



Alfred-Wegener-Institut für Polar- und Meeresforschung in der Helmholtz-Gemeinschaft

Physiological mechanisms linking climate to ecosystem change, investigated in populations of the lugworm *Arenicola marina*

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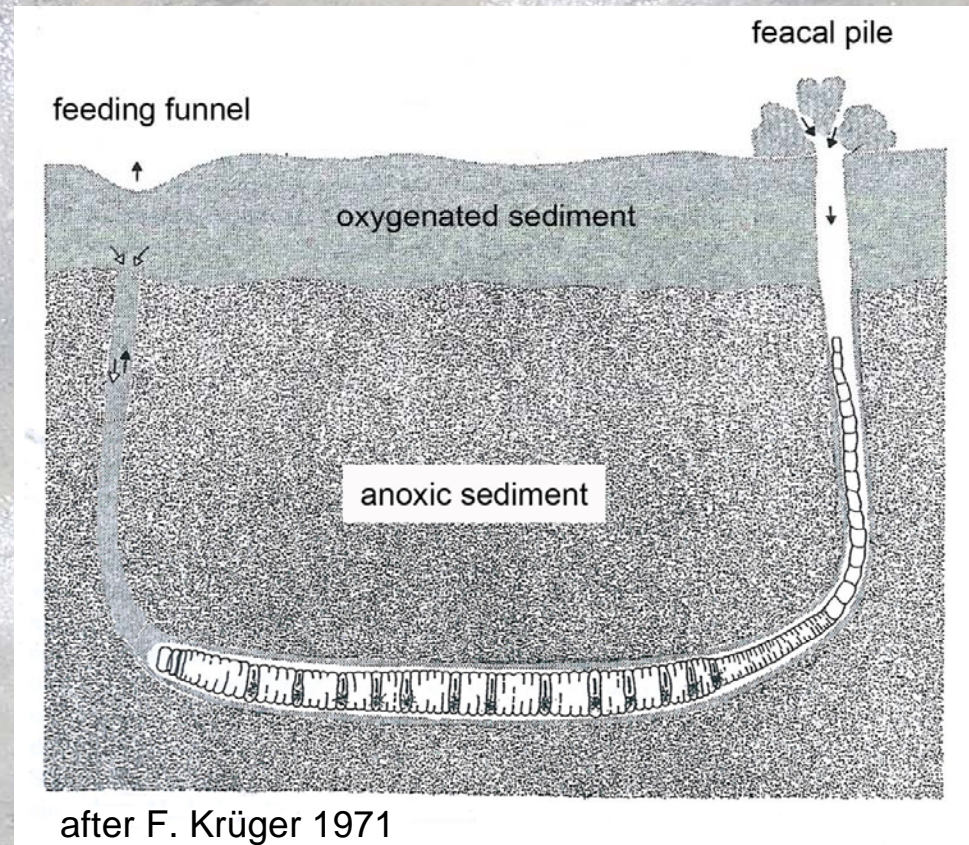
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Model organism

The lugworm *Arenicola marina*
beside it's burrow



Longitudinal section of the burrow



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Latitudinal adaptation

and

Seasonal acclimatization

- How does it work?
- Is adaptation to climate change possible?



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Populations



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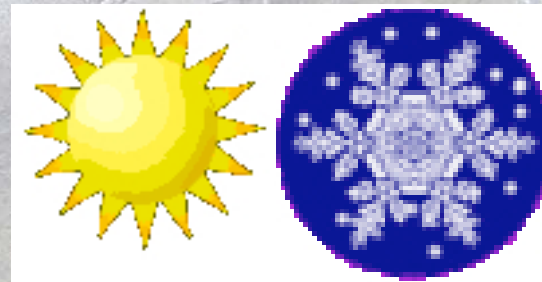


Latitudinal adaptation

and

Seasonal acclimatisation

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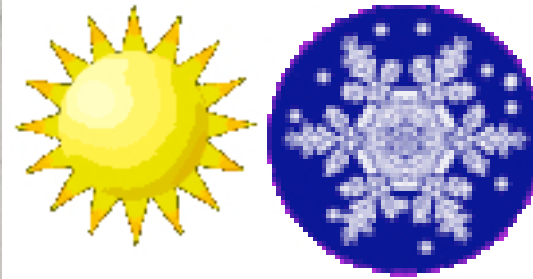


Seasonal comparisons in the same population

North Sea



Summer



Winter

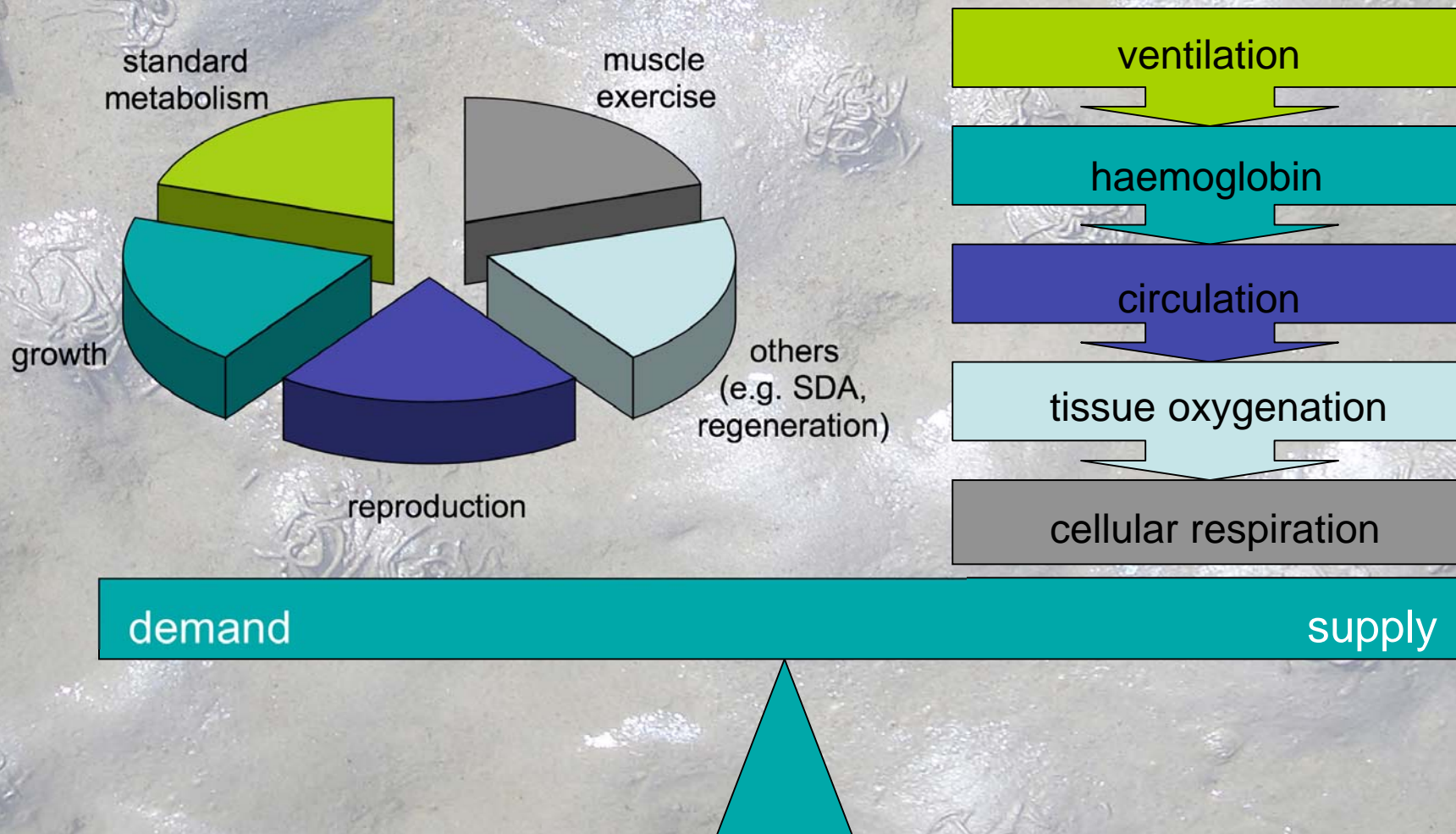


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Balance of oxygen demand and supply

