

➤ The role of fermented food microbiota
diversity on health: what contributions from
data sciences?

St phane CHAILLOU

Food Microbial Ecology lab

INRAE | Micalis institute | Universit  Paris Saclay

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<http://fme.micalis.fr/>

30 km



A background of projects (2022-2028)



<https://www.domino-euproject.eu/>



<https://healthferm.eu/>



<https://fermentedfoods.eu/>



Funded by
the European Union



<https://www.metasimfood.inrae.fr/>

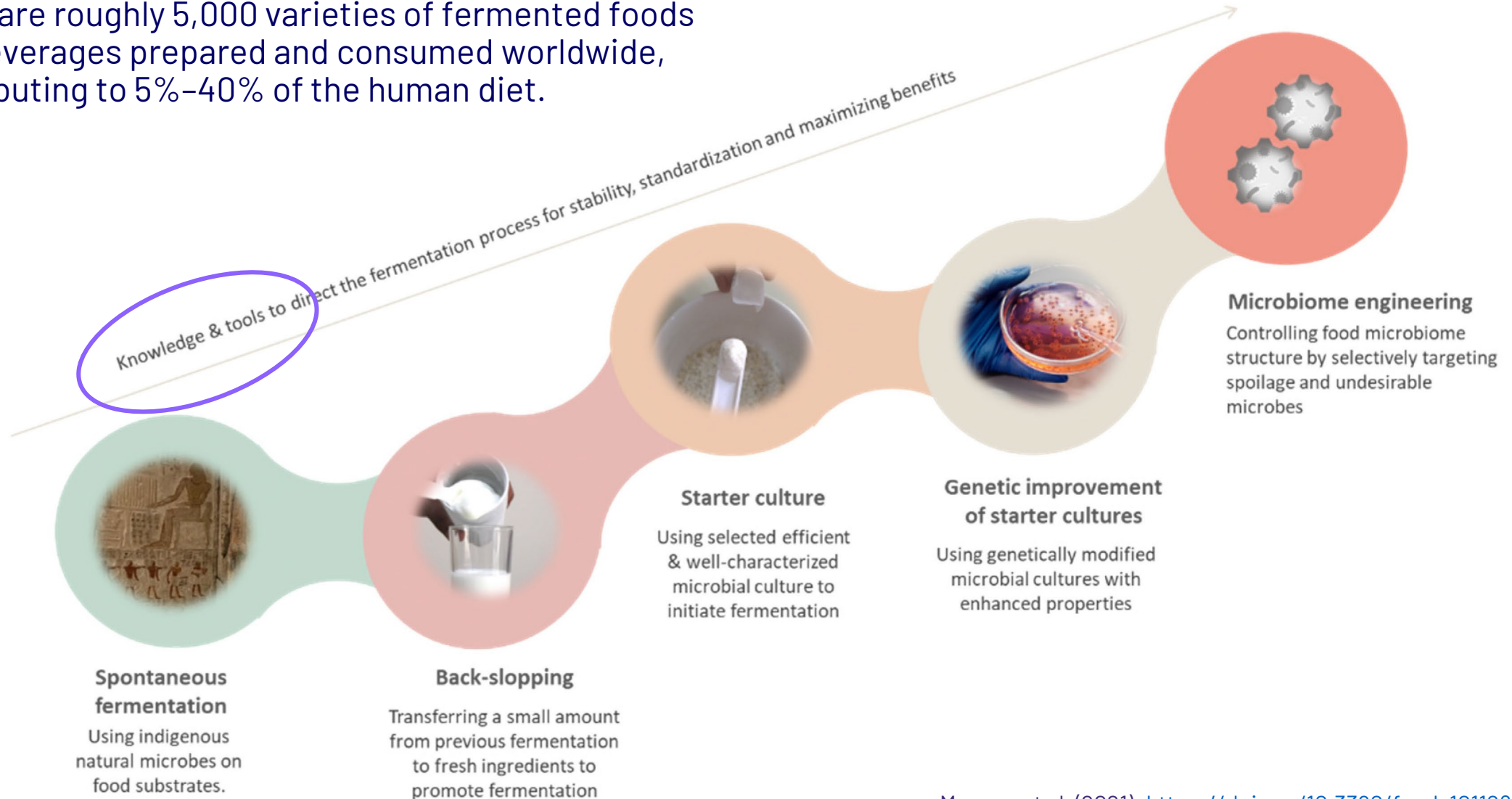


<https://www.fermentsdufutur.eu/>



Microbes in fermented food

- There are roughly 5,000 varieties of fermented foods and beverages prepared and consumed worldwide, contributing to 5%–40% of the human diet.



Mannaa et al. (2021): <https://doi.org/10.3390/foods10112861>

The relationship between fermented food and health

- Increasing amount of data indicate that a diet enriched with **fermented food** have a beneficial effect on health
- = a succession of linked effects.

RESEARCH ARTICLE

Metabolites of lactic acid bacteria present in fermented foods are highly potent agonists of human hydroxycarboxylic acid receptor 3

Anna Peters¹, Petra Krumbholz¹, Elisabeth Jäger², Anna Heintz-Buschart^{3,4}, Mehmet Volkan Çakir¹, Sven Rothmund⁵, Alexander Gaudl⁶, Uta Ceglarek⁷, Torsten Schöneberg¹, Claudia Stäubert^{1*}

Cell Host & Microbe

Volume 25, Issue 4, 10 April 2019, Pages 553-564.e7

Article

Human Salivary Amylase Gene Copy Number Impacts Oral and Gut Microbiomes

Angela C. Poole^{1,2,7}, Julia K. Goodrich¹, Nicholas D. Youngblut¹, Guillermo G. Luagu¹, Albane Ruaud¹, Jessica L. Sutter¹, Jillian L. Waters¹, Qiaojuan Shi², Mohamed El-Hadidi^{1,8}, Lynn M. Johnson⁴, Holm Y. Bar², Daniel H. Huson¹, James G. Booth⁶, Ruth E. Ley^{1,2,9}

Show more

Randomized Controlled Trial > Cell. 2021 Aug 5;184(16):4137-4153.e14.
doi: 10.1016/j.cell.2021.06.019. Epub 2021 Jul 12.

