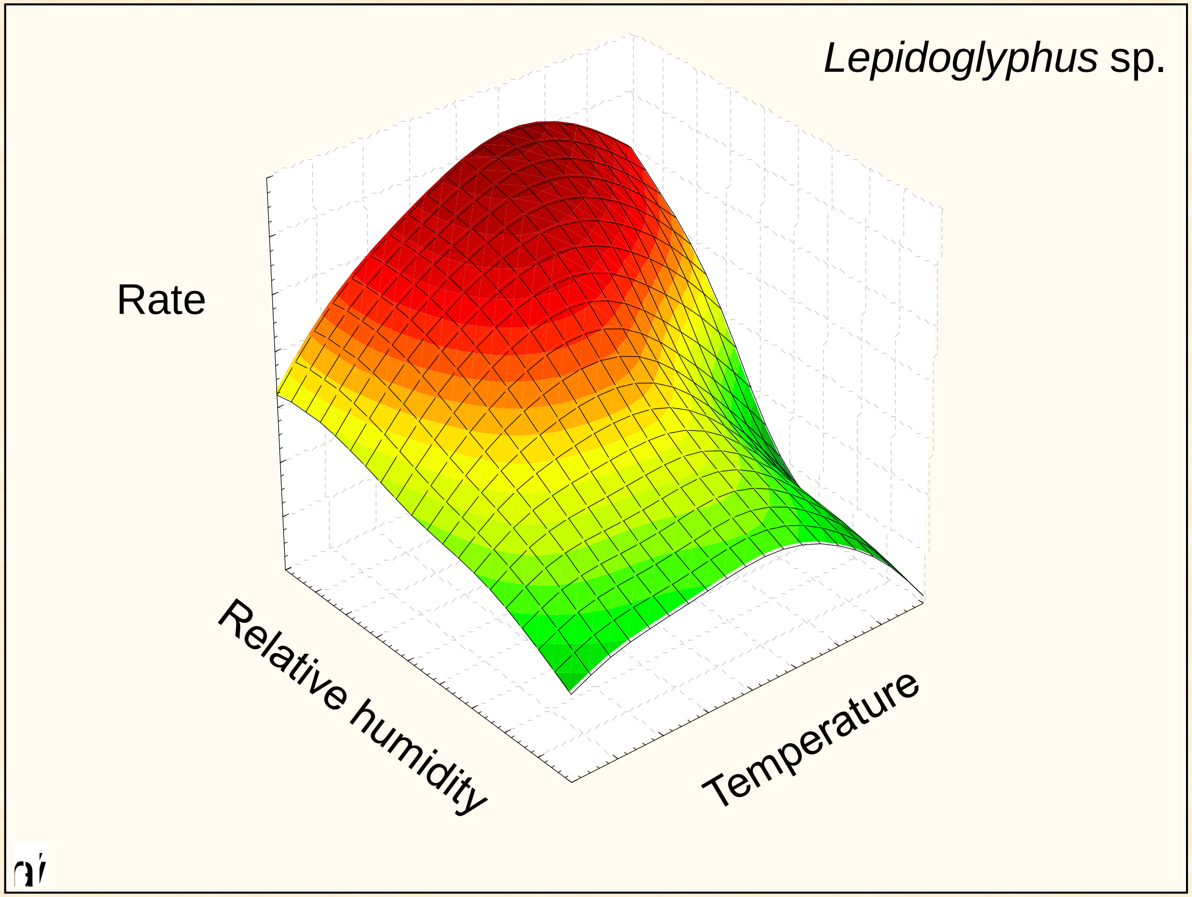
Temperature

„Populační ekologie živočichů“

Stano Pekár

Effect of conditions

- all conditions affect population growth via controlling metabolic processes in ectotherms
- temperature, humidity, day length, pH, etc.



