Temperature tolerance in the lugworm *Arenicola marina*
Protein biosynthesis and energy metabolism

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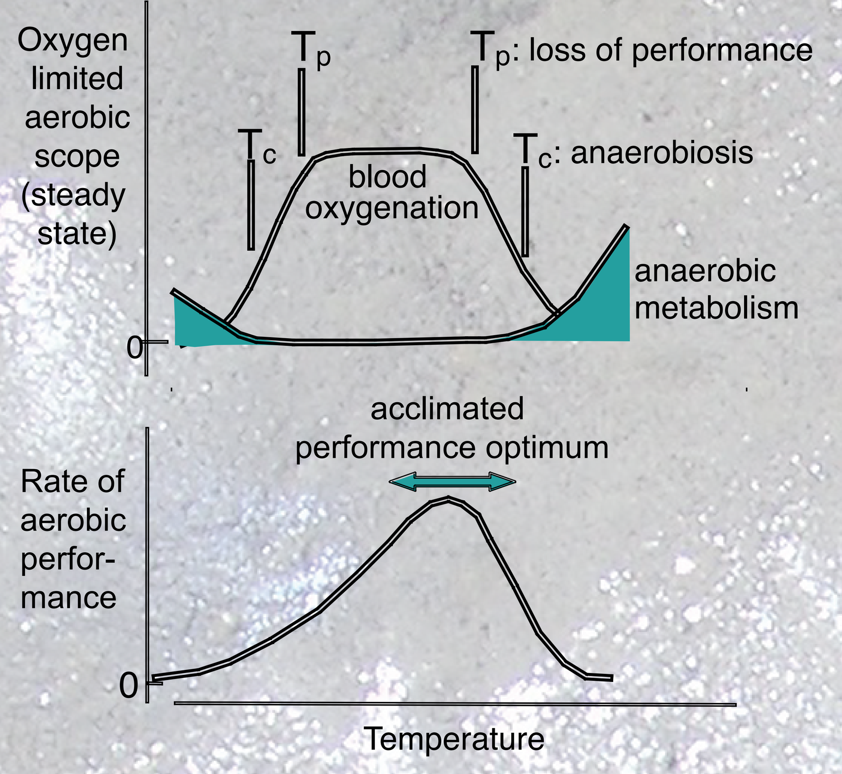
Introduction

Background



after Pörtner et al. 2004

The concept of oxygen limited thermal tolerance

Oxygen supply through ventilation and circulation reaches its limits at the pejus temperatures (Tp) leading to decreasing blood oxygenation. Above or below critical temperatures (Tc) metabolism turns anaerobic and allows survival only for a limited time.

The oxygen supply budget above basic metabolism is spent in varying proportions for muscle exercise, specific dynamic action, **growth** and reproduction. Towards the thresholds of the temperature tolerance window the rate of aerobic performance decreases and all functions except those essential for maintenance are reduced.

Questions

- ❋ How could climate change influence the zoogeography of marine invertebrates?
- ❋ Which is the acute temperature dependent growth potential in *Arenicola marina* for a given level of seasonal acclimatisation?
- ❋ How does the acute thermal window of growth change with seasons?
- ❋ Where is the optimum of growth performance located?
- ❋ Does energy metabolism show seasonal changes?

Organism

The lugworm *Arenicola marina* was chosen as a model organism from the intertidal zone.

