Increased seawater temperatures cause temporal shifts in catabolic pathways of Antarctic krill *Euphausia superba*

Tobias Mattfeldt[1], So Kawaguchi[2], Mathias Teschke[1], Natasha Waller[2], Bettina Meyer[1]

[1] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany

[2] Department of Environment and Heritage, Australian Antarctic Division, Australia

Contents

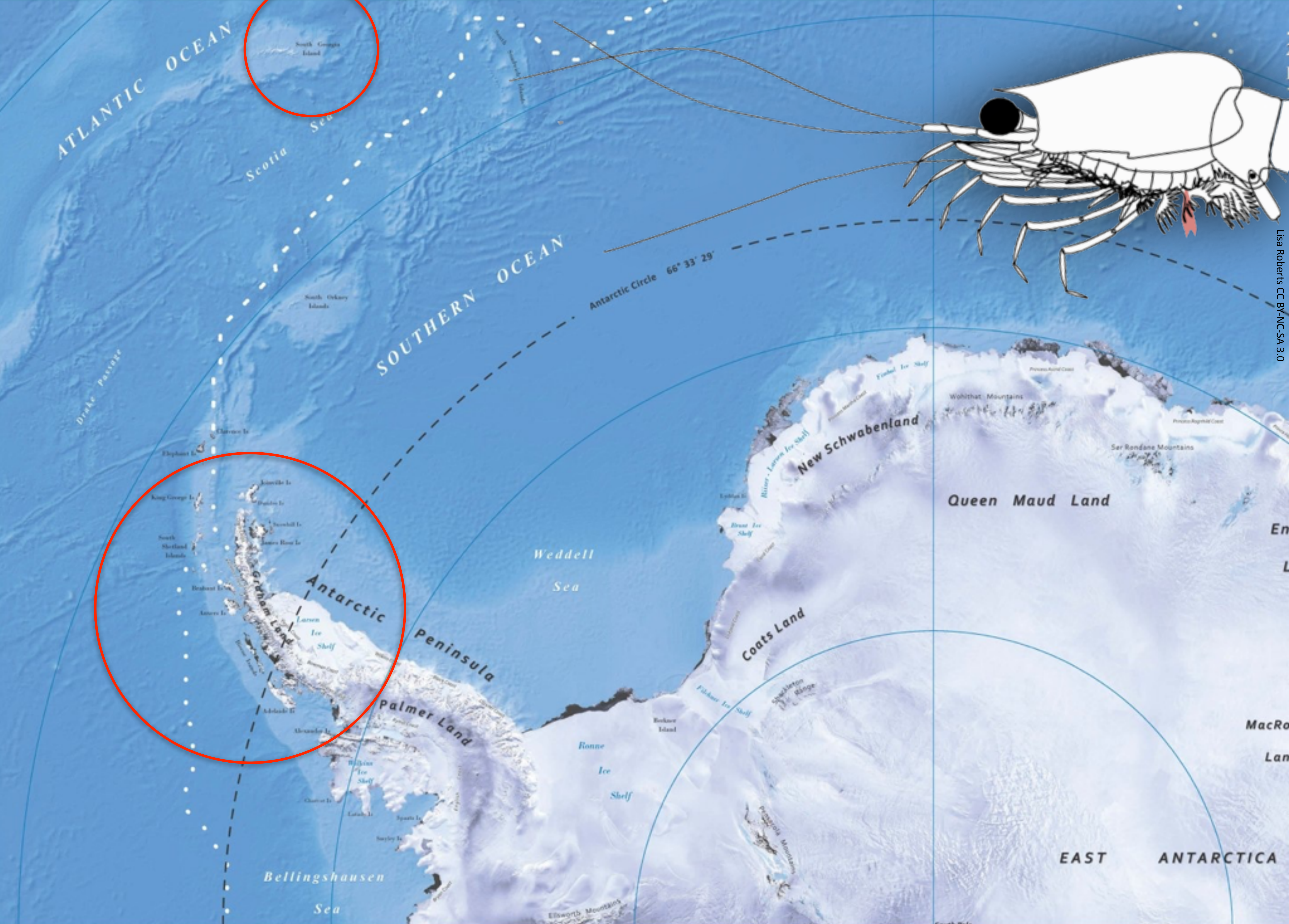


Image: polartec.com

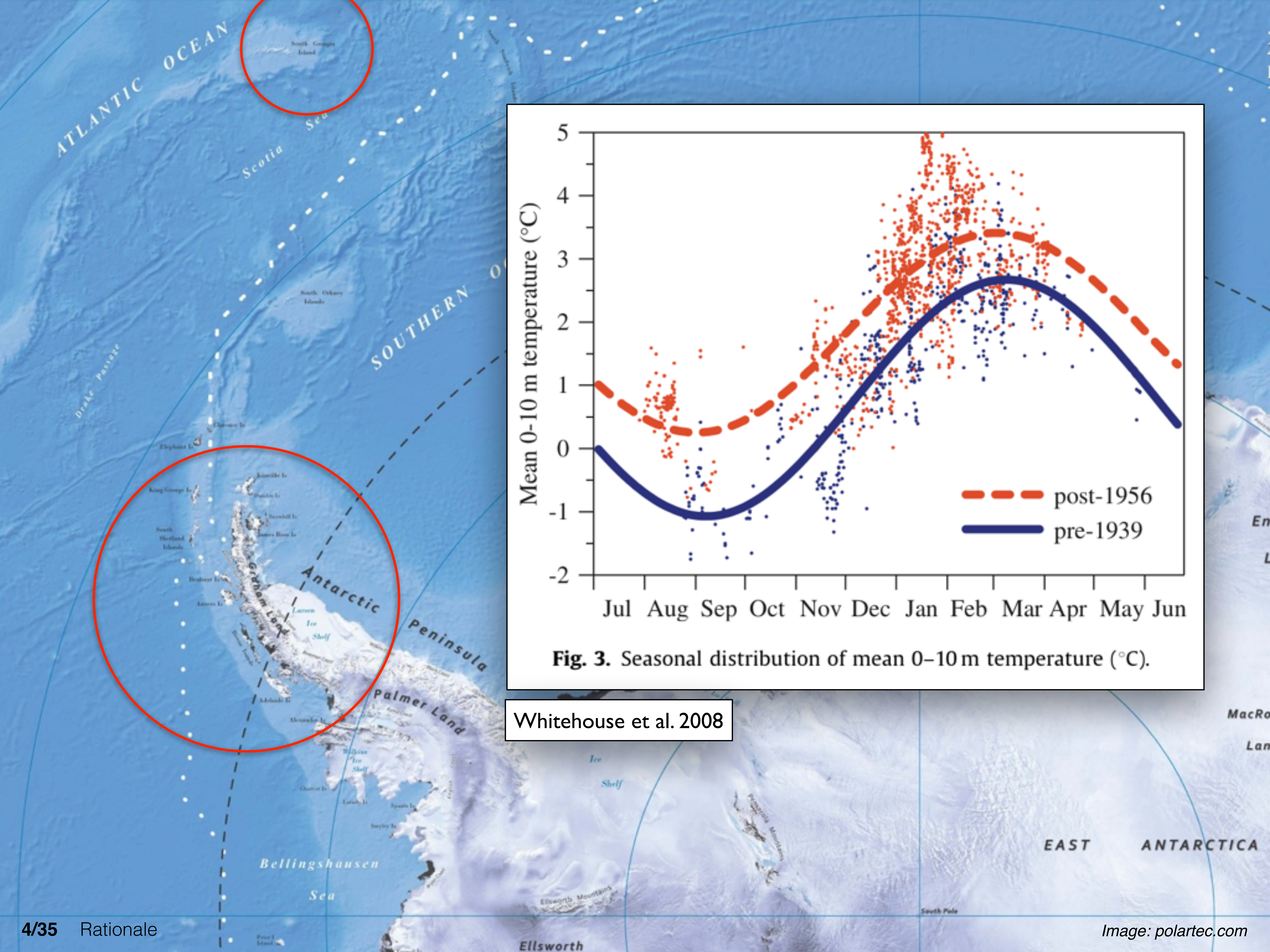


Fig. 3. Seasonal distribution of mean 0–10 m temperature (°C).

Whitehouse et al. 2008

Image: polartec.com

Hypothesis

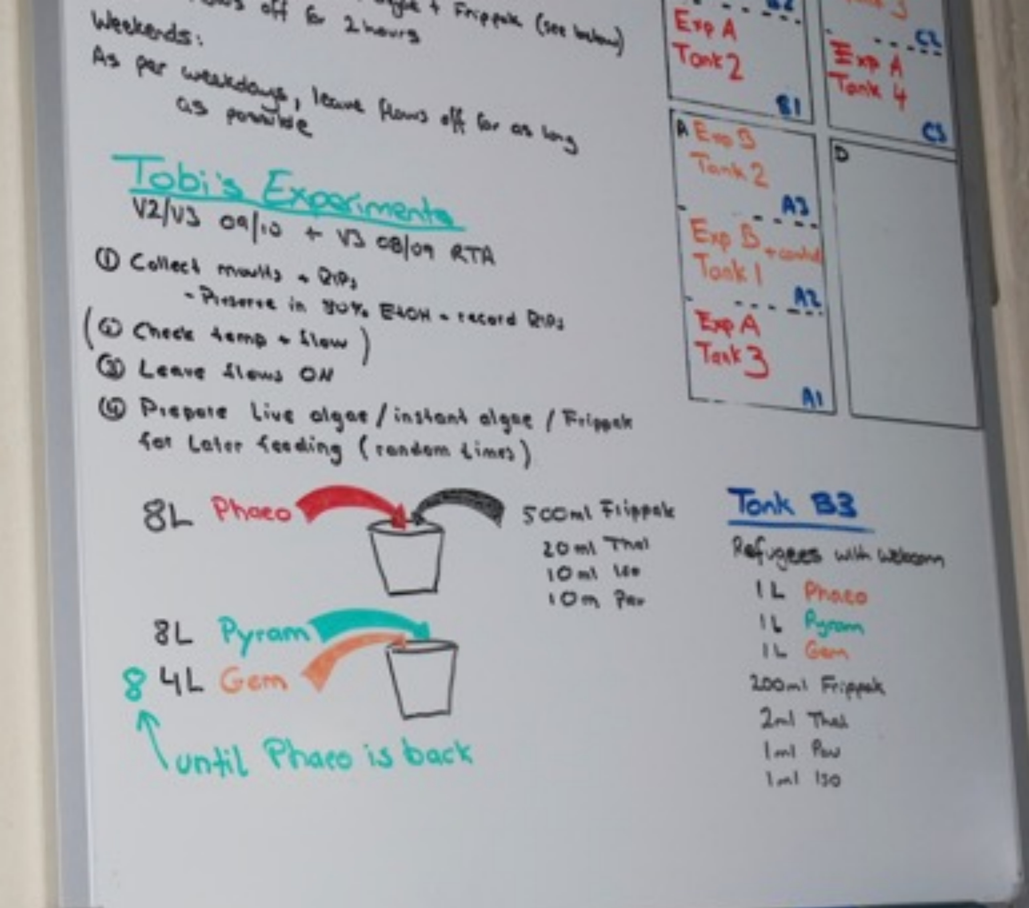
„Adult krill have a narrow temperature range of 0.5°C to 4°C for optimal growth and physiological functioning.“

