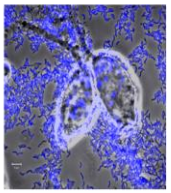
Pourquoi ai-je arrêté de modéliser les procédés de digestion anaérobie ?

JEAN-PHILIPPE STEYER

INRAE, LABORATOIRE DE BIOTECHNOLOGIE DE L'ENVIRONNEMENT, F-11100 NARBONNE

$$\frac{d\,\text{  }}{dt} = F\left(\text{  }, \text{  }, \text{  }, t\right)$$

Who am I ?

MSc in Electronics,
Electrotechnics and Automation

PhD in Applied Mathematics
and Artifical Intelligence
for pharmaceutical bioprocesses

Pergamon

Adv. Space Res. Vol. 14, No. 11, pp. (11)307–(11)312, 1994
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0273–1177/94 $7.00 + 0.00

QUALITATIVE REASONING METHODS FOR CELSS MODELING

F. Guerrin,* K. Bousson,** J.-Ph. Steyer*** and L. Travé-Massuyès**

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** *Centre National de la Recherche Scientifique, System Analysis and Automatic Control Laboratoire, 31077 Toulouse, France*
*** *Lehigh University, Chemical Process Modeling and Research Center, Bethlehem, PA 18015, U.S.A.*

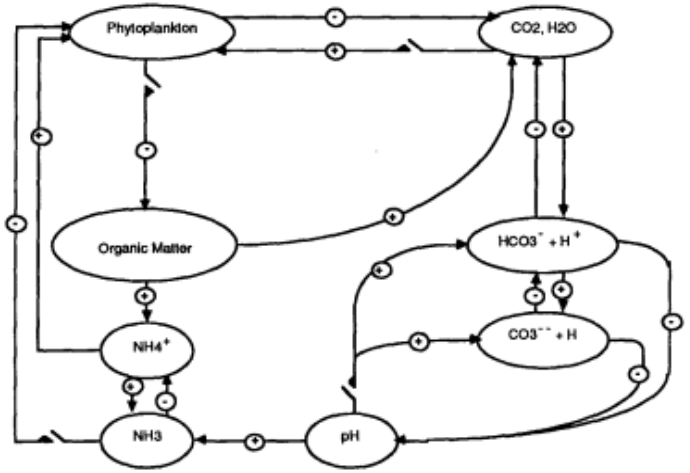
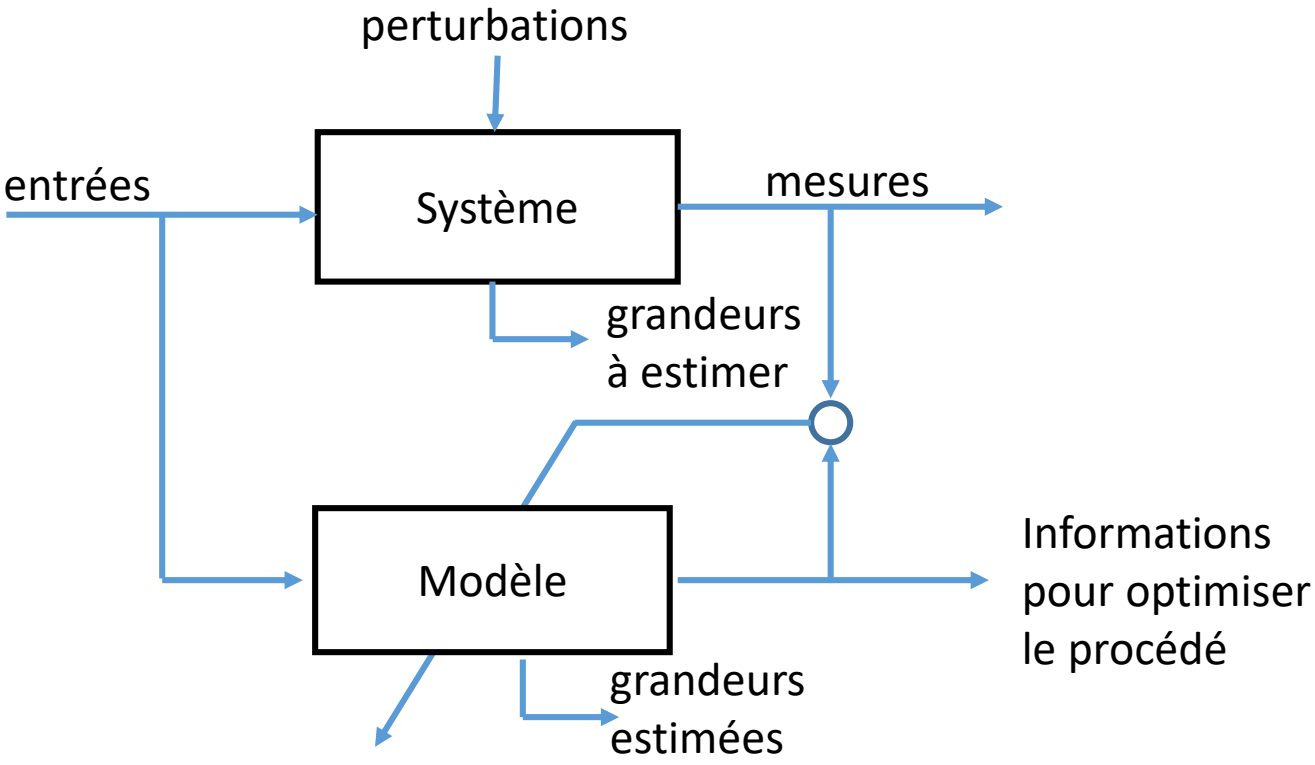


Fig. 1. Directed signed graph representation of a process in an aquatic ecosystem.

A quoi peut servir un modèle ?



Pour garantir certaines propriétés (stabilité par exemple), le modèle doit être simple !

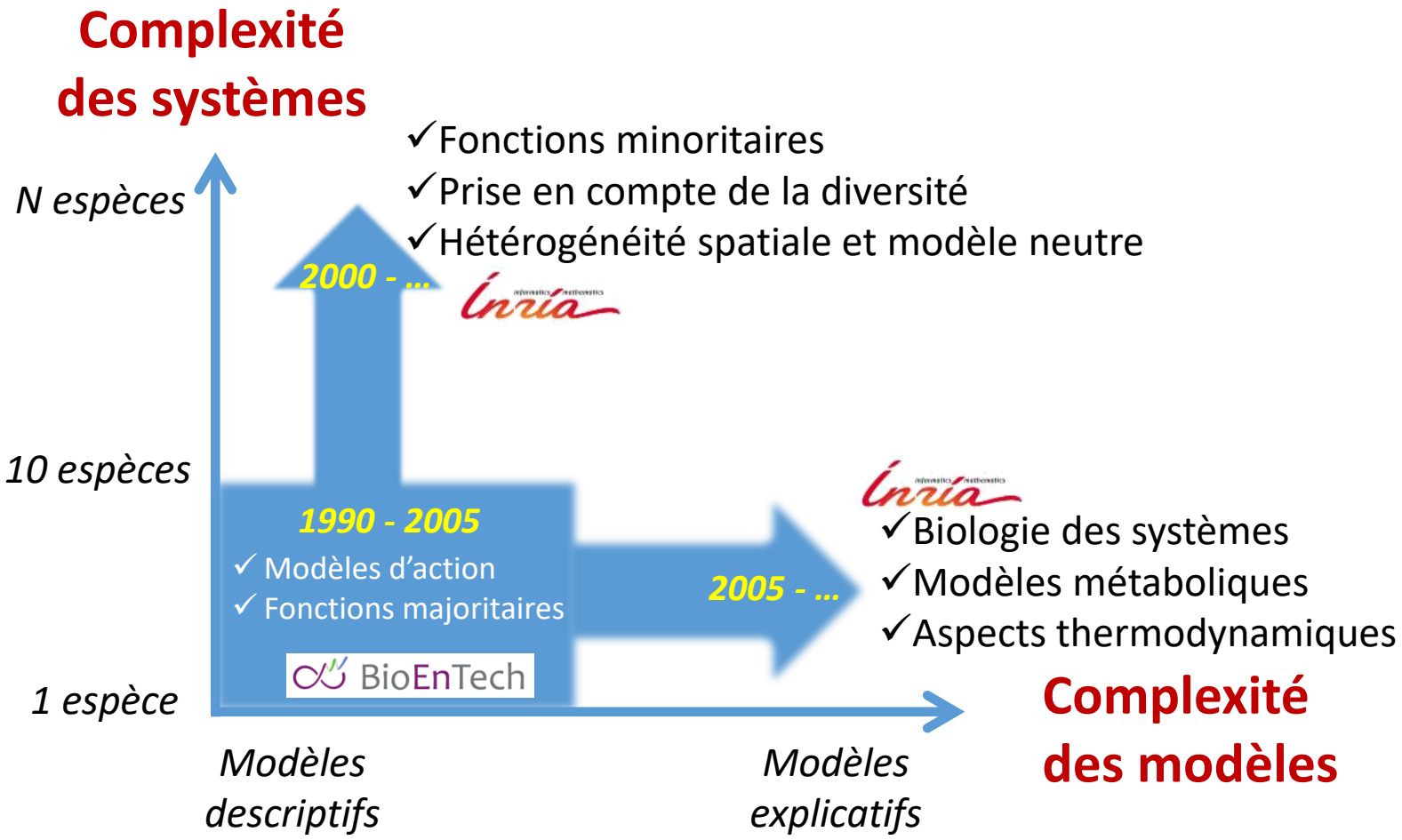
Some basic ideas

1) A model is nothing else than *a translation* (in mathematic form) *of the reality observed at the present time.*

2) A *good* model is a model built by someone who *really* knows the process.

3) Building a model without referring to its goal is a non-sense: *never forget the final objective of the model !*

Mes approches de la modélisation



Anaerobic digestion

A biological process in Nature that degrades organic matter (OM)

OM (without O_2) →  + CH_4 + CO_2 (+ residual OM)

(50 to 70%) (30 to 50%)