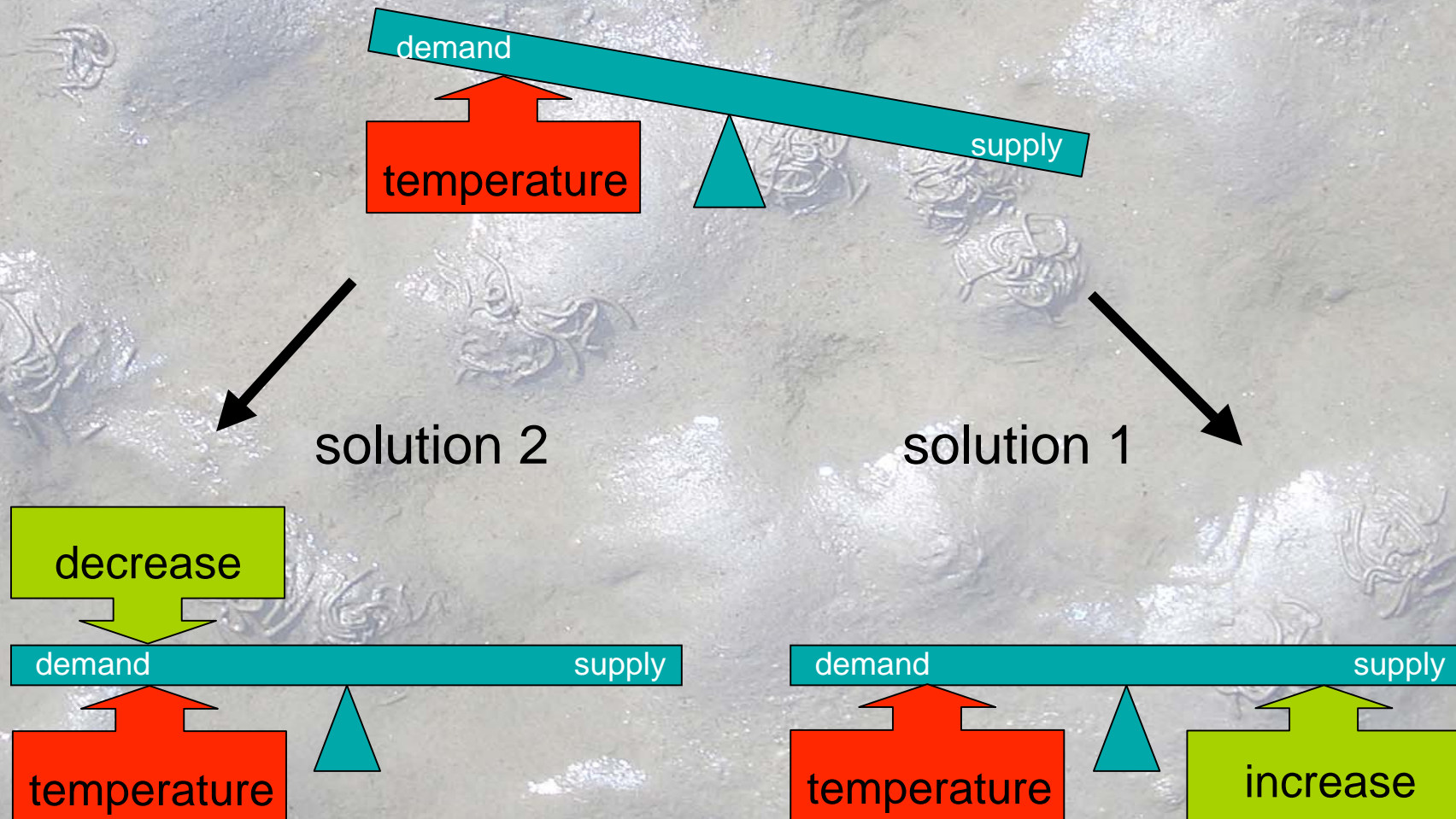


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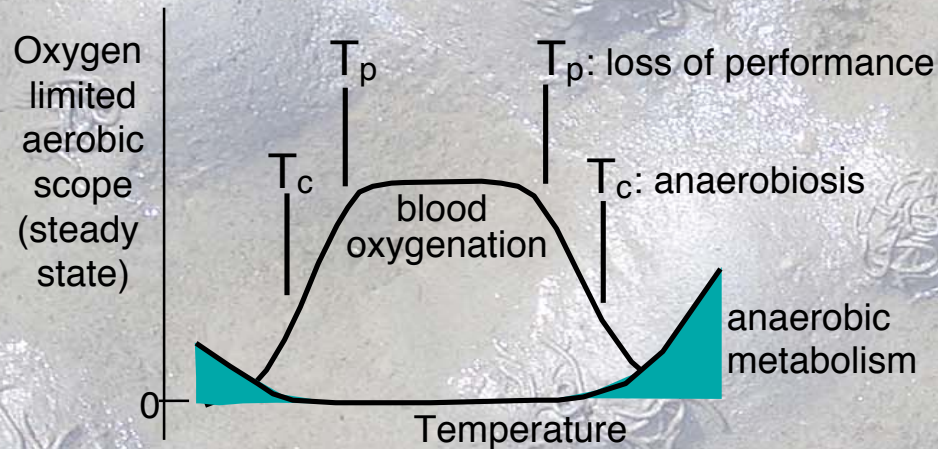
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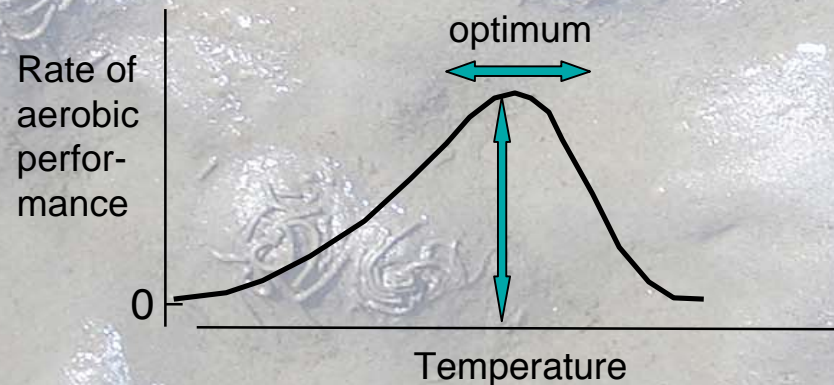
Mismatch of oxygen demand and supply



Temperature thresholds and performance



- T_p : pejus temperatures
oxygen supply limit
decreasing blood oxygenation
- T_c : critical temperatures
metabolism turns anaerobic
survival time limited unless
acclimatization occurs



As seen in fishes (Pörtner and Knust, SCIENCE, in press), long-term warming beyond pejus temperatures
=> reduced performance (growth, reproduction, muscle exercise,...)
=> ecological consequences:

