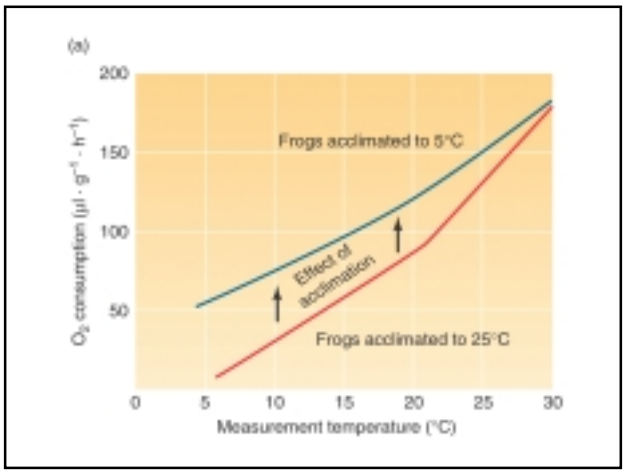
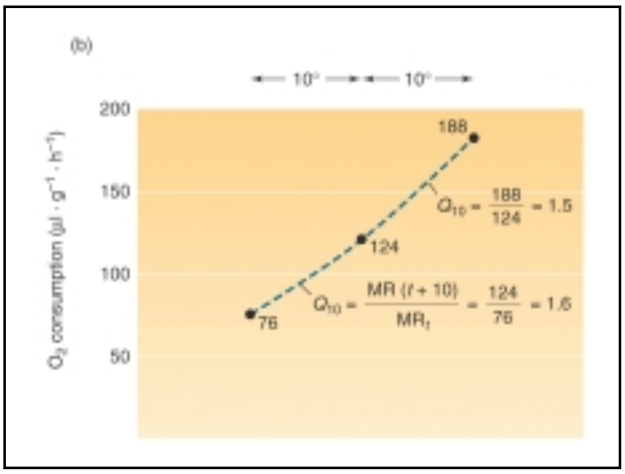
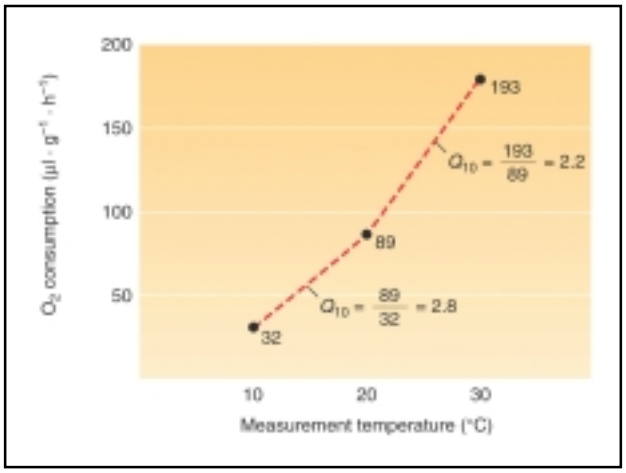
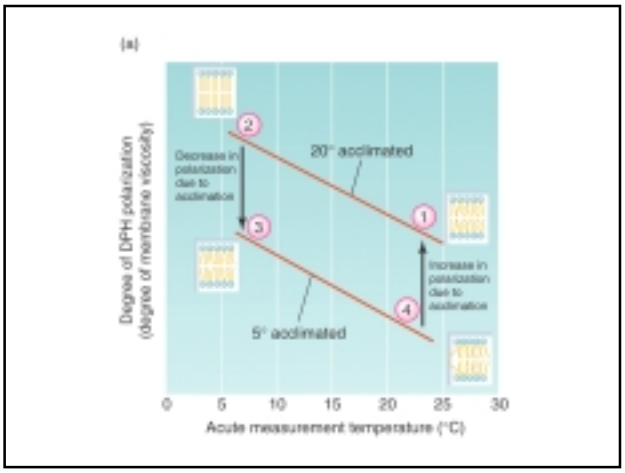
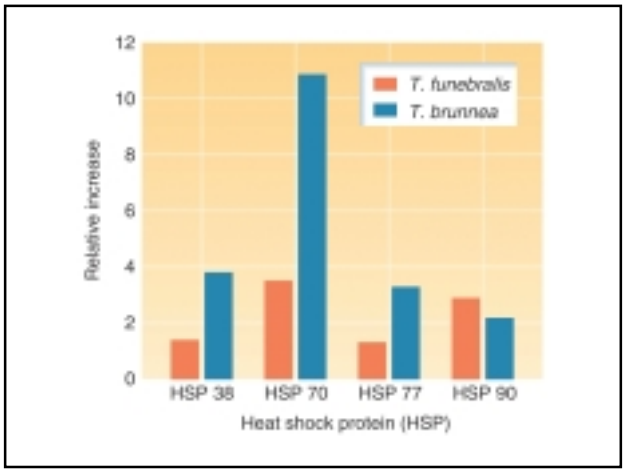
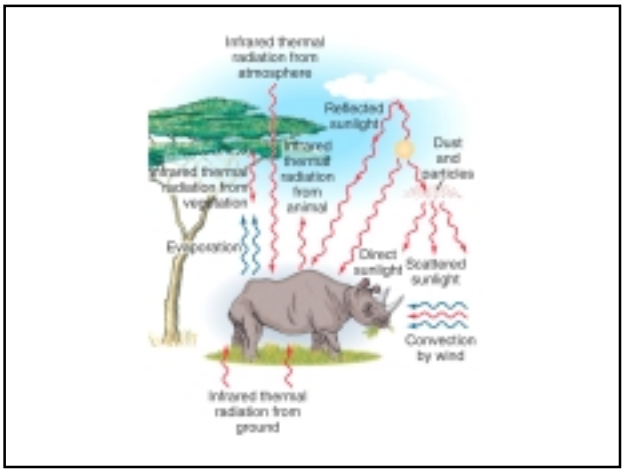

