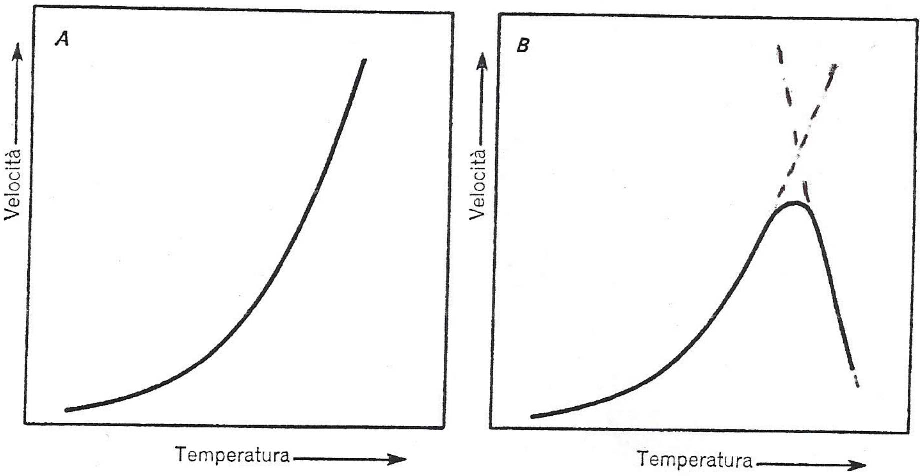


Fig. 266. Azione della temperatura sulla velocità di reazione.
A. Reazioni chimiche; *B*. Reazioni biologiche.
(Da R. Thauer, *Jahrbuch der Max-Planck-Gesellschaft*, 39-75, 1967, fig. 3).

$$k = Ae^{-\frac{E_A}{RT}}$$

METABOLIC (CHEMICAL) REACTIONS HAVE A SENSITIVE DEPENDENCE ON T

HENCE, REGULATION IS VERY IMPORTANT

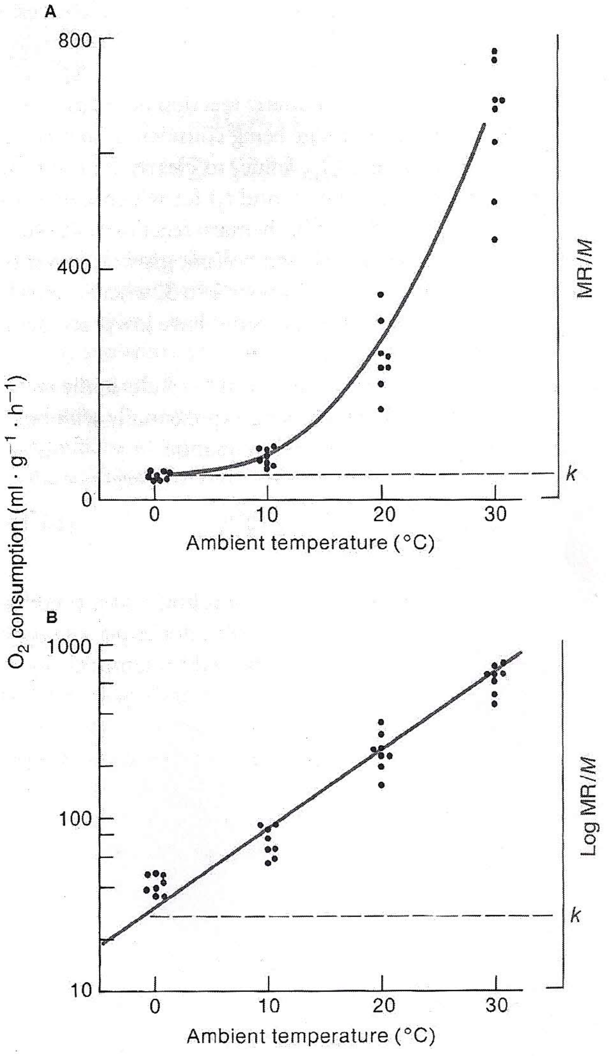


Figure 16-9 The oxygen consumption of the tiger moth caterpillar increases sharply as its body temperature increases. **(A)** Geometric coordinates. **(B)** Semilog coordinates. The generalized ordinates are shown in color at the right in reference to equations 16-11 and 16-12. The constant *k* is obtained by extrapolating the metabolic rate to a body temperature of 0°C and is the proportionality factor in equations 16-11 and 16-12. [From Scholander et al., 1953.]