Universal effect of temperature

- temperature affects population growth of ectotherms

- rate of metabolism increases approx. by 2.5x for every 10 °C

$$Q_{10} = 2.5$$

- physiological time – combination of time and temperature

- universal temperature dependence:

- rate of metabolism B:

$$B \sim e^{-\beta / T}$$

(T .. temperature)

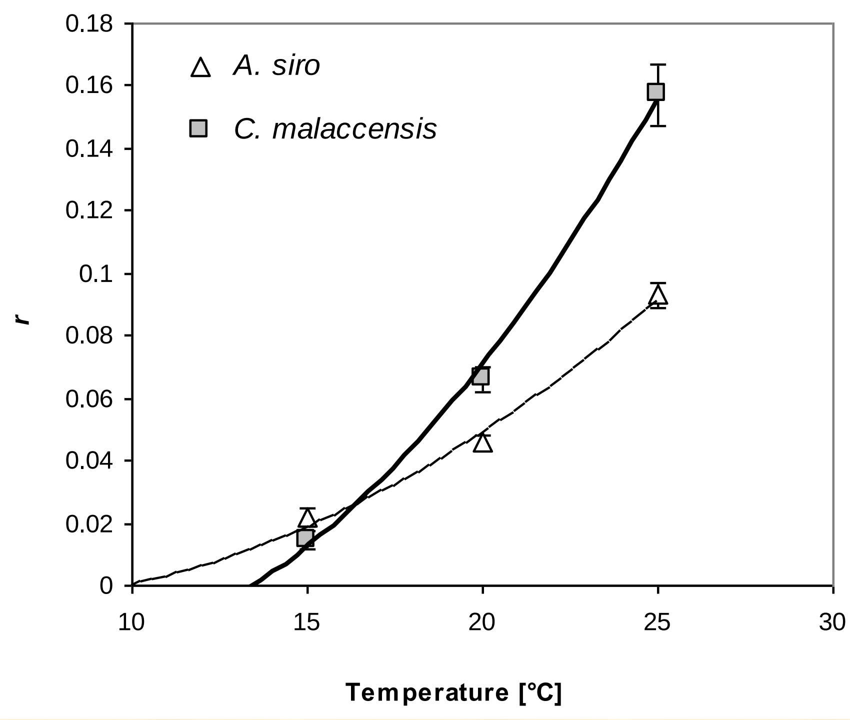
- rate increases with body mass (M):

per mass unit …

$$\frac{B}{M} \sim M^{1/4}$$

- biological time t_b:

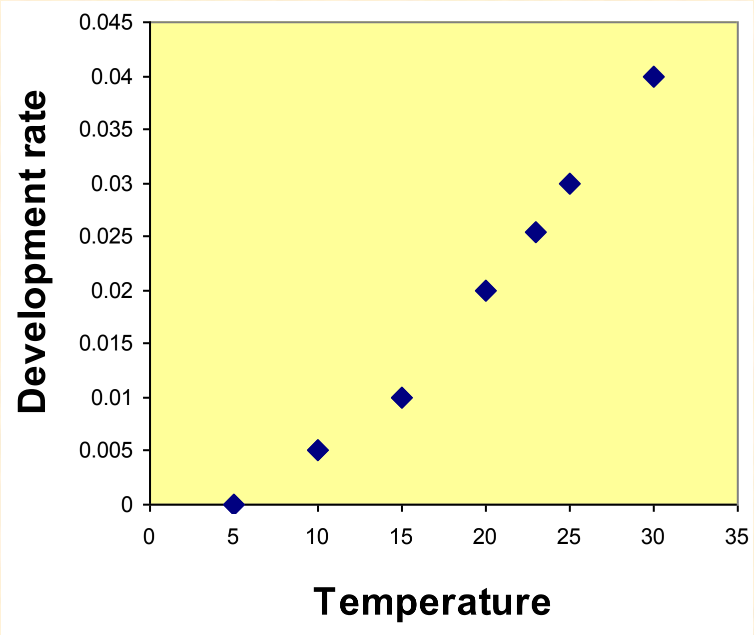
$$t_b \sim M^{1/4} e^{\beta / T}$$



Linear model

- model is based on the assumption that developmental rate is a linear function of temperature T
- valid for the region of moderate temperatures (15-25°)
- at low temperatures organisms die due to coldness

