

RADICAL AND RELATIONAL APPROACHES TO FERMENTATION & FOOD SOVEREIGNTY

<https://radicalfermentation.ucdavis.edu/>

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What is a fermented food?

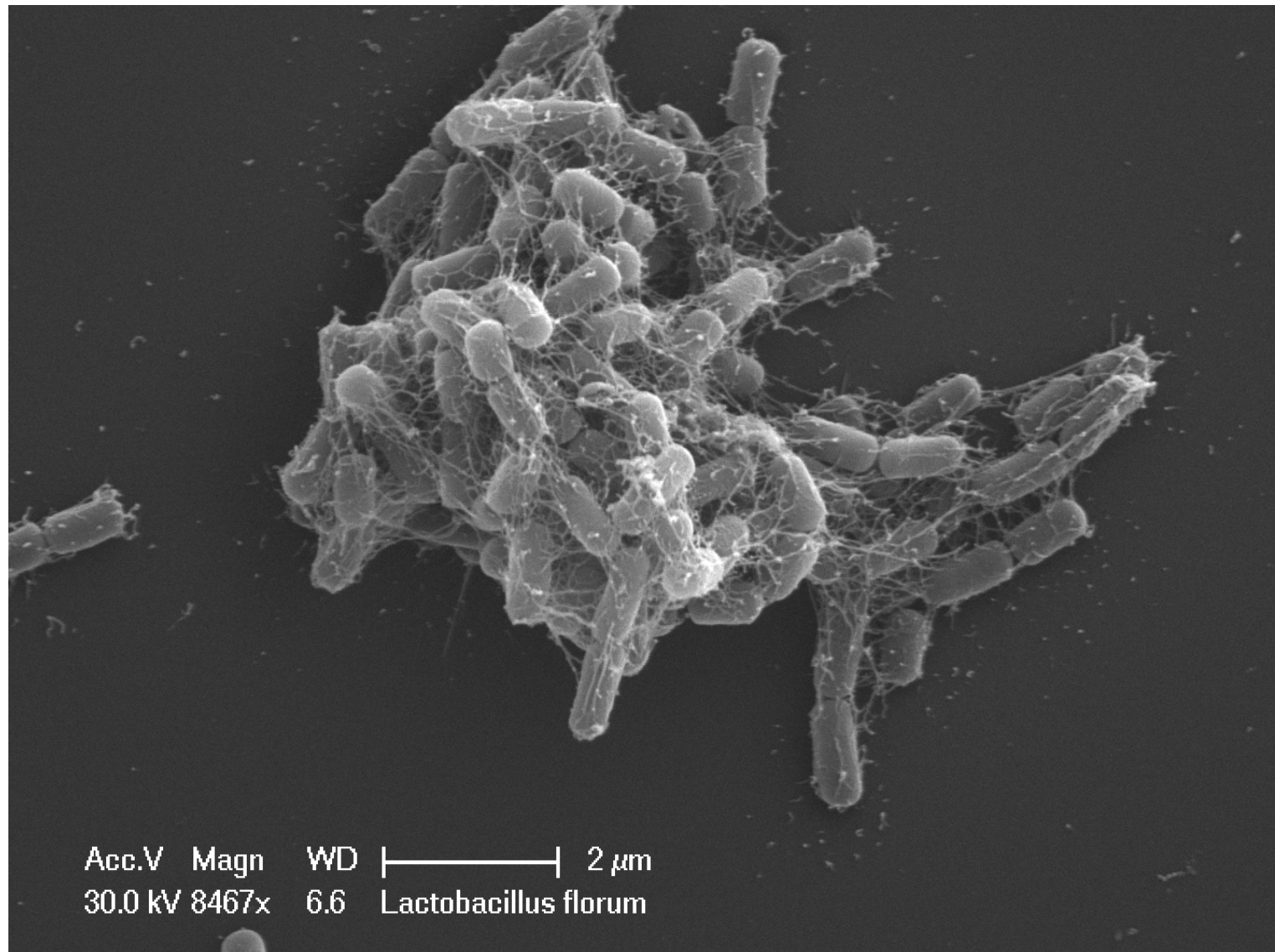
Maria L Marco

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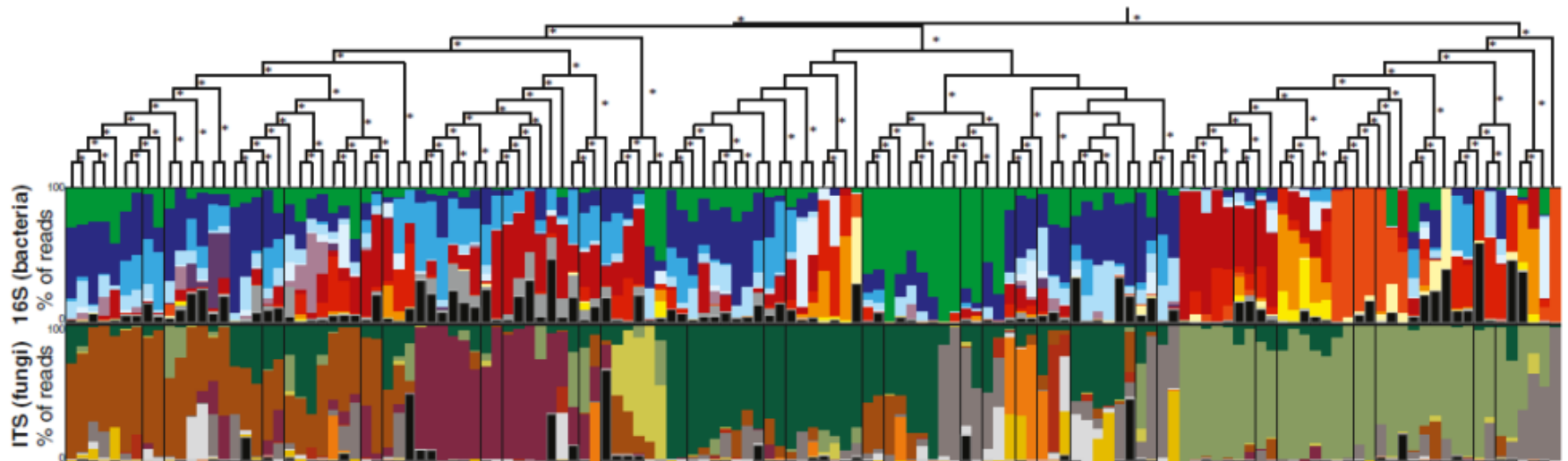




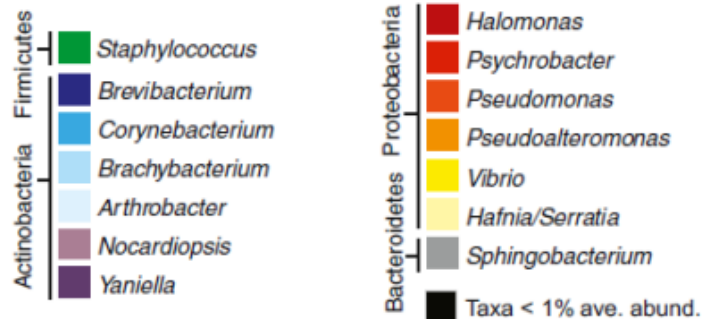




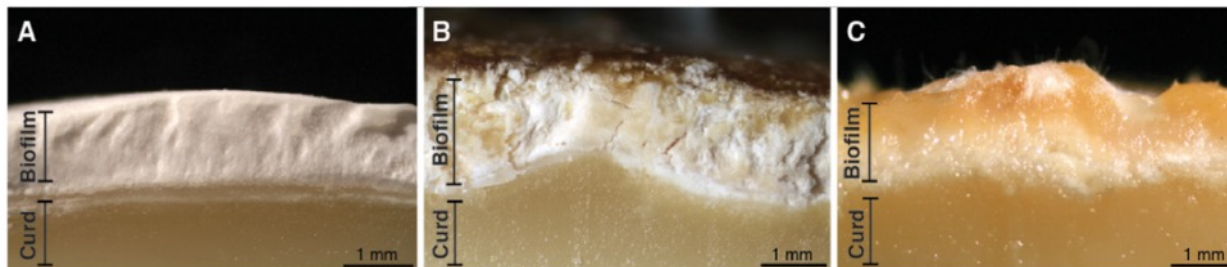
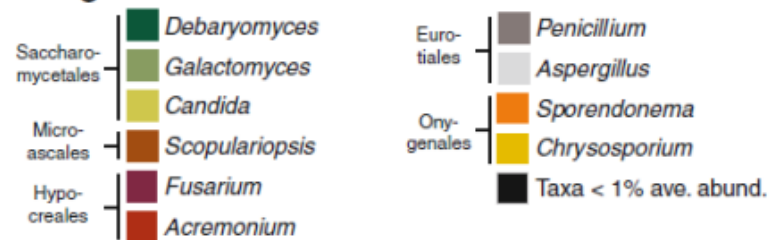
Scanning electron micrograph of *L. florum*
- Marco et al *unpublished*



Bacteria



Fungi



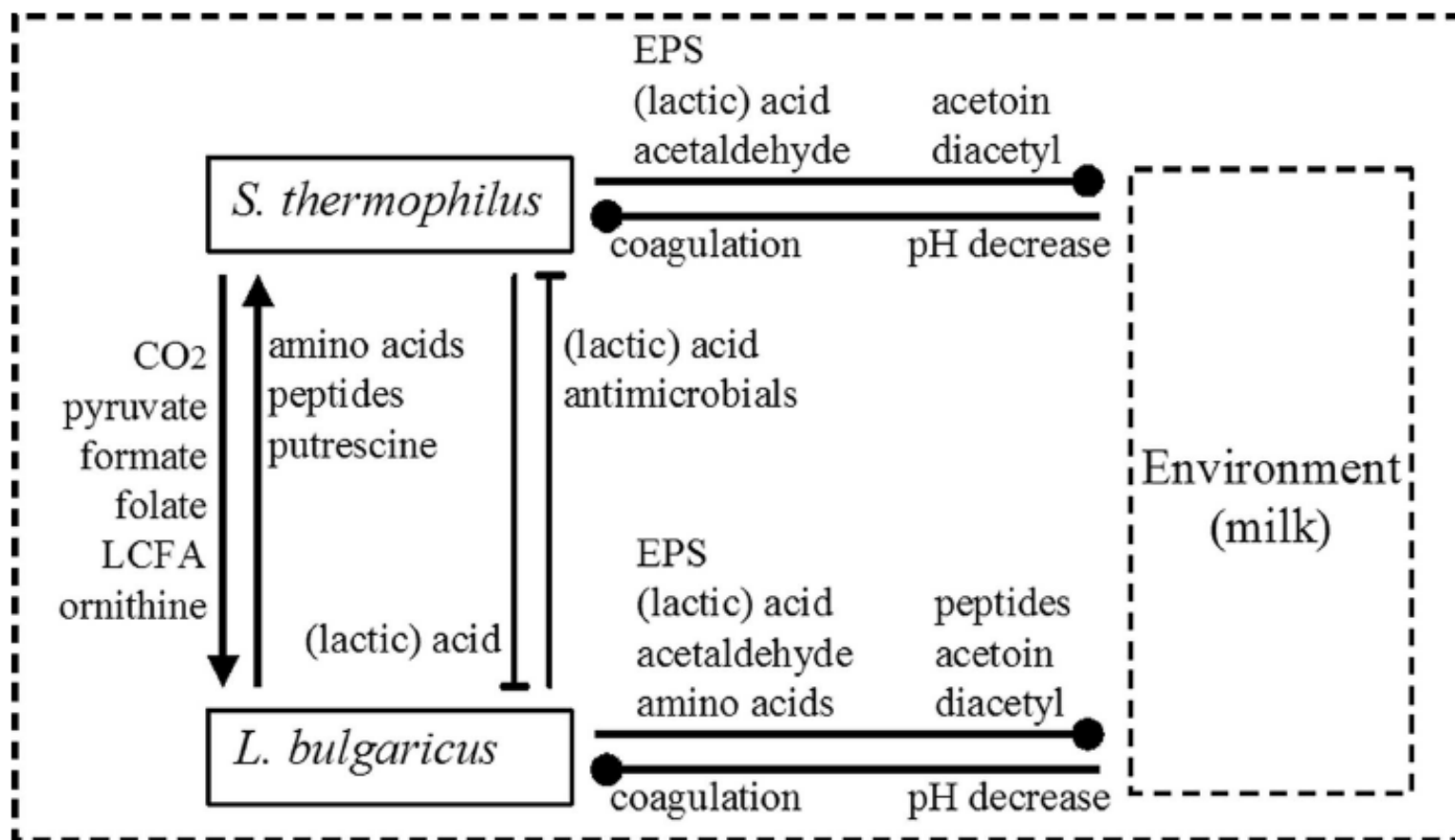


FIG. 1. Schematic representation of the validated and hypothesized interactions that occur between *Streptococcus thermophilus*, *Lactobacillus delbrueckii* subsp. *bulgaricus*, their environment, and the compounds relevant for yogurt characteristics. ▼, positive interactions; ⊥, negative interactions; ●, interactions that do not specifically promote or decrease the growth of the other species. LCFA, long-chain fatty acids. See text for references.



