

# Microbiology of Cheese Rinds



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**A Dairy Australia/ National Centre for  
Dairy Education webinar**

# Microbiology of Cheese Rinds

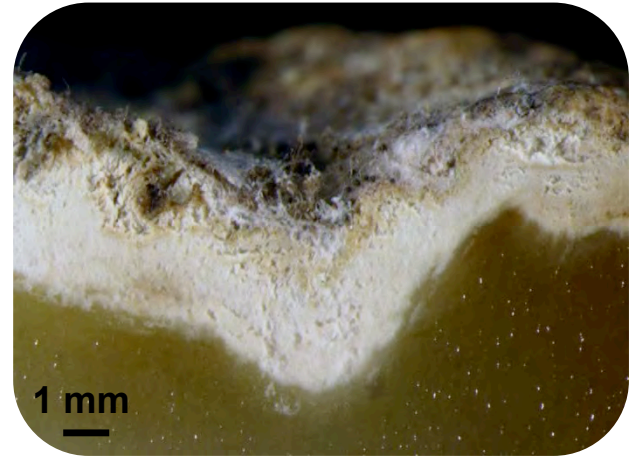
What is the microbial diversity of cheese rinds?

What are the design principles for cheese rinds?

How can we use this knowledge to improve cheese quality?



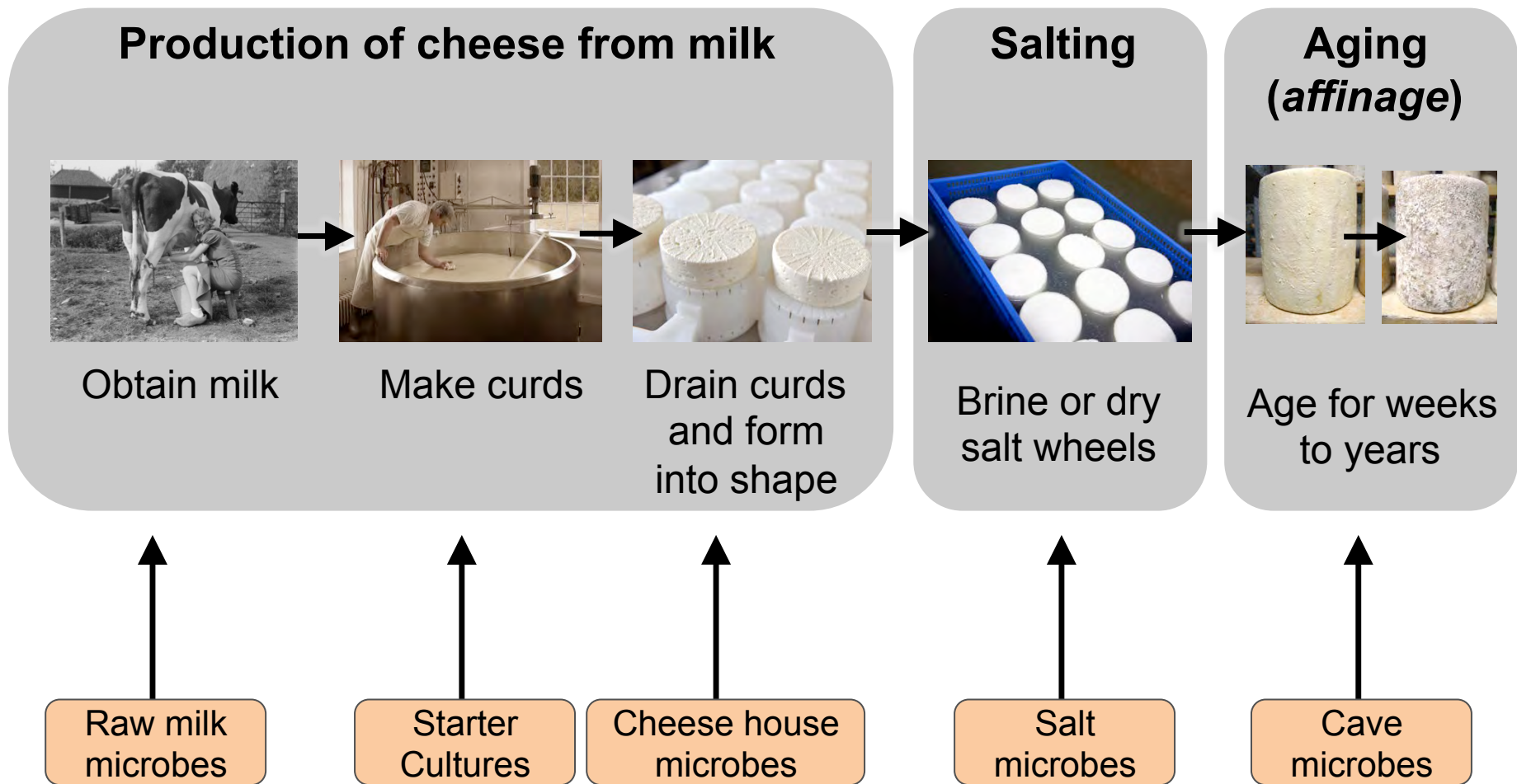
# Background: surface-ripened cheeses



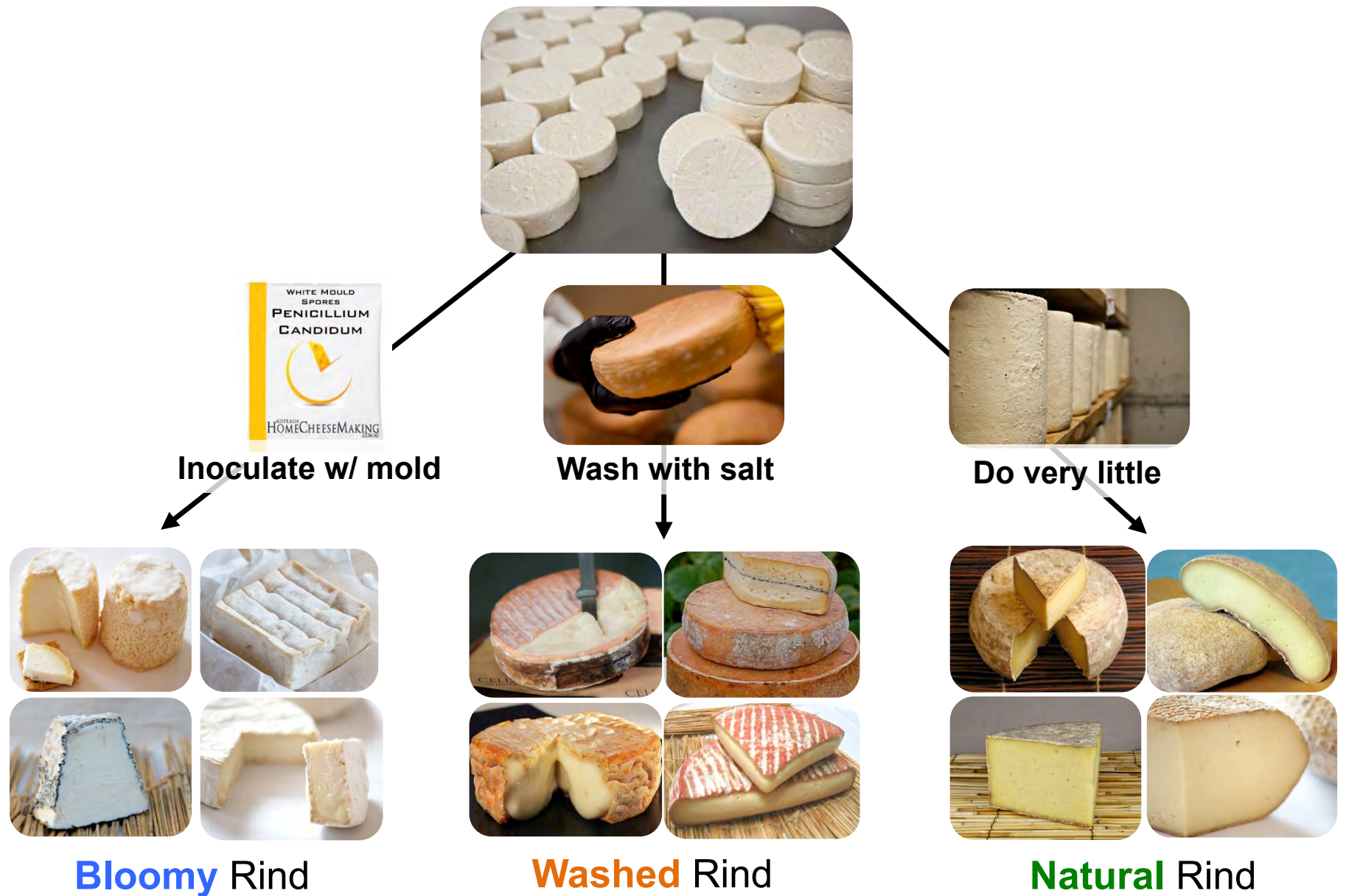
# Background: surface-ripened cheeses



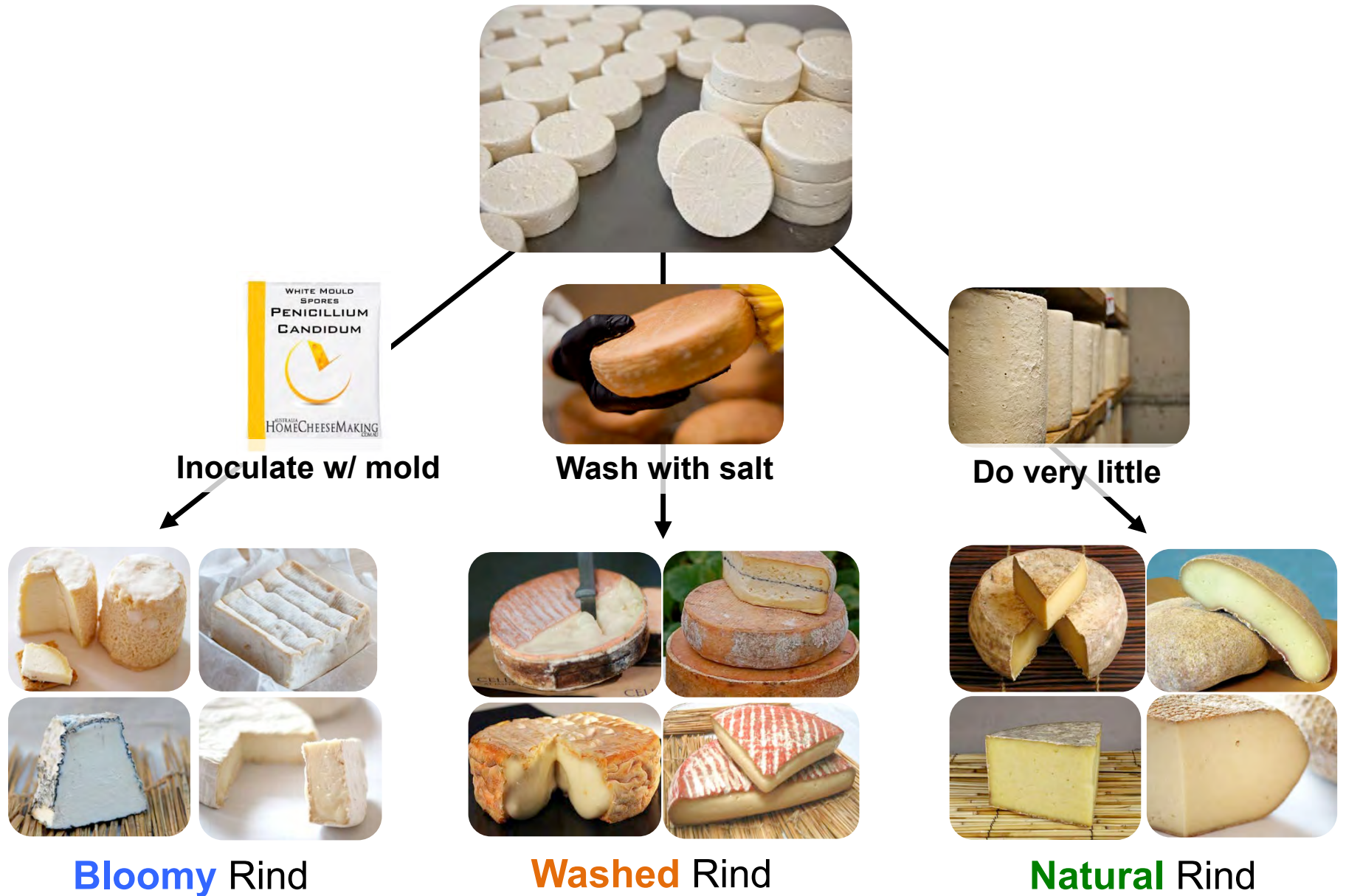
# Background: How cheese rinds develop



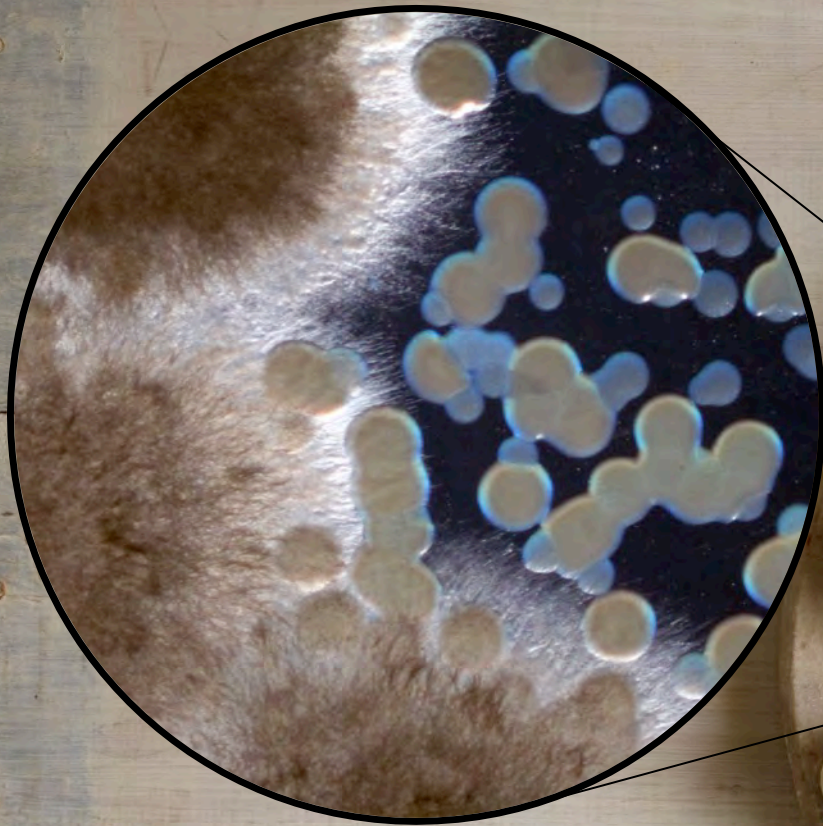
# Background: Three styles of microbial cheese rinds



