# NORMAL BODY TEMPERATURE REGULATION

- Temperature of the deep tissues of the body – core remains almost constant , within $\pm$ 0.6$^{o}$C day in and day out, except when a person develops febrile fever. In contrast, the skin temperature rises and falls with the temperature of the surroundings.
- When the rate of heat production in the body is greater than the rate at which it is lost, heat builds up in the body and the body temperature rises. Conversly when heat loss is greater, both the body heat and body temperature decreases.

# HEAT PRODUCTION

Factors that determine the rate of heat production include:

- Basal rate of metabolism of all cells of the body
- Extra rate of metabolism caused by muscular activity e.g. muscle contraction due to shivering
- Extra metabolism caused by the effect of thyroxine on cells
- Extra metabolism caused by the effect of epinephrine, norepinephrine and sympathetic stimulation of cells
- Extra metabolism caused by increased chemical activity in cells due to increase in cellular tempereature
- Extra heat gained by eating hot food, exposure to sun, warm air and exercise

# HEAT LOSS

- Most of the heat generated in the deeper tissues is transferred to the skin from where it is lost to the air and surroundings by evaporation of sweat from skin, conduction, convection and radiation.
- In faeces and urine
- In exhaled air from the lungs

Hence the rate at which heat is lost is determined entirely by two factors

- How rapidly the heat produced in the core tissues can be conducted to the skin
- How rapidly the heat can then be transferred from the skin to the surroundings

# INSULATOR SYSTEM OF THE BODY

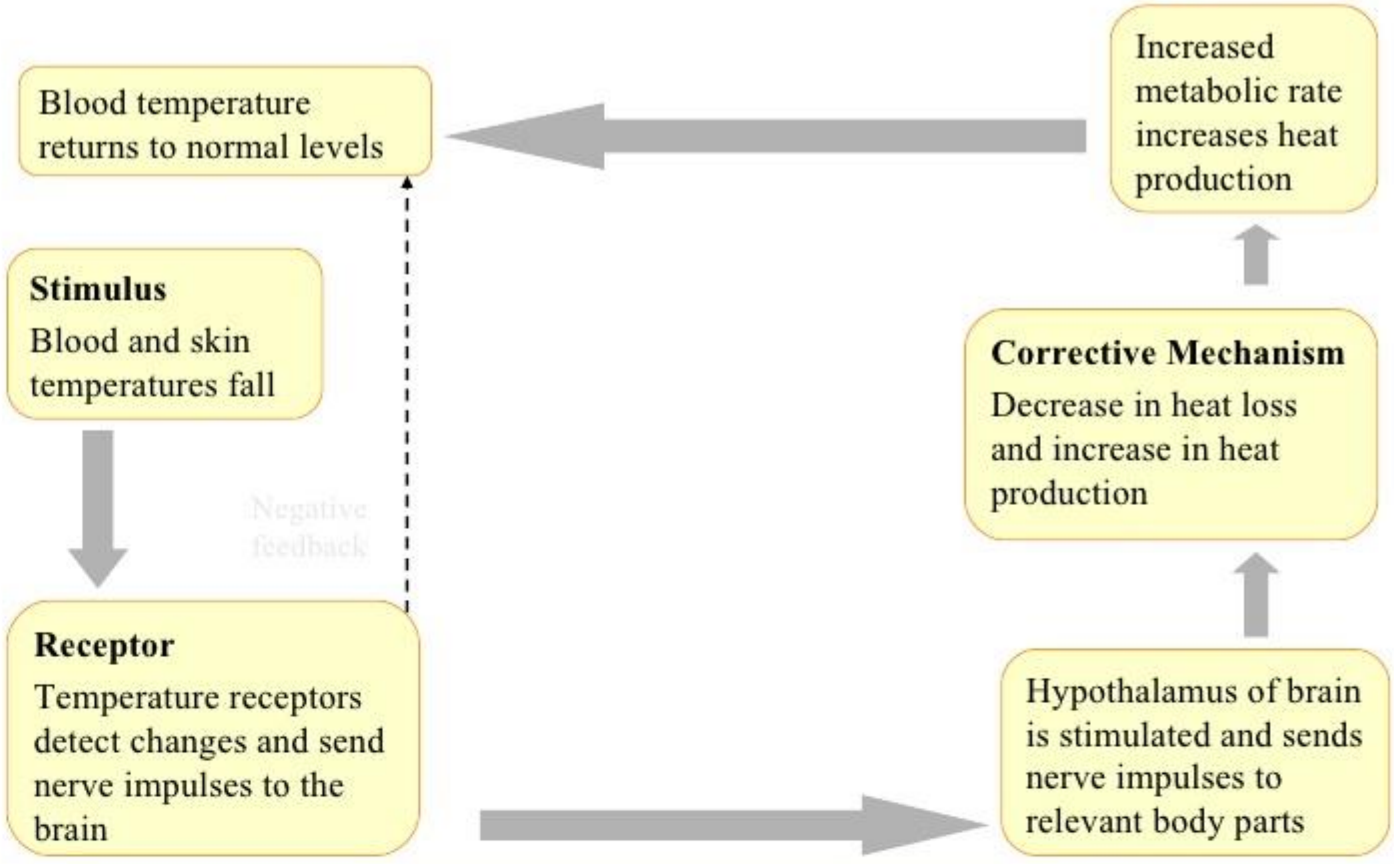
- Skin and subcutaneous tissues especially subcutaneous fat act as insulator of heat for the body. Fat conducts heat only one third as readily as other tissues.
- When no blood is flowing from the heated tissues to the skin, the insulating properties of a normal male body are about three quarters the insulating properties of the usual clothing. In women the insulation is better.
- The insulation beneath the skin is an effective means to maintain the normal core temperature, even though it allows the skin temperature to approach the temperature of the surroundings.