Microbial growth



Prepare

Chop
Salt
Spice
Pack
Soak
Heat

Incubate

Temperature
Oxygen
pH
Water activity



Thousands of fermented foods

1 White wines and cidre										2 Red and fruit wines										3 Light beer										4 Dark beer										5 Tubers and roots										6 Cereal beverages										7 Cereal porridges										8 Bread (wheat)										9 Bread (others)										10 Soy and bean										11 Condiments										12 Vegetable products										13 Dairy products										14 Soft cheese										15 Hard cheese										16 Surface ripened cheeses										17 Eggs and fish										18 Meats																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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Fermented foods

Definition:

Foods and beverages made through desired **microbial** growth and enzymatic conversions of food components

The International Scientific Association
for Probiotics and Prebiotics (ISAPP)
consensus statement on fermented
foods

Maria L. Marco¹, Mary Ellen Sanders², Michael Gänzle³, Marie Claire Arrieta⁴,
Paul D. Cotter^{5,6,7}, Luc De Vuyst⁸, Colin Hill⁹, Wilhelm Holzapfel¹⁰, Sarah Lebeer¹¹,
Dan Merenstein¹², Gregor Reid¹³, Benjamin E. Wolfe¹⁴ and Robert Hutkins¹⁵✉

-Marco *et al*/2020 Nat Rev Gastroenterol Hepatol

Fermented:

- Includes microbial respiratory and fermentation metabolic pathways
- Includes foods that are fermented and then pasteurized by heat or other methods



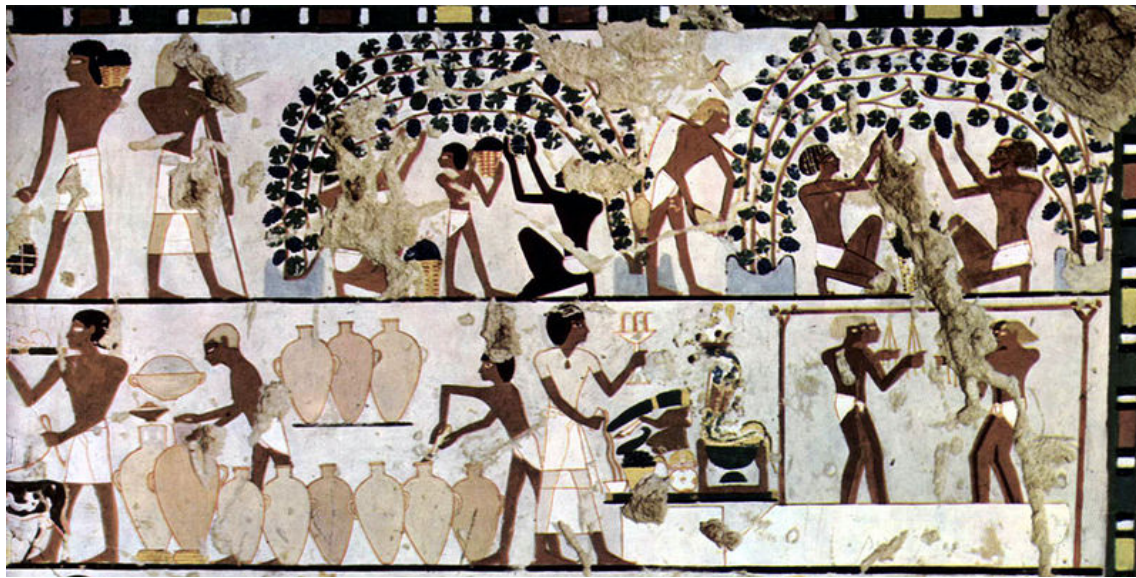
Not fermented:

- Pickled fruits and vegetables
- Food with a microbe added to the final product



Why fermented foods?





Preservation

Foods are less likely to spoil and can be stored for longer periods of time

- **Reduced water activity**
- **Acidic pH**
- **Low oxygen availability**
- **Antimicrobial compounds**

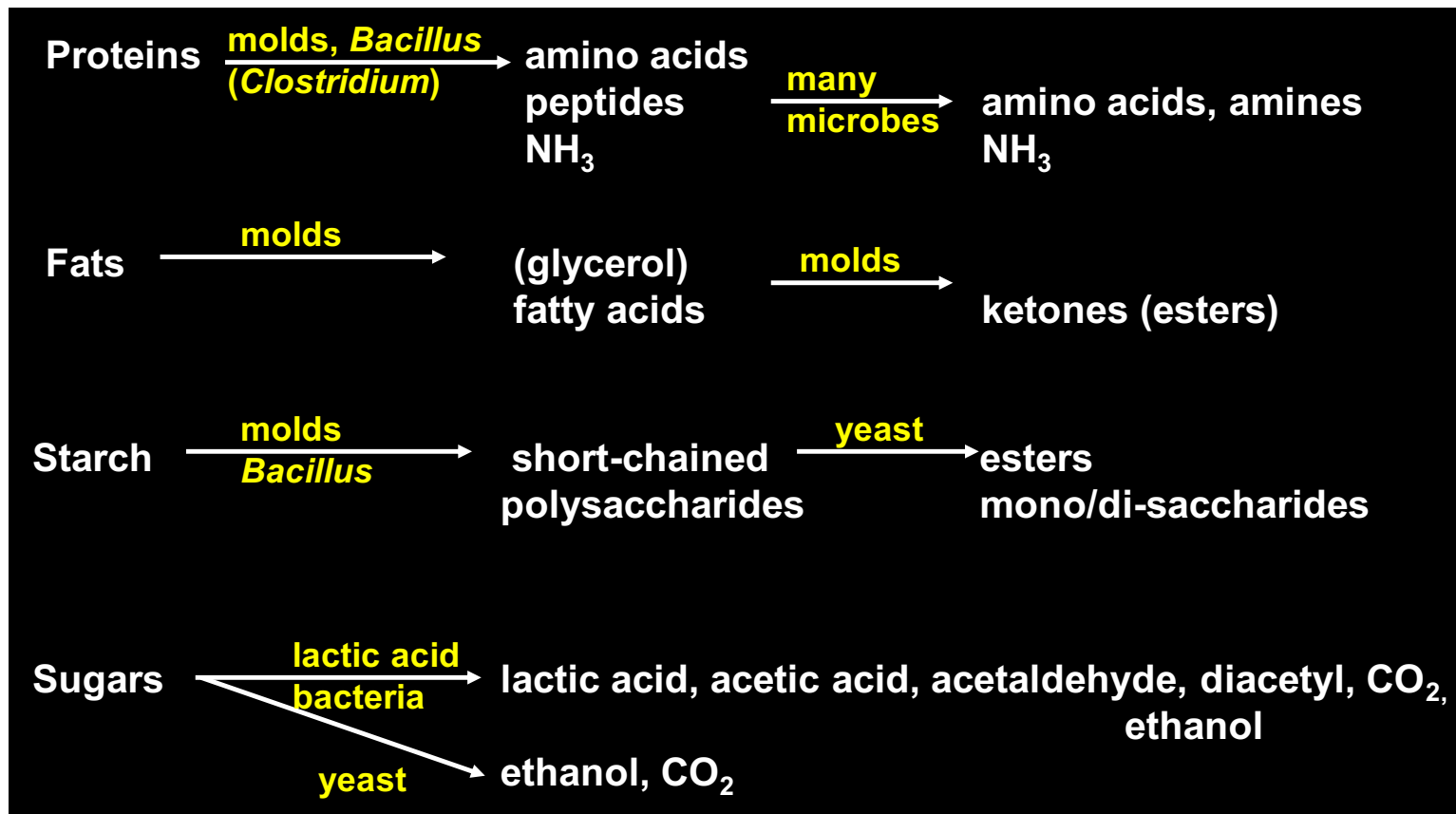
Safety

Reduced risk of biological and chemical hazards

- Acid pH ($\text{pH} < 4.6$)
- Detoxify (example, phytic acid removal from flour)



Taste



Fermentation provides unique tastes, textures, and aromas

Science of fermented foods

Microbial processes needed to make fermented foods:

- Understanding of fermented foods as microbial ecosystems
 - Making of traditional fermented foods
 - Scale-up commercial production quality and defects

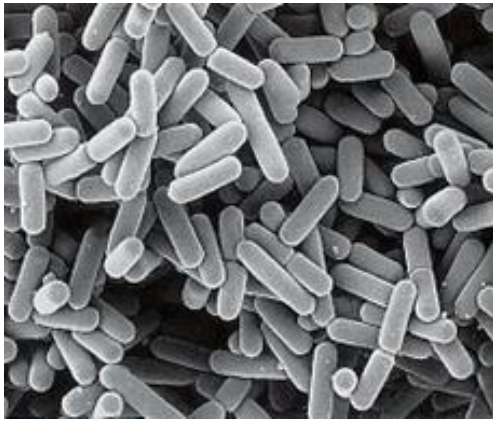
How fermented foods impact health:

- Human studies examining specific and general benefits of fermented food consumption
- Mechanistic studies designed to identify and understand the precise ways fermented foods alter organ function