Anaerobic digestion in practice






Anaerobic digestion in practice

Très grande diversité, complexité et variabilité de matières premières

Déchets alimentaires

Eaux résiduaires

Résidus agricoles

Boues

Déjection animales

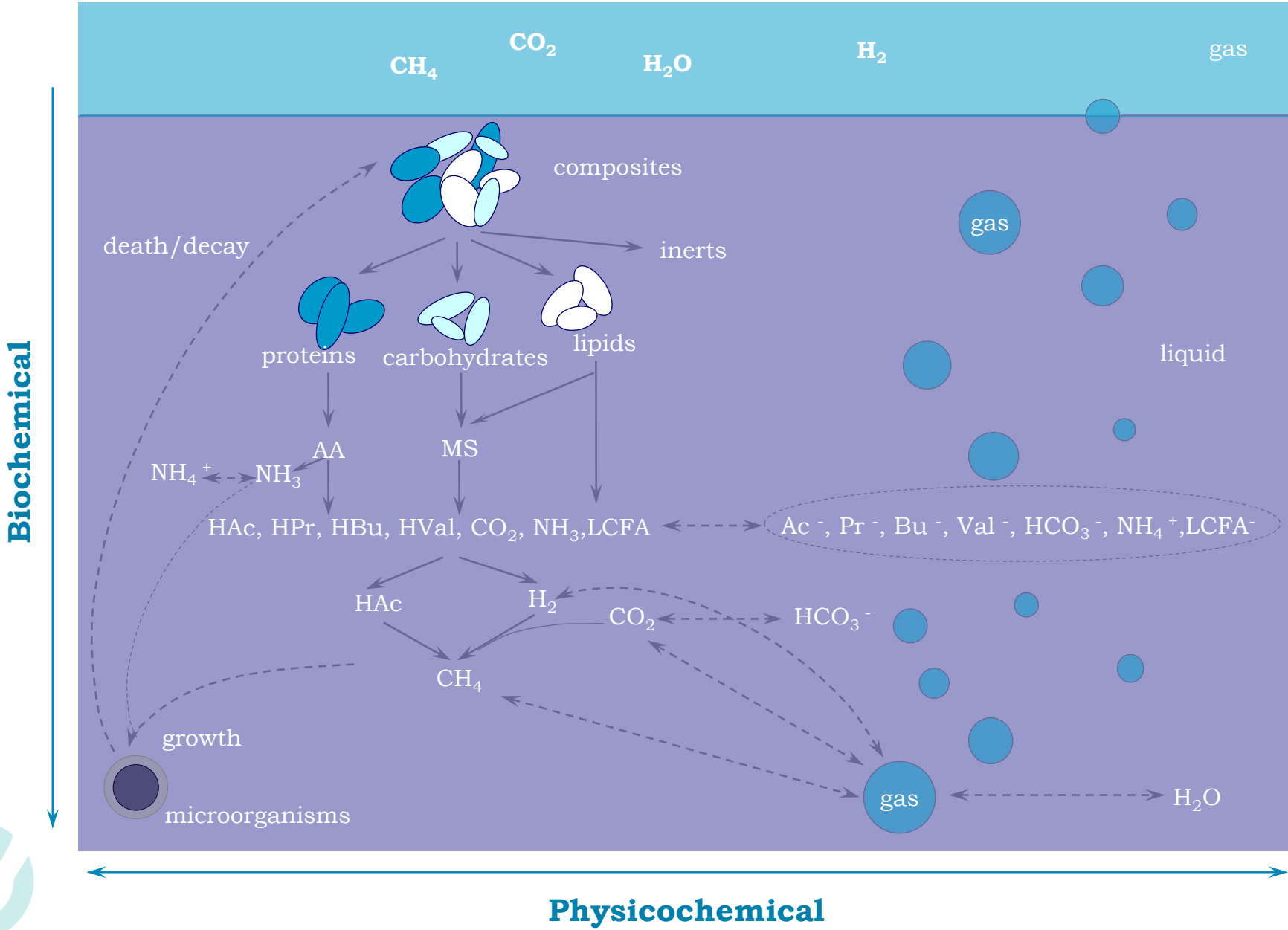
Déchets abattoir

Drèches

Cultures intermédiaires

CH_4 = ?

Conversion processes in AD process



Performances of AD Processes

Anaerobic lagoon

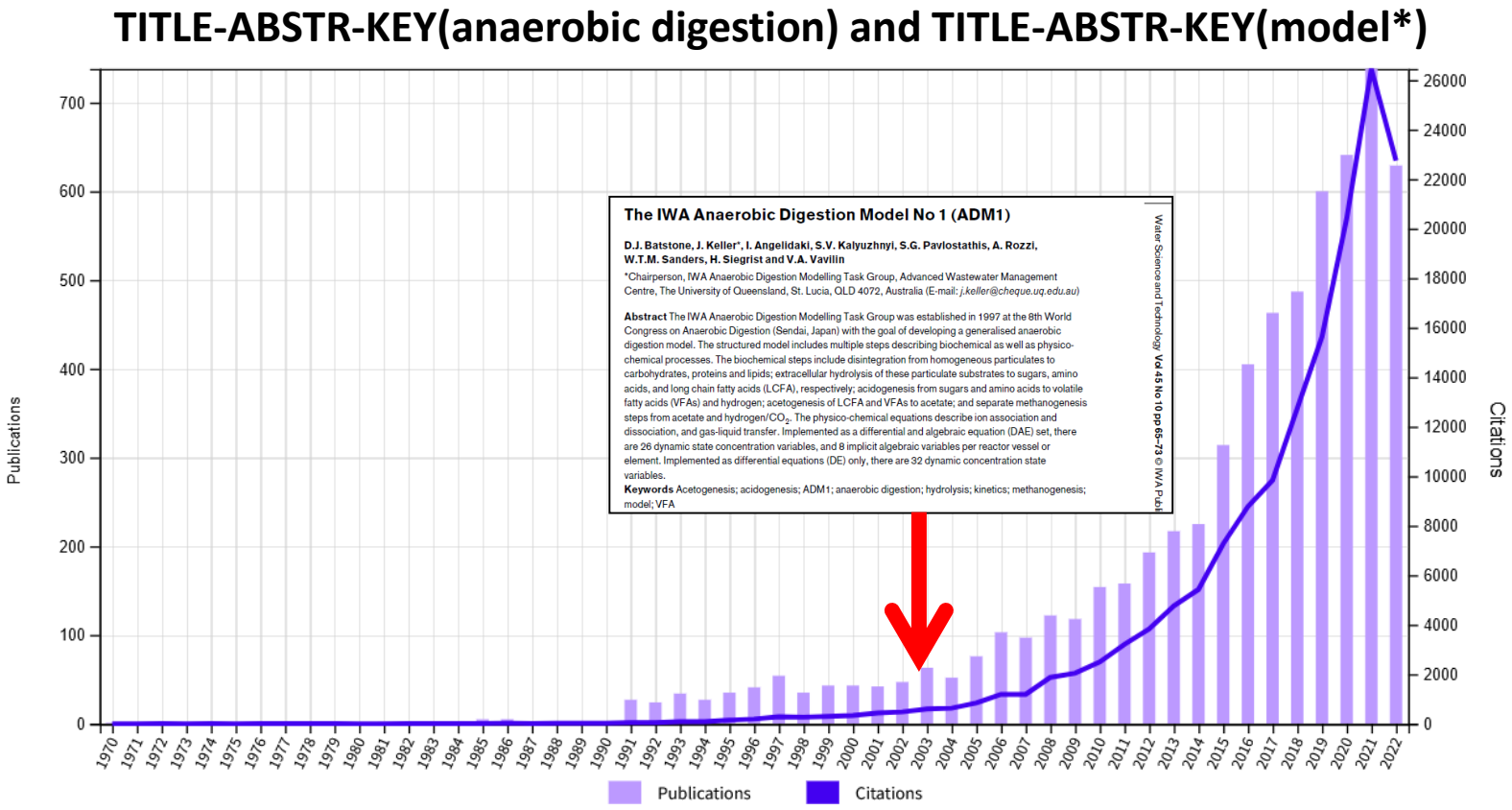
Fluidised bed reactor

Same wastewater, same quatity of COD removed and of biogas produced

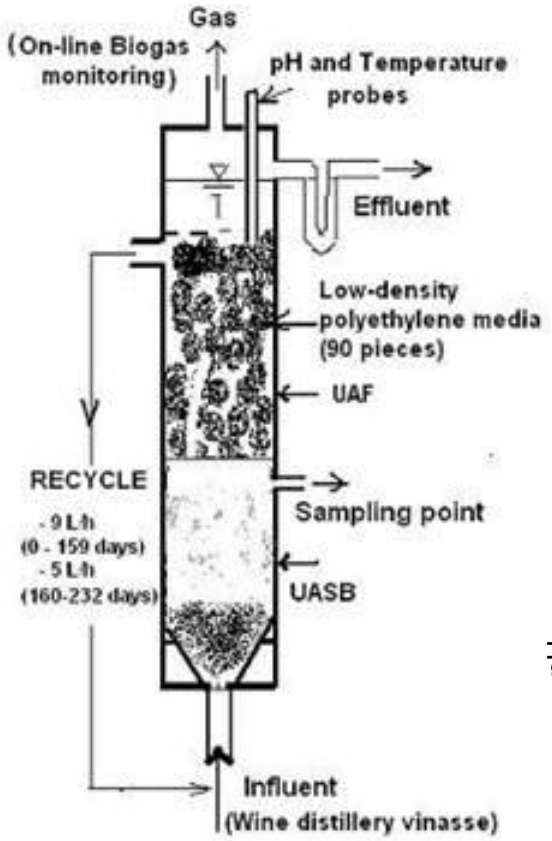
BUT...

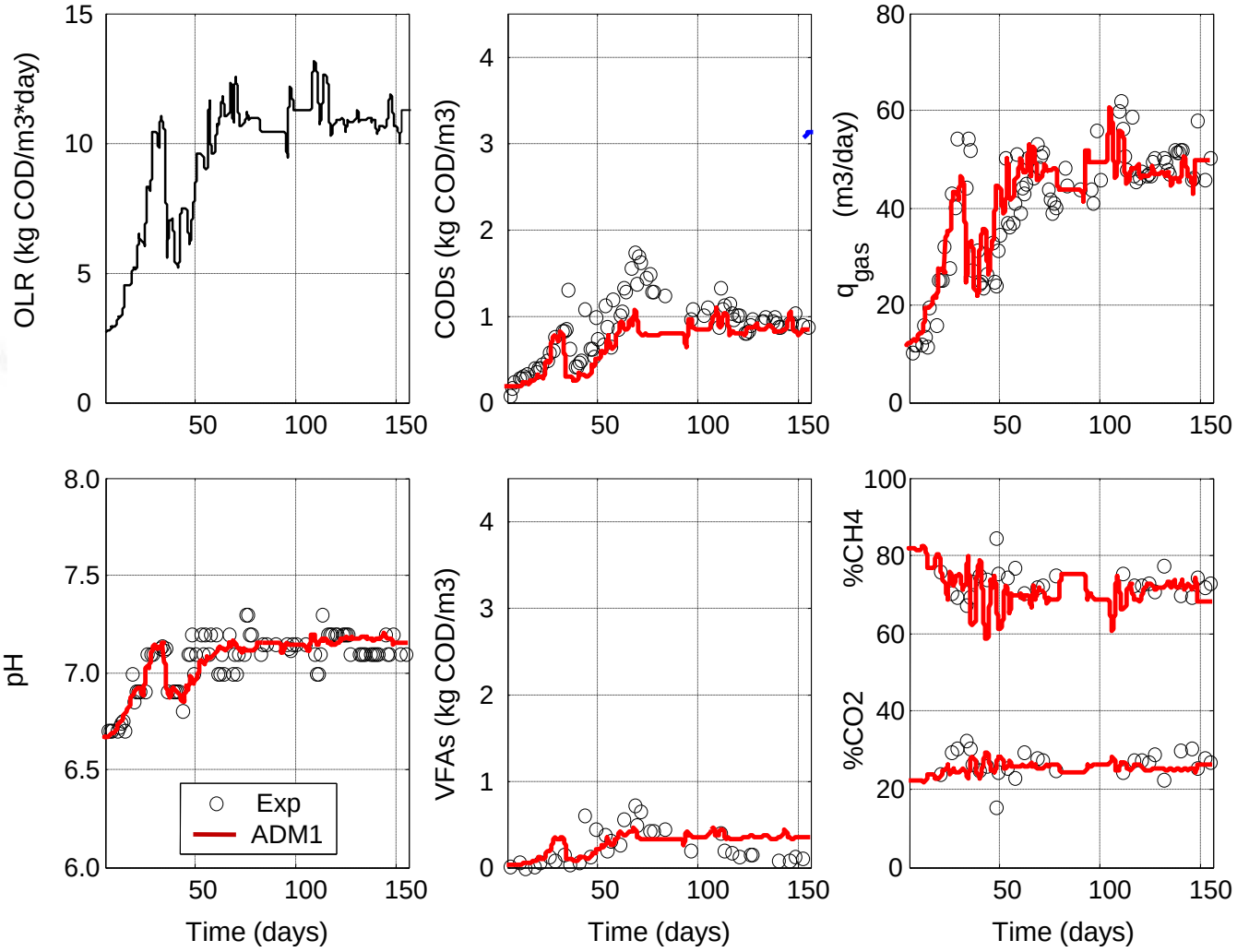
✓ 300 m^3	✓ 0.15 m^3
✓ 21 days	✓ 1 day
✓ open loop (no control)	✓ closed loop control

