Omics data to improve the understanding of adaptation mechanisms to heat stress in pigs

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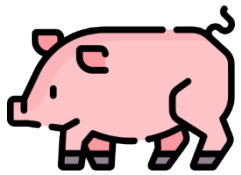
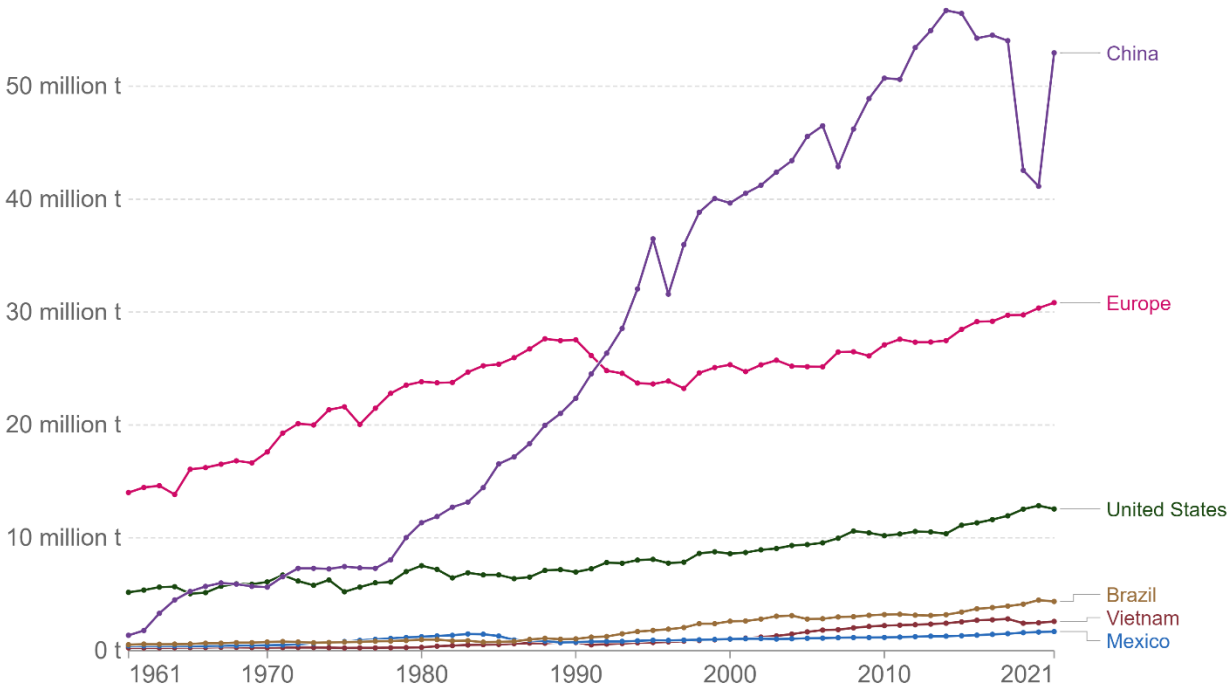


Production ⇑ in tropical areas ⇑

Consumption ⇑

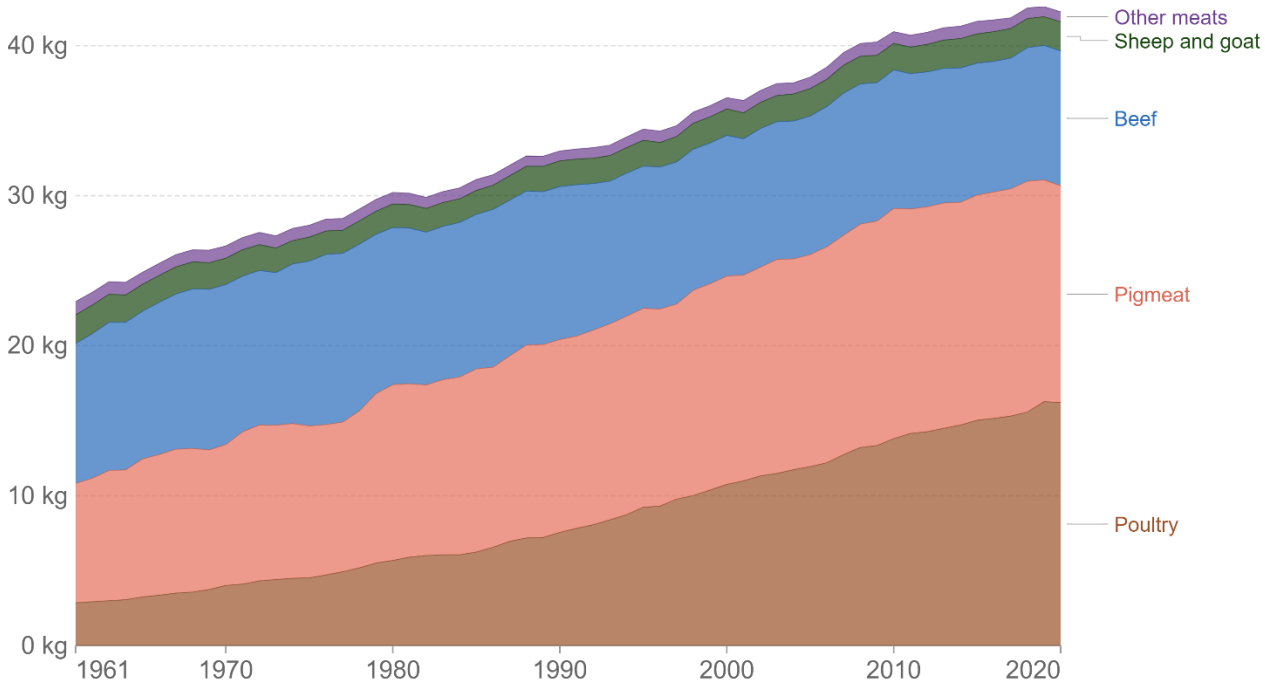
Pigmeat production



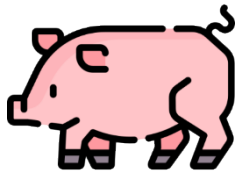
Source: Food and Agriculture Organization of the United Nations
OurWorldInData.org/meat-production • CC BY
Note: This refers to total meat production, from both commercial and farm slaughter. Data are given in terms of dressed carcass weight, excluding offal and slaughter fats.

Per capita meat consumption by type, World, 1961 to 2020

Per capita meat consumption is broken down by types of meat, and is measured in kilograms per person per year.

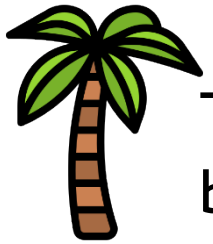


Source: Food and Agriculture Organization of the United Nations
OurWorldInData.org/meat-production • CC BY
Note: Data does not include fish and seafood. Figures do not correct for waste at the consumption level so may not directly reflect the quantity of food finally consumed by a given individual.



Production ⇑

Consumption ⇑



Tropical area breedin

What are the mechanisms behind heat stress adaptation in pigs ?

Climate change
- Mean T°C ⇑
- Frequency and intensity of heat waves ⇑

HS

Direct effects

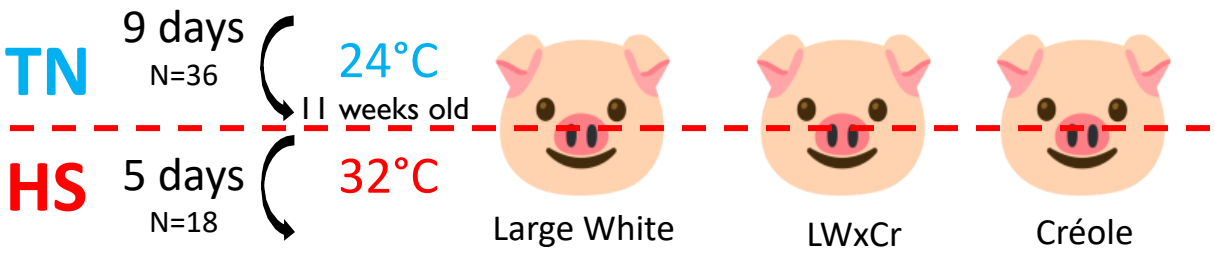
siological orders ive stress, ect..)