- decreased abundance
- local extinction
- shift in distribution

After: Pörtner et al. 2004

Performance curve: oxygen supply budget above basic metabolism

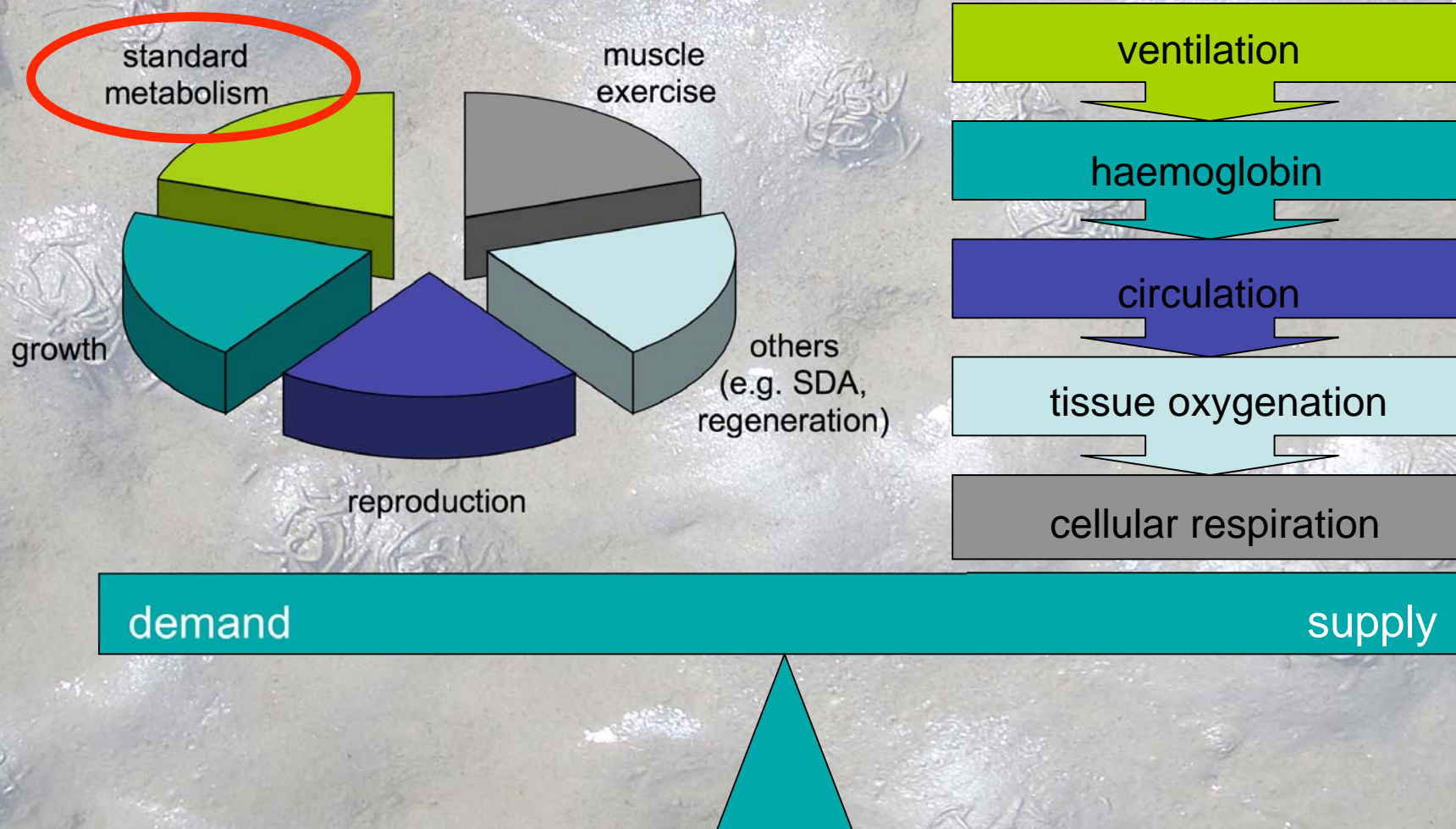


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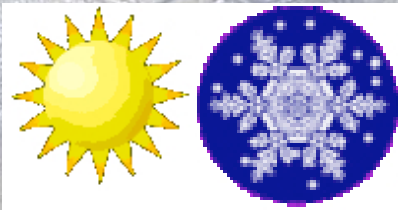
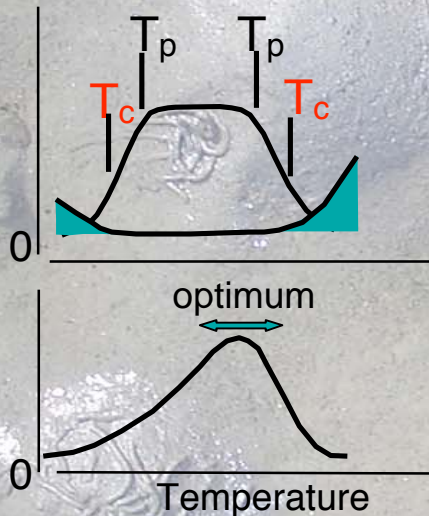
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Balance of oxygen demand and supply



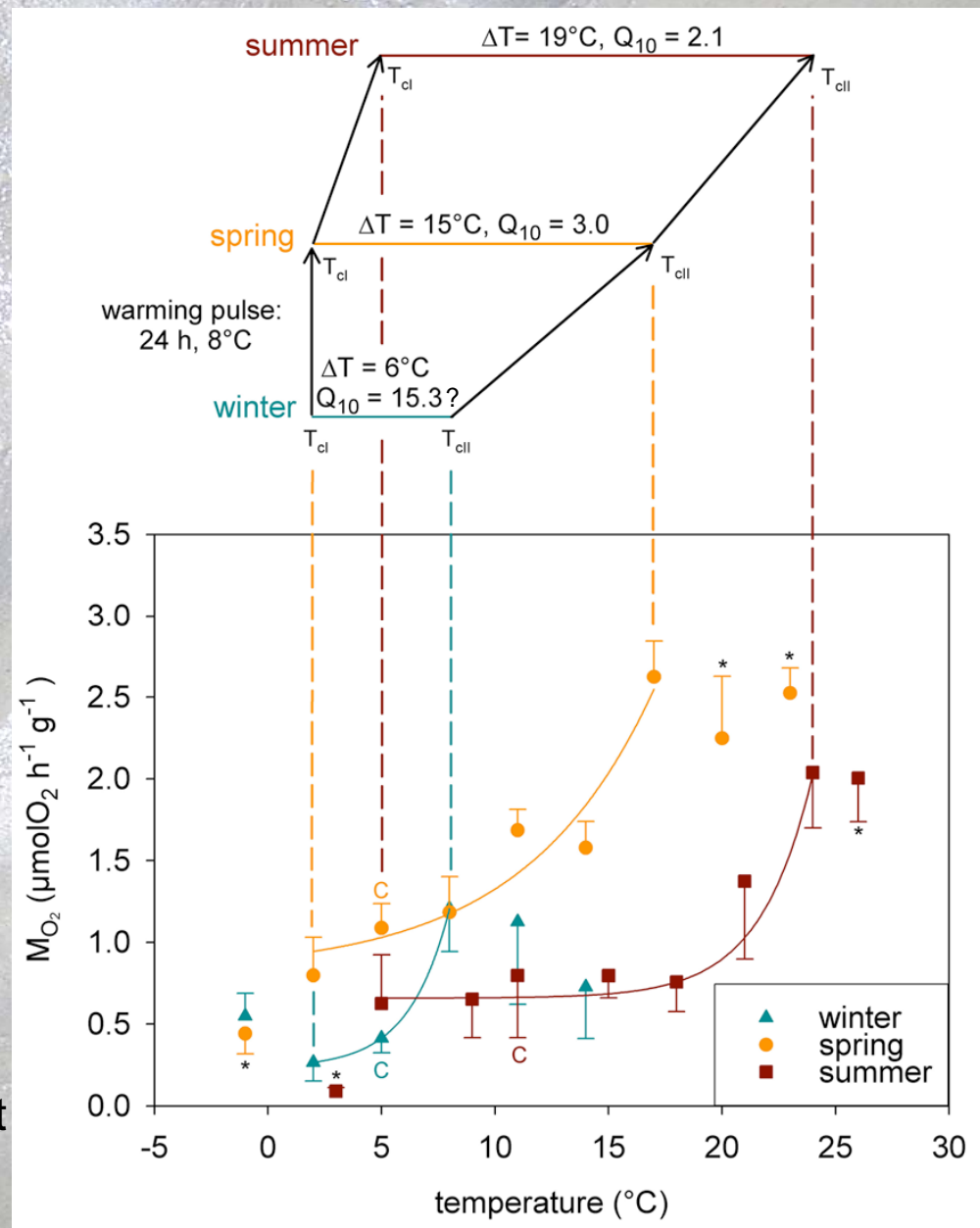
Oxygen consumption



North Sea

Thermal tolerance window:
temperature range with exponential
rise in oxygen consumption
according to Q_{10} relationship

- Winter: 2-8°C → widening
- Spring: 2-17°C → widening and shift
- Summer: 5-24°C