# Background: Three styles of microbial cheese rinds



# Background: basic microbiology of cheese rinds





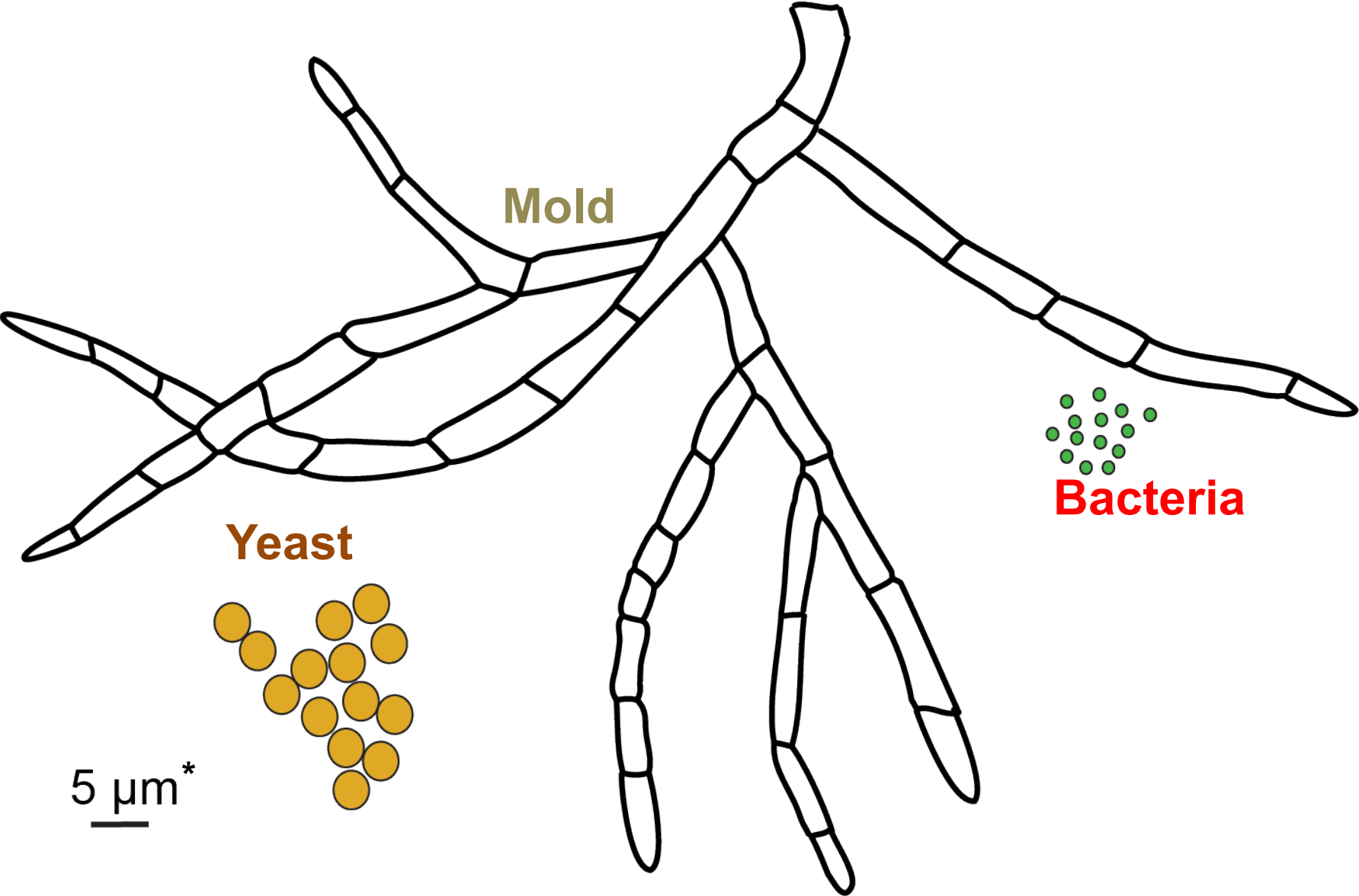
# Background: basic microbiology of cheese rinds

## Bacteria vs. Yeast vs. Mold



400X magnification

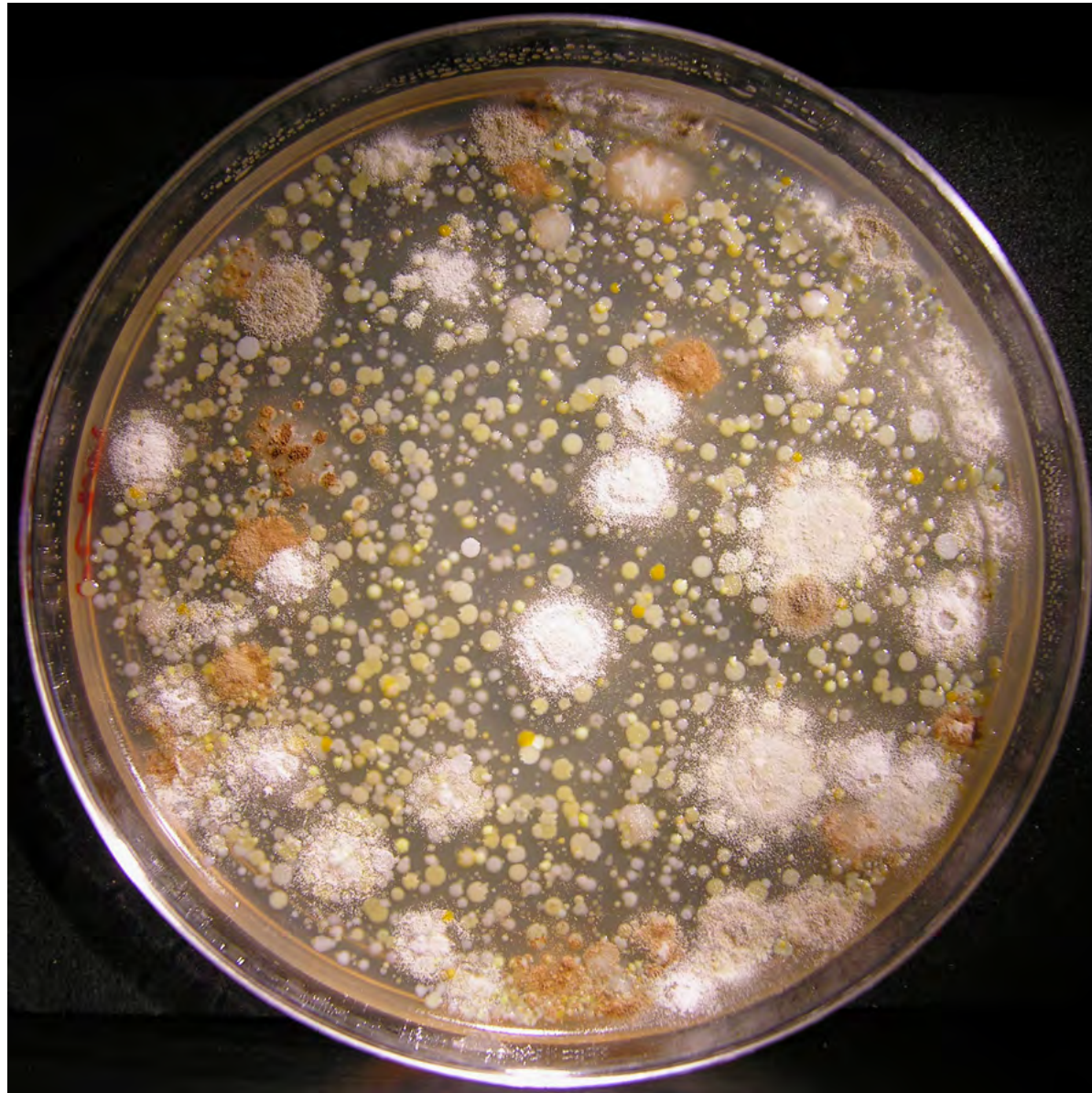
# Mold | yeast | bacteria



\*Period at end of sentence is 1000  $\mu\text{m}$

# **Background: basic microbiology of cheese rinds**

## **Bacteria vs. Yeast vs. Mold**



# Background: basic microbiology of cheese rinds

## Bacteria vs. Yeast vs. Mold

	Size	Cell Structure	Appearance in Culture
Bacteria	0.5 - 5 $\mu$ m	Single - celled	Smooth blobs
Yeast	3 - 5 $\mu$ m	Single - celled	Smooth blobs
Mold	up to 50 $\mu$ m long	Multicellular	Fuzzy/ diffuse

# Background: basic microbiology of cheese rinds

**Bacteria**



**Yeast**



**Mold**



# Microbiology of Cheese Rinds

What is the microbial diversity of cheese rinds?

What are the design principles for cheese rinds?

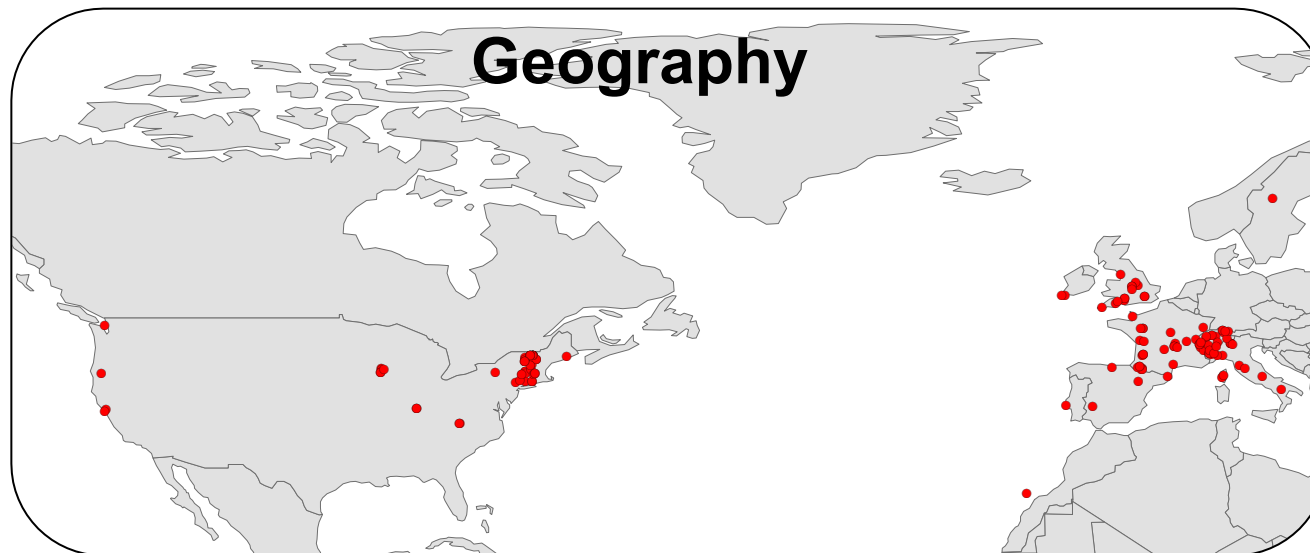
How can we use this knowledge to improve cheese quality?