Gut-microbiota-targeted diets modulate human immune status

Hannah C Wastyk¹, Gabriela K Fragiadakis², Dalia Perelman³, Dylan Dahan², Bryan D Merrill², Feiqiao B Yu⁴, Madeline Topf², Carlos G Gonzalez⁵, William Van Treuren², Shuo Han², Jennifer L Robinson³, Joshua E Elias⁴, Erica D Sonnenburg⁶, Christopher D Gardner⁷, Justin L Sonnenburg⁸

Affiliations + expand

PMID: 34256014 PMCID: PMC9020749 DOI: 10.1016/j.cell.2021.06.019

Free PMC article

Food & Function

REVIEW

Check for updates

Cite this: Food Funct., 2022, 13, 4804

Underlying evidence for the health benefits of fermented foods in humans

F. Rul^a, C. Béra-Maillet^a, M. C. Champomier-Vergès^a, K. E. El-Mecherfi^b, B. Foligné^c, M. C. Michalski^d, D. Milenkovic^{e,f} and I. Savary-Auzeloux^{a,g*}

Review > Nutrients. 2019 Aug 5;11(8):1806. doi: 10.3390/nu11081806.

Fermented Foods: Definitions and Characteristics, Impact on the Gut Microbiota and Effects on Gastrointestinal Health and Disease

Eirini Dimidi¹, Selina Rose Cox¹, Megan Rossi¹, Kevin Whelan²

Affiliations + expand

PMID: 31387262 PMCID: PMC6723656 DOI: 10.3390/nu11081806

Free PMC article

Fermented foods and cardiometabolic health: Definitions, current evidence, and future perspectives

Katherine J. Li^{1,2*}, Kathryn J. Burton-Pimentel¹, Guy Vergères², Edith J. M. Feskens¹ and Elske M. Brouwer-Brolsma¹

¹Division of Human Nutrition and Health, Wageningen University & Research, Wageningen, Netherlands; ²Agroscope, Bern, Switzerland



RESEARCH ARTICLE
Host-Microbe Biology



Consumption of Fermented Foods Is Associated with Systematic Differences in the Gut Microbiome and Metabolome

Bryn C. Taylor^a, Franck Lejzerowicz^b, Marion Poiriel^c, Justin P. Shaffer^b, Lingling Jiang^c, Alexander Aksenov^d, Nicole Litwin^e, Gregory Humphrey^b, Cameron Martino^e, Sandrine Miller-Montgomery^{b,f}, Pieter C. Dorrestein^{b,g,h}, Patrick Velga^g, Se Jin Songⁱ, Daniel McDonald^b, Muriel Derrien^g, Rob Knight^{b,h,i,j}

Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in
Biotechnology



Health benefits of fermented foods: microbiota and beyond

Maria L Marco¹, Dustin Heeney¹, Sylvie Binda², Christopher J Cifelli³, Paul D Cotter⁴, Benoit Foligné⁵, Michael Gänzle⁶, Remco Kort⁷, Gonca Pasin⁸, Anne Pihlanto⁹, Eddy J Smid¹⁰ and Robert Hutkins¹¹



Regular Consumption of Lacto-fermented Vegetables has Greater Effects on the Gut Metabolome Compared with the Microbiome

Guse K, Sharma A, Weyenberg E, Davison S, Ma Y, Choi Y, Johnson A, Chen C, Gomez A

Preprint from Qeios, 20 Dec 2022

https://doi.org/10.32388/xxegtw PPR: PPR622459

Review > Crit Rev Food Sci Nutr. 2019;59(3):506-527. doi: 10.1080/10408398.2017.1383355.

Epub 2017 Oct 20.

Health benefits of fermented foods

Nevin Şanlıer¹, Büğra Başar Gökçen², Aybülke Ceyhan Sezgin³

Affiliations + expand

PMID: 28945458 DOI: 10.1080/10408398.2017.1383355

Abstract

FULL TEXT LINKS



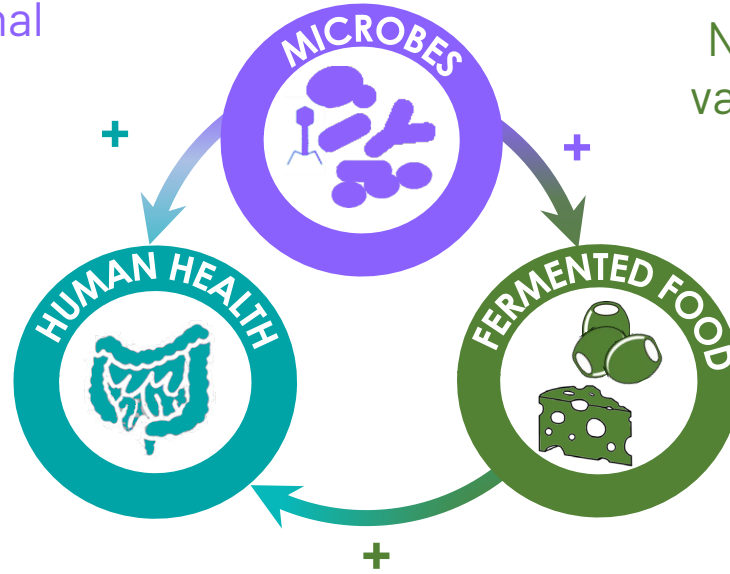
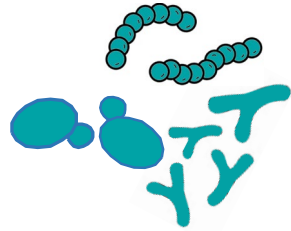
ACTIONS



