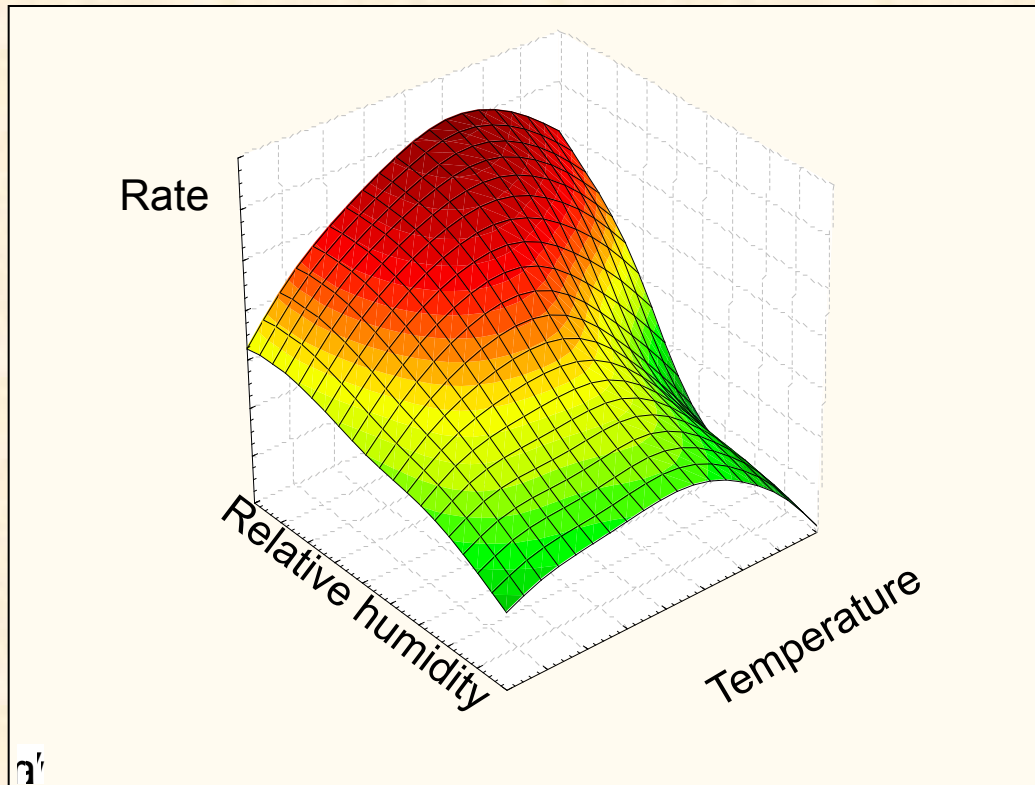


Temperature

Effect of conditions

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

Lepidoglyphus sp.



Universal effect of temperature

- ▶ with respect to body temperature: cold-blooded / warm-blooded
- ▶ with respect to temperature change: poikilotherms / homoiotherms
- ▶ with respect to production of temperature: endotherms / ectotherms

▶ temperature affects population growth of ectotherms

- rate of metabolism increases exponentially: 2.5x for every 10 °C

$$Q_{10} = 2.5$$

▶ physiological time – combination of physical time and temperature

▶ 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

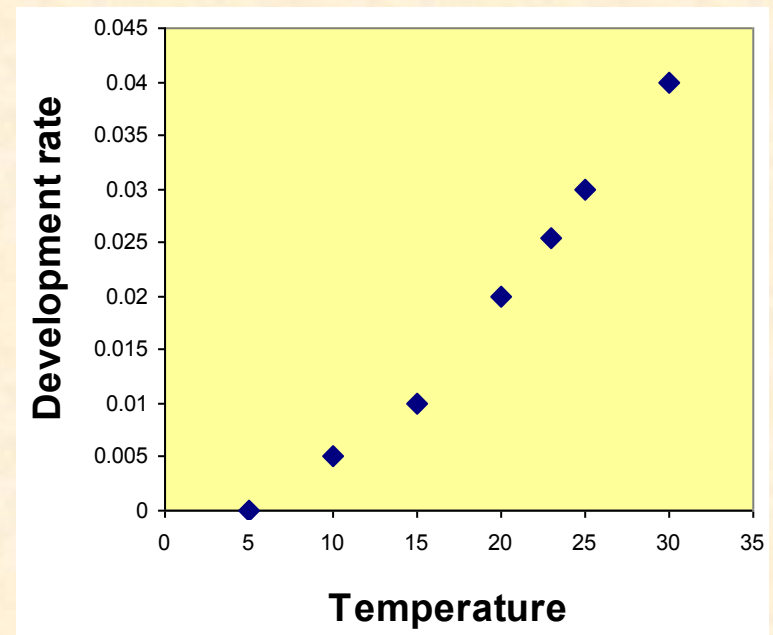
D .. development time (days)