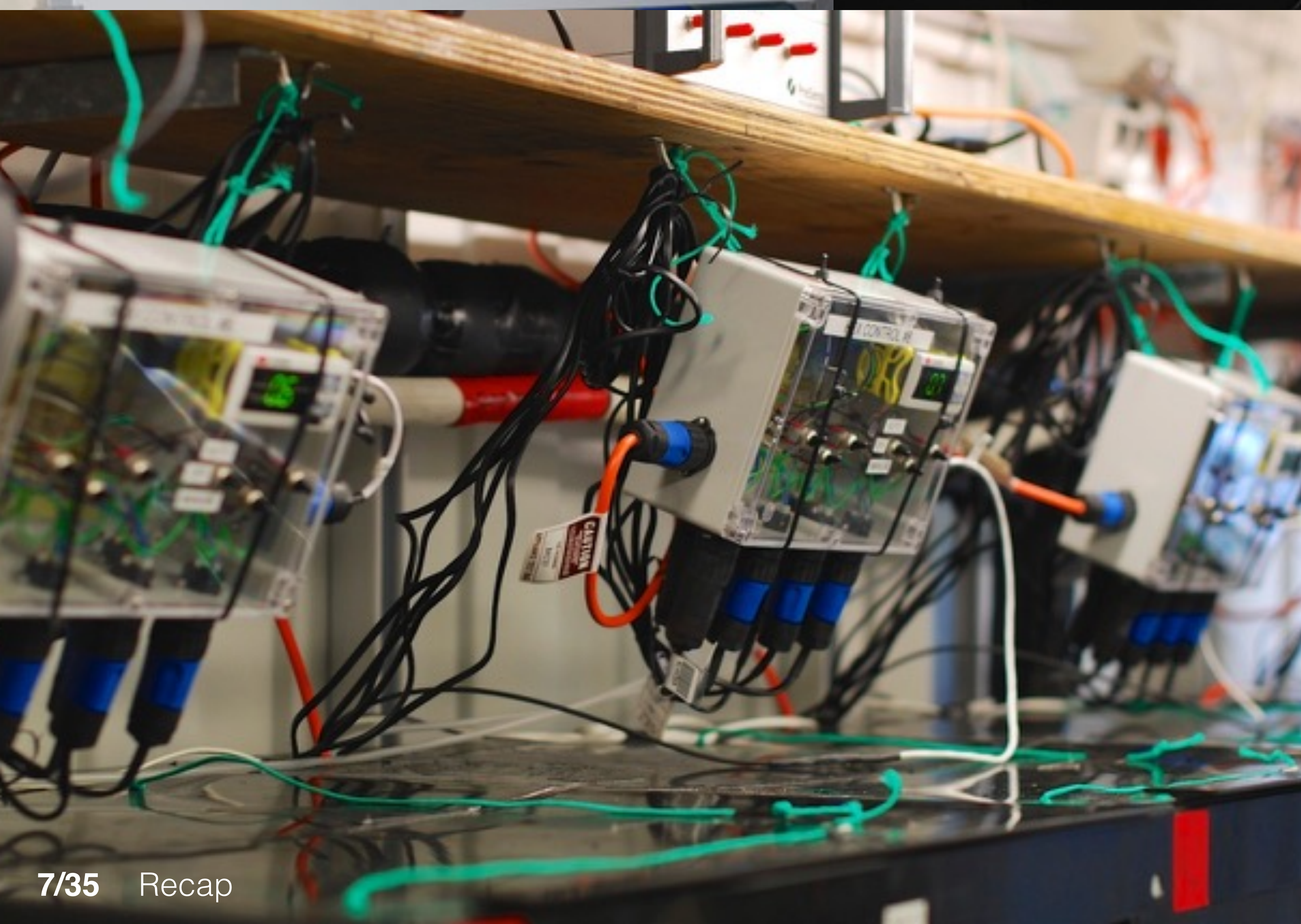




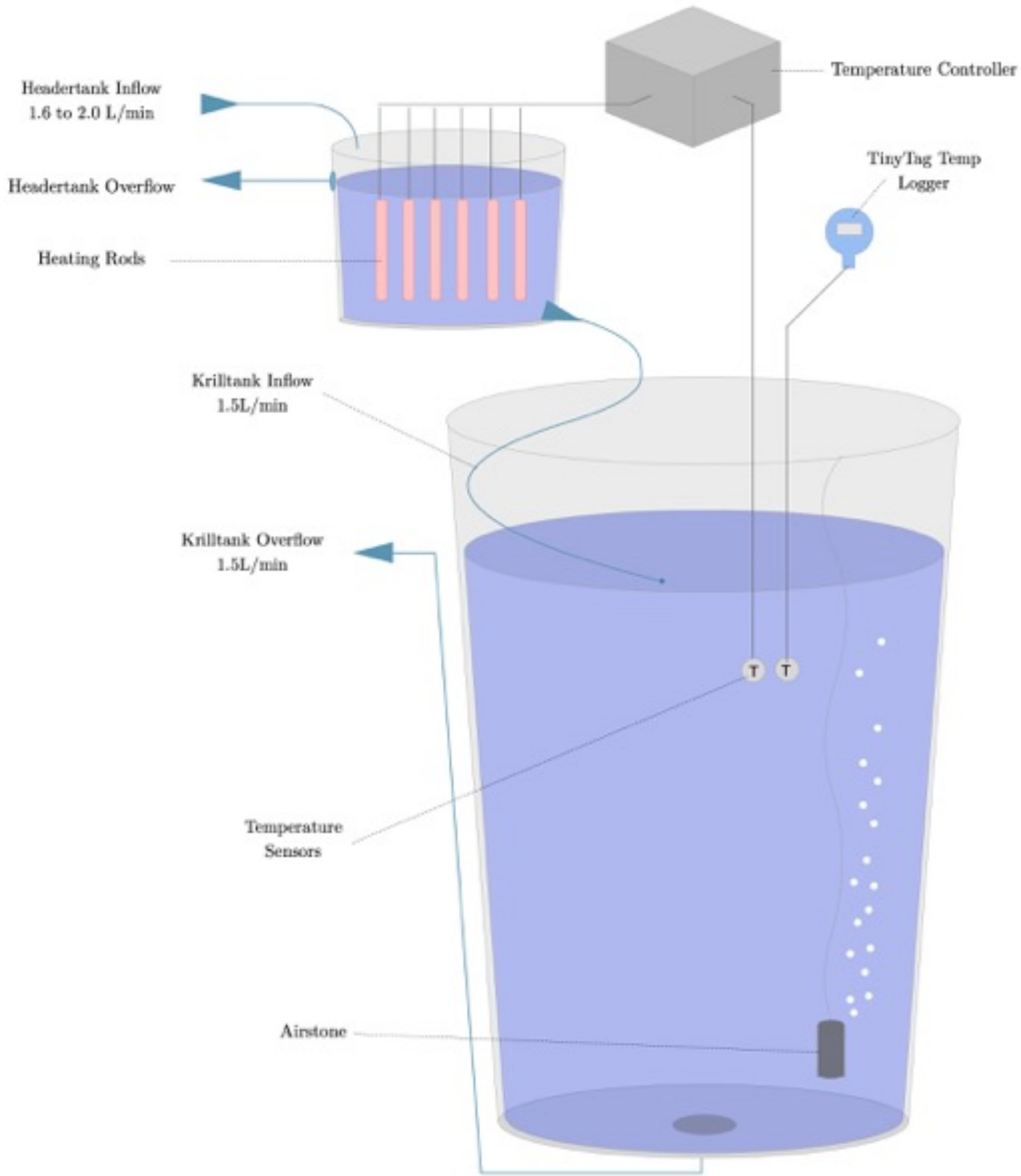
AWI

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division


Weekends:
As per weekdays, leave flows off for as long as possible
Tobi's Experiments
V2/V3 09/10 + V3 08/09 RTA
Check temp + flow
Leave flows ON
Prepare Live algae / instant algae / Frippak for Later feeding (random times)
8L Phaeo
500ml Frippak
20ml Thal
10ml Iso
10ml Pav
8L Pyram
8 4L Gem
until Phaeo is back
Tank B3
1L Phaeo
1L Pyram
1L Gem
200ml Frippak
2ml Thal
1ml Pav
1ml Iso
Exp A Tank 2
Exp A Tank 4
Exp B Tank 2
Exp B Tank 1
Exp A Tank 3