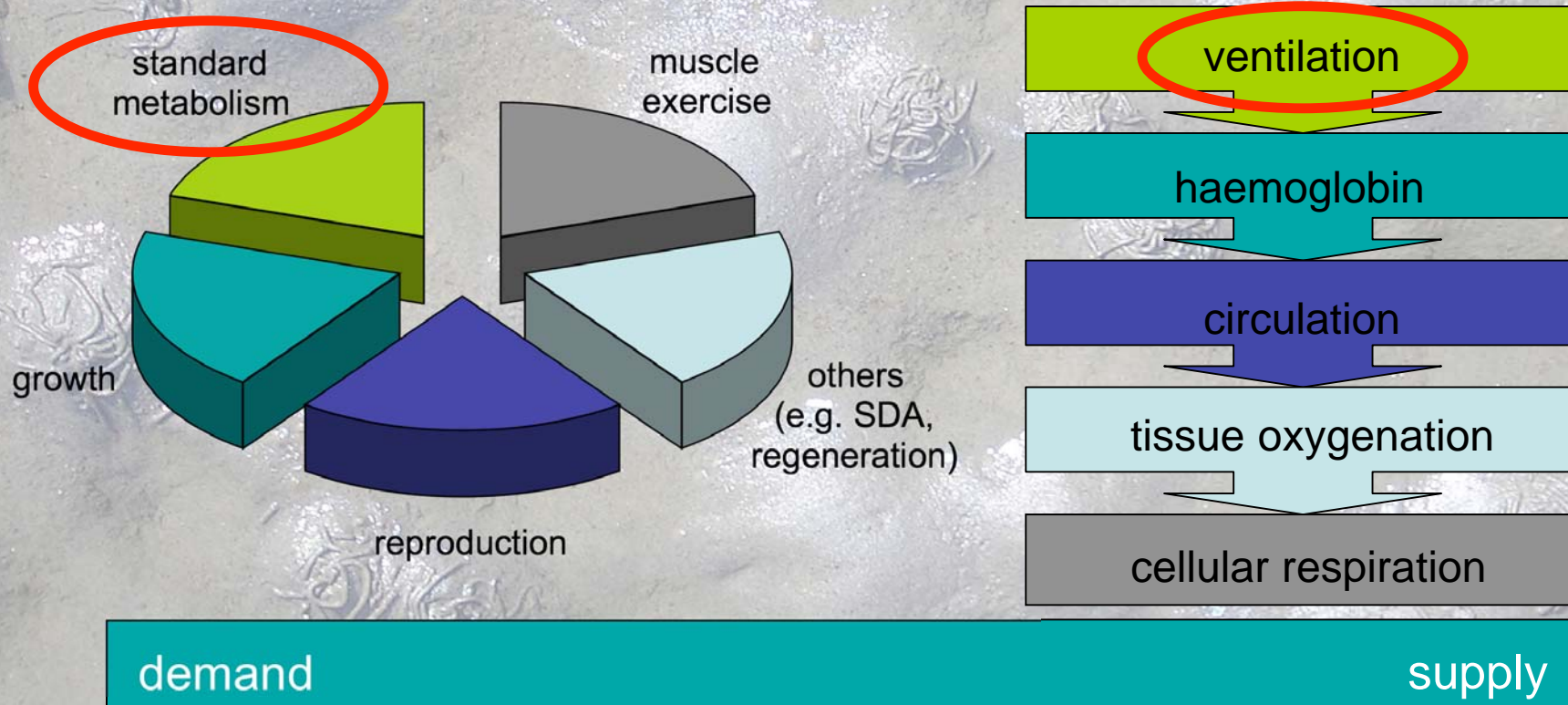


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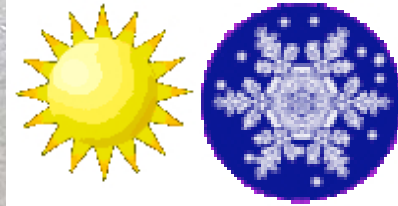
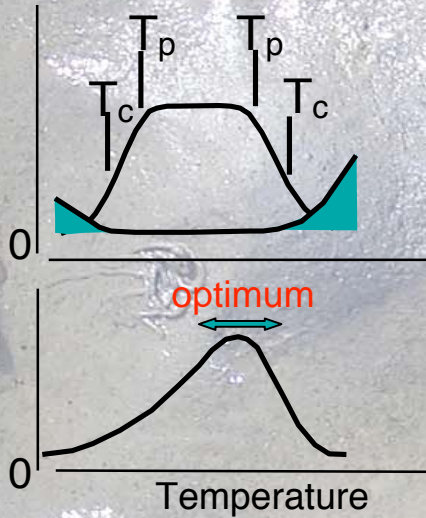
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Ventilation



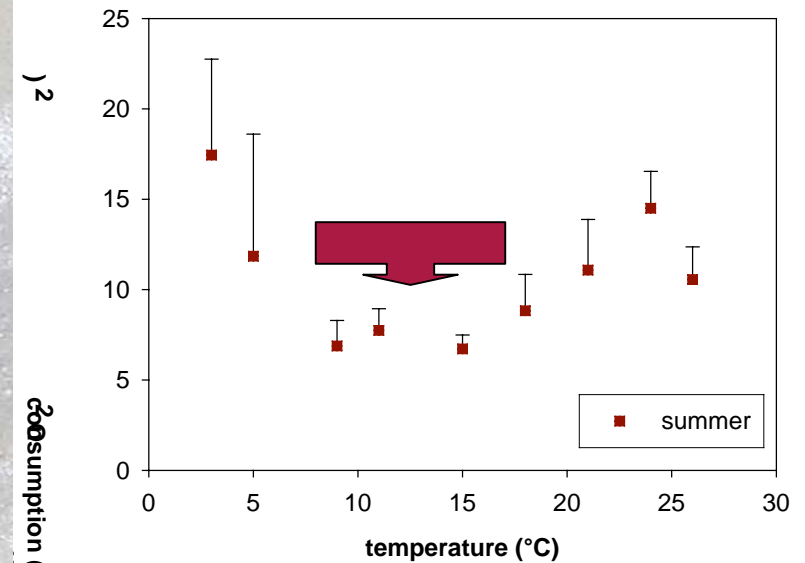
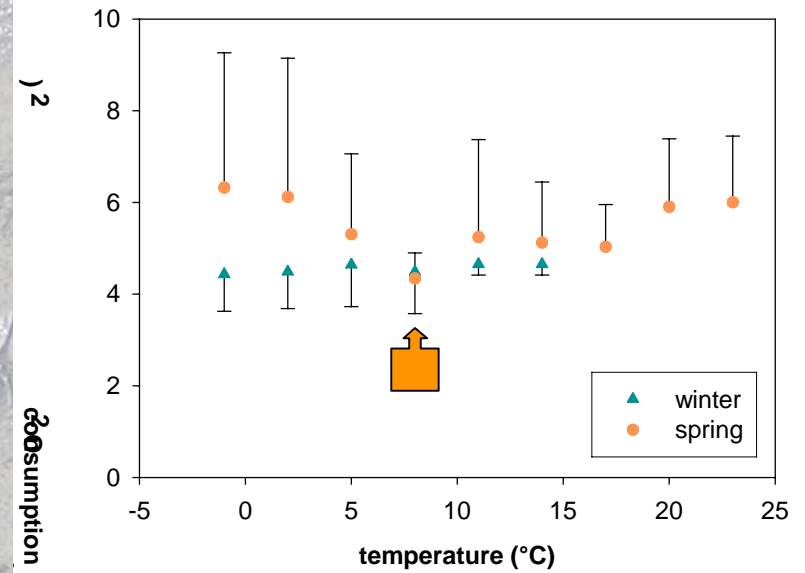
North Sea

- Oxygen extraction efficiency: pumped water volume for provision of $1 \mu\text{mol O}_2$
- minimum of this curve: minimal costs and optimal efficiency => performance optimum?

•Spring: 8°C

•Summer: $9-15^\circ\text{C}$

shift and widening

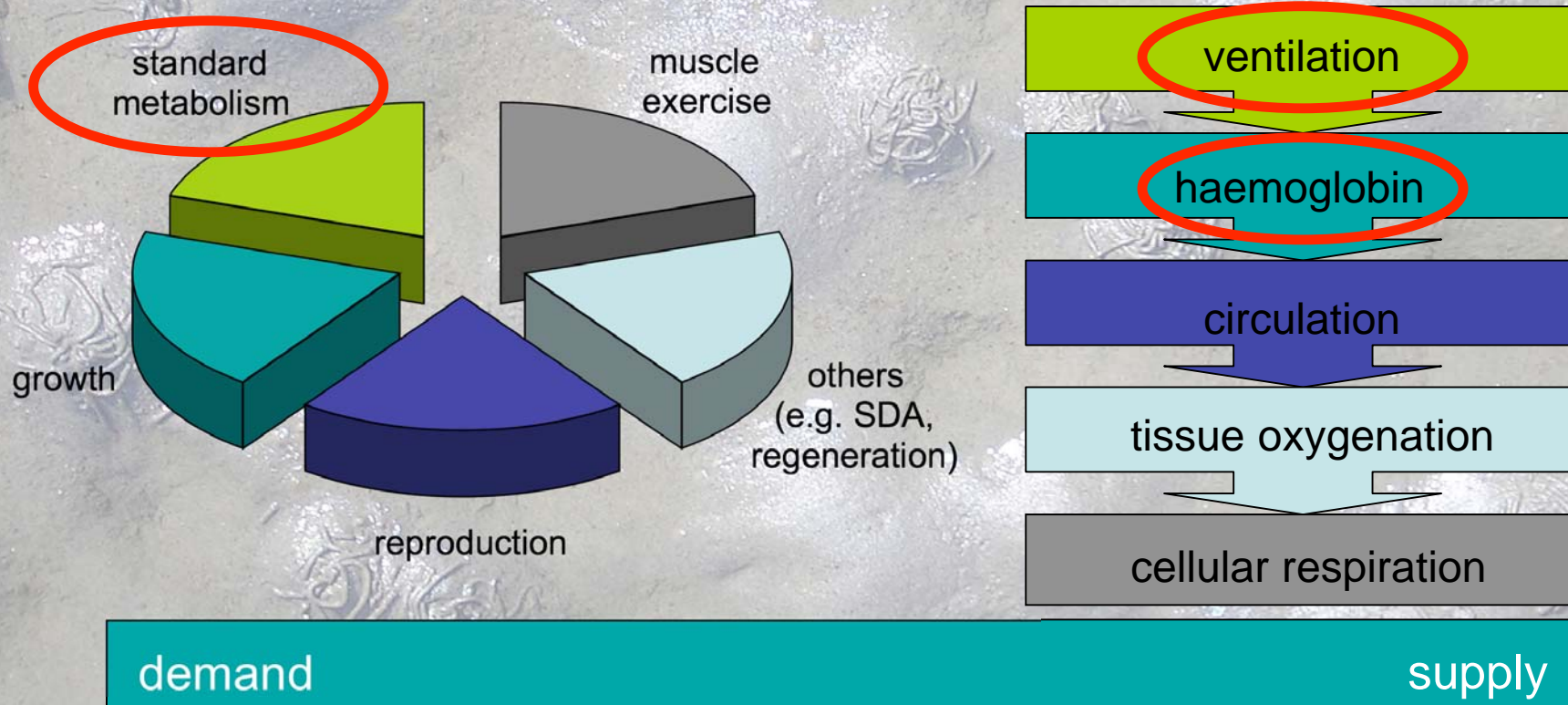


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Balance of oxygen demand and supply