# Large-scale survey of rind microbial diversity

137 different cheeses

362 wheels of cheese



## Rind Type



**Bloomy (24)**

**Washed (52)**

**Natural (61)**

# How do we measure cheese rind microbial diversity?

**EXTRACT** DNA from  
cheese rind sample

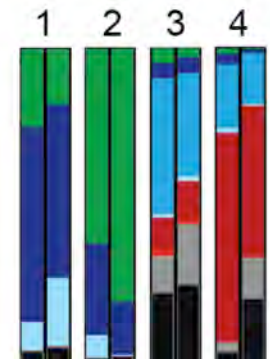


**AMPLIFY**  
“fingerprint”  
genes

**SEQUENCE** DNA



**MATCH** DNA  
to sequences in  
databases



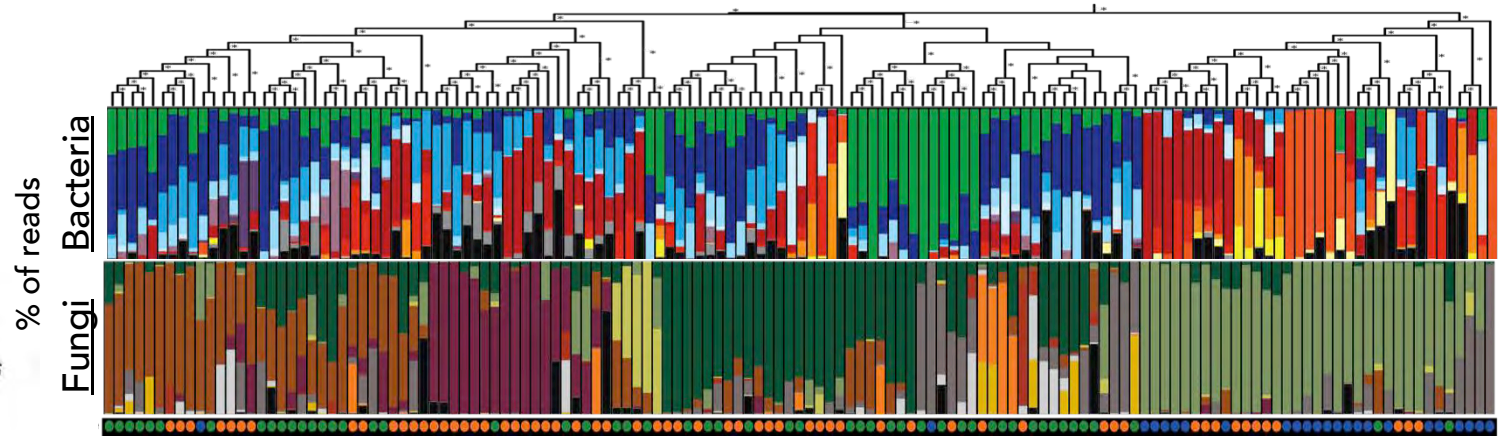
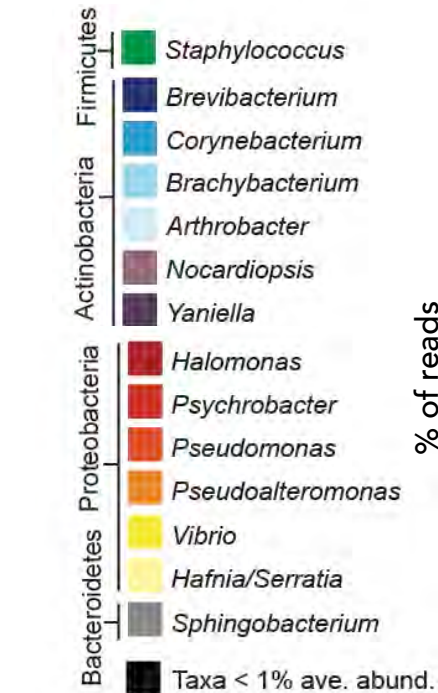
*Staphylococcus*  
*Brevibacterium*  
*Brachybacterium*

.....

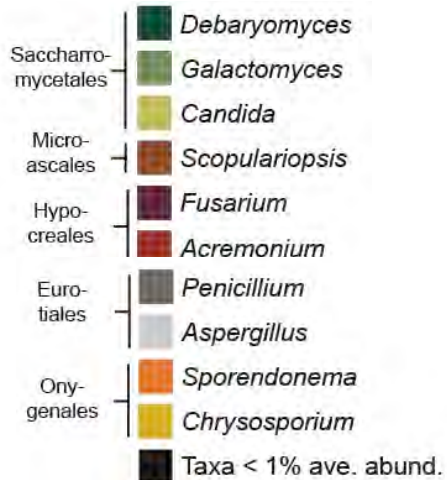


# Microbial diversity of 137 different cheese rinds

## Bacteria



## Fungi



Rind communities are relatively simple:

7 bacterial genera/cheese, 14 dominant genera across samples

3 fungal genera/cheese, 10 dominant genera across samples

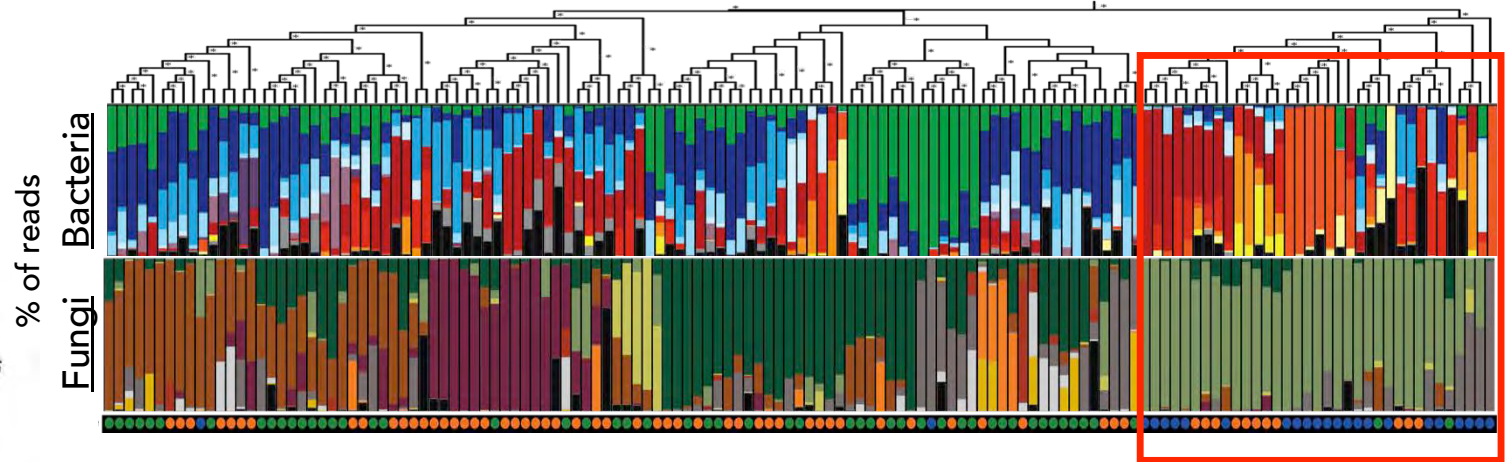
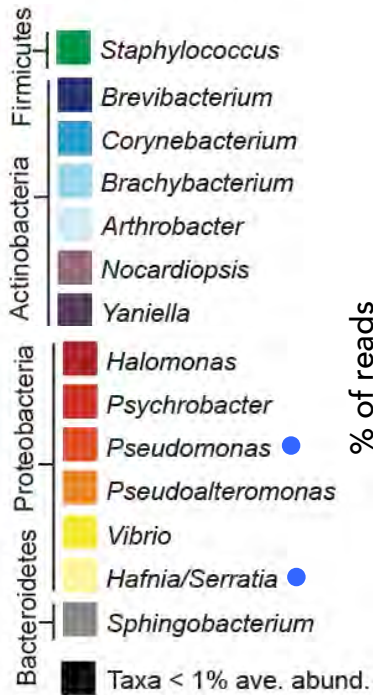
For closer look see Wolfe et al. 2014, *Cell*, 158: 422-433

OR

[MicrobialFoods.org](http://MicrobialFoods.org)

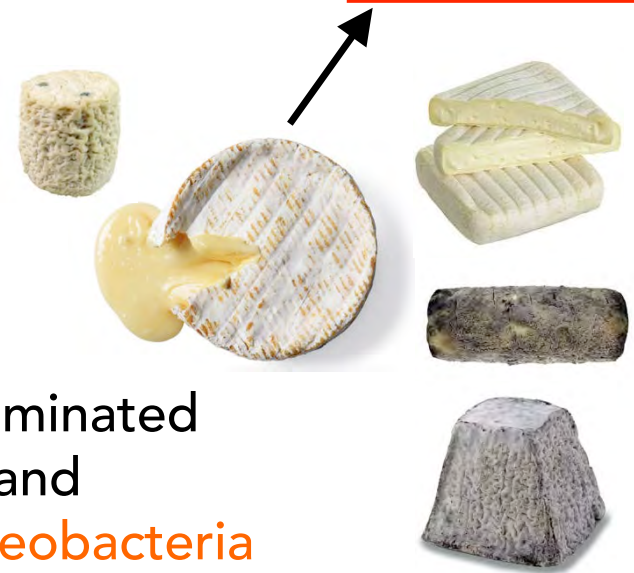
# Bloomy rind cheeses

## Bacteria

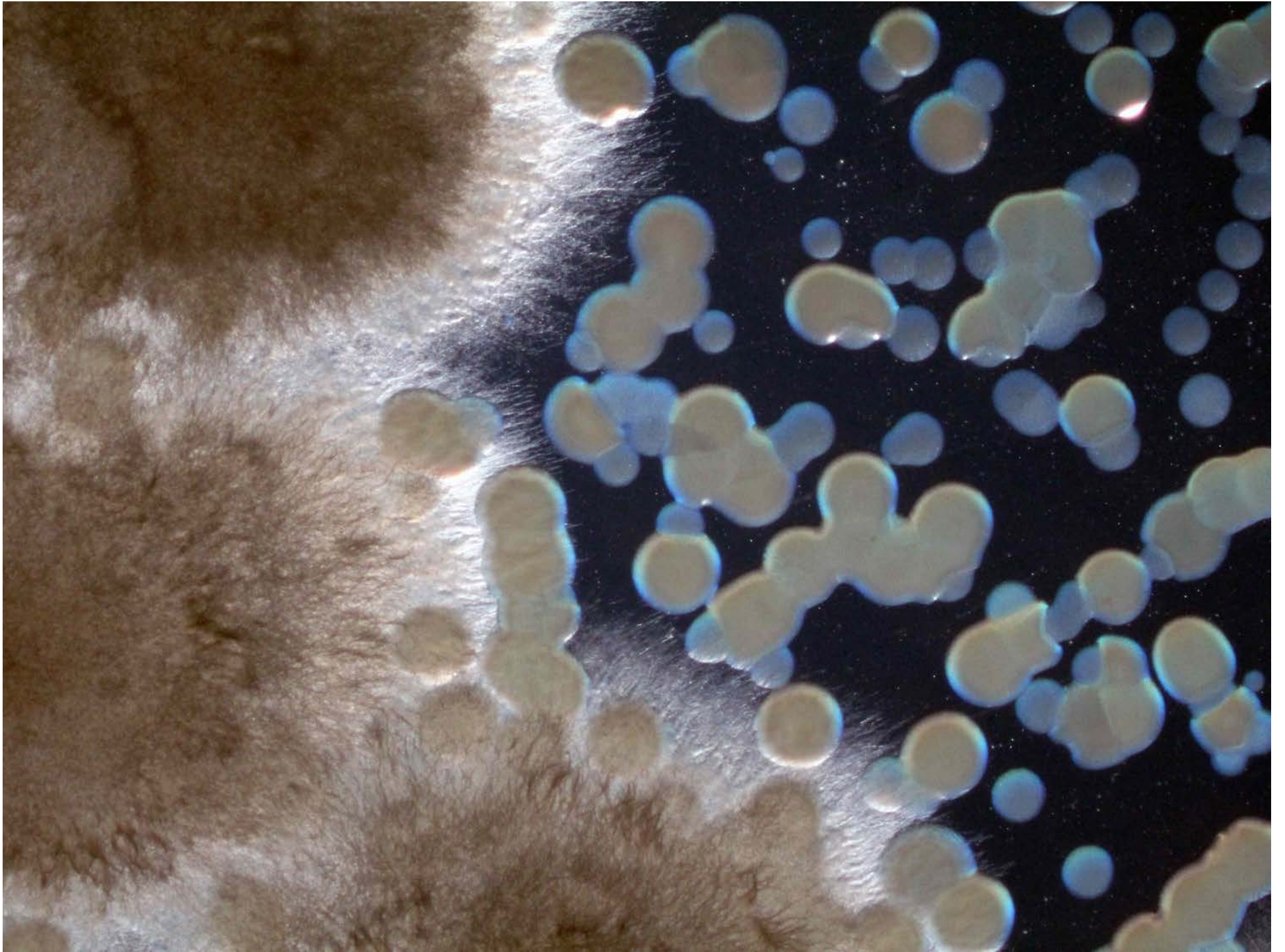


● Bloomy rind  
● Natural rind  
● Washed rind

## Fungi



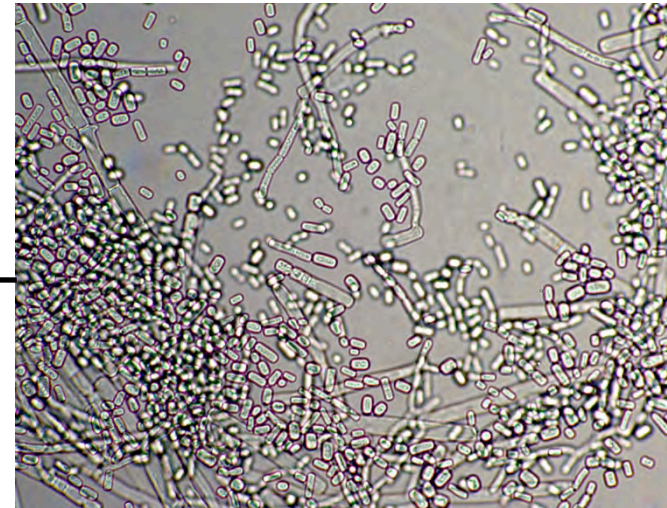
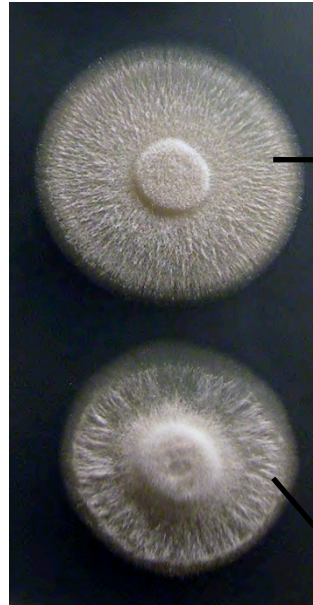
**Bloomy** rind cheeses are dominated by the fungi *Galactomyces* and *Penicillium* and various **Proteobacteria**