$M = W_B =$ weight

Randall et al. Animal Physiol. 1997

Because of the T effect on enzymes:

$$\frac{MR}{W_B} = K\,10^{bT}$$

$$\log \frac{MR}{W_B} = \log K + bT$$

MR = metabolic rate; W_B = body weight

k, b = constants; T = temperature

VELOCITY CONSTANT = K $= \frac{K_B T}{h} \exp\left(-\frac{\Delta G^{\ddagger}}{RT}\right)$

$$Q_{10} = \frac{k_{T_2}}{k_{T_1}} = \frac{T_2}{T_1} \exp\left(\frac{\Delta G_1^{\ddagger}}{RT_1} - \frac{\Delta G_2^{\ddagger}}{RT_2}\right)$$

T is absolute temperature, so $\frac{T_2}{T_1} \simeq 1$

E.g., for $T_1 = 298\,K = 25°C$
$T_2 = 308\,K = 35°C$ $\longrightarrow \frac{308}{298} = 1.03$

For DIFFUSIVE PROCESSES, $\Delta G^{\ddagger}$ is small ($\simeq 5$ Kcal mol^{-1}K^{-1})

Thus: $Q_{10} \simeq \exp\left[\frac{1}{2}\left(\frac{5000}{298} - \frac{5000}{308}\right)\right] = 1.3$

R in cal

For CHEMICAL REACTIONS or COMPLEX CONFORMATIONAL TRANSITIONS, $\Delta G^{\ddagger}$ is usually much higher.

e.g., $Q_{10} \simeq \exp\left[\frac{1}{2}\left(\frac{20000}{298} - \frac{20000}{308}\right)\right] \simeq 3$

(Van't HOFF)

$$Q_{10} = \left(\frac{K_{T_2}}{K_{T_1}} \right)^{\frac{10}{T_2 - T_1}}$$

K's = RATE CONSTANTS of a reaction/process

$$T_2 > T_1$$

It can be applied to single reactions
or complex processes (running, metabolism, etc.)

	Temperatura (°C)	Q_{10}
Fenomeno fisico		
Diffusione	20	1,03
Fenomeno biochimico		
Citocromo reduttasi (opossum)	>20	1,5
	<20	2,5
Piruvato chinasi V_{max} (ratto)	>25	1,7
	<25	3,2
Precipitazione dell'emoglobina	60	13,8
Fenomeno fisiologico		
Consumo di ossigeno (anemone)	5	2,0
	15	2,3
Frequenza cardiaca (gambero d'acqua dolce)	5	2,4
	15	1,6
	25	0,8
Movimenti branchiali (crostaceo)	5	3,8
	15	1,7
Consumo di ossigeno (coleottero)	10	2,4
	20	2,1
Induzione termica della diapausa (insetto)	20	1,4
	10	3,7
Consumo di ossigeno (mammifero torpido)	20	4,1

Willmer et al. Fisiol. Amb. degli Animali

ONE MUST SPECIFY THE RANGE OF T's FOR WHICH Q_{10} IS MEASURED.

TEMPERATURE REGULATION IN ANIMALS: TERMINOLOGY I

Warm or cold blood: it does not consider that body temperature varies with environment, with physiological state (sleep, hibernation, etc.).

Traditional distinction:

Homeotherms (constant T) or **poikilotherms** (variable T, as a function of environment).

It has drawbacks:

- sea animals have constant T because of the constant T of sea water;
- many poikilotherms are good regulators of body T, but need an external heat source;
- body T can vary a lot in many mammals and birds (locally or globally).

TEMPERATURE REGULATION IN ANIMALS: TERMINOLOGY II

ENDOTHERMS: Internal source of heat (from metabolism, animals with high metabolism).

Body T is much higher than average environmental T.

The real endotherms can increase metabolic rate (in liver, viscera, etc.) to increase body T.

