

IRSN

INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

Mechanistic and ecophysiological study of carbon 14 transfer in fish



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PSE-ENV/SRTE/LECO

SOULOUMIAC Audrey

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- Natural sources: reaction of cosmic rays on nitrogen neutrons in the high atmosphere → carbon dating...

- With ^3H , ^{14}C is one of the radionuclides rejected in greatest amounts by Nuclear Power Plant in French rivers.

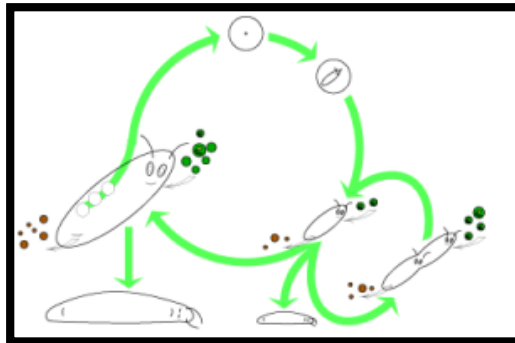


- Assimilated ^{14}C contributes in a major part to estimated – small – doses received by local populations, essentially through fish ingestion.

 Need to better assess the environmental (both health and ecological) risks

Problem: Current models used to predict ^{14}C transfer in aquatic ecosystems are very simplistic:

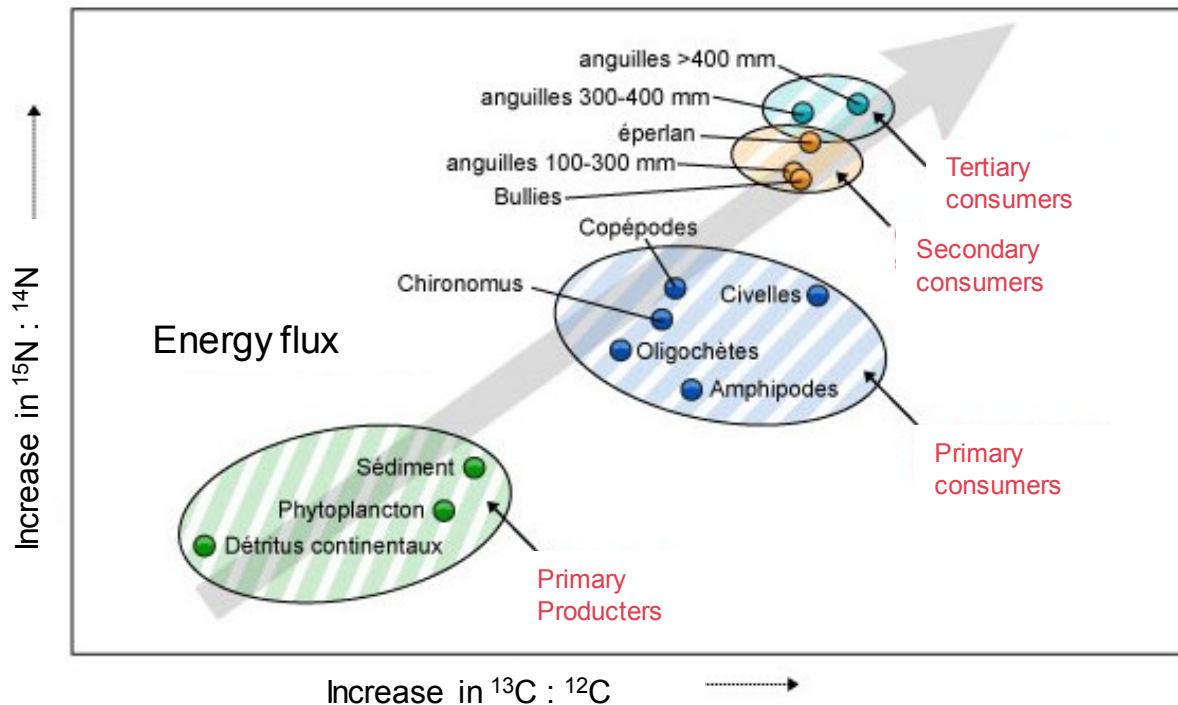
- Unability to explain the variability in ^{14}C activity observed in fish samples collected from different rivers.
- Great variations in ^{14}C releases \rightarrow No equilibrium in concentration (Sheppard et al., 2006 ; Smith, 2006).
- Models of fish do not take account of the potential influence of fish physiology and environmental factors, depending on species.



\rightarrow DEB model is a physiology-based dynamic model = more adequate to describe variation in ^{14}C activity in different compartments of the aquatic ecosystem.

DIB model: Dynamic isotope budget

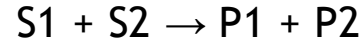
- Used in ecology to study the dynamics and structure of trophic networks and trace elements fluxes in ecosystems. (Post, David M. 2002. « Using Stable Isotopes to Estimate Trophic Position: Models, Methods, and Assumptions ». *Ecology* 83 (3): 703-18.).



→ Increase in stable isotopes with trophic level

→ DIB model is used for stable isotope analyses


- Aim to quantify dynamics of four biogenic elements (C, H, N and O) and their isotopes within organism by coupling fluxes of elements with those of molecules involved in metabolism.