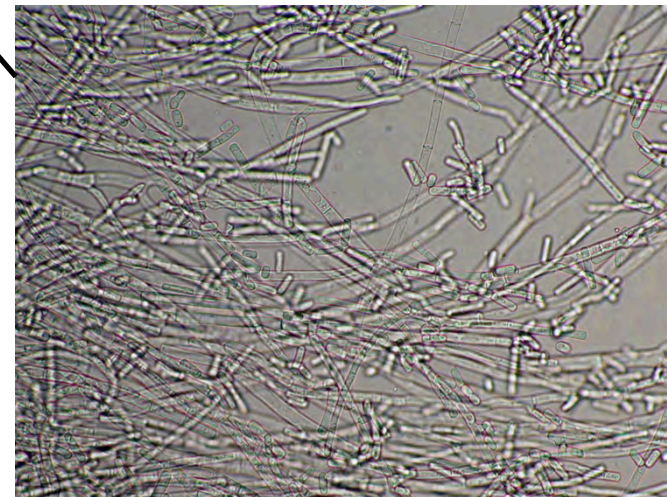
# *Penicillium camemberti*



# *Galactomyces geotrichum* (aka “Geo”)



Yeast like (arthrospore forming)



Filamentous (few arthrospores)

# *Mucor*



# ***Rhodotorula* and *Rhodospiridium***

*Rhodospiridium*



Common on washed  
rind cheeses

*Rhodotorula mucilaginosa*



Common contaminant  
on bloomy rind cheeses

# Proteobacteria

## Marine Bacteria

*Pseudoalteromonas*

*Vibrio*

*Halomonas*

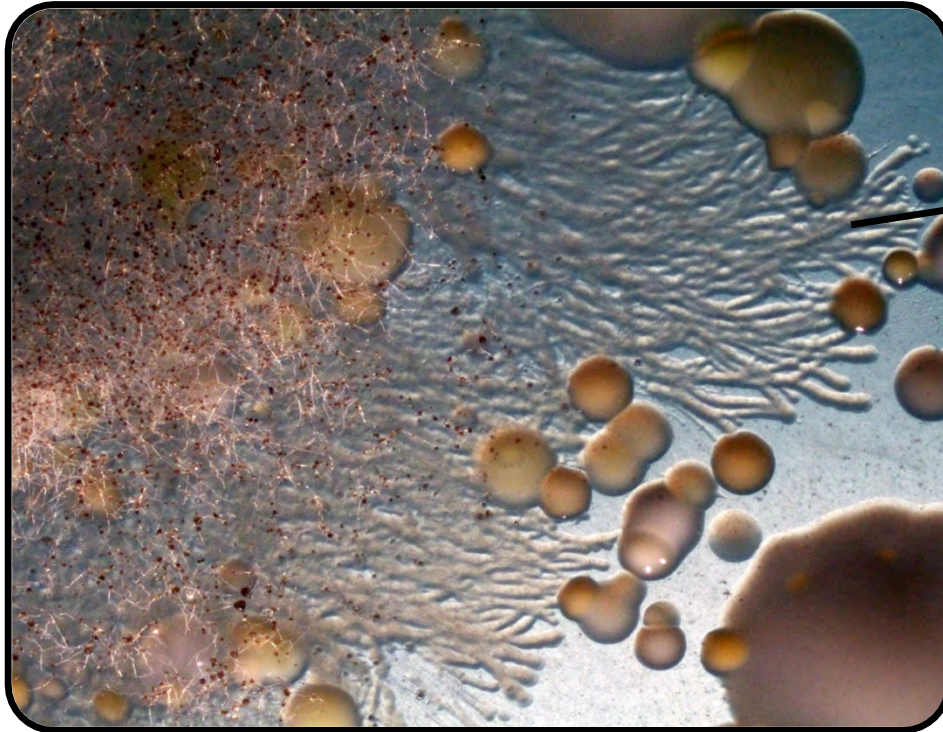


Starter culture ***Hafnia*** and other Proteobacteria make many volatile sulfur compounds that we perceive as cooked cabbage

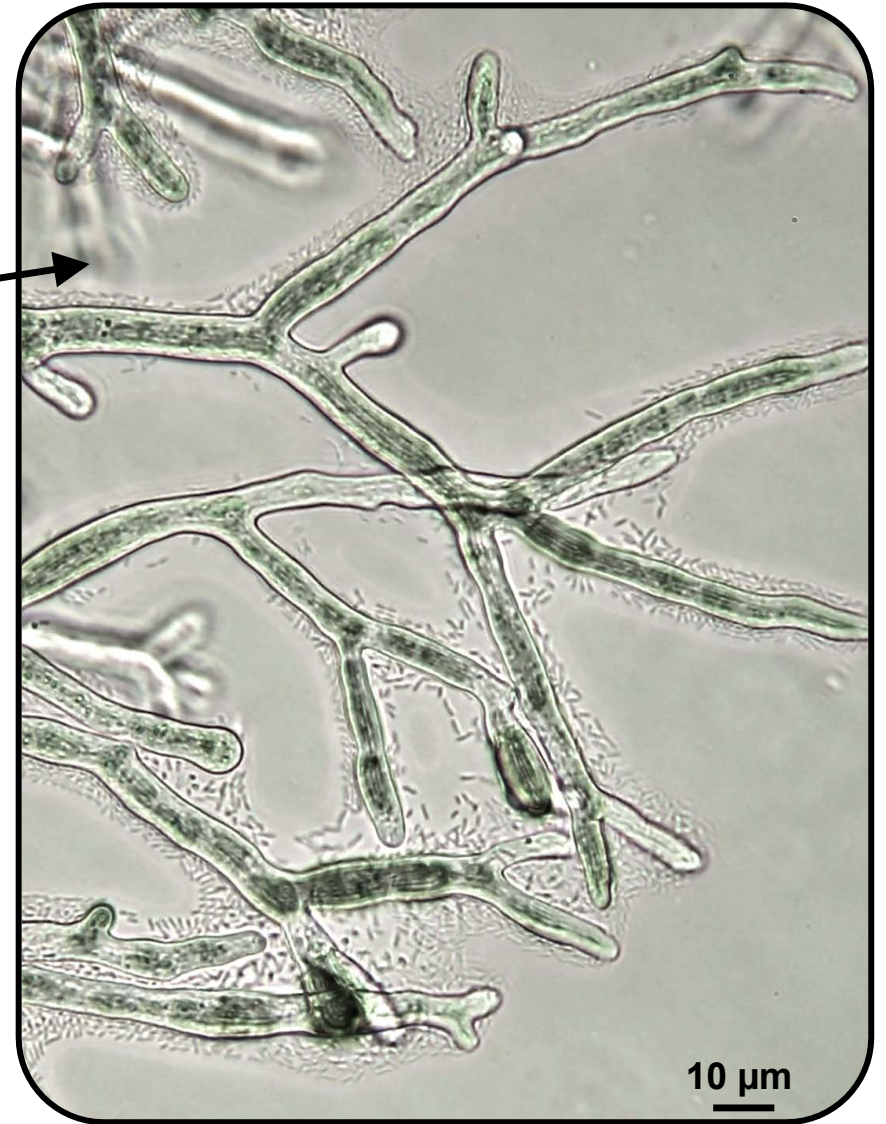


# Proteobacteria

Motile bacteria that love to 'swim' around cheese

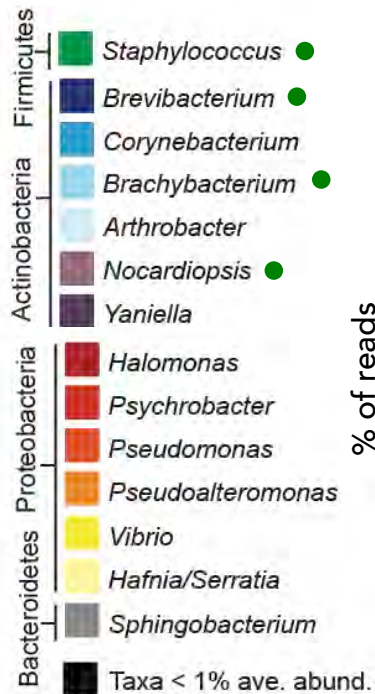


*Serratia proteamaculans* (**bacterium**) on  
*Mucor lanceolatus* (**fungus**) hyphae

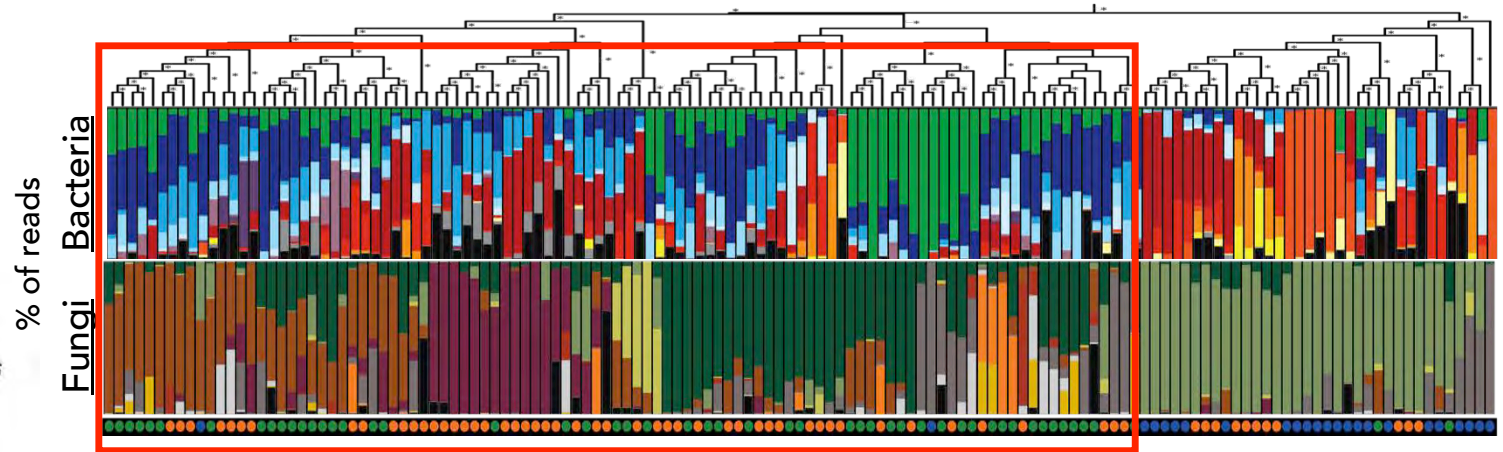
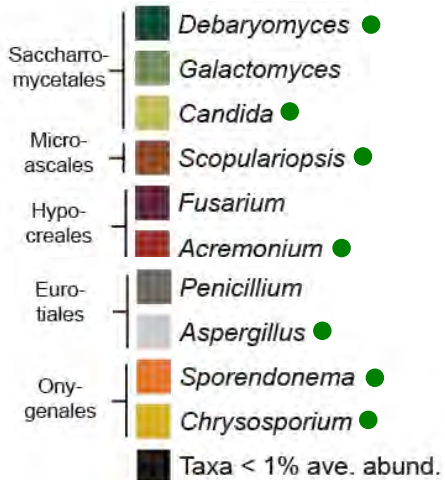


# Natural rind cheeses

## Bacteria



## Fungi



**Natural** rind cheeses are dominated by *Staphylococcus*, Actinobacteria, notably *Brevibacterium*, the yeast *Debaryomyces*, and various filamentous fungi (especially *Scopulariopsis*)





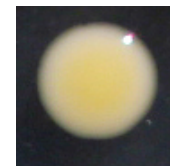
# ***Staphylococcus* in my cheese?!**

Not *S. aureus* !