Simplistic view

Fungi

Bacteria



Lactic acid bacteria

-*Lactobacillus*

-*Leuconostoc*

Bacillus

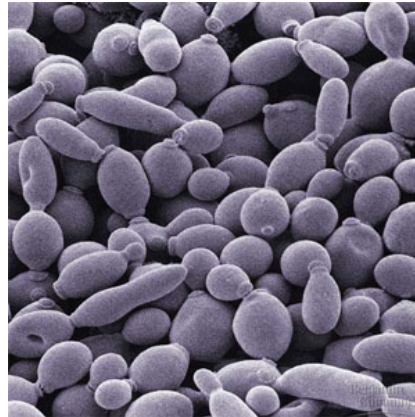
***Brevibacterium* &**

Propionibacterium

***Acetobacter* and**

Gluconobacter

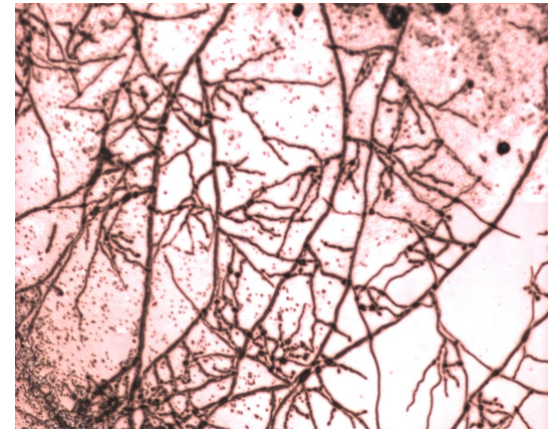
Yeast



Saccharomyces

cerevisiae

Molds



Rhizopus

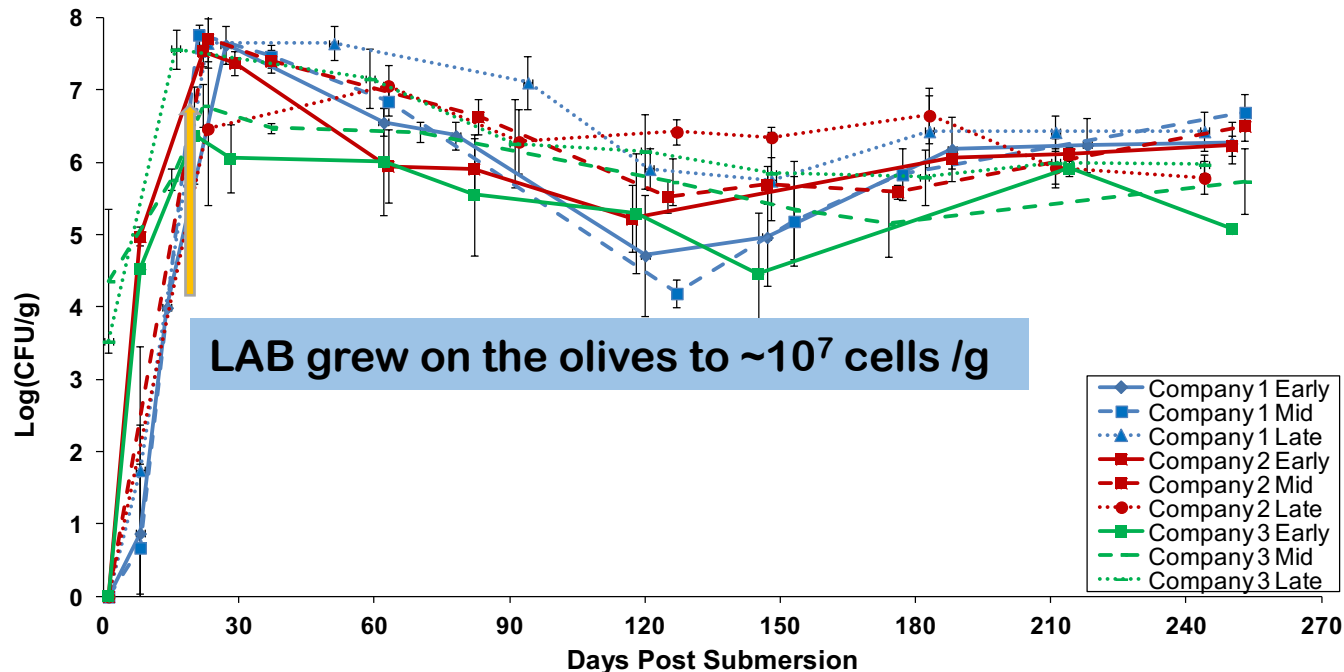
Mucor

Penicillium

Aspergillus

Olive fermentations

Lactic acid bacteria (LAB) are the most abundant microbes in olive fermentations

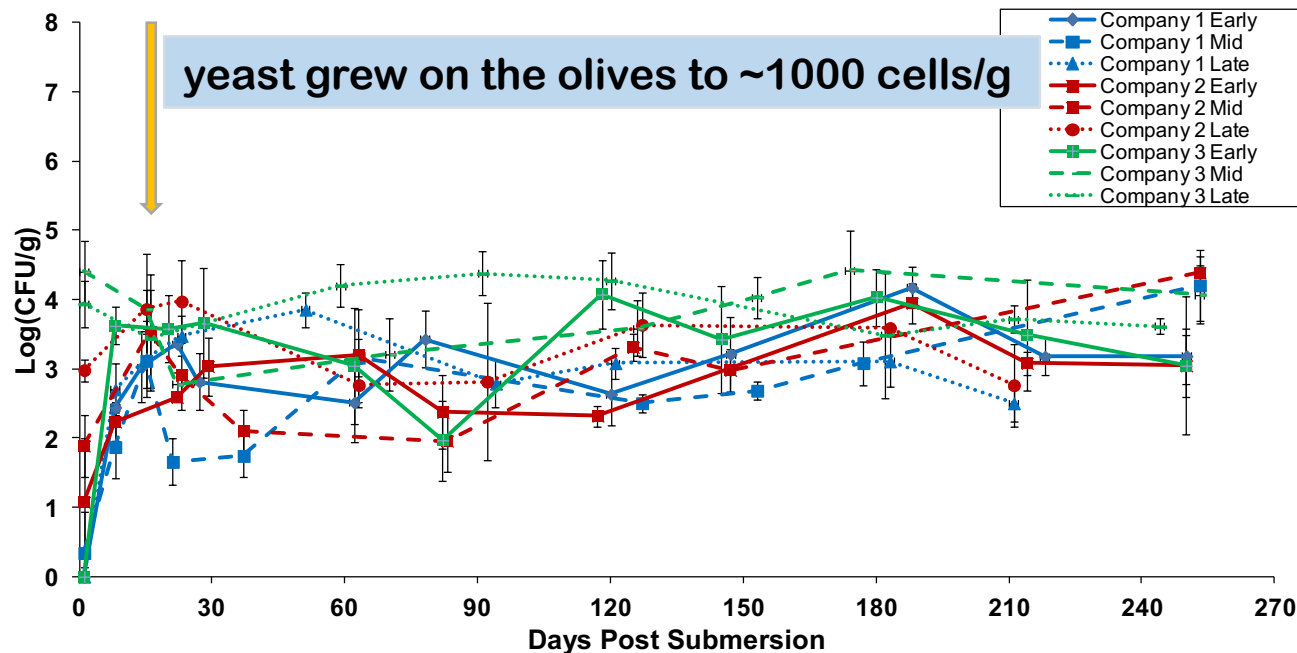


LAB were quantified on MRS medium containing Natamycin (25 ug/ml)
avg \pm stdev CFU/g of 5 replicates per processor are shown

Zaragoza, Bendiks et al *unpublished*

Olive fermentations

Yeast contribute to olive fermentations

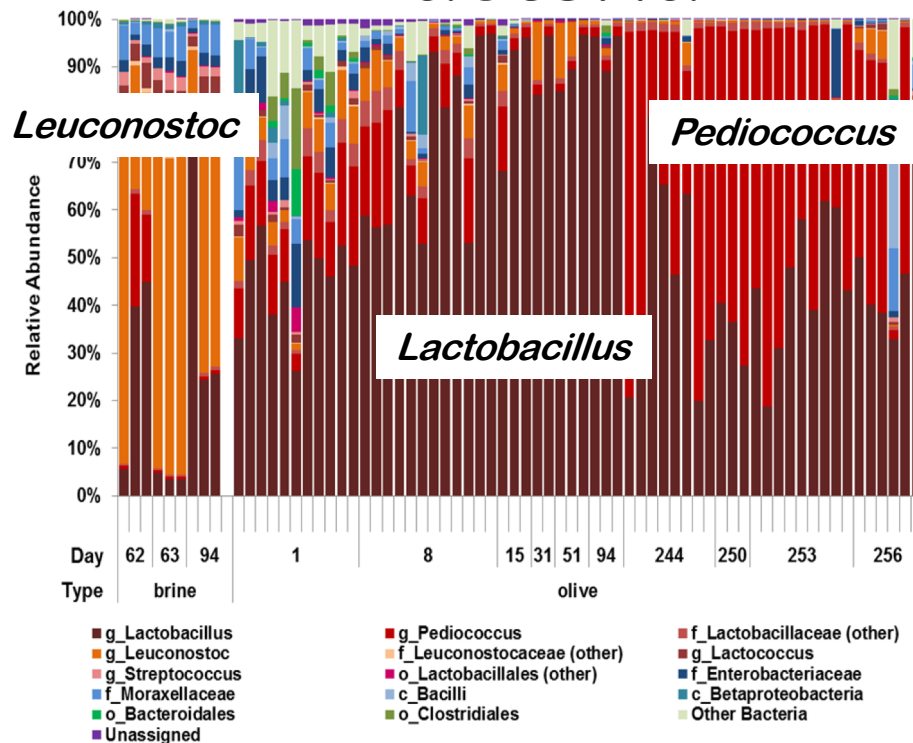


Yeast were quantified on RBCA medium containing Chloramphenicol (100ug/ml)
avg \pm stdev CFU/g of 5 replicates per processor are shown

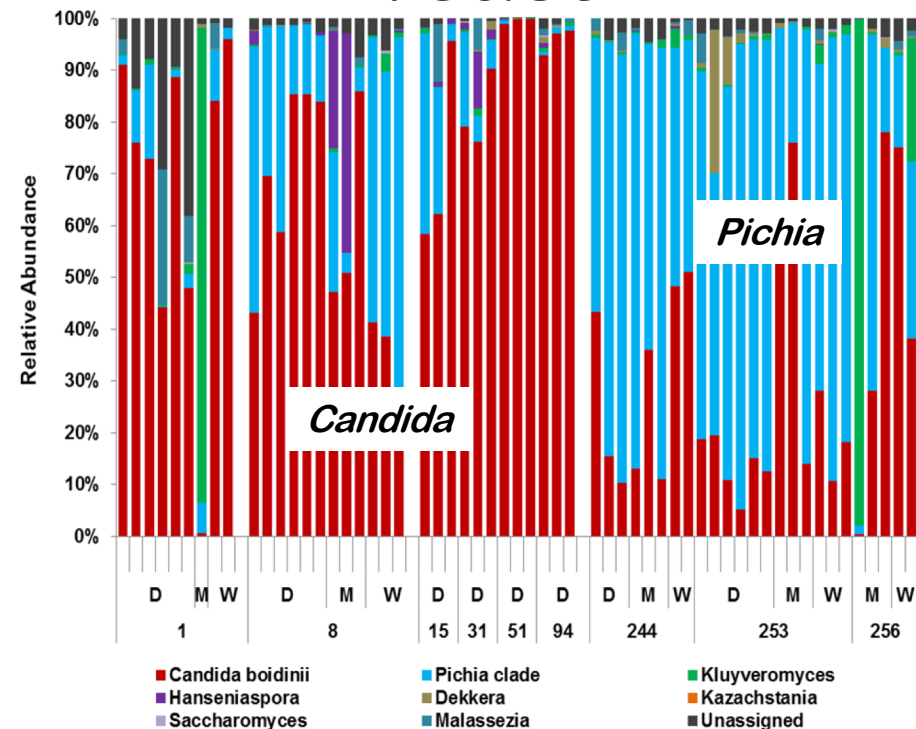
Zaragoza, Bendiks et al

Food fermentations are dynamic microbial ecosystems

Bacteria



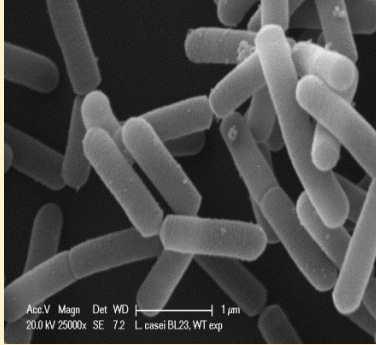
Yeast



Bacteria and yeast were identified by 16S rRNA and intergenic transcribed spacer (ITS) DNA sequencing, respectively

