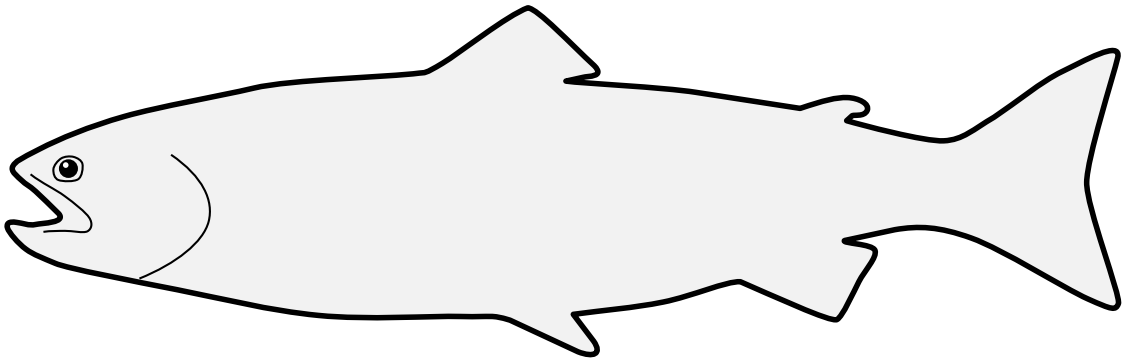
U N I V E R S I T Y O F B E R G E N

Department of Biological Sciences

To Feed or not to Feed

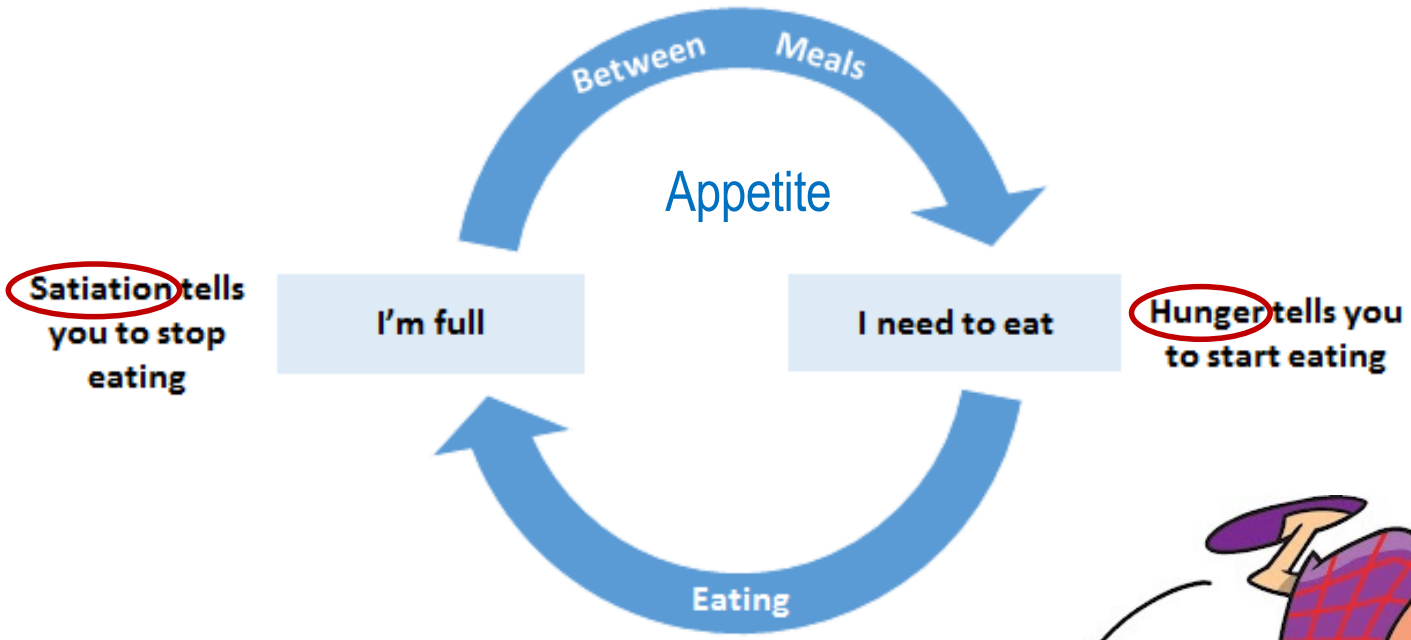
- that is my question



Ivar Rønnestad, Prof in Fish Physiology

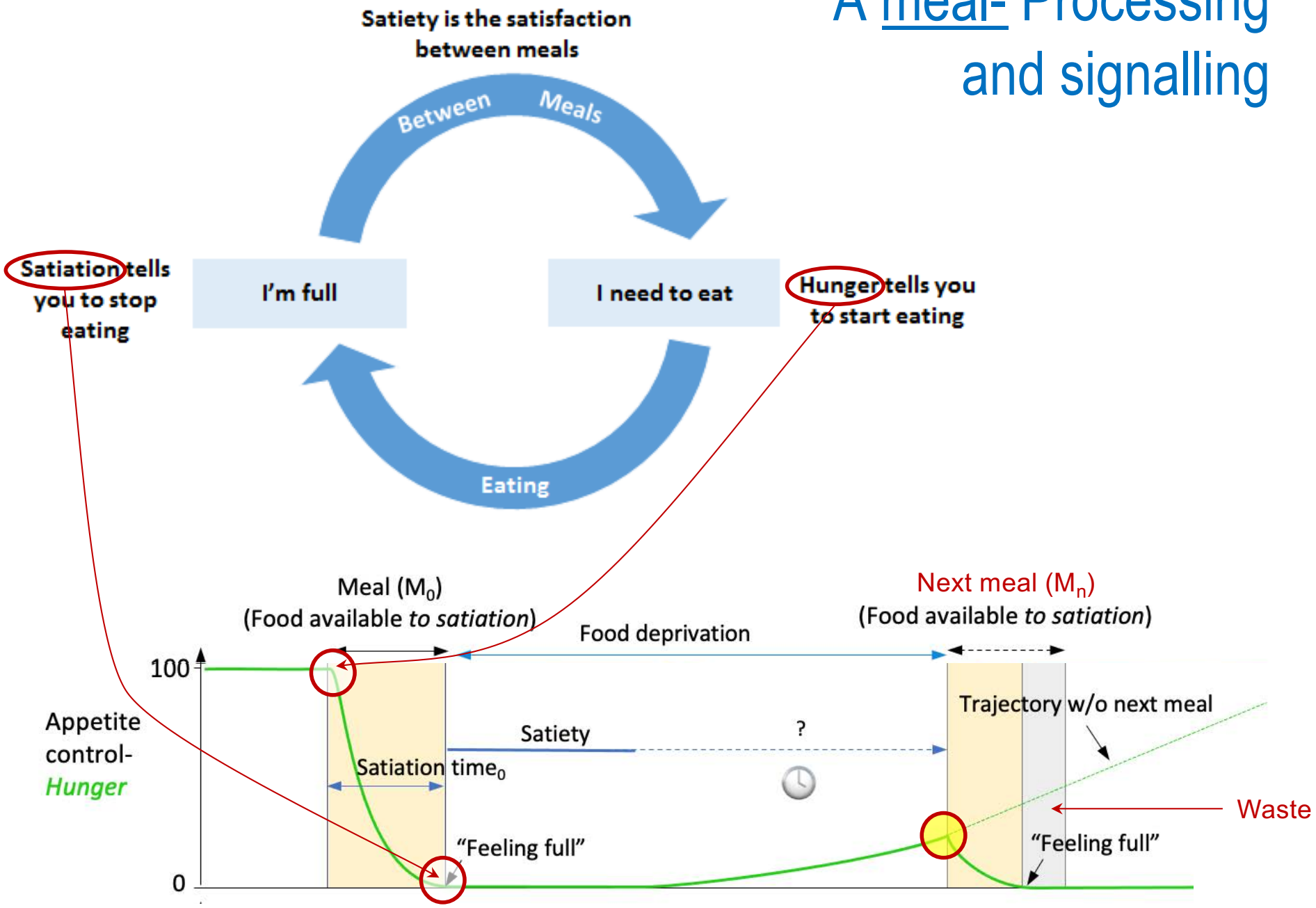
"What it is to be a salmon" workshop, Bergen 18.11.2022

Satiety is the satisfaction between meals

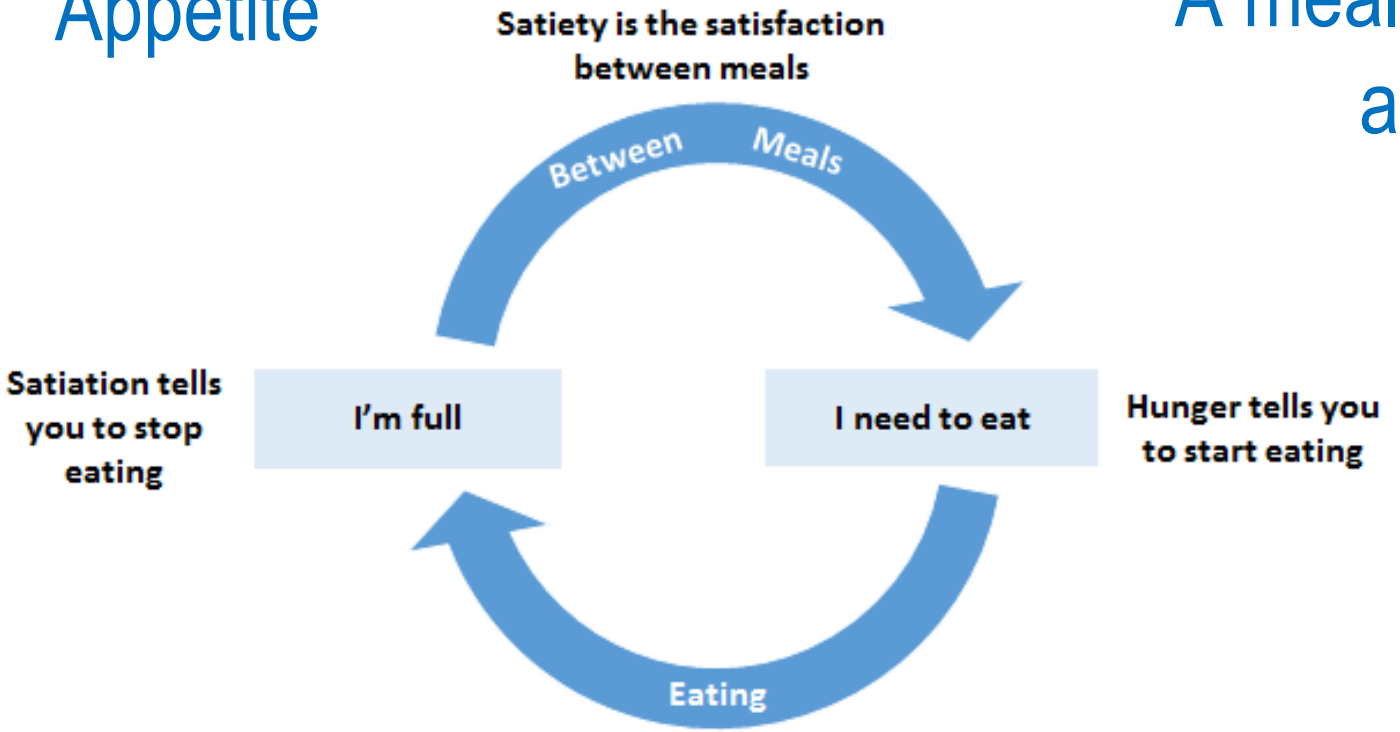


Aim: to model the initiation, continuation and cessation of meals.
Which determinants are relevant to understand food intake (hrs & days)