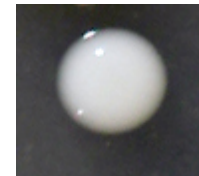
Coagulase-negative *Staphylococcus* (sometimes CNS)

‘Good staph’ that play roles in rind development and aromas

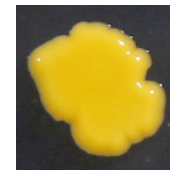
Also very common on salami surface



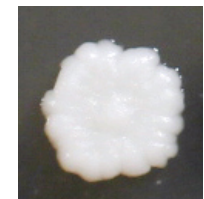
*S. saprophyticus*



*S. equorum*



*S. xylosus*



*S. succinus*

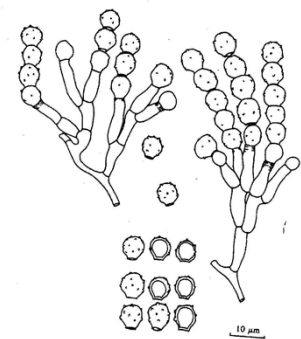
# ***Brevibacterium***

Usually thought of as important in washed rinds, but also very common on natural rinds

Likes higher pH and needs *Staph* and yeast to grow

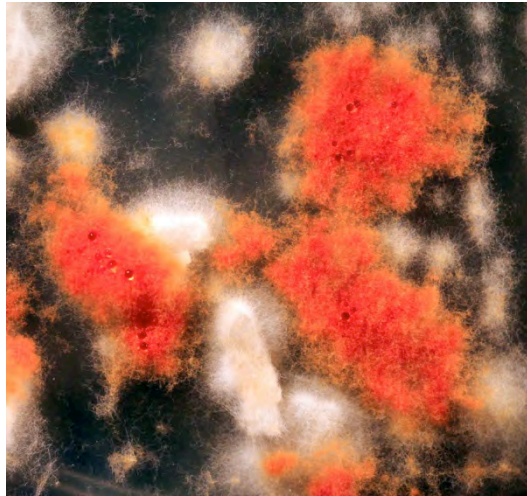


# *Scopulariopsis*



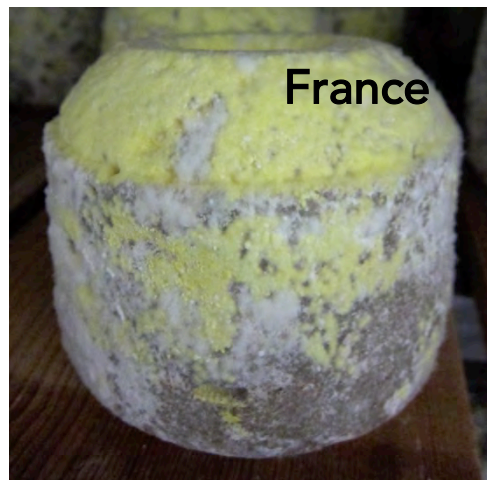
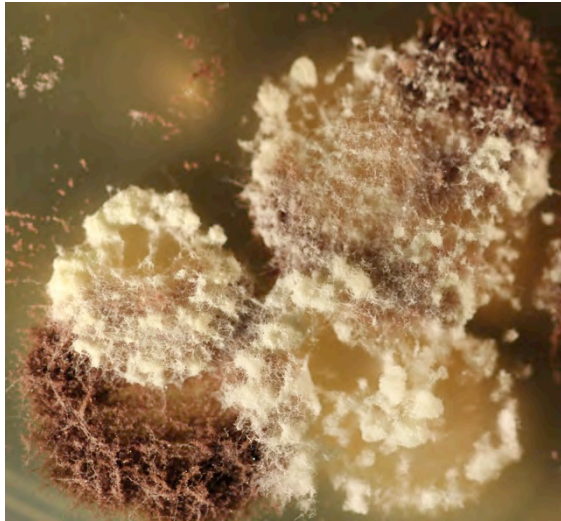
[mycota-crcc.mnhn.fr/](http://mycota-crcc.mnhn.fr/)

# *Sporendonema casei*



Murray's cave (NY)

# *Chrysosporium sulfureum*

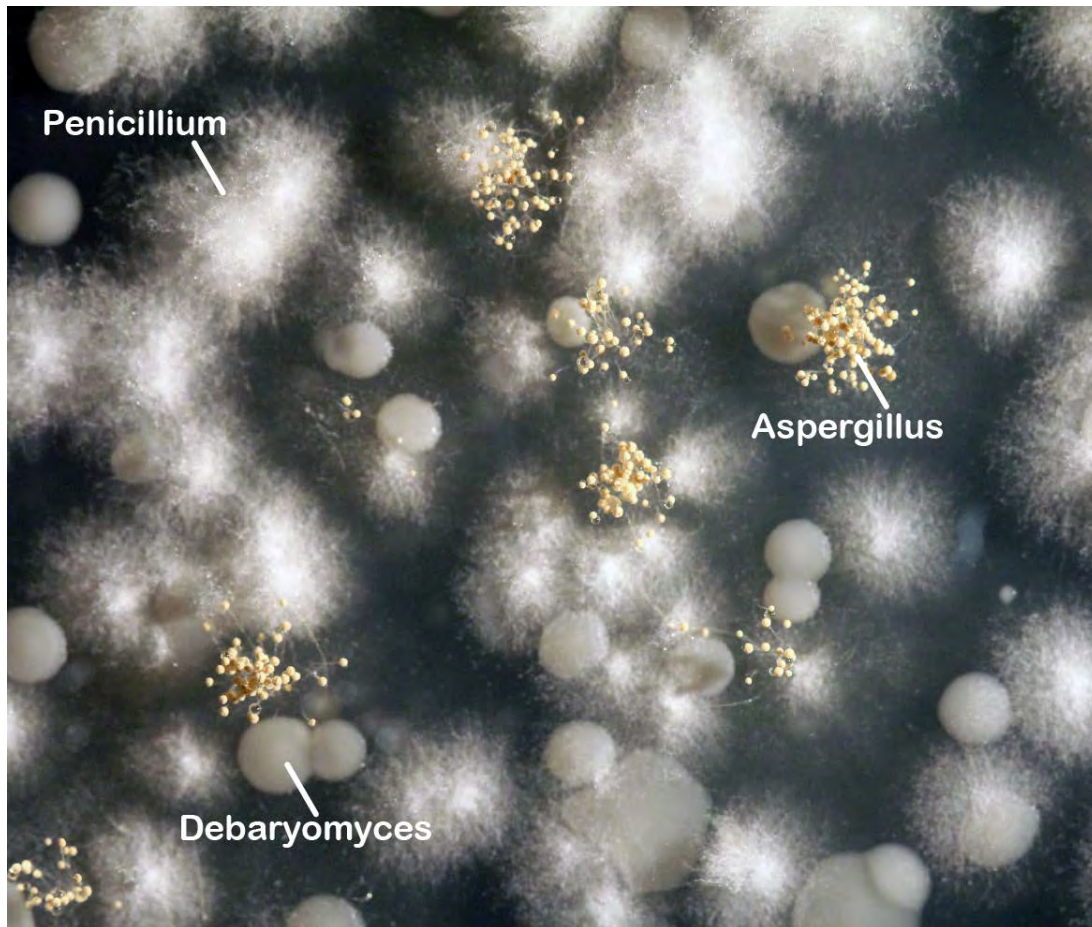




# *Acremonium*



# *Aspergillus*



- Mycotoxin production is significant in many of these species
- Aflatoxins are especially dangerous
- Few reports of mycotoxins in cheese, but probably best to be precautionary and keep this mold in low abundance on rinds
- Especially abundant on cheeses that are covered in plant material

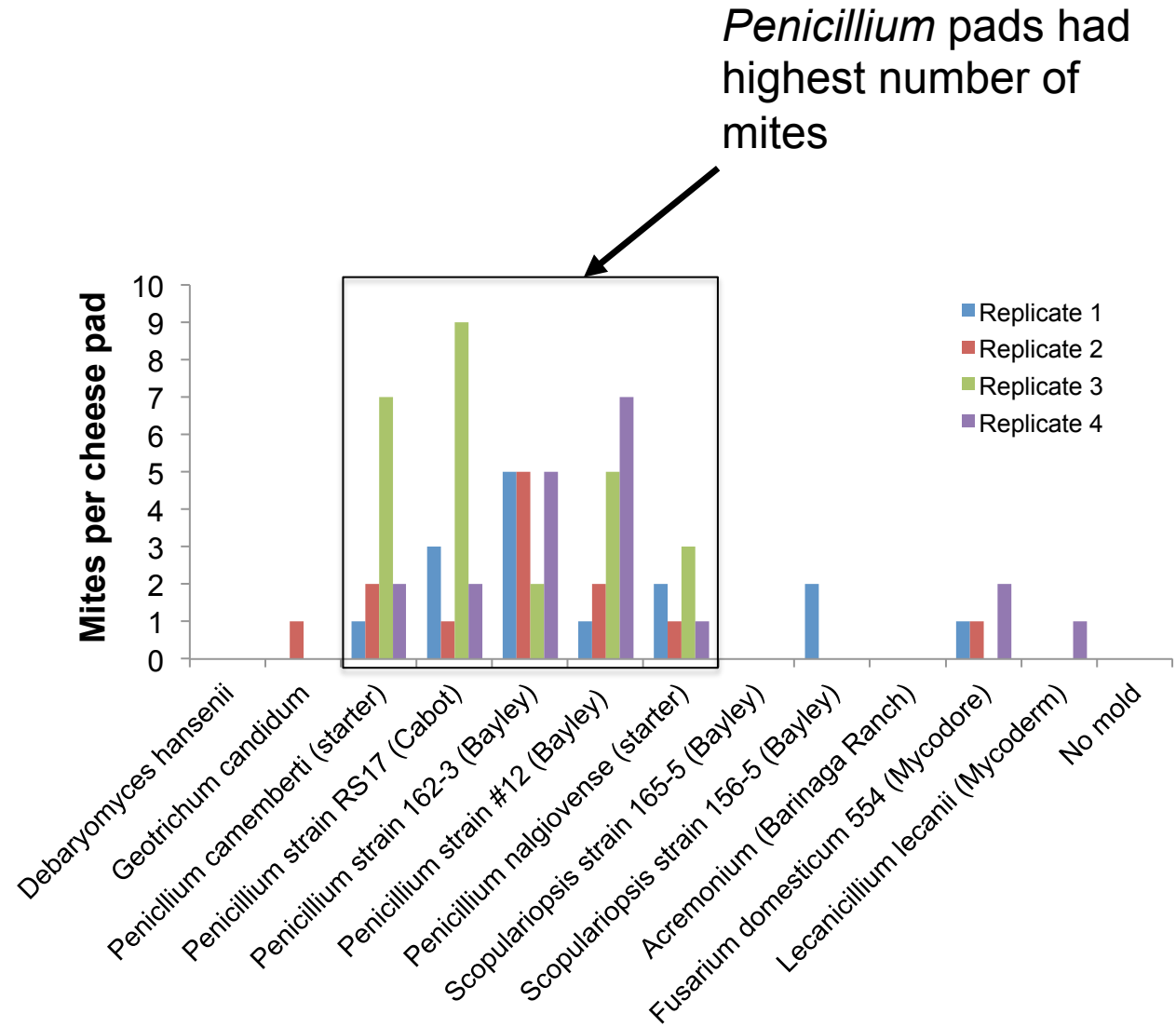
**Natural rinds are a wonderland for cheese mites!**



# Cheese mites mold preferences

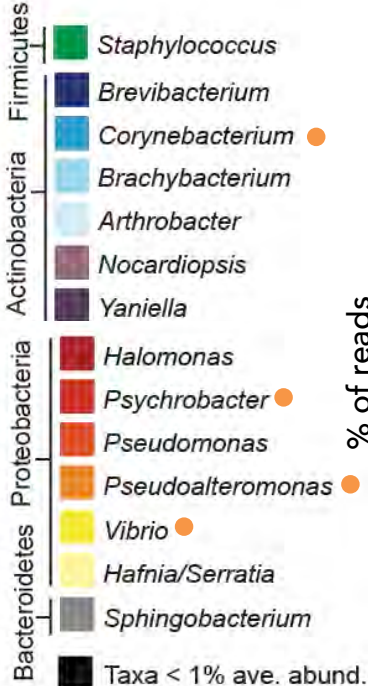


# Cheese mites mold preferences

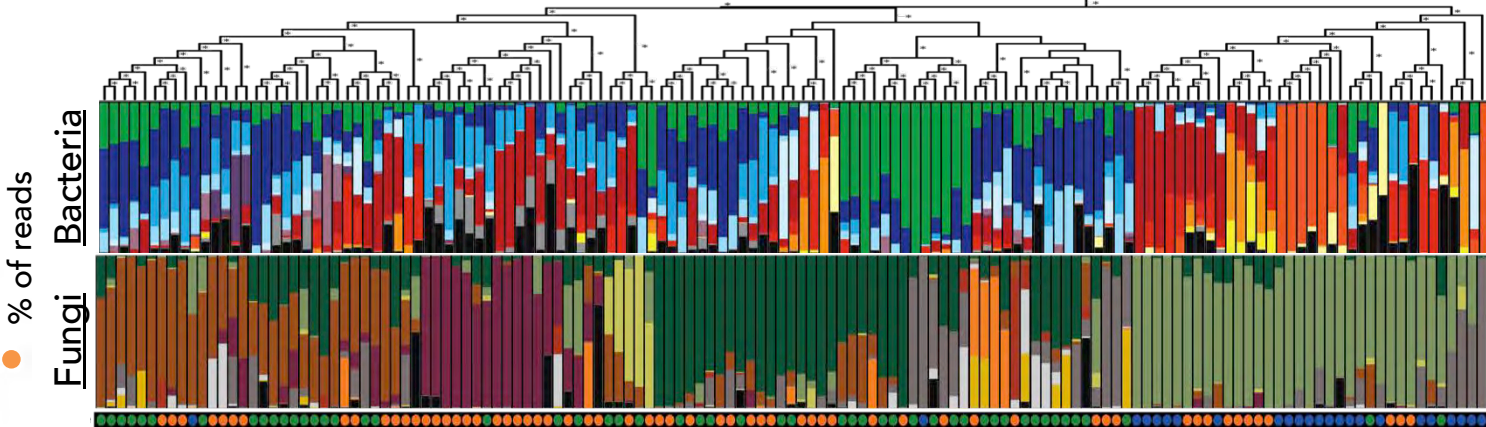
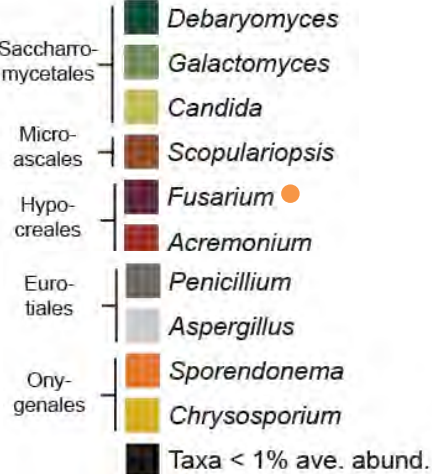