- 1) Mobilisation : Mobilisation of atoms from a pool of atoms. **Does not change isotopic ratio**

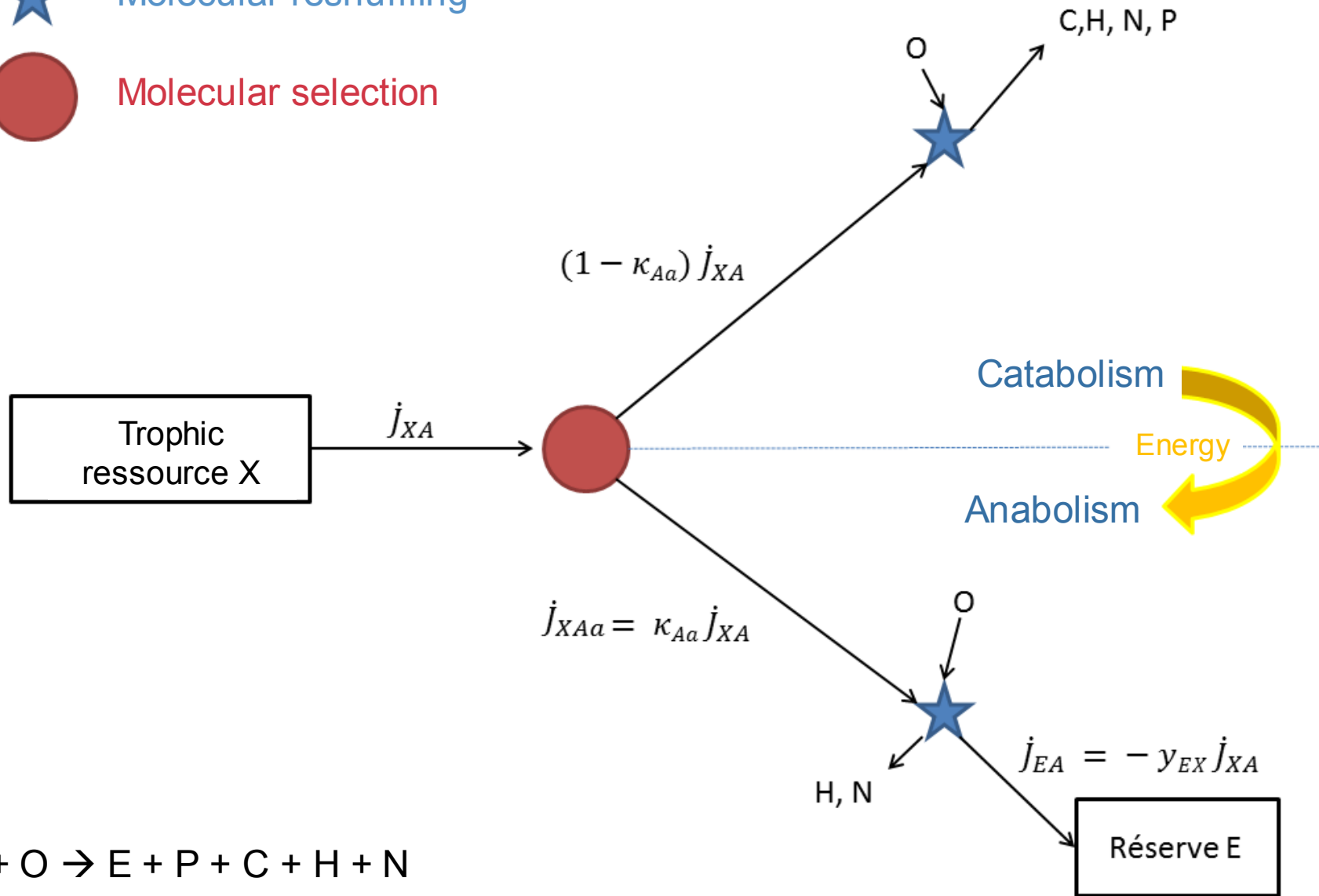
- 2)  **Molecular selection**

Selection for anabolic or catabolic routes. Probability depends on fate of atoms (heavy for catabolic route).