A meal- Processing and signalling

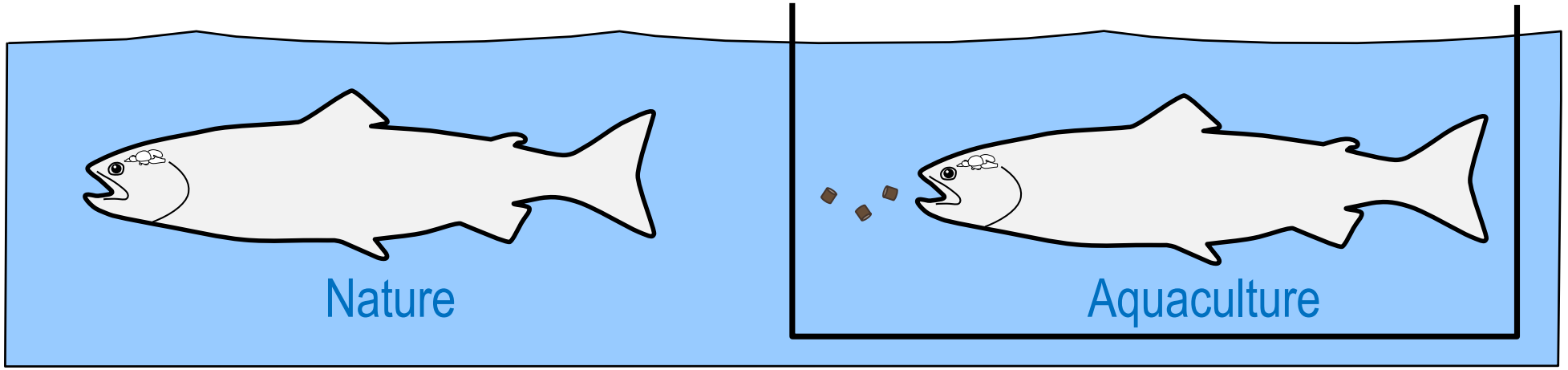


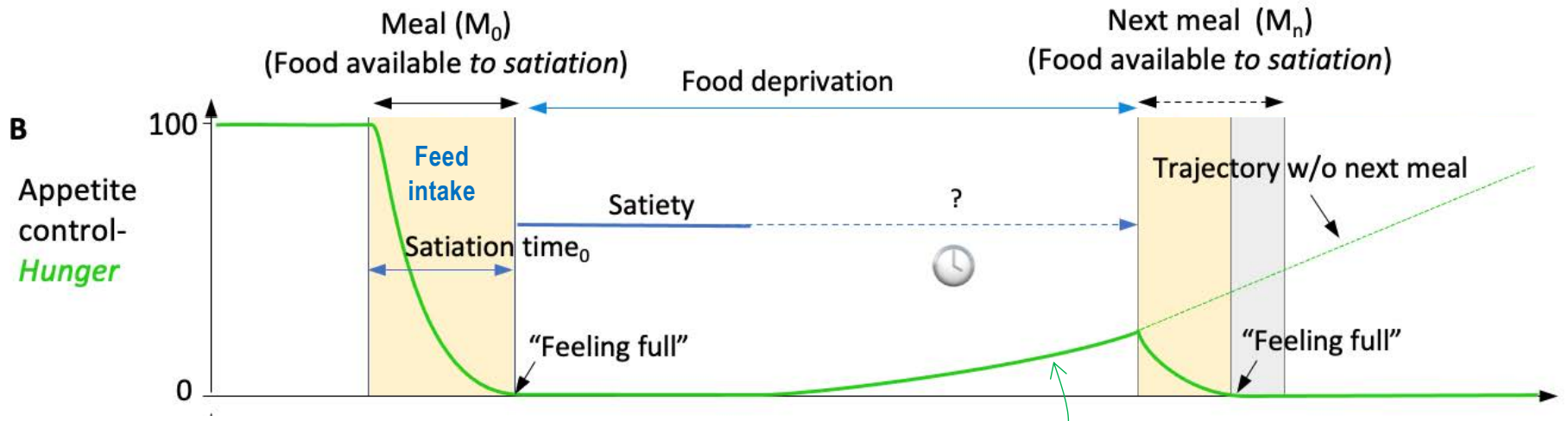
Appetite

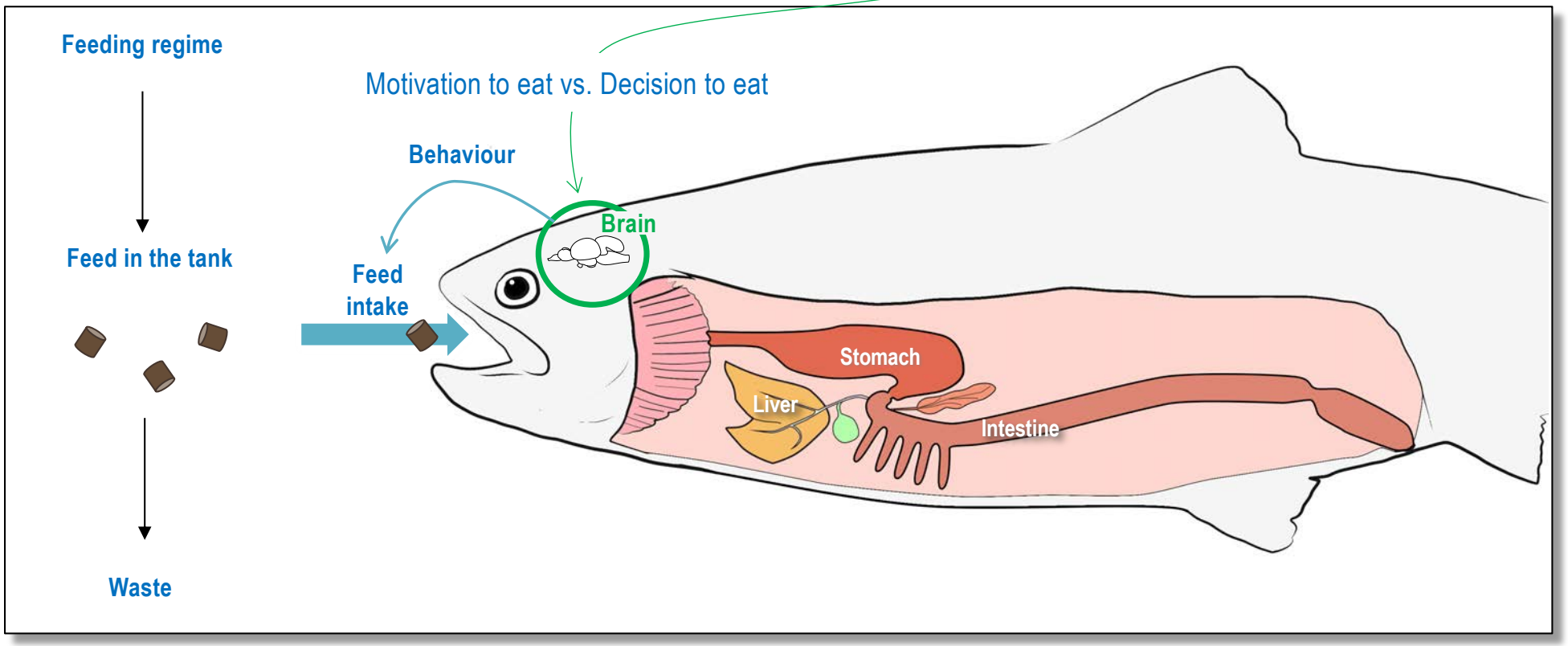


A meal- Processing and signalling

How is appetite and feed intake controlled in salmon?

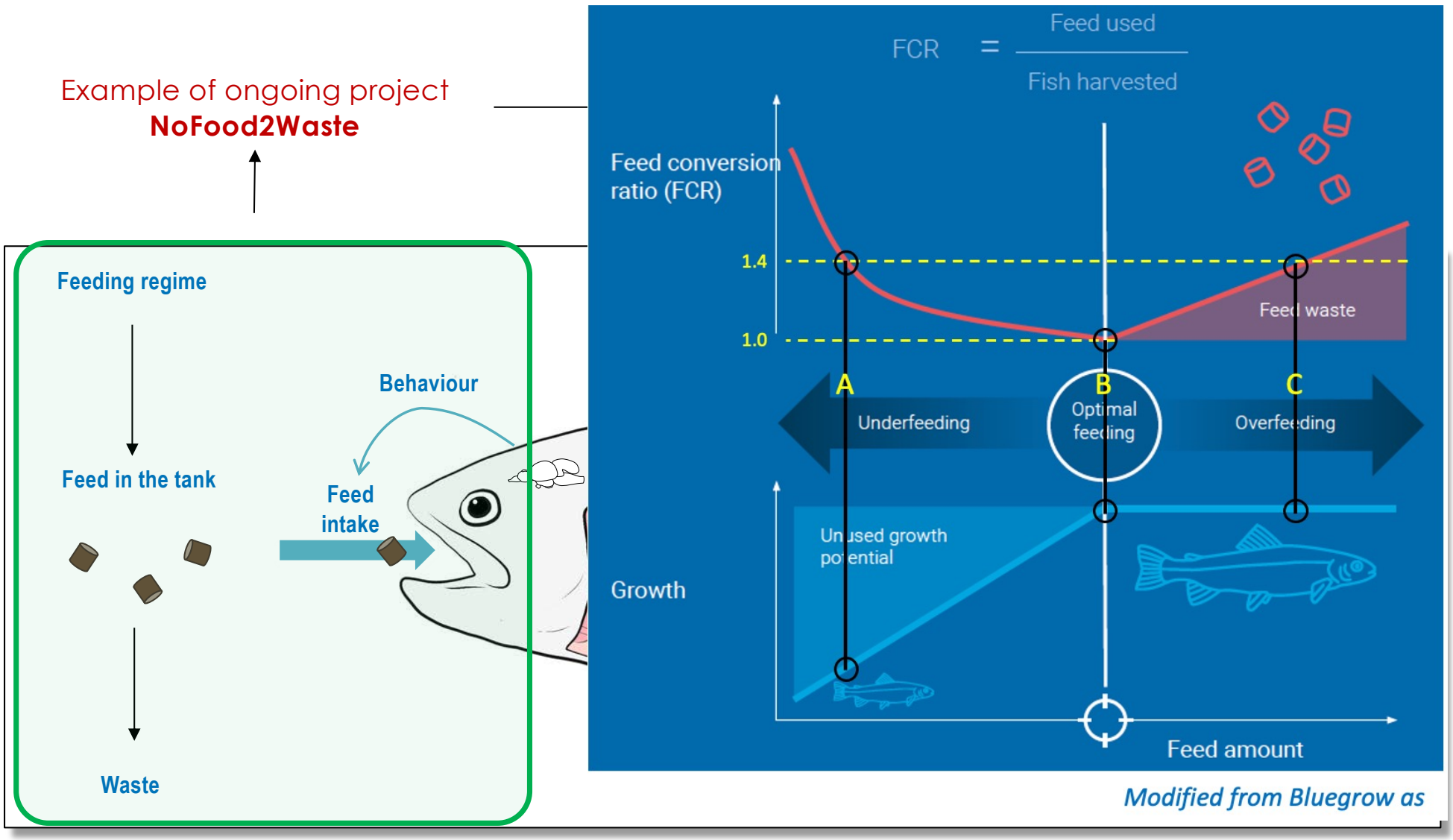



Meal (M_0)
(Food available *to satiation*)
Food deprivation
Next meal (M_n)
(Food available *to satiation*)
B
100
0
Appetite control-
Hunger
Feed intake
Satiation time$_0$
Satiety
?
Trajectory w/o next meal
"Feeling full"
"Feeling full"


Feeding regime
Feed in the tank
Waste
Motivation to eat vs. Decision to eat
Behaviour
Brain
Feed intake
Stomach
Liver
Intestine

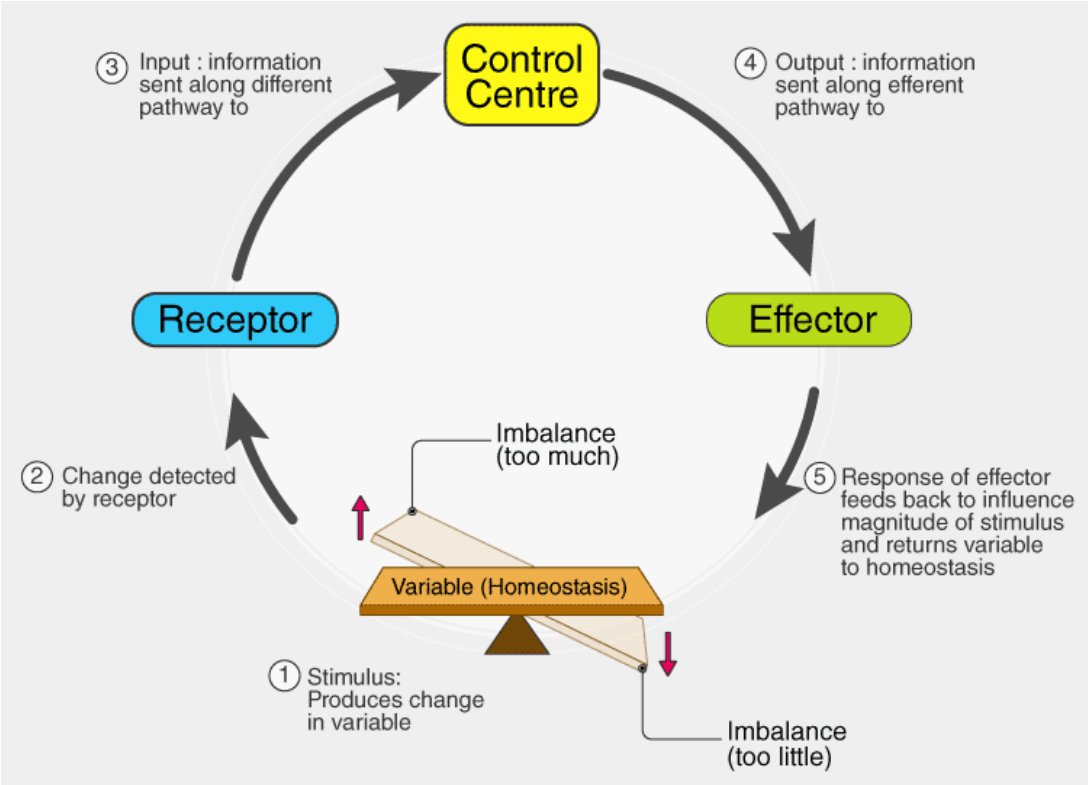
Appetite control- an applied approach

Example of ongoing project
NoFood2Waste

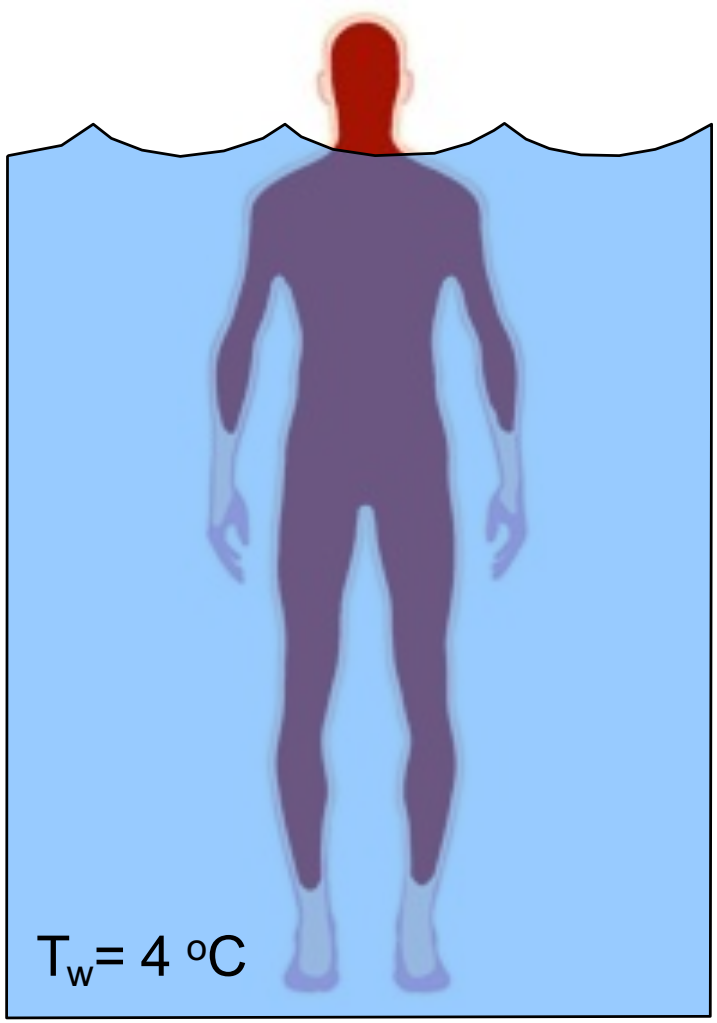


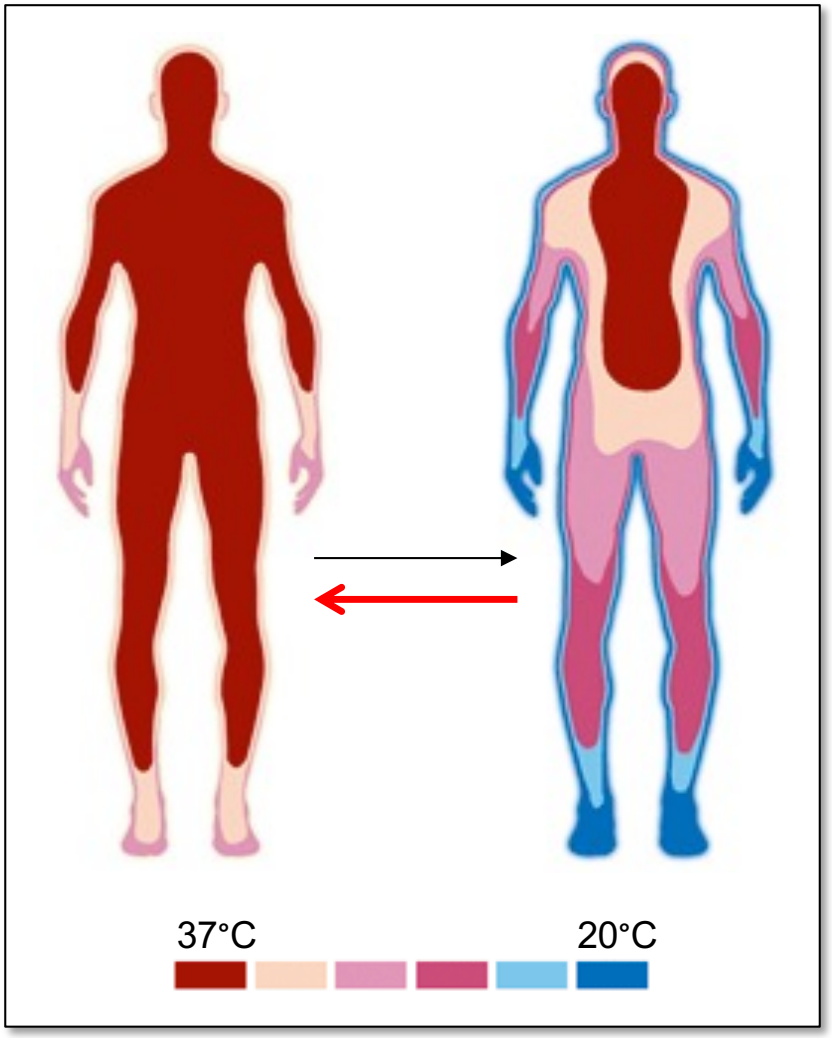
Physiological modelling- concept and design

- What is the design principle for modelling appetite?
- Is there a homeostatic regulation of a key variable that determine appetite and feed intake?