Intra-species bacterial diversity

Lactobacillus strains



70% genetically related

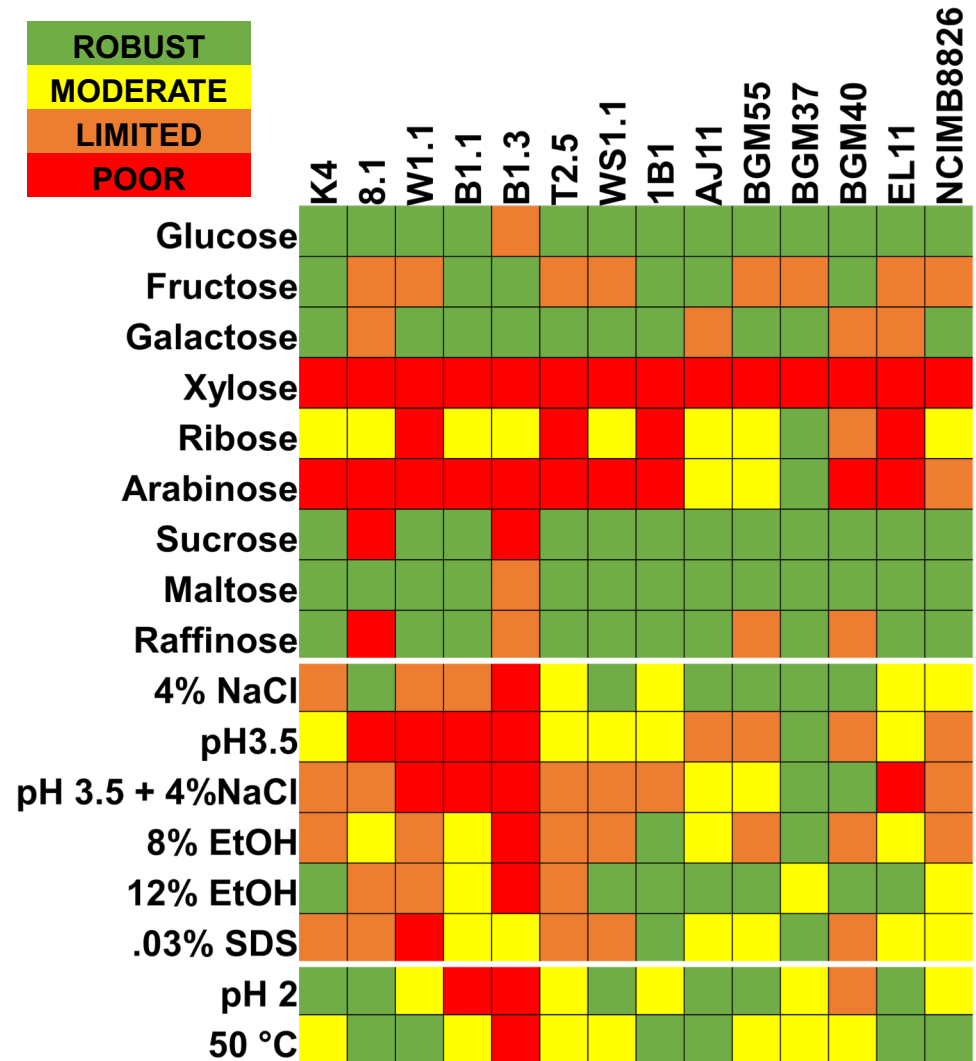
lemurs

people



78% genetically related

Lactiplantibacillus plantarum strains

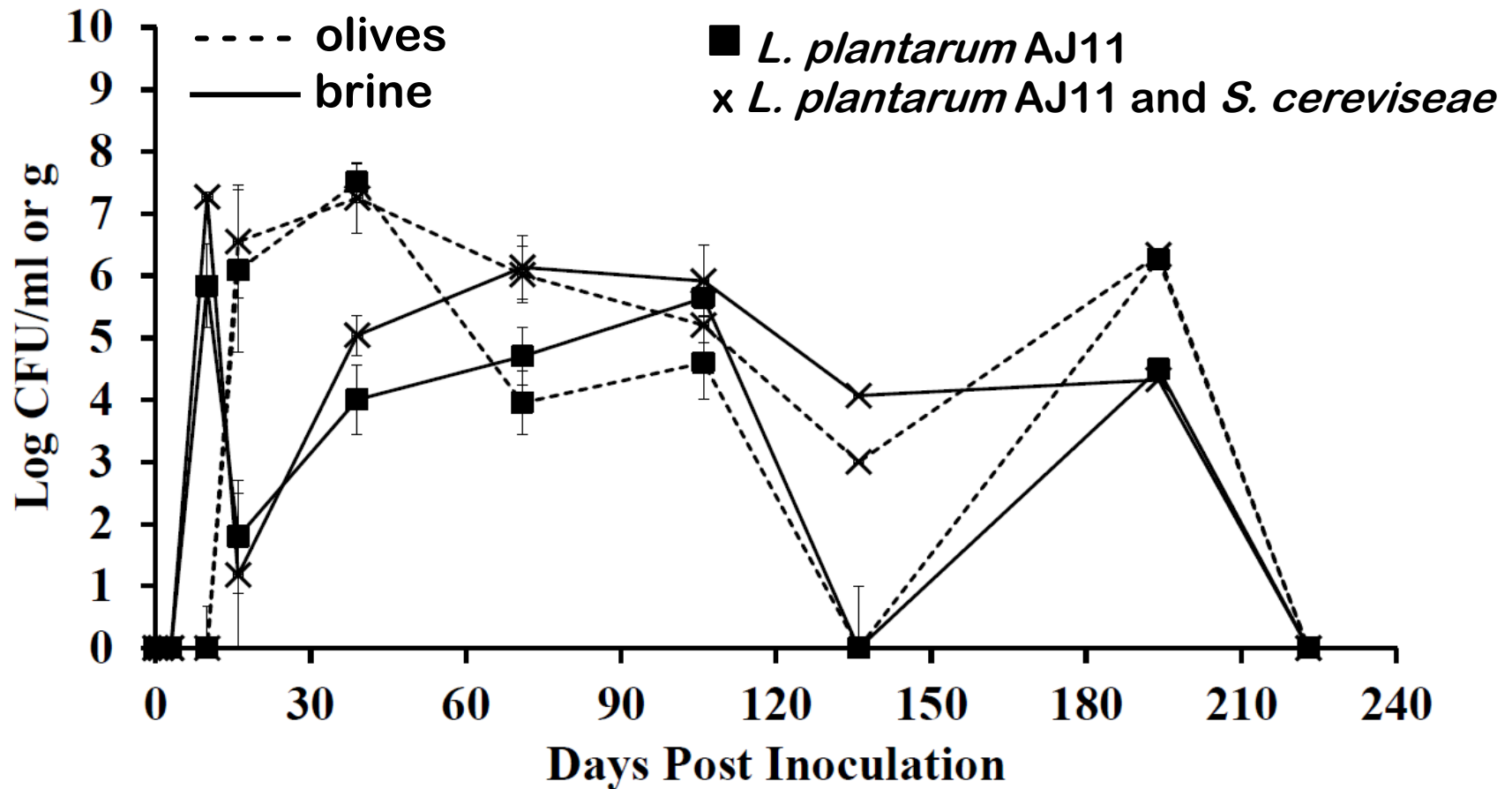


Staley 1997 Cur Op Biotechnol

Yu et al *unpublished*

* DNA homology

Populations of individual strains change over time during fermentation



L. plantarum AJ11 enumerated on MRS containing Rifampicin

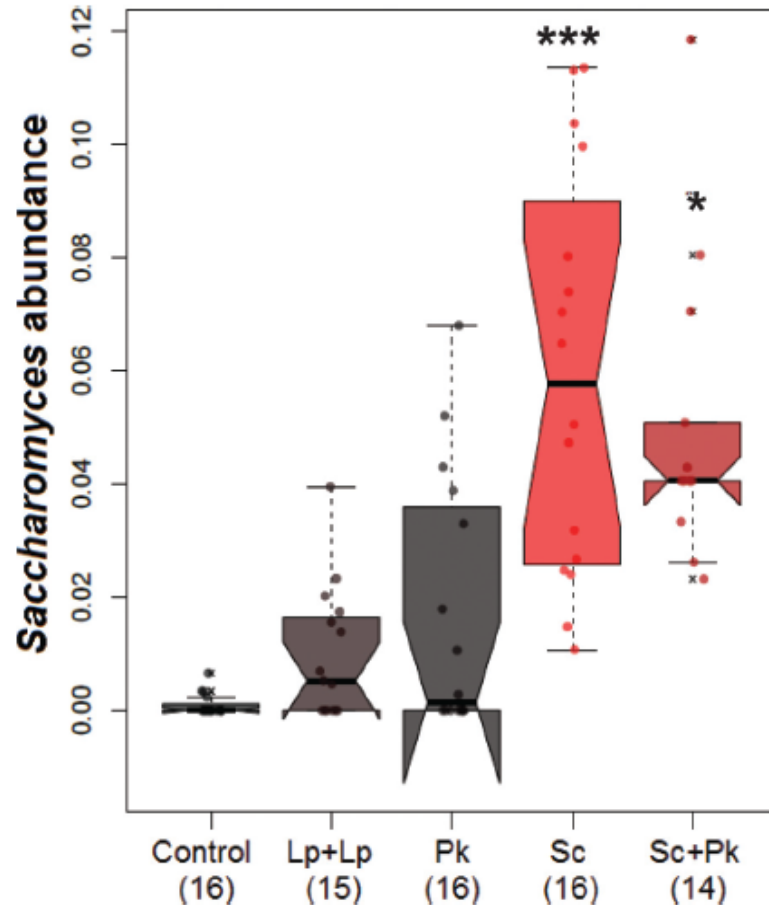
Single strains in low numbers are sufficient to cause extensive spoilage



Controls



Inoculated with 10^7 cells of *S. cerevisiae* 09-448



Multivariate analysis was performed using MaAsLin. ***, $P < 10^{-9}$; *, $P < 10^{-4}$

Science of fermented foods

Microbial processes needed to make fermented foods:

- Understanding of fermented foods as microbial ecosystems
 - Making of traditional fermented foods
 - Scale-up commercial production quality and defects

How fermented foods impact health:

- Human studies examining specific and general benefits of fermented food consumption
- Mechanistic studies designed to identify and understand the precise ways fermented foods alter organ function

Fermented foods and....

Digestive health
& infection

Mood & behavior

Inflammatory
bowel syndrome

Immunity

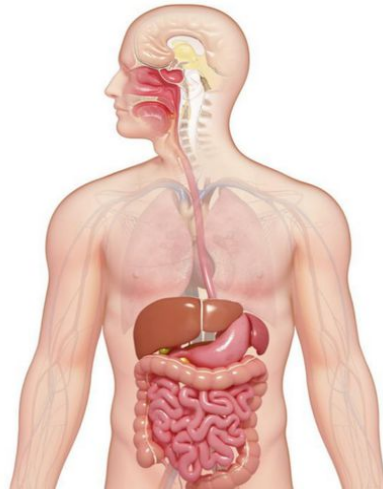
Weight loss &
obesity

Bone health

Type 2 Diabetes

Cancer

Cardiovascular
disease



Human studies

Many fermented foods have only 1 to 2 human studies (RCT or observational)

Digestive health
& infection

kefir, sourdough

Mood & behavior

wine/beer, coffee

Inflammatory
bowel syndrome

sauerkraut, sourdough

Immunity

kimchi

Weight loss &
obesity

yogurt, kimchi,

Bone health

yogurt, kefir, natto

Type 2 Diabetes

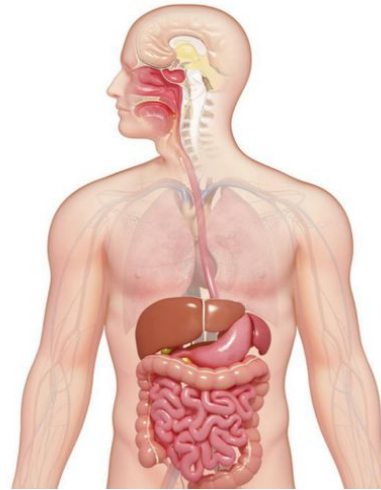
yogurt, cheese, kimchi,
sourdough, coffee, vinegar