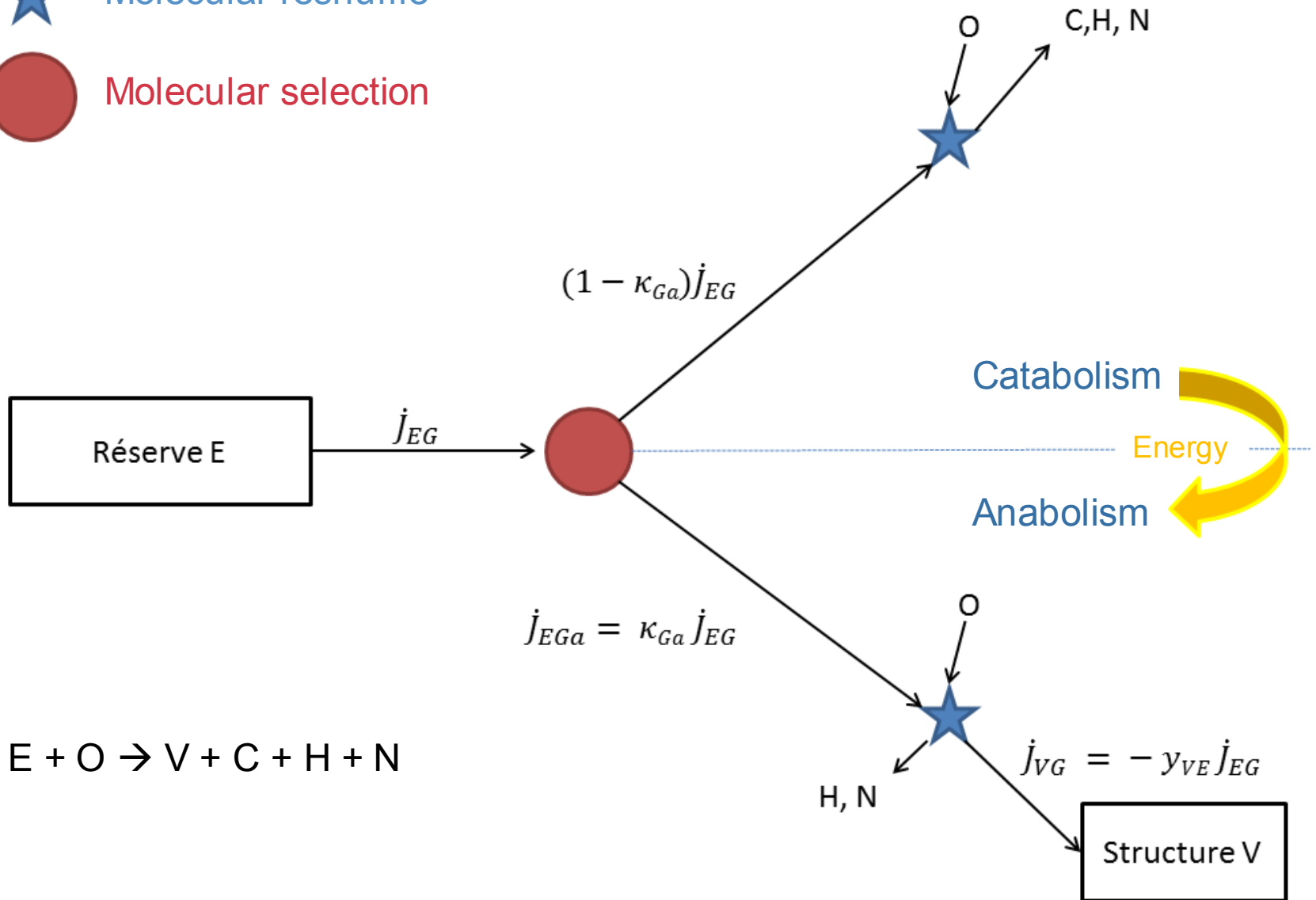
- 3)  **Molecular reshuffling**

The concept of atom reshuffling recognizes that molecules are not completely disassembled into elements during chemical reactions.

- ★ Molecular reshuffling
- Molecular selection



- ★ Molecular reshuffle
- Molecular selection



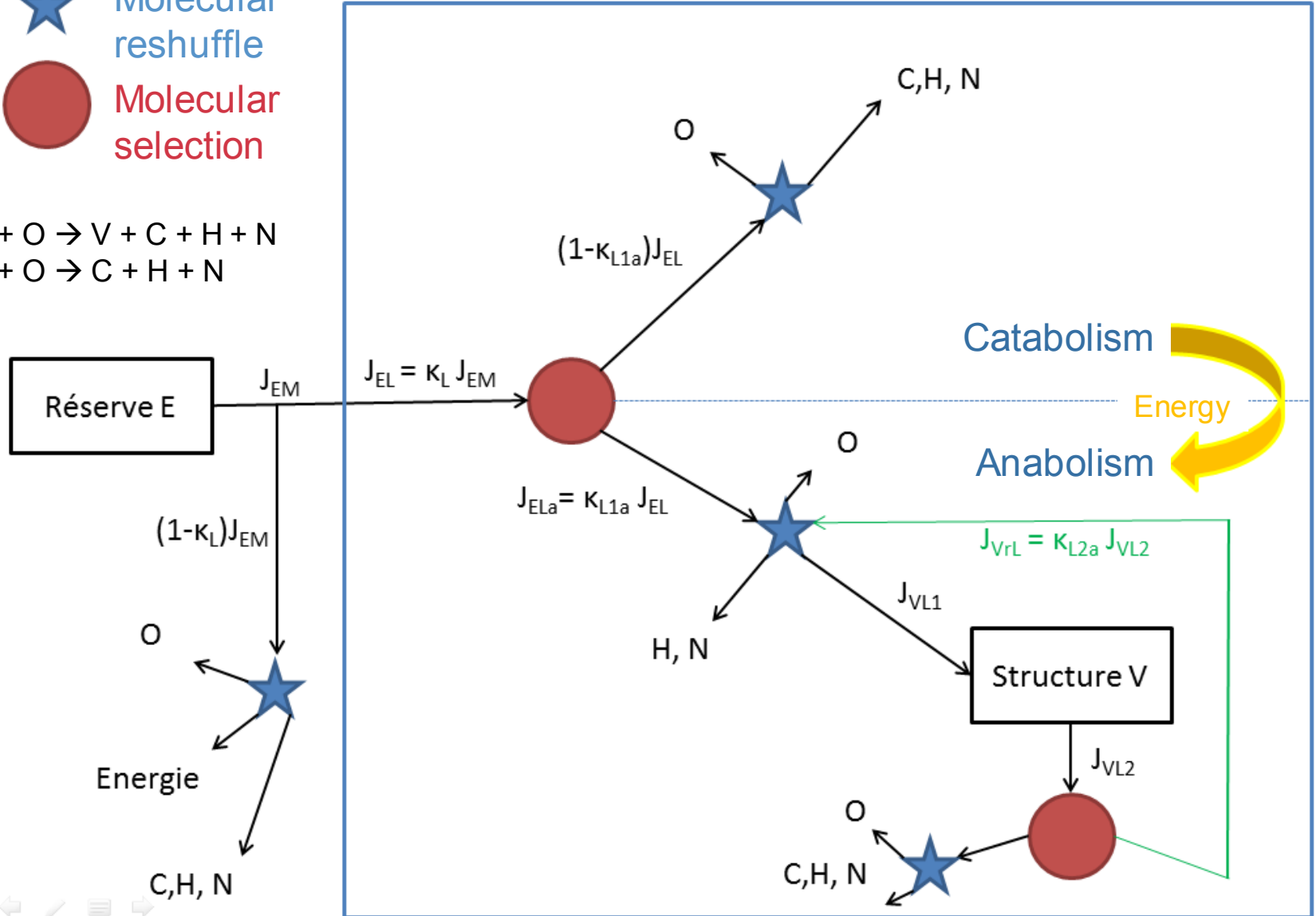
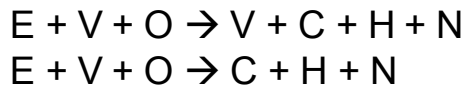
Structure turnover



Molecular reshuffle



Molecular selection



Catabolism

Energy

Anabolism

Theoretical values of DIB parameters are available for stable isotopes ^{15}N and ^{13}C and are validated in *Crassostrea gigas* (Pacific oyster).