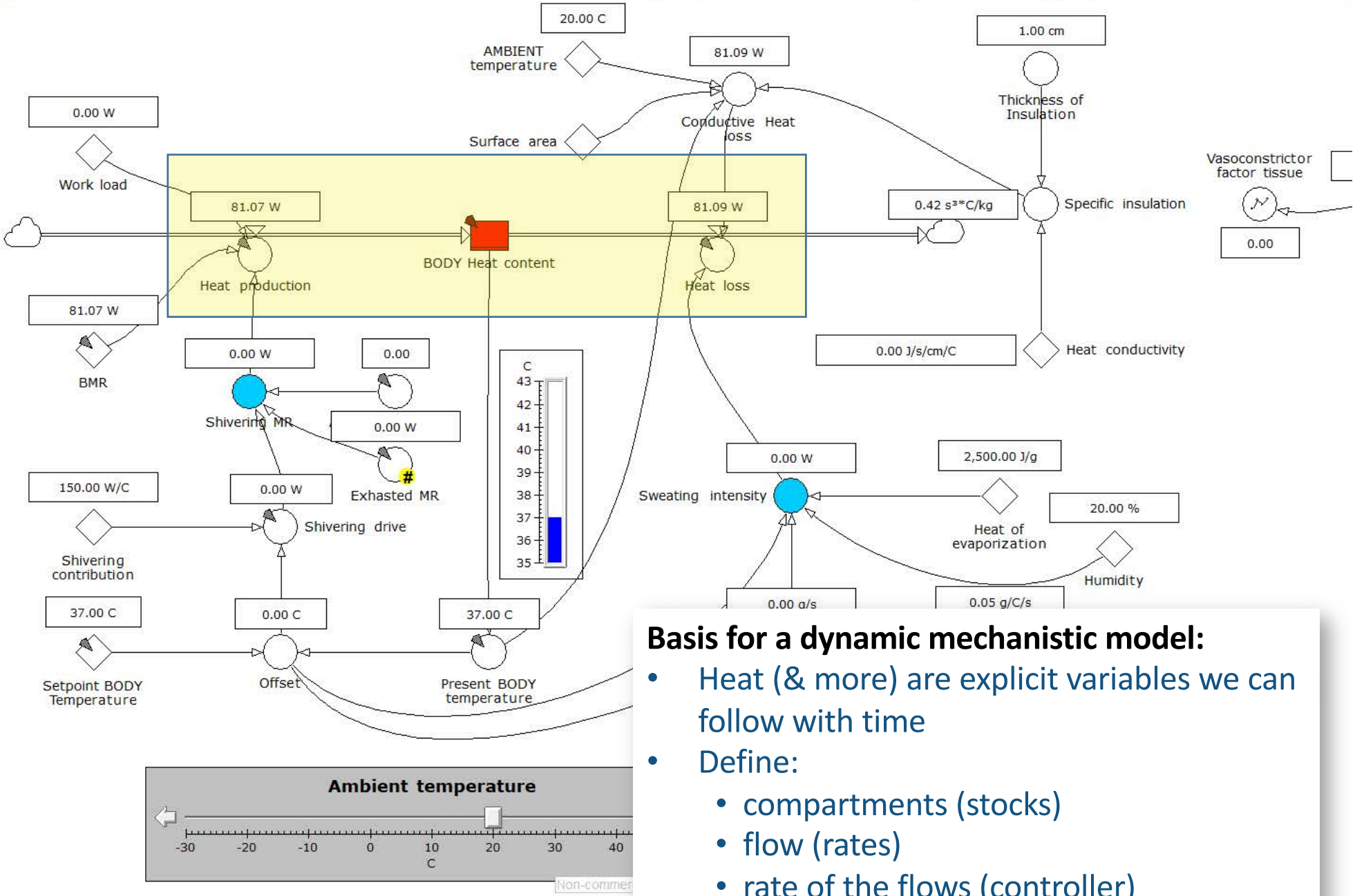


A classical homeostatic system w/ regulation based on a apparent set-point



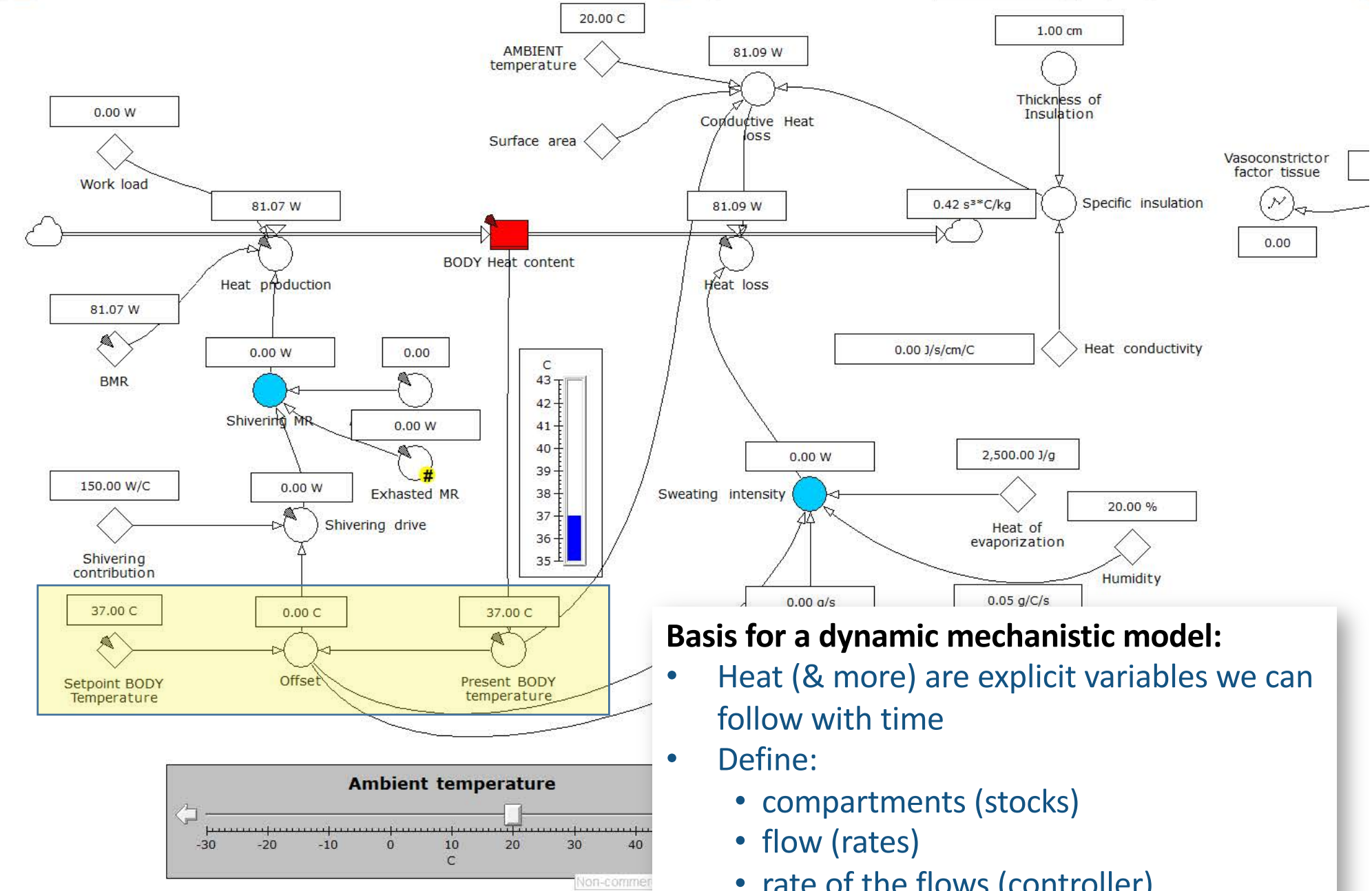


A dynamic self-adjusting system



Basis for a dynamic mechanistic model:

- Heat (& more) are explicit variables we can follow with time
- Define:
  - compartments (stocks)
  - flow (rates)
  - rate of the flows (controller)
  - feedback systems
  - initial states



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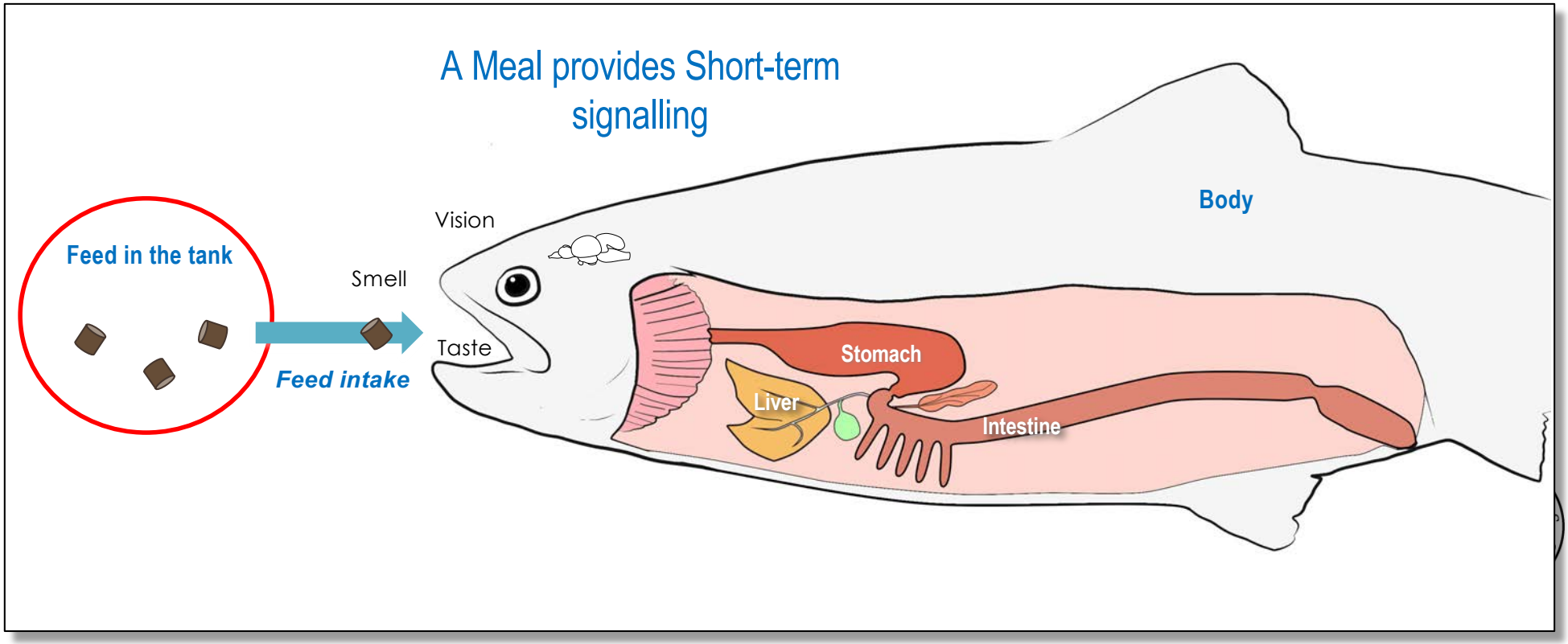
Modelling concept and design

Essensial for life

- **Feed intake supply energy and indispensable nutrients**
  - This supply chain provides inputs that affect appetite control
  - These afferent (mainly physiological) signals include
    - Anticipation (based on conditioning)
    - Presence of food in the external environment (vision, olfaction)



Modelling concept and design

Provides Short-term signalling related to a meal

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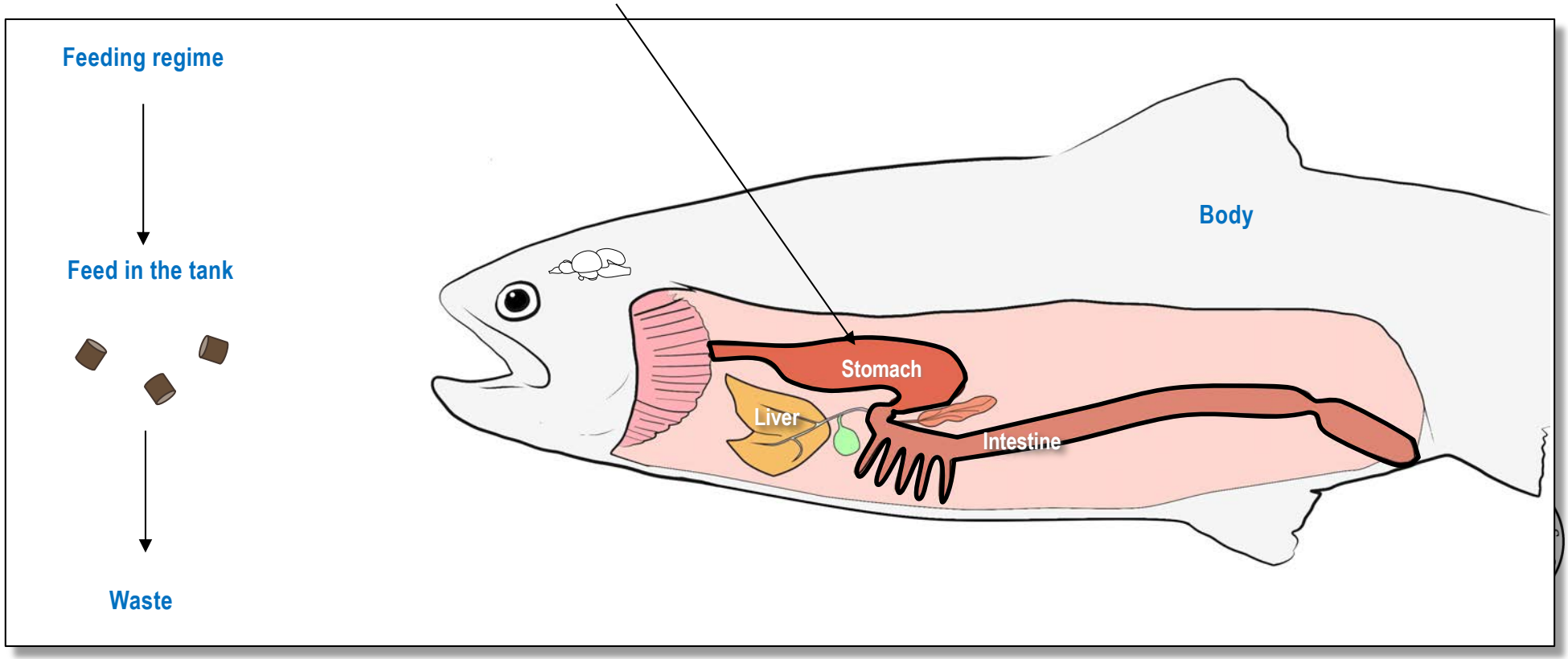
    - Presence of food in the GI-tract; a secured reservoir, not yet absorbed