Modeling AD processes in literature

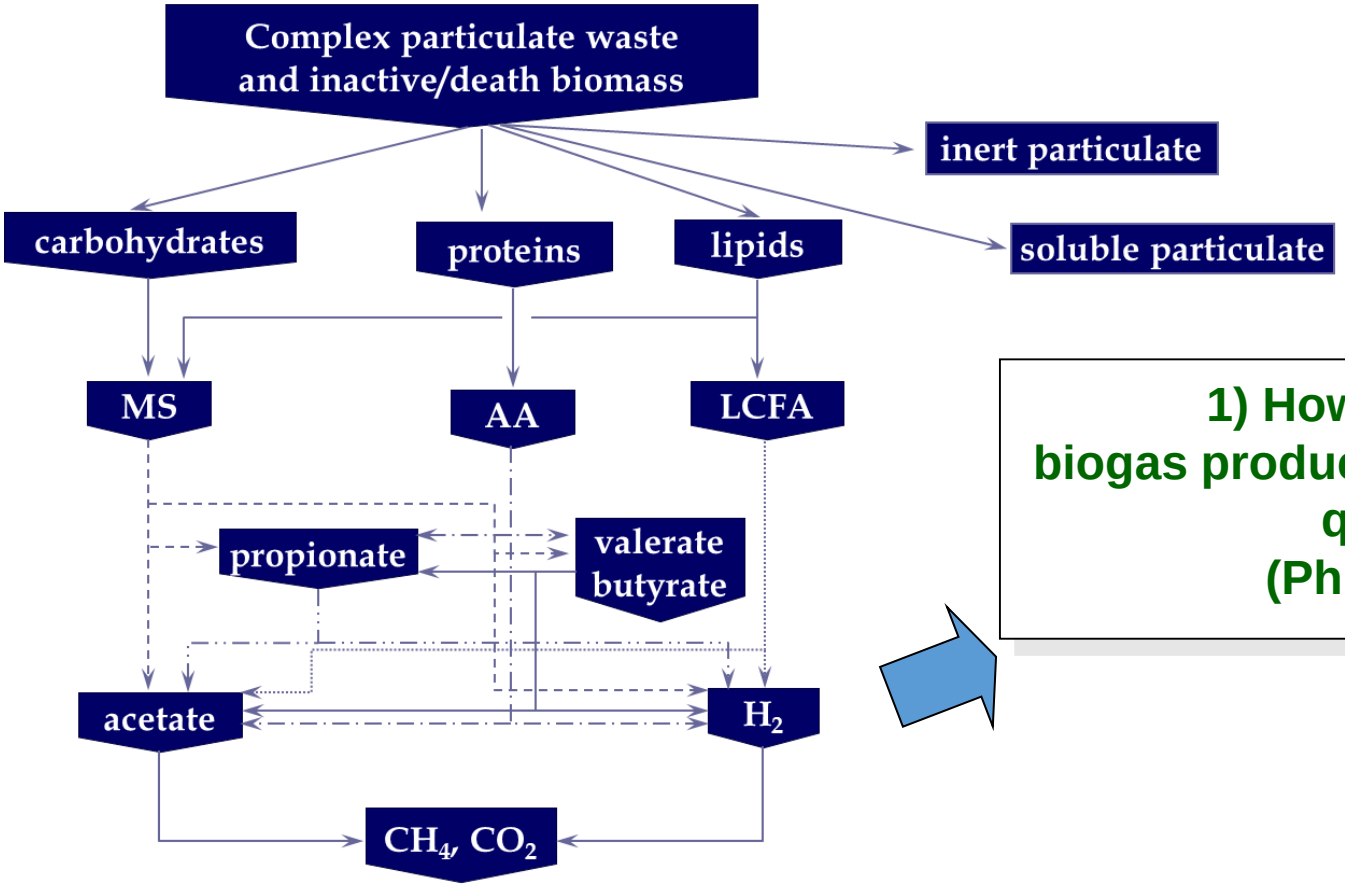


ADM1 works !!!


Gas
(On-line Biogas monitoring)
pH and Temperature probes
Effluent
Low-density polyethylene media (90 pieces)
UAF
RECYCLE
- 9 L/h
(0 - 159 days)
- 5 L/h
(160-232 days)
Sampling point
UASB
Influent
(Wine distillery vinasse)


OLR (kg COD/m3*day)
CODs (kg COD/m3)
q_{gas} (m3/day)
pH
VFAs (kg COD/m3)
%CH4
%CO2
Exp
ADM1
Time (days)
Time (days)
Time (days)

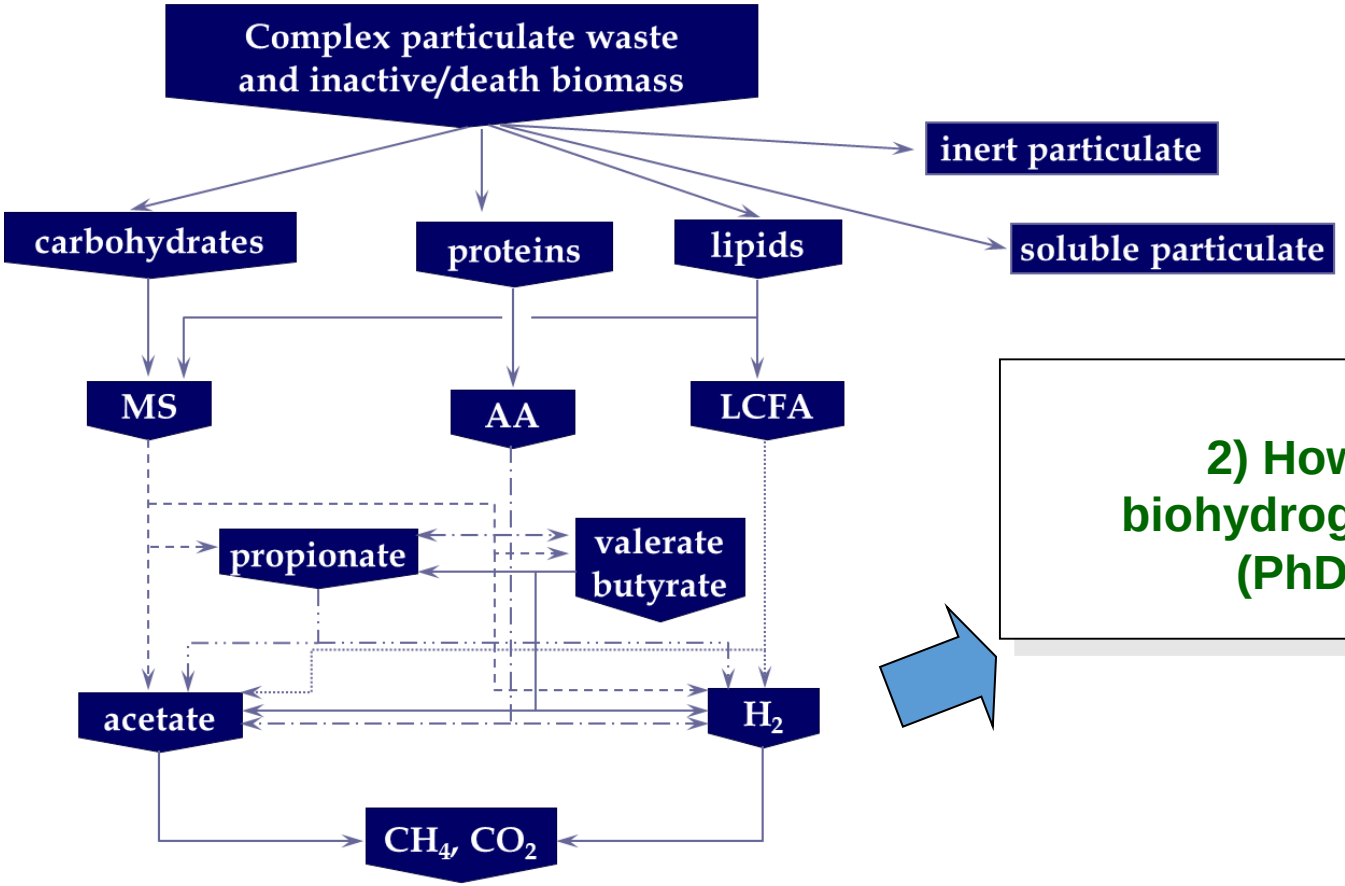
Modeling of AD processes



1) How to optimise biogas production in quantity *and* quality ?
(PhD J. Hess)

In terms of applications: Better understanding of the dynamic link between complex substrate and biogas quantity and quality

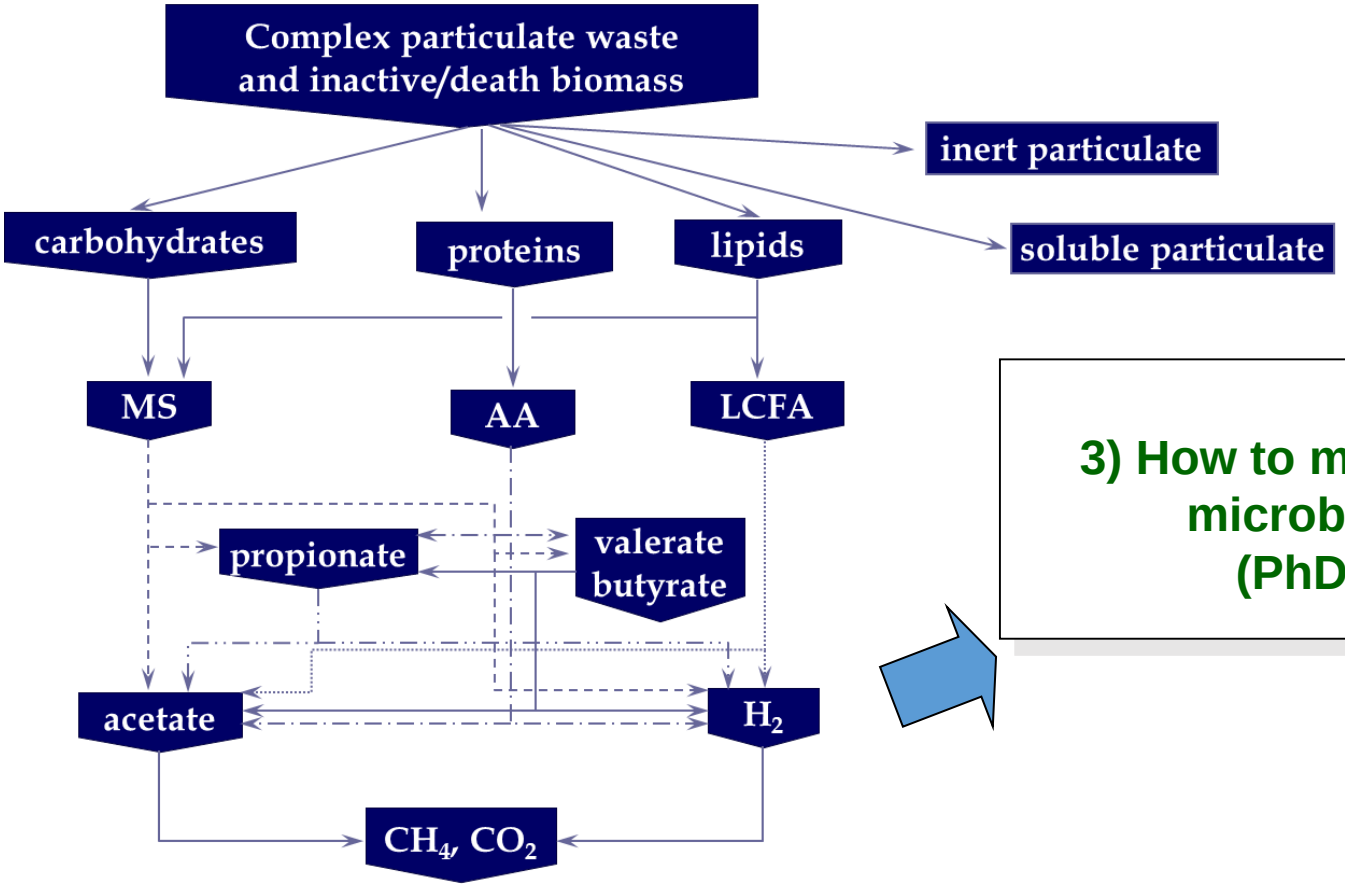
Modeling of AD processes



2) How to optimise biohydrogen production ? (PhD C. Aceves)

In terms of applications: How to drive the process to « inactivate » some species and favour others?