- Parameterize values for the case of ^{14}C in two fish species of fish
- Improvement of DEB model for Common carp (literature search)
- Validation of predictive capacity in Zebrafish



Cyprinus carpio

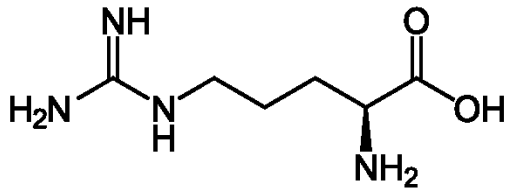


Danio rerio

Measurements of ^{14}C **assimilation**, **incorporation** and **elimination** kinetics depending the biochemical composition of ^{14}C **sources**.

Different sources of ^{14}C

Amino acid: Arginine



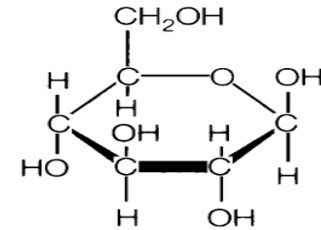
PROTEIN METABOLISM

Glycerol



LIPID METABOLISM

Glucose

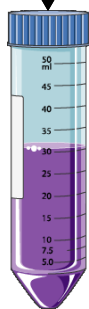


CARBOHYDRATE METABOLISM

Conception of contaminated food

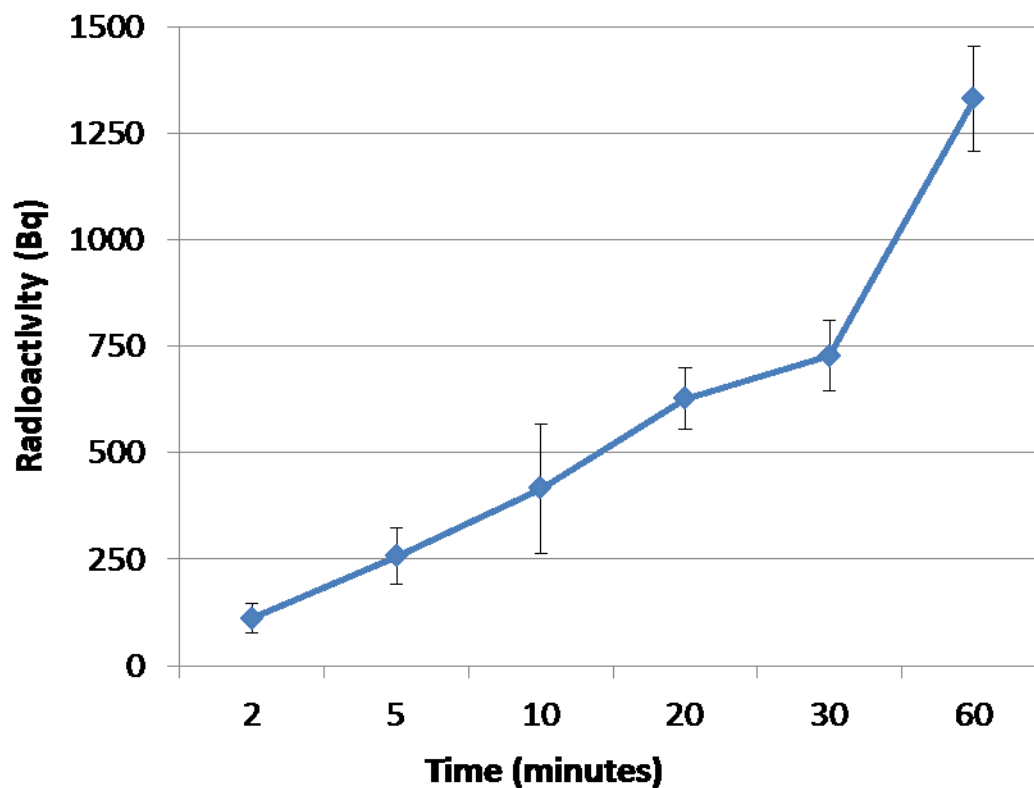


5mL water



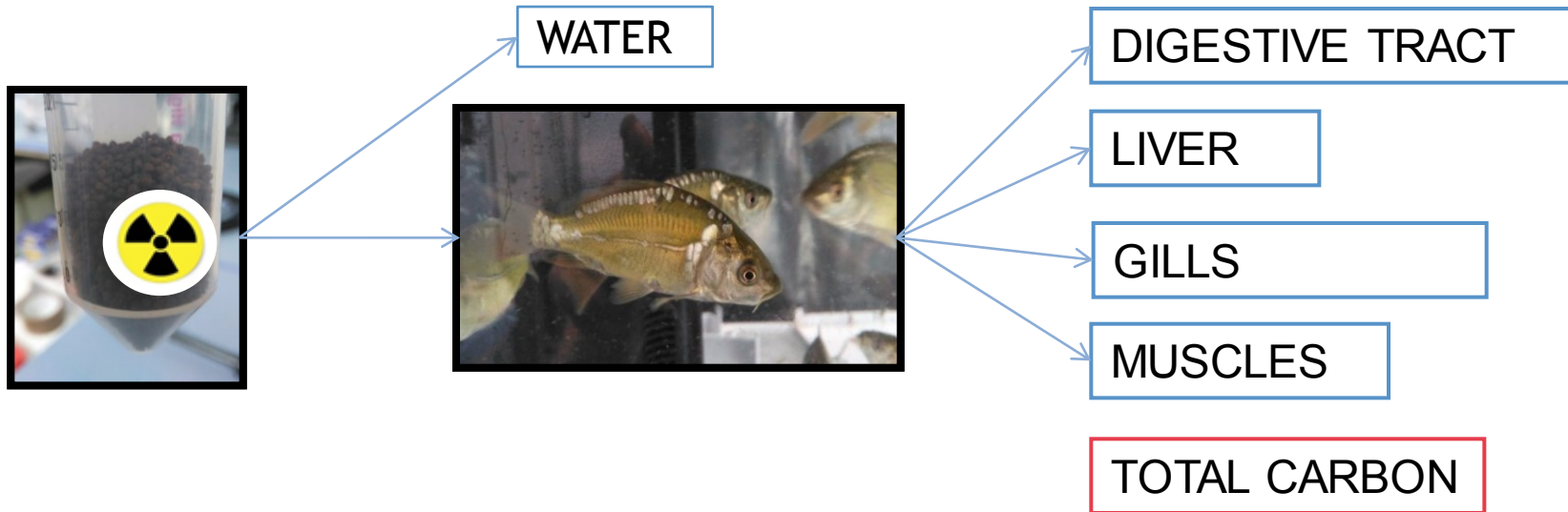
- Mineralisation in NaOH for **48 hours**
- Quantification by liquid scintillation analysis