# Washed rind cheeses

## Bacteria



## Fungi



Washed rind cheeses have a mix of both bloomy and natural rind microbes, as well as unique genera: *Vibrio*, *Pseudoalteromonas*, *Corynebacterium*, and *Fusarium*

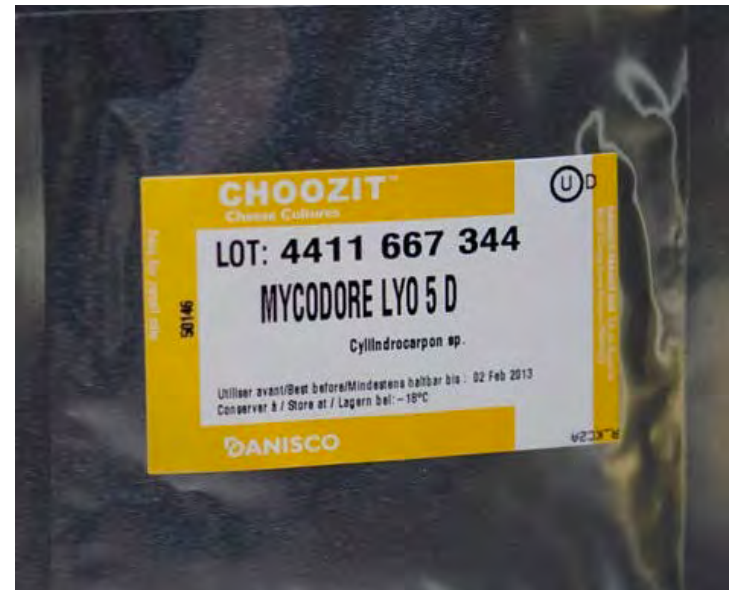
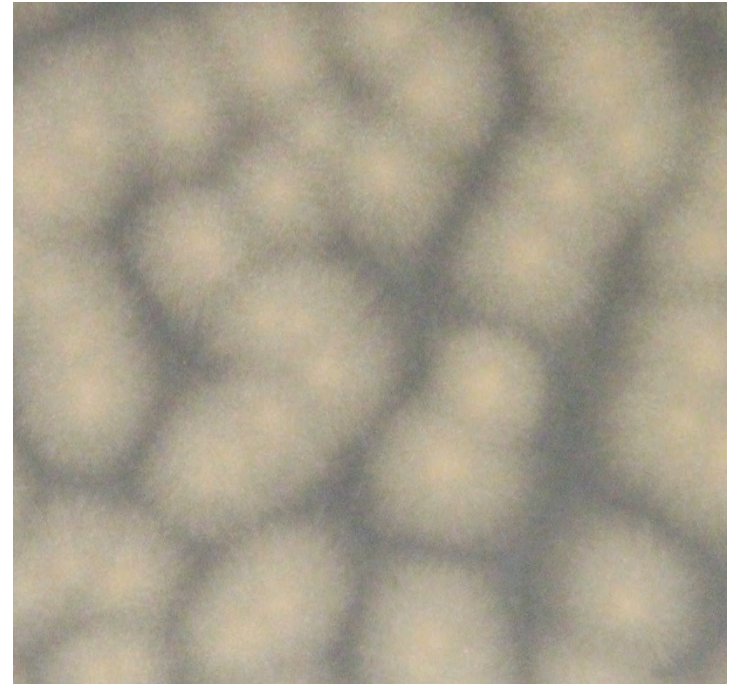


# *Fusarium domesticum*



Common on washed  
rind cheeses

Important for cheese  
rind stability



# *Fusarium domesticum*



Cardo (goat, UK)



Twig Washed Wheel (goat, USA)

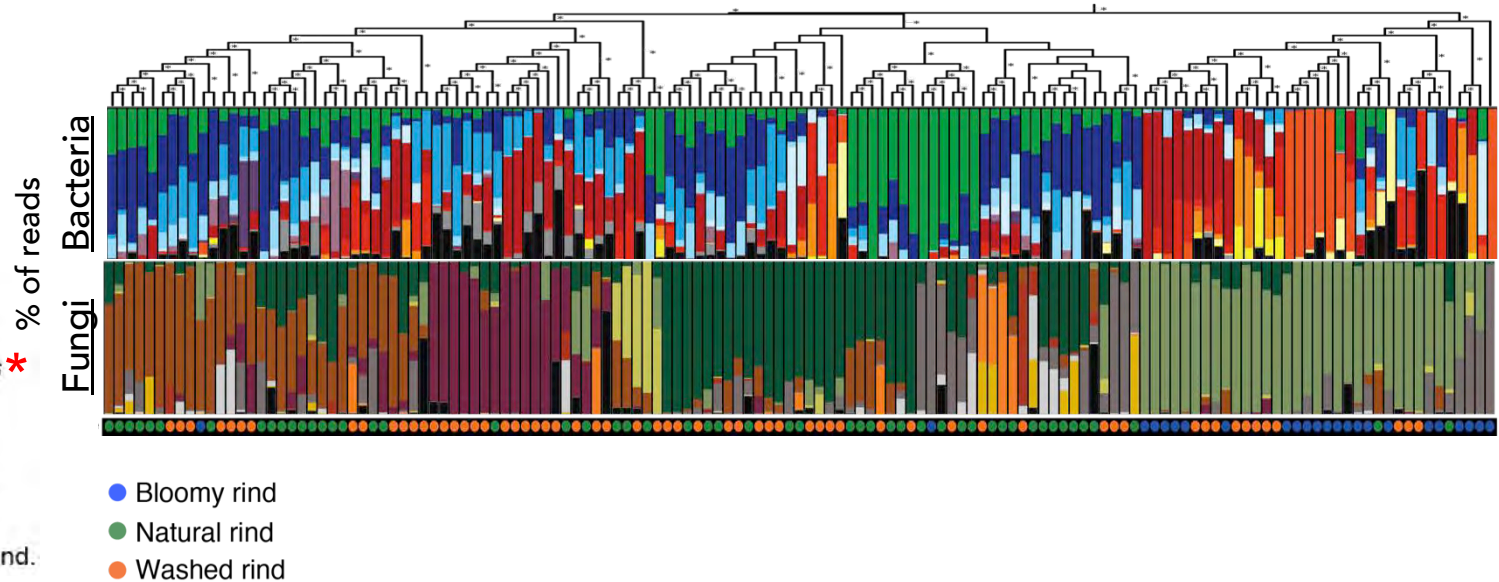
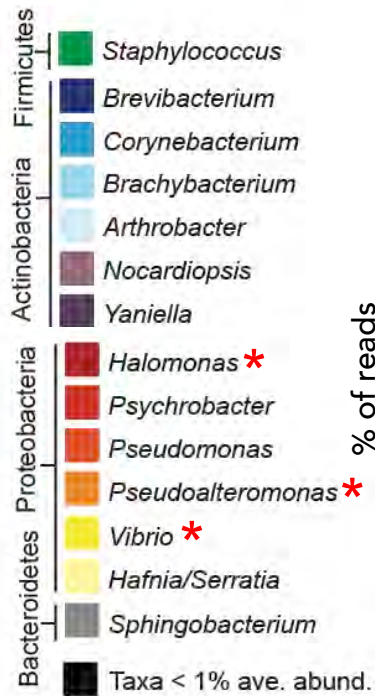


Manigodine (Cow, France)



# Marine-associated bacteria are common in cheese rinds

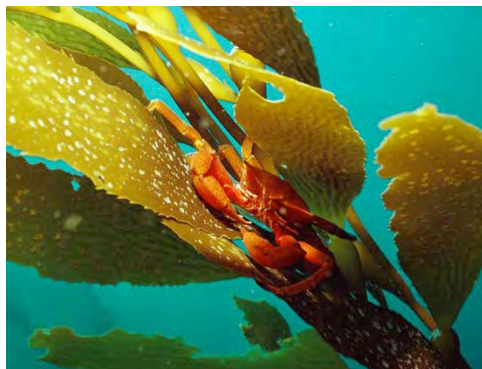
## Bacteria



## Fungi

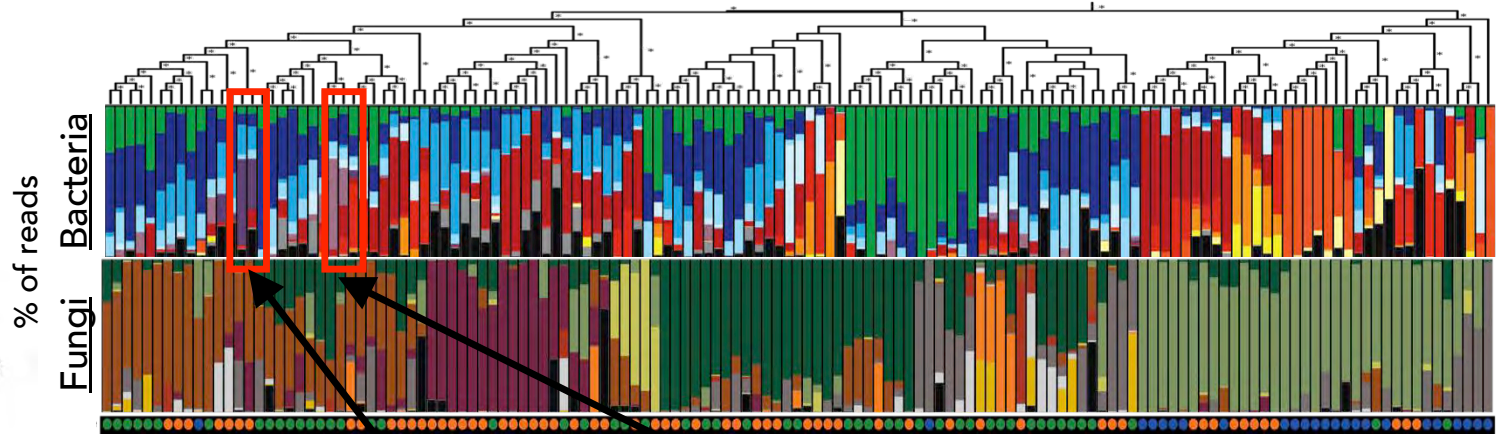
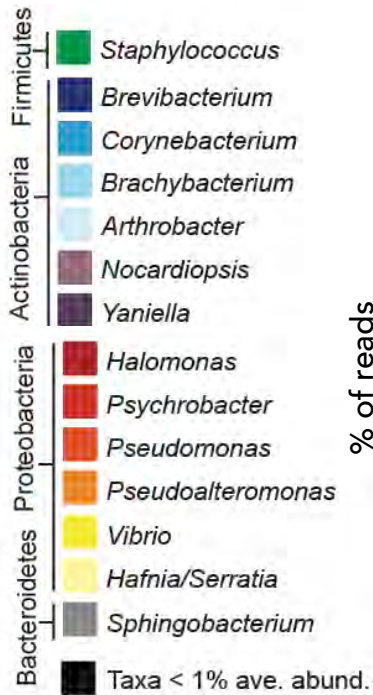


*Pseudoalteromonas*, *Vibrio*, and *Halomonas* are associated with the marine environment