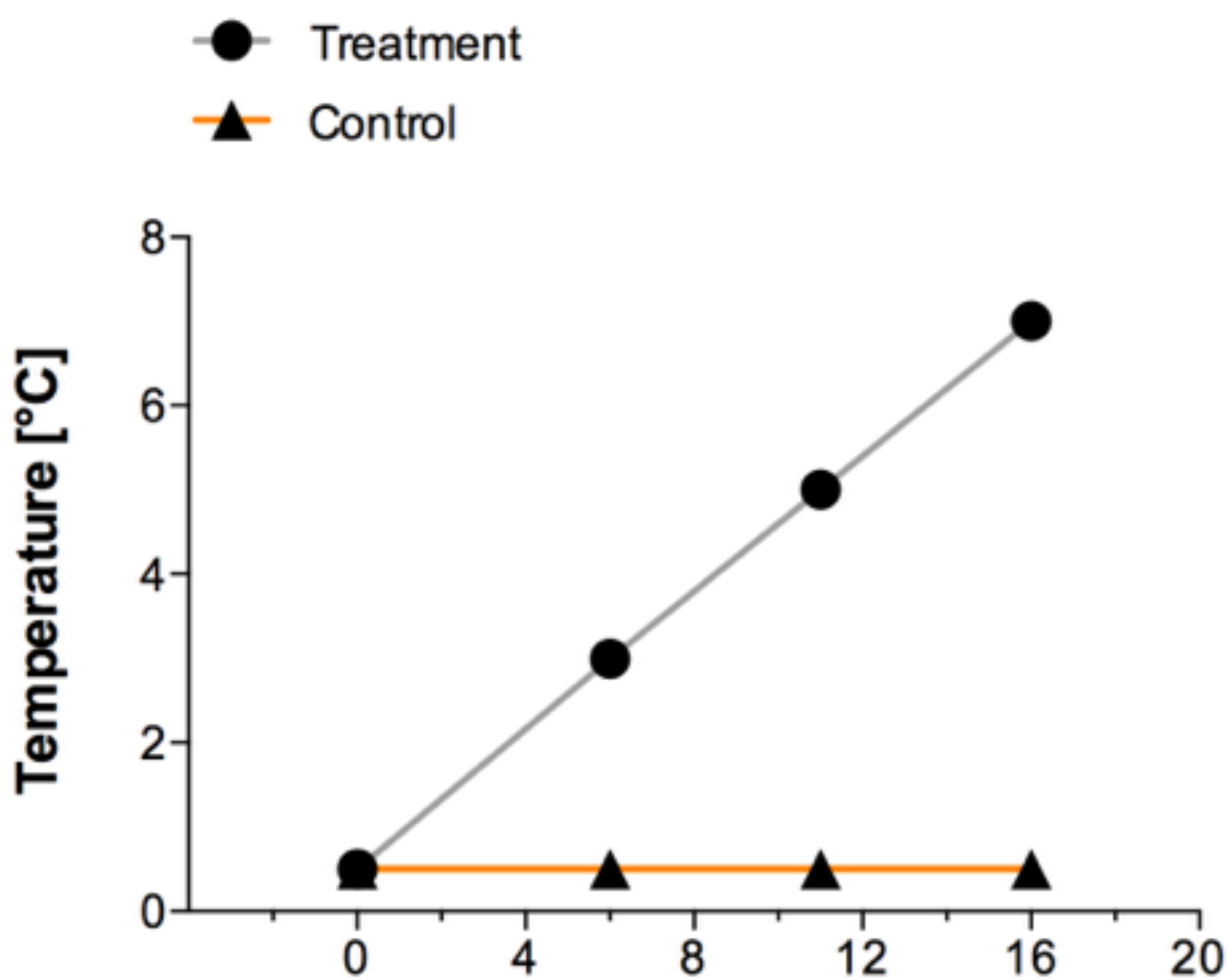


Experimental Setup



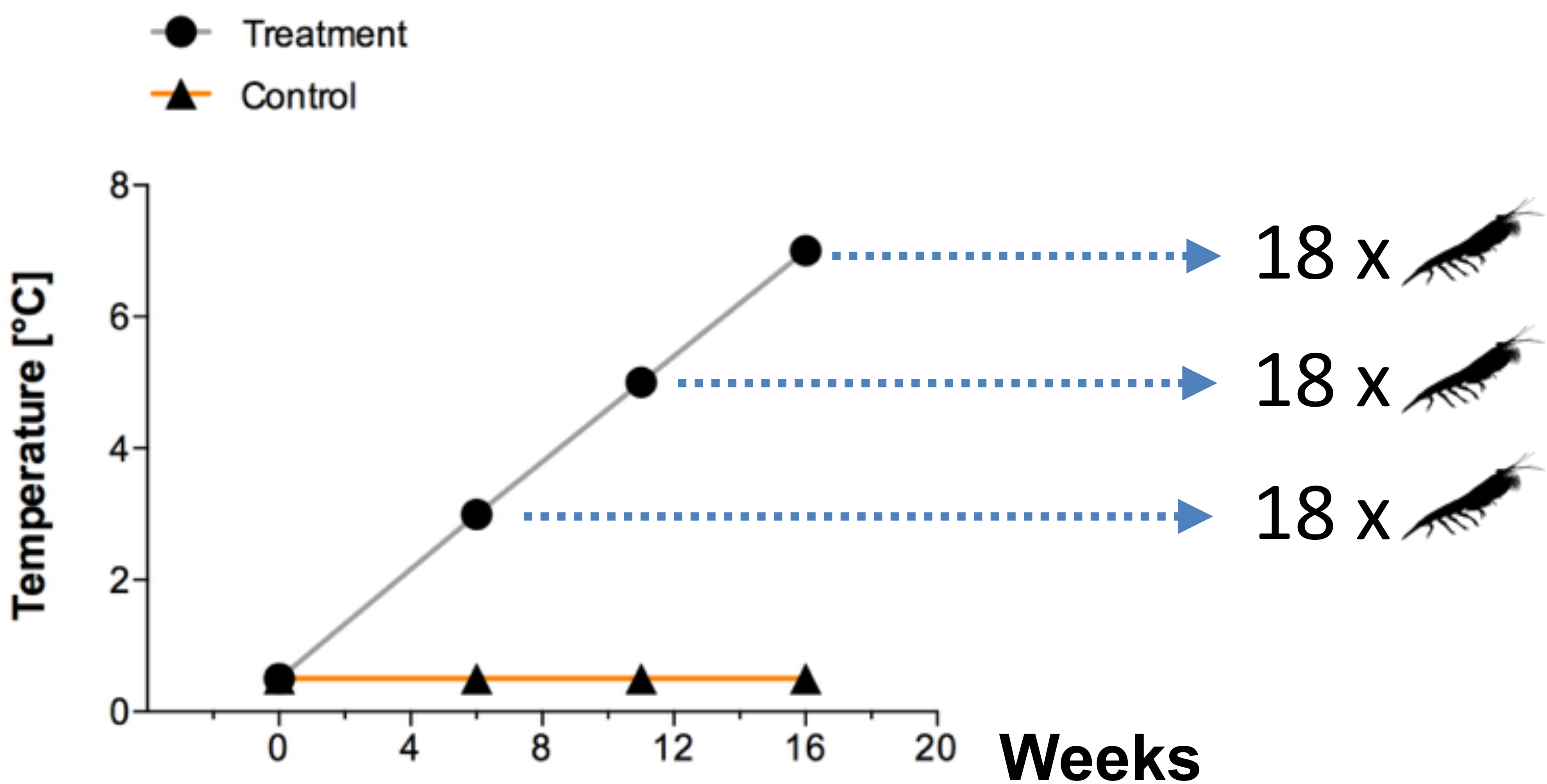
AWI
Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

Sampling Scheme

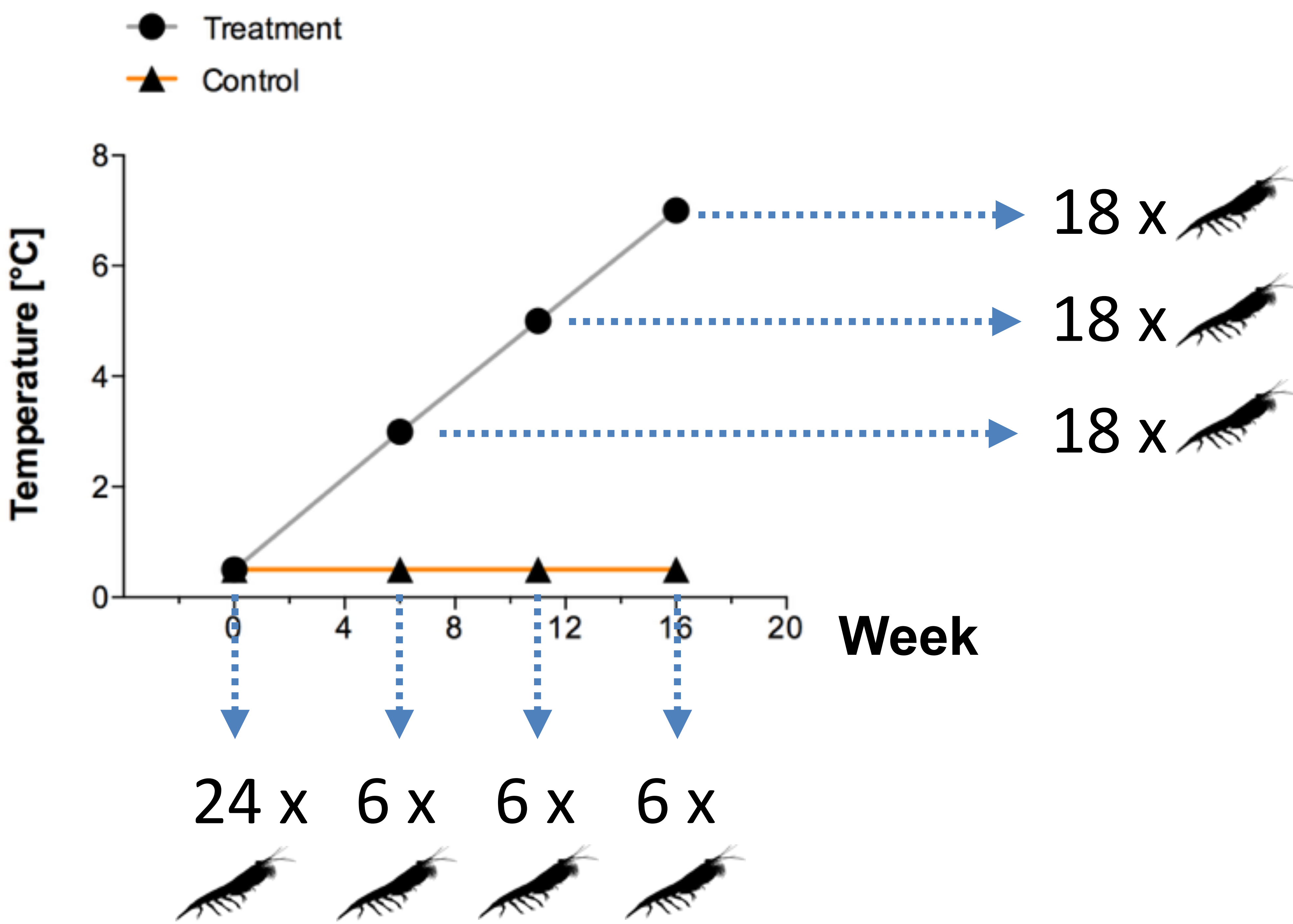


Weeks

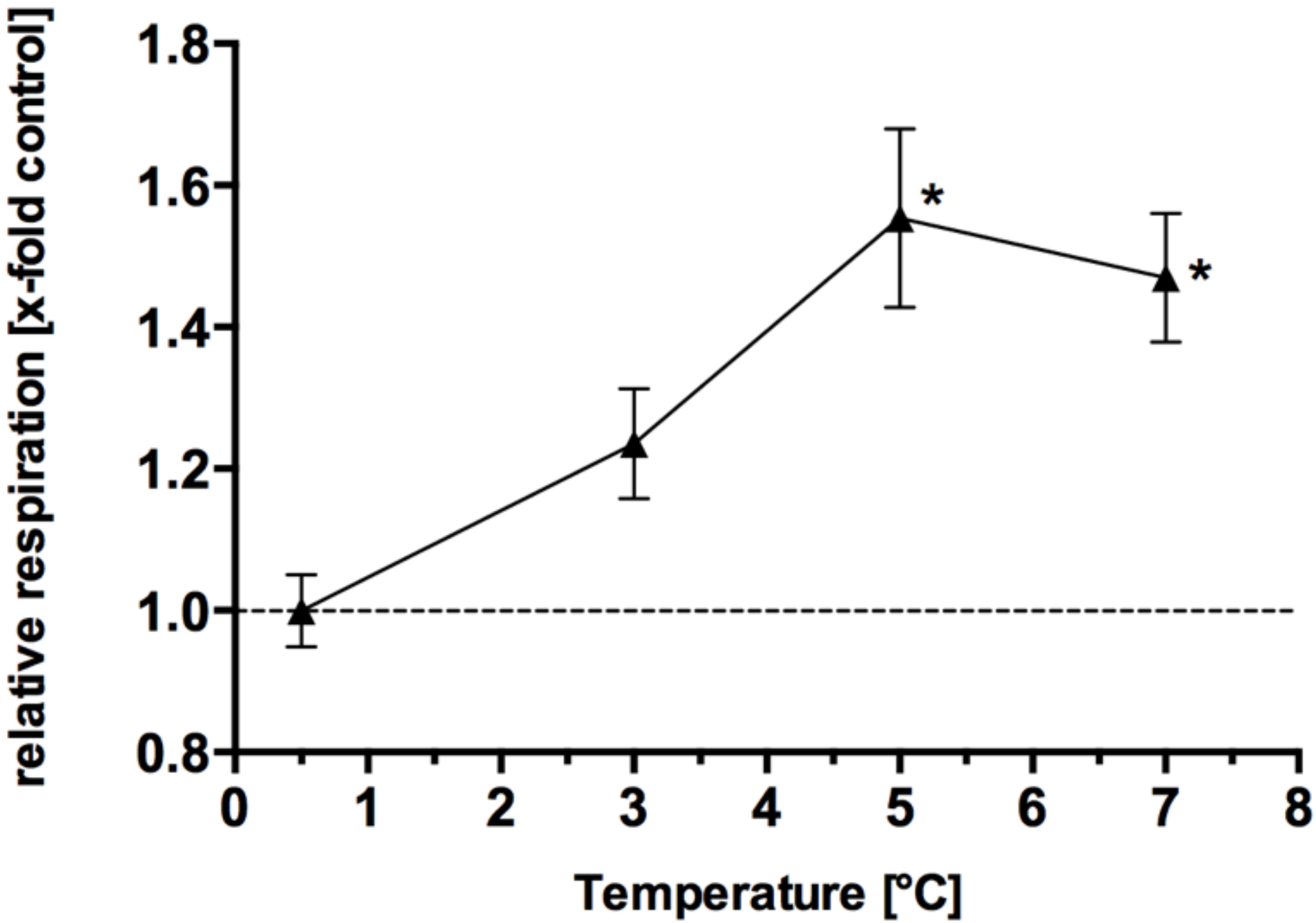
Sampling Scheme



Sampling Scheme



Respiration



Respiration -> Energy Requirement

	Temperature [°C]	Equation from linear regression	Individual energy requirement [Joule/d]
Treatment	0.5	$y = 0.3117x$	1,12
	3	$y = 0.4021x$	1,45
	5	$y = 0.5903x$	2,13
	7	$y = 0.6268x$	2,26
Control	0.5	$y = 0.3544x$	1,28
	3	$y = 0.3753x$	1,35
	5	$y = 0.3587x$	1,29
	7	$y = 0.4155x$	1,50