Direct lost of ^{14}C into water



Preliminary experiment

Contamination duration: range of **1 to 4 days**
Dissection **24h** after last food supply



CONTAMINATION

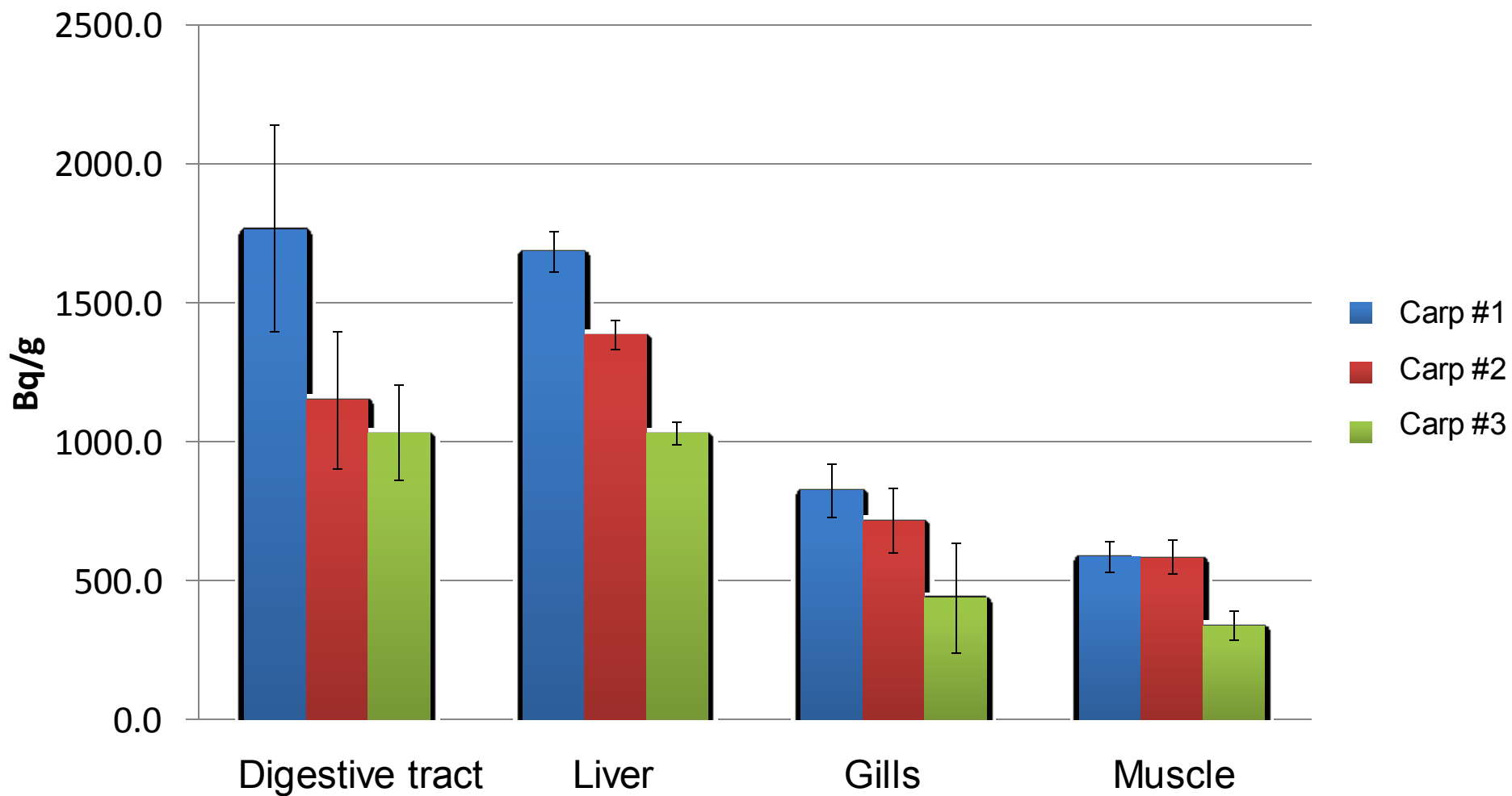