Well-being ⇘

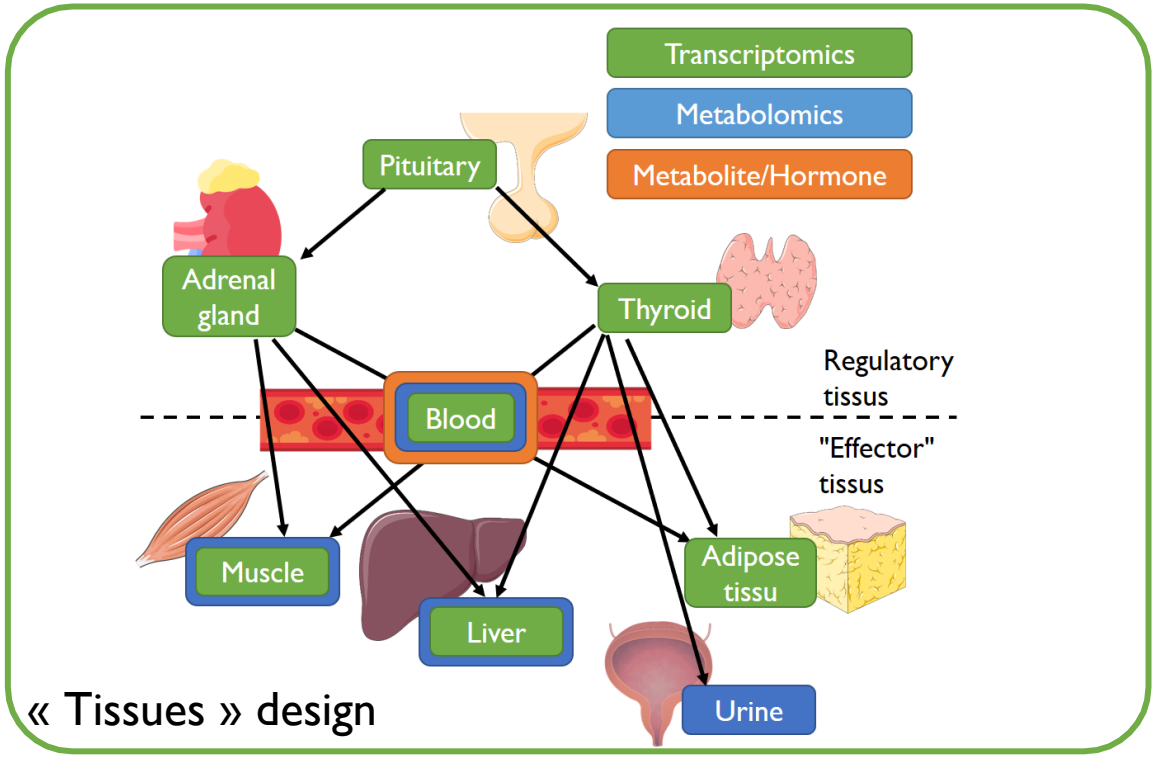
⇘ Performance (meat)

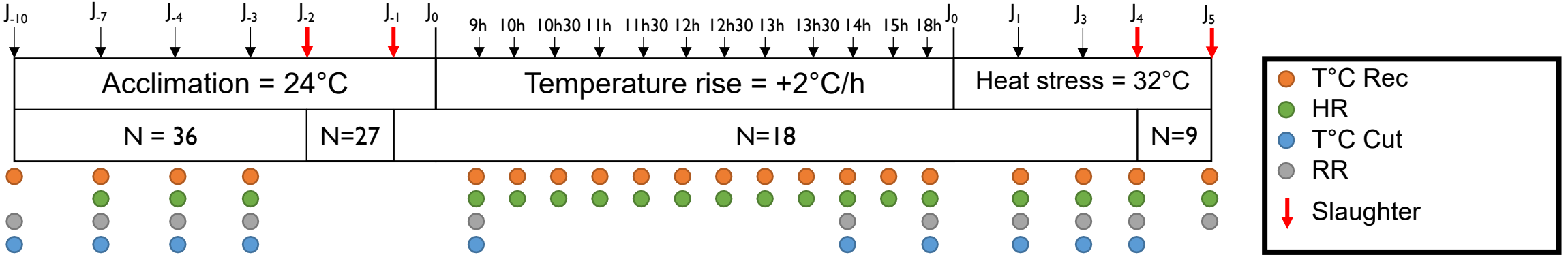
Economic losses
e.g. : yearly cost for US industry = $ 2.4 billion (St Pierre et al, 2003)

Multi-tissues and multi-omics design

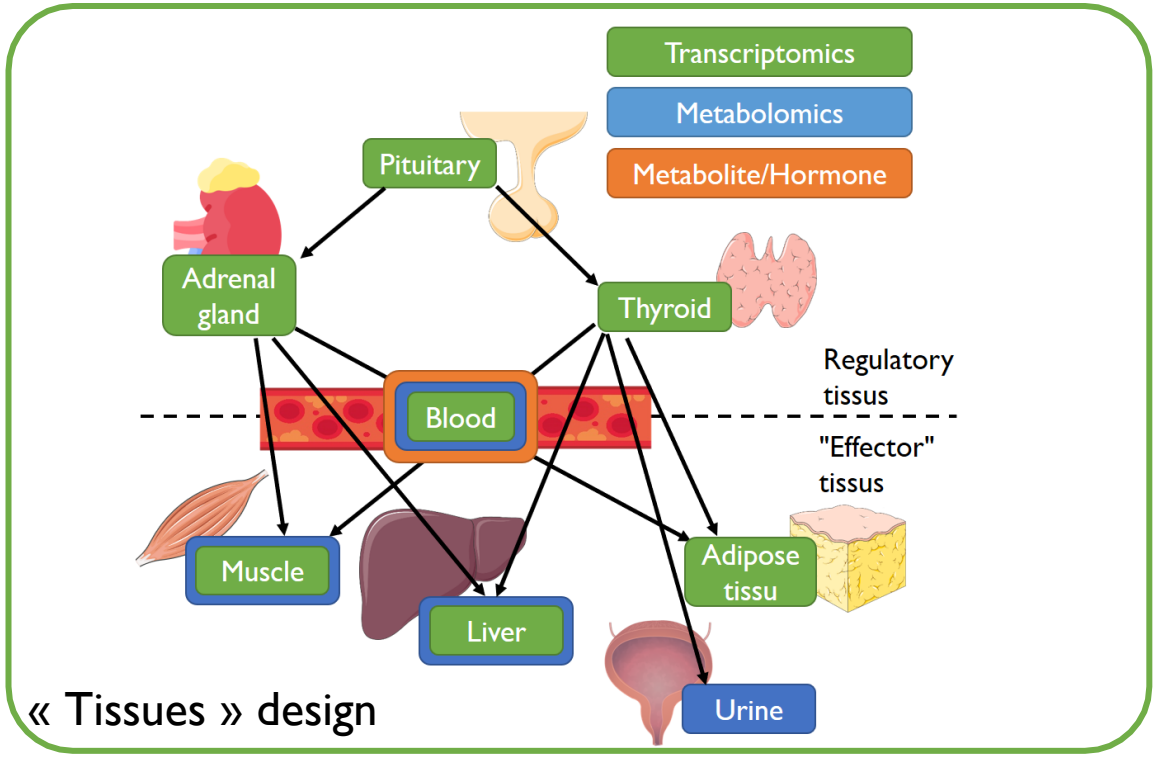


- Animal sacrifice before (TN) and after (HS) the start of the challenge
- *Ad libitum* water and feeding with a commercial animal feed





Multi-tissues and multi-omics design

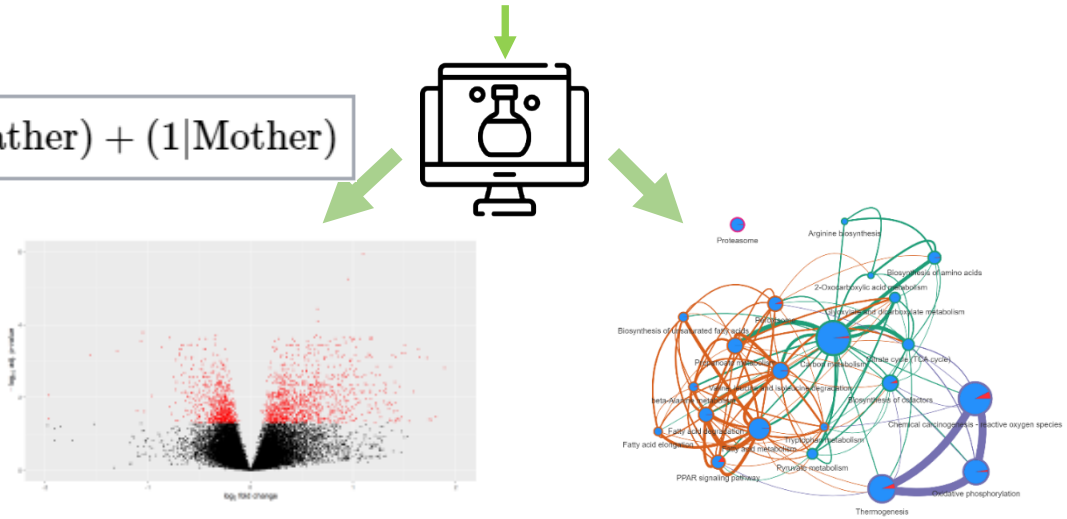


« Tissues » design

Multi-tissues	Multi-omics
Blood	Transcriptome
Liver	Metabolome
Muscle	Blood metabolites
SCAT	Hormones
Thyroid glands	Response variables to heat stress
Pituitary anterior glands	
Adrenal glands	
Urine	

$$y = 0 + Race + Temp + (1|loge : (Temp : Race)) + (1|abatt : Temp) + (1|Father) + (1|Mother)$$