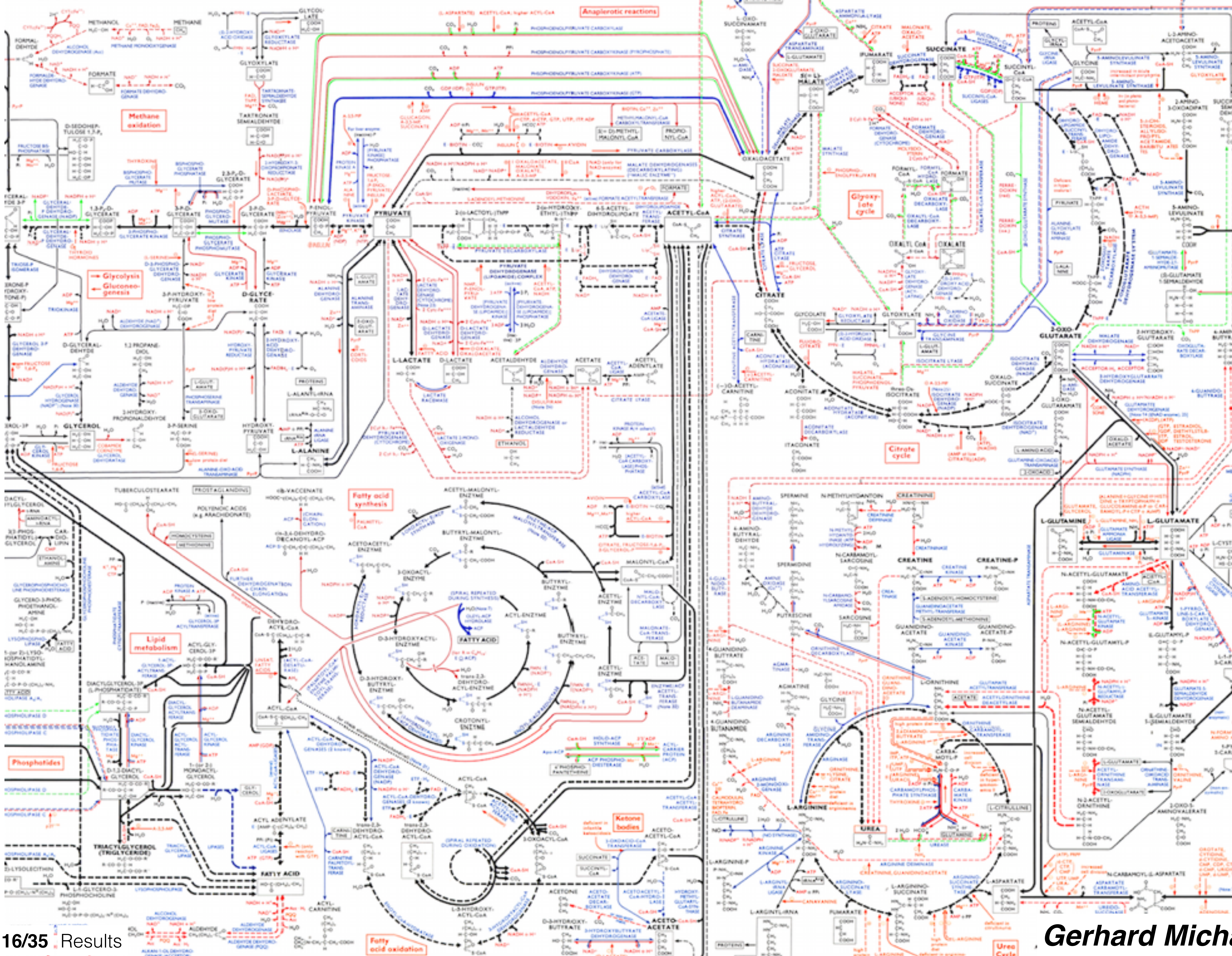
Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

Respiration -> Energy Requirement

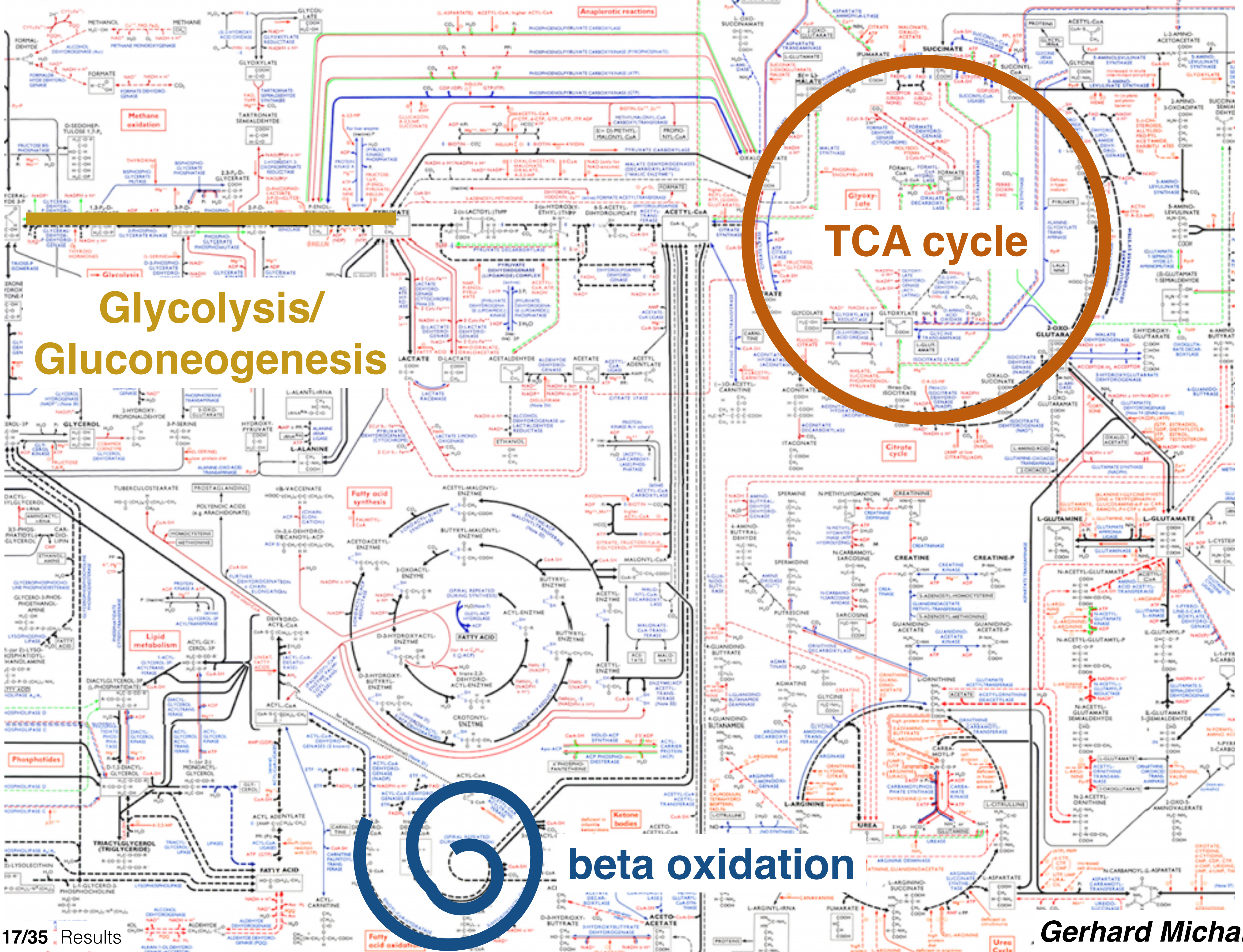
	Temperature [°C]	Equation from linear regression	Individual energy requirement [Joule/d]
Treatment	0.5	$y = 0.3117x$	1,12
	3	$y = 0.4021x$	1,45
	5	$y = 0.5903x$	2,13
	7	$y = 0.6268x$	2,26
Control	0.5	$y = 0.3544x$	1,28
	3	$y = 0.3753x$	1,35
	5	$y = 0.3587x$	1,29
	7	$y = 0.4155x$	1,50

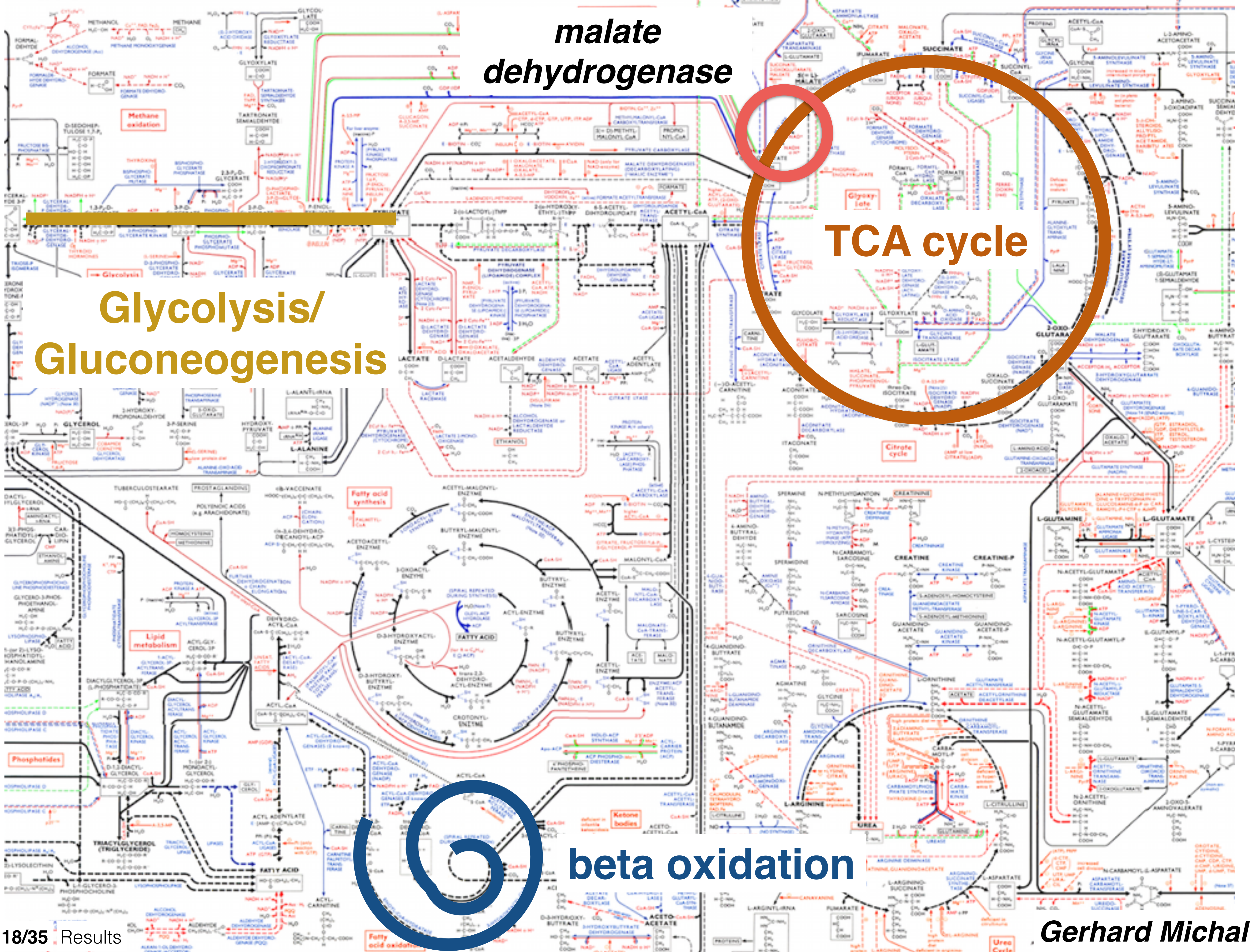
How are energy demands met?