(a)
Frogs acclimated to 5°C
Effect of acclimation
Frogs acclimated to 25°C
O_2 consumption (µl · g^{-1} · h^{-1})
Measurement temperature (°C)

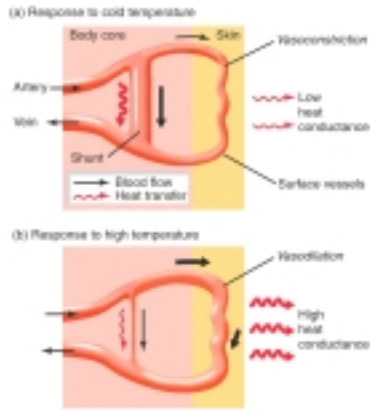

(b)
10°
10°
188
124
76
$Q_{10} = \frac{188}{124} = 1.5$
$Q_{10} = \frac{MR\ (t + 10)}{MR_t} = \frac{124}{76} = 1.6$
O_2 consumption (µl · g^{-1} · h^{-1})

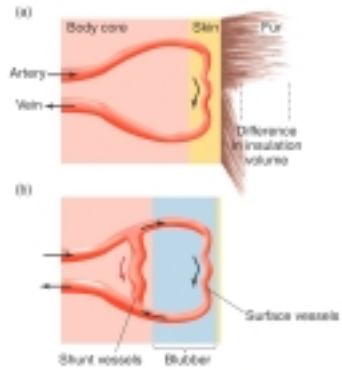

193
89
32
$Q_{10} = \frac{193}{89} = 2.2$
$Q_{10} = \frac{89}{32} = 2.8$
O_2 consumption (µl · g^{-1} · h^{-1})
Measurement temperature (°C)