# Two new rind-associated bacteria

## Bacteria



- Bloomy rind
- Natural rind
- Washed rind

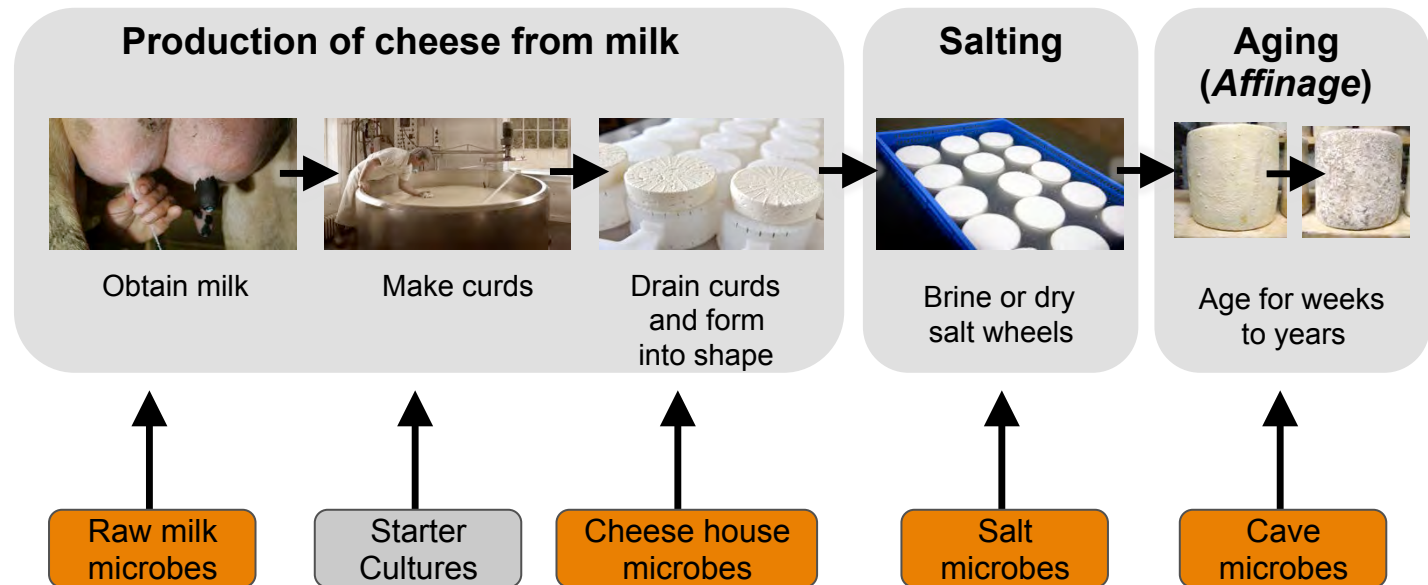
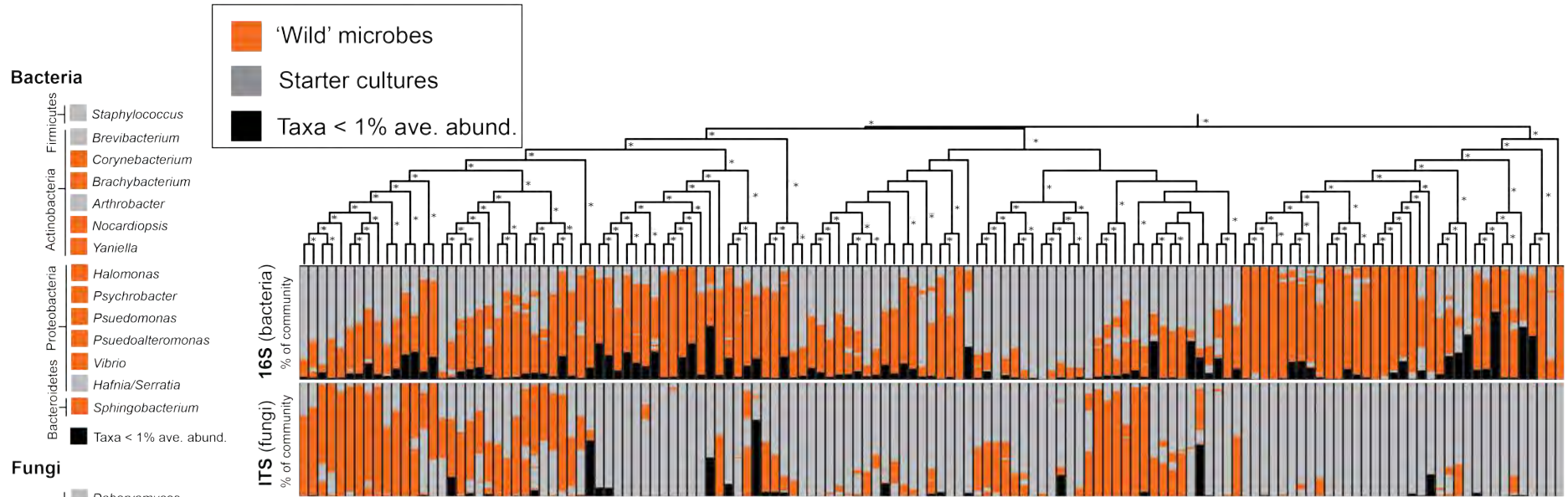
*Nocardiopsis* and *Yaniella* have never been reported on cheese before

*Yaniella* is mostly found on Swiss alpine style cheeses

## Fungi



# 'Wild' microbes make up a large portion of rind communities



# Microbiology of Cheese Rinds

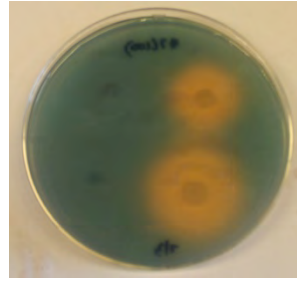
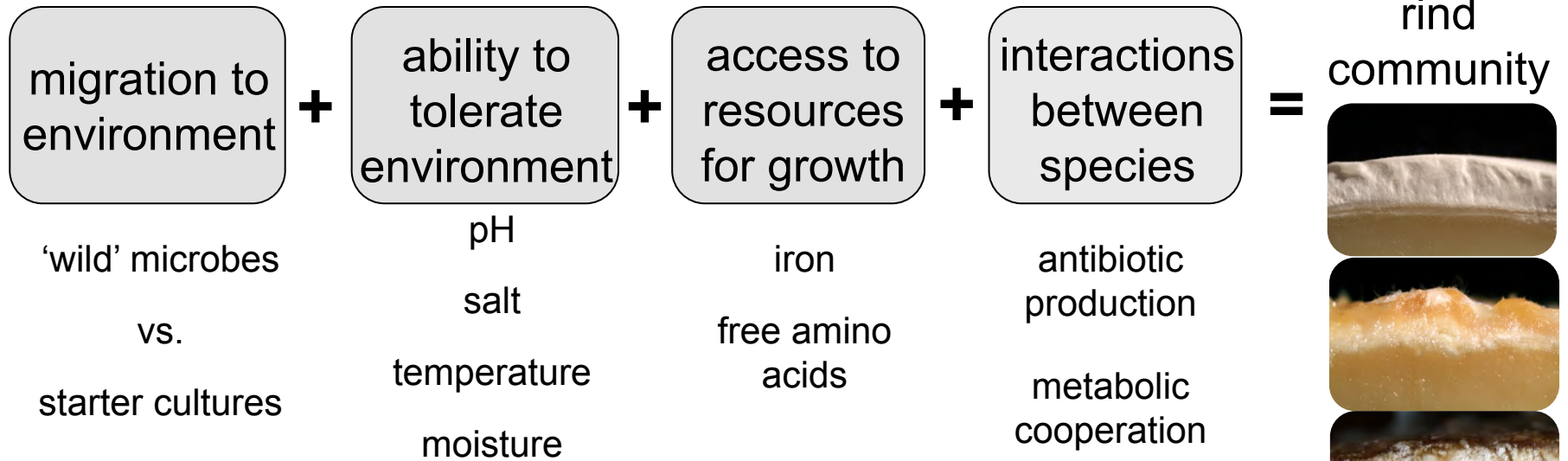
What is the microbial diversity of cheese rinds?

What are the design principles for cheese rinds?

How can we use this knowledge to improve cheese quality?

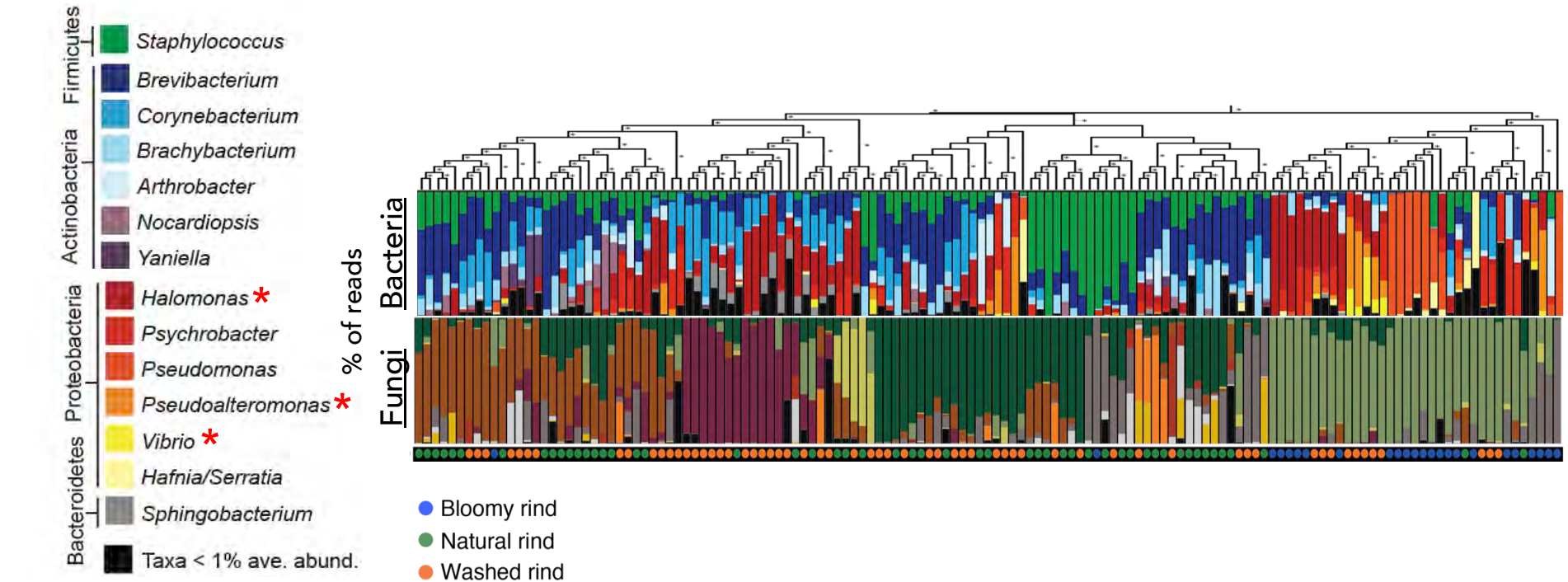


# Cheese rind design principles

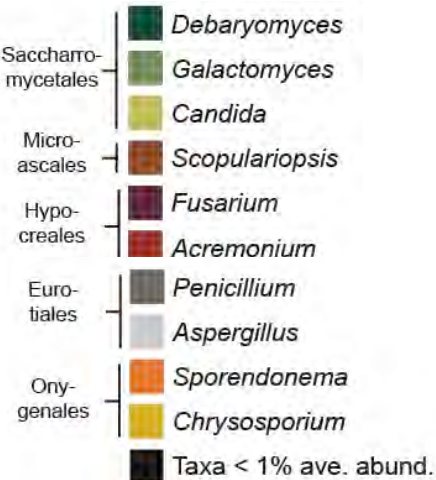


# Discovering design principles from our cheese survey

## Bacteria



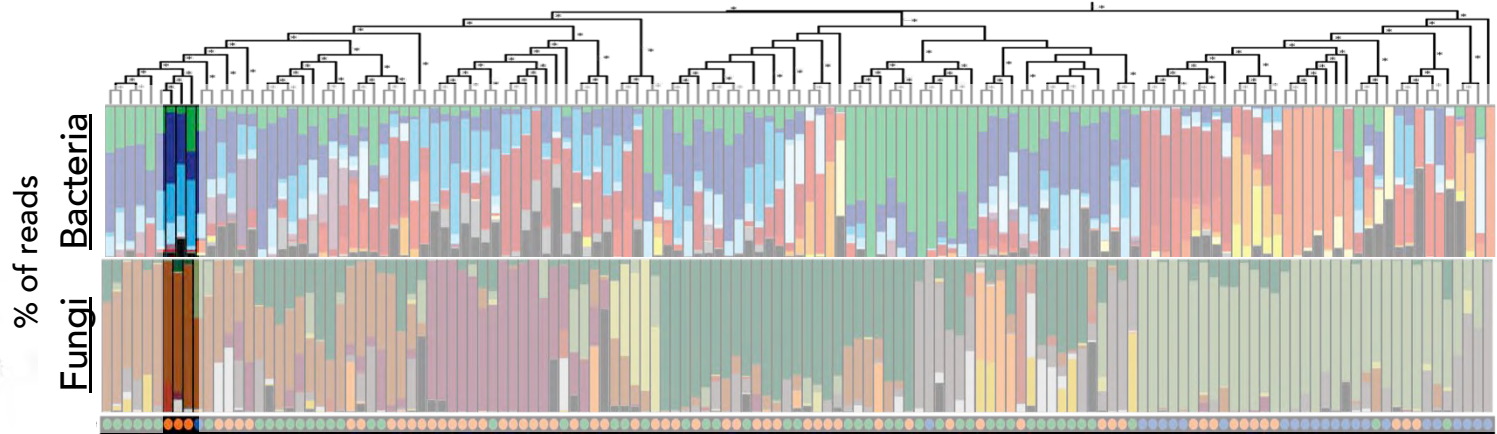
## Fungi



# Geography doesn't matter... but, big caveats

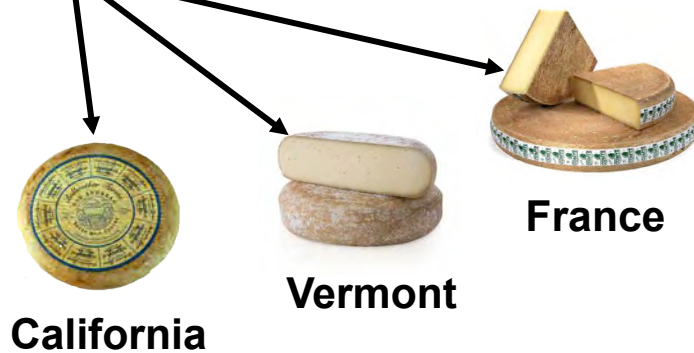
## Bacteria

- Firmicutes
  - *Staphylococcus*
  - *Brevibacterium*
  - *Corynebacterium*
- Actinobacteria
  - *Brachybacterium*
  - *Arthrobacter*
  - *Nocardioopsis*
  - *Yaniella*
- Proteobacteria
  - *Halomonas*
  - *Psychrobacter*
  - *Pseudomonas*
  - *Pseudoalteromonas*
- Bacteroidetes
  - *Vibrio*
  - *Hafnia/Serratia*
  - *Sphingobacterium*
  - Taxa < 1% ave. abund.