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division



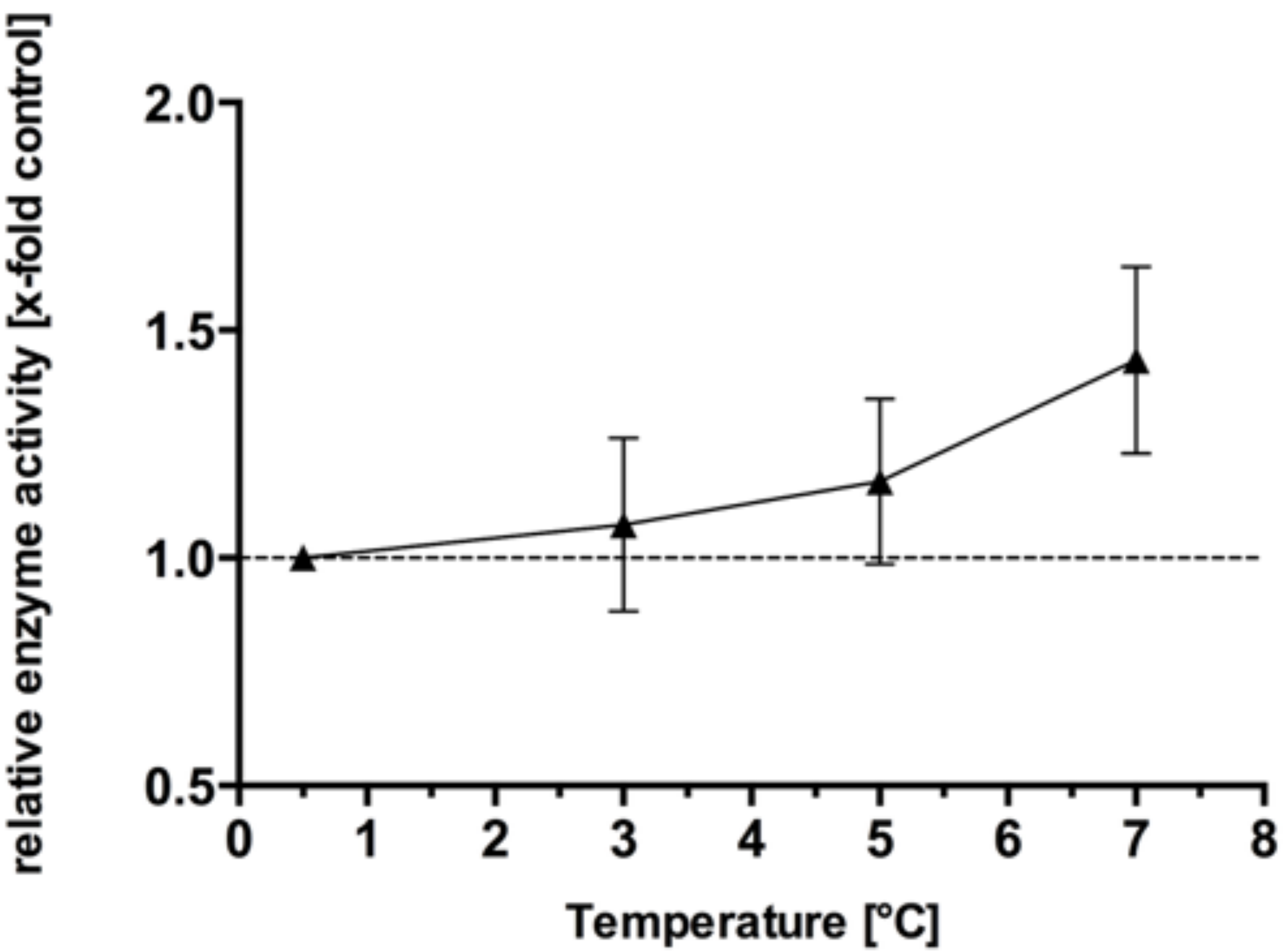
Gerhard Michal


Glycolysis/
Gluconeogenesis
TCA cycle
beta oxidation
Gerhard Michal

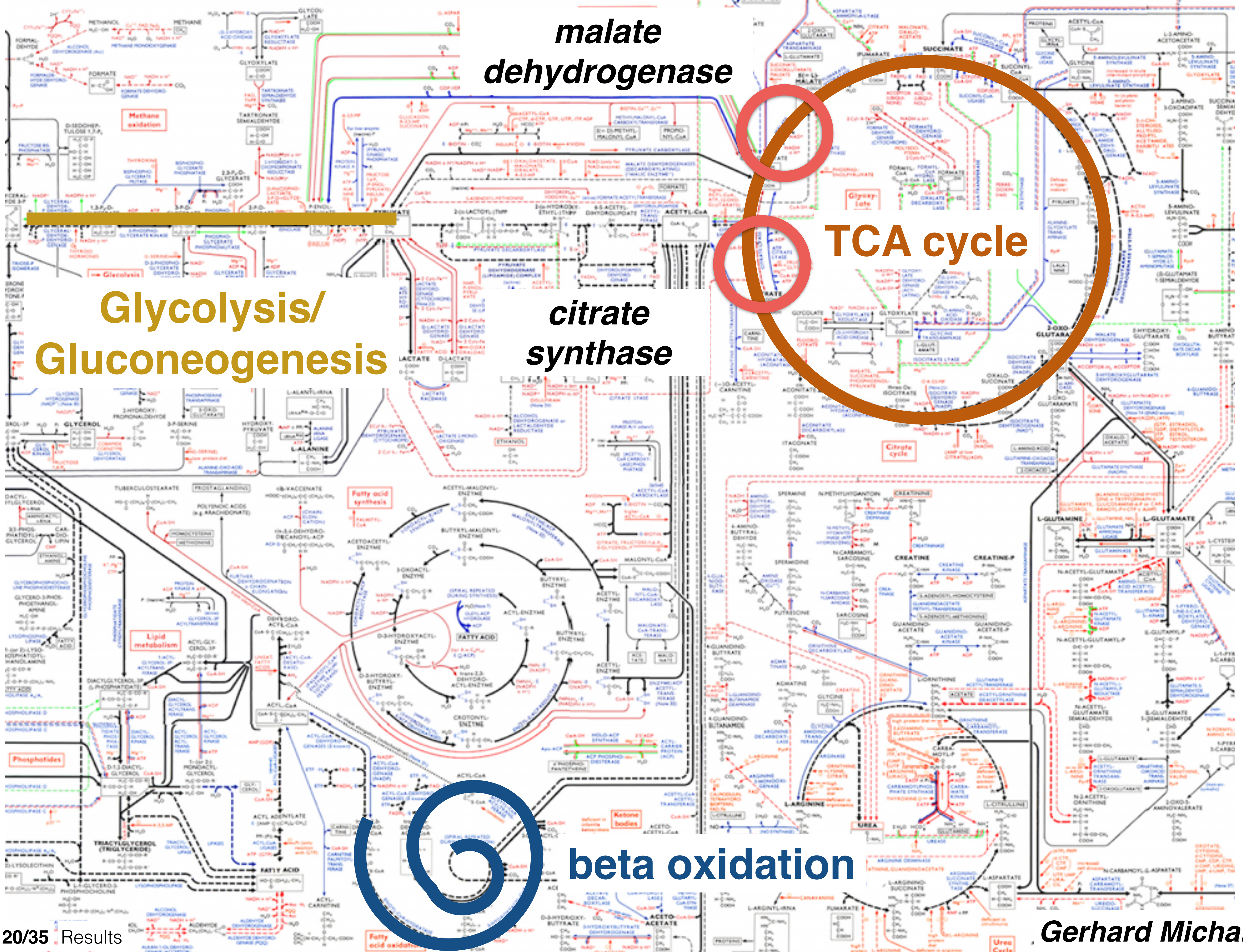


Gerhard Michal

Malate Dehydrogenase MDH

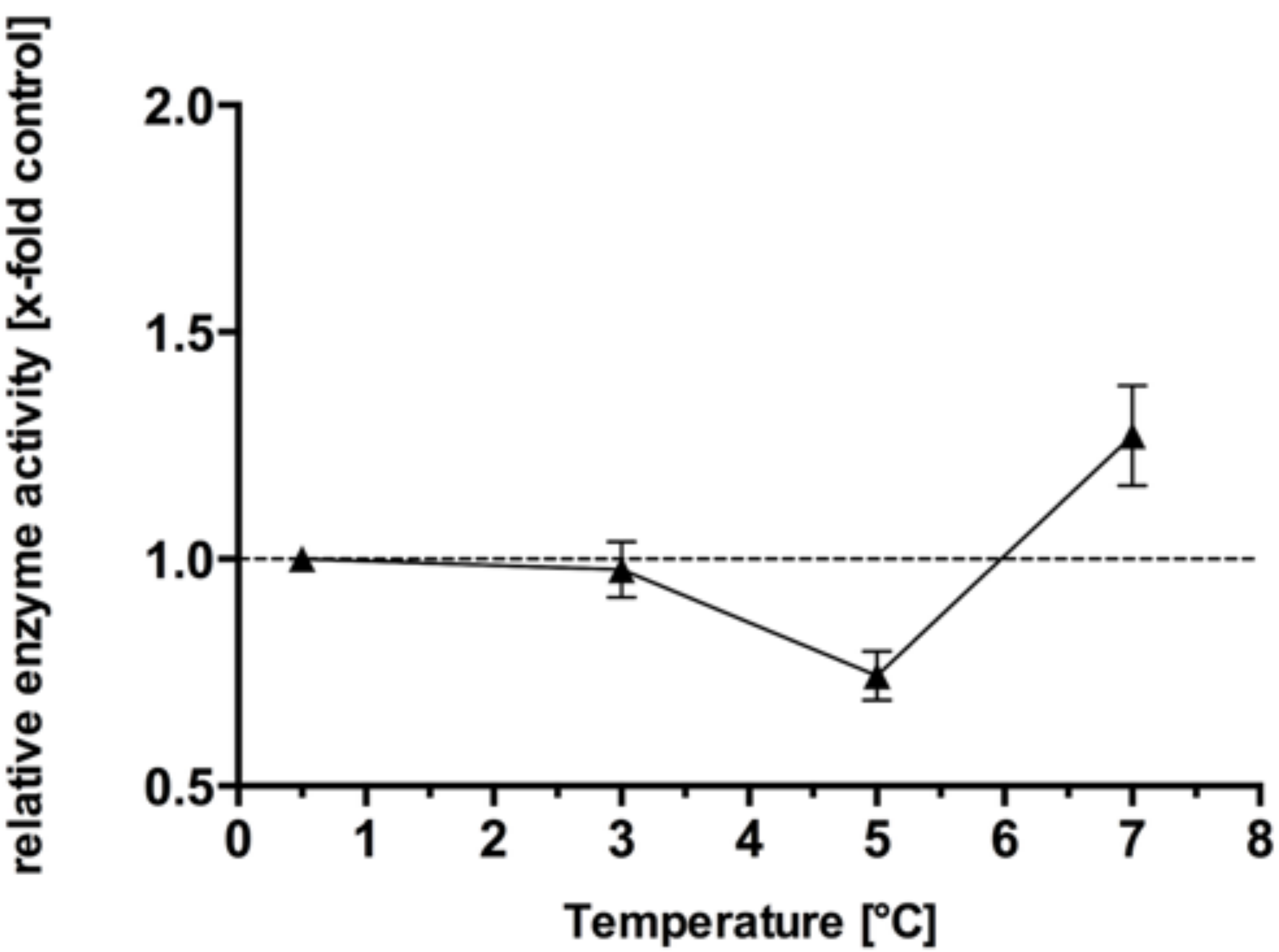


- Key enzyme in TCA cycle, catalyzes oxidation of malate to oxaloacetate
- also involved in other pathways (shuttling of TCA intermediates to cytosol)
- mirrors respiration to some extent