Modelling concept and design

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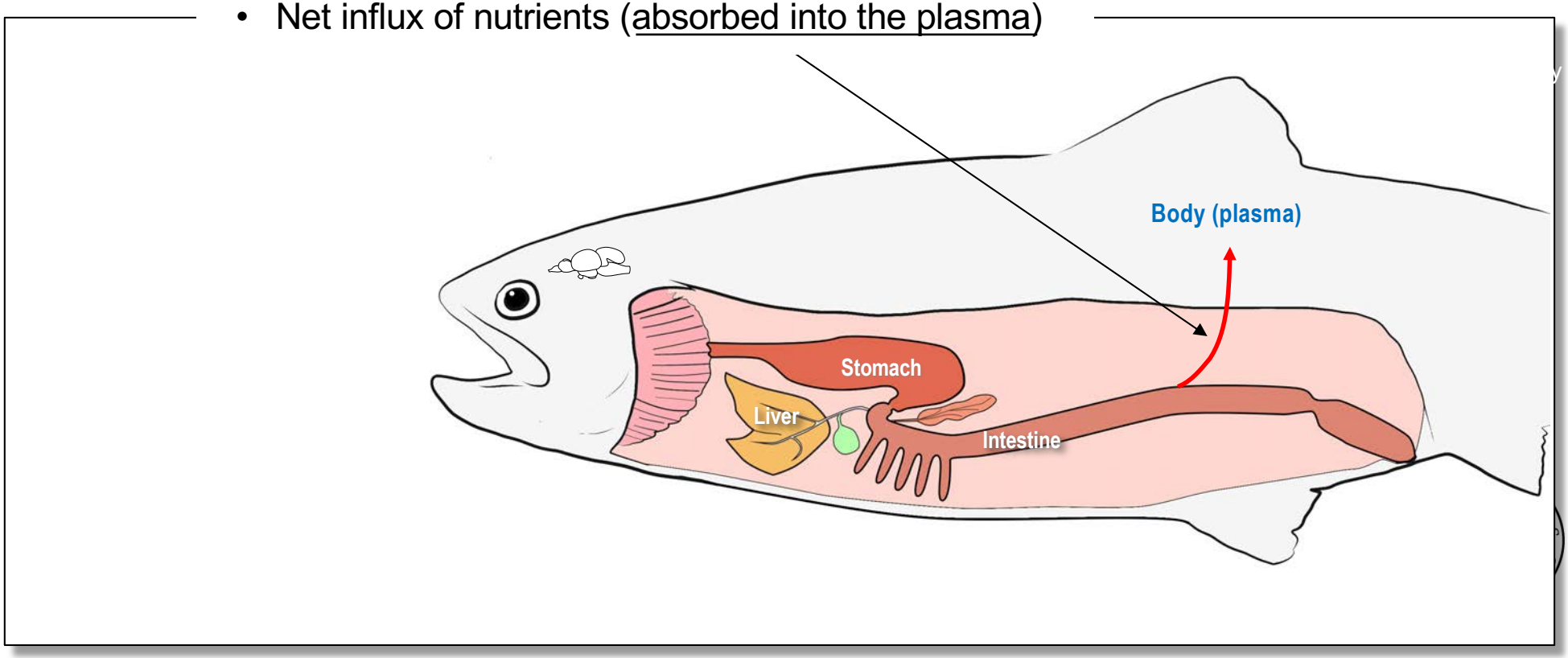
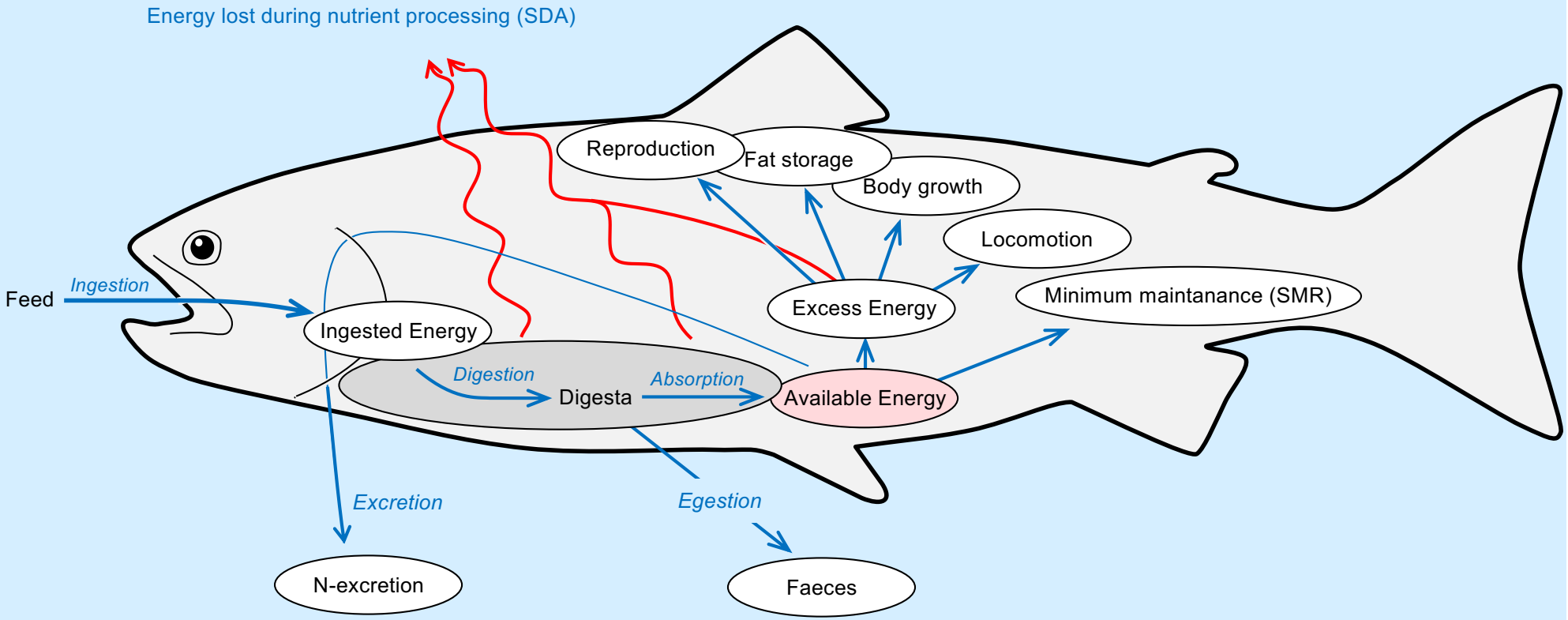
    - Presence of food in the external environment (vision, olfaction)
    - Presence of food in the GI-tract (a secured reservoir, not yet absorbed)
    - Net influx of nutrients (absorbed into the plasma)