SHARE

The relationship between fermented food and health

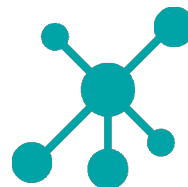
Interaction of food (dietary) microbiota with the intestinal microbiota



Nutritional & safety added value of the fermented food



Molecules resulting from fermentation are stimulating physiological signals

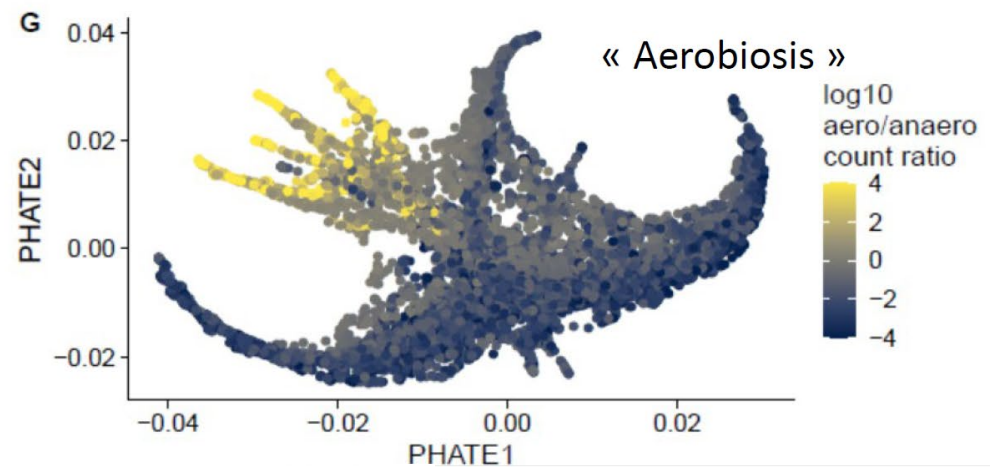
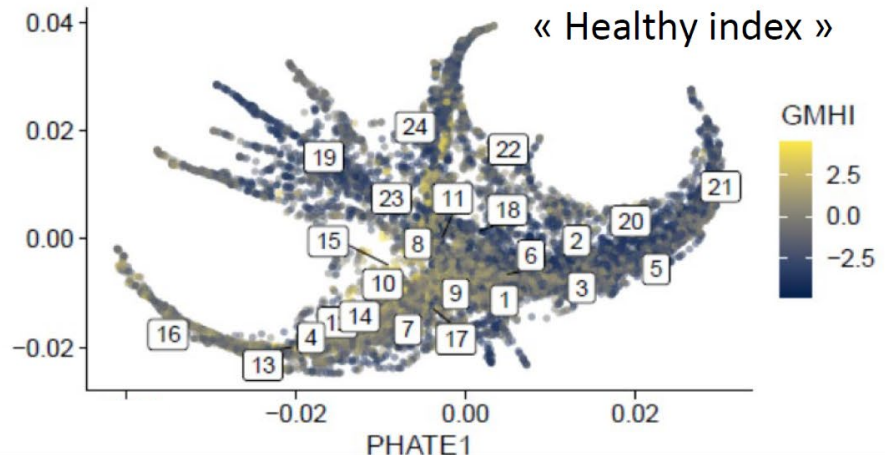
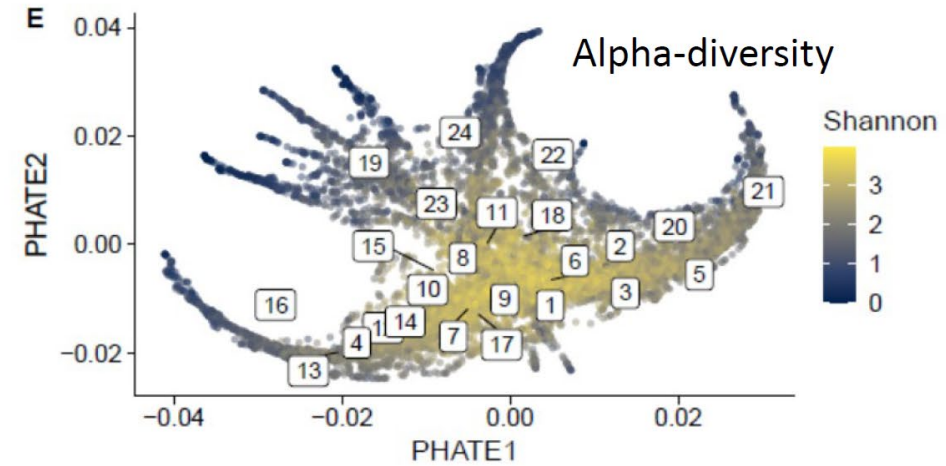
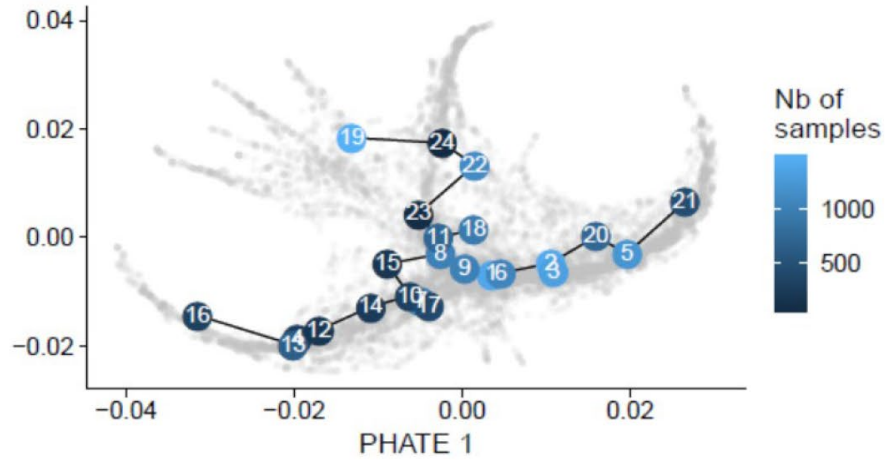