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 [$^{\circ}\text{D}$] required to complete development

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

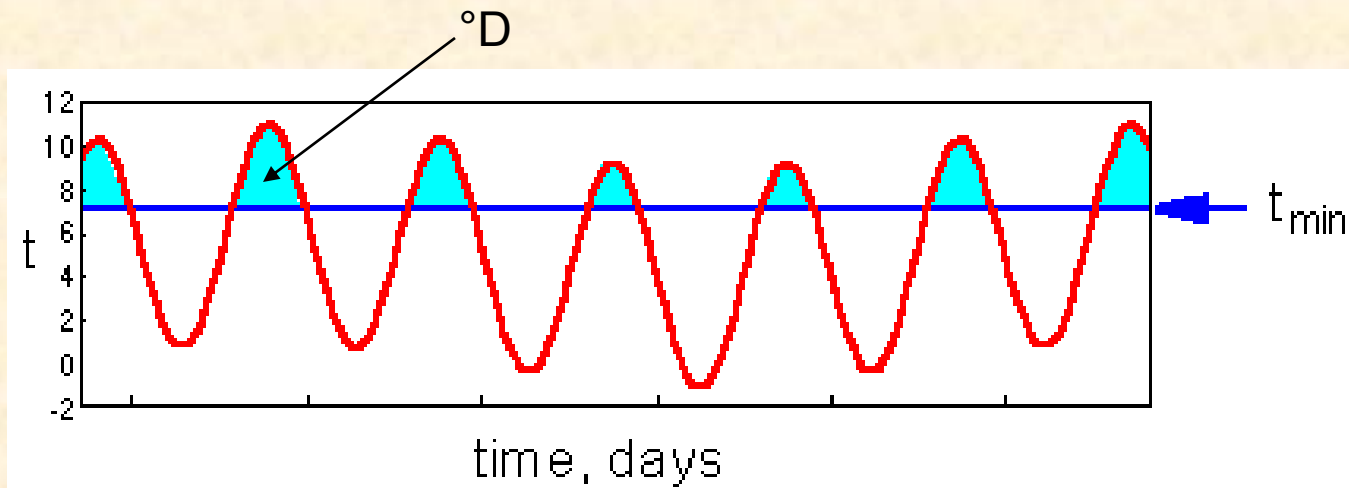
T_{\min} and S can be estimated from the regression line of $v = a + bT$

$$T_{\min} : \quad a + bT = 0 \quad \rightarrow \quad T_{\min} = -\frac{a}{b}$$

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

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

- ▶ sum of effective temperature (S) [$^{\circ}\text{D}$] 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