# SYSTEM OF HEAT TRANSFER

- Blood flow from the core tissues to the skin provided heat transfer
- Blood vessels penetrate the fatty sub-cutaneous insulator tissues and are distributed profusely beneath the skin
- Especially important is a continuous venous plexus that is supplied by inflow of blood from the skin capillaries. In most exposed areas of the body- hands, feet and ears, blood is also supplied to the plexus directly from the small arteries through highly muscular arteriovenous anastomoses.

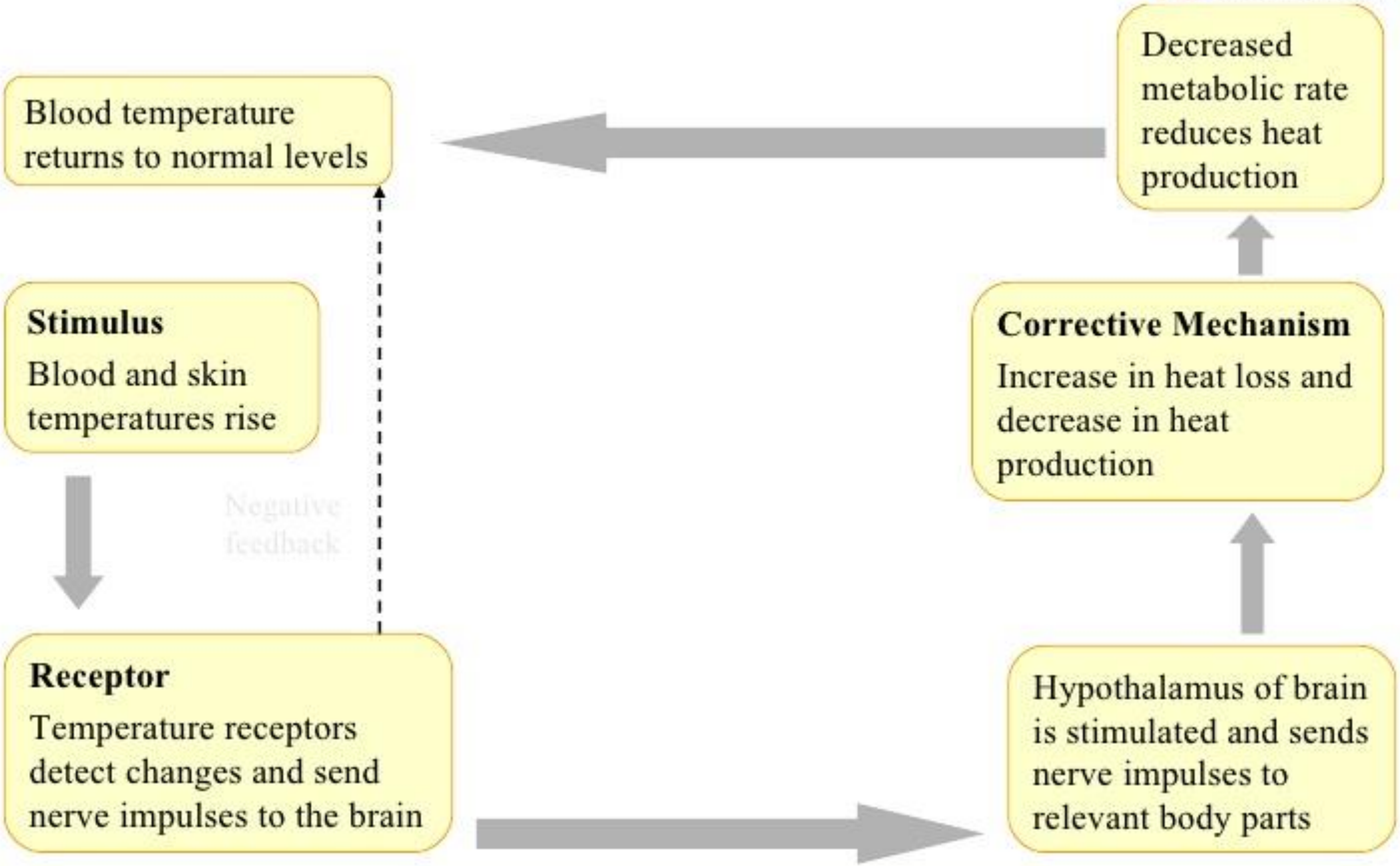
# Regulating Body Temperature - on a Cold Day

