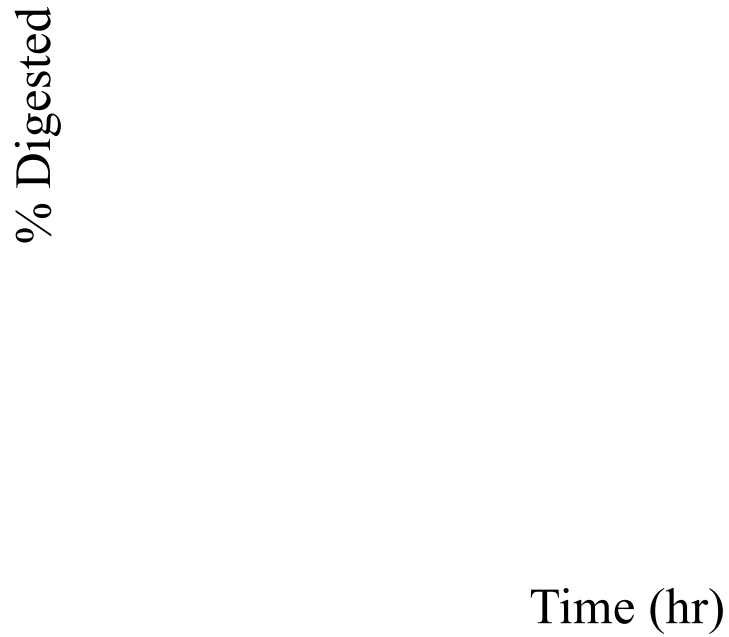
a > b > c > d

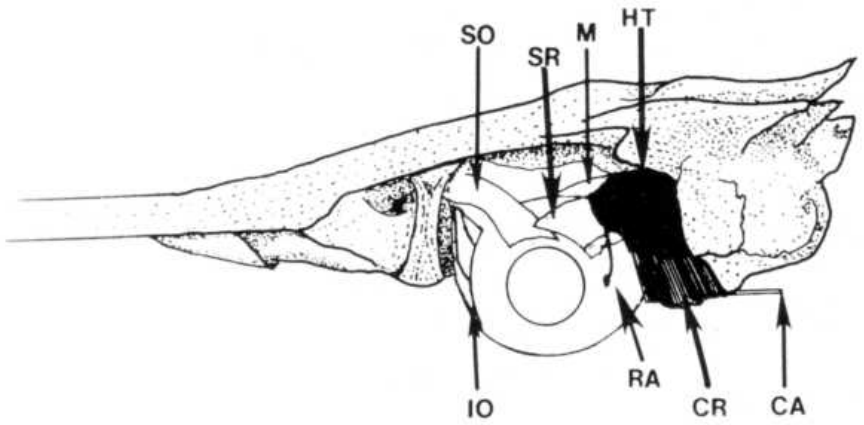
LDH in WM at 15ºC





Individual	mass (kg)	mass of ration (g)	average SST (° C)	Average stomach temperature ($T_X=T_a-T_s$) (° C)	Time (h)	% digested
mako 1 [121 cm Fork length (*FL*)]	18.00	198	19.05	4.5	4	54
mako 2 (127 cm *FL*)	21.00	150	20.25	4.25	2.5	70
mako 2		137			5.43	100
mako 2		149			5.75	100





L. Diagram of the eye, eye muscles, and heater in the head of a white marlin, *Tetrapturus albidus* as a left, lateral view with the lower jaw removed. Only four of the six extraocular eye muscles are shown. CA, carotid artery; CR, carotid rete; HT, heater tissue; IO, inferior oblique; M, medial rectus; SO, superior oblique; SR, superior rectus; RA, retinal-heater artery.