- i.e. the  DOMINO effect

The 35,000 gut microbiomes structured as branches and local states

Tap et al. (2023): <https://doi.org/10.1038/s41467-023-38558-7>

- The low-diversity tips of branches display functional shifts



- But we don't know yet how to define what is a healthy gut microbiome...

Microbes, fermented foods, health & sustainability...

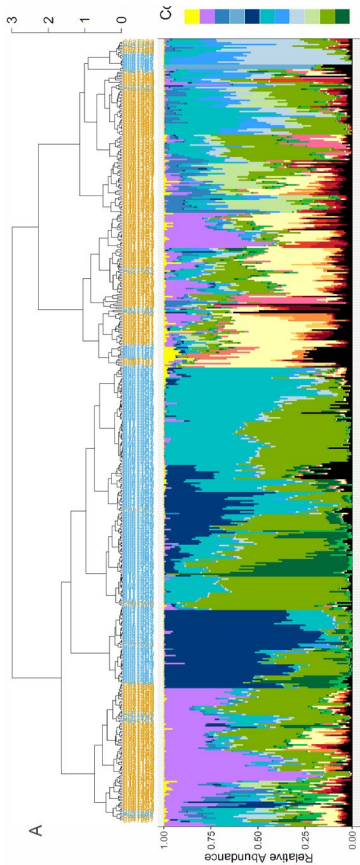
... a complex equation between societal and technological challenges

... what contributions of data sciences ?

1. Identifying the diversity of microbial solutions (*i.e.* microbial consortia)
2. Building strategies for design & resolving experimental bottlenecks
3. Implementing health benefits in the design
4. Knowledge-based R&D : curated databases -> modelling tools -> AI

From spontaneous fermentations to designed consortia

Fermented food metagenome = a diversity of microbial communities



How to learn from?
A lack of data

A diversity of microbial interactions and dynamics

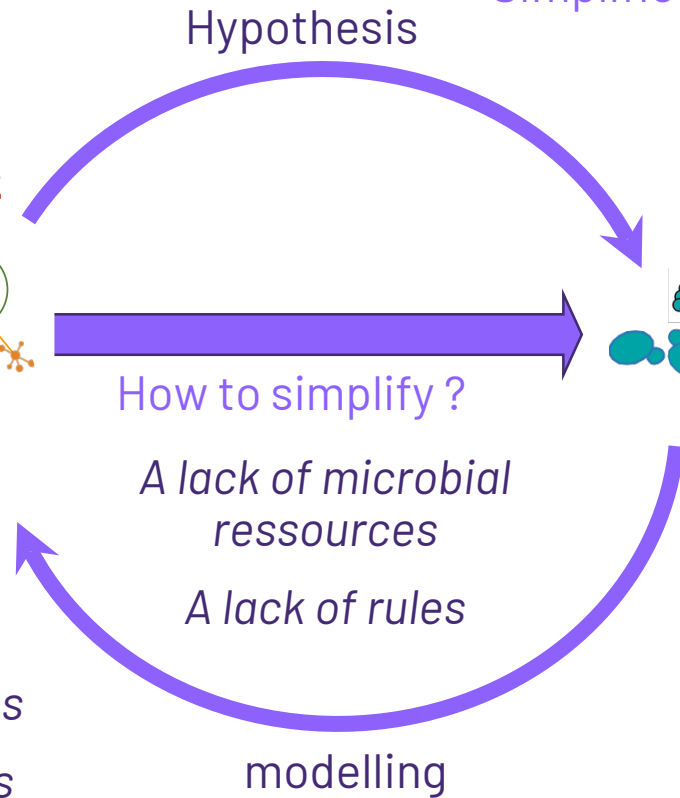
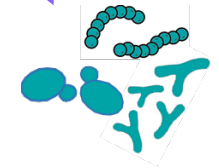
Spontaneous models



How to understand?
A lack of tools & strategies
Experimental bottlenecks

Functional-core community

Simplified models



Implementing Health benefit in the design of consortia

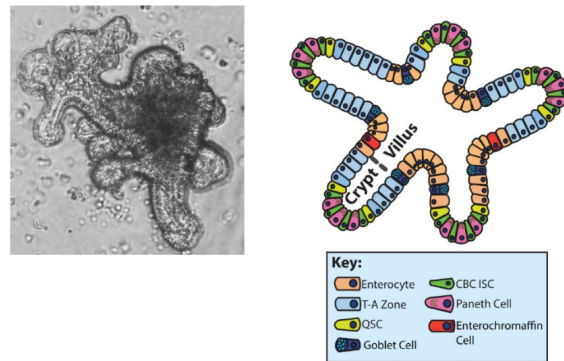
- Human nutritional intervention are the 'golden rule' but long, tedious and expensive;
- It is very likely that long-term diet are necessary for establishing health benefit.
- Setting standard protocols for rapid estimation of health benefit using *in-vitro/ex-vivo* models ?