Marshall Cavendish



# Regulating Body Temperature - on a Hot Day

Marshall Cavendish



# FUNCTIONS OF PARTS OF THE SKIN

- Blood vessels: brings oxygen to the cells of the skin. the arterioles can dilate or constrict to regulate the amount of blood flowing through the skin which helps to regulate the body temperature.
- Sweat glands: produces sweat which can help cool down the body temperature
- Hair: can help trap air to insulate the body
- Nerve endings (temperature receptors): detect changes in temperature of the external environment
- Adipose tissue: stores fat and serves as an insulator, preventing heat loss
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# REGULATION OF BODY TEMPERATURE

Hypothalamus in the brain:

- monitors and regulates the body temperature
- receives information about the heat changes in the external environment from the temperature receptors in the skin
- monitors the temperature of blood that passes through it

When the body temperature drops:

- Heat lost by the body → activates the temperature receptors in the skin → nerve impulses sent to the heat gain centre of the hypothalamus → following mechanisms are initiated:
- Vasoconstriction → sweat glands become less active → metabolic rate increases → contraction of hair erector muscles → shivering (if the above reactions are insufficient)
- Hormonal output → epinephrine and norepinephrine increase basal heat production; prolonged cold – thyroxin

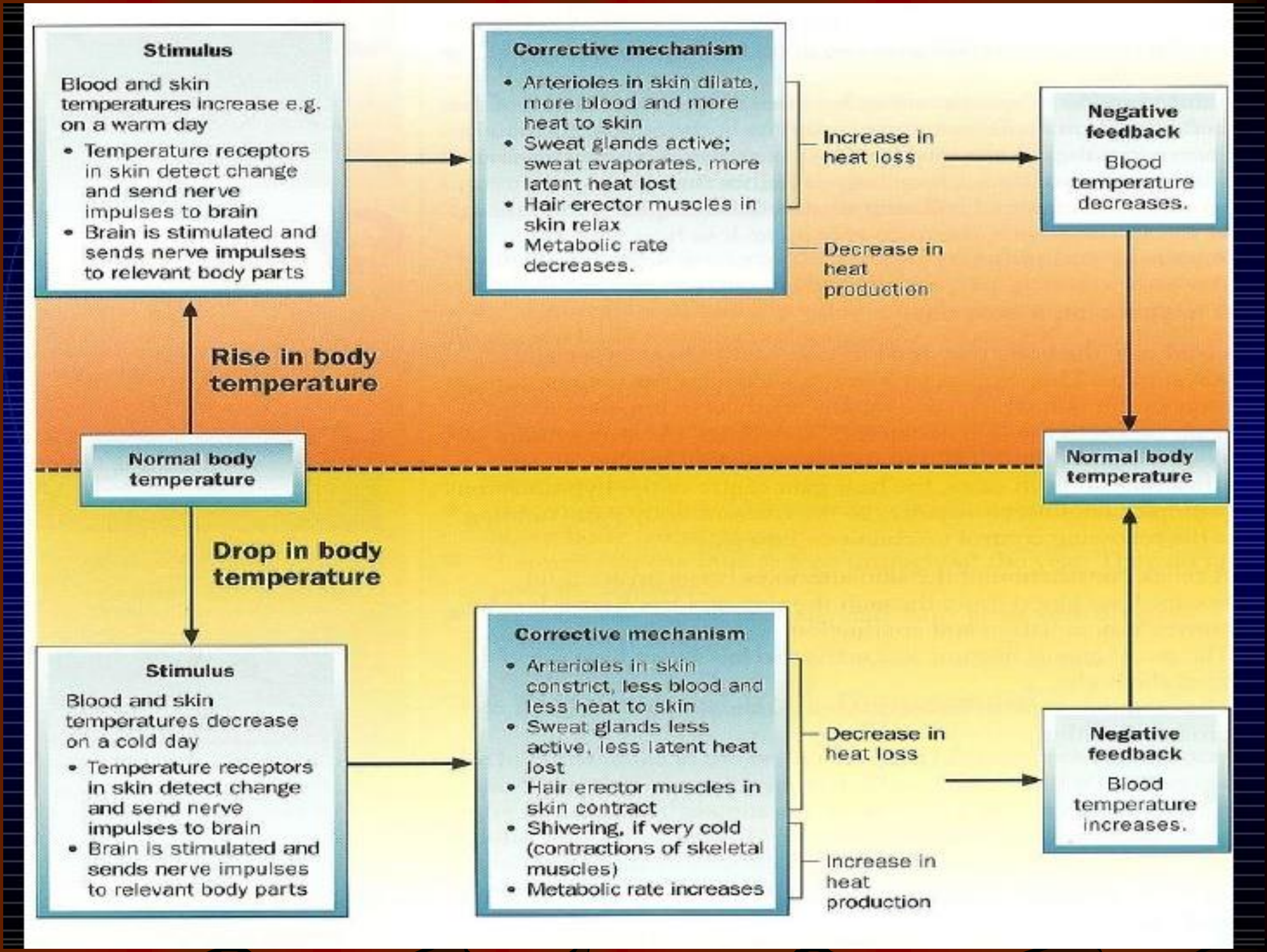
Hence body temperature remains constant as extra heat is produced