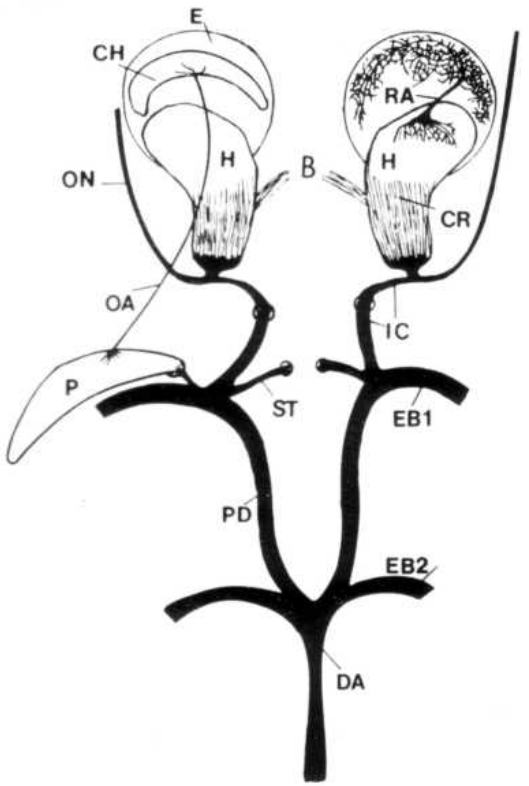
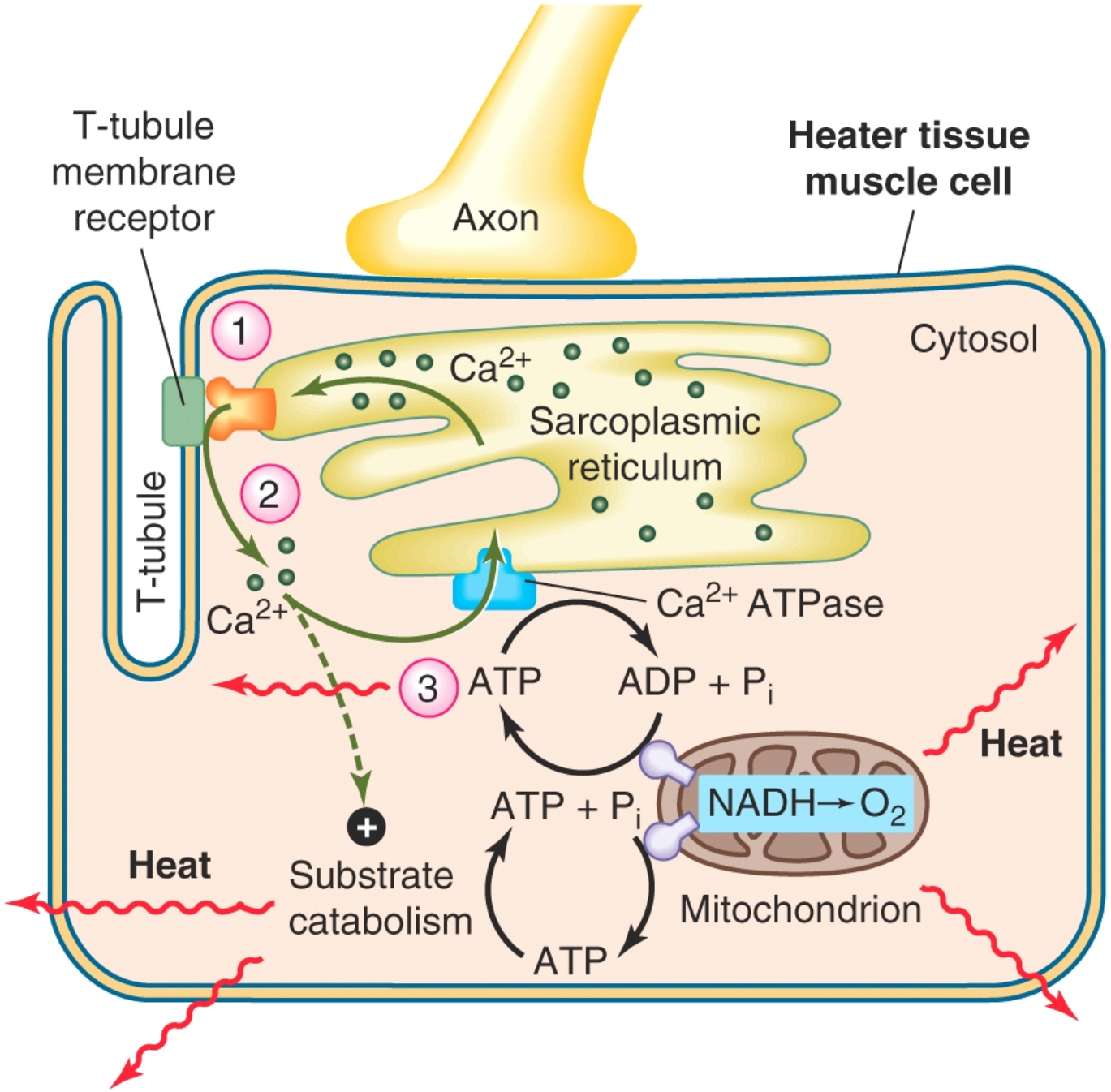


Fig. 7. Diagram of the circulation to the brain and eye in a blue marlin, *M. nigricans*. This pattern is representative of the other billfishes. B, brain; CR, carotid rete; CH, choroid rete; DA, dorsal aorta; E, eye; EB1, first efferent branchial artery; EB2, second efferent branchial artery; H, heater tissue; IC, internal carotid; OA, ophthalmic artery; ON, orbital-nasal artery; P, pseudobranch; PD, paired dorsal aorta; RA, retinal-heater artery; ST, stapedial artery.


T-tubule membrane receptor
Axon
Heater tissue muscle cell
Cytosol
1
Ca^{2+}
Sarcoplasmic reticulum
2
T-tubule
Ca^{2+}
Ca^{2+} ATPase
3
ATP
$ADP + P_i$
Heat
$ATP + P_i$
$NADH \rightarrow O_2$
Heat
Substrate catabolism
Mitochondrion
ATP