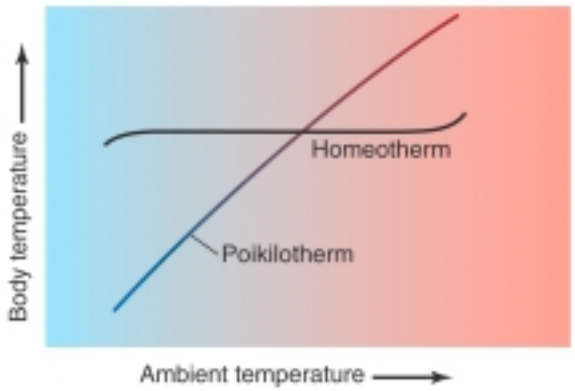

(a)
20° acclimated
5° acclimated
Decrease in polarization due to acclimation
Increase in polarization due to acclimation
Degree of DPH polarization (degree of membrane viscosity)
Acute measurement temperature (°C)

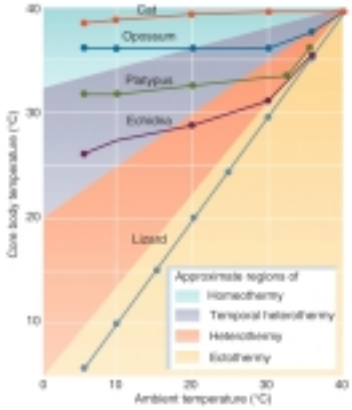

T. funebralis
T. brunnea
Relative increase
HSP 38
HSP 70
HSP 77
HSP 90
Heat shock protein (HSP)

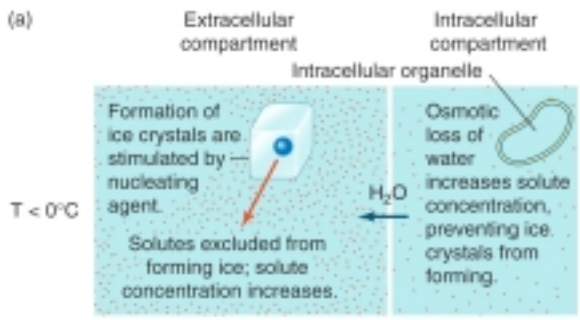

Infrared thermal radiation from atmosphere
Reflected sunlight
Dust and particles
Infrared thermal radiation from vegetation
Infrared thermal radiation from animal
Evaporation
Direct sunlight
Scattered sunlight
Convection by wind
Infrared thermal radiation from ground

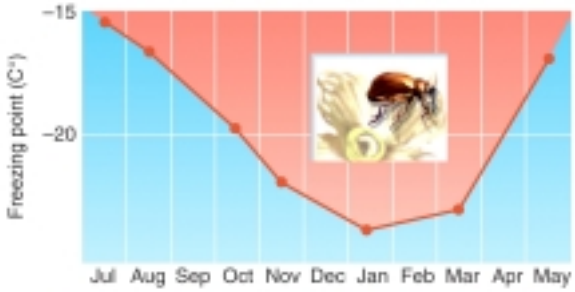

(a) Response to cold temperature
Body core
Skin
Vasoconstriction
Artery
Vein
Shunt
Low heat conductance
Surface vessels
Blood flow
Heat transfer
(b) Response to high temperature
Vasodilation
High heat conductance

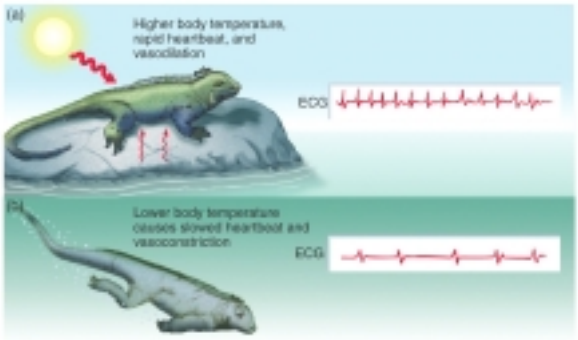

(a)
Body core
Skin
Fur
Artery
Vein
Difference in insulation volume
(b)
Surface vessels
Shunt vessels
Blubber