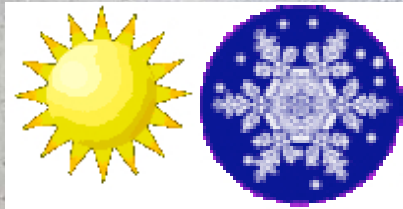
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Haemoglobin properties

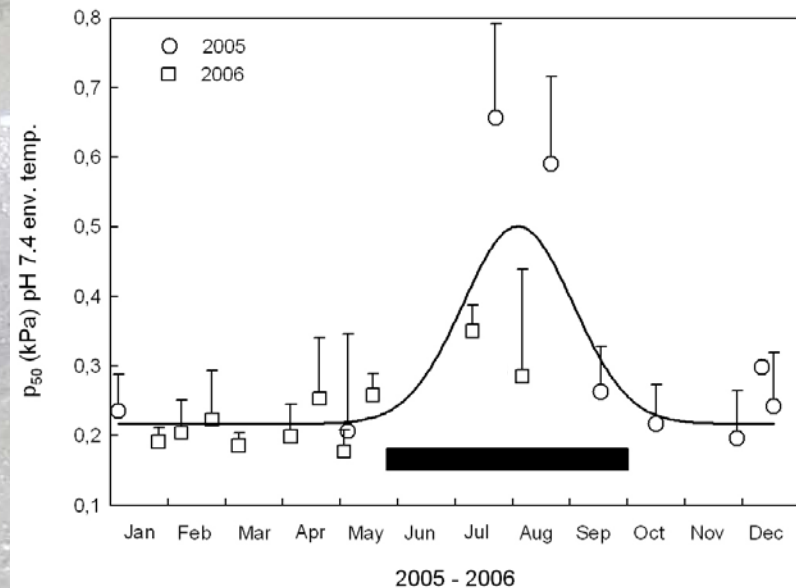
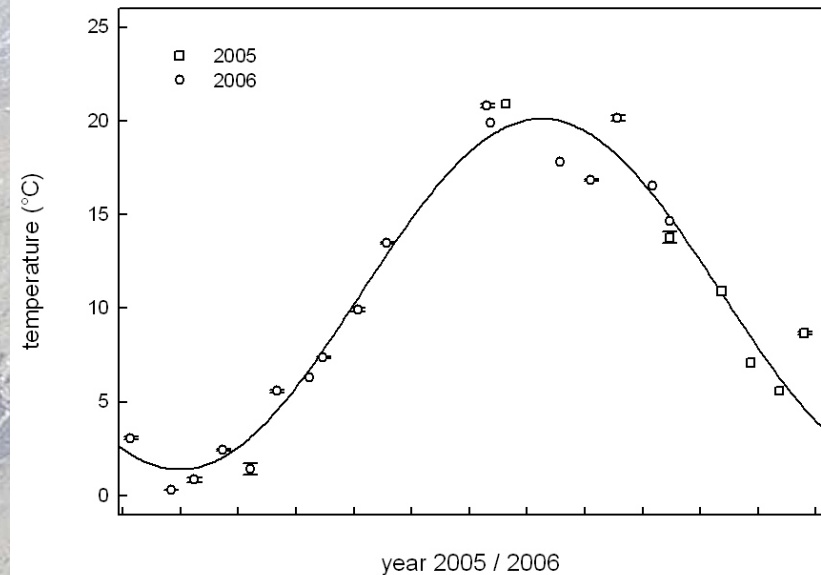


North Sea

Temperature in
20 cm depth

Seasonal changes of P_{50} (oxygen partial pressure when haemoglobin is half saturated)

- increased p_{50} in summer
- facilitated oxygen release to tissues during reproductive phase (June-September)
- effects on performance?