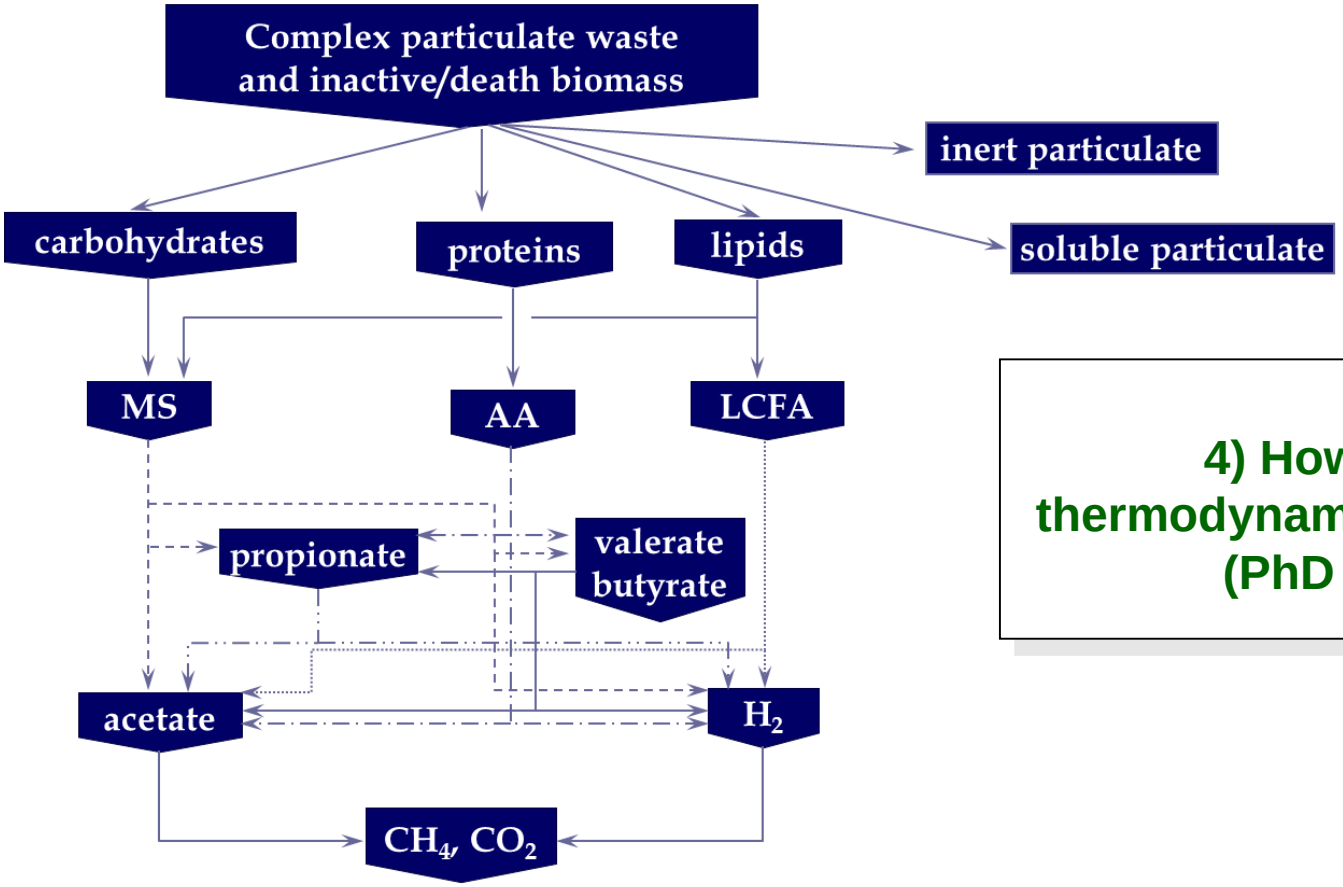
Modeling of AD processes



3) How to model and optimise microbial diversity ? (PhD I. Ramirez)

In terms of applications: could we find relationships between process performance and microbial community structure ?

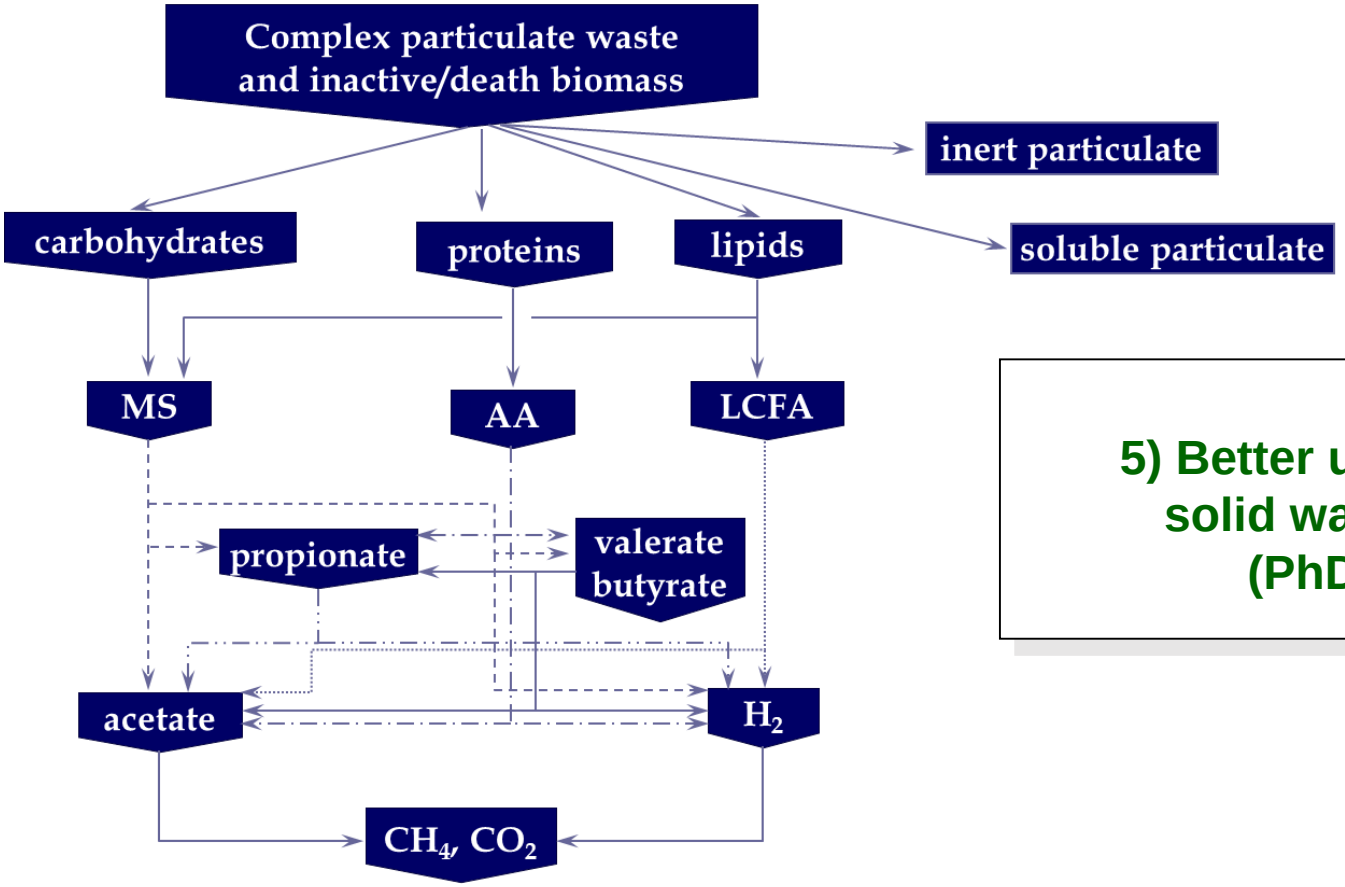
Modeling of AD processes



4) How to integrate thermodynamical consideration ? (PhD J. Bastidas)

In terms of applications: a better handling of physico-chemical conditions for a better modeling and a new class of controllers

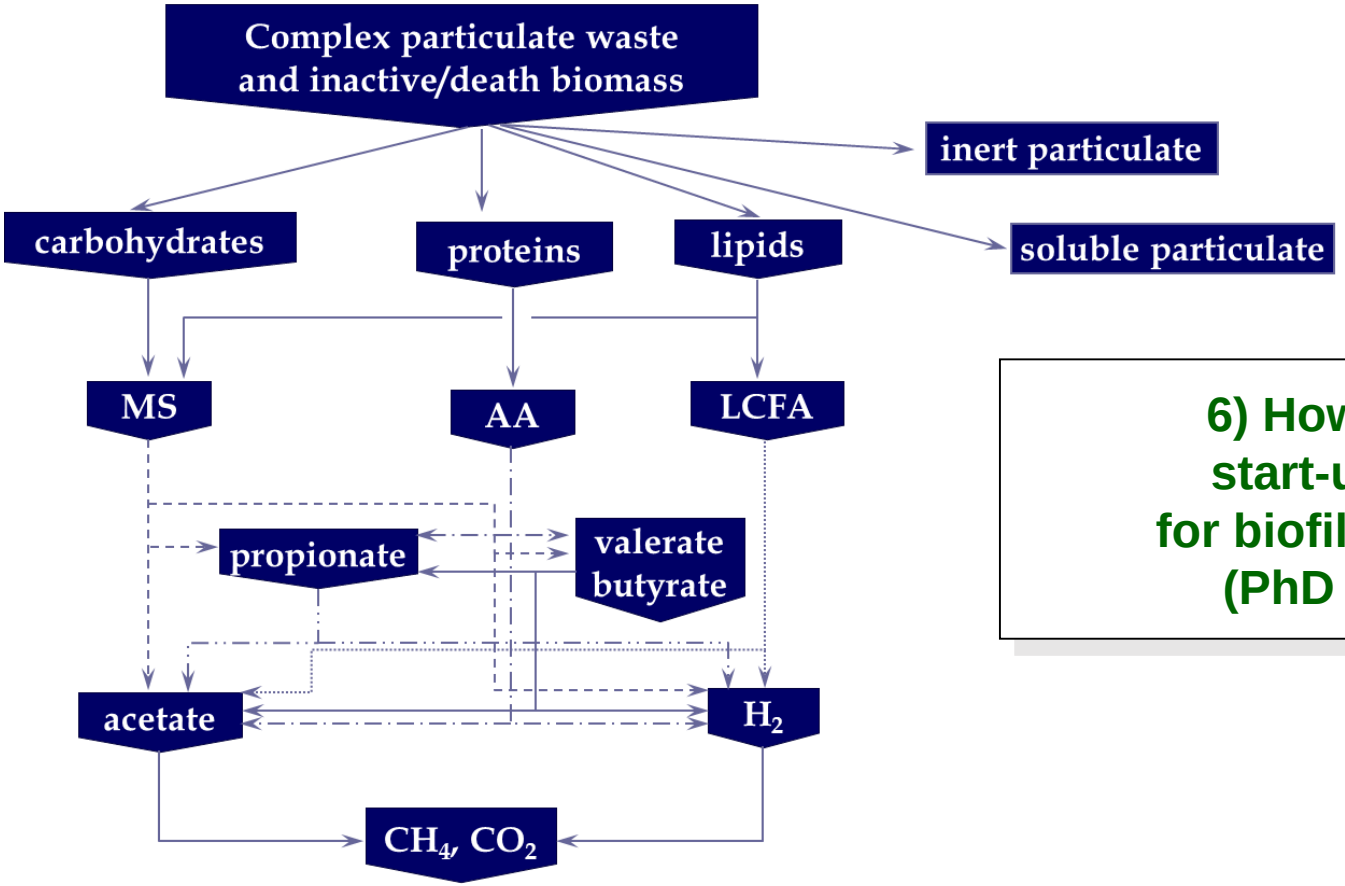
Modeling of AD processes



5) Better understanding of solid waste hydrolysis (PhD A. Mottet)

In terms of applications: could we find easy and reliable indicators to predict solid waste biodegradaility ?