Cancer

coffee, wine/beer

Cardiovascular
disease

yogurt, cheese,
coffee, wine/beer,
vinegar



Yogurt is inversely associated with cardiometabolic disease risk



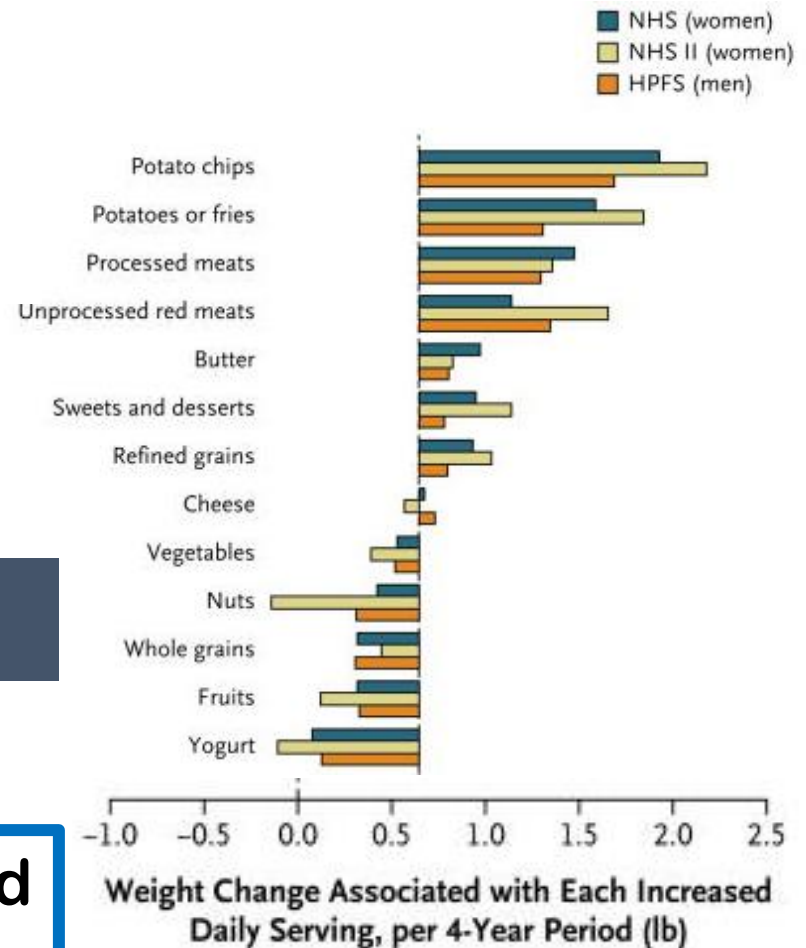
The NEW ENGLAND
JOURNAL of MEDICINE

Changes in Diet and Lifestyle and Long-Term Weight Gain in Women and Men

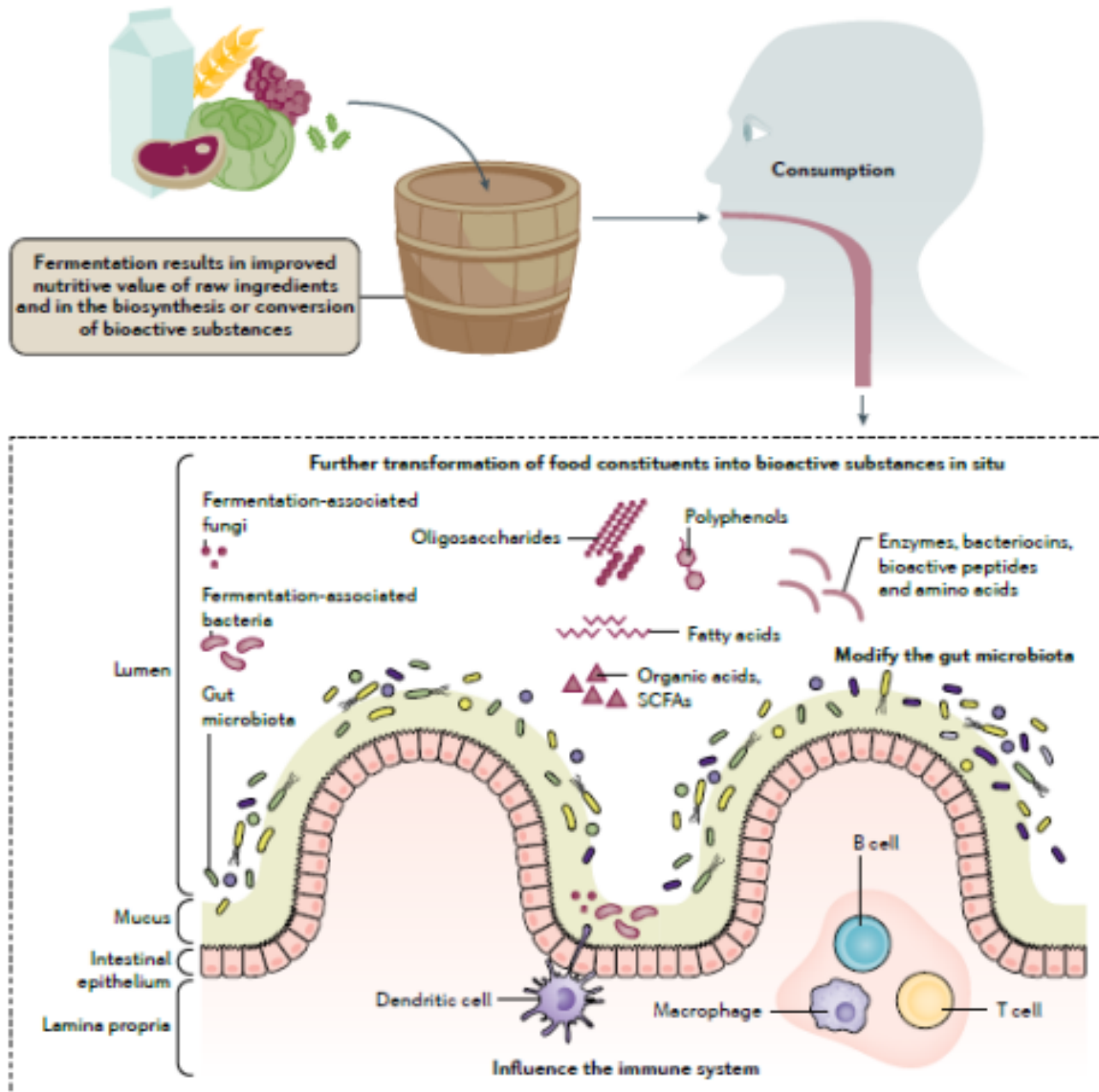
Dariush Mozaffarian, M.D., Dr.P.H., Tao Hao, M.P.H., Eric B. Rimm, Sc.D.,
Walter C. Willett, M.D., Dr.P.H., and Frank B. Hu, M.D., Ph.D.

3 Cohort Studies (NHS I & II, HPFS)
~290,000 women and men

Yogurt consumption is associated
with -0.82 lb. change in weight
over 4 years



Health benefits?



Transformation

lactose

fermentation



**Improve
tolerance
to dairy
foods**

Fermentation can result in the breakdown and removal of unwanted compounds in the food ingredients

Synthesis

fermentation

Vitamin K

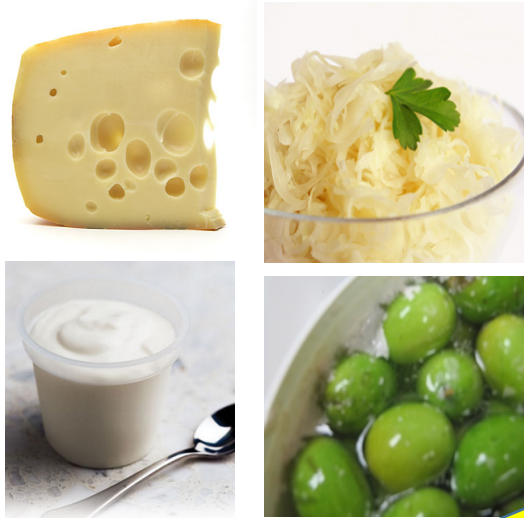


**Associated with
increased bone
density**

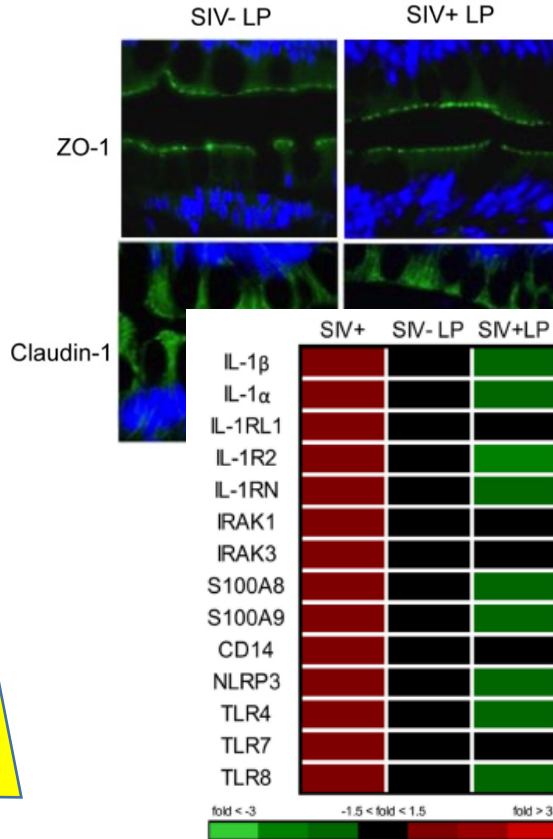
**Needed for
blood clotting**

Fermentation can result in the synthesis of bioactive compounds that are not present in the food ingredients

Beneficial microbes



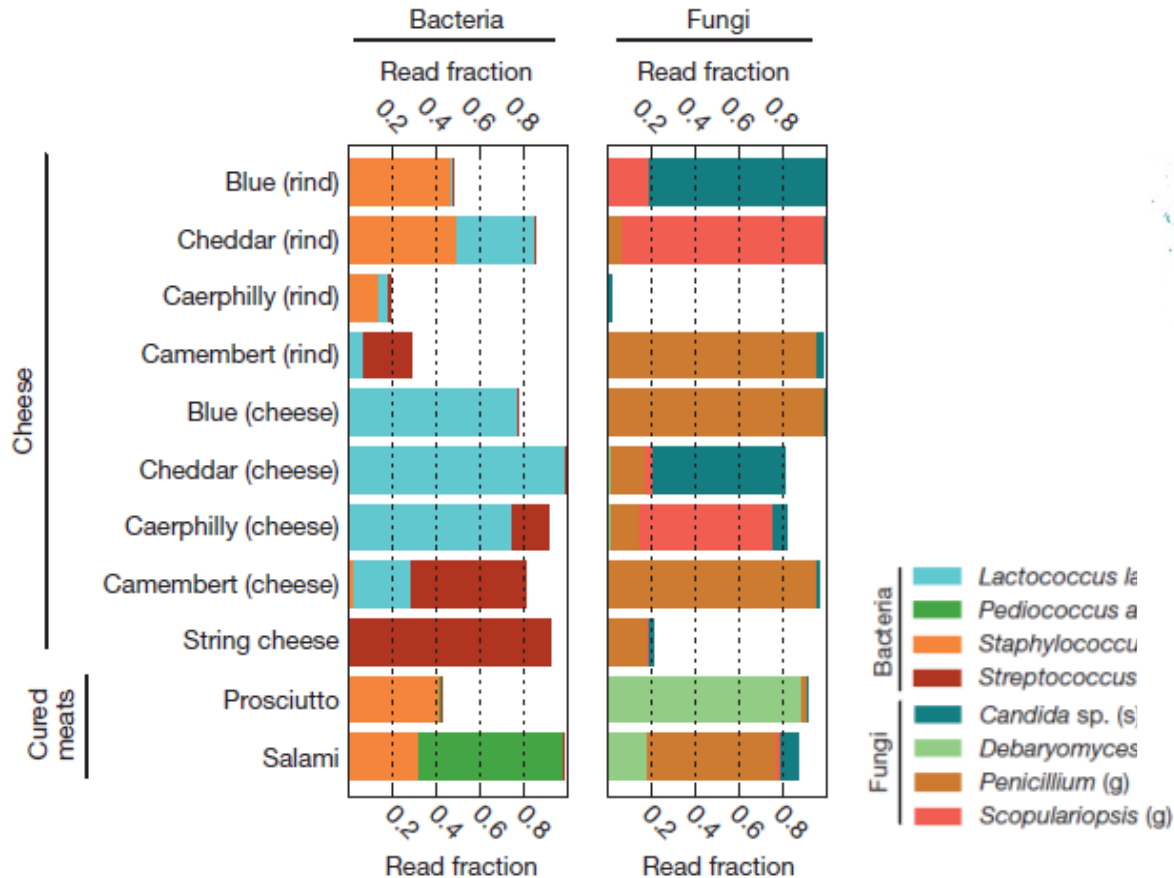
Microbes
($10^6 - 10^9$ cells / g)



**Improved
intestinal barrier
integrity and
immune response**

Fermentation can increase the number microorganisms entering the digestive tract by over 1000-fold

Interactions with the human microbiome



Lang *et al*/2014 Peer J; Derrien *et al*/2015 Trends Microbiol;
Ple *et al*/2015 Int J Food Microbiol; David et al 2013 Nature

Summary

We trust microorganisms by our making and eating of fermented foods.