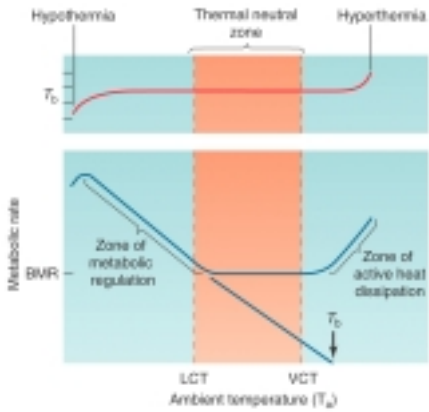

Body temperature
Homeotherm
Poikilotherm
Ambient temperature

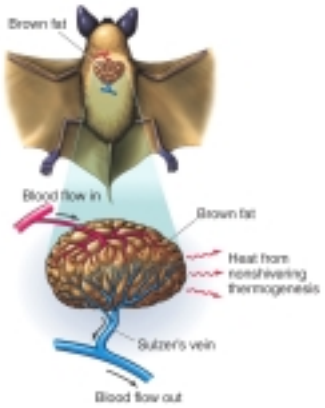

Cat
Opossum
Platypus
Echidna
Lizard
Core body temperature (°C)
Ambient temperature (°C)
Approximate regions of
Homeothermy
Temporal heterothermy
Heterothermy
Ectothermy

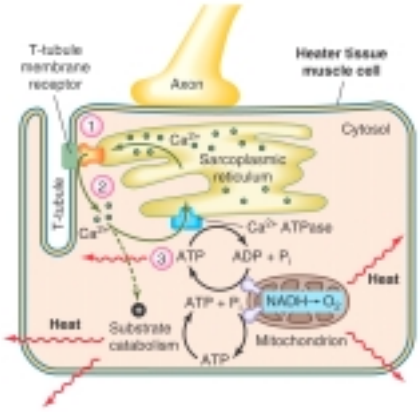

(a)
Extracellular compartment
Intracellular compartment
Intracellular organelle
Formation of ice crystals are stimulated by nucleating agent.
Osmotic loss of water increases solute concentration, preventing ice crystals from forming.
T < 0°C
H_2O
Solutes excluded from forming ice; solute concentration increases.

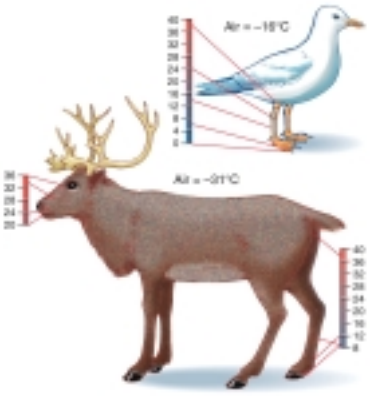

Freezing point (C°)
−15
−20
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May

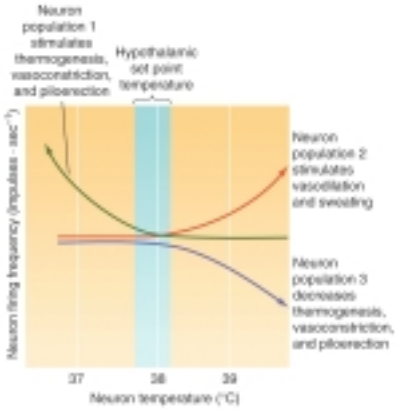

(a)
Higher body temperature, rapid heartbeat, and vasodilation
ECG
(b)
Lower body temperature causes slowed heartbeat and vasoconstriction
ECG