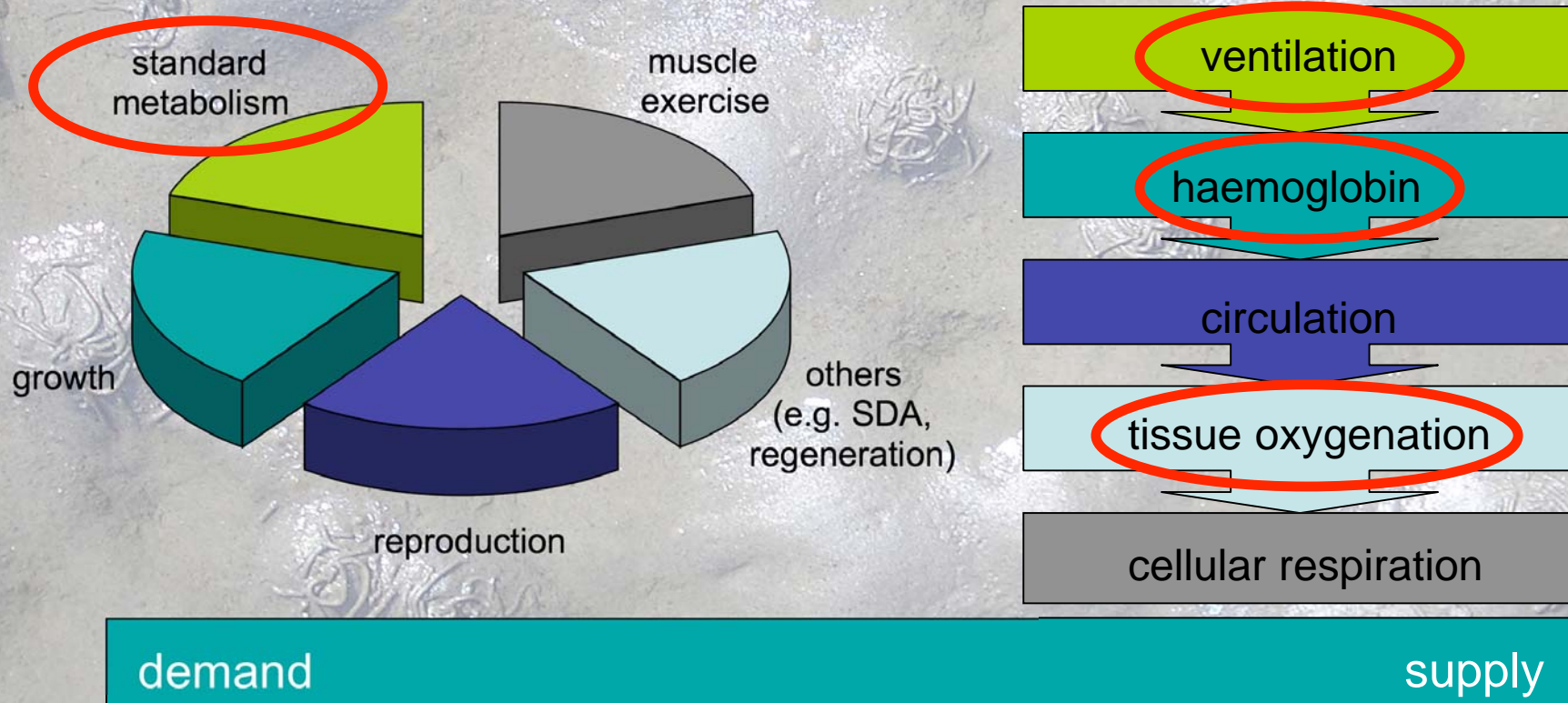


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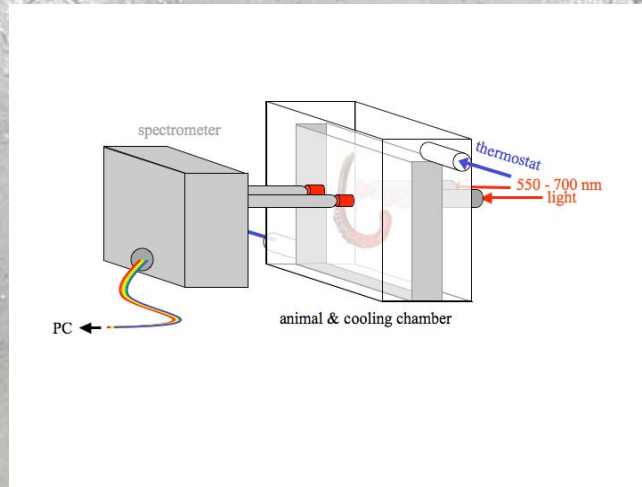
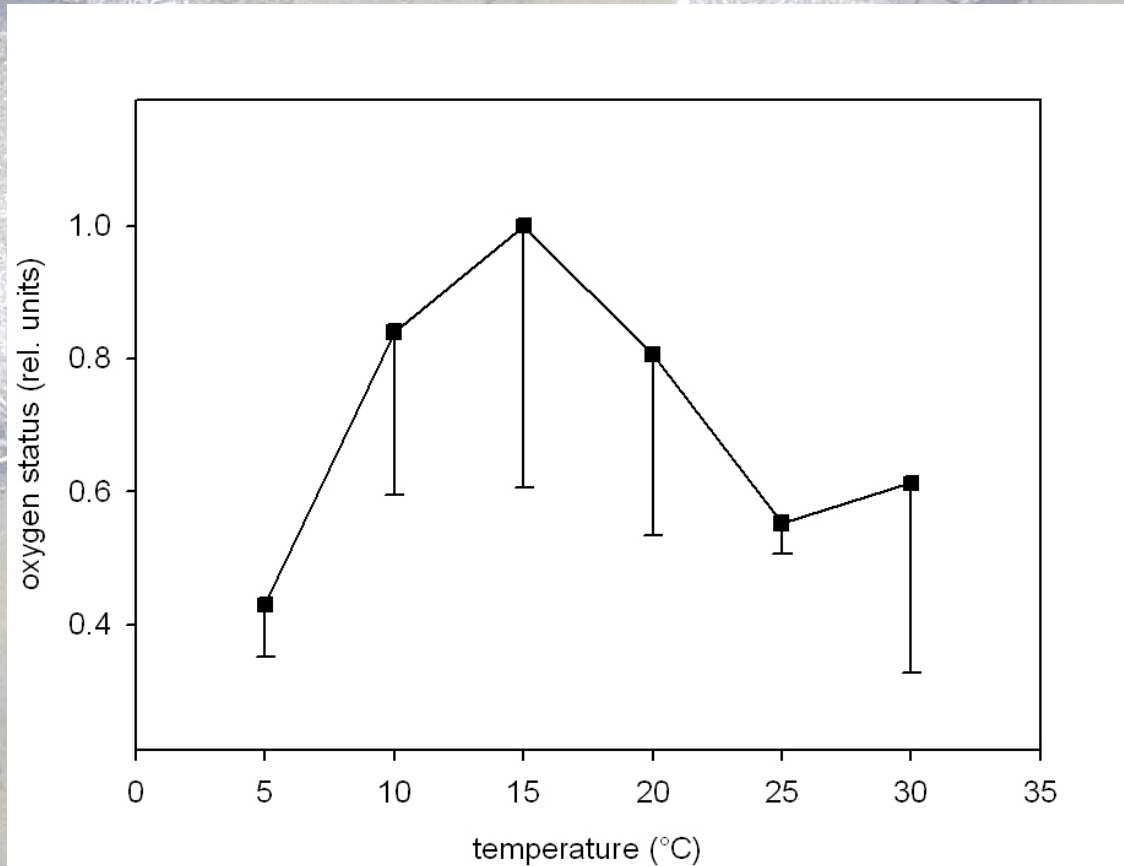
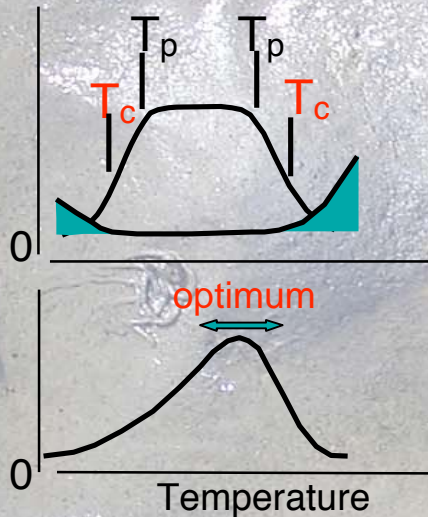
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Balance of oxygen demand and supply



Tissue oxygenation



North Sea Summer: 5-25°C, optimum at 15°C
corresponds well to oxygen consumption and ventilation data

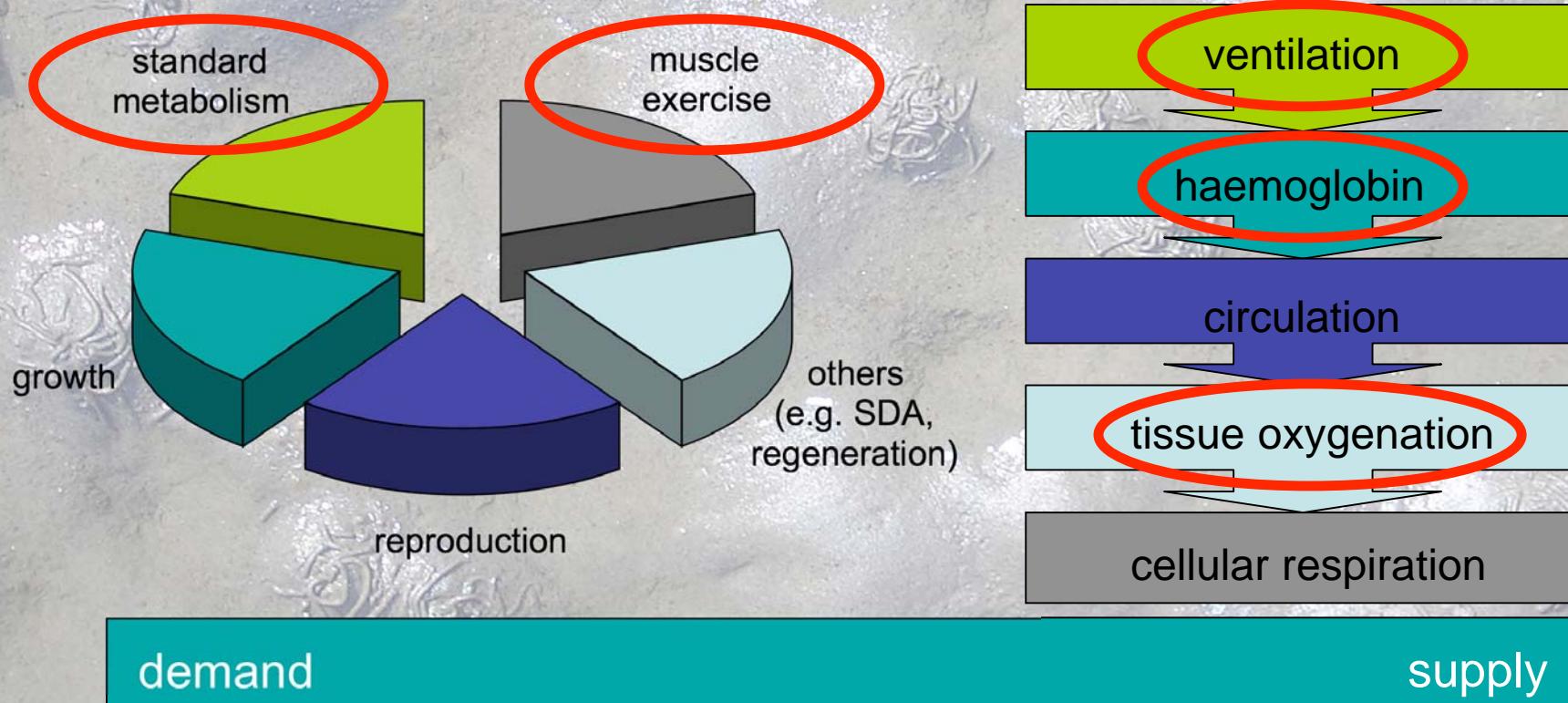


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Balance of oxygen demand and supply



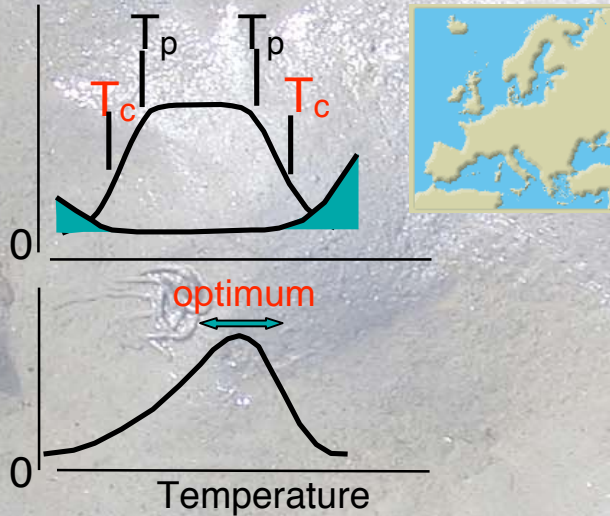
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Digging activity