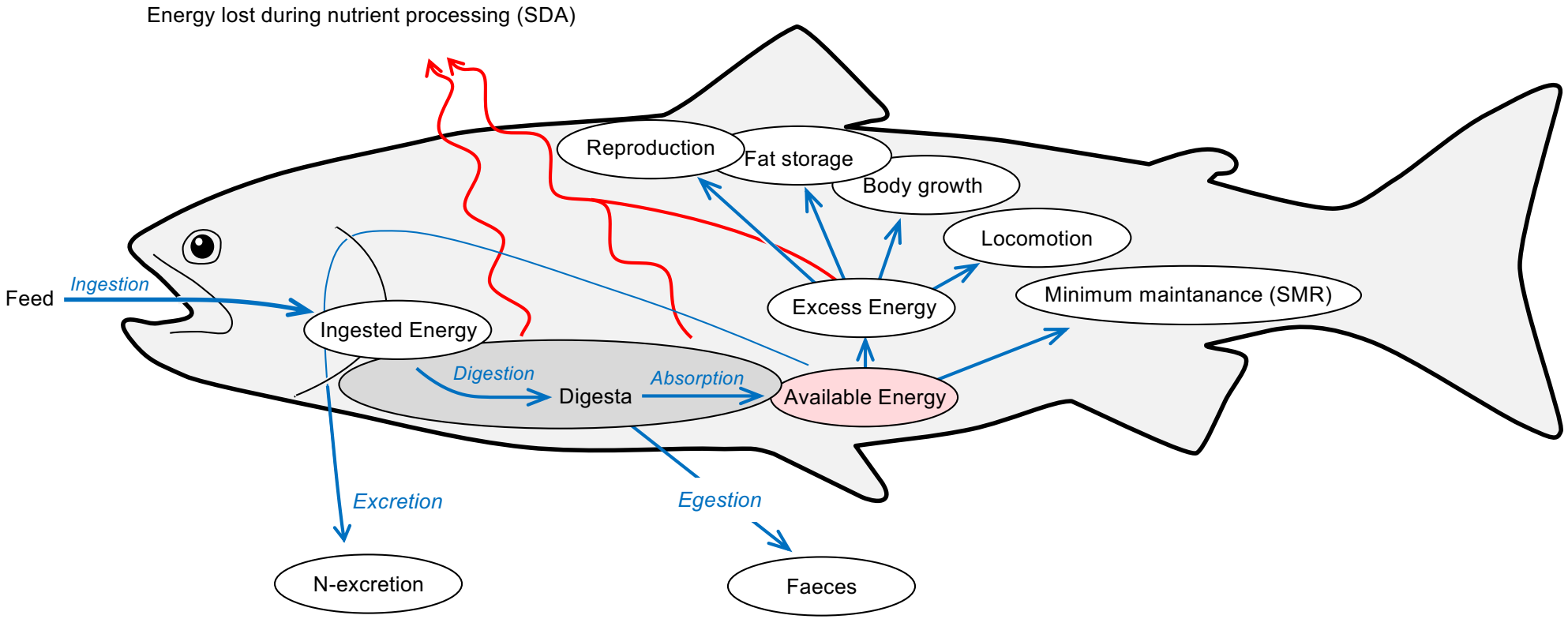


Modelling concept and design

Appetite control- input from the Energy homeostasis

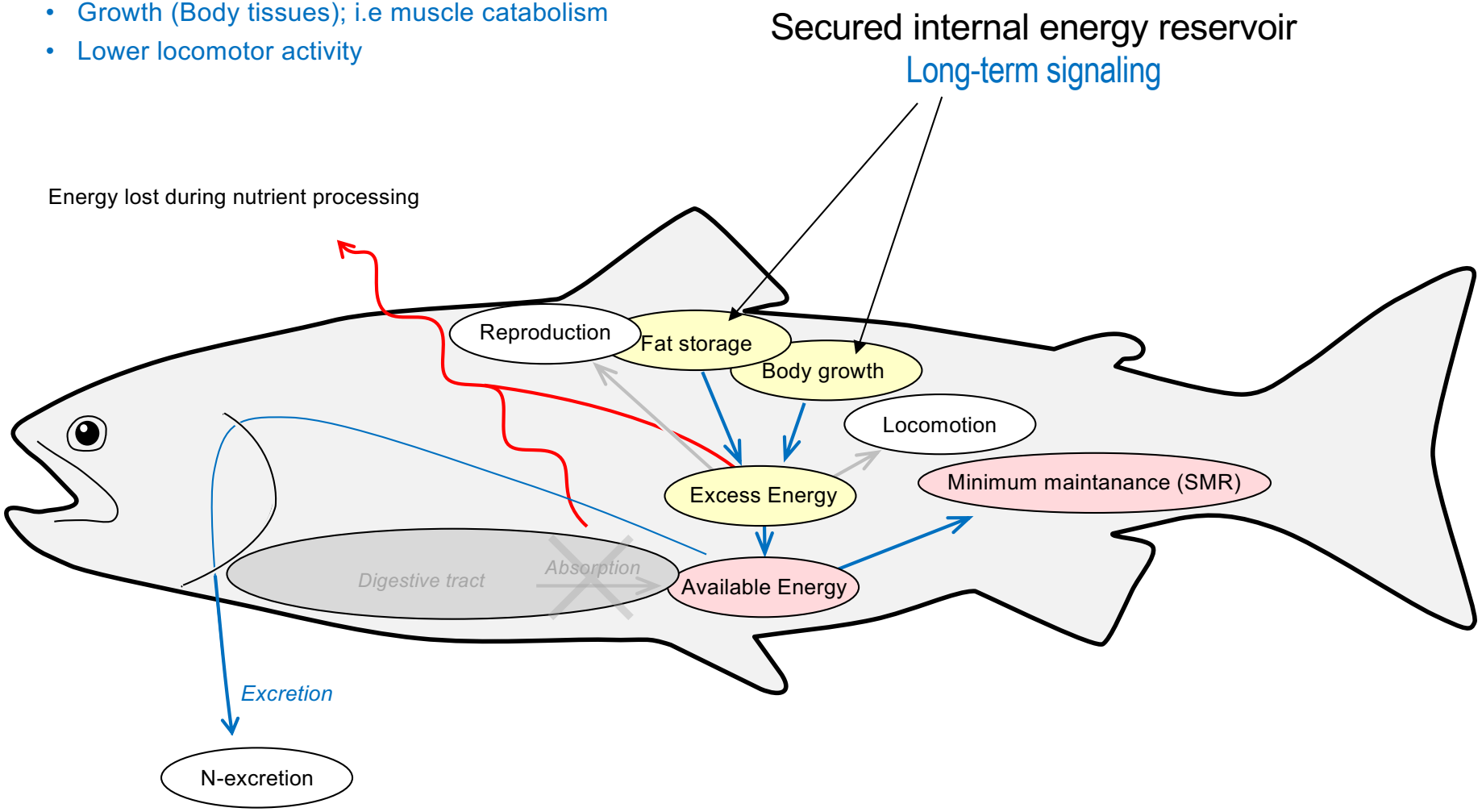


Energy homeostasis- Fed fish

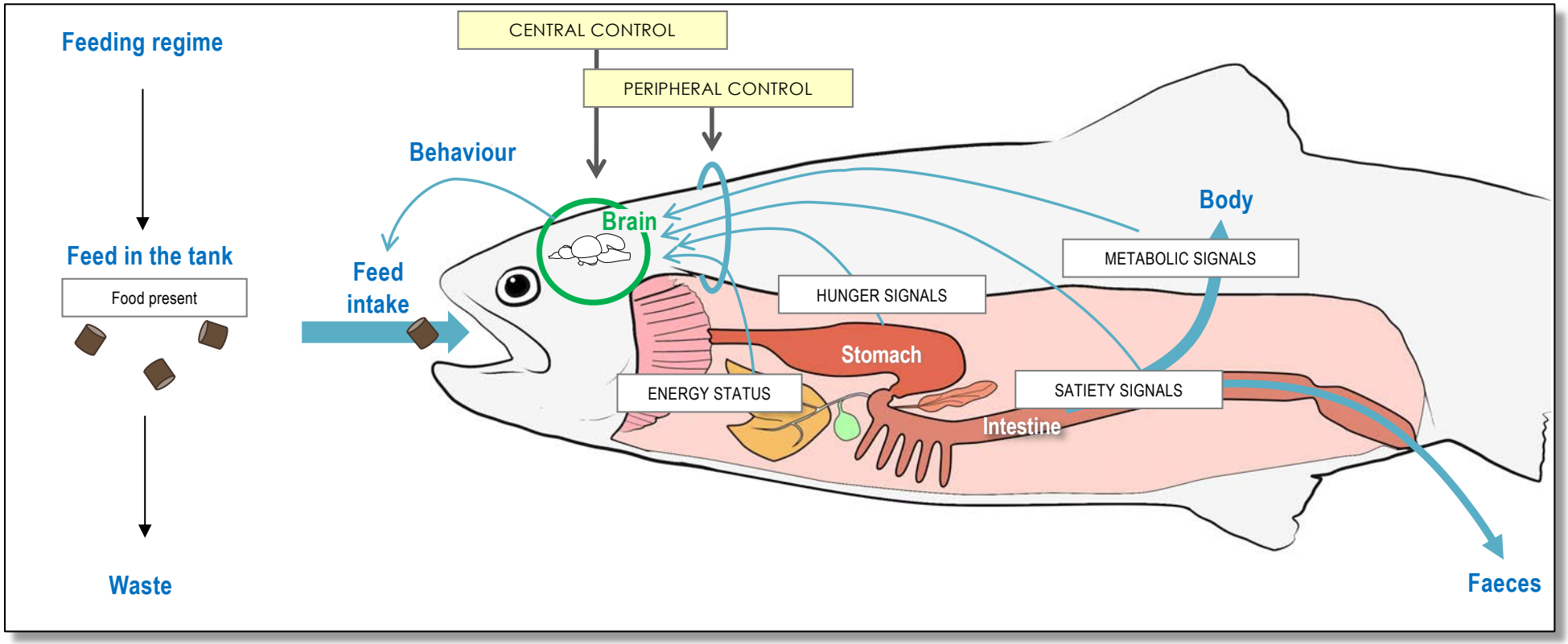


Energy homeostasis- Fasting fish

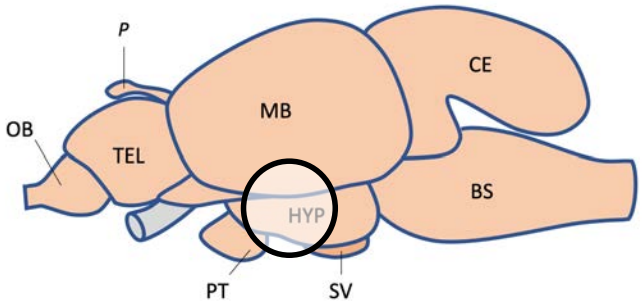
- Physiological goal: maintain Maintanance metabolic rate (SMR)
- If: Absorption < Available Energy
- Then: Recruit energy from
  - Storage (Fat)
  - Growth (Body tissues); i.e muscle catabolism
  - Lower locomotor activity

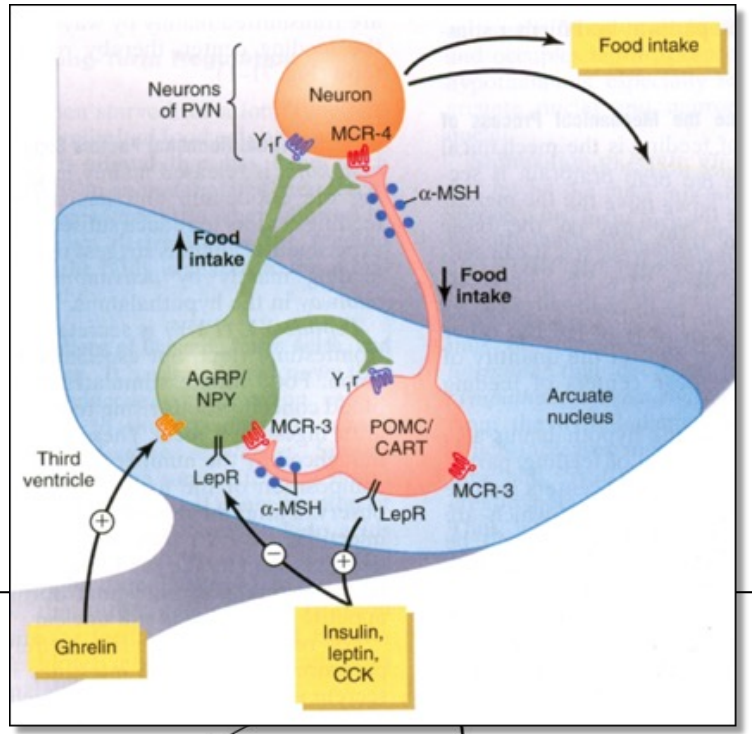


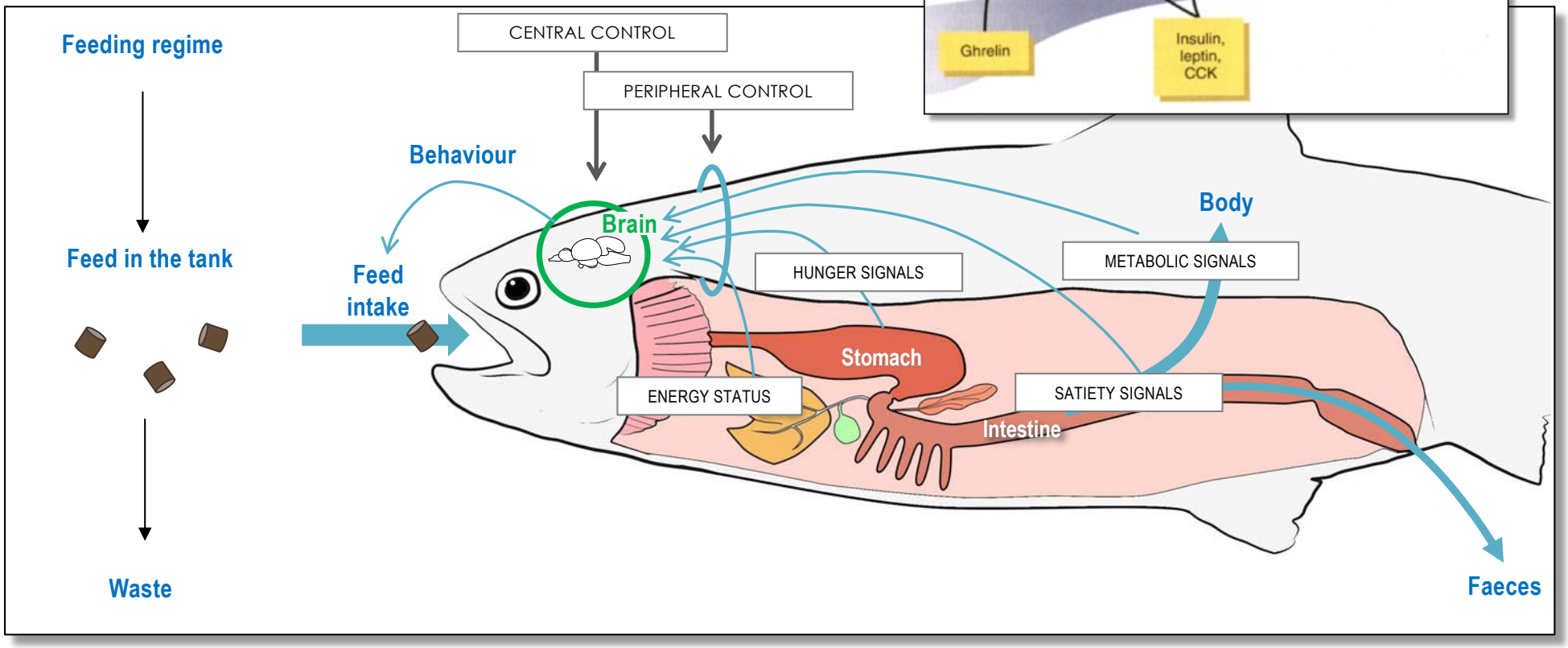
Appetite control- afferent signaling



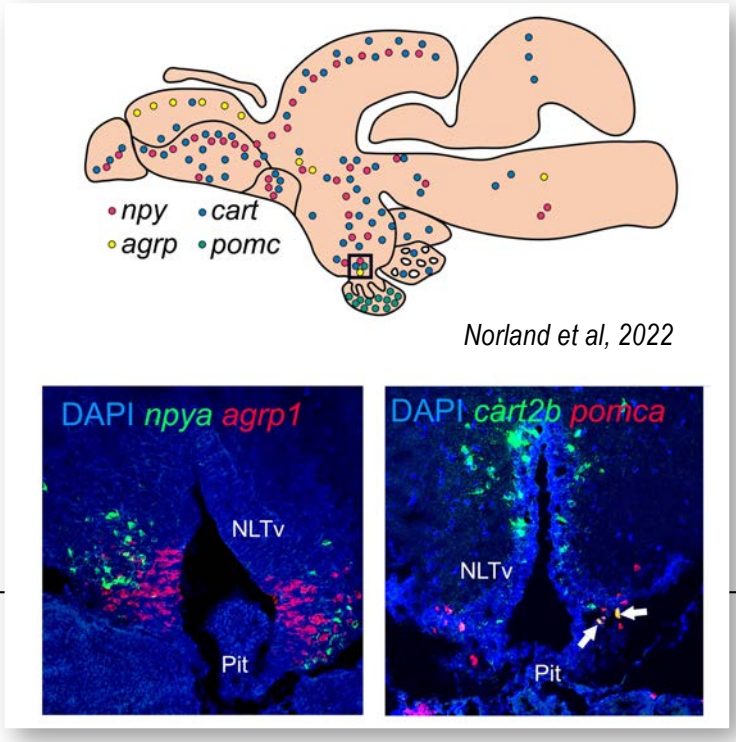
Appetite control

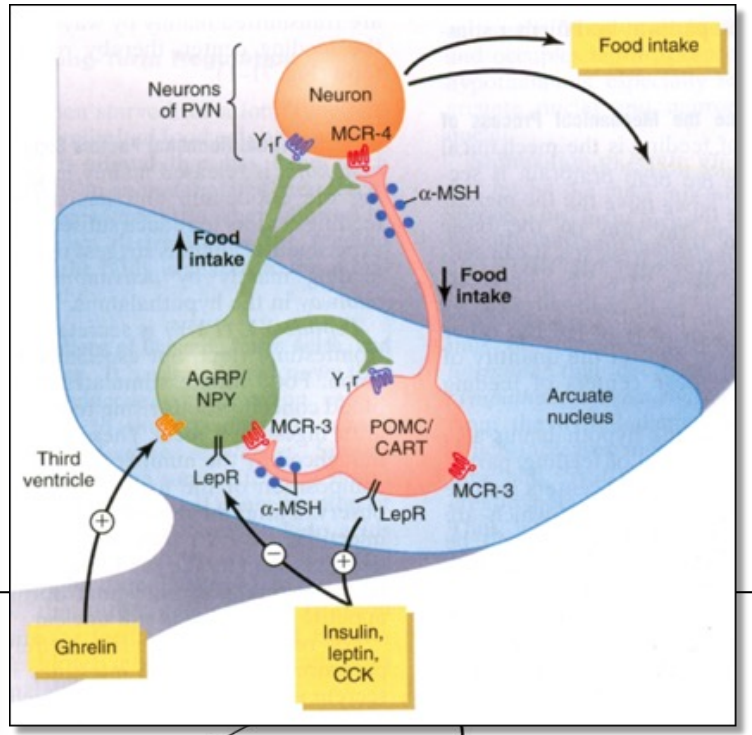


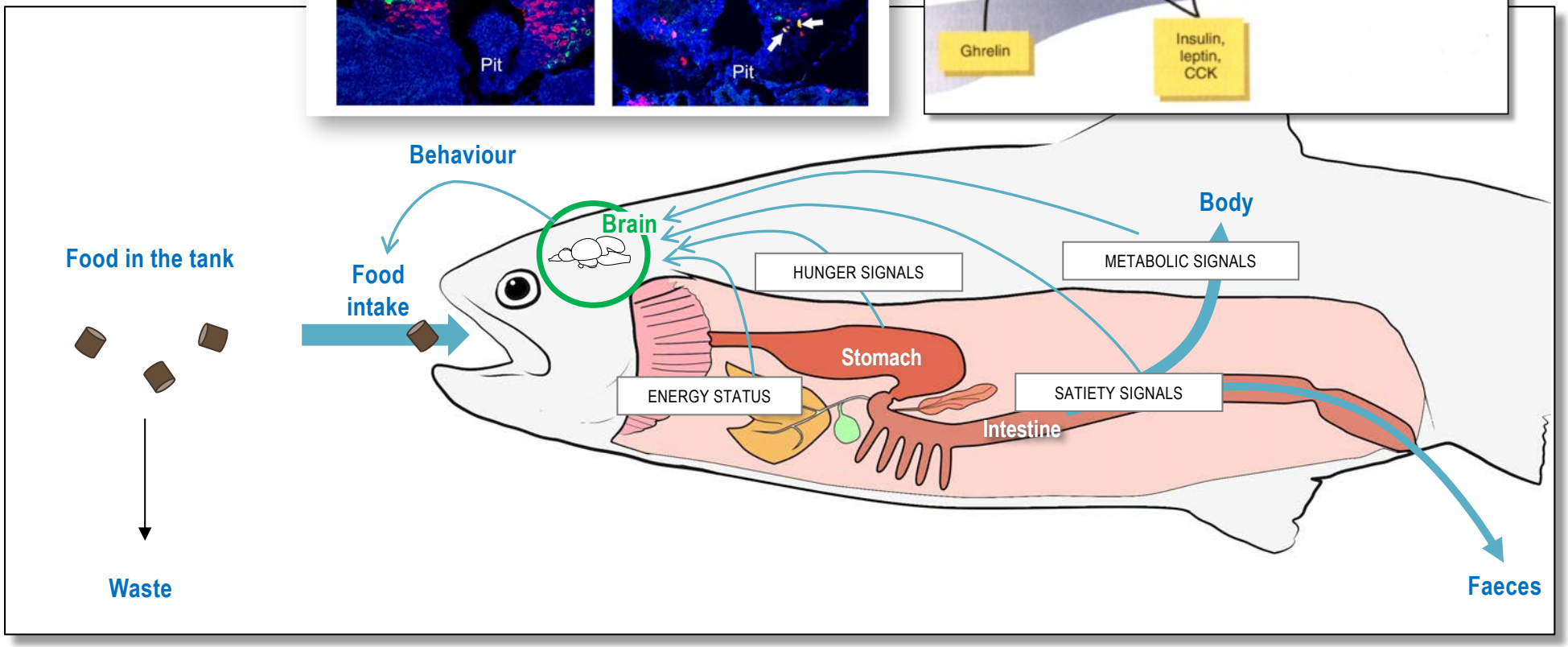




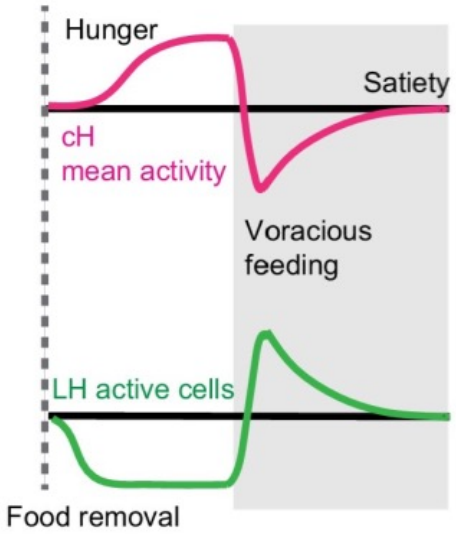
Appetite


npy
cart
agrp
pomc
Norland et al, 2022
DAPI npya agrp1
NLTv
Pit
DAPI cart2b pomca
NLTv
Pit