<https://doi.org/10.3389/fmicb.2018.01844>

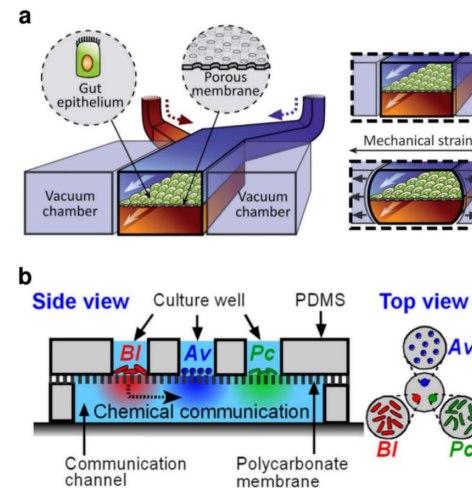
1. Distal colon models

Influence on gut microbiota
Functional activity in micro-bioreactors



<https://doi.org/10.1097/MPG.0000000000001411>

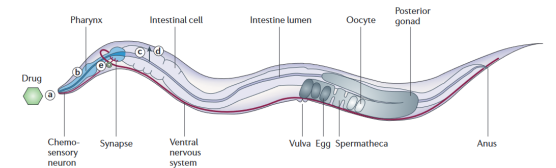
2. Intestinal Organoids
absorption capacity of
bioactive molecules



<https://doi.org/10.1016/j.jcmgh.2017.12.010>

3. Gut-on-Chip

Impact on microbiotas and food components on gut microbiome composition, permeability of CACO2 cells and immune cells response



<https://doi.org/doi:10.1038/nrd2031>

4. *Caenorhabditis elegans* model

Feeding behavior of the worm,
Study of longevity/survival,
host response and mechanistic studies (RNAseq/mutants)

Harnessing the microbial potential of fermented food for healthy & sustainable food systems

Stéphane CHAILLOU and the DOMINO consortium

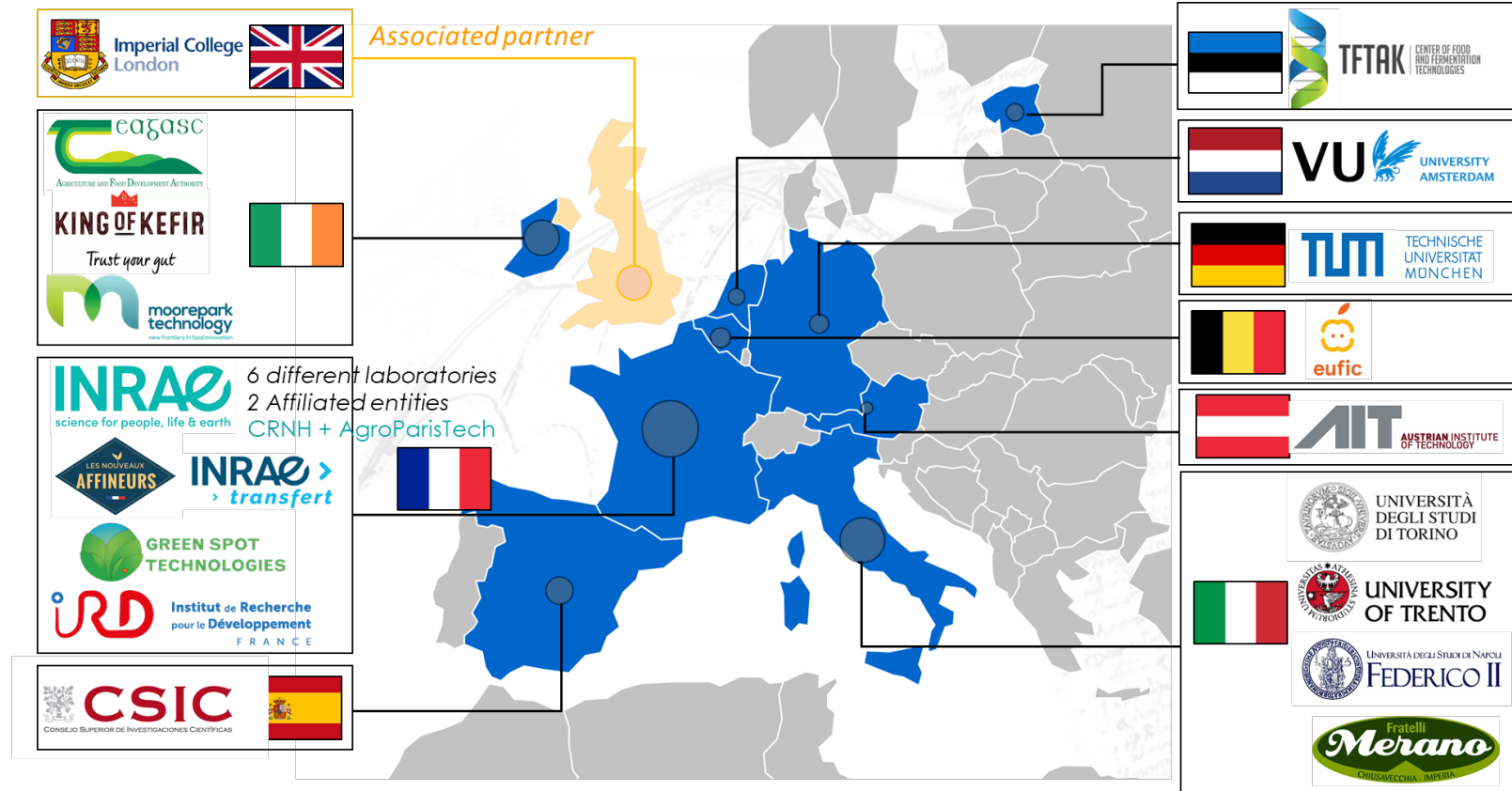
INRAE, France

MICALIS Institute (*Food & Gut Microbiology for Human Health*)



DOMINO summary in a few numbers

- Coordinated by INRAE.
- kick-off 1st March 2023
- 5 years (2023-2028) and budget of 12 M€
- 19 partners in 10 EU countries
- Over 100 scientists in more than 8 scientific disciplines
- Over 10,000 of fermented food; animal & human gut 'omics' data



About the project

What is DOMINO?