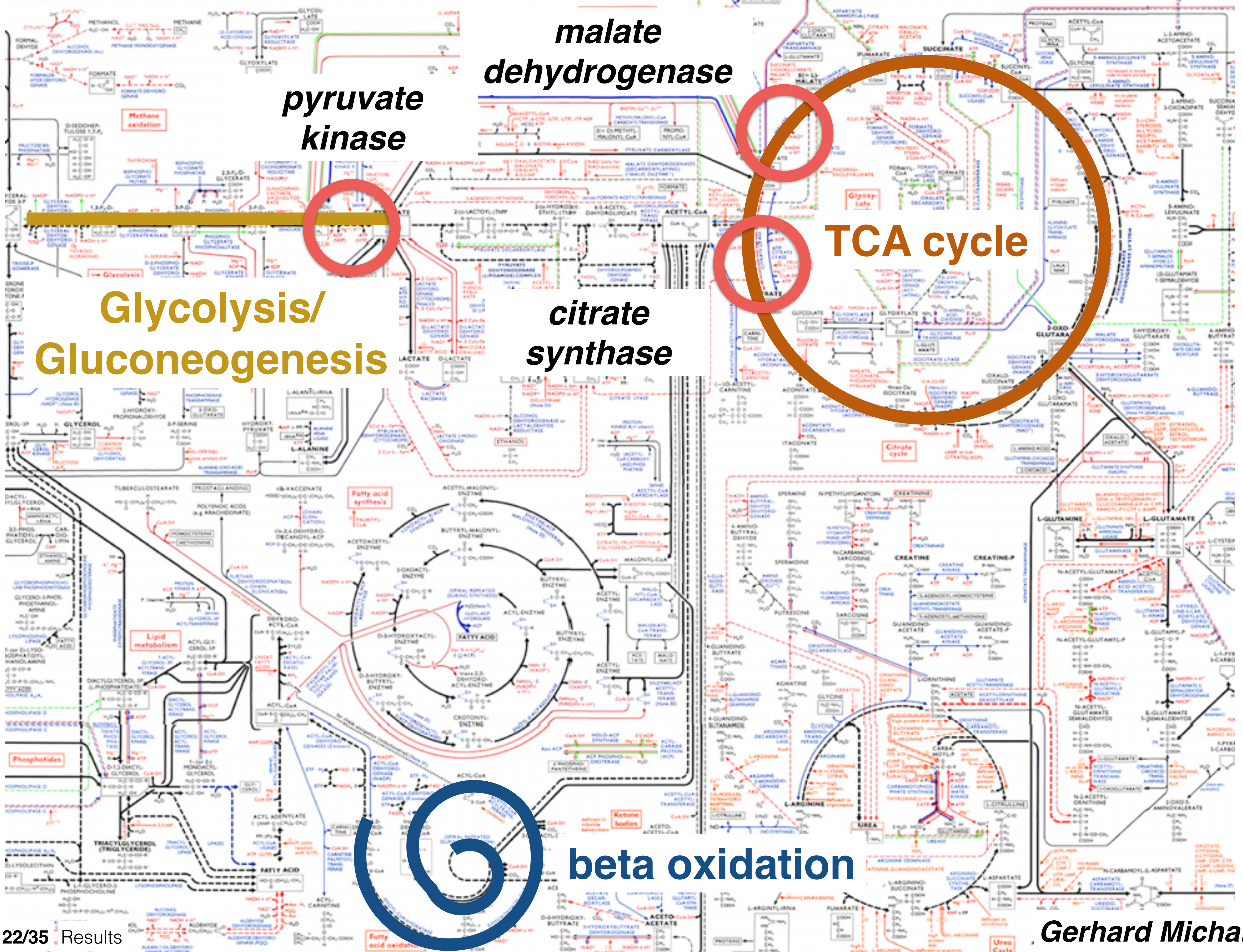


Gerhard Michal

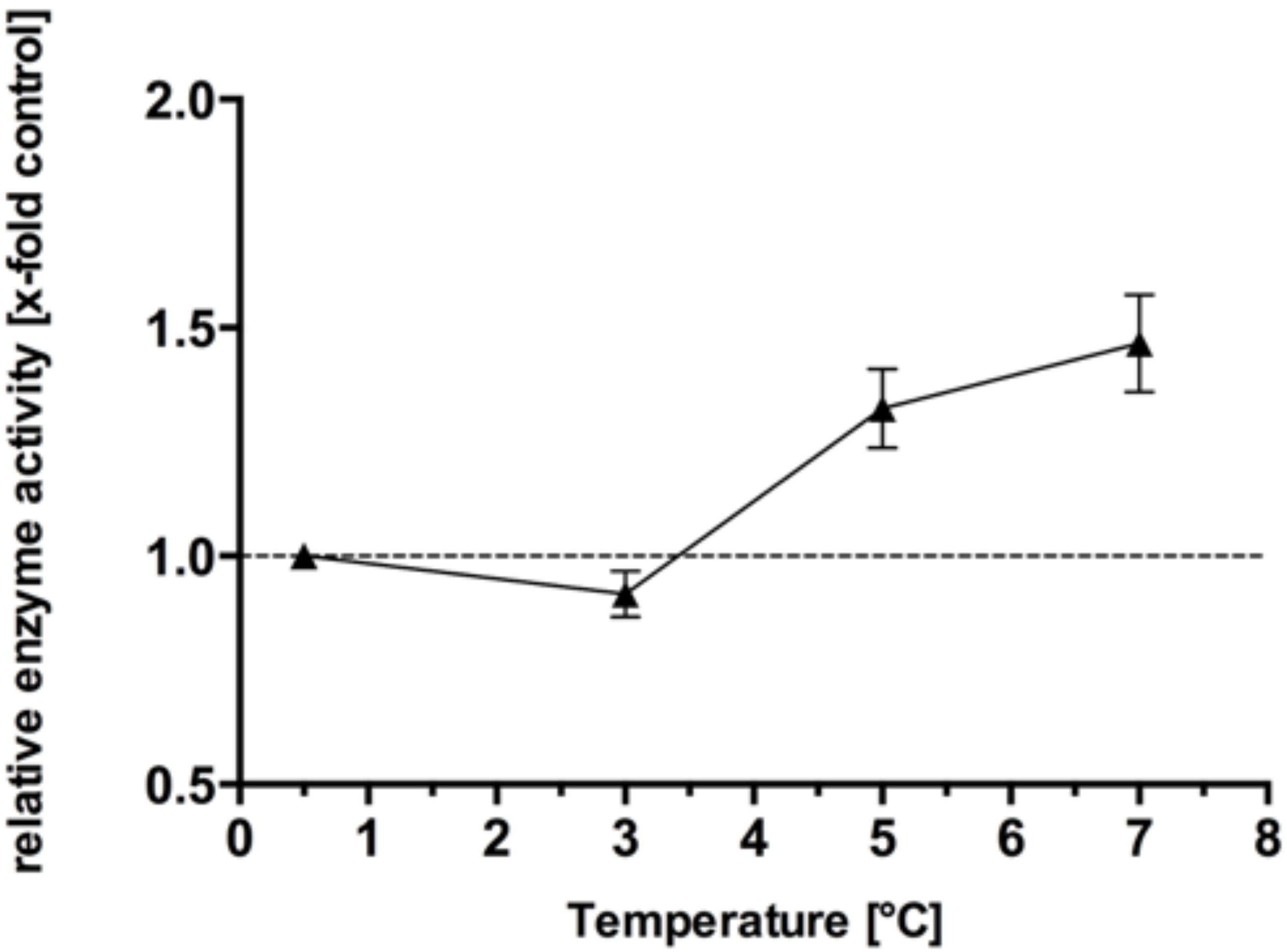
Citrate Synthase CS



- catalyzes first reaction in the cycle: condensation of the acetate residue from Acetyl CoA and one molecule oxaloacetate
- acts as central crossing point for various pathways
- balances oxidative and biosynthetic pathways
- entry point for fat synthesis (Acetyl-CoA shuttle to cytosol)

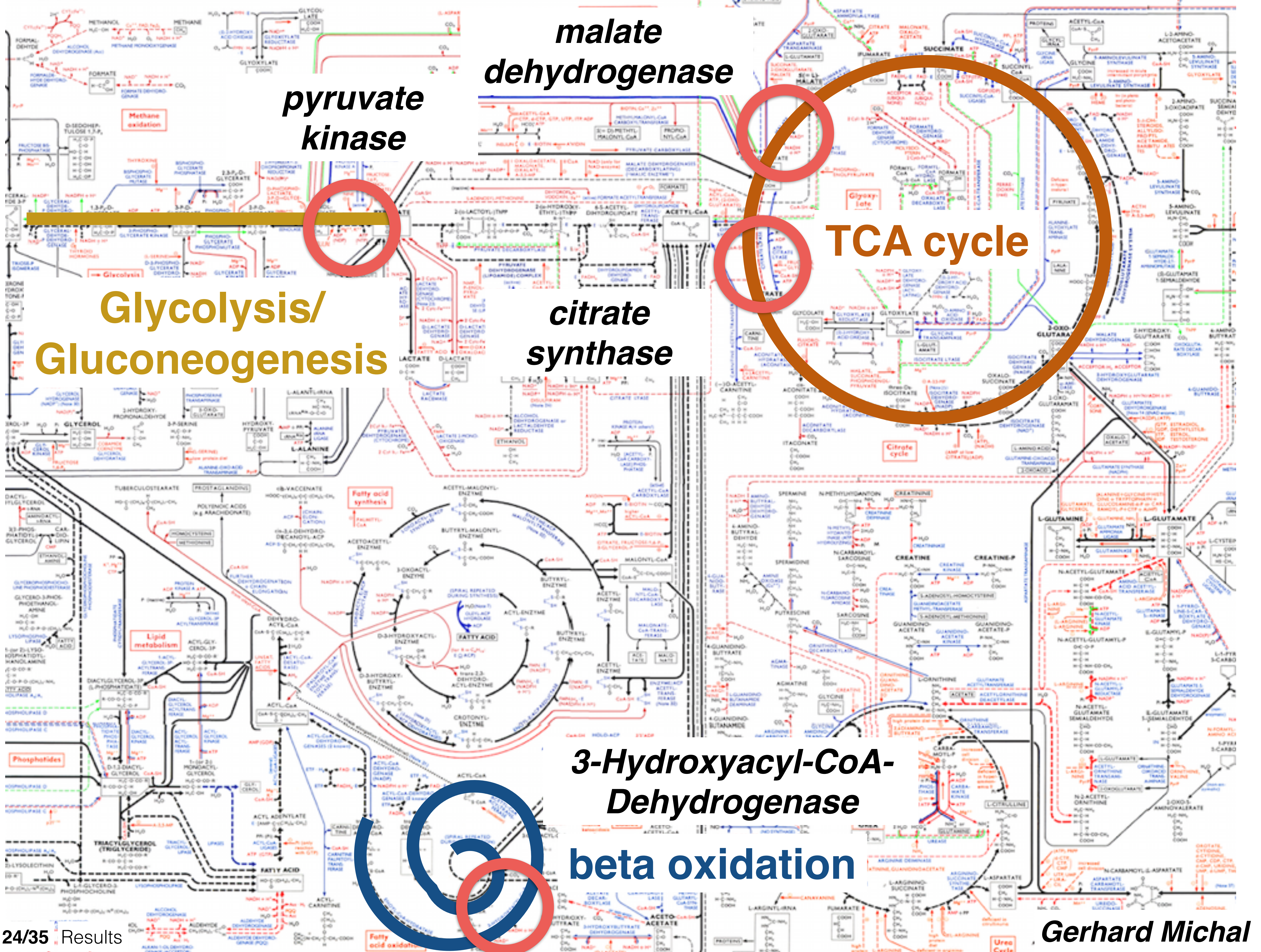

malate dehydrogenase
pyruvate kinase
TCA cycle
Glycolysis/ Gluconeogenesis
citrate synthase
beta oxidation
Gerhard Michal