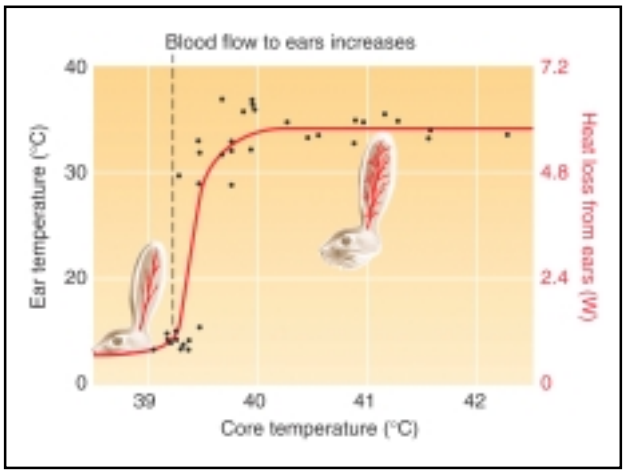

Hypothermia
Thermal neutral zone
Hyperthermia
T_b
Metabolic rate
BMR
Zone of metabolic regulation
Zone of active heat dissipation
T_b
LCT
UCT
Ambient temperature (T_a)

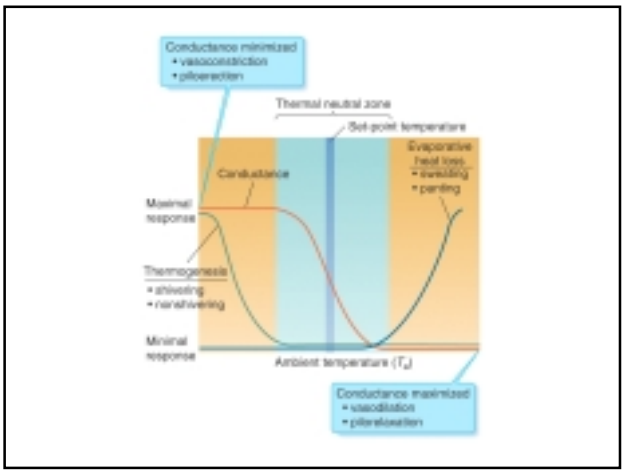

Brown fat
Blood flow in
Brown fat
Heat from nonshivering thermogenesis
Sulzer's vein
Blood flow out

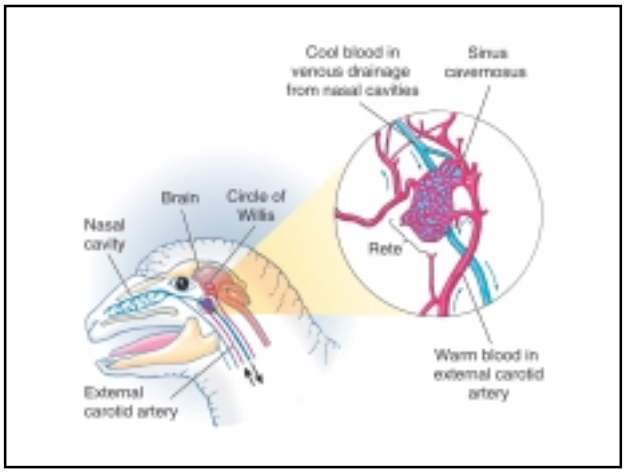

T-tubule membrane receptor
Axon
Heater tissue muscle cell
Cytosol
Sarcoplasmic reticulum
T-tubule
Ca^{2+} ATPase
ATP
ADP + P_i
ATP + P_i
NADH + O_2
Heat
Heat
Substrate catabolism
Mitochondrion
ATP