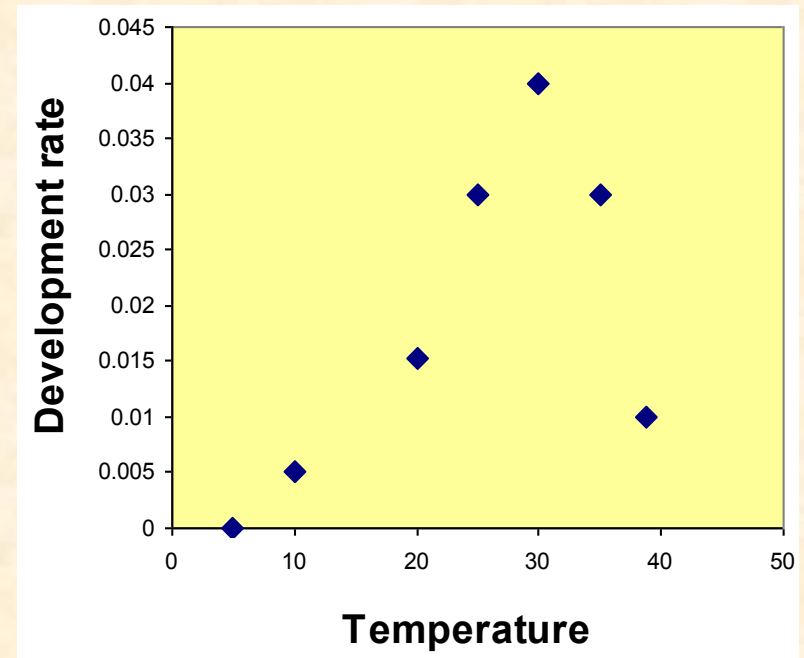


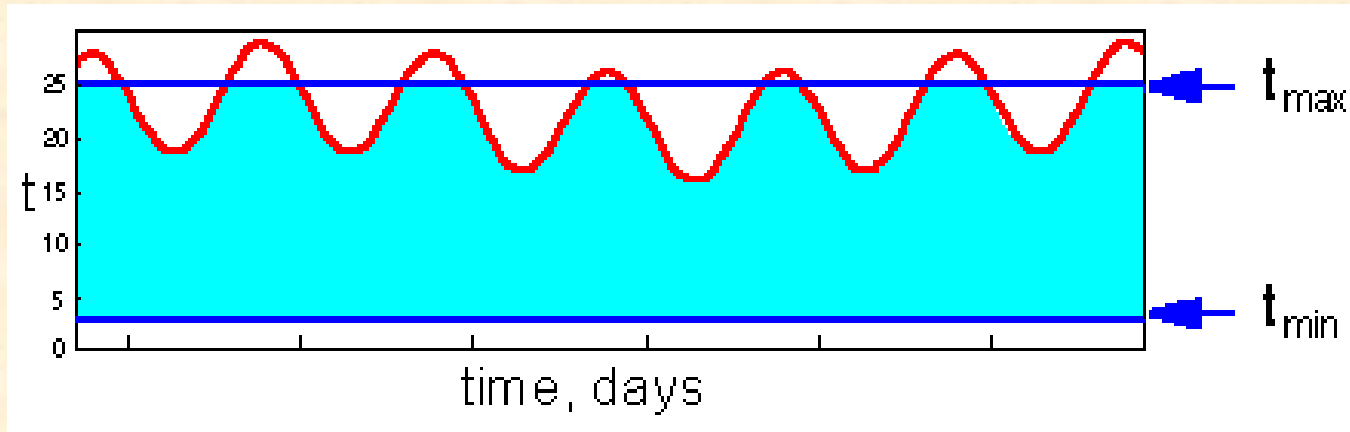
$$S = \sum_{i=1}^n T - T_{\min}$$

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 ($=1/D$)

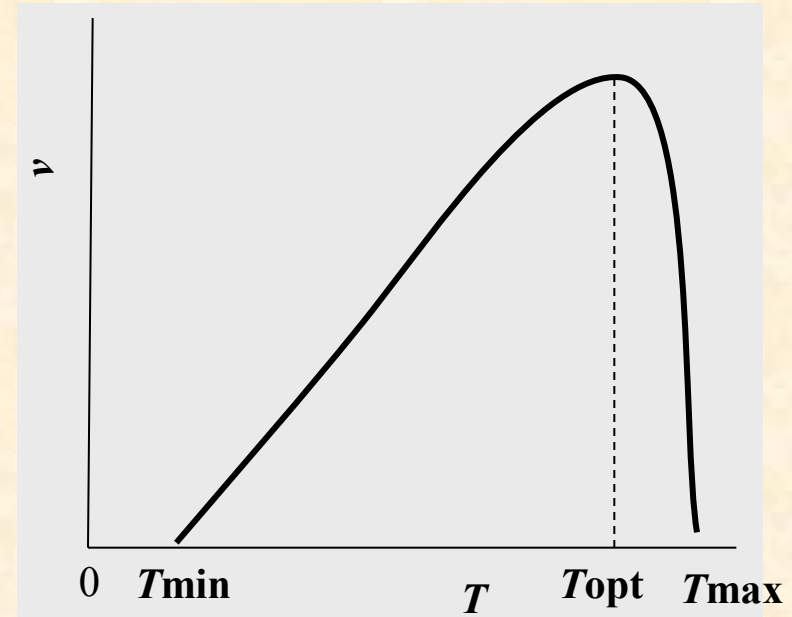
T .. experimental temperature

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

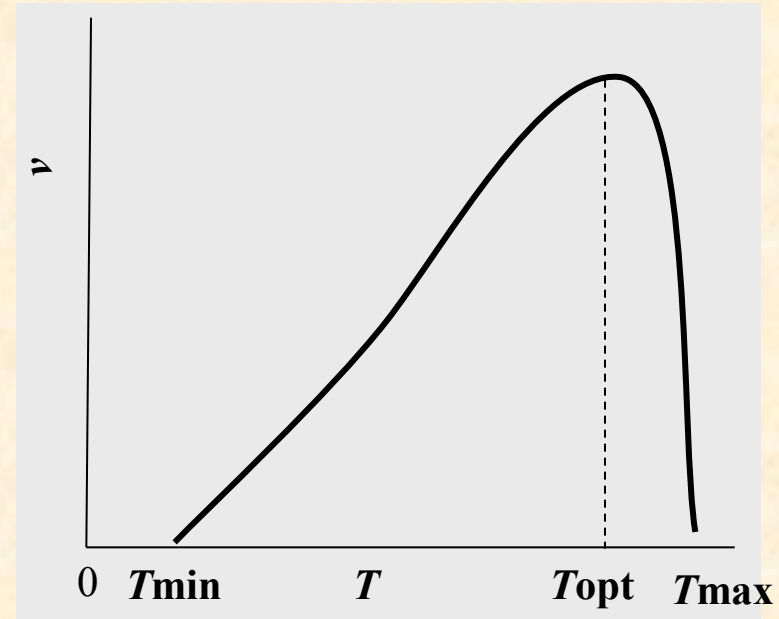
Lactin et al. (1995)

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

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:

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