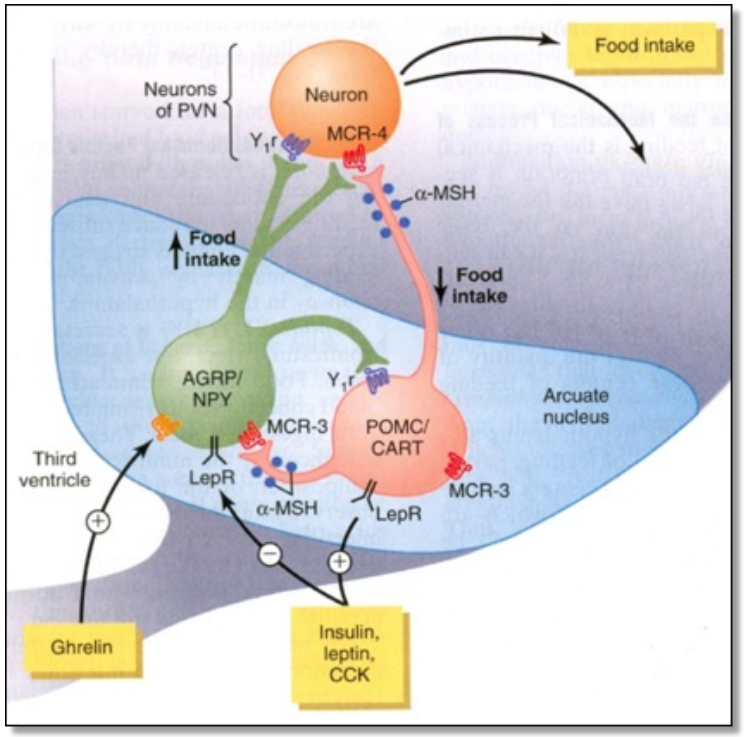

Food intake
Neurons of PVN
Neuron
MCR-4
α-MSH
Food intake
Food intake
AGRP/ NPY
MCR-3
LepR
α-MSH
POMC/ CART
LepR
MCR-3
Arcuate nucleus
Third ventricle
Ghrelin
Insulin, leptin, CCK

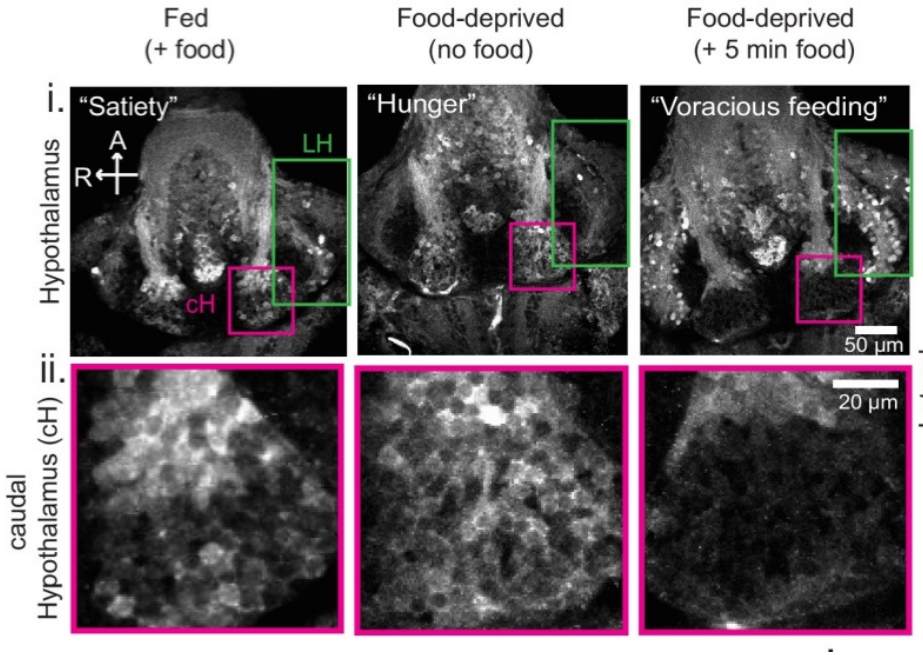

Behaviour
Food in the tank
Food intake
Brain
Body
HUNGER SIGNALS
METABOLIC SIGNALS
Stomach
ENERGY STATUS
SATIETY SIGNALS
Intestine
Waste
Faeces

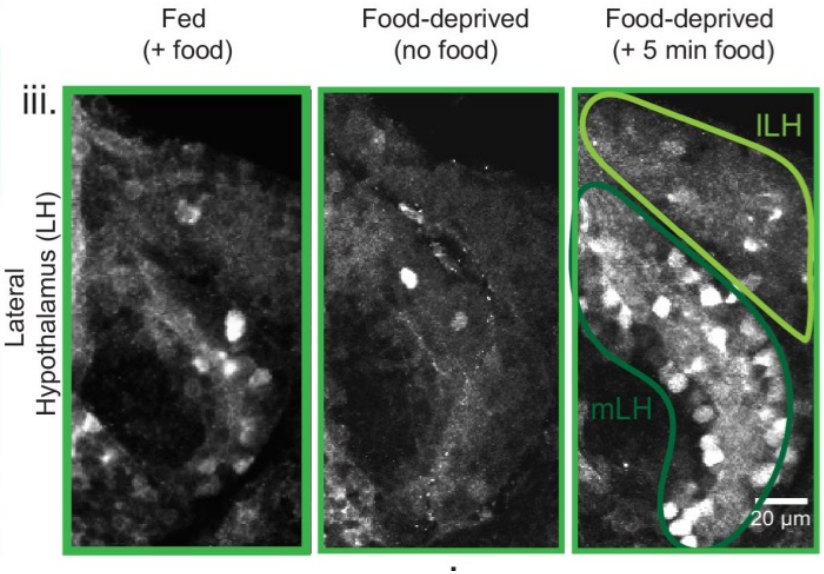
Appetite control



Wee, et al., 2019

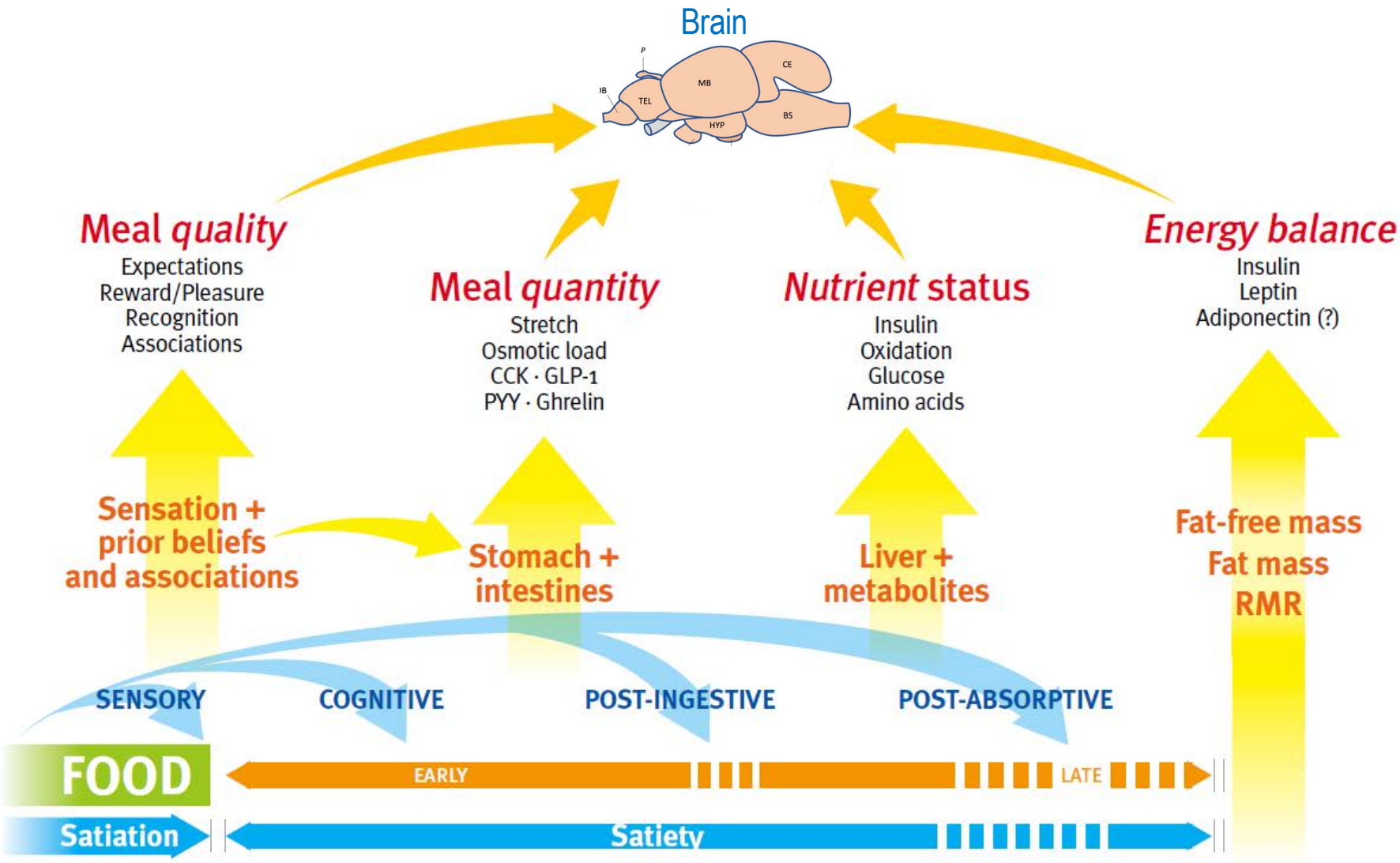




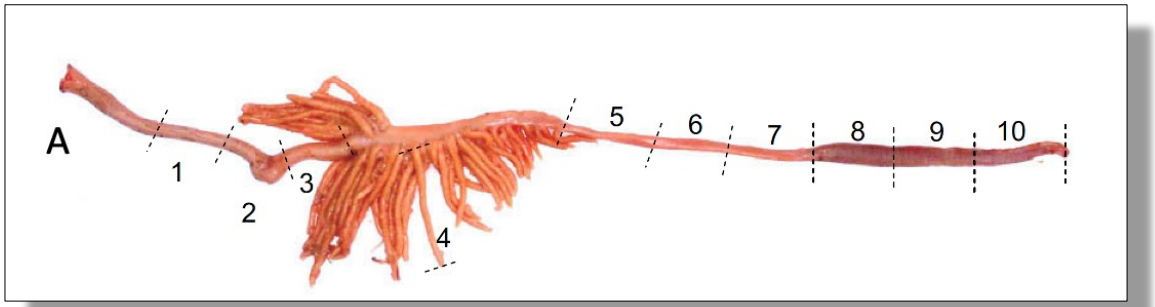


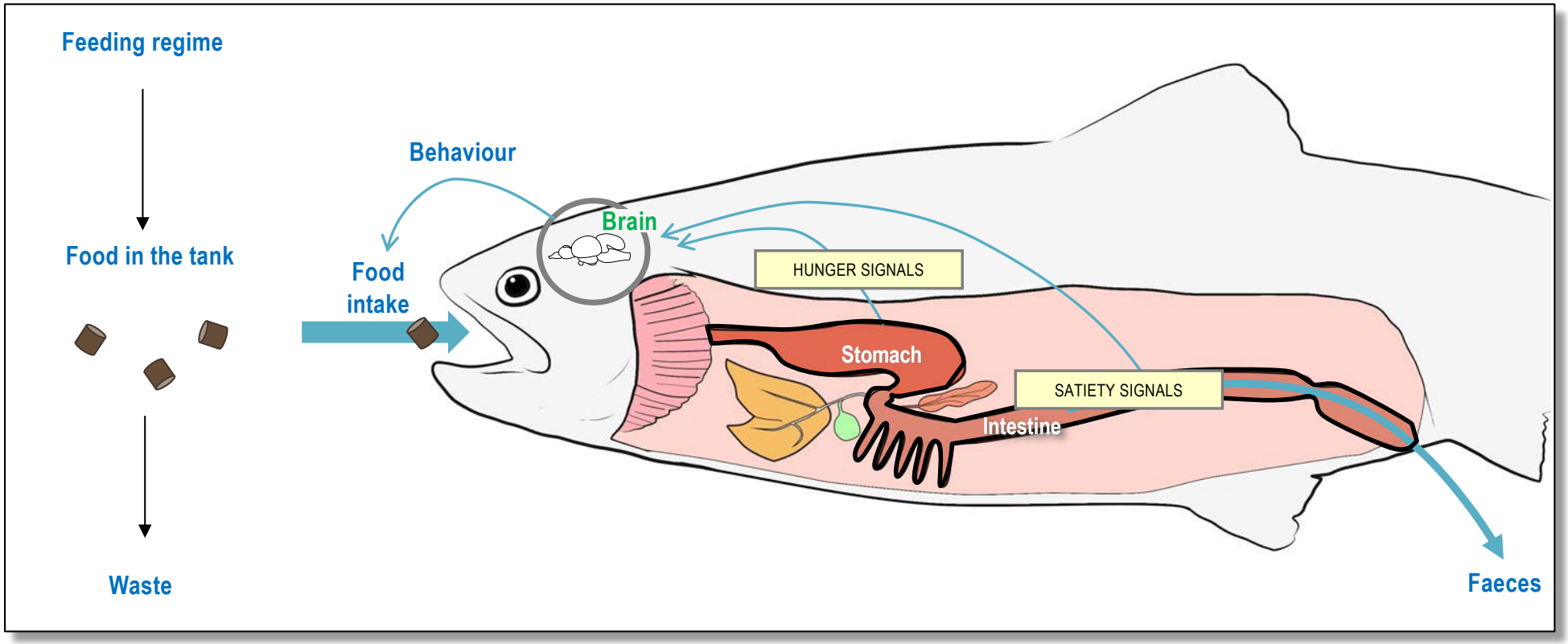
Appetite control- Summary

The Satiety Cascade (Blundell et al)