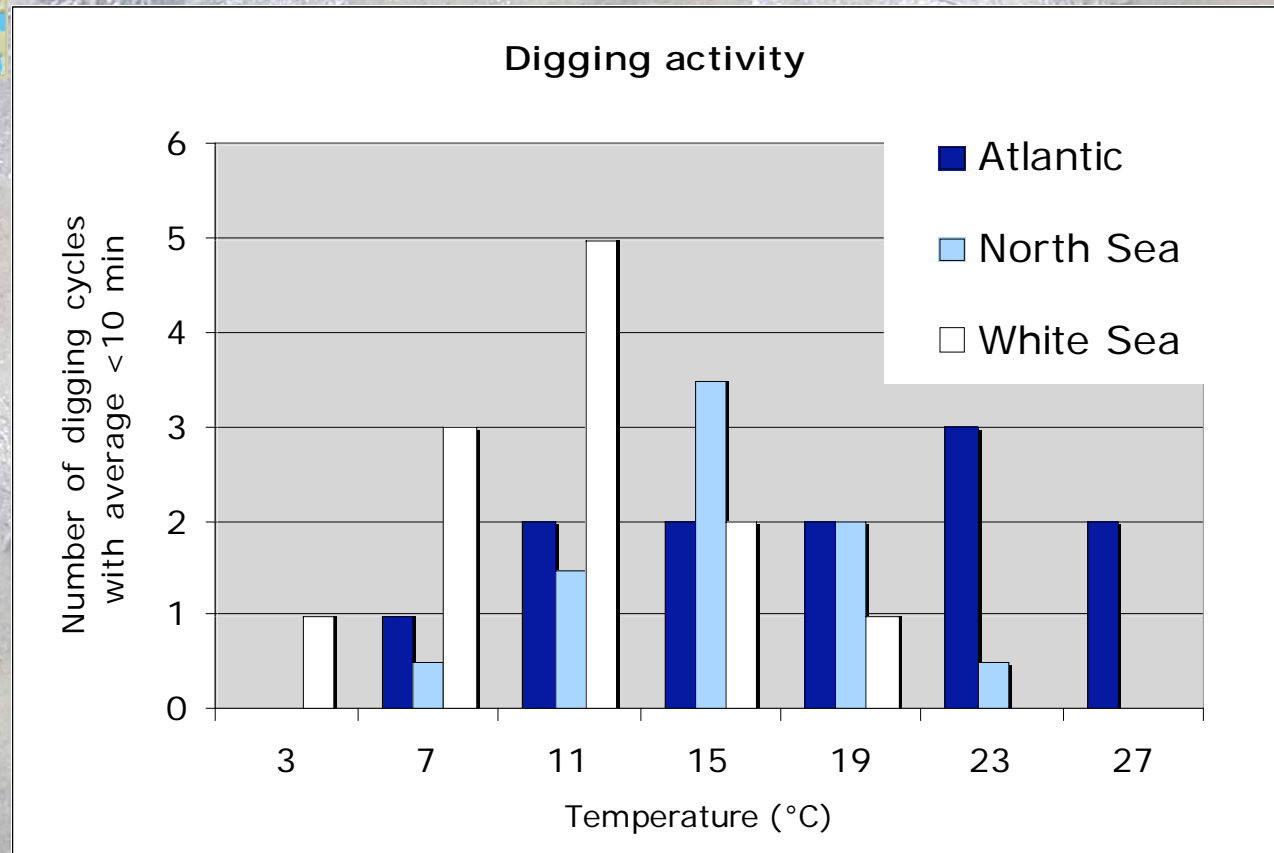
North Sea data correspond well to oxygen consumption, ventilation and tissue oxygenation data.

Summer

White Sea: $\Delta T=16^\circ\text{C}$, optimum at 11°C

North Sea: same width, optimum at 15°C , lower performance curve

Atlantic: optimum at 23°C , performance curve lower, but wider window

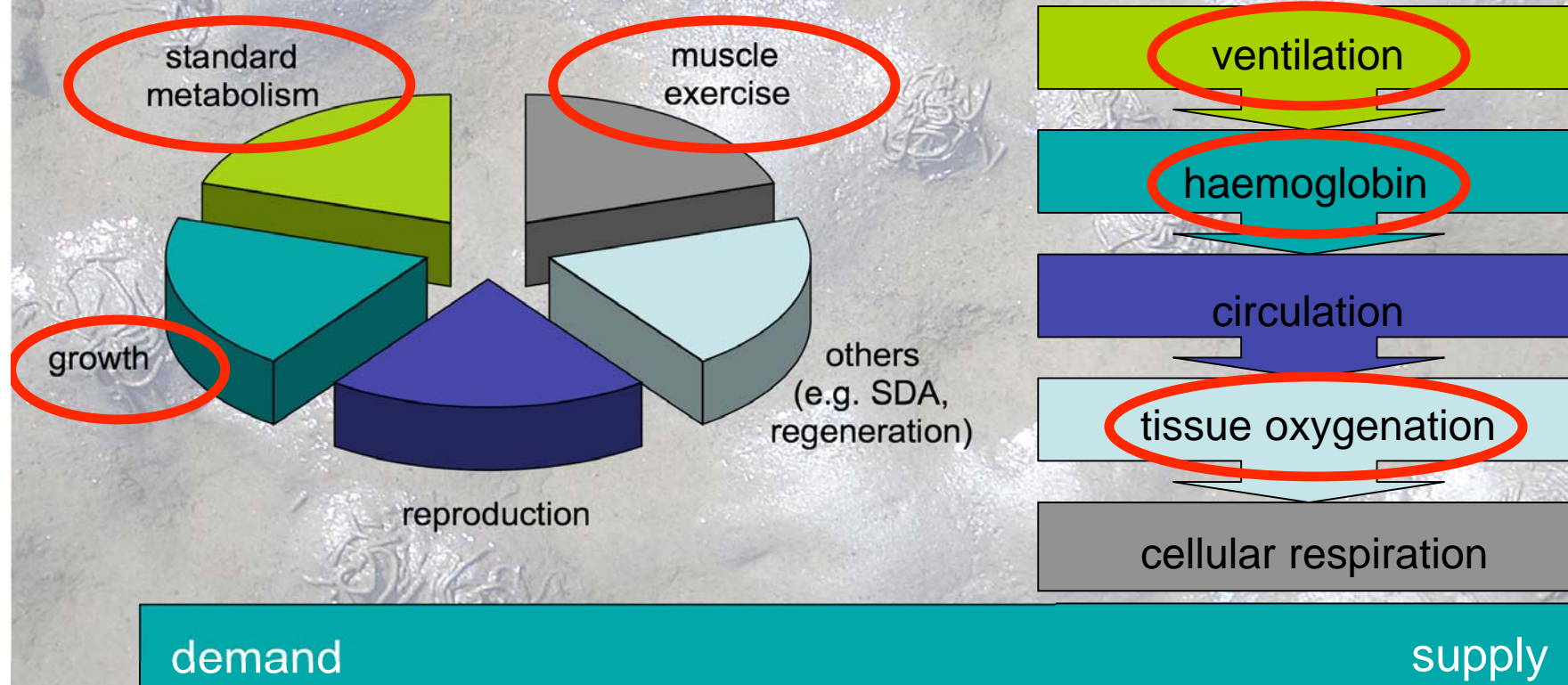


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Balance of oxygen demand and supply