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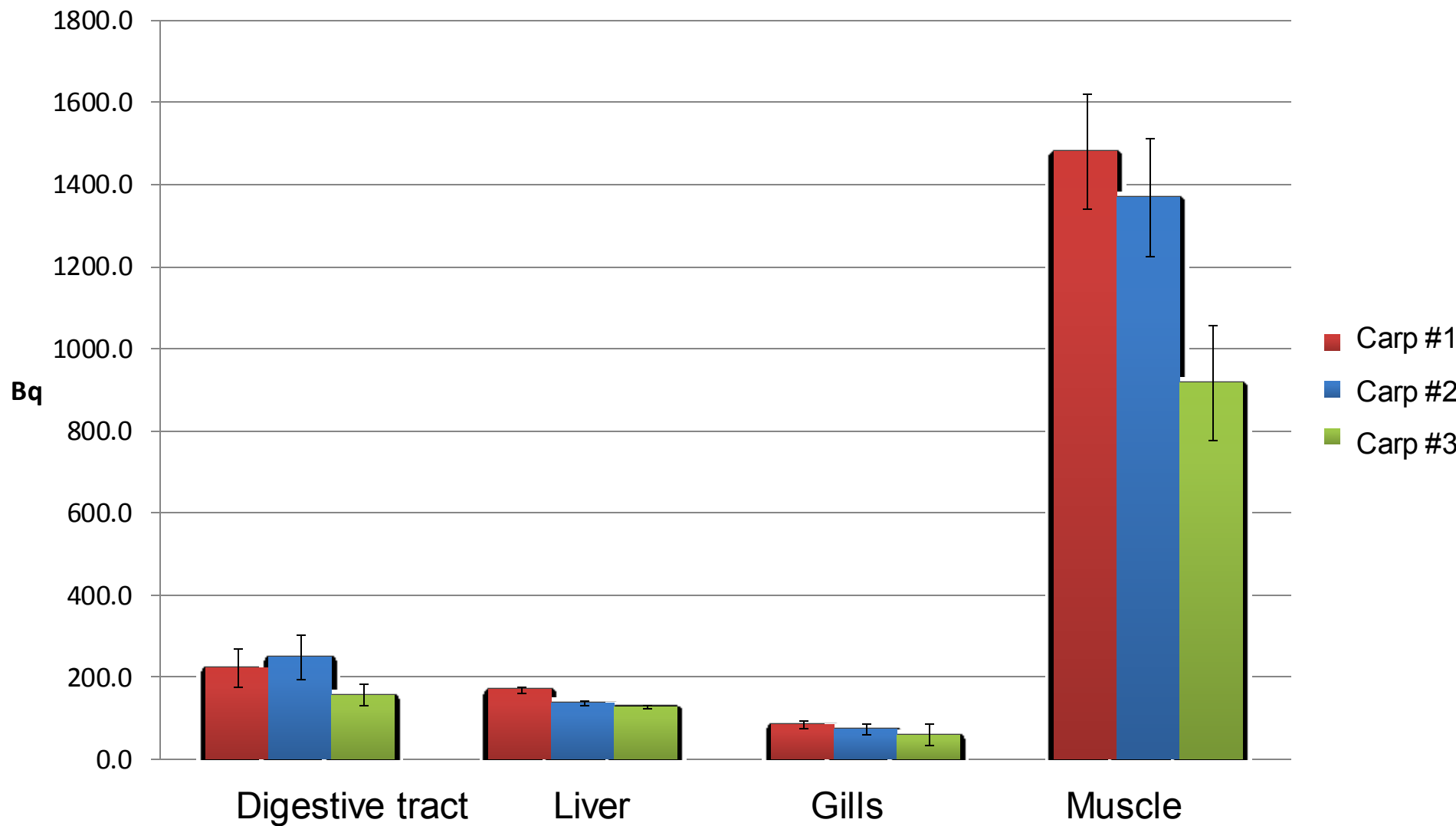
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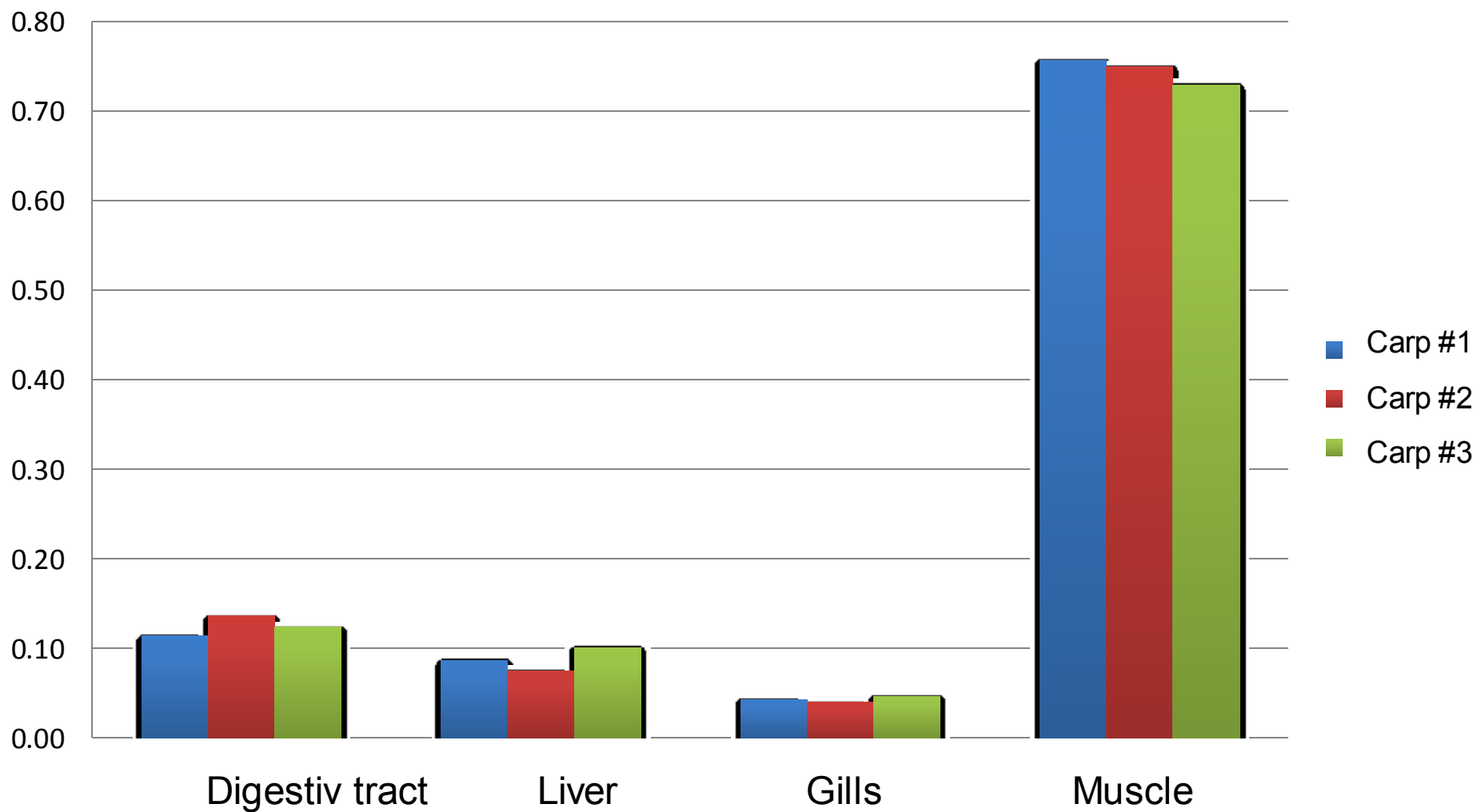
Mass-specific activity of ^{14}C