Appetite control- input from the Digestive tract

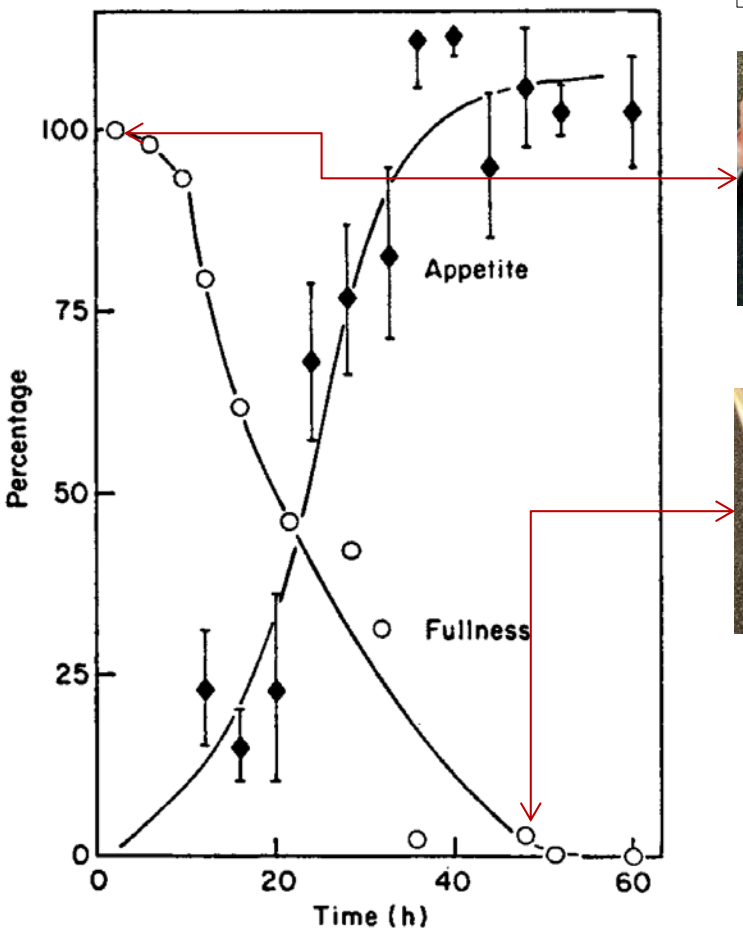


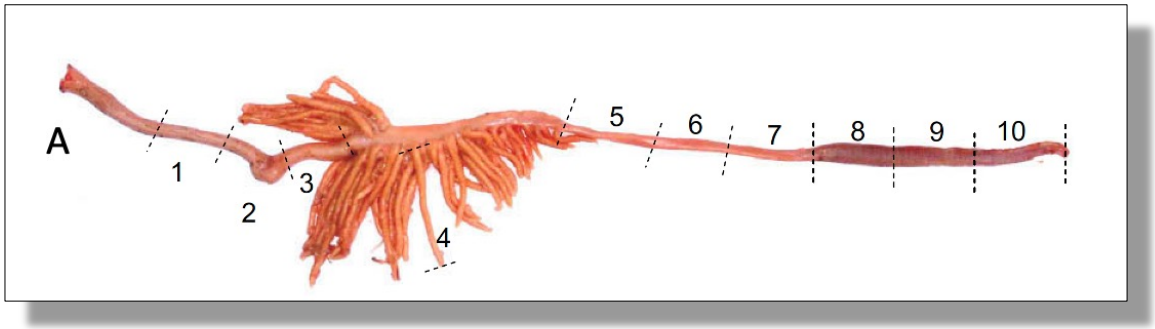


Appetite control- input from the Digestive tract

Return of appetite and stomach fullness in **rainbow trout** at 11-12 C. (Grove et al., 1978).

Stomach

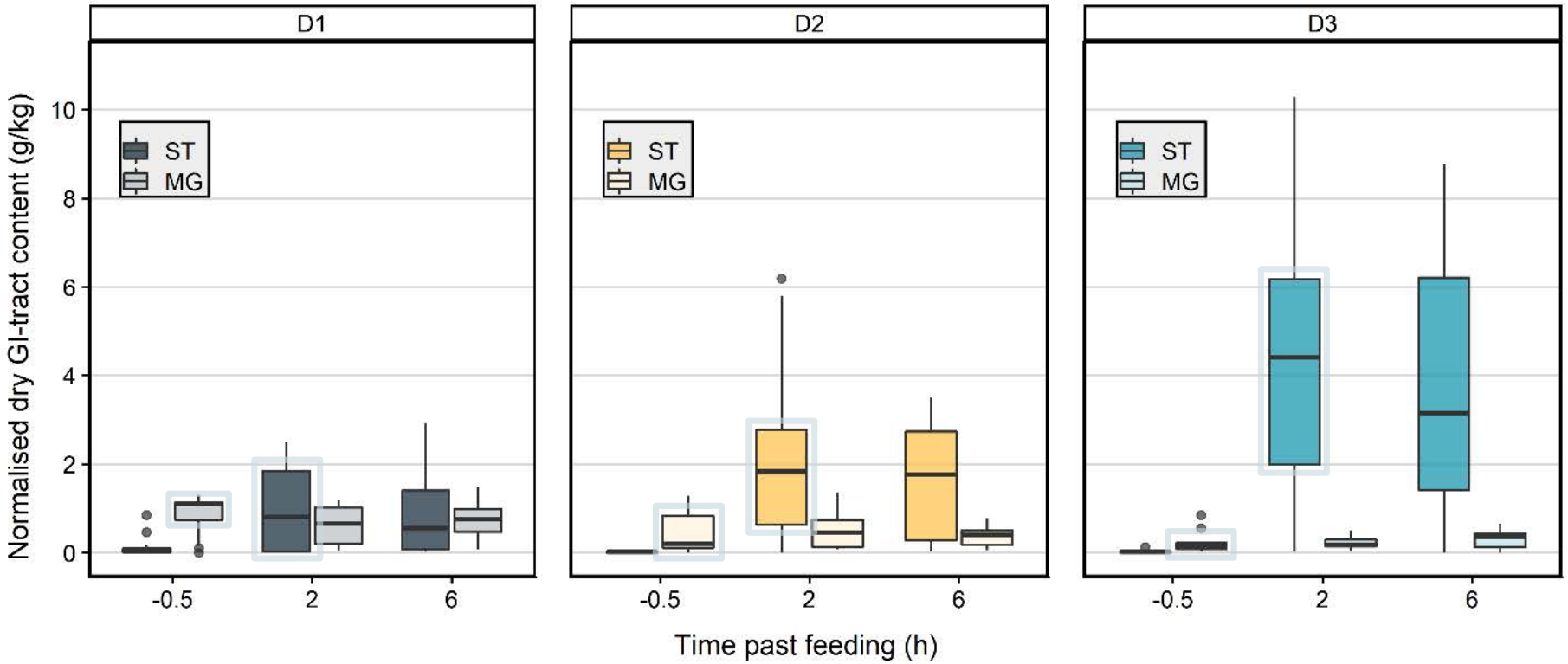




- spotted dogfish (*Scyliorhinus canicula*) (Sims et al., 1996)
- sockeye salmon (*Oncorhynchus nerka*) (Brett, 1971)
- Nile tilapia (*Oreochromis niloticus*) (Azaza and Dhraief, 2020; Riche et al., 2004)
- turbot (*Scophthalmus maximus*) (Grove et al., 1985)
- common dab (*Limanda limanda*) (Gwyther and Grove, 1981)

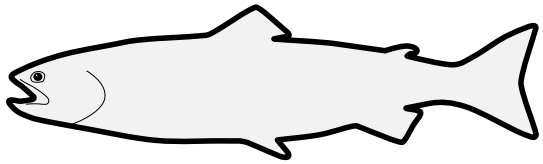
Appetite control- input from the Digestive tract

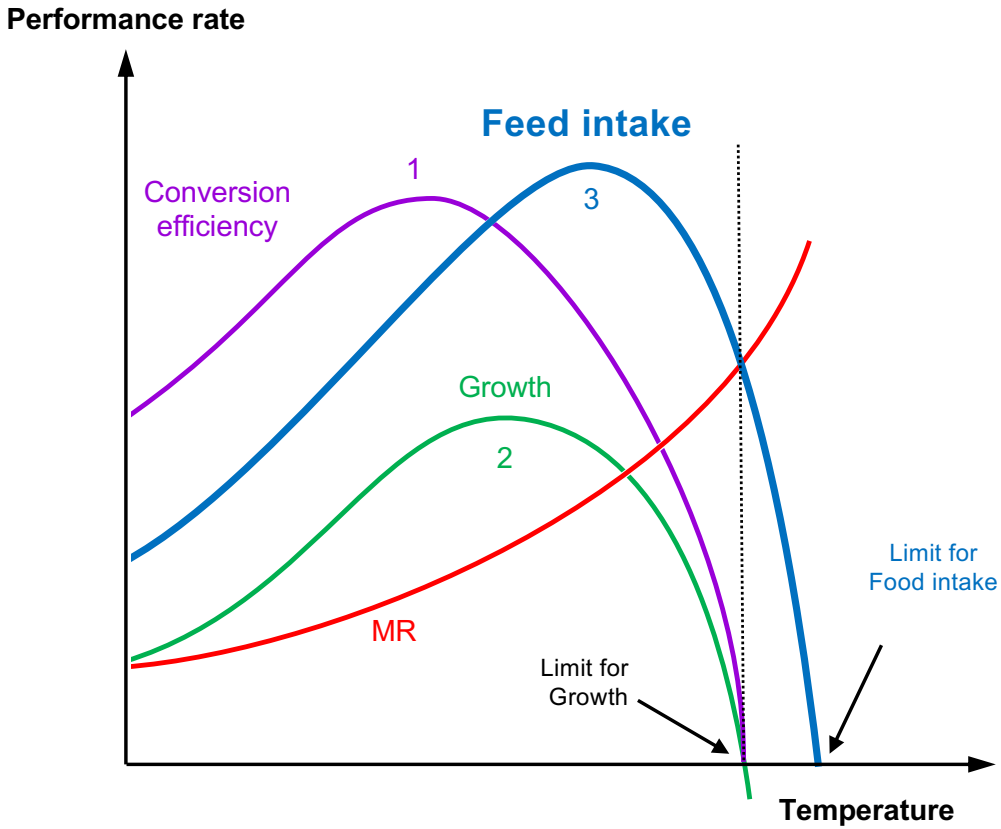
Return of appetite is not correlated with gastric emptying