Linear mixed model



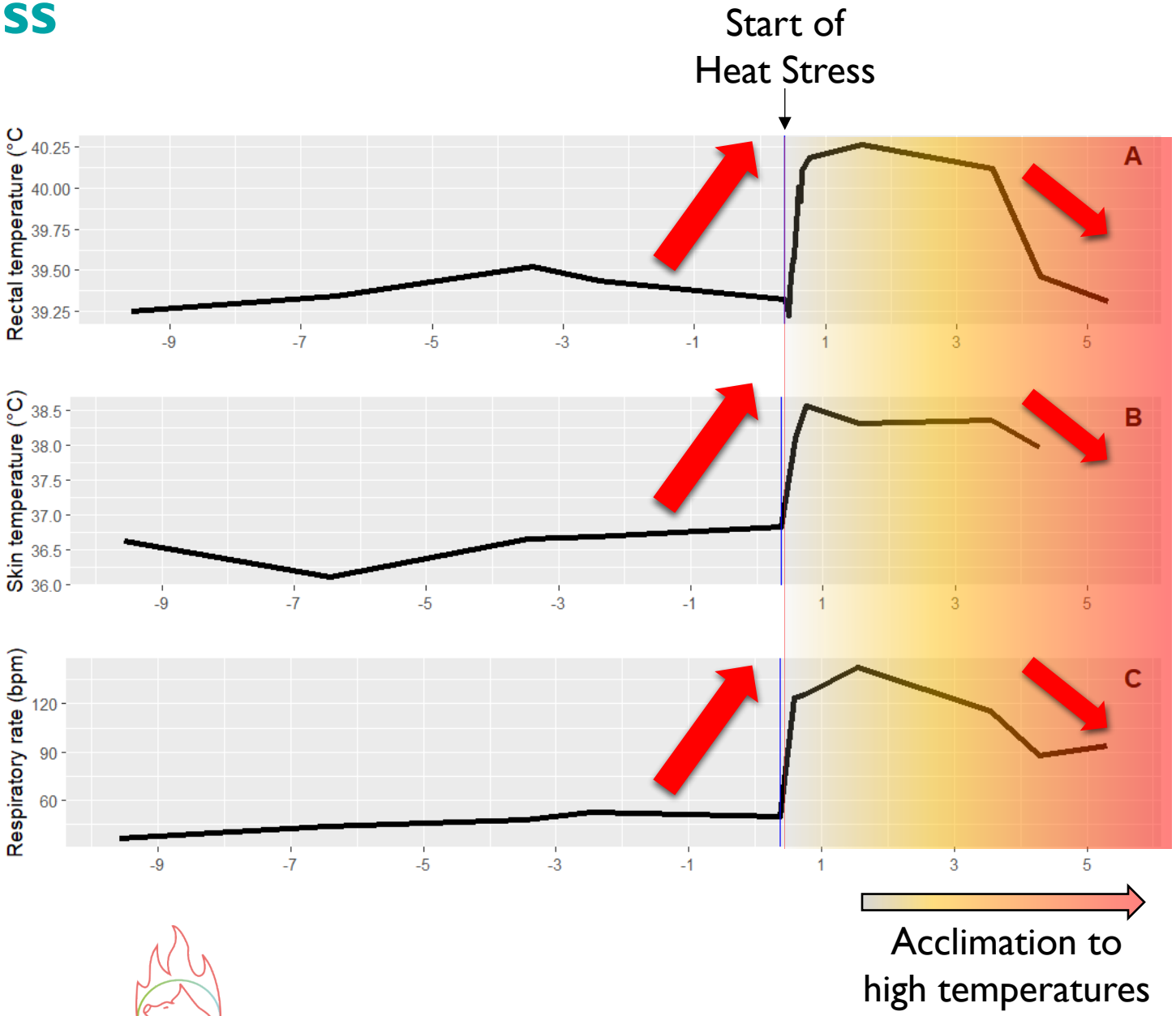
Response to heat stress

- Study of the acclimation phase (j_{+5})

- Bi-modal reaction to heat stress
  - Increase in RT, ST, RR
  - Then smaller decrease

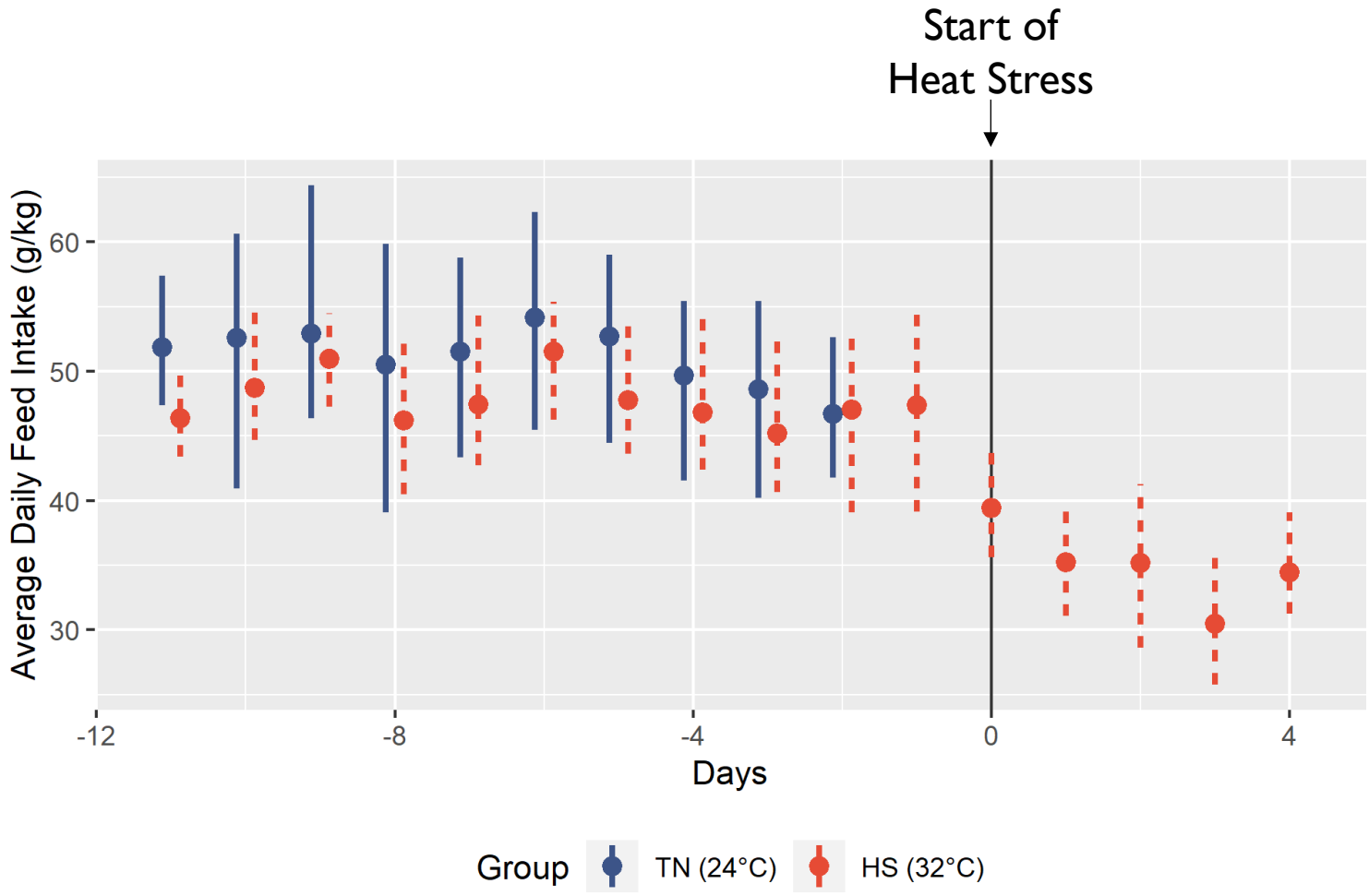
⇩

Acclimation

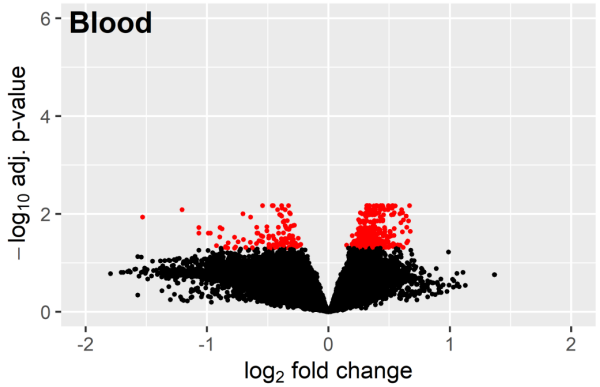


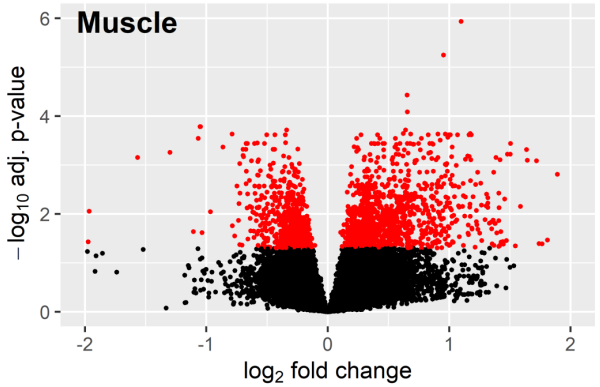
Response to heat stress

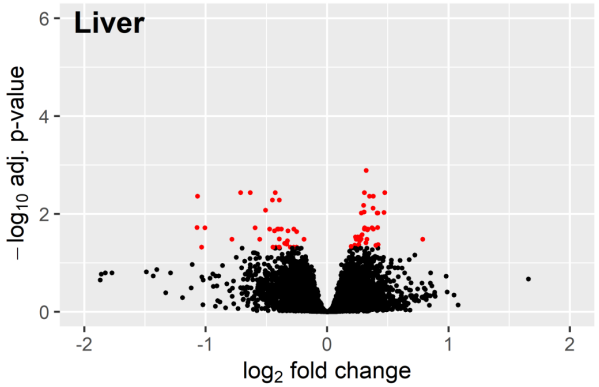
- Study of the acclimation phase (j_{+5})
- Bi-modal reaction to heat stress
  - Increase in RT, ST, RR
  - Then smaller decrease
- Average Daily Feed Intake decrease
  - 1560 vs. 1707 g/d; p<0.01
  - -18.4 g.°C^{-1}.d^{-1}