Modeling of AD processes



6) How to optimise start-up strategies for biofilm processes ? (PhD R. Cresson)

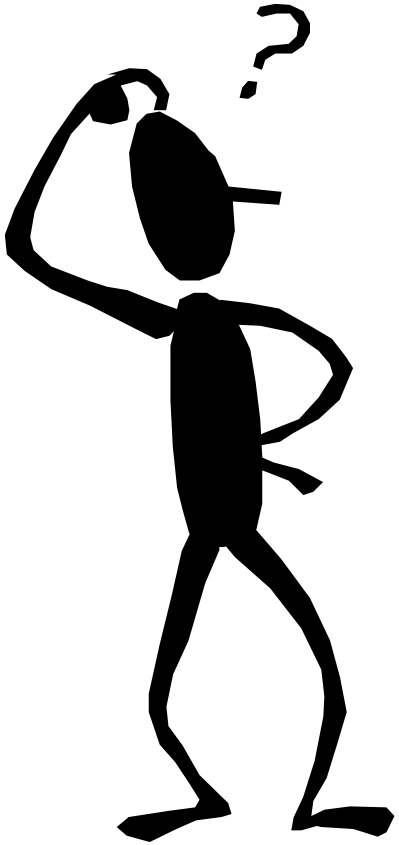
In terms of applications: Minimise the start-up to achieve specific peformances while maximising flexibility of the microbial population

As a conclusion on modeling

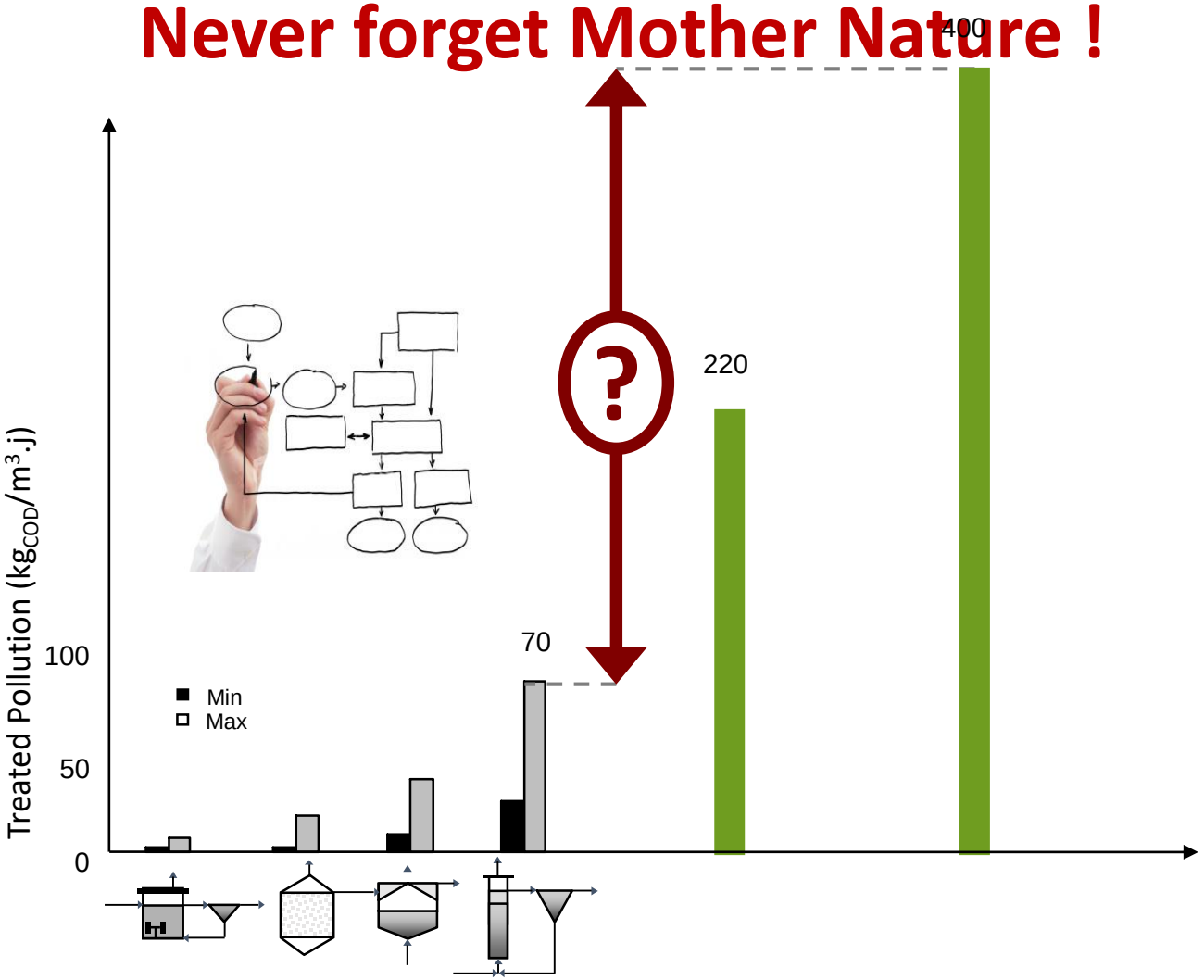
Anaerobic Digestion Modelling
A Practical Scientist's Tool ?
A Practical Scientist's Toy ?

BOTH !!! ***And both are very useful !***

Tout est résolu ?



Never forget Mother Nature !



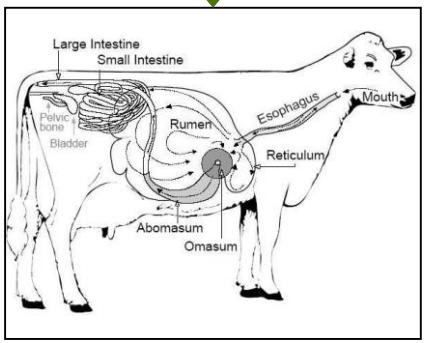



Never forget Mother Nature !

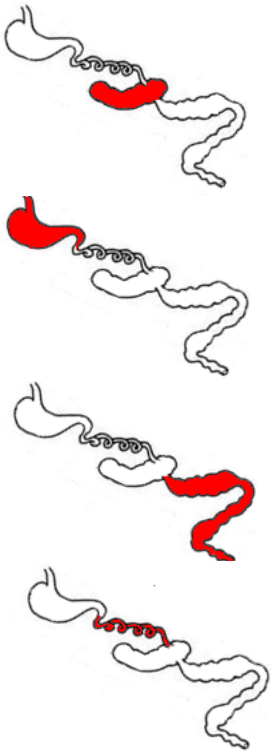
Bioenerg. Res. (2013) 6:1063–1081
DOI 10.1007/s12155-013-9339-y

Overview of the Oldest Existing Set of Substrate-optimized Anaerobic Processes: Digestive Tracts

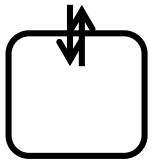
Jean-Jacques Godon · Laure Arcemisbéhère · Renaud Escudié · Jérôme Harmand · Edouard Miambi · Jean-Philippe Steyer



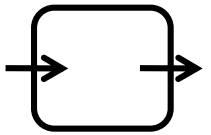
Never forget Mother Nature !



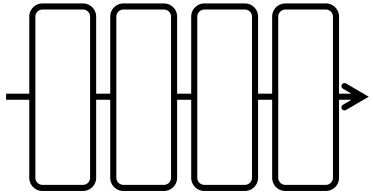
Batch reactor



Continuous stirred tank reactor (CSTR)