- Demonstrating the health benefit of fermented foods-based diet.
- Designing microbial consortia for plant-based fermented foods.
- Involving citizens and food system actors in several EU living labs.



DOMINO
from objectives to  impacts

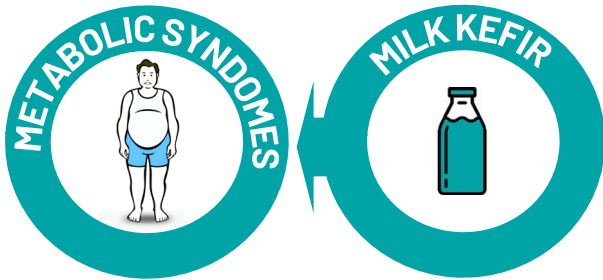


1. Health assessment of fermented food based diet 16

#1. MULTICENTRIC HUMAN NUTRITIONAL INTERVENTION (UK, Italy & France)

Targeting on Milk Kefir

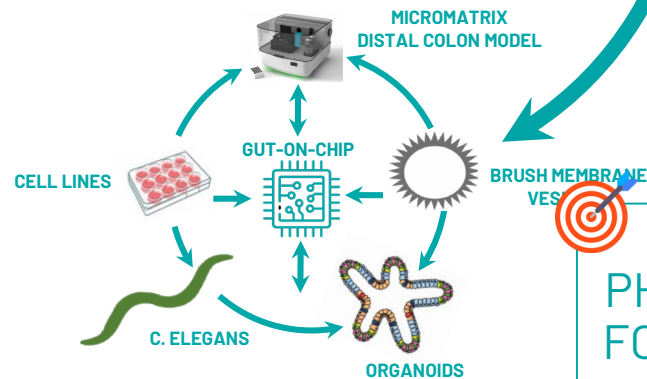
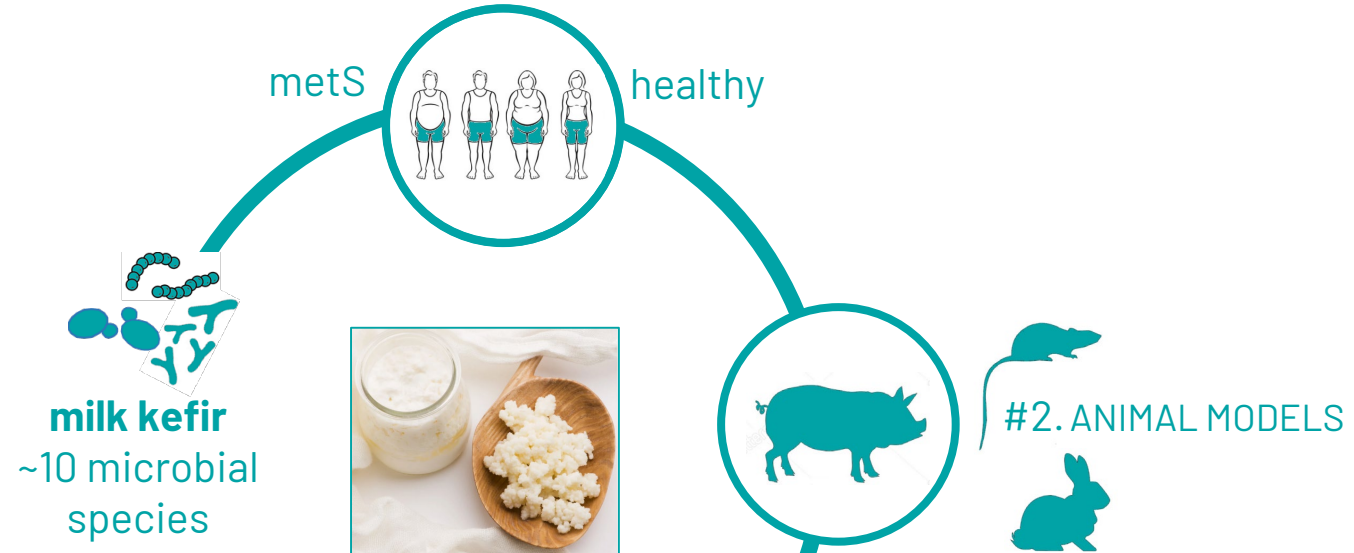
Some health benefits already claimed.



(MetS)

Already studied with some background data

Need long trials before to see an effect (~6 months)



#3. EX-VIVO MODELS

MATCHING PATTERN OF MICROBIOMES, PHYSIOLOGY AND EX-VIVO DATA TO BETTER FOCUS ON HEALTH BIOMARKERS LINKED TO FERMENTED FOOD

2. Design of six healthy plant-based fermented food prototypes from sustainable sources ¹⁷



Fermented Vegetables & Table Olives

Many claims for health benefits

Cereal-based food

Lots of traditional recipes from non-EU culture
Could have many nutritional health benefits

Legumes (Pulses)

More complete meal than other plant-based products
= high protein content

Biowastes

Could be used as side-streams for bringing ingredients into fermented food – Rich in fibers