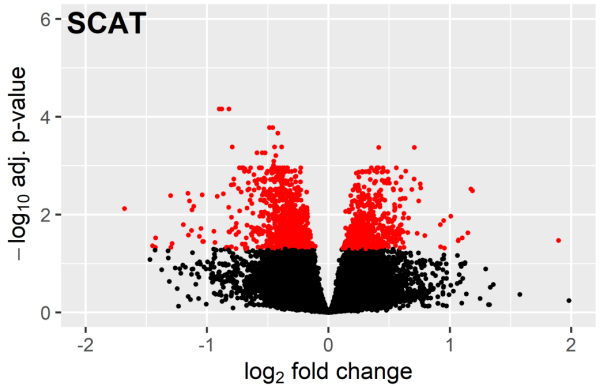


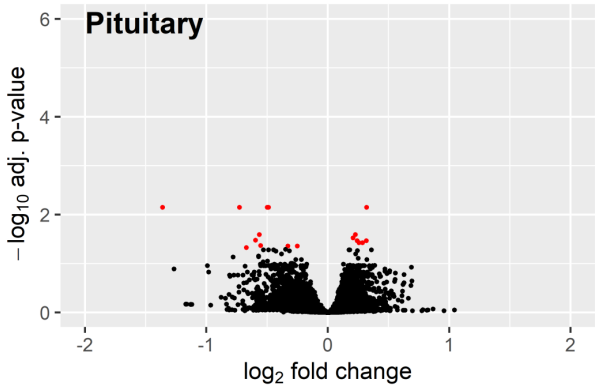
Identification of Differentially Expressed Genes

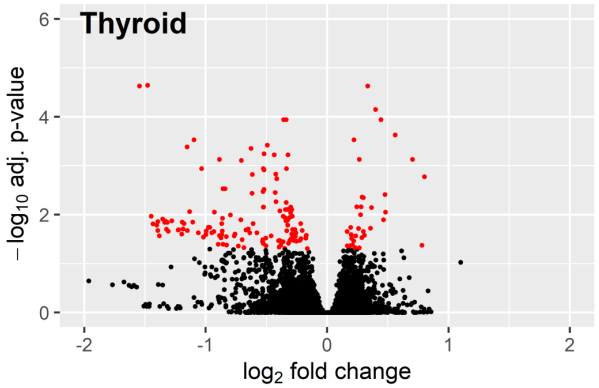


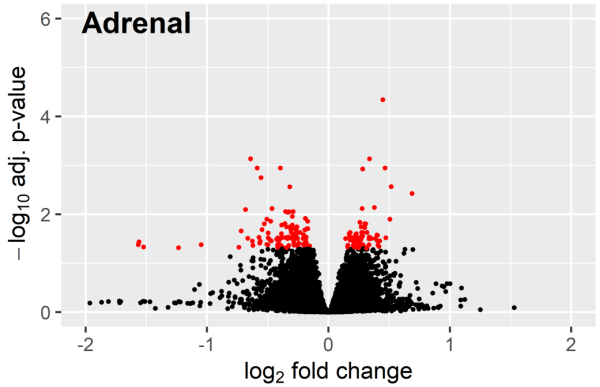








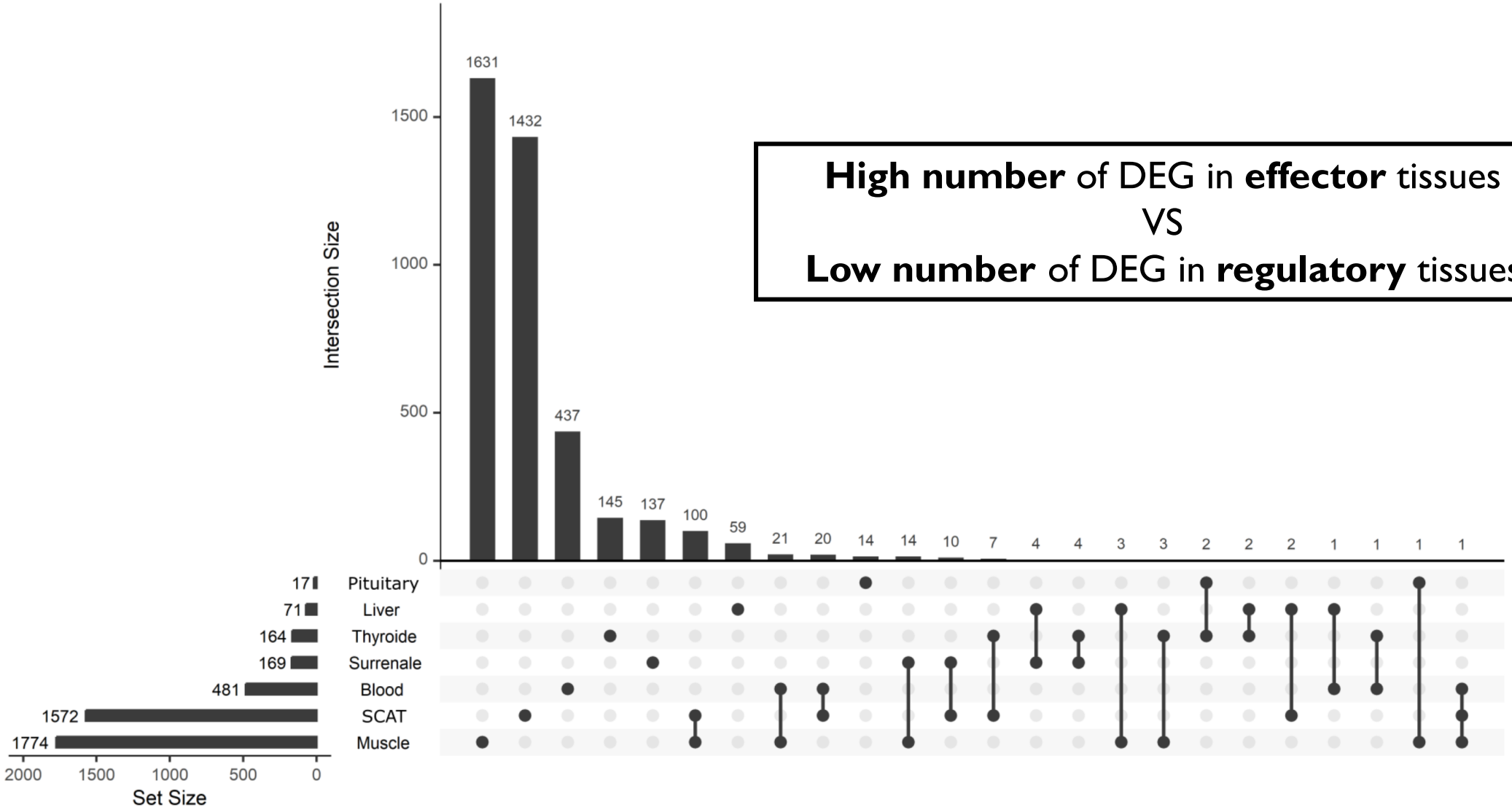




Using a linear mixed model with R packages *limma* and *variancePartition*

$$y = 0 + \text{Race} + \text{Temp} + (1|\text{loge} : (\text{Temp} : \text{Race})) + (1|\text{abatt} : \text{Temp}) + (1|\text{Father}) + (1|\text{Mother})$$