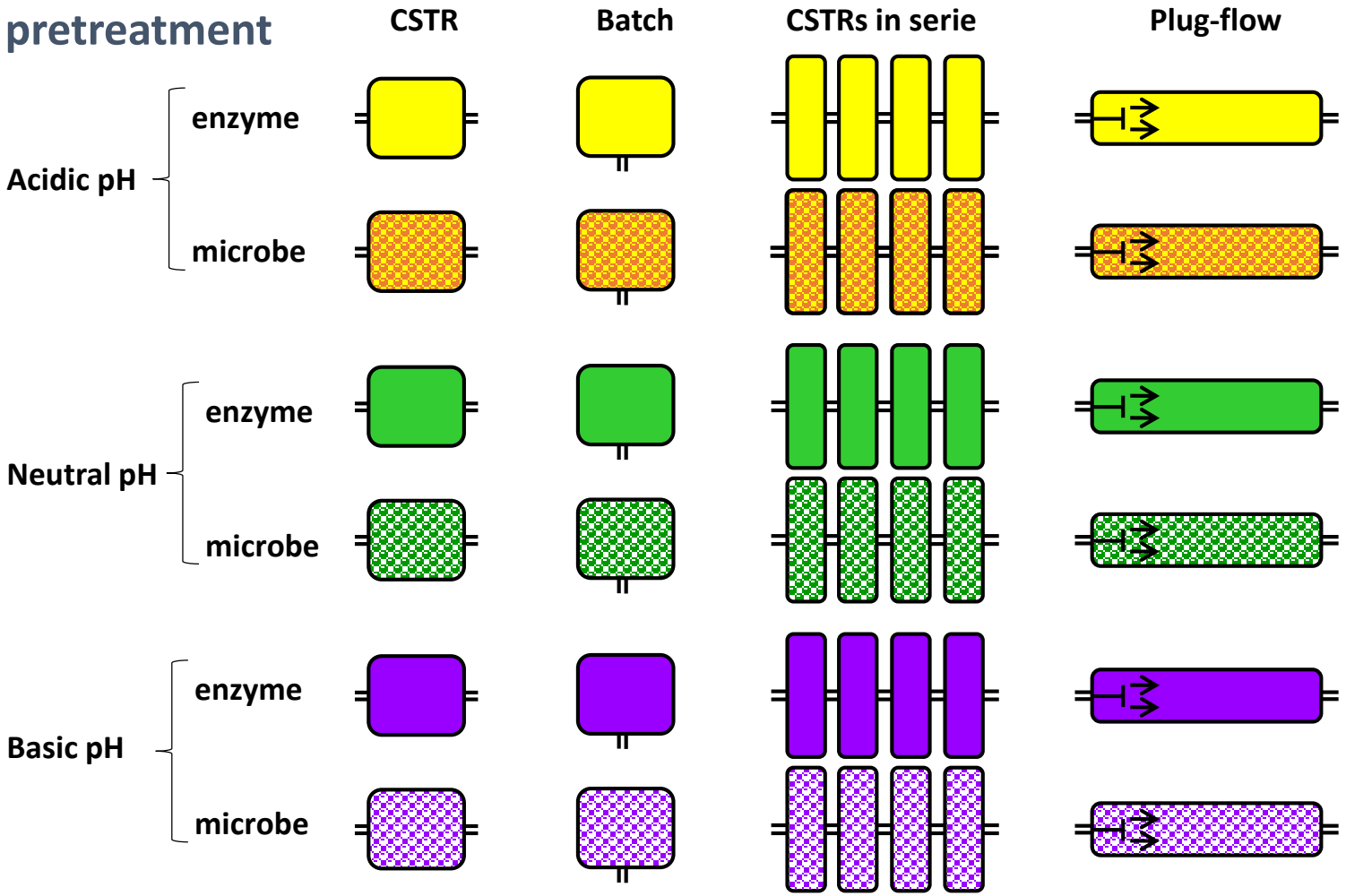
CSTRs in serie



Plug-flow reactor

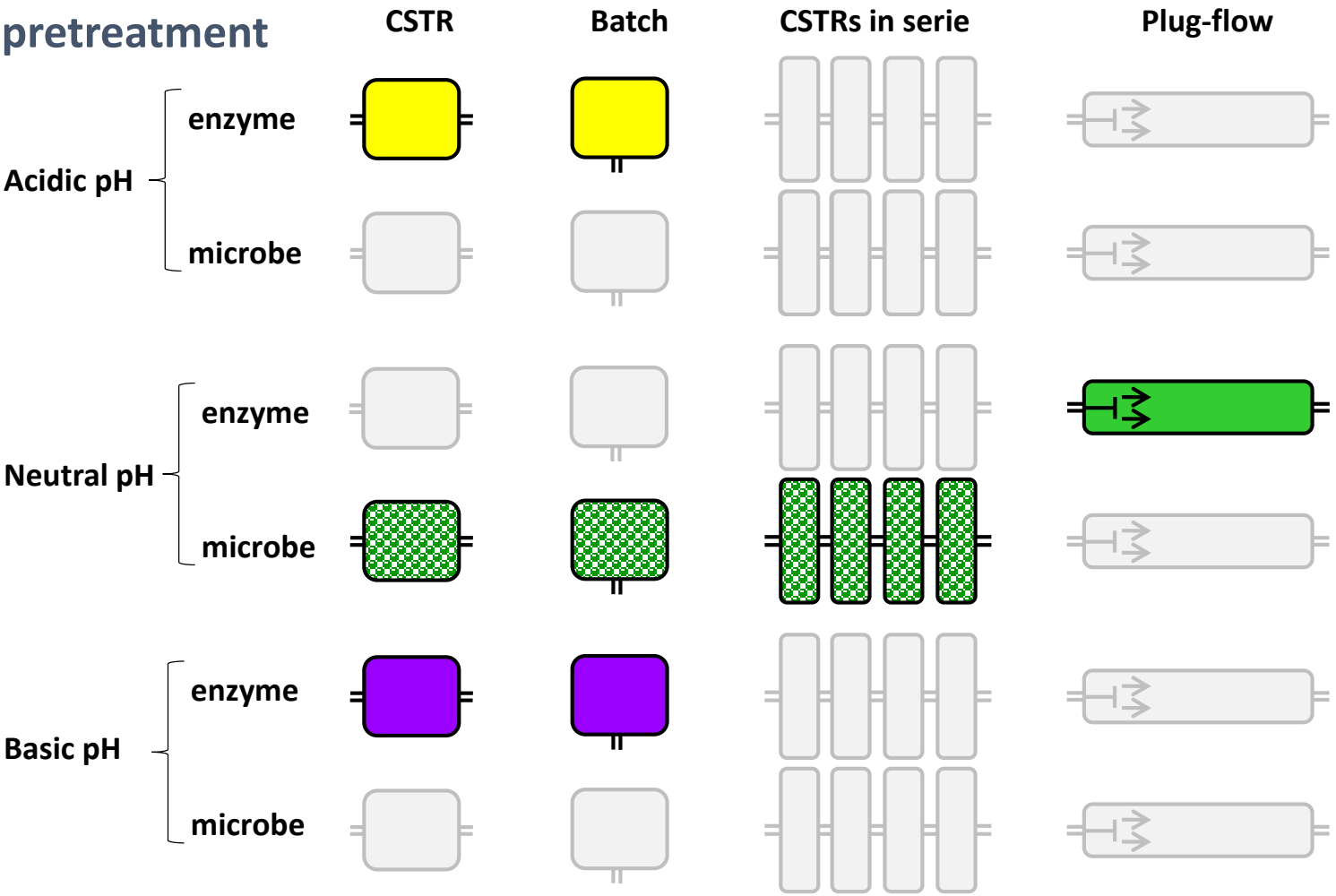
Never forget Mother Nature !

In terms of pretreatment



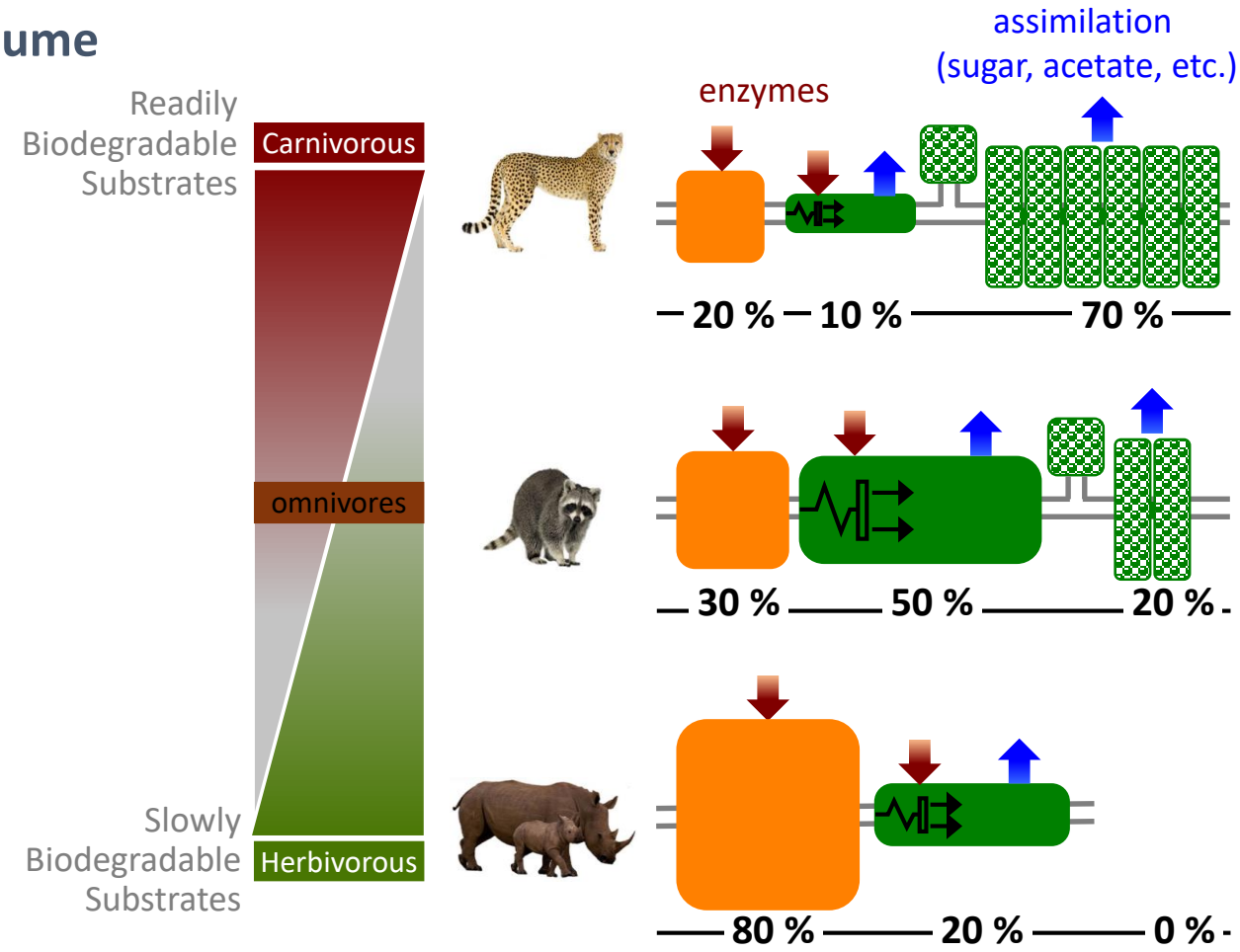
Never forget Mother Nature !

In terms of pretreatment



Never forget Mother Nature !

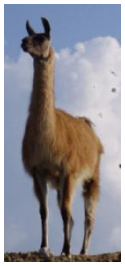
In terms of volume



Never forget Mother Nature !

The ‘herbivorous’ configuration

Cow



Lama

Hoazin

Kangaroo

Never forget Mother Nature !

From the analysis of 190 digestive tracts

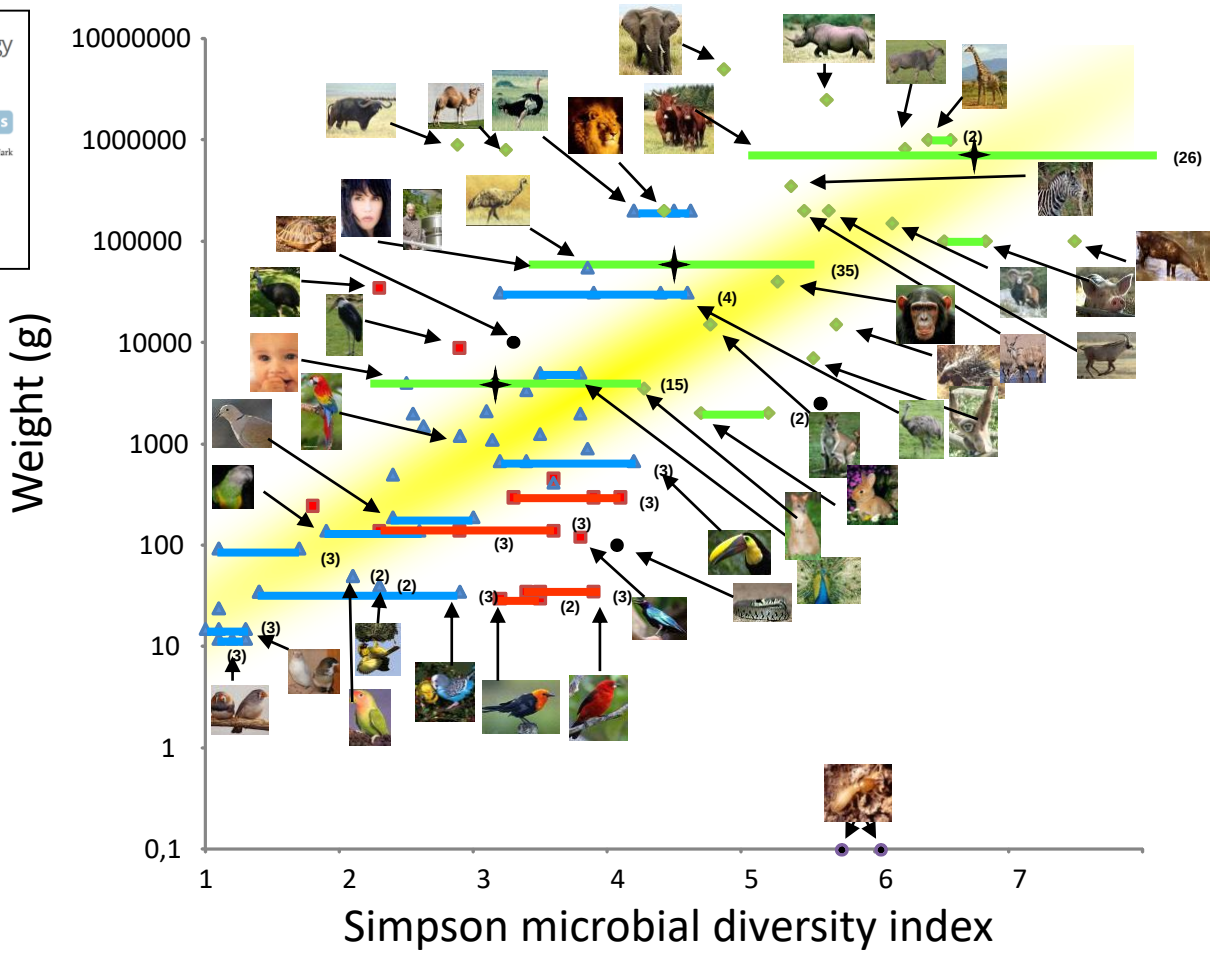
Godon et al. BMC Ecol (2016) 16:12
DOI 10.1186/s12898-016-0071-2