When body temperature begins to rise:

- Vigorous muscular activities → heat produced → rise in blood temperature → heat loss centre in hypothalamus activated → nerve impulses sent to different body parts → followings mechanisms initiated:

- Vasodilation → sweat glands increases activity → rapid breathing → metabolic rate slows down

Hence body temperature remains constant as extra heat is removed


Stimulus
Blood and skin temperatures increase e.g. on a warm day
• Temperature receptors in skin detect change and send nerve impulses to brain
• Brain is stimulated and sends nerve impulses to relevant body parts
Corrective mechanism
• Arterioles in skin dilate, more blood and more heat to skin
• Sweat glands active; sweat evaporates, more latent heat lost
• Hair erector muscles in skin relax
• Metabolic rate decreases.
Increase in heat loss
Decrease in heat production
Negative feedback
Blood temperature decreases.
Rise in body temperature
Normal body temperature
Normal body temperature
Drop in body temperature
Stimulus
Blood and skin temperatures decrease on a cold day
• Temperature receptors in skin detect change and send nerve impulses to brain
• Brain is stimulated and sends nerve impulses to relevant body parts
Corrective mechanism
• Arterioles in skin constrict, less blood and less heat to skin
• Sweat glands less active, less latent heat lost
• Hair erector muscles in skin contract
• Shivering, if very cold (contractions of skeletal muscles)
• Metabolic rate increases
Decrease in heat loss
Increase in heat production
Negative feedback
Blood temperature increases.