D .. development time (days)
v .. rate of development = $1/D$
T_{min} .. lower temperature limit
- temperature at which developmental rate = 0



ET.. effective temperature .. developmental temperature between *T* and T_{min}

S .. sum of effective temperature .. number of day-degrees [°D] required to complete development

.. does not depend on temperature = $D*ET$

T_{min} and *S* can be estimated from the regression line of $v = a + bT$

T_{min} :

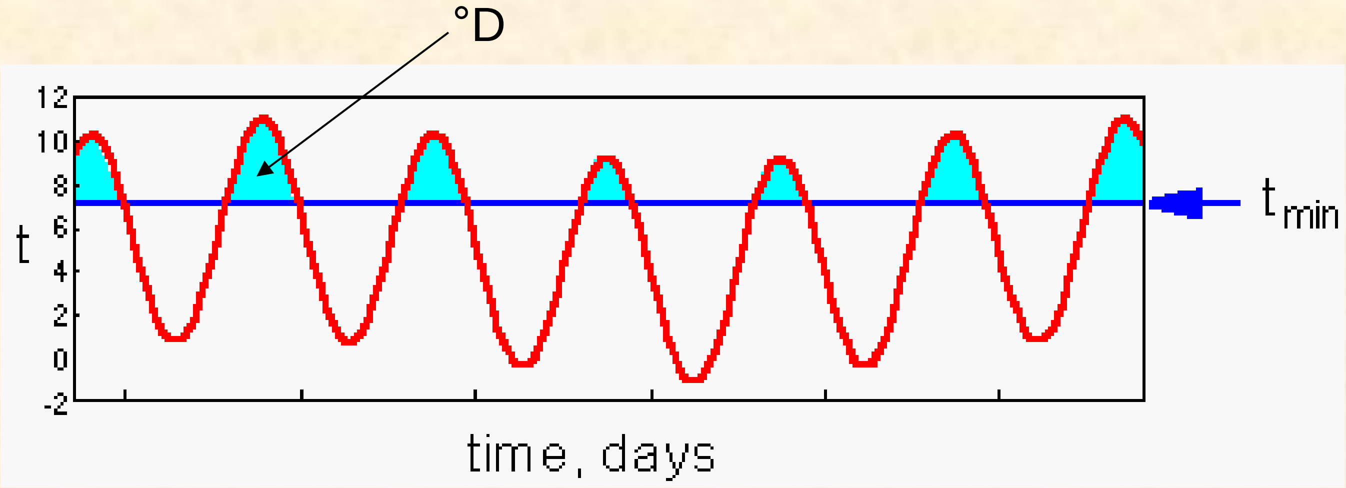
$$a + bT = 0 \quad \Rightarrow \quad \boxed{T_{min} = -\frac{a}{b}}$$

S :

$$S = D(T - T_{min}) = D\left(T + \frac{a}{b}\right)$$

$$D = \frac{1}{v} = \frac{1}{a + bT} \quad \Rightarrow \quad S = \frac{T + a/b}{a + bT} \quad \Rightarrow \quad \boxed{S = \frac{1}{b}}$$

- sum of effective temperature (S) [°D] is equal to area under temperature curve restricted to the interval between current temperature (T) and T_{min}
- biofix .. the date when day-degrees begin to be accumulated