BMC Ecology

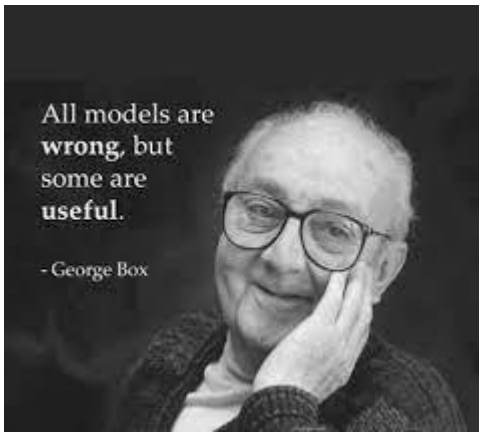
RESEARCH ARTICLE Open Access

Vertebrate bacterial gut diversity: size also matters

Jean-Jacques Godon[1*], Pugazhendi Arulazhagan[1,2], Jean-Philippe Steyer[1] and Jérôme Hamelin[1]



Pour conclure…

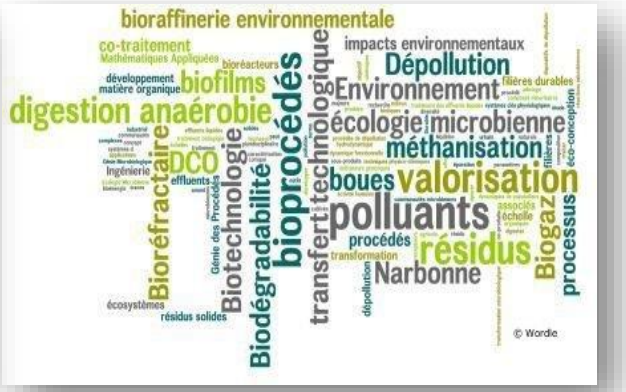


- Apporter une **vision intégrative et systémique** de la formalisation des **interactions microbiennes** (modèle = médiateur disciplinaire pour formaliser)

- Identifier, comprendre et prédire les **propriétés émergentes** des écosystèmes (y compris les dysbioses)

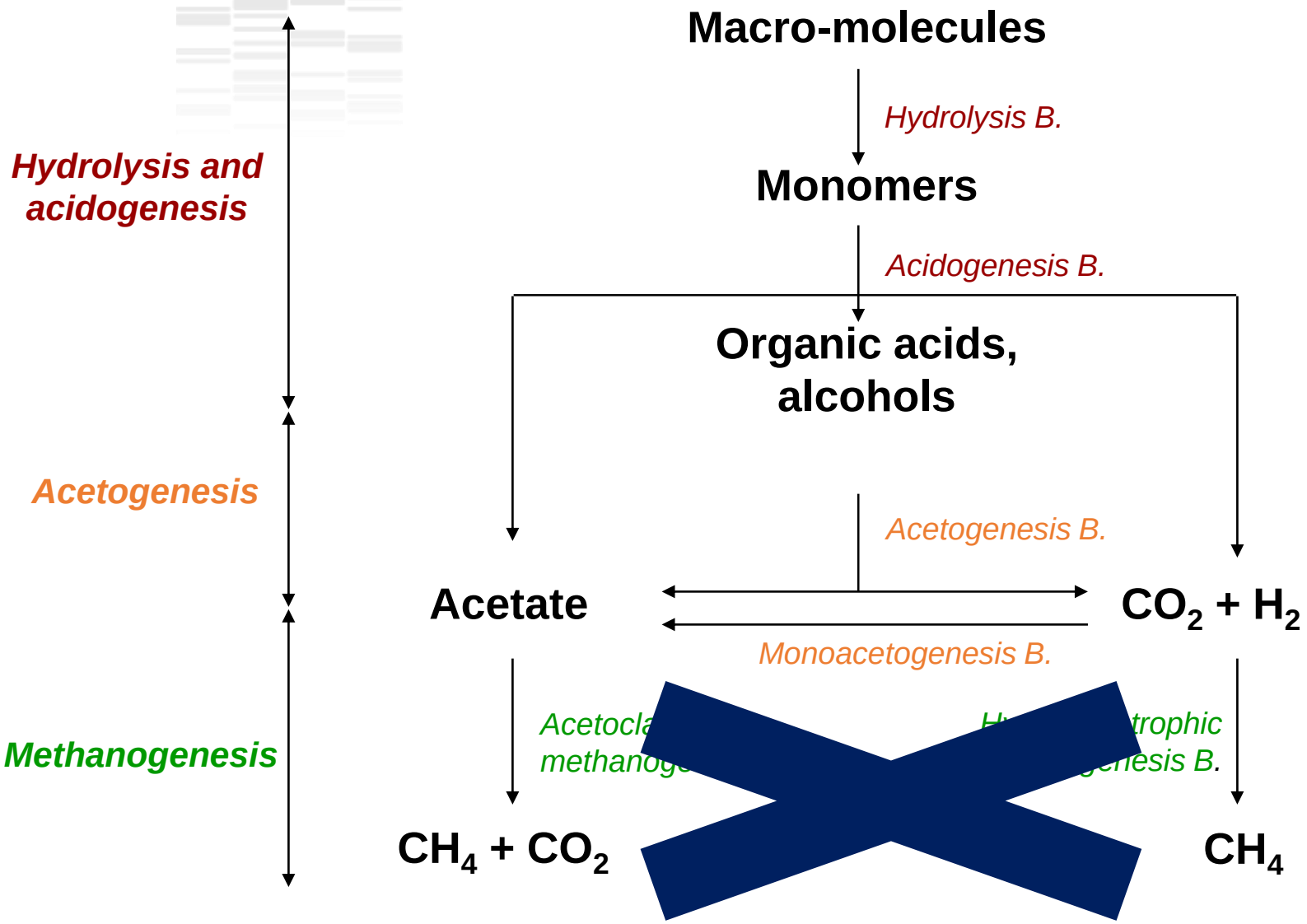
- Maitriser les interactions entre les « **éléments du systèmes** » : les fonctions, les individus, les populations,… chacun des éléments du systèmes pouvant être regardé **à différent niveaux d'intégration** (ingénierie des écosystèmes)

Merci de votre attention !



http://www.montpellier.inrae.fr/narbonne
Jean-philippe.steyer@inrae.fr

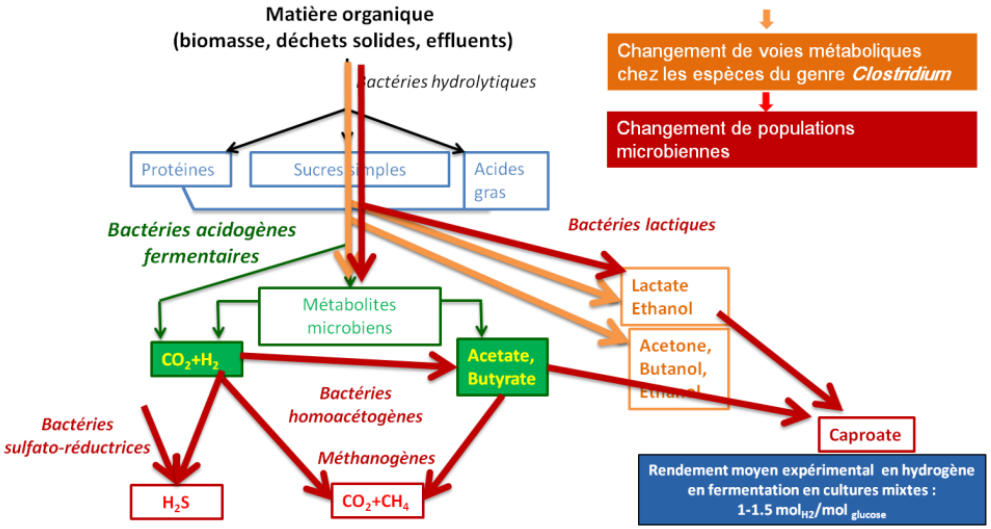
Dark fermentation for VFAs and bioH_2 production



Dark fermentation : low pH and short HRT favoring H_2 and metabolites production !

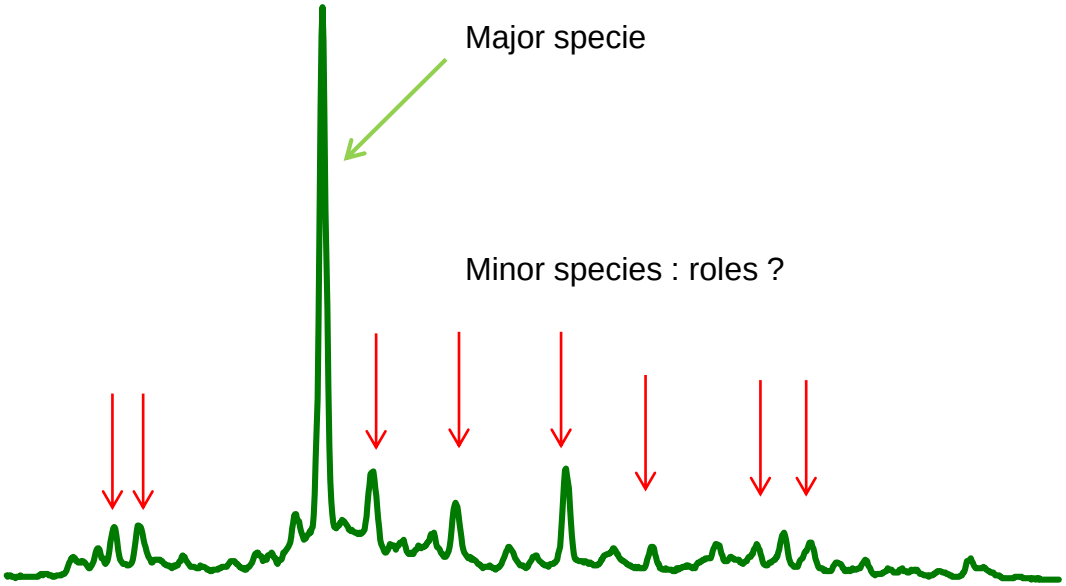
Ecological Engineering for biotic control