Only a few fermented foods have been extensively studied (e.g. yogurt, beer). Even for those foods, there are still many unanswered questions.

Despite the prevalence of fermented foods human diets, their importance for health and well-being is not understood.



Evaluating And Testing Lacto-ferments Across the Country

If you make your own fermented fruits and vegetables, please donate to our community science project!

<https://www.eatlac.org/>
[@eat.lac.project](https://www.eatlac.org/@eat.lac.project)

Collaboration with
Dr. Erin DiCaprio
Food Science and Technology
UC Davis

<https://www.facebook.com/EATLAC/>



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<http://www.marcolab.net>



Marcolab



Robert Mondavi Institute

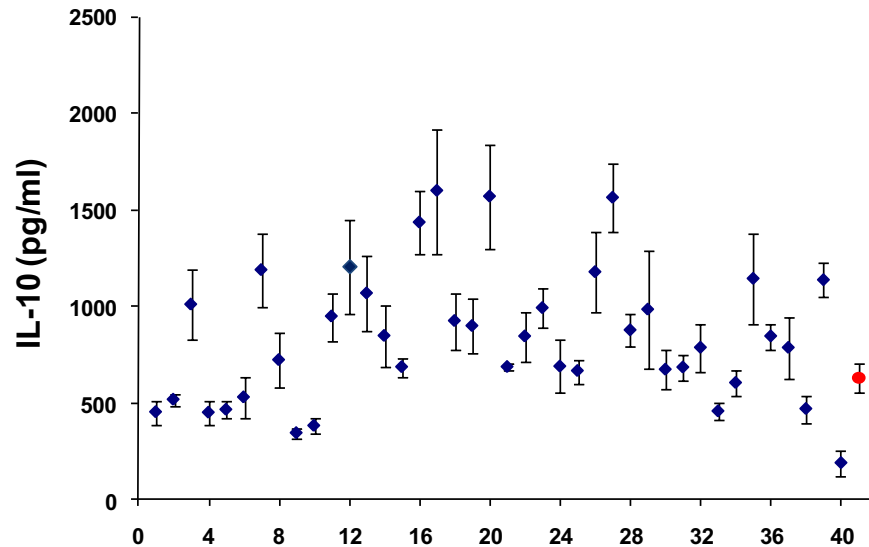


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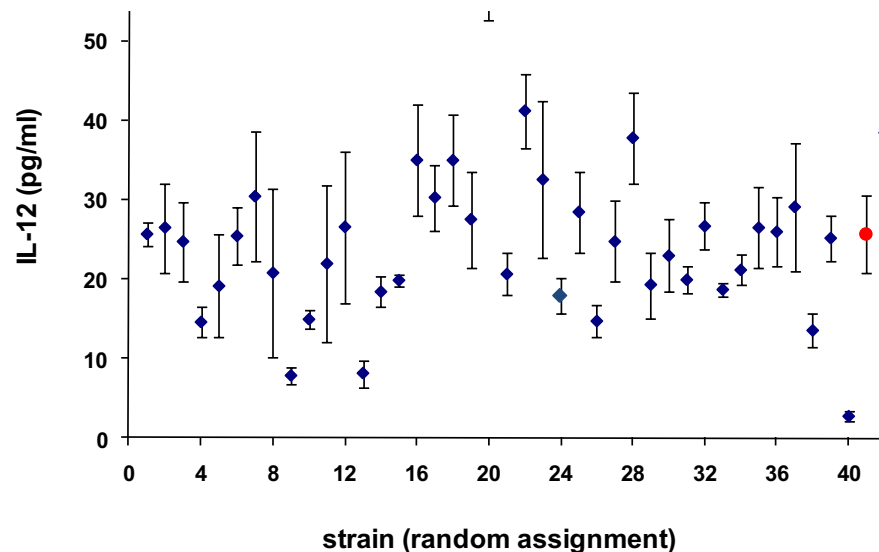
L. plantarum strain-specific immune responses

L. plantarum incubated for 24 h with human peripheral blood mononuclear cells (PBMCs)



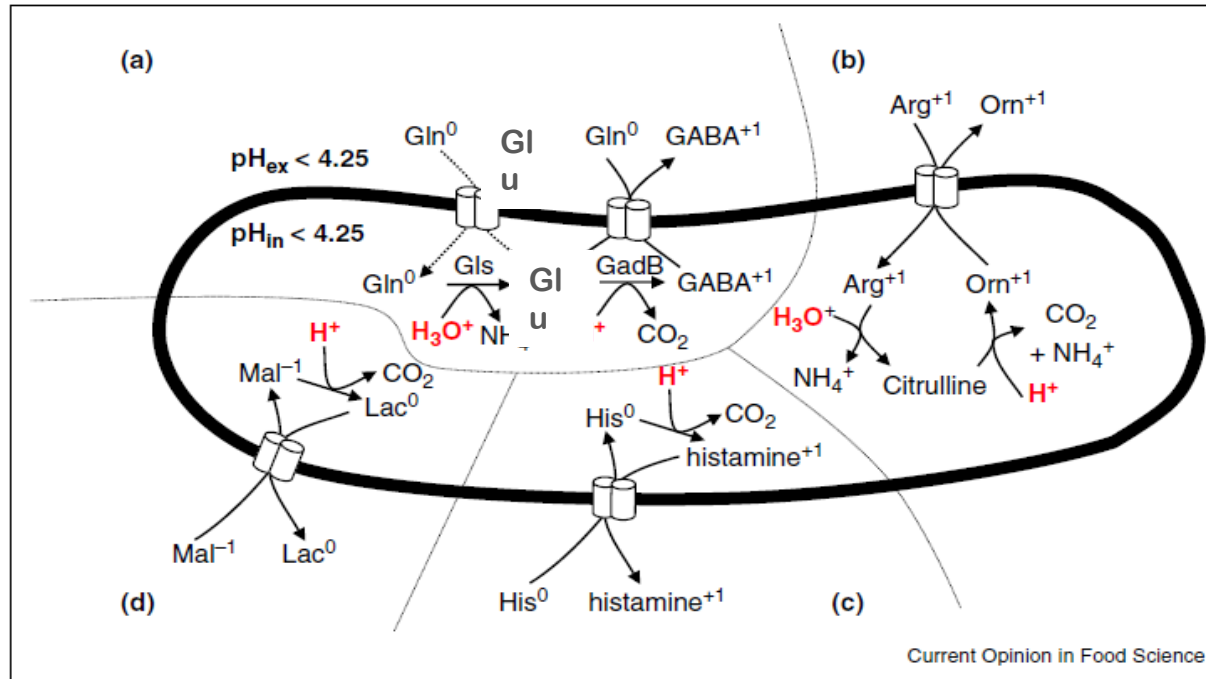
Anti-inflammatory cytokine IL-10 induced over an 8-fold range

Variation in PBMC responses was greater than found between different genera



Pro-inflammatory cytokine IL-12 induced over a 16-fold range

Microbial Metabolism: Causes and Consequences of Different End Products



- Lactic acid bacteria make organic acids which lower the pH of foods
- To maintain intracellular pH, LAB can use amino acids and malate and this results in the production of flavor and health-impacting compounds

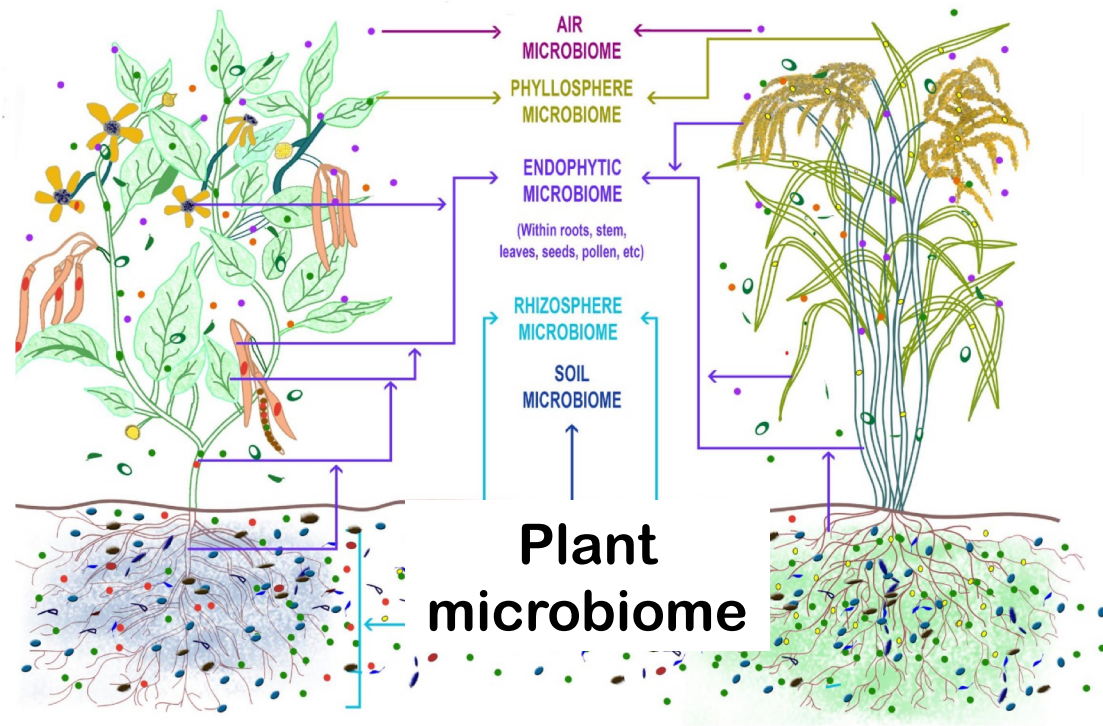
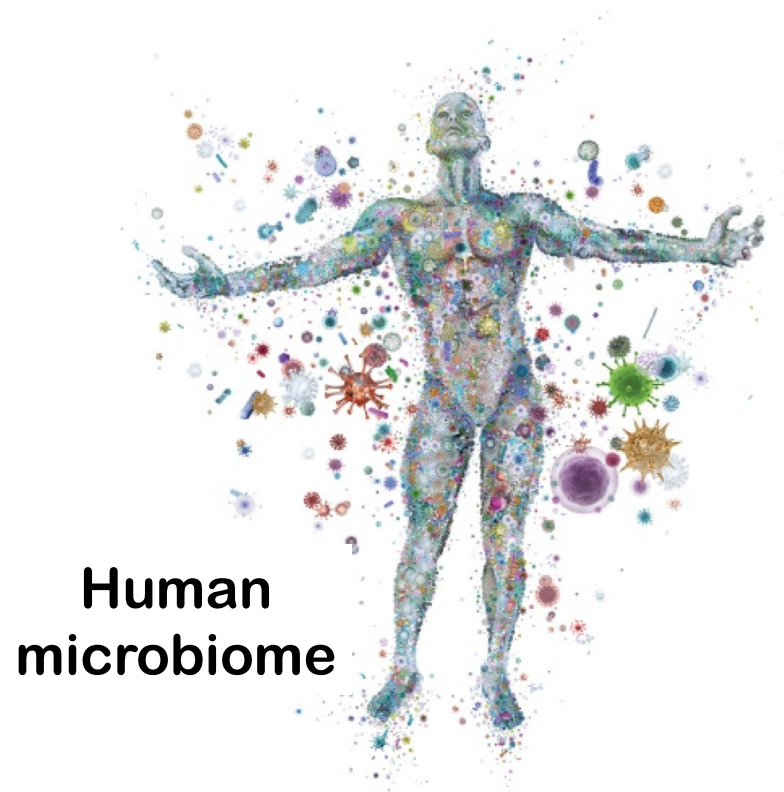
Microbes in foods?