Identification of Differentially Expressed Genes

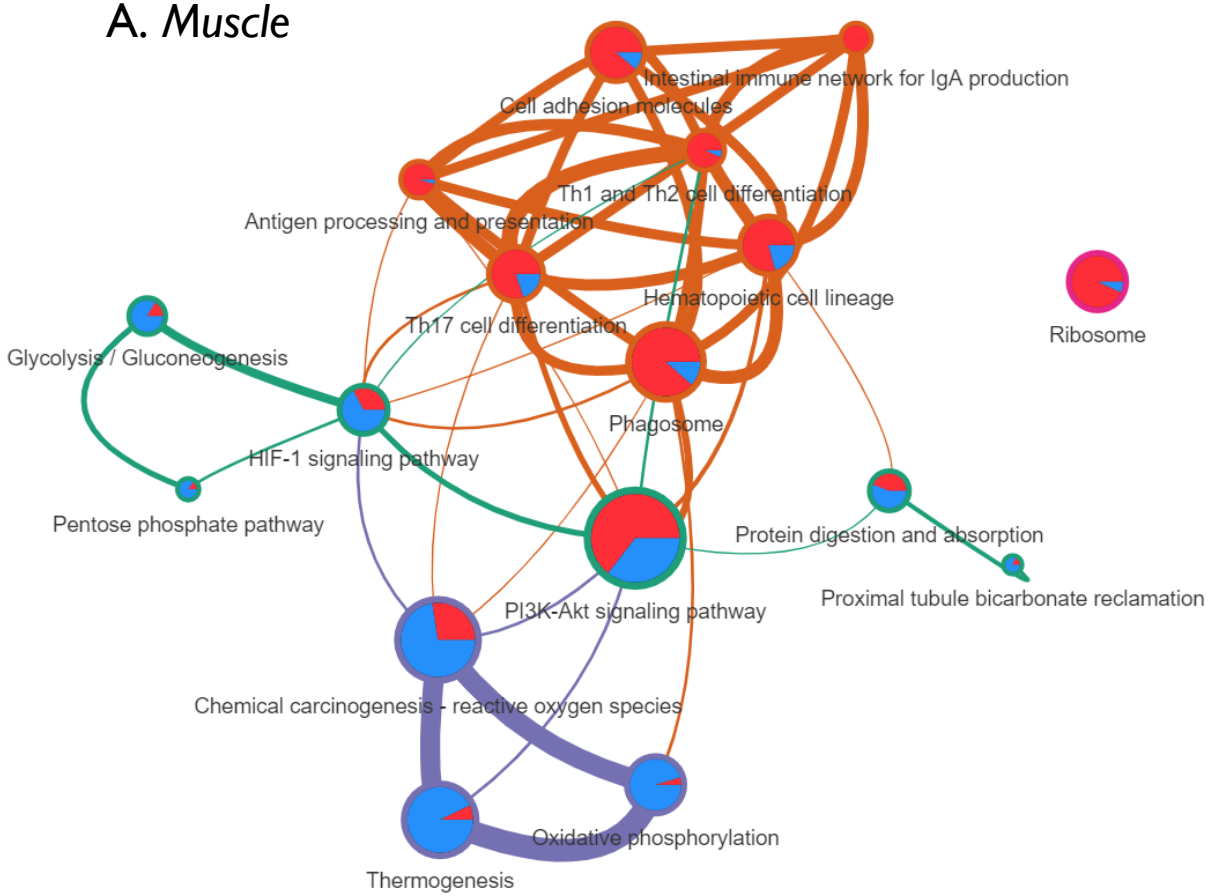


High number of DEG in **effector** tissues
VS
Low number of DEG in **regulatory** tissues

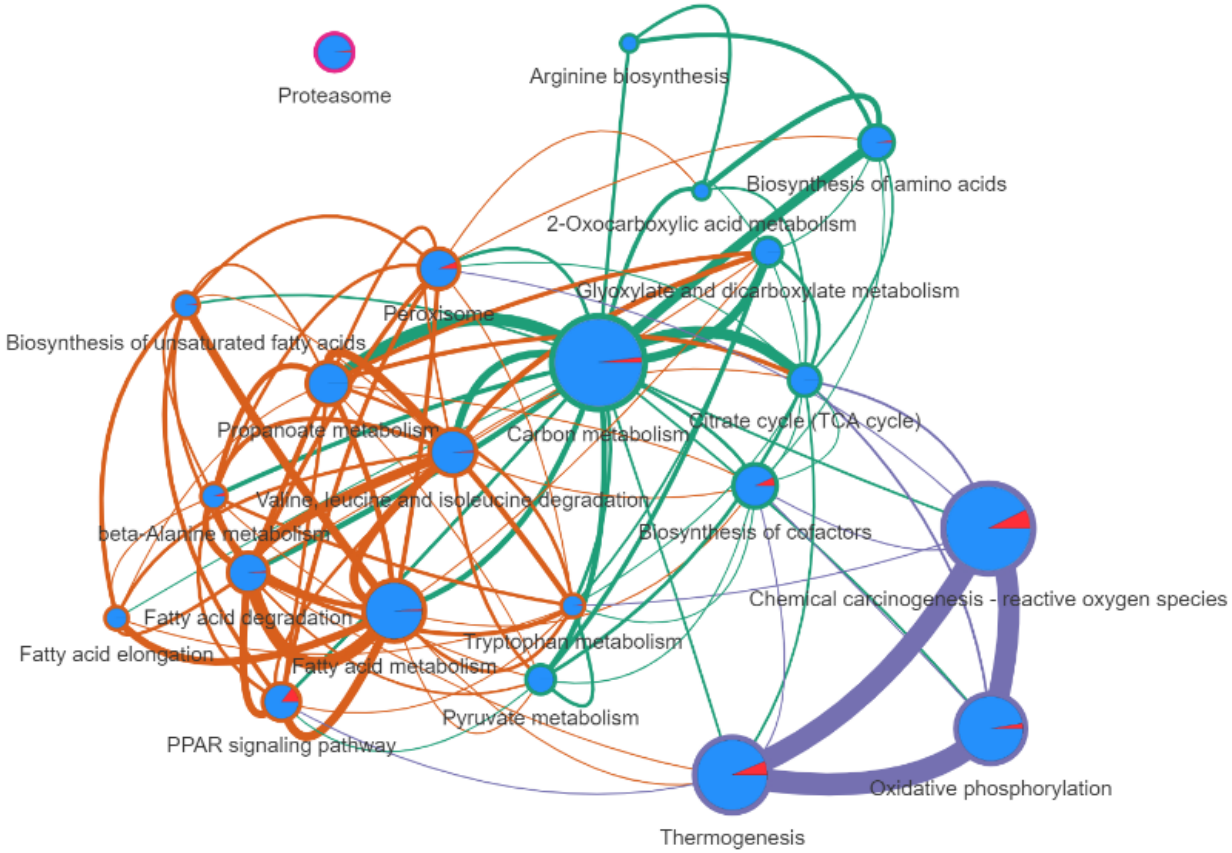
Enrichment analysis of pathways

Visualisation with KEGG database
Analysis with KEGG, GO:BP, and REACTOME database

A. *Muscle*



B. *Sub-cutaneous adipose tissue*



Enrichment analysis of pathways

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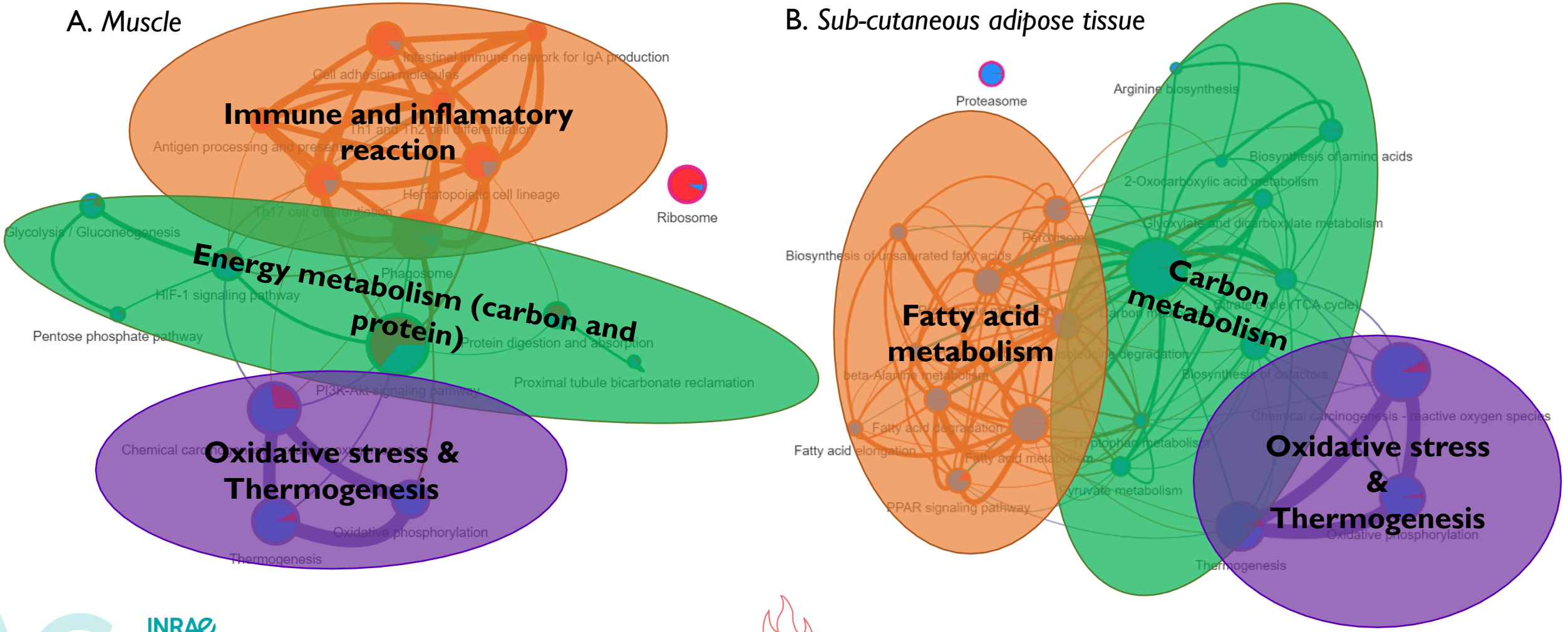
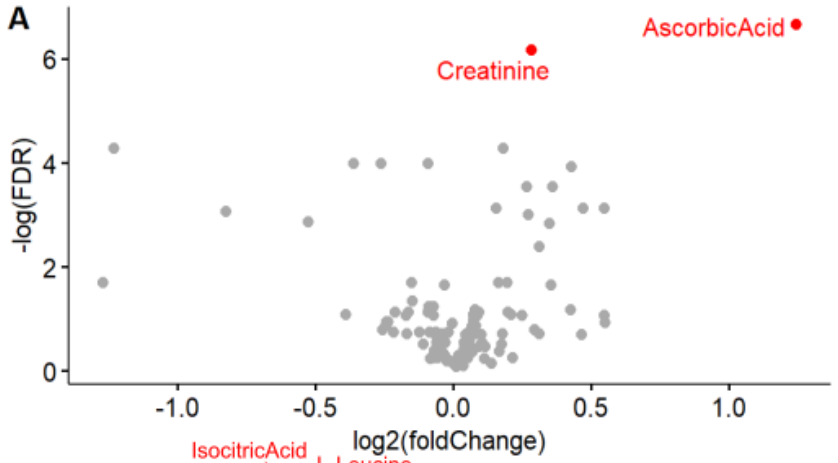
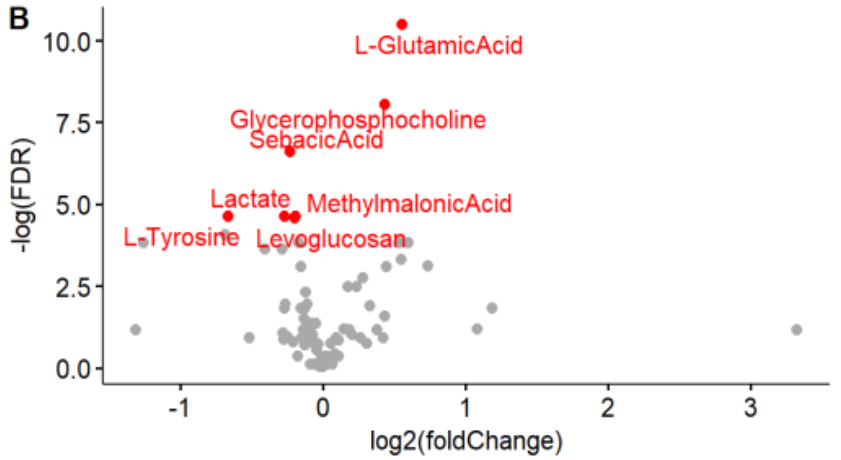