Arenicola marina beside its natural burrow

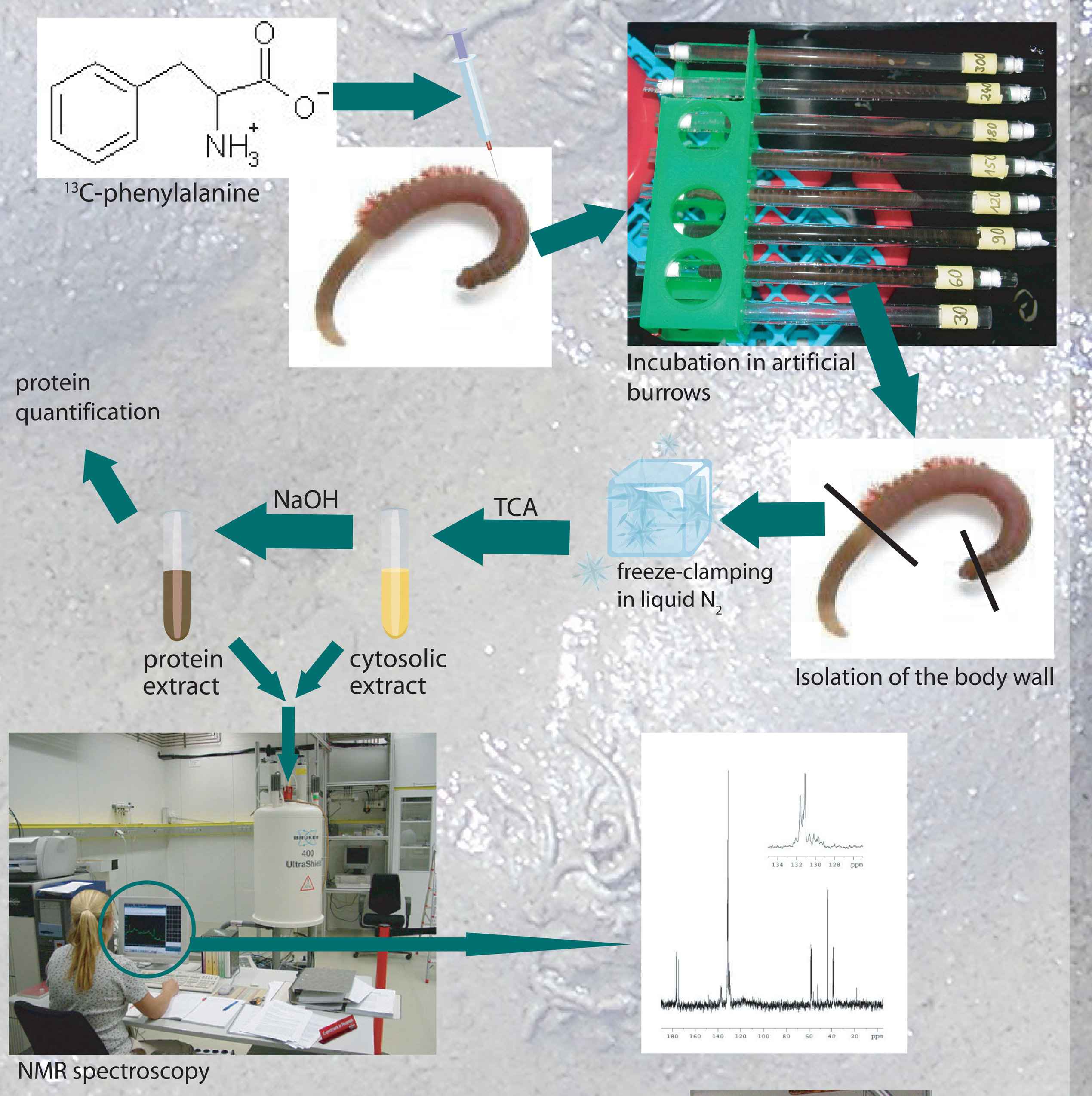
Methods

Protein biosynthesis: a measure for growth performance

Protein biosynthesis is the most important cellular process which forms the basis of organismal growth.

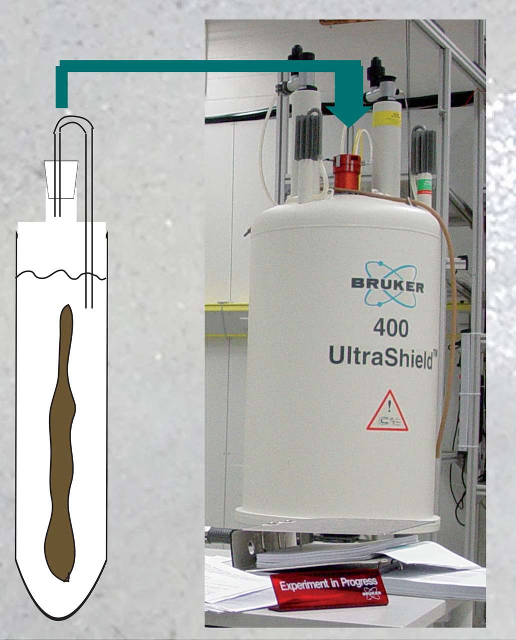
Uniformly ^{13}C-labeled phenylalanine is injected into the worm's coelomic cavity, taken up into the cytosol of the cells and incorporated in the proteins.