Metabolic rate is about 5 times as high as in ectotherms, per unit weight

'Tachimetabolism' and 'Bradimetabolism'

Homeotherms endotherms: mammals and birds.

Local endotherms heterotherms: terrestrial reptiles, sharks, tuna, some flying insects.

ECTOTHERMS: External source of heat.

Low production of metabolic heat.

Often high thermal conductivity.

- Adopt behavioral thermoregulation (avoidance)
- Exploit microclimates

TEMPERATURE REGULATION IN ANIMALS: TERMINOLOGY III

HETEROTHERMS: Intermediate situations.
They can control the internal production of heat,
but do not maintain a restricted body T range,
like homeotherms do.

Temporal endothermia: - *facultative* (e.g., global body heating by muscle activity in bees, etc.);
- *partial* (small endotherms with frequent torpor or even metabolic block, seasonal or nocturnal);
- *regional*: e.g., deep muscle activity in fishes or reptiles;

Regional heterothermia: e.g., circulation control in periphery.

Inertial homeo-/heterothermia: low surface to volume ratio (e.g., Dinosaurs?).

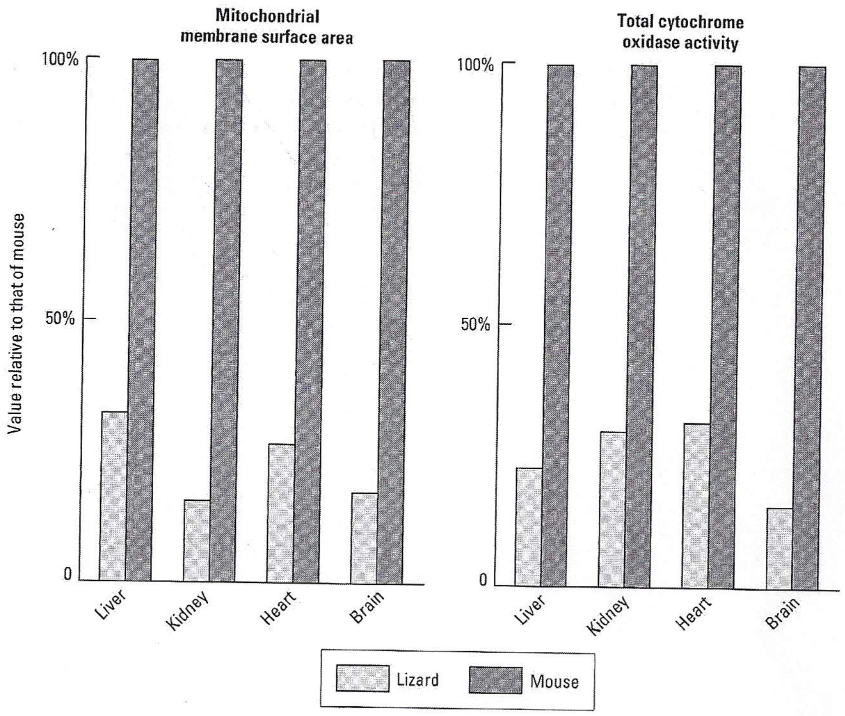
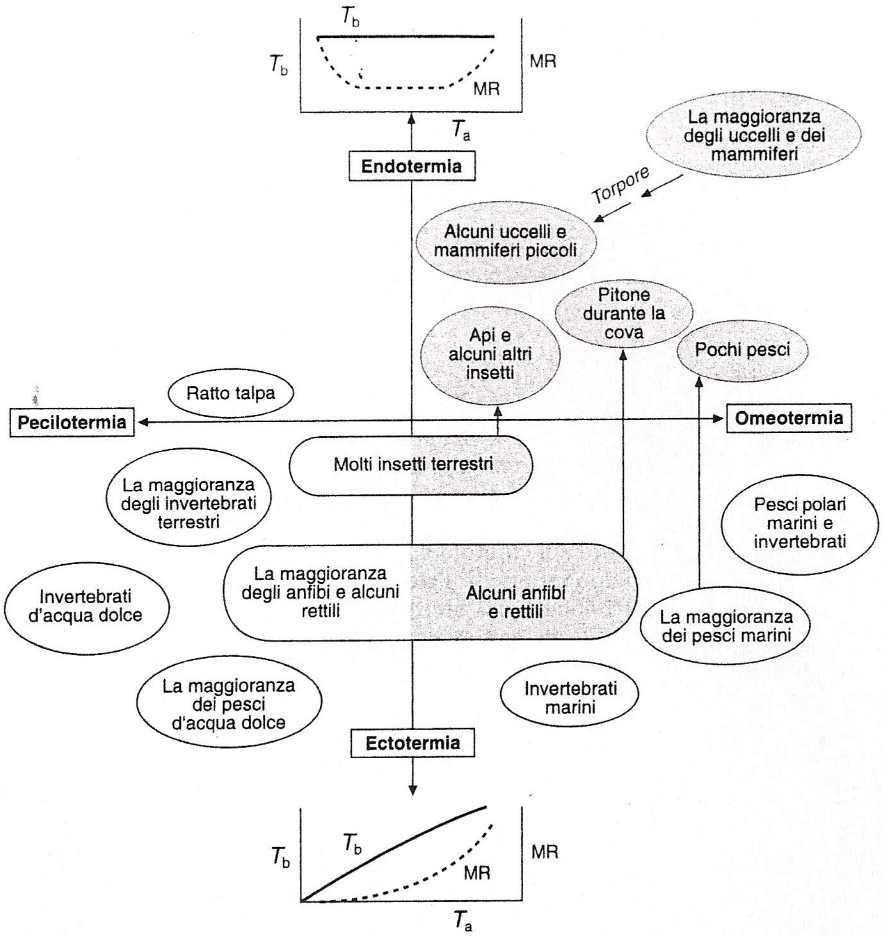