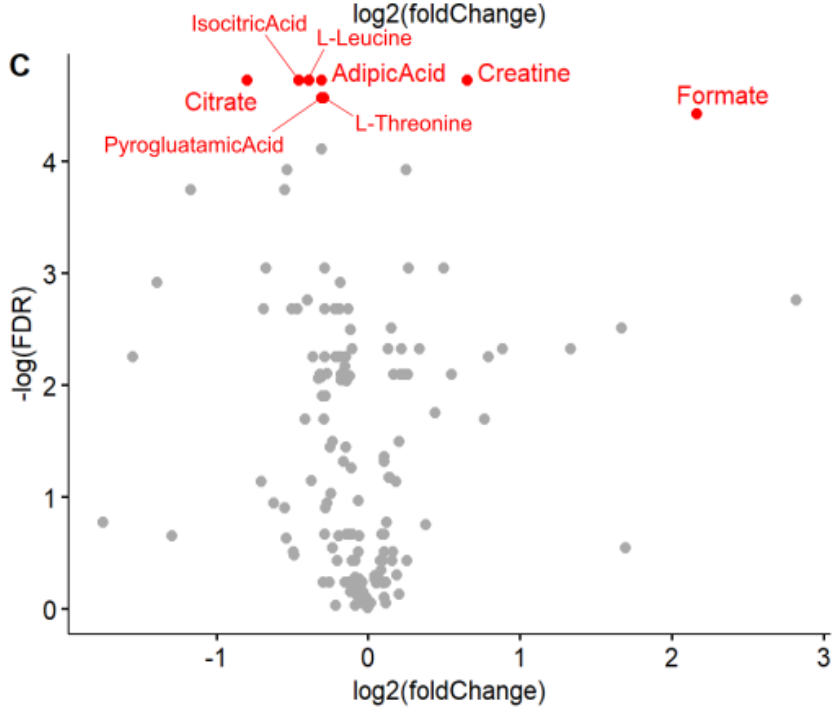
Identification of Differentially Produced Metabolites

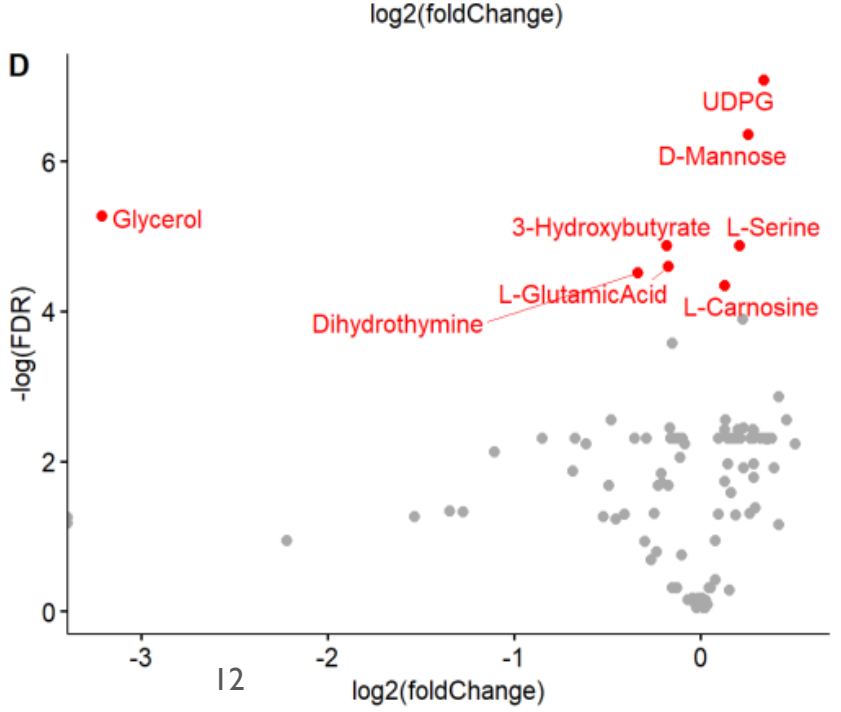
Plasma





Muscle





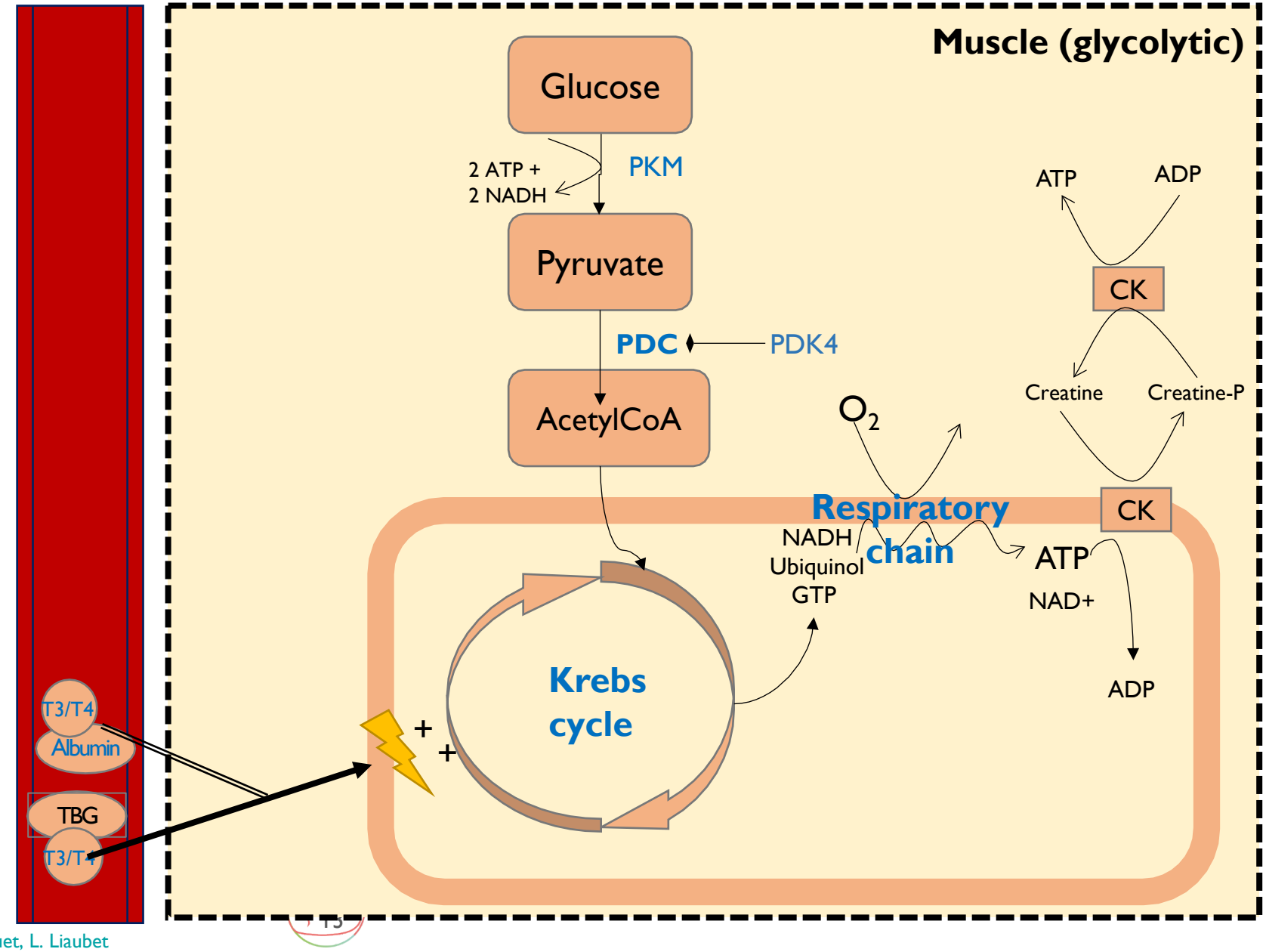
Urine

Liver

Automatic identification and quantification of 1H-NMR spectra with ASICS procedure