#5. A DIVERSITY OF PRODUCT DESIGN




SYNTHETIC ECOLOGY AS AN EXPERIMENTAL STRATEGY FOR MICROBIAL CONSORTIA DESIGN


#6. HARNESSING THE MICROBIAL DIVERSITY OF FOOD-BORNE MICROBES

3. Implementing health benefit in the design

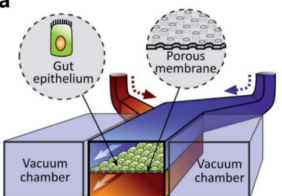
1. Distal colon models



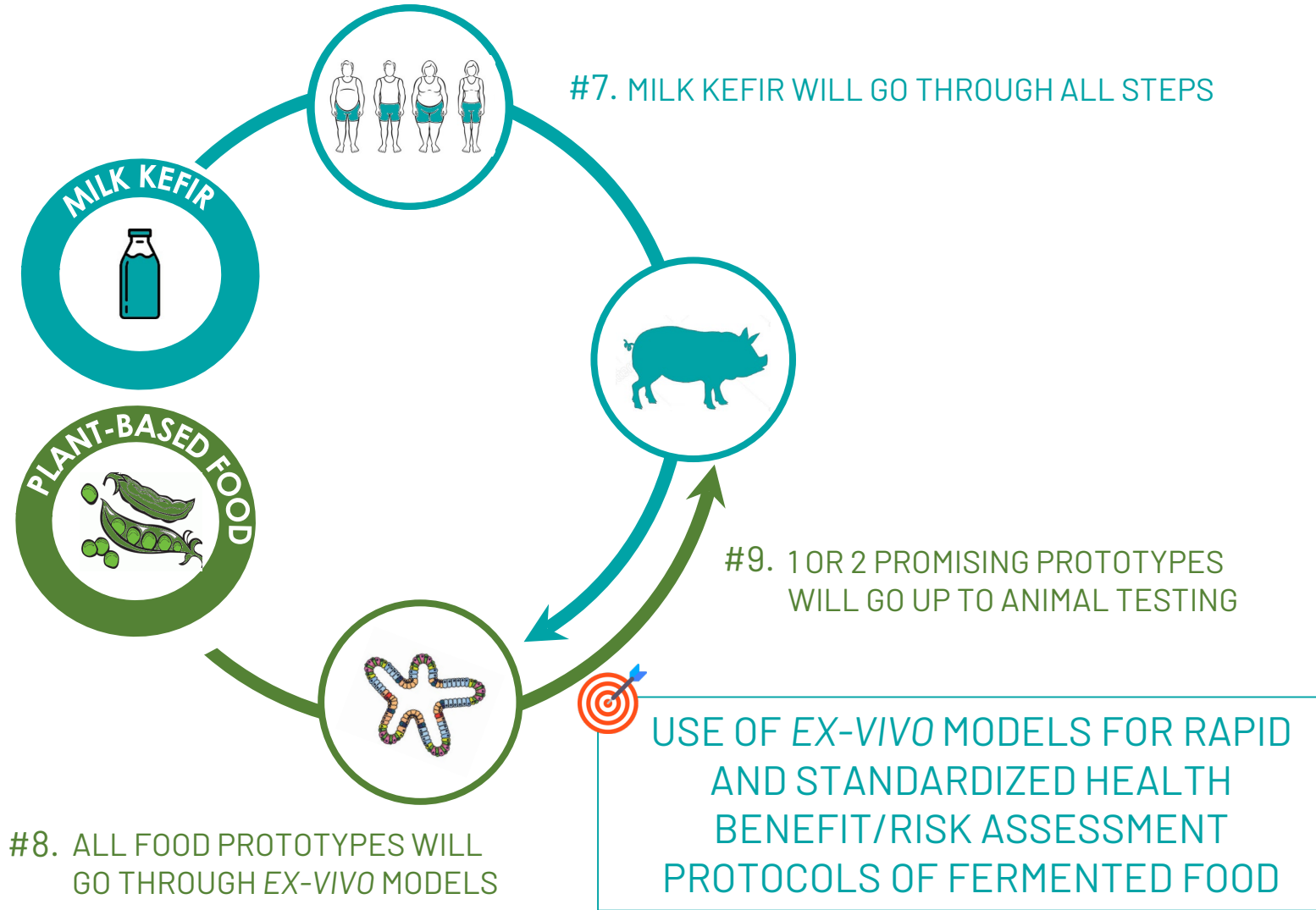
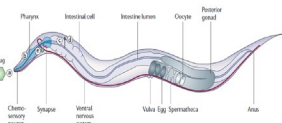
2. Intestinal Organoids