Ferments acquire microbes:

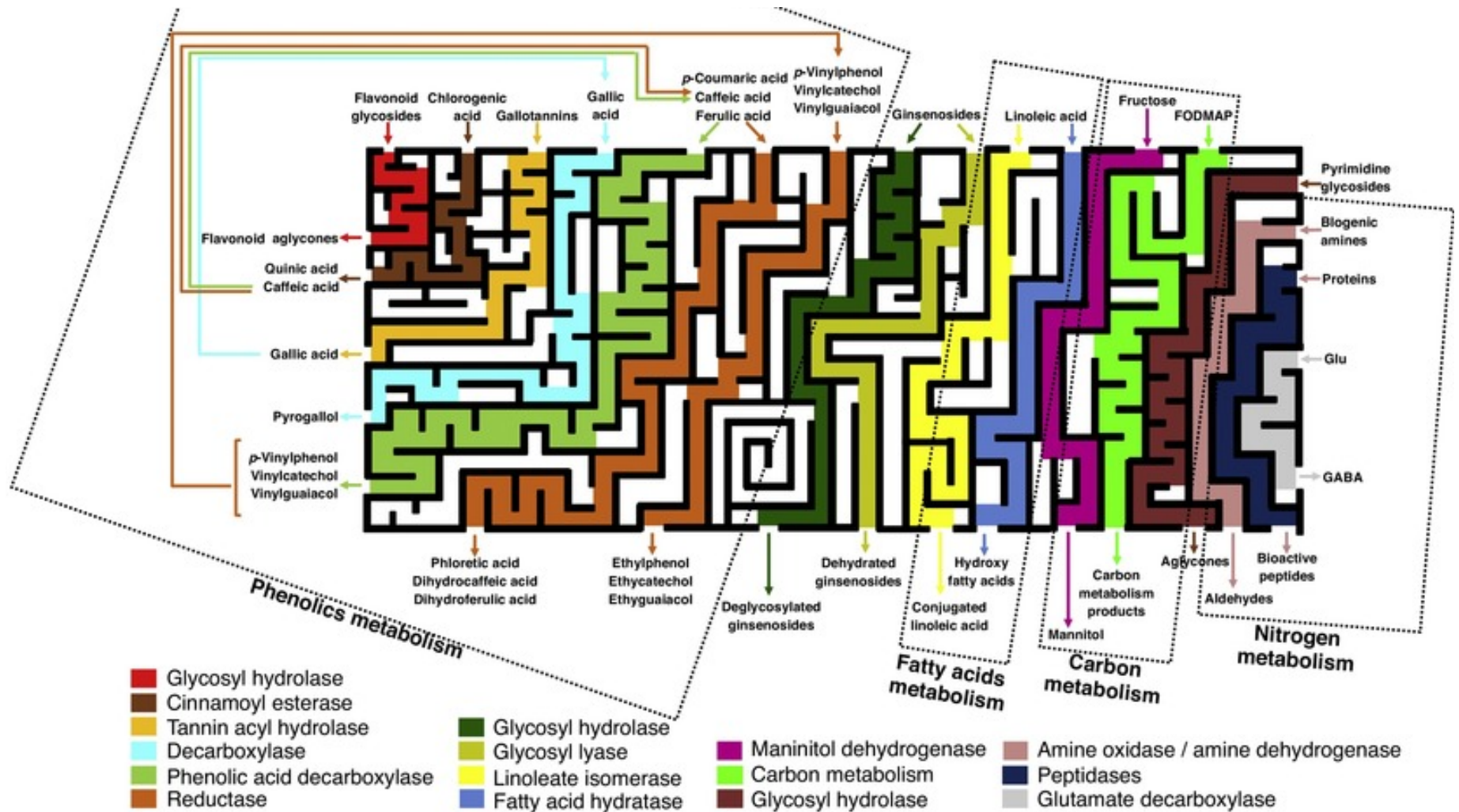
- from the starting ingredients
(example: sauerkraut)
- by “backslopping” a prior ferment
(example: kefir)
- from starter cultures
(example: most wines)

Fermented Food Microbiota

Microbiota: The collection of microorganisms inhabiting an ecosystem



Microbial Metabolic Networks: More Than Just Flavor



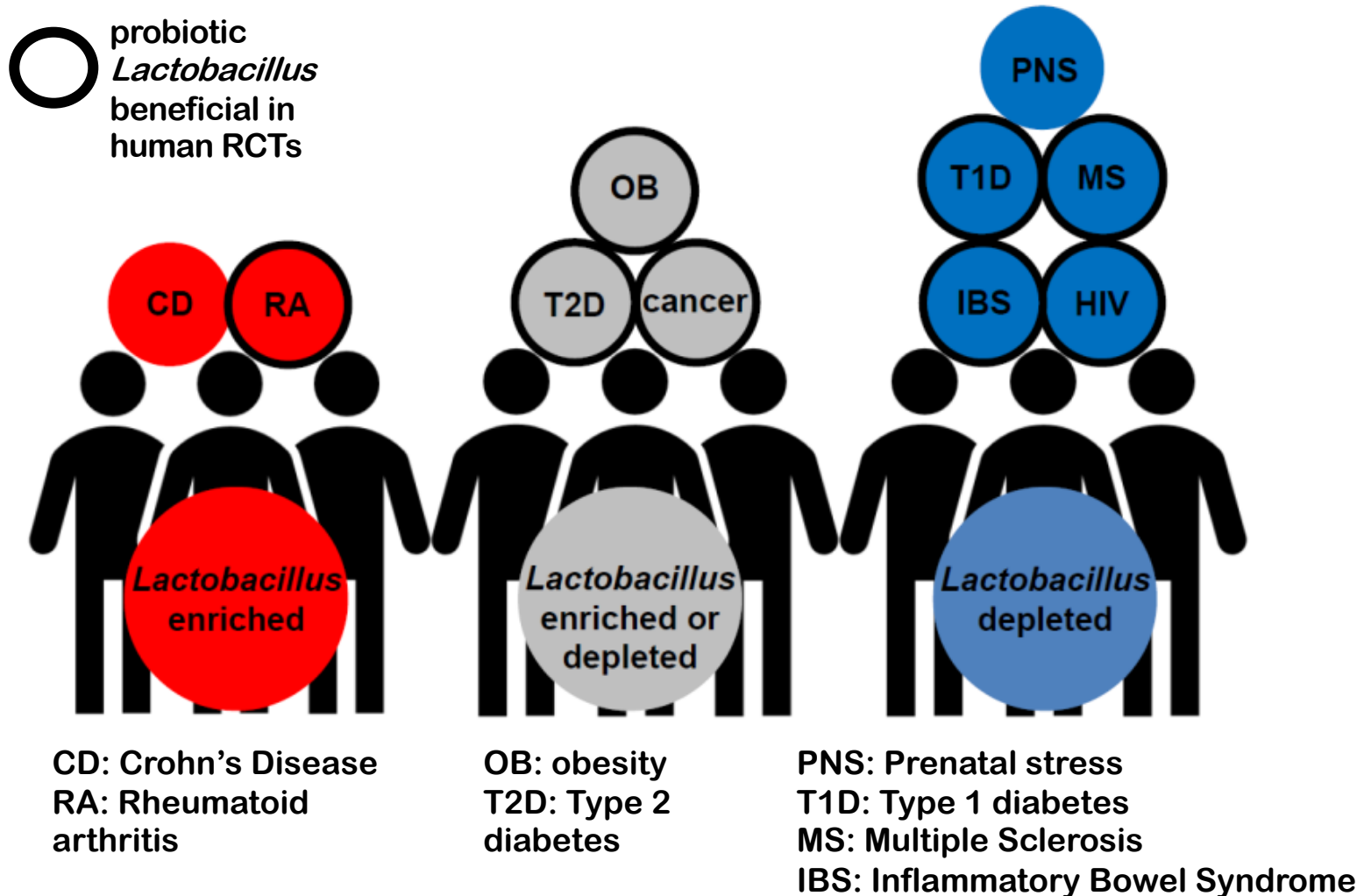
Current Opinion in Biotechnology

Presence of live microbes

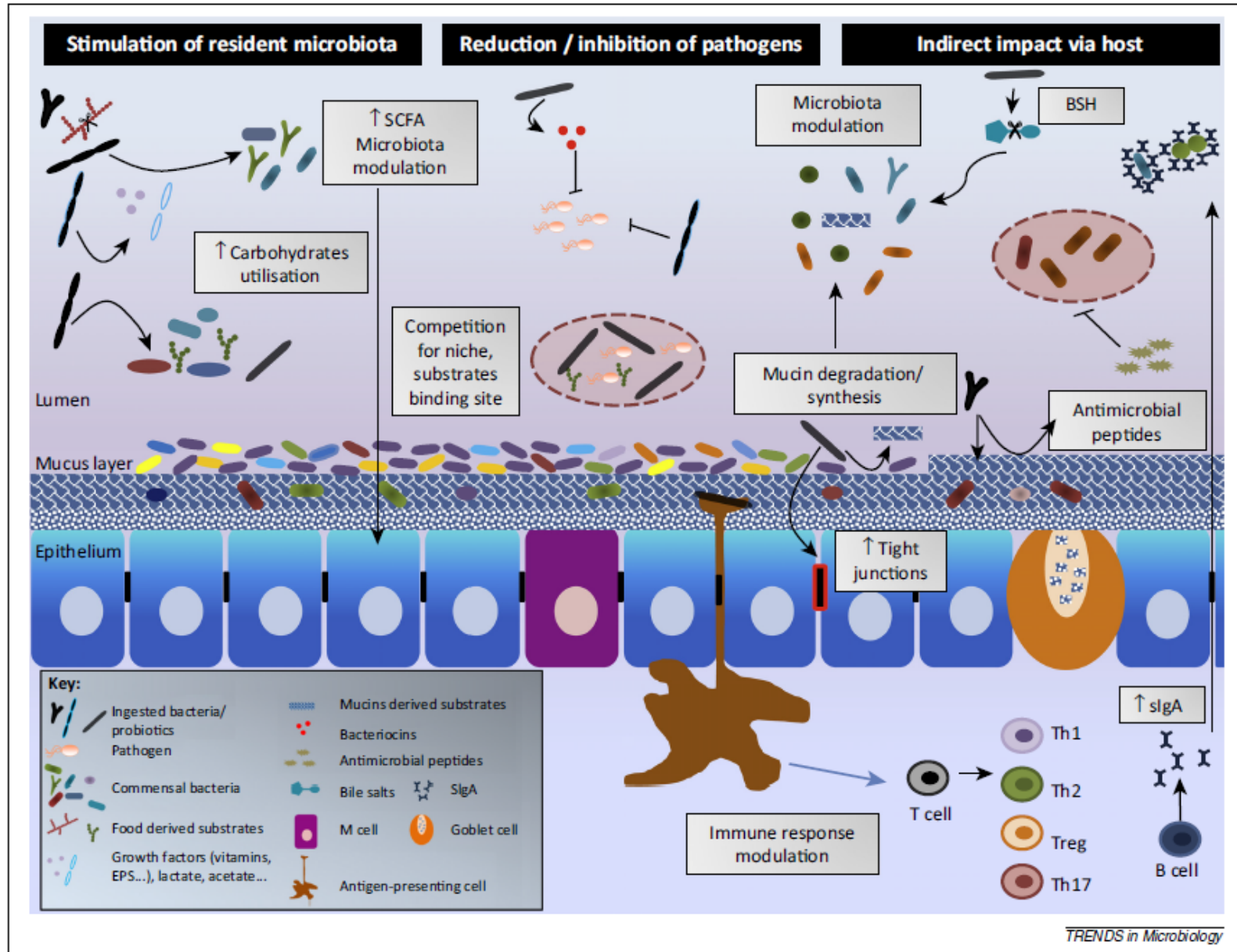
Fermented	
Live microbes present	Live microbes absent
Yogurt	Bread
Sour cream	Heat-treated or
Kefir	pasteurized fermented
Most cheeses	vegetables, sausage, soy
Miso	sauce, vinegar, some
Natto	kombuchas
Tempeh	Wine, most beers, distilled
Non-heated fermented	spirits
vegetables	Coffee and chocolate
Some sausages	beans (after roasting)
Fermented cereals	
Most kombuchas	
Some beers	