^{13}C-phenylalanine can be detected with NMR (nuclear magnetic resonance) spectroscopy of the extracts. Integration of the peak areas for each incubation time gives a measure for the newly synthesised protein (see Wittmann et al. for details).



Energy metabolism: *in vivo* ^{31}P-NMR spectroscopy

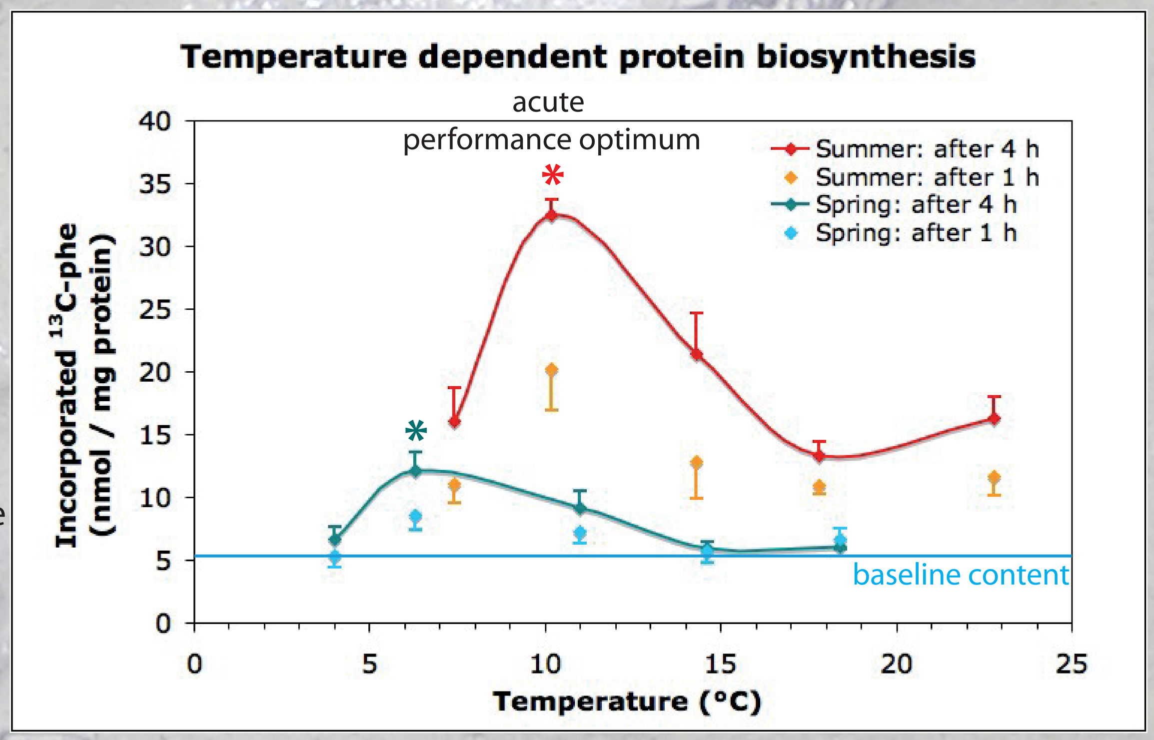
Living worms were inserted into acrylic glass tubes enabeling them to pump sea water through it. The experimental setup was arranged in an 20 mm NMR tube and ^{31}P-NMR spectra were recorded *in vivo* in a Bruker 400 MHz wide bore spectrometer.



Results

Protein biosynthesis

^{13}C-L-phenylalanine content of the body wall protein after incubation. Spring animals from Roscoff, summer animals from La Hume (Atlantic), n=4, mean ± SE.



Spring:

14.6°C and **18.4°C**: no increase in ^{13}C-phe content over time => no protein synthesis. The obtained value of around 6 nmol ^{13}C-phe / mg protein should be the baseline value, deriving from naturally abundant ^{13}C-phe and impurities during the extraction procedure.

4°C: a small rise in ^{13}C-phe content over time but both values close to the baseline value => protein synthesis can be considered as zero.

6.3°C and **11°C**: obvious rise in incorporated ^{13}C-L-phenylalanine over time => protein synthesis takes place.
* significantly higher than all values at 4°C, 14.6°C and 18.4°C and the value for 1 h at 11°C.