Distribution of ^{14}C activity among organs

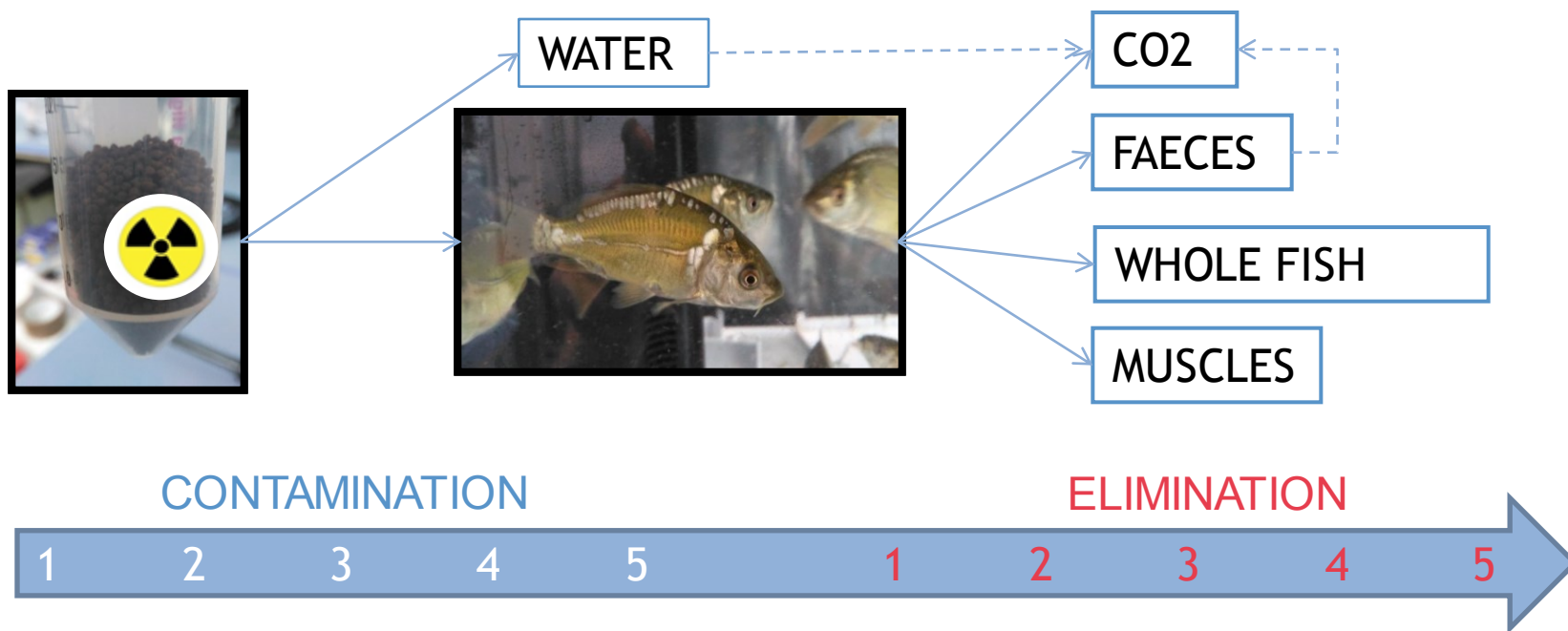


Proportion of ^{14}C activity among organs

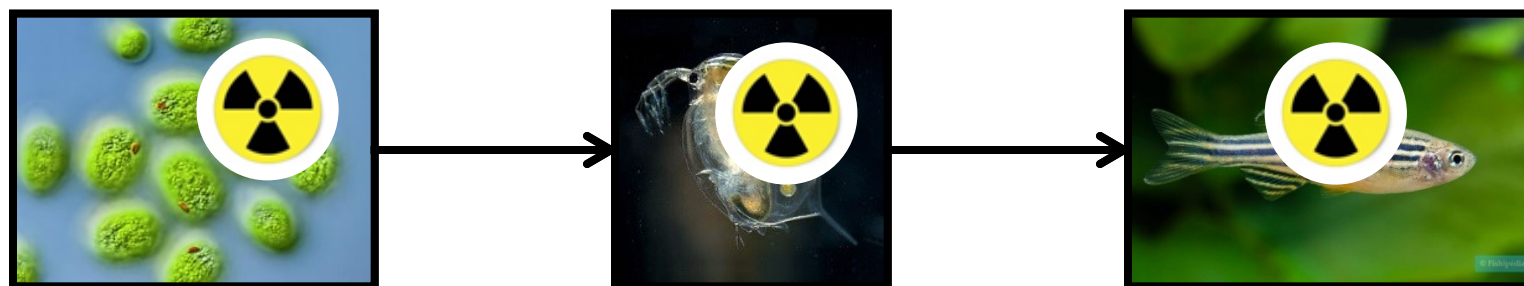


Experimental plan

- ^{14}C kinetics in Common carp

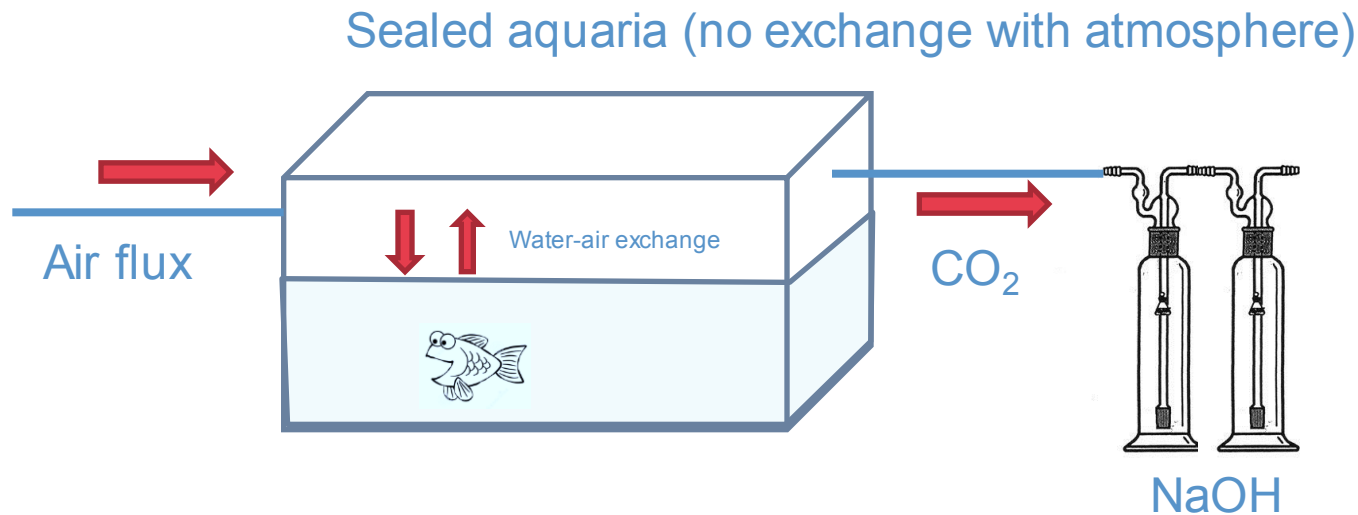


- Model validation on a simple trophic chain



Objectif : Quantification of ¹⁴C released through respiration

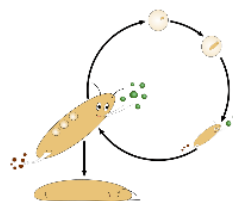
- To obtain ¹⁴C complete budget among all metabolic processes.
- CO₂ gas traps will be set up with air bubbling in NaOH solution (1M).



Thank for attention!



- IRSN PhD congress 2018 (Poster) and 2019 (platform)
- Congress of Doctoral school (Aix-Marseille University)(Poster)
- Sixth International Symposium on DEB theory (Brest)



DEB2019 1-12 April 2019 / Brest (France)

Sixth International Symposium and Thematic School
on DEB theory for metabolic organization

Espèces	Bq/kg C		
	Min	Max	Moyenne
Silure glane	237	334	286
Perche	234	931	466
Lamproie marine	247		
Hotu	202	212	207
Grande alose	249		
Gardon	231	1262	453
Chevesne	200	2000	465
Carpe commune	559	581	570
Brochet	234	340	270
Brème commune	201	2830	1138
Barbeau fluviatile	204	2300	528
Anguille	213	1393	587

Catabolique appauvrissement et anabolique enrichissement

The dimensionless reshuffling coefficients (α)