Fig. 8.31 A comparison of mitochondrial density and cytochrome oxidase activity in the tissues of an ectotherm (lizard) and endotherm (mouse) of similar body mass. Values are given relative to the mouse as 100%, and are roughly one-third to one-fourth as high for the lizard. (From Else & Hulbert 1985.)

ECTOTHERMS:
- LOW MR
- ↑ REPROD. INVEST.
- ↓ NEED of FOOD and WATER
- SMALLER
- DEPEND on EXTERNAL T
- USUALLY LOW ACTIVITY and OFTEN ANAEROBIOSIS

ENDOTHERMS:
- OPPOSITE ADVANTAGES and DISADVANTAGES
- ADVANTAGES ESPECIALLY IN TEMPERATE and COLD CLIMATES

Figura 8.15. La terminologia nel campo della termoregolazione. Viene mostrato quanto i termini siano distinti o sovrapposti. L'ombreggiatura indica gli animali termoregolatori e il bianco quelli termoconformi; le frecce si riferiscono all'eterotermia temporale. MR, tasso metabolico; T_a, temperatura ambientale; T_b, temperatura corporea.



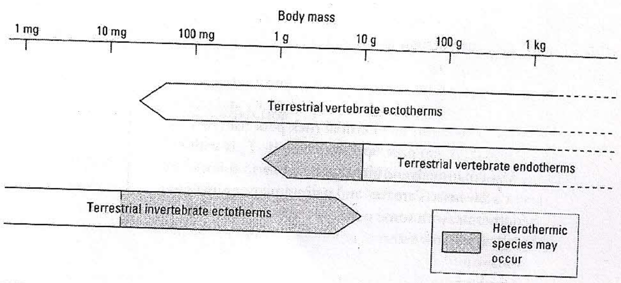


Fig. 8.16 Relative sizes of ectotherms and endotherms, showing the size ranges for the occurrence of temporal heterothermy.

EFFECTS OF HIGH TEMPERATURE

a) Protein denaturation / coagulation

b) Alteration of enzyme activity

c) Alteration of membrane structure (weak interactions, ‘liquid crystal’ structure, synapses are very sensitive)

d) Inadequate oxygen supply.

e) Other complex effects….

EFFECTS OF LOW TEMPERATURE

a) Small T changes: fiirst of all effects on nervous system and respiration

b) Freezing: - mechanical damage
- osmotic damage

c) Decreased enzyme activity and altered membrane viscosity

d) Instability of microtubules (< 4 °C, in mammals).