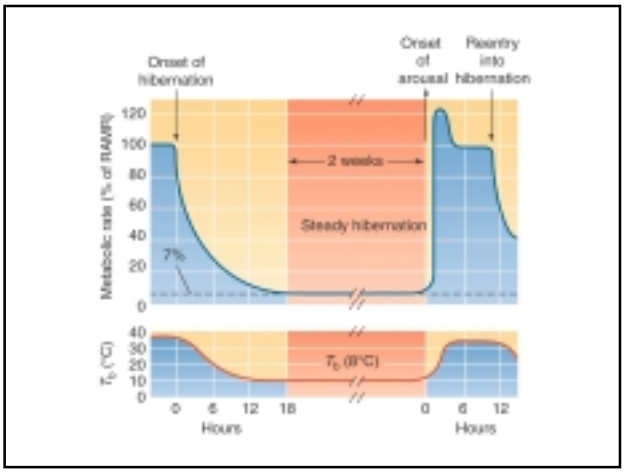

Air = −16°C
Air = −31°C

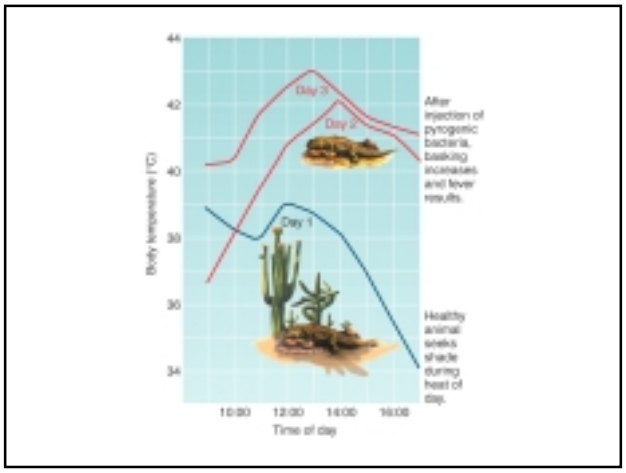

Neuron population 1 stimulates thermogenesis, vasoconstriction, and piloerection
Hypothalamic set point temperature
Neuron population 2 stimulates vasodilation and sweating
Neuron population 3 decreases thermogenesis, vasoconstriction, and piloerection
Neuron firing frequency (impulses · sec⁻¹)
37
38
39
Neuron temperature (°C)

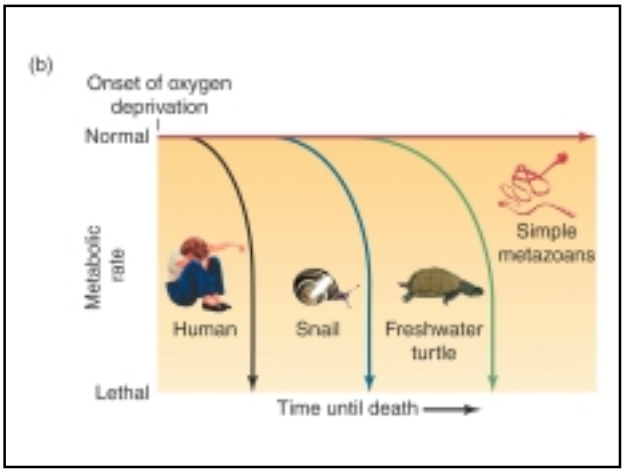

Blood flow to ears increases
Ear temperature (°C)
Heat loss from ears (W)
Core temperature (°C)
40
30
20
0
7.2
4.8
2.4
0
39
40
41
42


Conductance minimized
• vasoconstriction
• piloerection
Thermal neutral zone
Set-point temperature
Conductance
Evaporative heat loss
• sweating
• panting
Maximal response
Thermogenesis
• shivering
• nonshivering
Minimal response
Ambient temperature (T_a)
Conductance maximized
• vasodilation
• piloerelaxation


Cool blood in venous drainage from nasal cavities
Sinus cavernosus
Brain
Circle of Willis
Nasal cavity
Rete
Warm blood in external carotid artery
External carotid artery


Onset of hibernation
Onset of arousal
Reentry into hibernation
Metabolic rate (% of RMR)
120
100
80
60
40
20
0
2 weeks
Steady hibernation
7%
T_b (°C)
40
30
20
10
0
T_b (8°C)
0
6
12
18
Hours
0
6
12
Hours


Body temperature (°C)
44
42
40
38
36
34
Day 3
Day 2
Day 1
After injection of pyrogenic bacteria, basking increases and fever results.
Healthy animal seeks shade during heat of day.
10:00
12:00
14:00
16:00
Time of day


(b)
Onset of oxygen deprivation
Normal
Metabolic rate
Lethal
Human
Snail
Freshwater turtle
Simple metazoans
Time until death