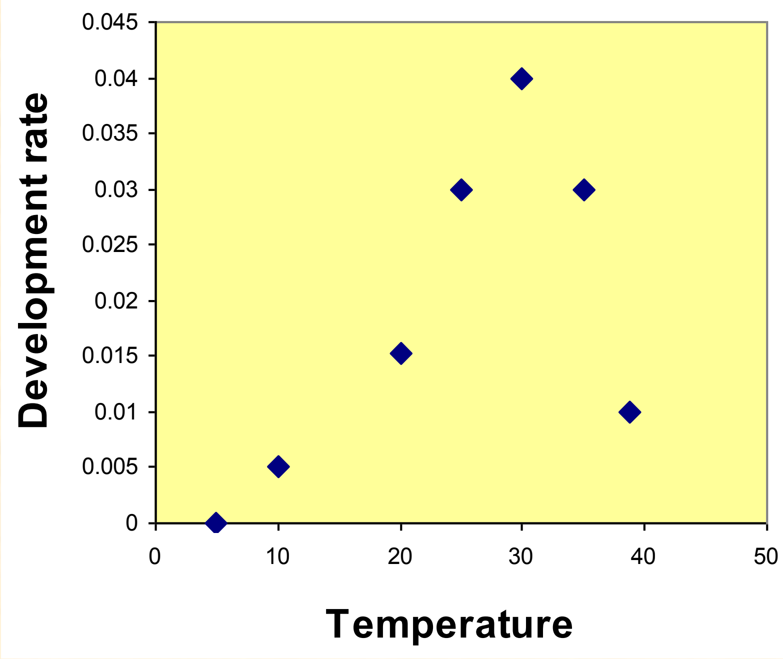


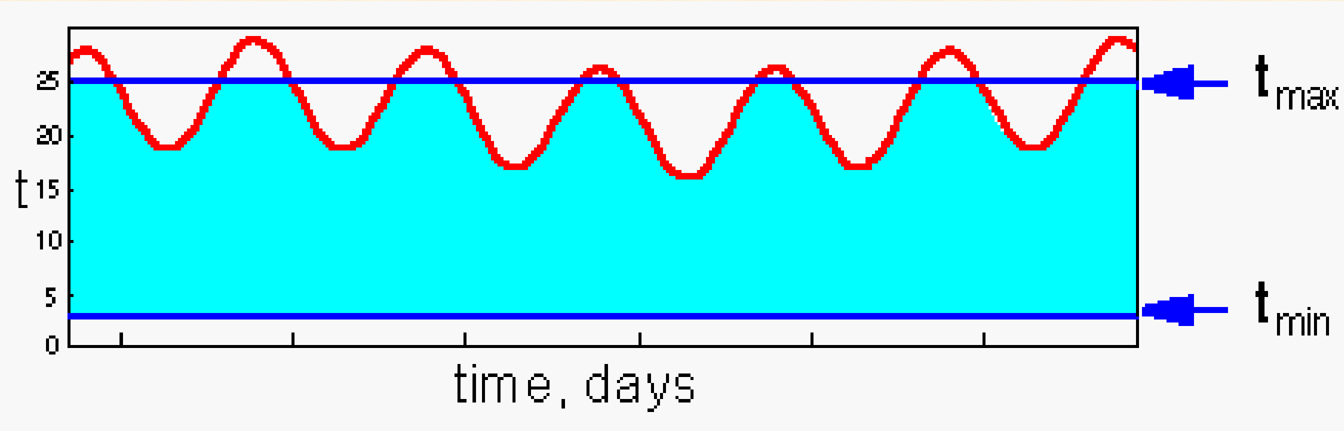
$$S = \sum_{i=1}^{n} T - T_{min}$$

Non-linear models

- when development rate is a non-linear function of temperature
- *ET*.. developmental temperature between T_{min} and T_{max}
- at high temperatures organisms die due to overheating

T_{max} .. upper temperature threshold
- temperature at which
developmental rate = 0