# PHYSIOLOGICAL RESPONSE IN POIKILOTHERMS

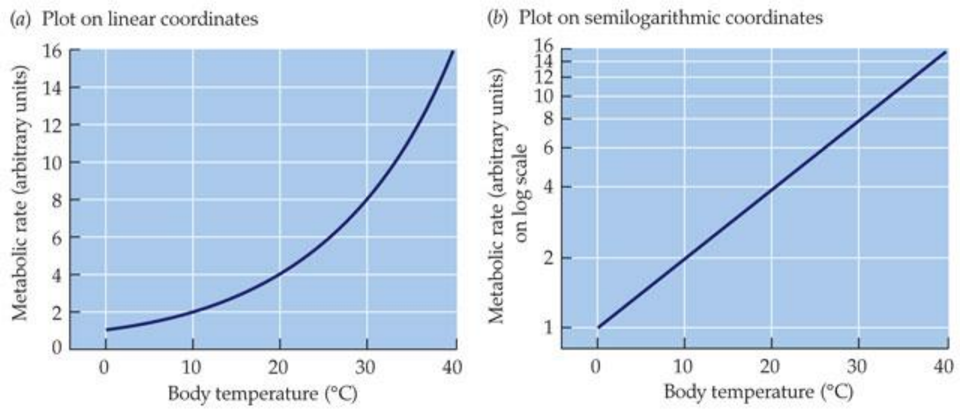
- Acute response: rapid changes in metabolic rate → follows an exponential function of body temperature

- Factor by which the metabolic rate increase when body temperature increase by 10° = temperature coefficient $Q_{10}$

- $Q_{10}$= Rt/R(t-10) where r is the rate, t is the temperature

- a unitless quantity, as it is the factor by which a rate changes, and is a useful way to express the temperature dependence of a process.

- Around 2-3 for poikilotherms

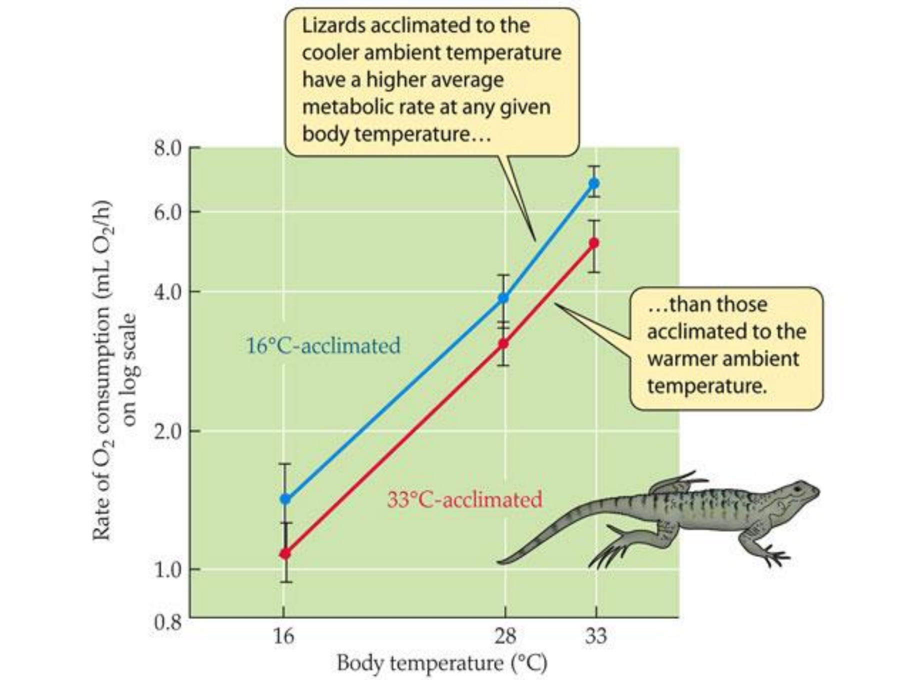


# PHYSIOLOGICAL RESPONSE IN POIKILOTHERMS

- Chronic response: Exposure to different temperature will induce different metabolic response → acclimation

- Initial response is a drop in metabolism
- Followed by an increase → compensation