Pyruvate Kinase PK

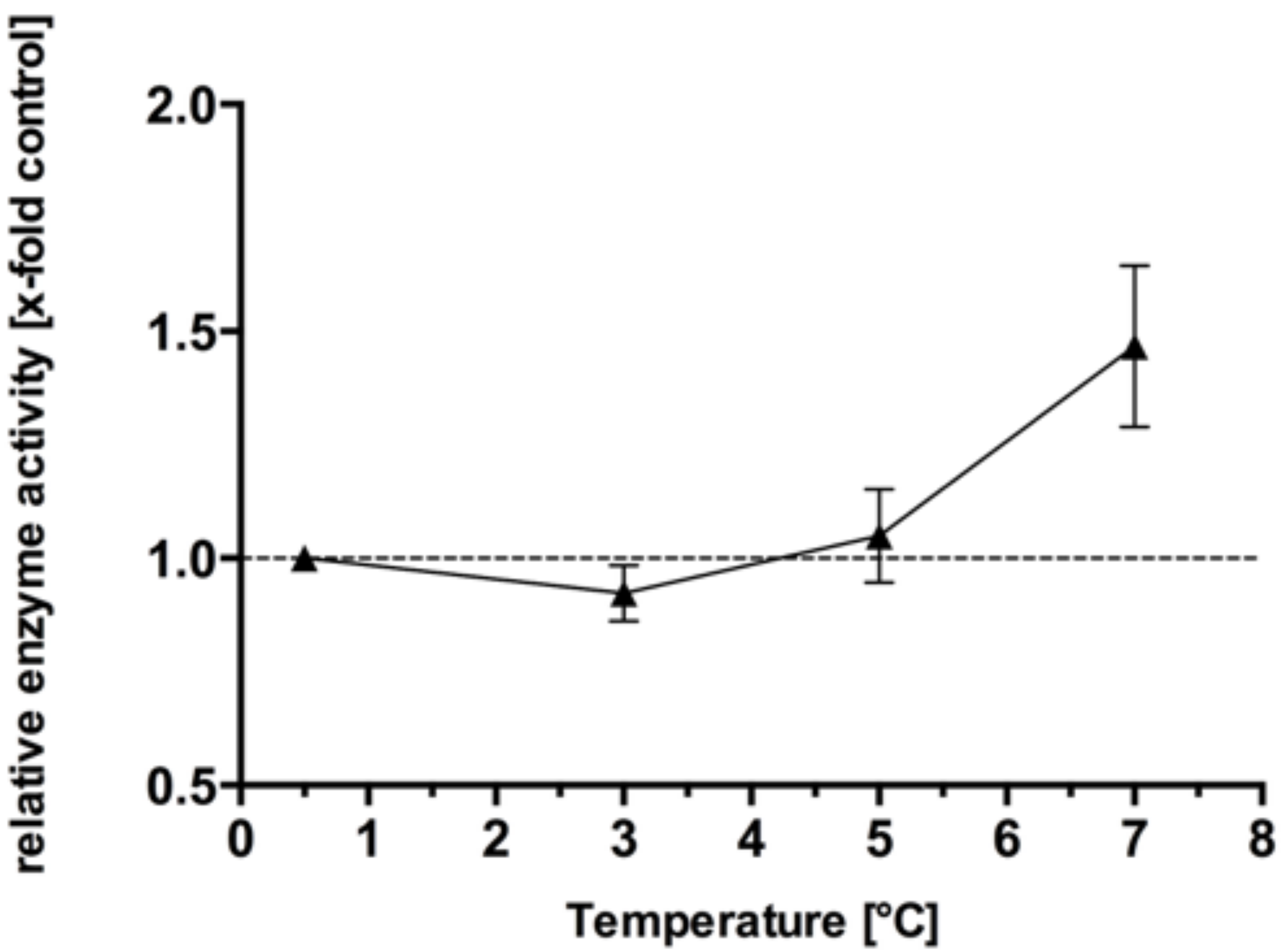


- Key enzyme in glycolytic pathway, catalyzes transphosphorylation from PEP and ADP to pyruvate and ATP
- constitutes primary metabolic intersection *(Munoz 2003)*
- suggested to play an important role in the transition to anaerobic metabolism *(Vial et al. 1992)*

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division


malate dehydrogenase
pyruvate kinase
TCA cycle
Glycolysis/ Gluconeogenesis
citrate synthase
3-Hydroxyacyl-CoA-Dehydrogenase
beta oxidation
Gerhard Michal

3-Hydroxyacyl-CoA-DH HOAD

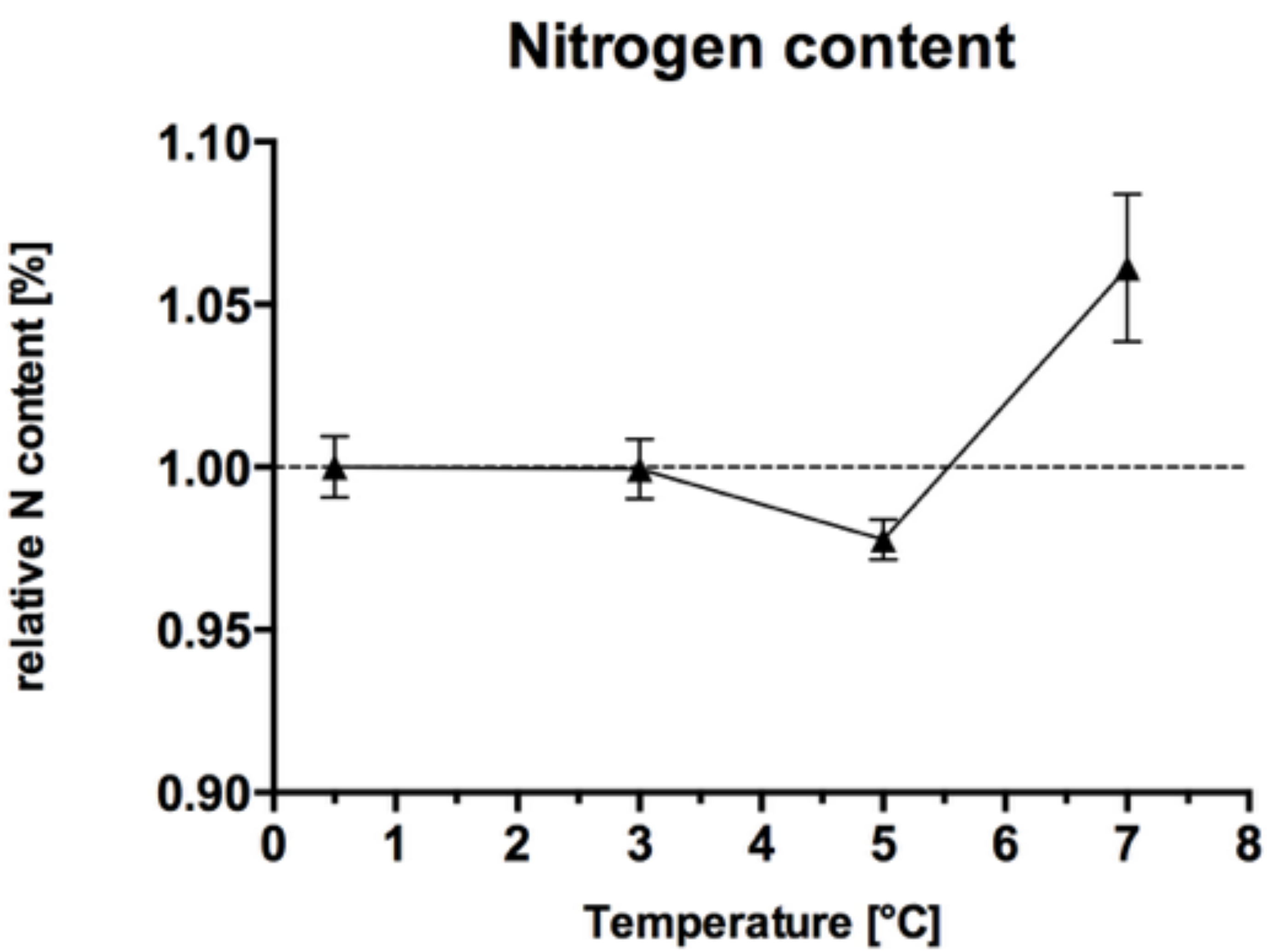


- 3rd step in beta oxidation
- marker enzyme for utilization of lipids

Glucose Catabolism

- ATP is allosteric inhibitor of PK -> upregulation of PK when ATP required
- upregulation -> less gluconeogenesis, no demand for synthesis of glucose

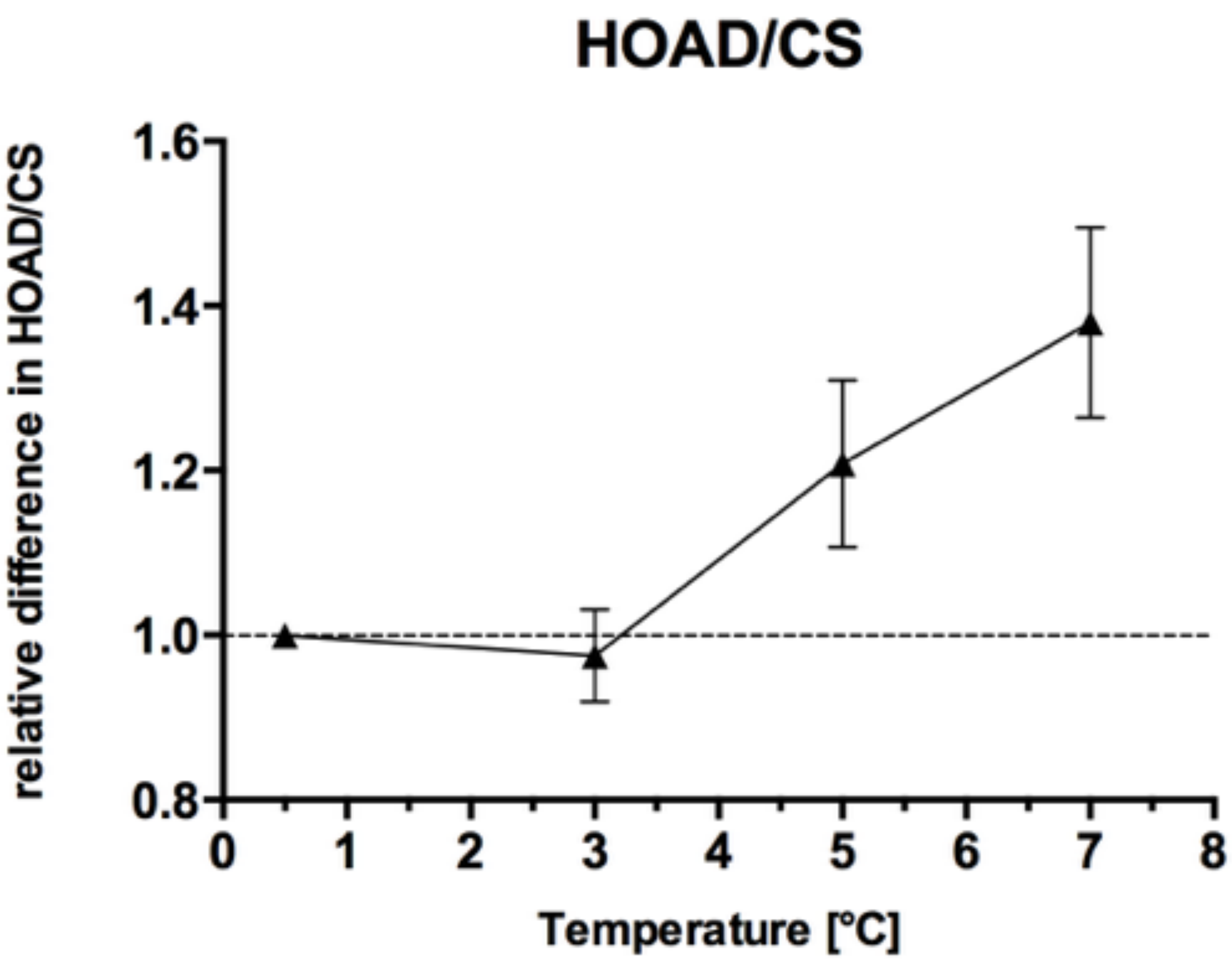
Protein Catabolism



MDH going up <-> not mirrored by CS:

- points to a role of MDH other than that in the cycle series: downstream shuttling of intermediates of protein catabolism into TCA?
- other studies show higher capacity for protein breakdown with increasing temperature (Schwerin et al. 2009)

Lipid Catabolism



Normalization to CS as central crossing point in metabolism (Windisch et al. 2011):

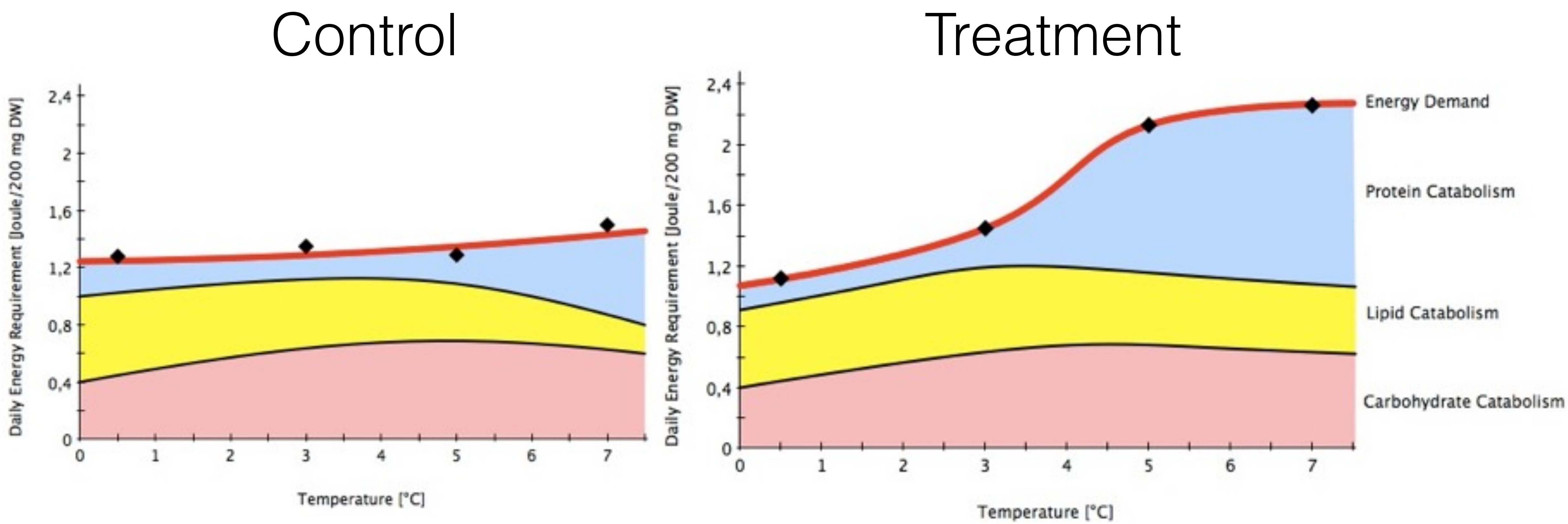
- increase in ratio hints at tendency towards lipid oxidation, NOT lipid synthesis

Conclusions

- Increased seawater temperature possibly leads to:
  - *earlier onset and heavier reliance on protein catabolism*
  - *prolongation of lipid oxidation*

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

Conclusions



Implications:

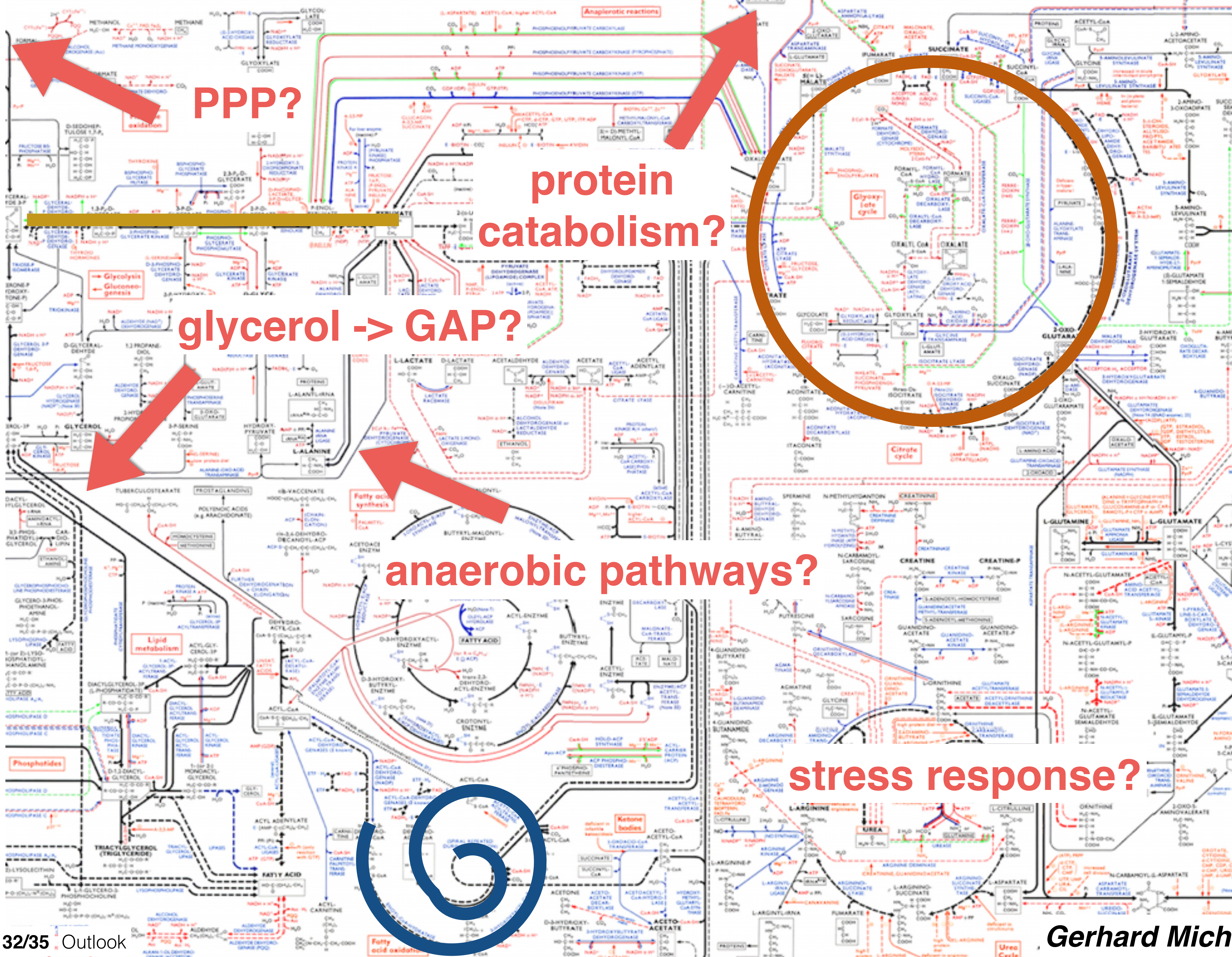
- Krill relies on productive summer months to accumulate lipid reserves for winter - prolonged lipid oxidation may impede the buildup of these crucial reserves - overwinter-ability affected
- Energy channeled towards higher maintenance will lack elsewhere, for example maturation

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

Outlook

Differential Gene Expression

- validate enzyme activities on genetic level
- fill gaps in the puzzle



Gerhard Michal

Outlook

Temperature Compensation of Clock Genes

- Dissociation of environmental events (blooms, sea-ice retreat) and endogenously controlled physiology (regression, maturation, spawning)

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

Acknowledgments

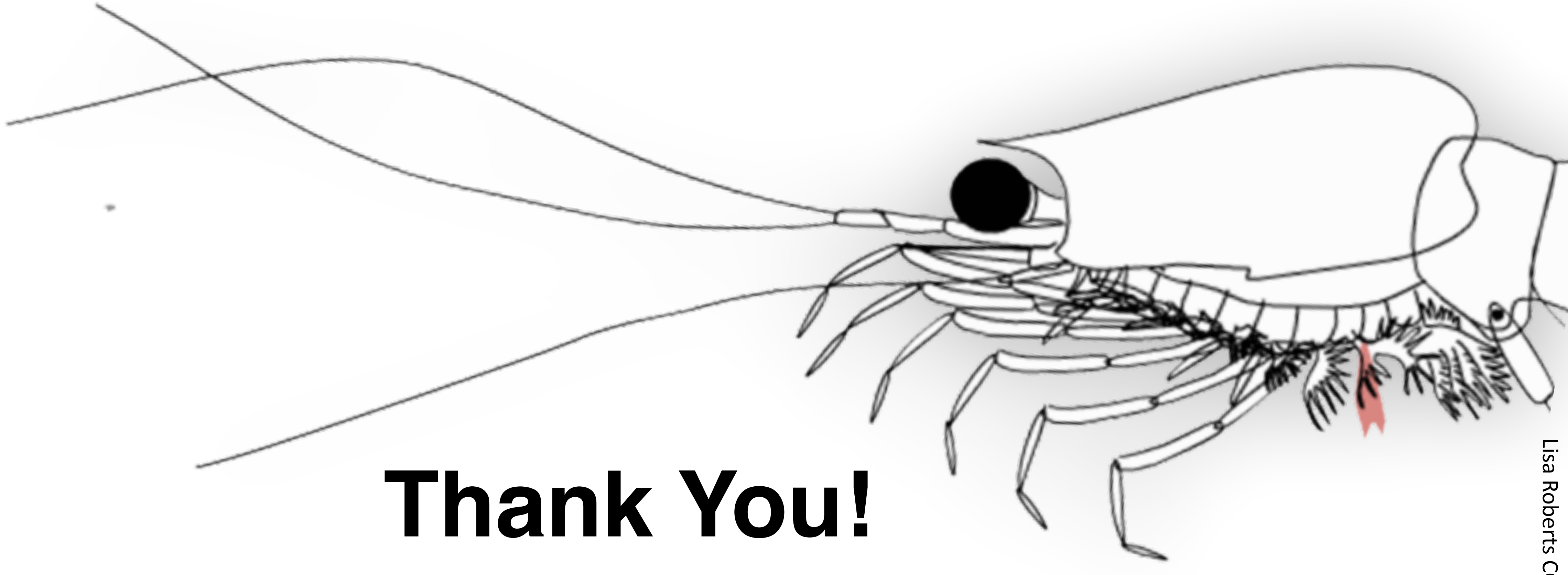
So Kawaguchi, Rob King, Tasha Waller,
Jessica Holan, Bianca Sfiligoj, Debbie Lang,
Adam Ward, Jesse McIvor, Dave

POLMAR
Helmholtz Graduate School
for Polar and Marine Research

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

AWI
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
UND MEERESFORSCHUNG

HELMHOLTZ
GEMEINSCHAFT



Thank You!

POLMAR Helmholtz Graduate School for Polar and Marine Research

Australian Government Department of Sustainability, Environment, Water, Population and Communities Australian Antarctic Division

AWI ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

HELMHOLTZ GEMEINSCHAFT