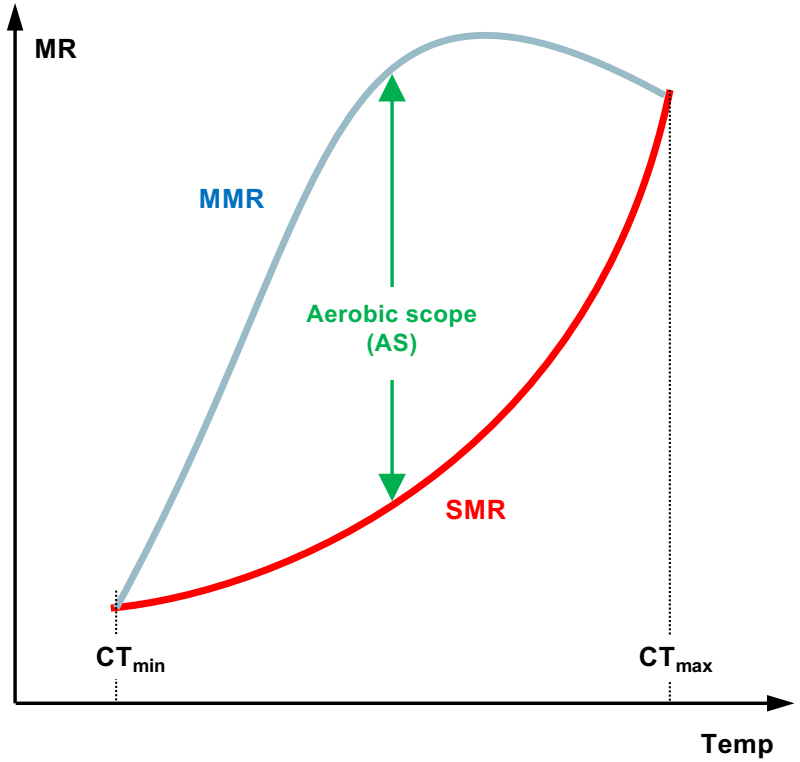


Lygre et al, in prep

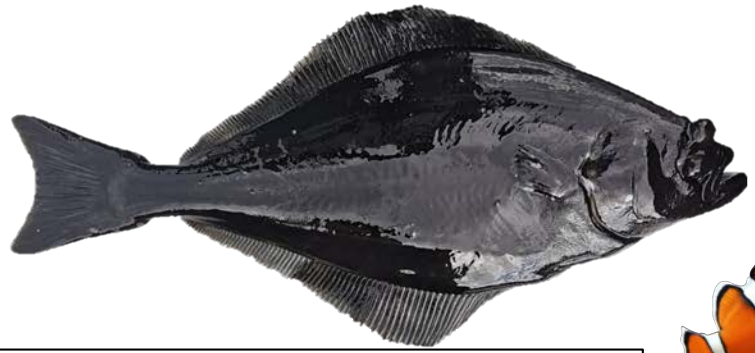
Feed intake- Effects of temperature



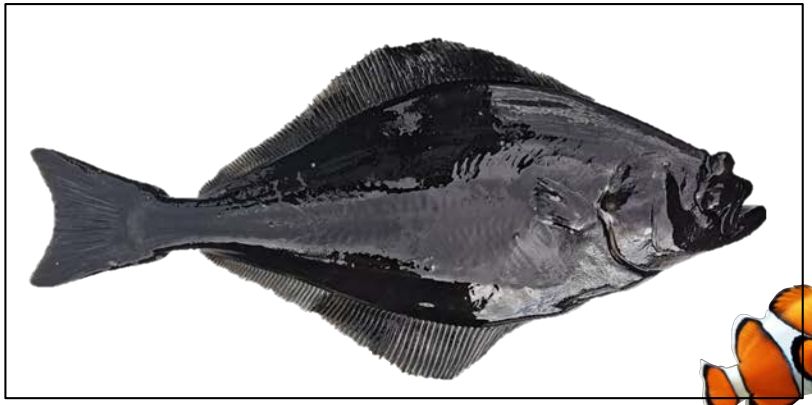


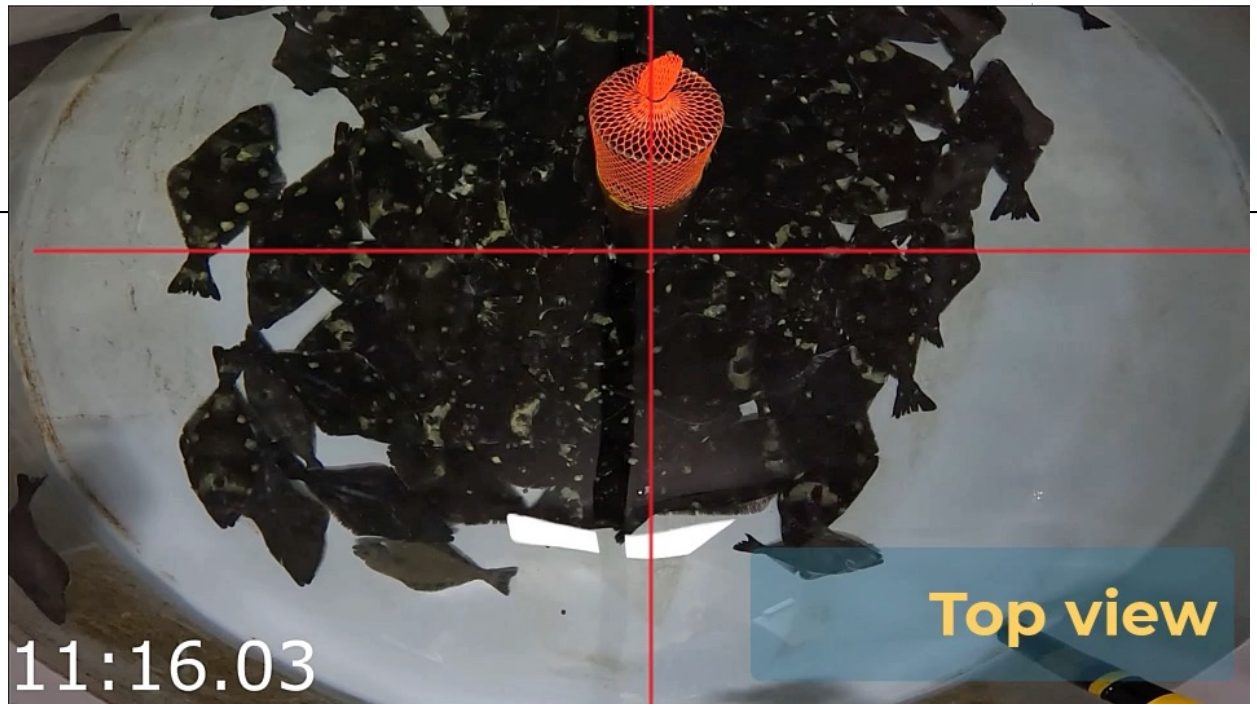


Feeding behaviour varies among fish



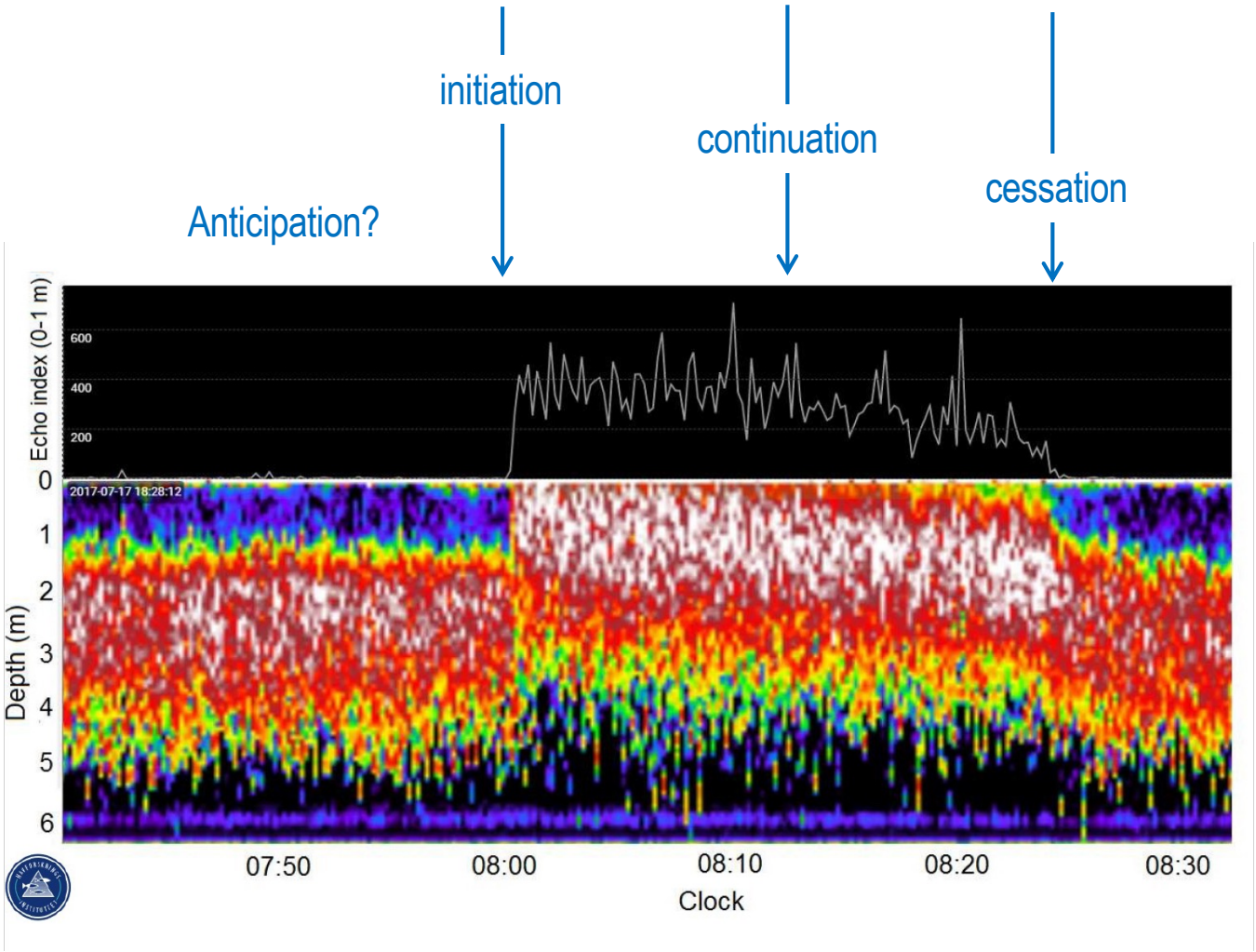
Appetite varies among fish

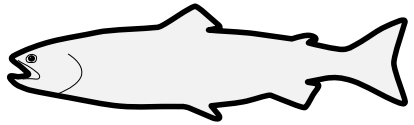


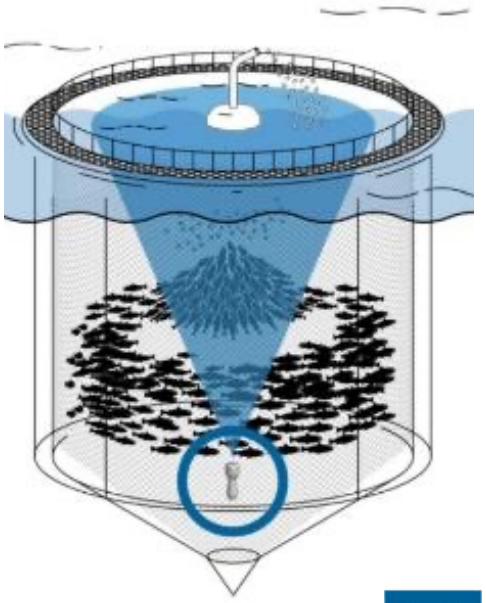


Appetite varies among fish

Behaviour response to feeding



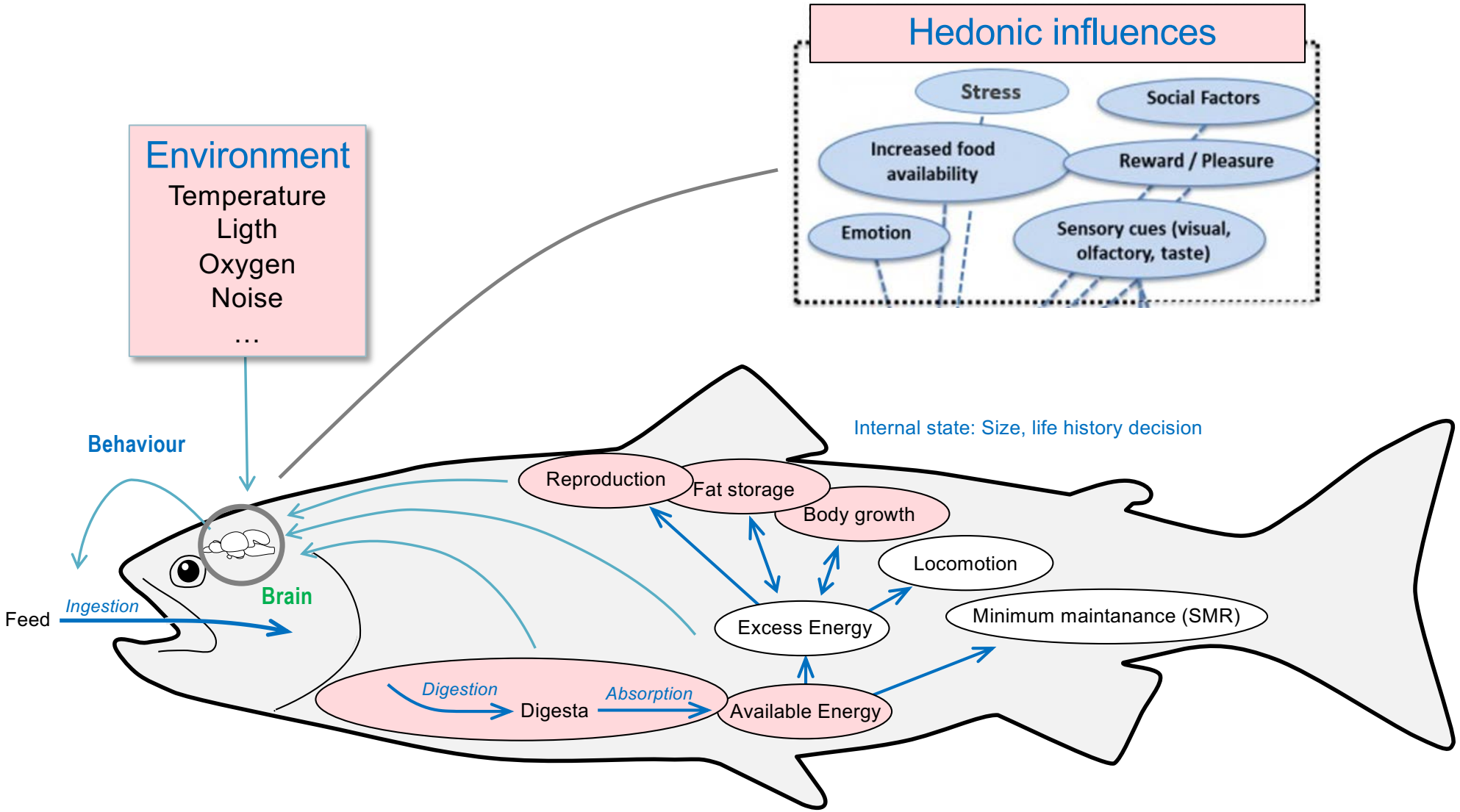




EchoFeeding
CageEye

Photo: Ole Folkedal (IMR)

Appetite and the decision- to eat or not to eat

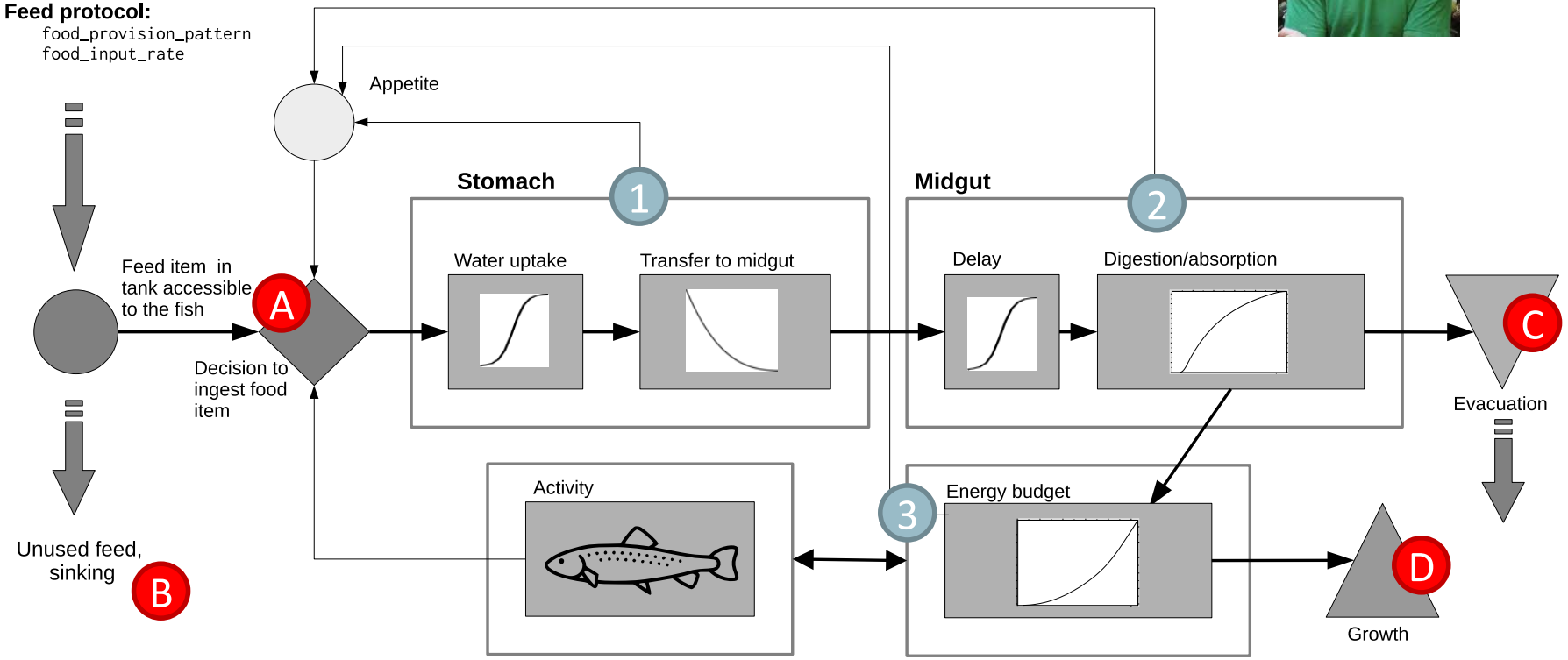


What sets the upper envelope for feed intake under ideal conditions

- Maximise feed intake- limited by supply capacity through digestion processing?

FishMet* – From concept to program (digital twin)

Implementation in fortran 2008



Physiological modelling- concept and design challenges

- Is there a homeostatic regulation of a key parameter?
  - Lipostat model in mammals (little suport)
  - Glucostat model in mammals (maybe, but does not prevent obesity)
  - Body weight (not supported)
- Identifying key parameters that set the orexigenic drive of appetite
  - Most periferal signals are anorexigenic (except ghrelin)
- What is the design principle for modelling appetite and motivation to eat
  - Eat whenever possible- prevent starvation
  - Salmon can grow the whole life, & excess fat likely not a problem (buoyancy, predation)
  - Is there a negative feedback from adiposity?
  - What sets the upper envelope for feed intake under ideal conditions
    - Maximise feed intake- limited by supply capacity through digestion processing?
- Motivation to eat in salmon is also affected by external environmental factors and also behaviour related to life history (e.g. smoltification, reproduction)
- Strong effects of hedonic factors (appetite is the most sensitive parameter for welfare)
- Challenge: Can we analyse key parameters?
- Challenge: Can the size of the next meal be predicted?

Comparative aspects of strategies for controlling appetite