Metabolic pathways that produce or consume bio-hydrogen

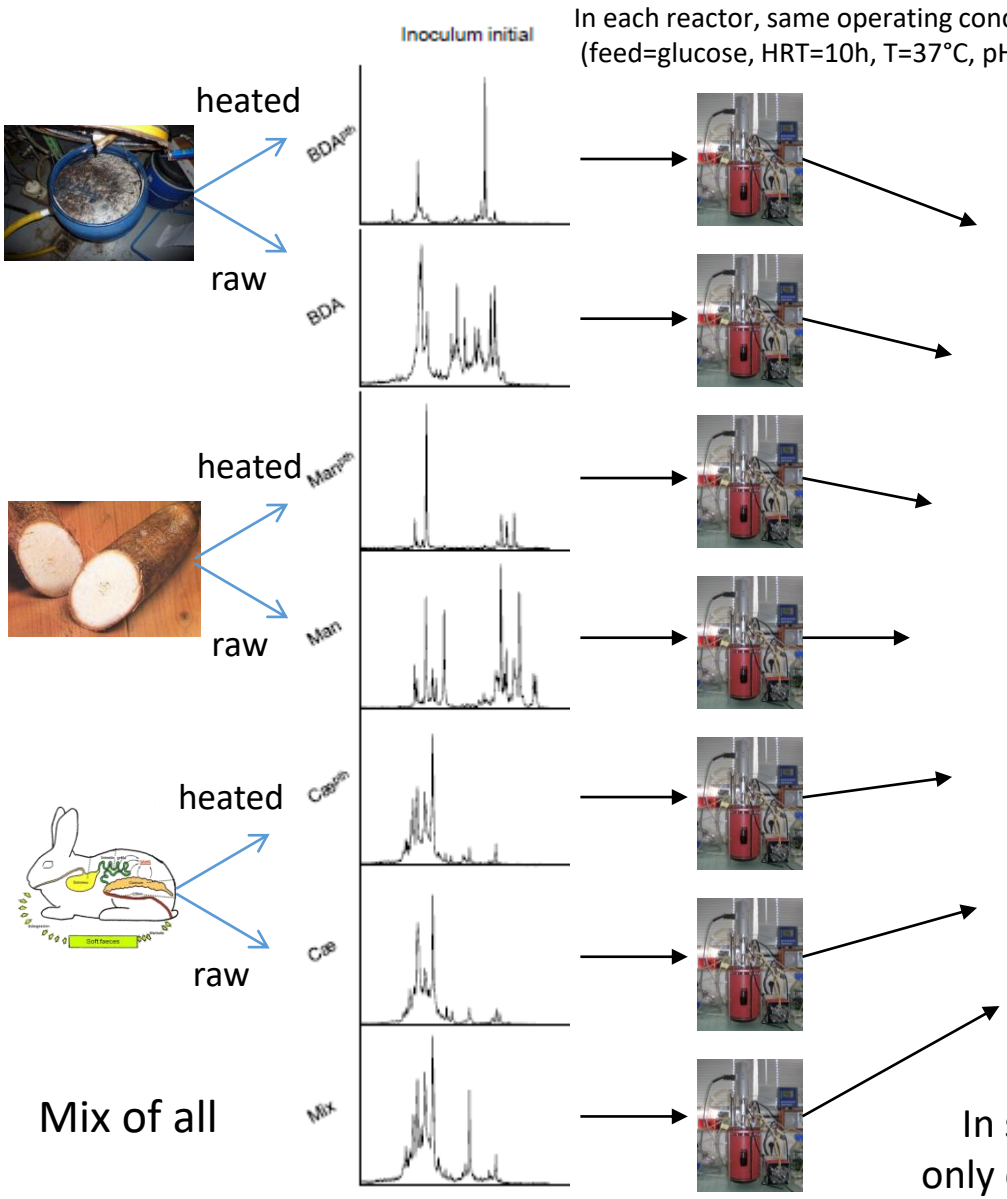


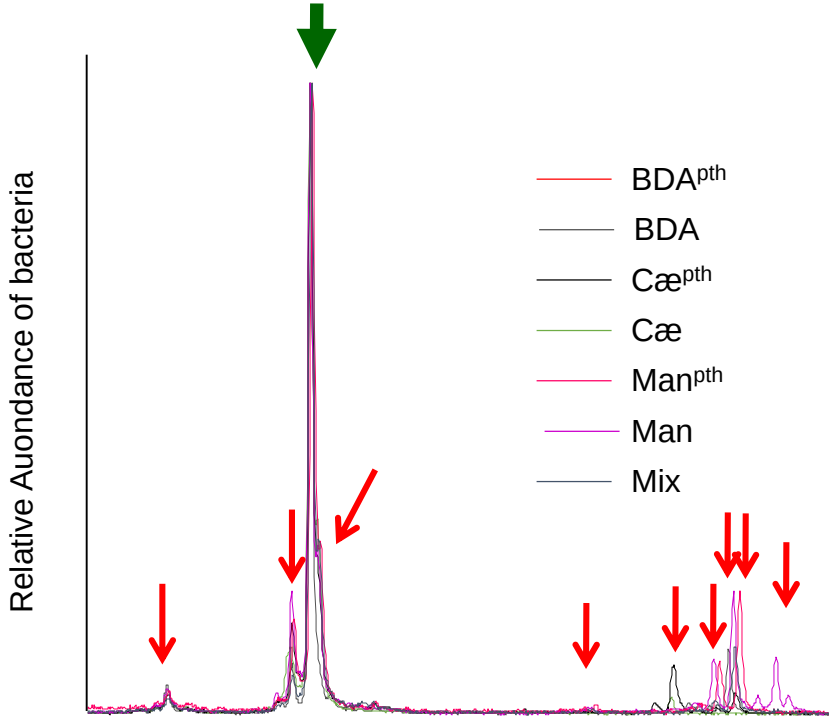
Operating conditions (pH, °C, HRT…) are very well studied

Biotic interactions (link between structure and function of the ecosystem) ?



Ecological Engineering for biotic control



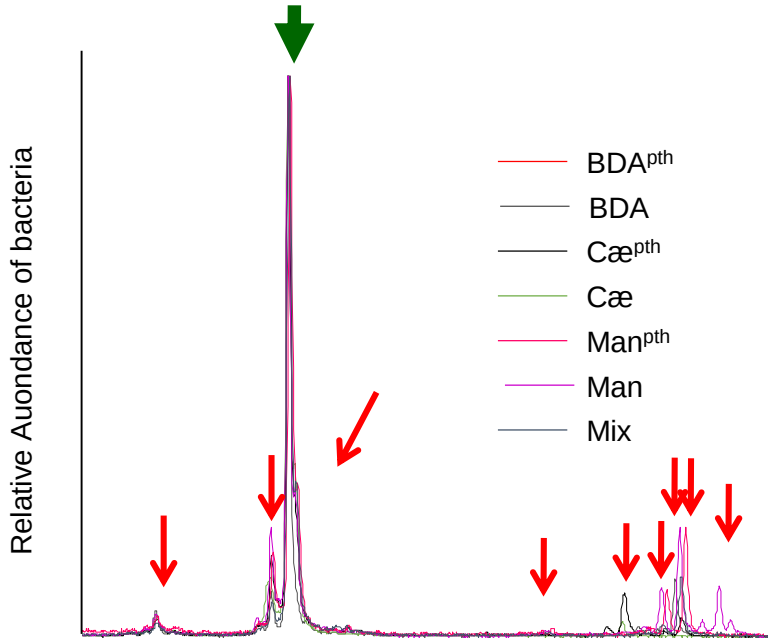


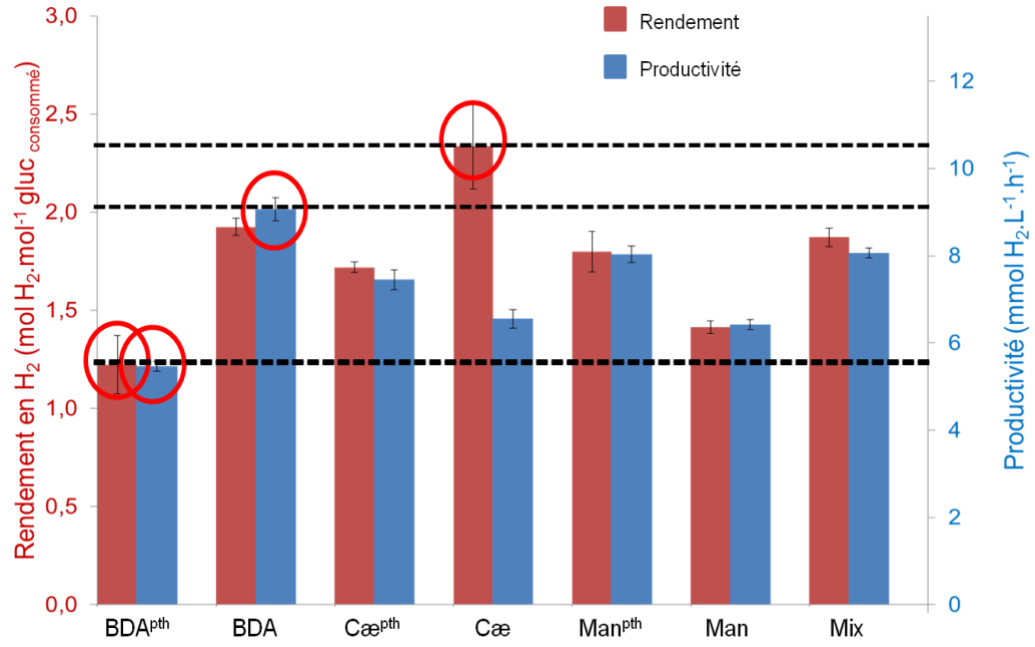
In steady state in each reactor (after several HRTs),
only one major specie (difference only in minor species)

Ecological Engineering for biotic control

Identical major bacteria,
so identical performance, isn't it ?….

NO !!!



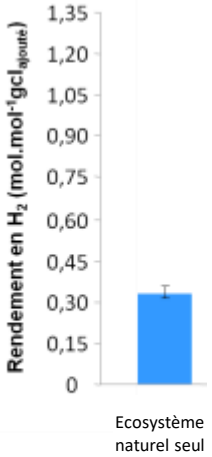


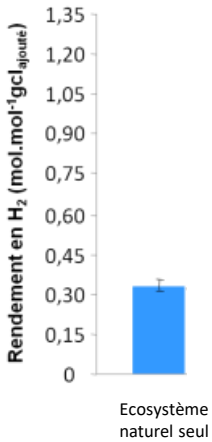
Link between structure and function of the ecosystem ?

Diversity and Engineering of Microbial Ecosystems

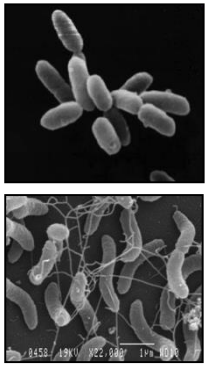
Study of the interactions in microbial ecosystems

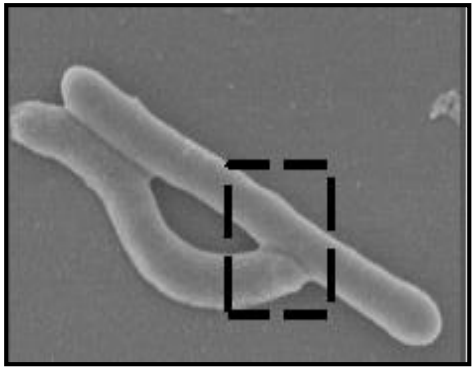
Biotic control of metabolim (biohydrogen)

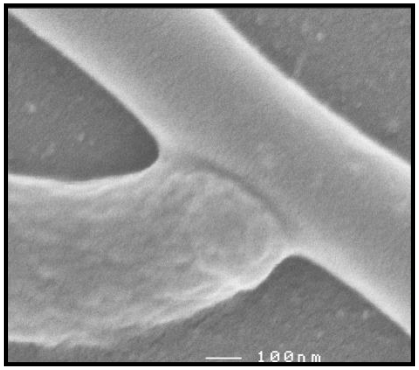


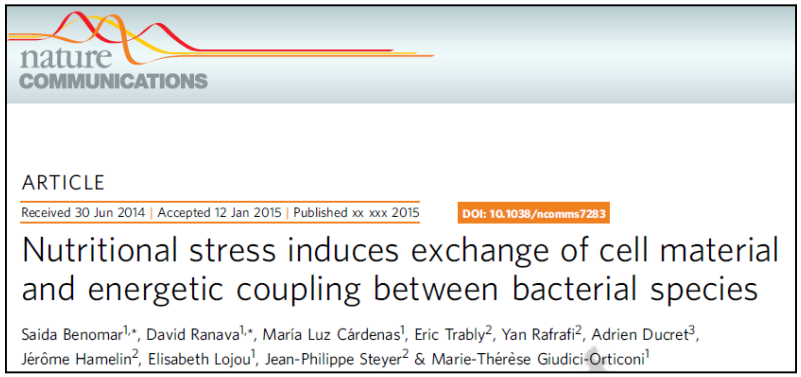


Study of the interactions in simplified microbial ecosystems








nature COMMUNICATIONS

ARTICLE

Received 30 Jun 2014 | Accepted 12 Jan 2015 | Published xx xxx 2015

DOI: 10.1038/ncomms7283

Nutritional stress induces exchange of cell material and energetic coupling between bacterial species

Saida Benomar[1,*], David Ranava[1,*], María Luz Cárdenas[1], Eric Trably[2], Yan Rafrafi[2], Adrien Ducret[3], Jérôme Hamelin[2], Elisabeth Lojou[1], Jean-Philippe Steyer[2] & Marie-Thérèse Giudici-Orticoni[1]