3. Gut-on-Chip



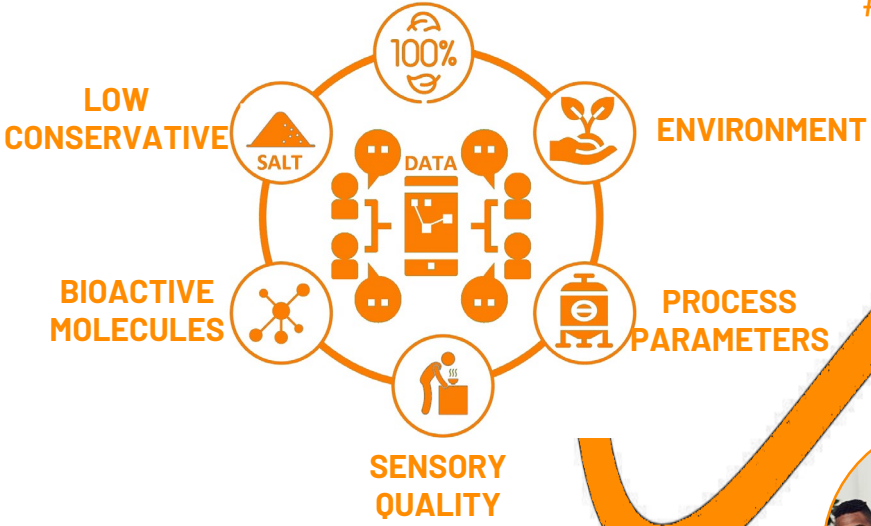
4. Caenorhabditis elegans model



4. Living Labs for multi-actor engagements

LIVING-LABS IN SIX DIFFERENT EU CULTURAL AREAS

CONSUMERS' ACCEPTANCE



#11. Building trust in the food system

PHASE 2



TRANSPARENCY & VALIDATION
THAT THE OUTCOME OF THE
PROJECT IS RELEVANT TO THE
EUROPEAN SOCIETY



#10. Sharing the vision

PHASE 1



#12. Consumer acceptance

PHASE 3

5. The open Food Microbiome Database (FMD)

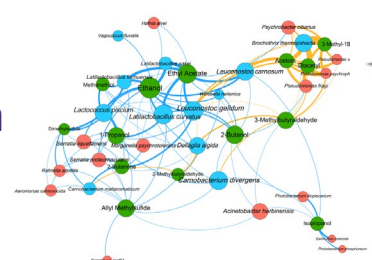
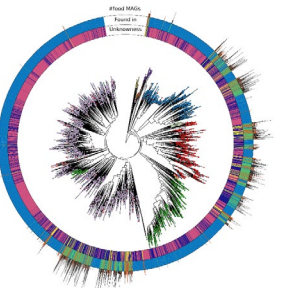
Microbial strains genomic data
(public & those generated within the project)

Metagenomic & MAGs data
(public & those generated within the project)

Metadata

Microbiome profiling tools

Metabolic Functional Profiling tools
of microbial metatranscriptomes



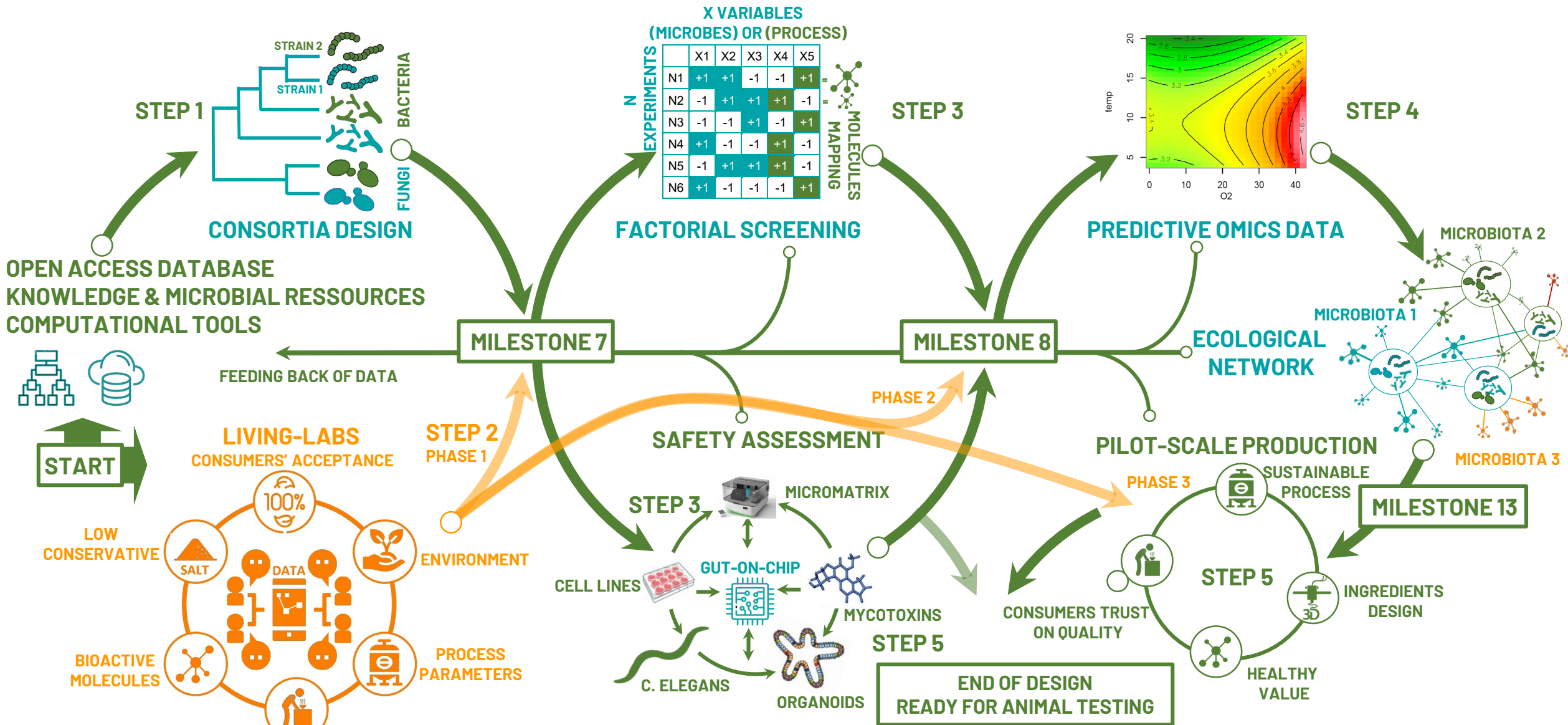
#13. Construction of microbial consortia & metabolic ecological networks

FOOD MICROBIOME DATABASE (FMD)

#14. Profiling food microbiome in gut microbiome

User-friendly FMD
EMBL-EBI

PUBLIC RELEASE OF FOOD & GUT MICROBIOME DATA & ANALYTICAL TOOLS FOR SCIENTIFIC COMMUNITY & FOOD PRODUCTION ENGINEERS



synthetic ecology design in DOMINO



Funded by
the European Union



UK Research
and Innovation

THANK YOU!

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<http://fme.micalis.fr/>



www.domino-euproject.eu



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This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101060218

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