Lactobacillus is a member of the human gut microbiome



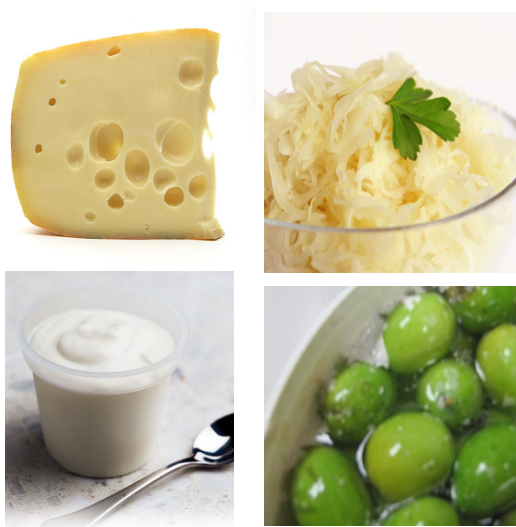
Yet - dietary bacteria change the intestine



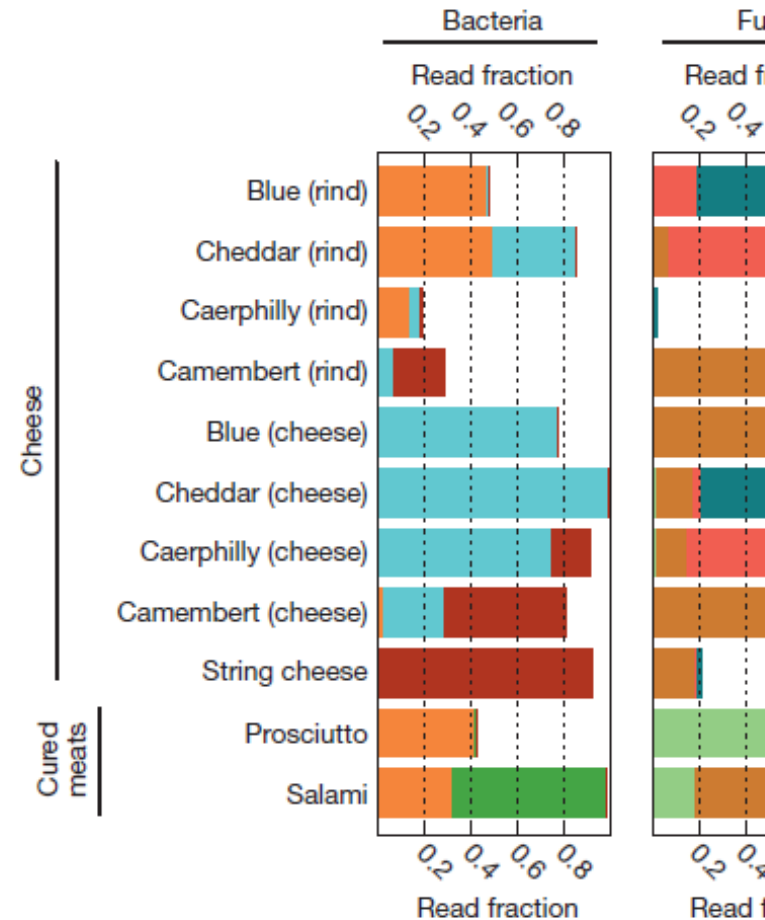
Beneficial microbes



Fresh fruits & vegetables
($10^3 - 10^7$ cells/ g)



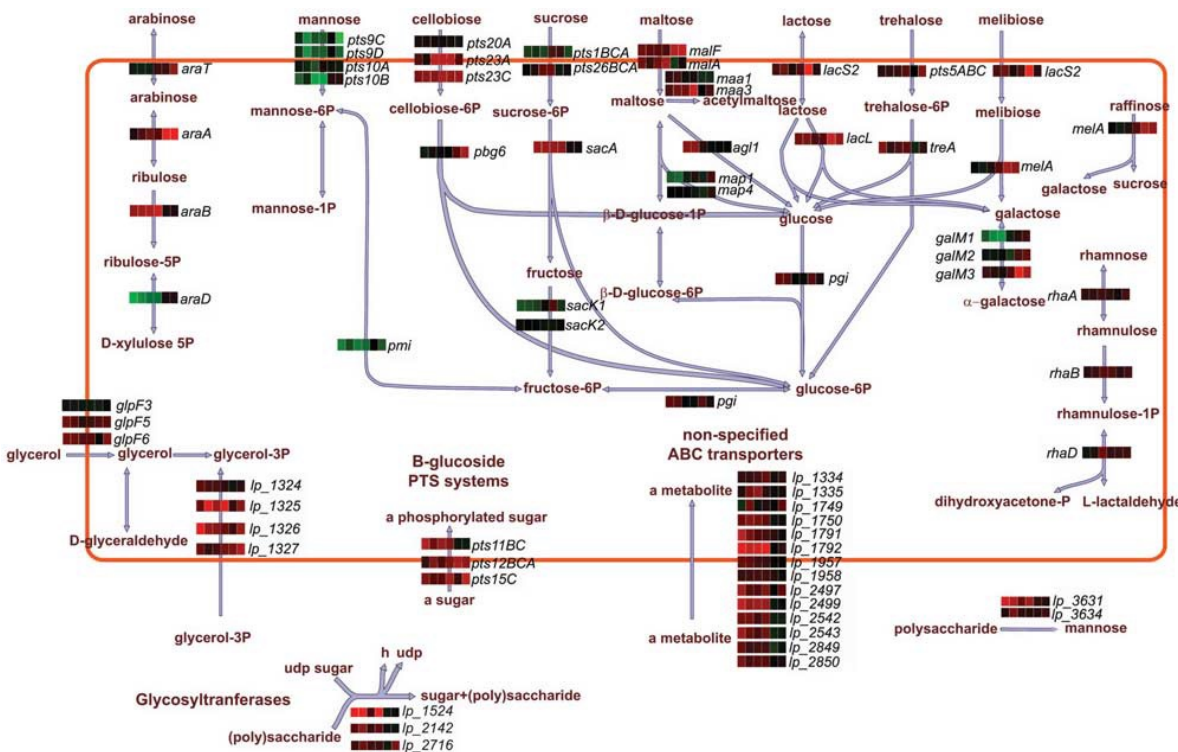
Fermented foods
($10^6 - 10^9$ cells / g)



Lactobacillus plantarum



L. plantarum persists and is active in the digestive tract for several days after it is ingested



Carbohydrate metabolism

Amino acid biosynthesis

Cell surface properties



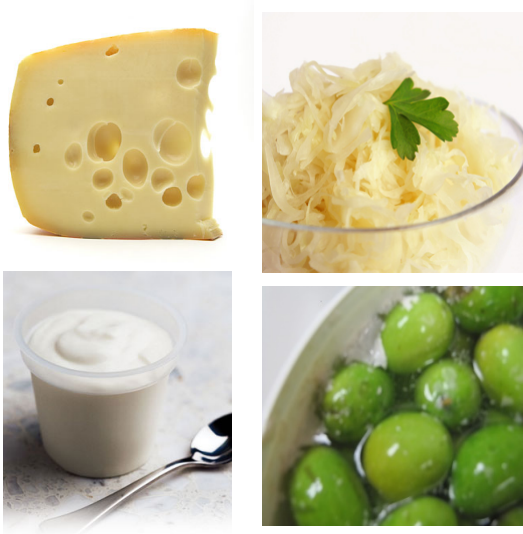
The Mediterranean and USDA recommended diets which include fermented foods have over $>10^9$ bacteria per day

Live microbes?

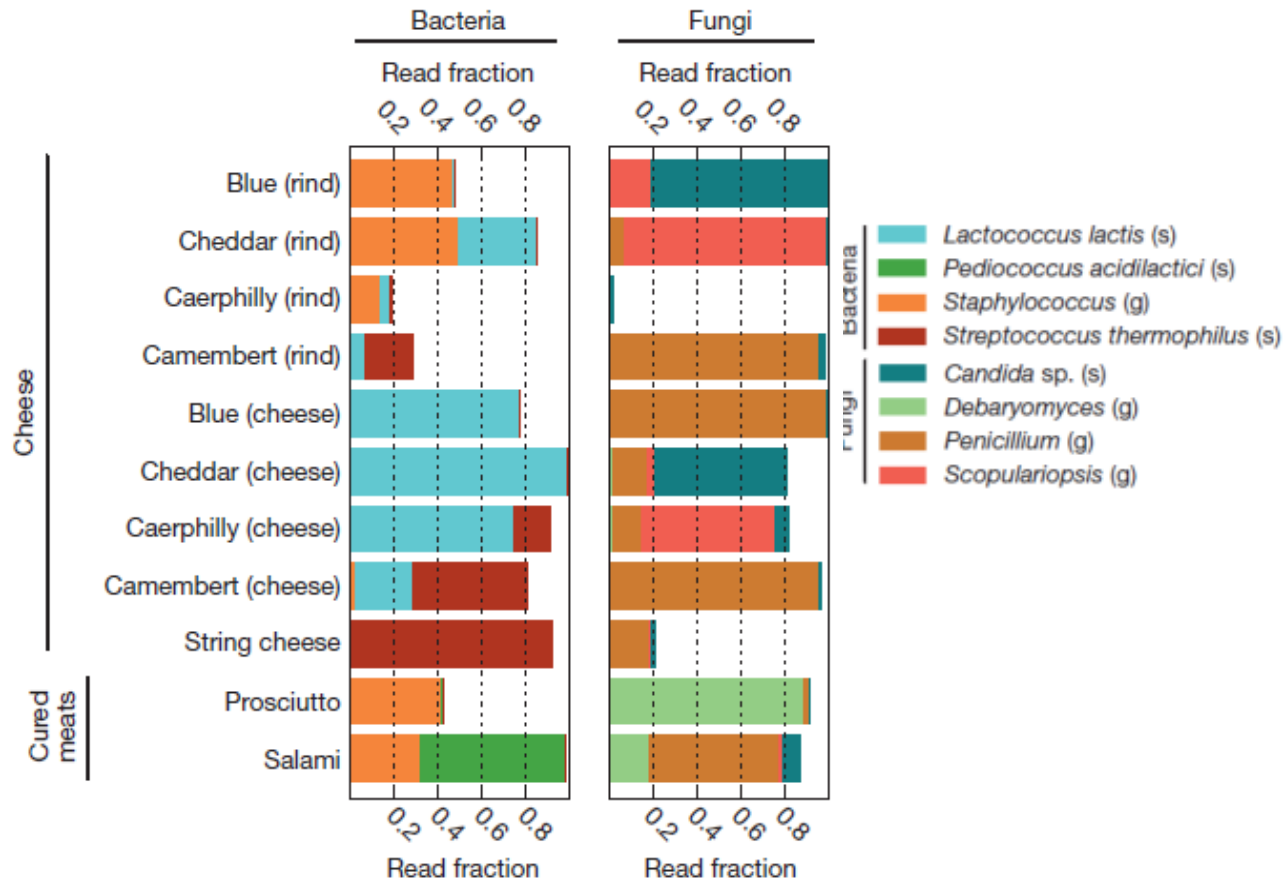


The typical American diet has $<10^6$ bacteria per day

Beneficial microbes



Fermented foods
($10^6 - 10^9$ cells / g)



**Increase microorganisms entering the digestive tract
over 1000-fold**