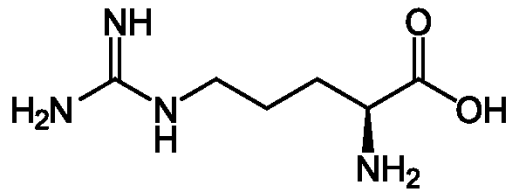
1) specify what fraction of N atoms in substrate s ends up in product p in transformation k ($k \in \{A, G, L1, L2\}$).

- Among four compartments: food (X), Feces (P), Reserve (E), structure (V)
- One elemental composition each
- Stoichiometric equilibrium

Two reactions at a time: Energy for anabolism is brought by catabolism : We detail the catabolic and anabolic routes of each chemical transformation to allow selection of substrate molecules depending on their isotopic composition. The catabolic route of a transformation uses substrates to produce energy for the anabolic route of the transformation. The anabolic route of a transformation uses this energy and substrates as a source of building blocks to produce a given compound. In the growth transformation for instance, reserve is used as a source of energy as well as building blocks to produce structure.

Different sources of ^{14}C

Amino acid: Arginine



PROTEIN METABOLISM

Structure (collagen)

Contraction (myosin)

Transport (albumin)

Immune system
(immunoglobulin)

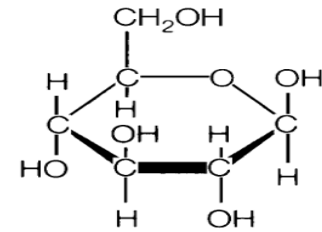
Glycerol



LIPID METABOLISM

Mono-, Di- and Tri-
glycerids, Phospholipids

Glucose



CARBOHYDRATE
METABOLISM

Glycogen or
triglycérid
(muscle, liver)