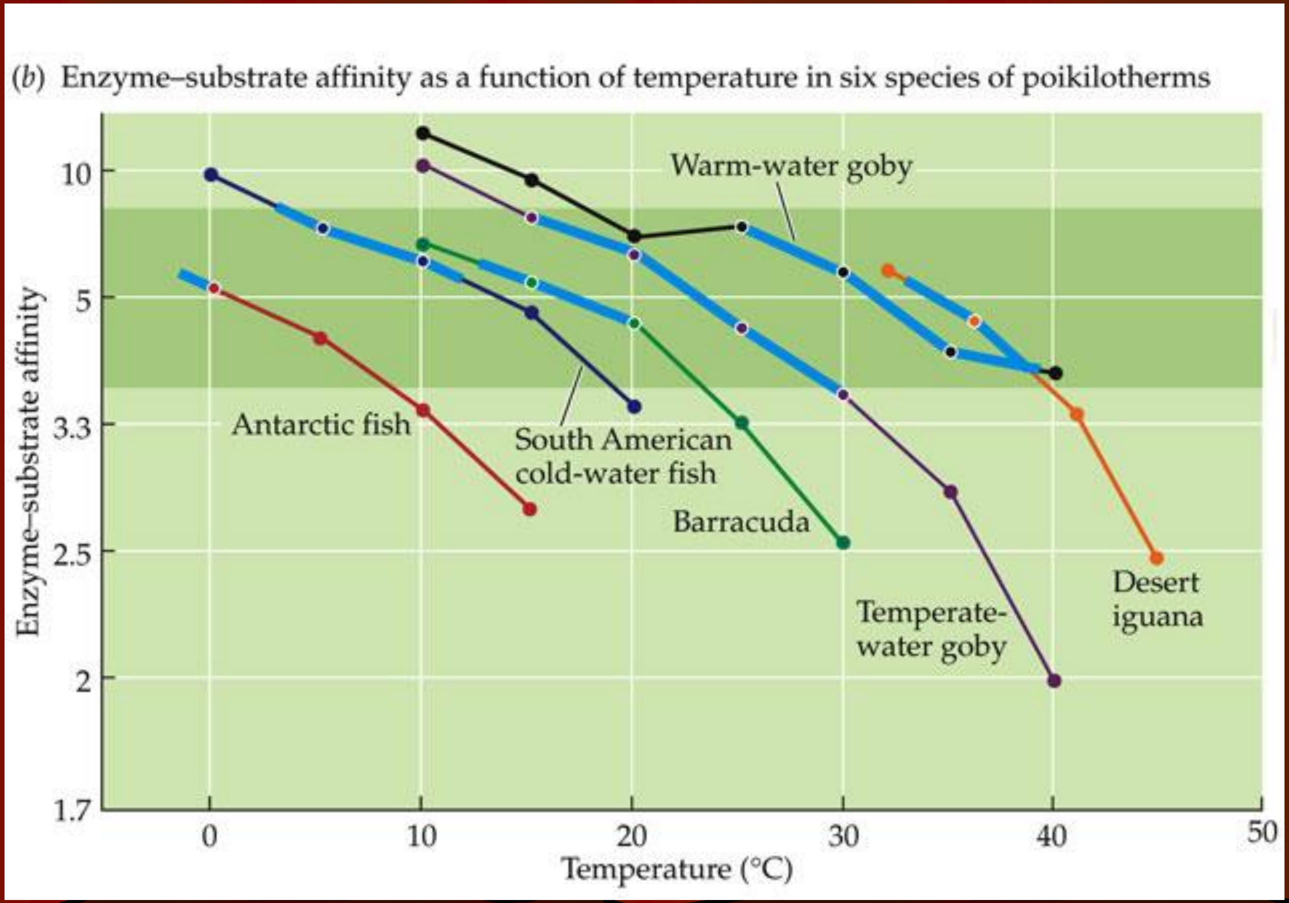
- Acclimation is due to a change in the number and activities of enzymes involved in metabolism.