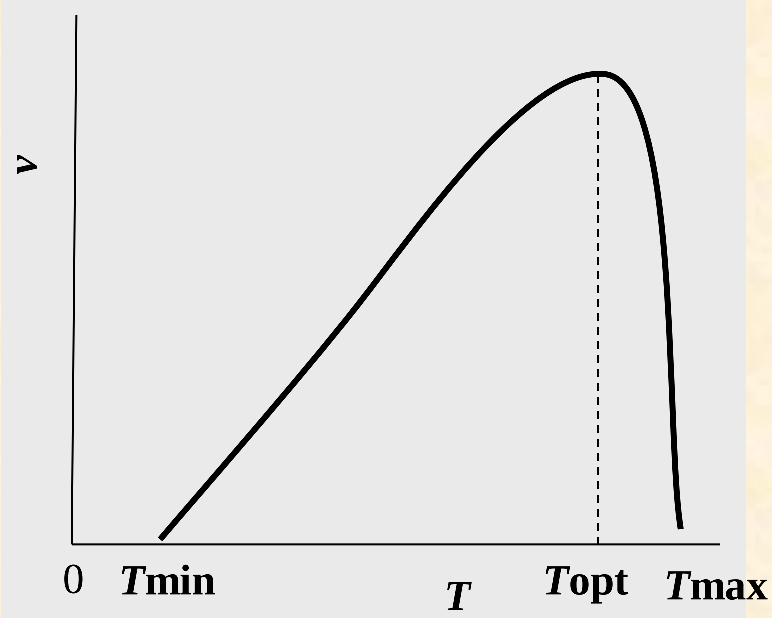


- several different non-linear models (Briere, Lactin, etc.)
- allow to estimate T_{min}, T_{max} and T_{opt} (optimum temperature)
- easy to interpret for experiments with constant temperature
- instead of using average day temperature, use actual temperature

Briere et al. (1999)

$$v = a \times T \times (T - T_{\min}) \times \sqrt{T_{\max} - T}$$

v .. rate of development (=1/D)
T .. experimental temperature
$T_{\min}$ .. low temperature threshold
$T_{\max}$ .. upper temperature threshold
a .. unknown parameter



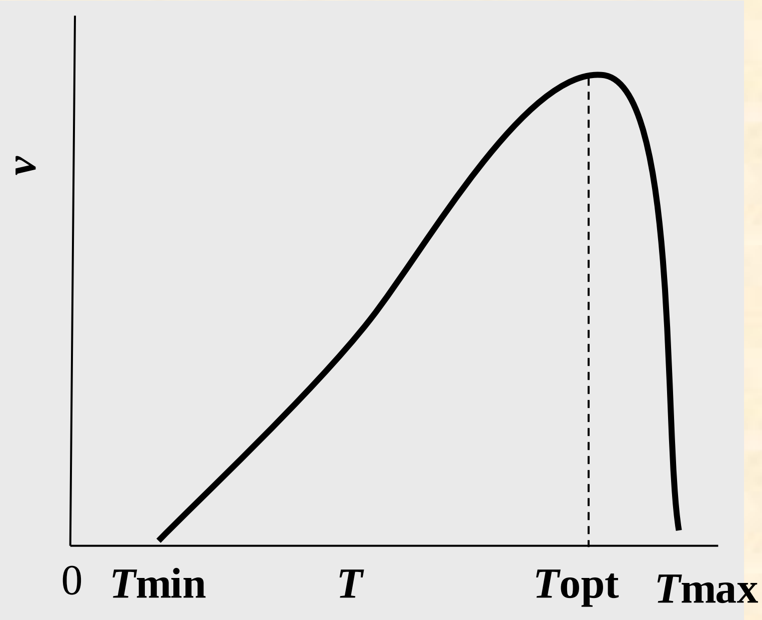
Optimum temperature:

$$t_{opt} = \frac{4T_{\max} + 3T_{\min} + \sqrt{16T_{\max}^2 + 9T_{\min}^2 - 16T_{\min}T_{\max}}}{10}$$

- parameters are estimated using non-linear regression

Lactin et al. (1995)

$$v = e^{\rho T} - e^{\left(\rho T_m - \frac{T_m - T}{\Delta}\right)} + \phi$$



v .. rate of development
T .. experimental temperature
T_m, Δ, ρ, ϕ .. unknown parameters

T_{max} and T_{min} can be estimated from the formula:

$$0 = e^{\rho T} - e^{\left(\rho T_m - \frac{T_m - T}{\Delta}\right)} + \phi$$

T_{opt} can be estimated from the first derivative:

$$\frac{\partial v(T)}{\partial T} = \rho e^{\rho T} - \frac{1}{\Delta} e^{\rho T_m - \frac{T_m - T}{\Delta}}$$