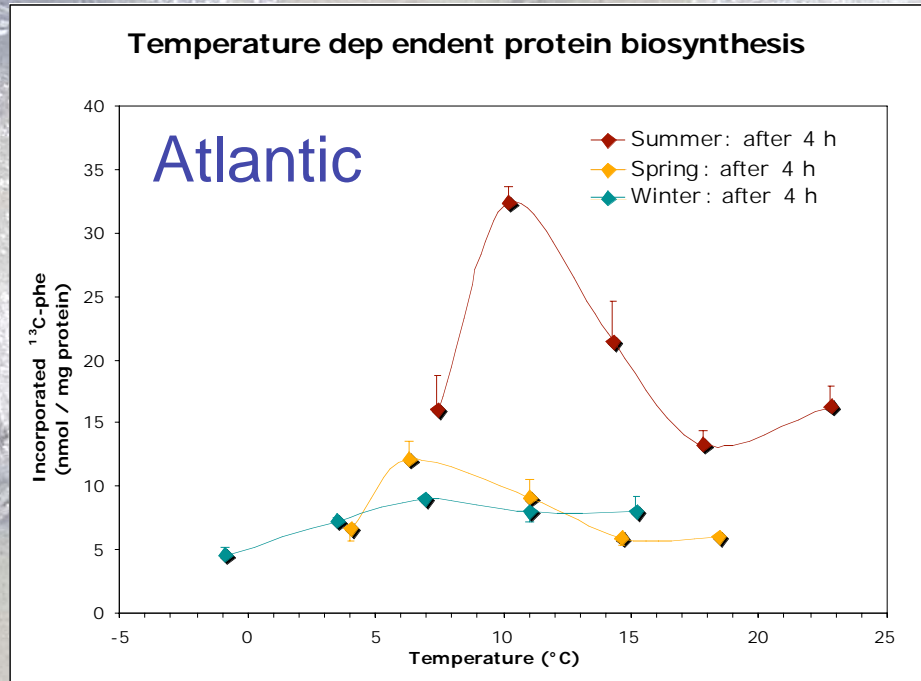
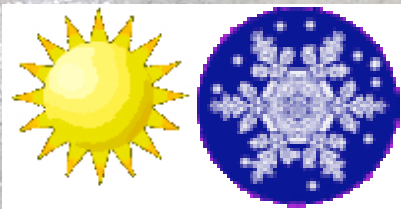
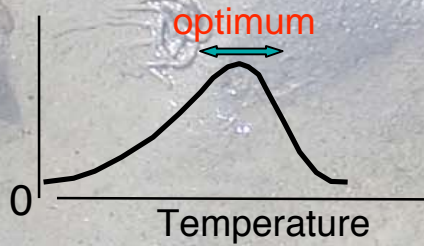
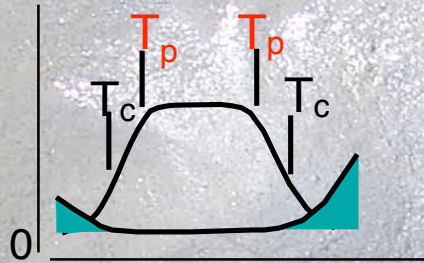
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Protein biosynthesis (= growth?)



Atlantic:

Protein synthesis detectable in **spring** → shift
 highest synthesis performance in **summer** ←

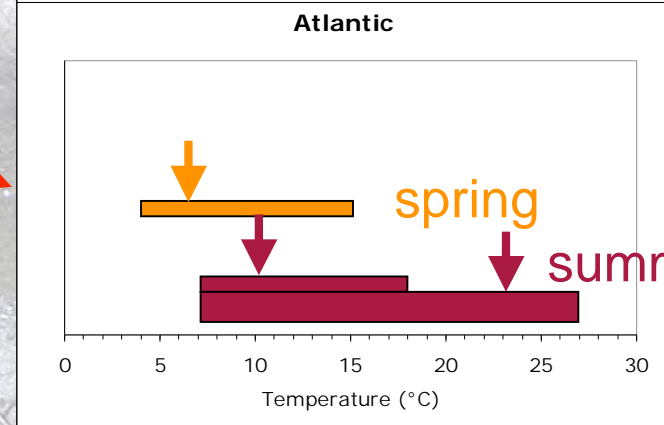
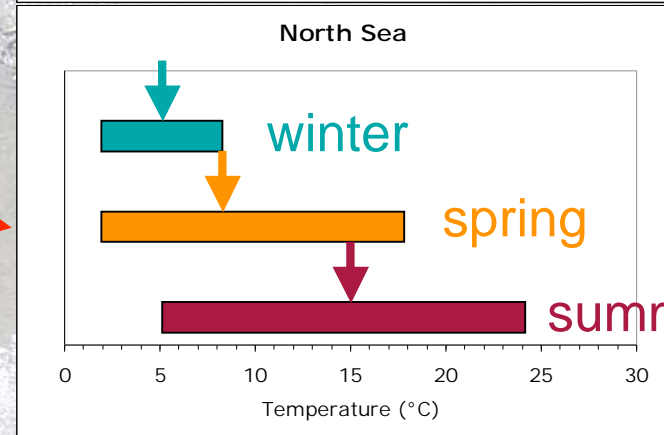
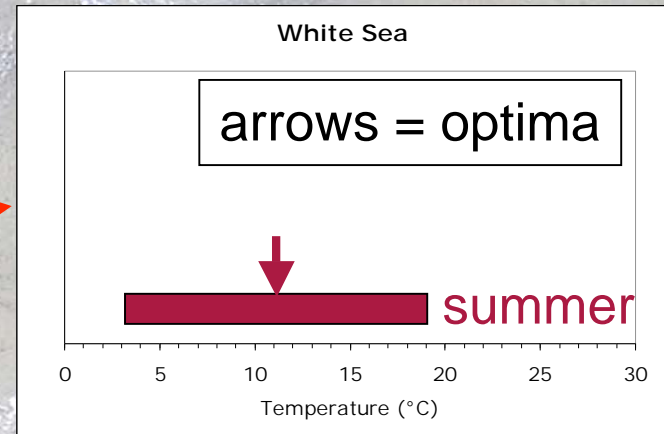


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Summary



Thermal tolerance windows:

- seasonal shifts and changing width
- latitudinal specialization

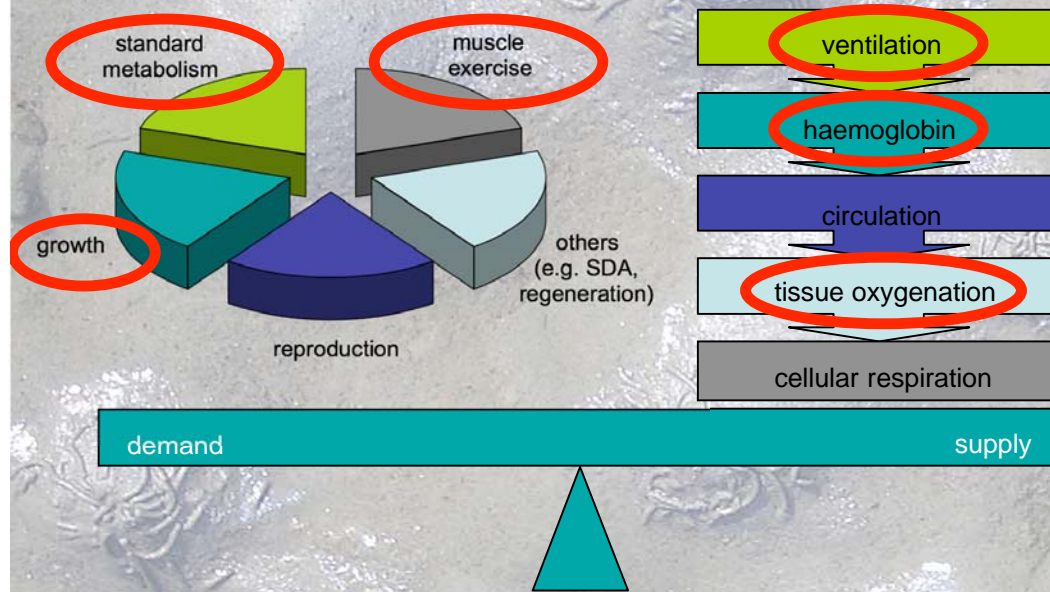


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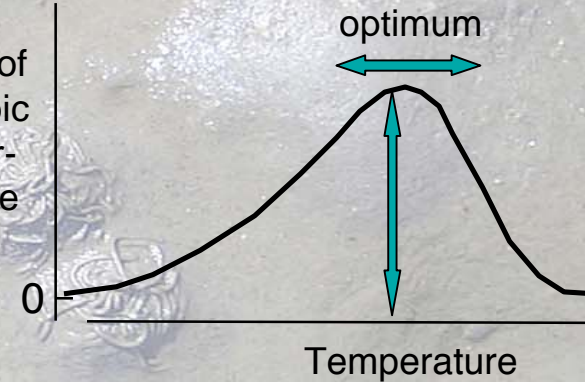
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Conclusions



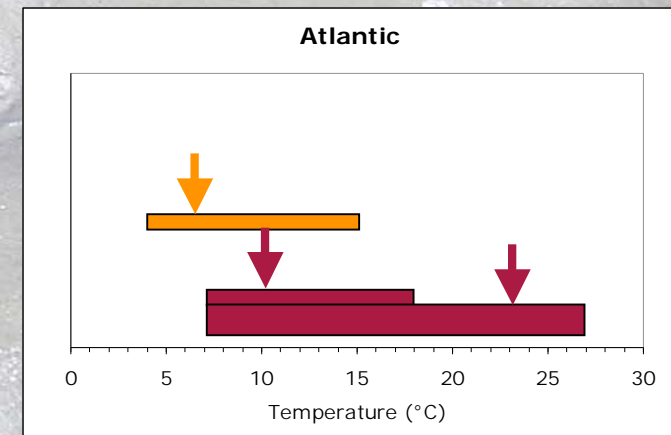
Rate of aerobic performance



© The investigated processes show capacities for seasonal acclimatization to regain balance in oxygen demand and supply.

© Climate change: application of the same mechanisms!

© Southernmost populations: Have they reached their adaptation limits?



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Thank you
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attention!

Questions?
Comments?

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