Effect of heat stress on muscle metabolism

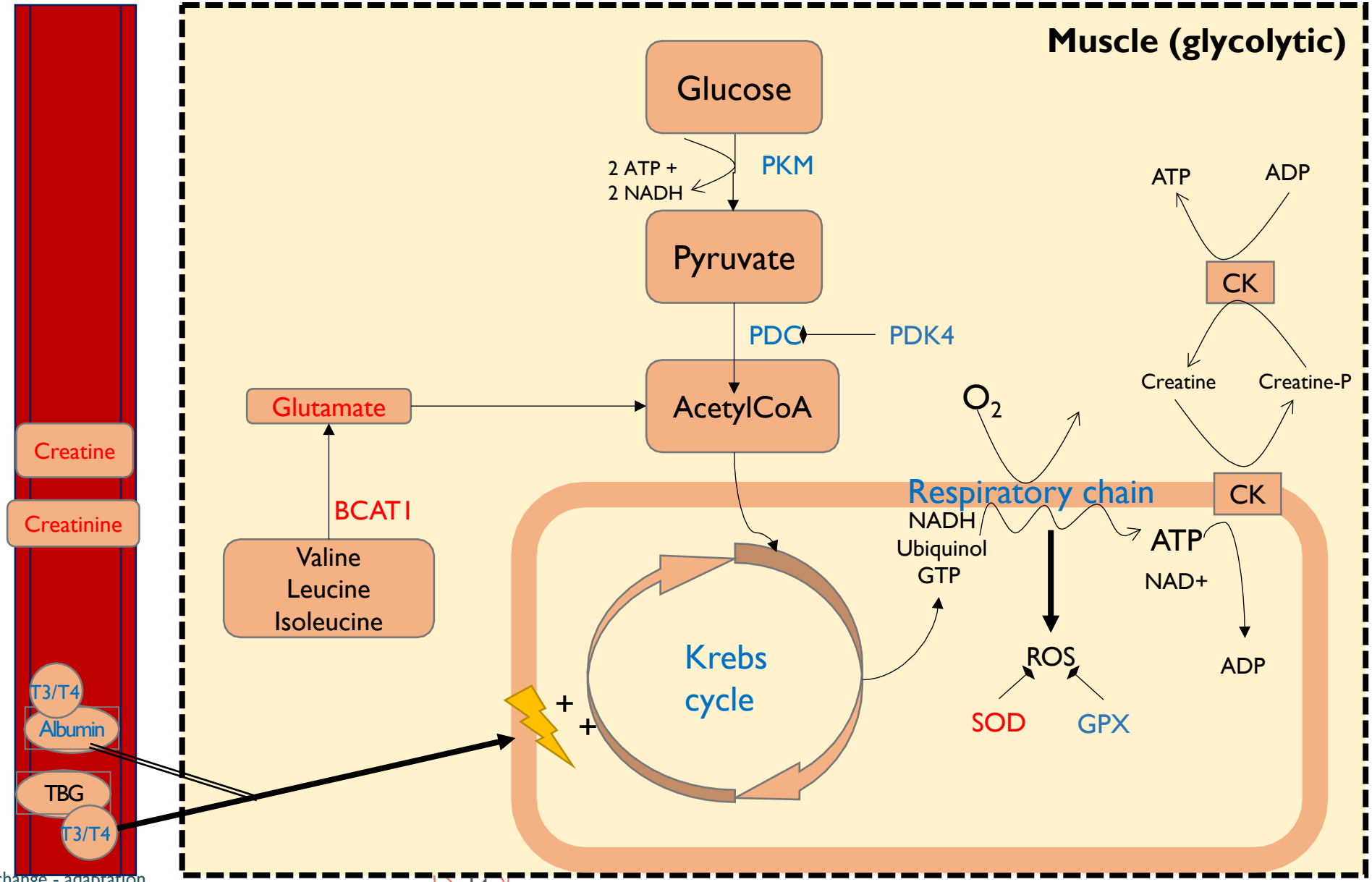
Global decrease of energy metabolism linked with the thyroid hormone decrease