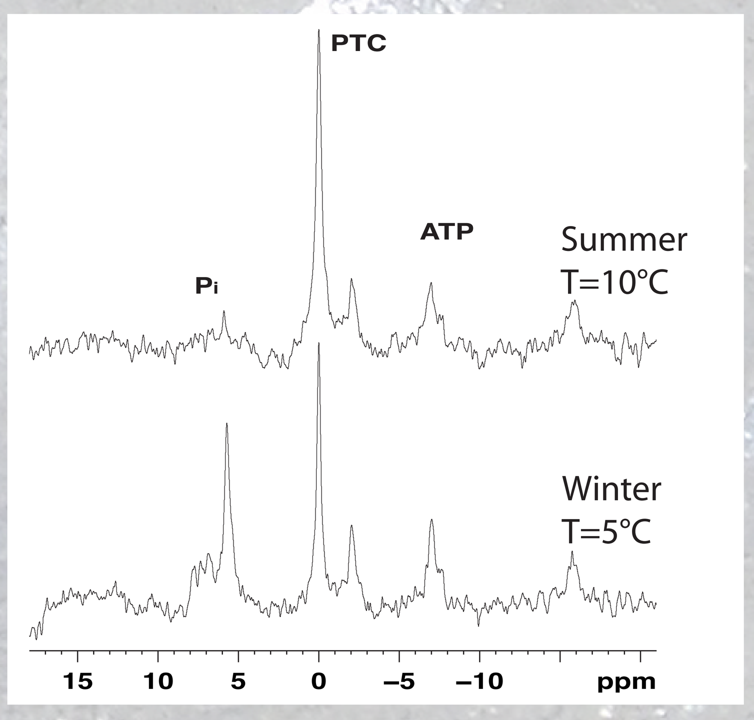
Summer:

7.4°C, **17.8°C** and **22.8°C**: only small rises in ^{13}C-phe content over time => slow protein synthesis.

10.2°C and **14.3°C**: conspicuous increase in ^{13}C-phe content over time => fast protein synthesis.
* significantly higher than all other values.

A **maximum protein biosynthesis rate** of 1.51 nmol ^{13}C-phe / mg protein * h is reached in spring animals at 6.3°C. Summer animals show a 2.5fold higher maximum growth rate of 3.76 nmol ^{13}C-phe / mg protein * h at 10.2°C.

Energy metabolism



In vivo ^{31}P-spectra obtained from summer animals and winter animals, both from Dorum (North Sea), acquisition time: 5 min.

The obtained spectra show the relationship of phosphotaurocyamine (phosphorus storage substance) to inorganic phosphate as well as the intracellular pH.

Winter animals exhibit a higher proportion of inorganic phosphate to phosphotaurocyamine than summer animals. The amount of ATP stays constant.

The intracellular pH, indicated by the location of the P_i peak, doesn't change seasonally.

Discussion

- ❋ From our data an optimum temperature range between 4°C and 14.6°C for spring animals and between 7.4°C and 17.8°C for summer animals can be deduced, since exposure to temperatures beyond pejus thresholds leads to reduced growth performance (Pörtner and Knust, in review).
- ❋ The width of the acute thermal growth windows is the same for spring and summer animals, but a 3°C shift towards higher temperatures takes place with summer acclimatisation.
- ❋ The acute growth performance maximum seems to be located close to the lower T_p, in contrast to the acclimated optimum frequently seen at the upper T_p (Pörtner et al. 2004). Acclimated growth curves are not available for *Arenicola marina*.
- ❋ The seasonal differences in energy metabolism indicate a distinct physiological transition during acclimatisation (Juretschke and Kamp 1995), probably reflecting the shift to aerobic metabolic design (Sommer and Pörtner 2002).
- ❋ Climate dependent long-term warming beyond pejus thresholds might reduce individual growth and reproduction and thus lead to decreased abundance in the field or even to a shift in the species' distribution range.

Outlook

❋ Comparisons between animals from various latitudes:
- Kartesh (White Sea, Russia)
- Dorum-Neufeld (North Sea, Germany)
- La Hume (Atlantic, France)

❋ Comparisons of the spring and summer data to winter animals from the same population, respectively

❋ Energy metabolism (^{31}P-NMR) measurements will be combined with tissue oxygenation, respiration and ventilation recordings.

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