*Animal Physiology 2e*, Figure 9.11

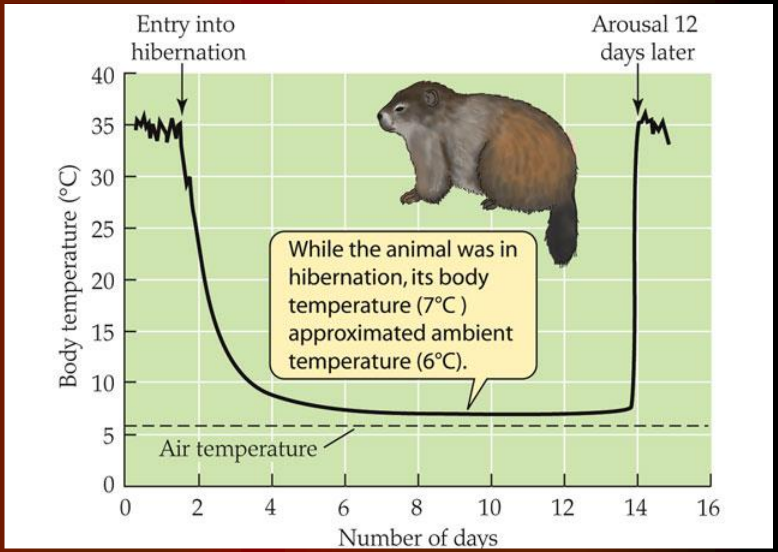
# EFFECTS OF TEMPERATURE AT BIOCHEMICAL LEVEL

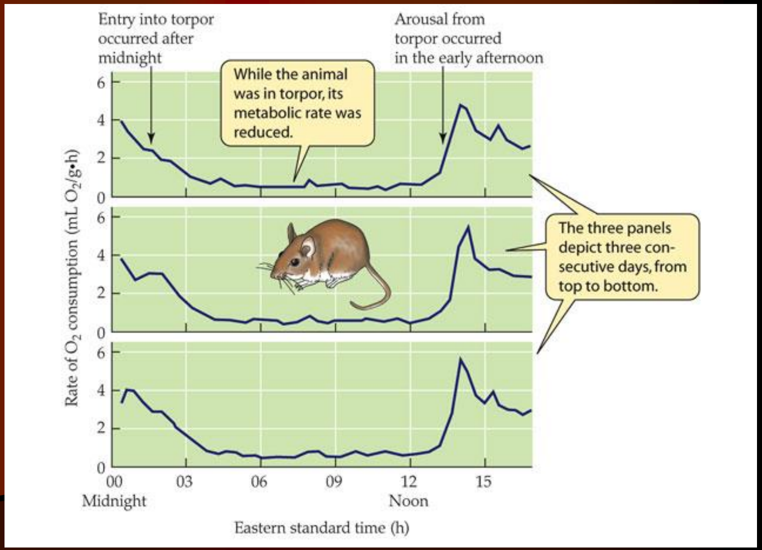
- Enzymes work faster at higher temperatures
- Lipids are more fluid at higher temperatures



# Hibernation – Aestivation – Daily torpor

- A mean to escape the demands of homeothermy
  - Torpor
  - Controlled hypothermia
- Body temperature fall to close approximate ambient temperatures
- During winter → hibernation
- During summer → estivation
- During certain part of the day → daily torpor



# Temperature Dependence of Equilibrium Constant

The equilibrium constant is related to the standard free energy change of the reaction

$$\Delta G^o = - RT \ln K_{eq}$$

The free energy change upon reaction is related to both the enthalpy and entropy changes

$$\Delta G^o = \Delta H^o - T\,\Delta S$$

Although the **free energy change is strongly dependent on temperature**, usually the enthalpy and entropy changes upon reaction are **NOT** temperature dependent (or at least not very much so). This implies that the free energy is a linear function of temperature. Combining the above two equations:

$$\frac{\Delta G^o}{T} = \frac{\Delta H^o}{T} - \Delta S^o$$

Substituting in the equilibrium constant

$$\frac{- RT\ln K}{T} = \frac{\Delta H^o}{T} - \Delta S^o$$

or $$\ln K = \frac{\Delta H^o}{RT} + \frac{\Delta S^o}{R}$$

The enthalpy and entropy changes are regarded as constants with respect to temperature, so the equilibrium constant is exponentially dependent on temperature (Arrhenius equilibrium).

The relative change in equilibrium constant as a function of temperature is usually not expressed as above but as the ***van't Hoff equation***

$$\ln \left[ \frac{K_2}{K_1} \right] = \frac{\Delta H^o}{R} \left[ \frac{1}{T_2} - \frac{1}{T_1} \right]$$