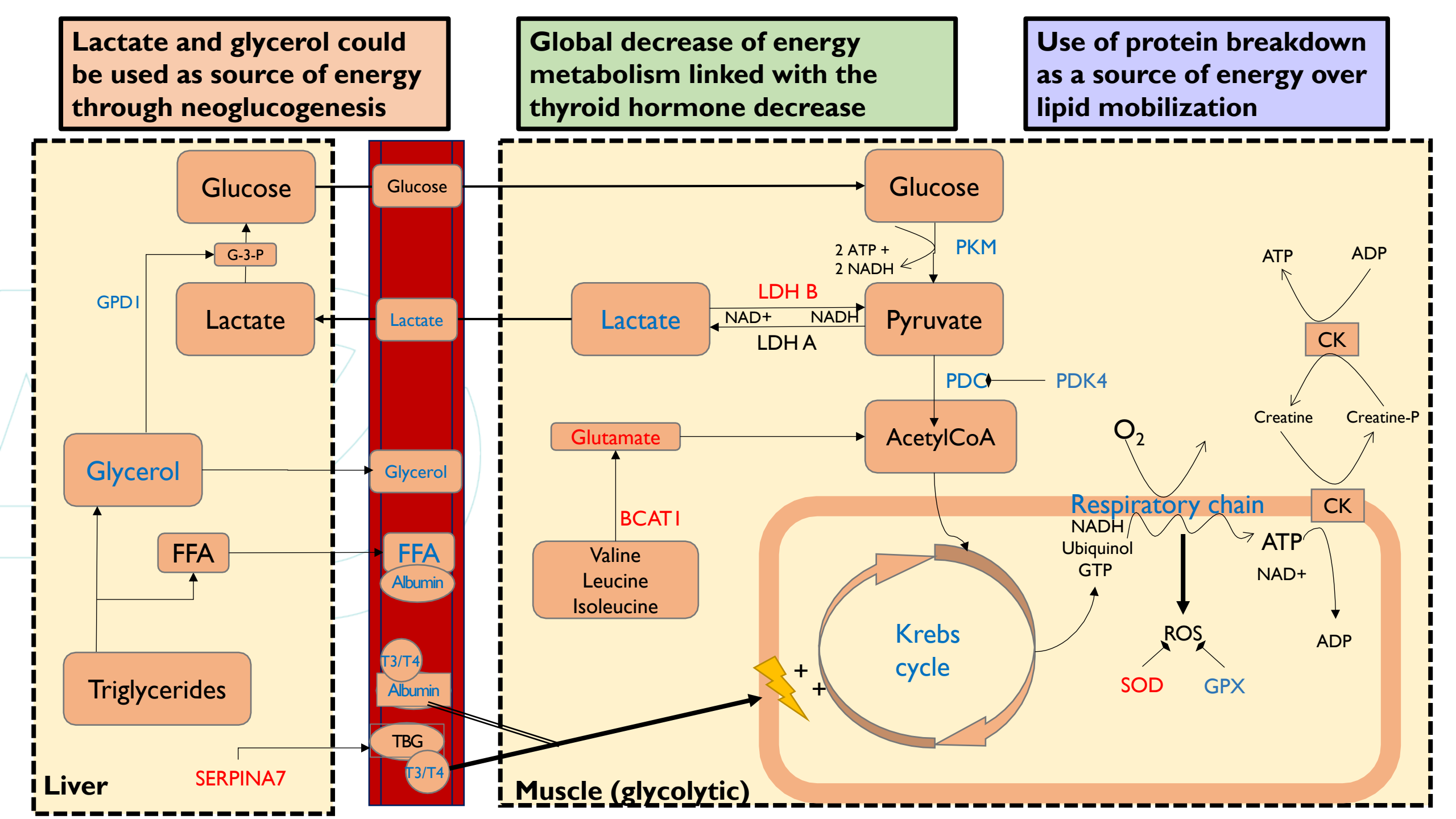


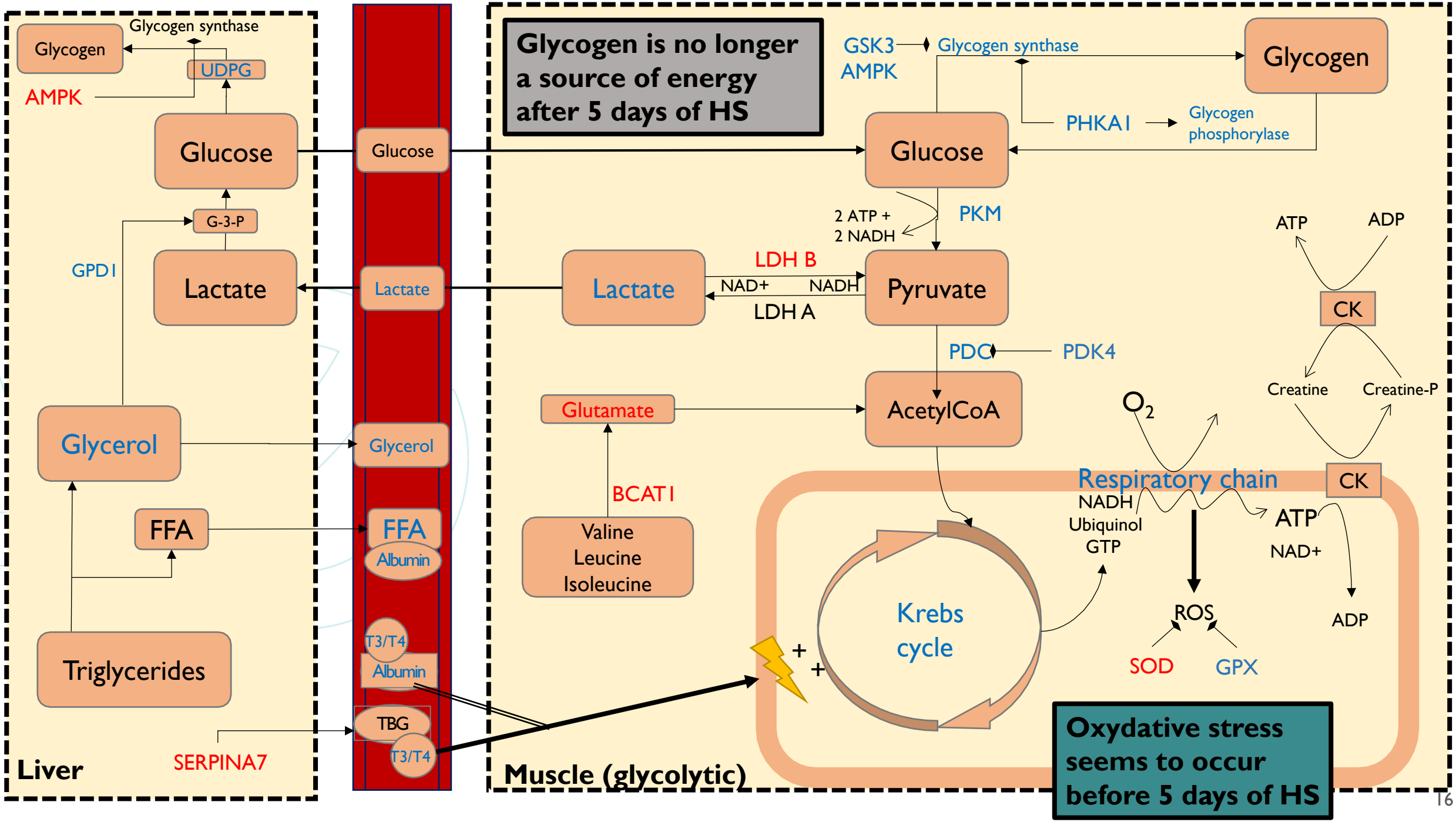
Effect of heat stress on muscle metabolism

Global decrease of energy metabolism linked with the thyroid hormone decrease

Use of protein breakdown as a source of energy over lipid mobilization




Lactate and glycerol could be used as source of energy through neoglucogenesis
Global decrease of energy metabolism linked with the thyroid hormone decrease
Use of protein breakdown as a source of energy over lipid mobilization
Glucose
G-3-P
GPD1
Lactate
Glycerol
FFA
Triglycerides
Liver
SERPINA7
Glucose
Lactate
Glycerol
FFA
Albumin
T3/T4
Albumin
TBG
T3/T4
Glucose
2 ATP +
2 NADH
PKM
LDH B
NAD+
NADH
LDH A
Lactate
Pyruvate
PDC
PDK4
AcetylCoA
Glutamate
BCAT1
Valine
Leucine
Isoleucine
Krebs cycle
+
+
Respiratory chain
NADH
Ubiquinol
GTP
ROS
SOD
GPX
ATP
NAD+
ADP
ATP
ADP
CK
Creatine
Creatine-P
CK
O2
Muscle (glycolytic)

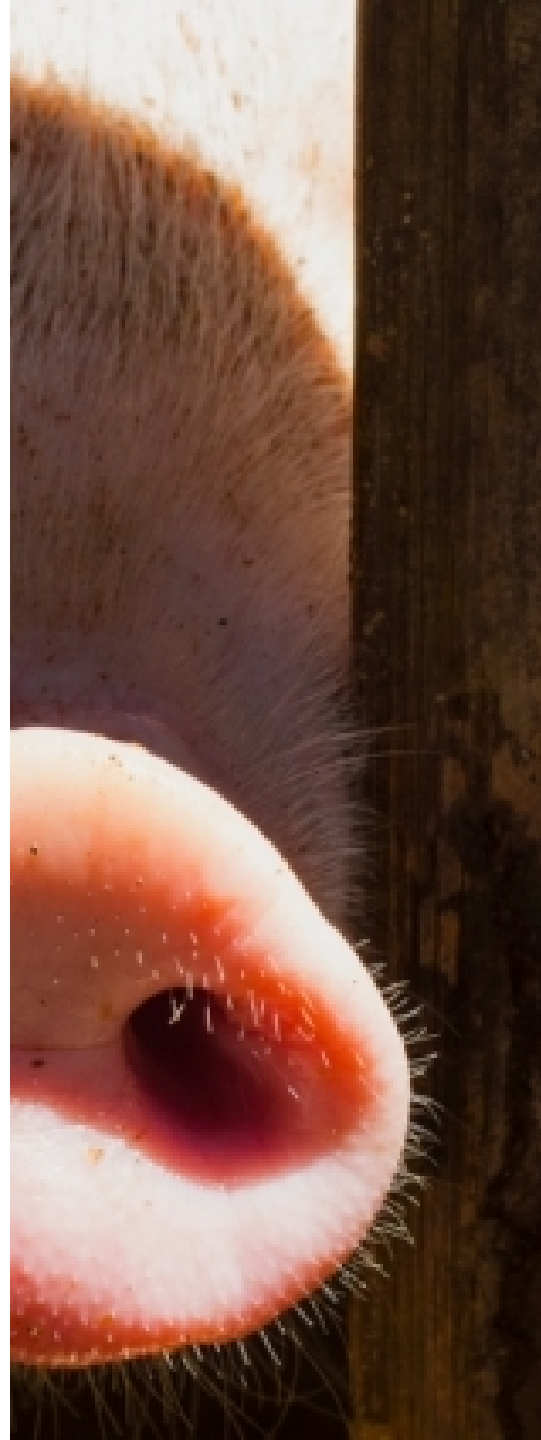

Glycogen
Glycogen synthase
UDPG
AMPK
Glucose
G-3-P
GPD1
Lactate
Glycerol
FFA
Triglycerides
Liver
SERPINA7
Glucose
Lactate
Glycerol
FFA
Albumin
T3/T4
Albumin
TBG
T3/T4
Glycogen is no longer a source of energy after 5 days of HS
GSK3
AMPK
Glycogen synthase
Glycogen
PHKA1
Glycogen phosphorylase
Glucose
2 ATP +
2 NADH
PKM
LDH B
NAD+
NADH
LDH A
Lactate
Pyruvate
PDC
PDK4
AcetylCoA
Glutamate
BCAT1
Valine
Leucine
Isoleucine
ATP
ADP
CK
Creatine
Creatine-P
CK
O2
Respiratory chain
NADH
Ubiquinol
GTP
ATP
NAD+
ADP
ROS
SOD
GPX
Krebs cycle
+
+
Muscle (glycolytic)
Oxydative stress seems to occur before 5 days of HS

Take-away ideas

- After 4 to 5 days of HS, acclimation starts to take place and still coexists with mechanisms from the acute phase of HS.
- Direct and indirect effects of HS affect pigs tissues in specific ways and can even counter-balance each others
- Few DEG in regulatory tissues and higher number of DEG in muscle and SCAT
- Different sources are used as cellular fuel with a reduced metabolism: for the muscle, protein catabolism and carbohydrates acquired through neoglucogenesis seems to be favorited over lipids
- Oxidative stress seems to take place before 5 days of heat stress for pigs

Prospects

- Continuation of better understanding of the inter-tissue communication during HS
- Evaluation of the breed effects
- Understanding other sides of the heat stress adaptation mechanisms of pigs
    - Differences of the acclimation mechanisms to heat stress between acute phase and acclimation phase, but also between heat-wave and tropical heat stress
- Identification of biomarkers for sensibility to heat stress



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Thanks for your attention ! 🐷

Any questions ? 🐷