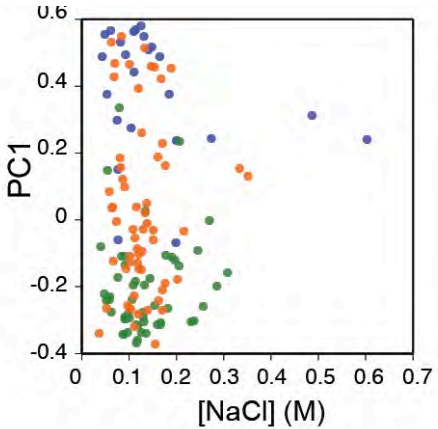
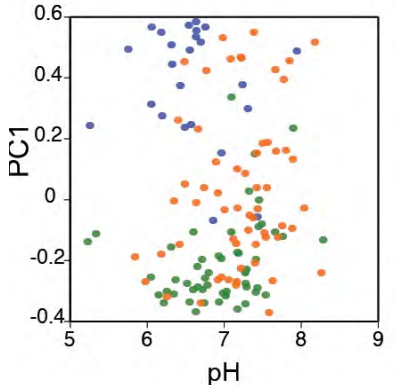
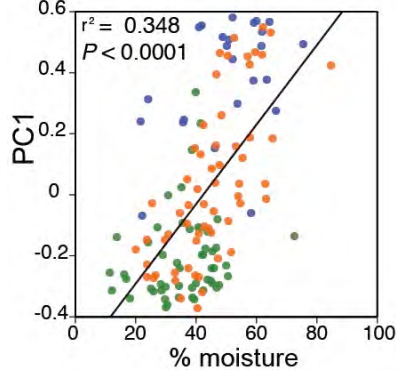
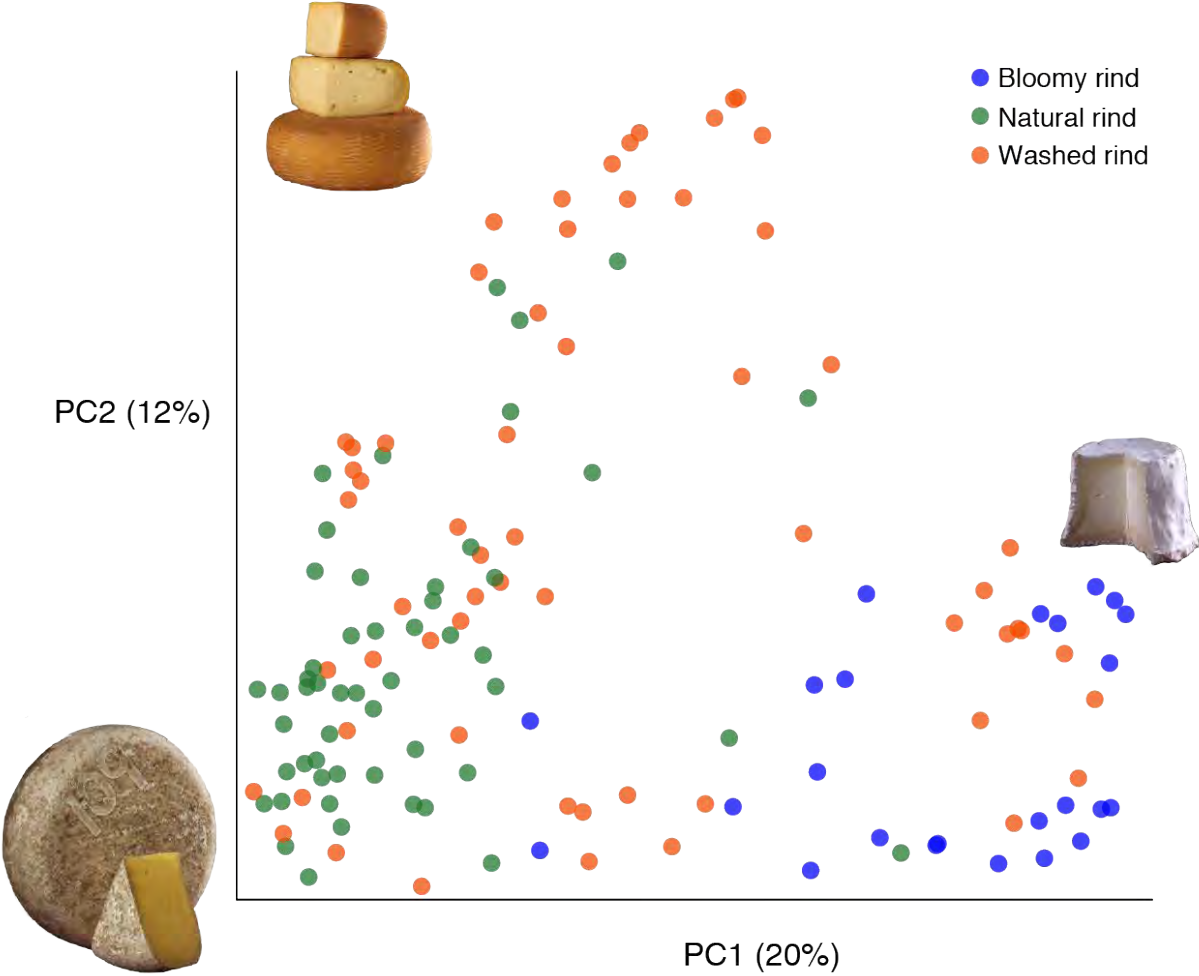
## Fungi

- Saccharomycetales
  - *Debaryomyces*
  - *Galactomyces*
  - *Candida*
- Microascales
  - *Scopulariopsis*
- Hypocreales
  - *Fusarium*
  - *Acremonium*
- Eurotiales
  - *Penicillium*
  - *Aspergillus*
- Onygenales
  - *Sporendonema*
  - *Chrysosporium*
  - Taxa < 1% ave. abund.



Geographic Distance	Mantel Correlation	p-Value
	0.0353	0.074

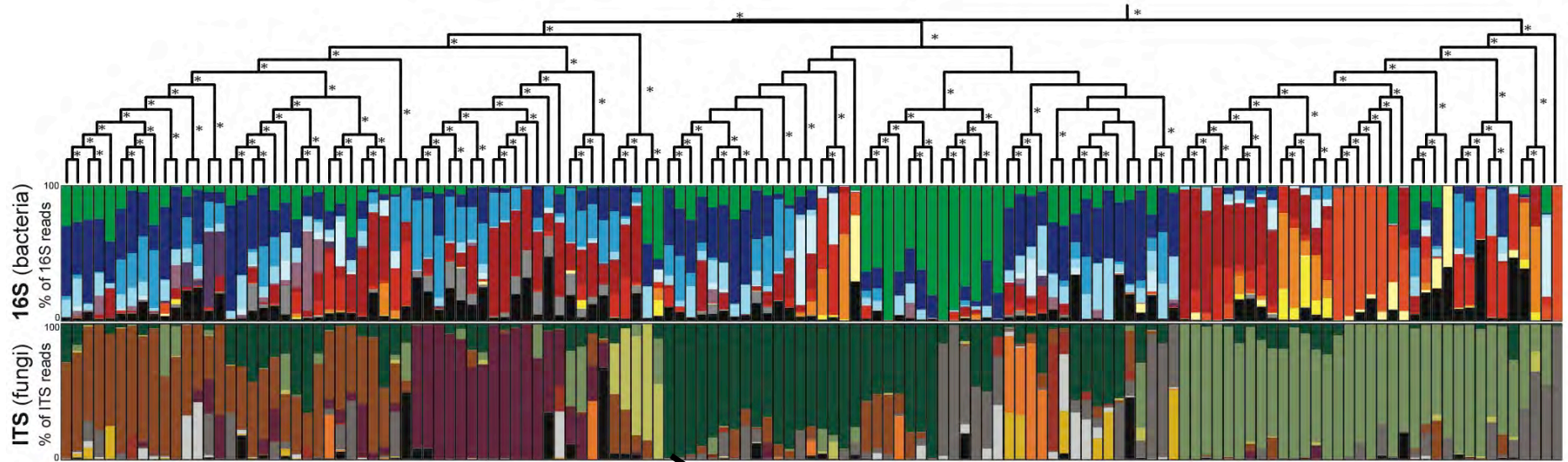
# Environment (moisture) matters





# Watching the assembly of a cheese rind

These data represent final communities



Can we create lab models that mimic finer-scale patterns of community assembly?



Bayley Hazen Blue  
natural rind



Cellars at Jasper Hill

**0 days**



**21 days**



**42 days**



**63 days**



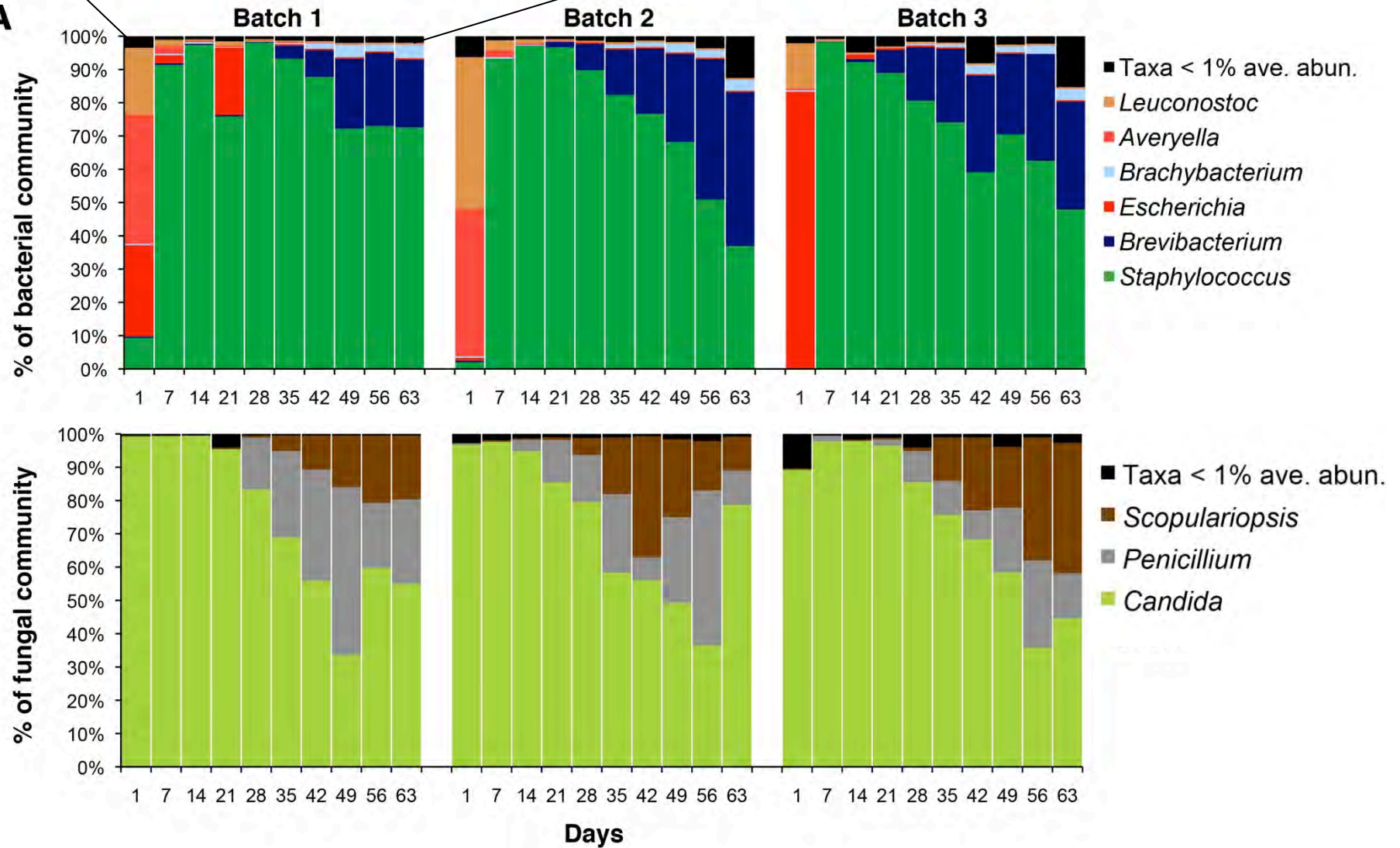
# *In vitro* communities: community development over time

0 days

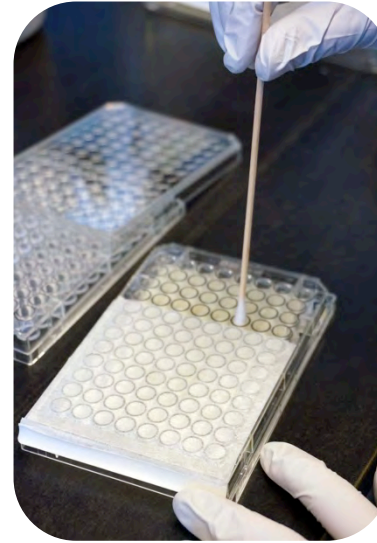
63 days



**A**



# Discovering cheese rind design principles in the lab



# Quantifying microbial war and peace

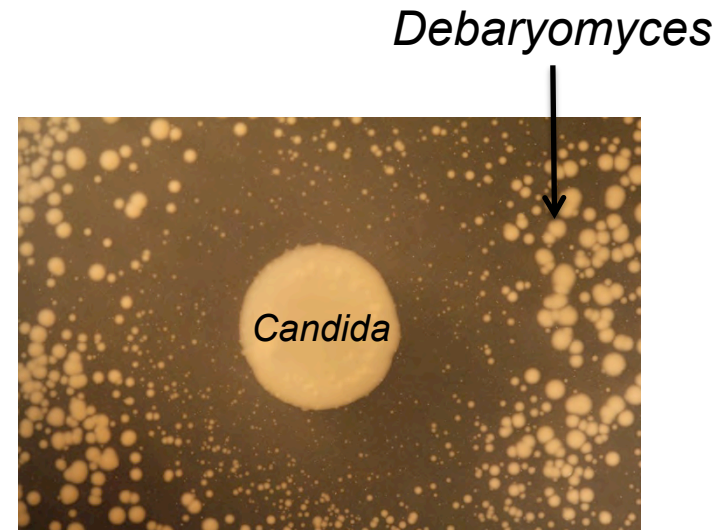
Uninoculated  
Bacterium alone  
*Candida*  
*Debaryomyces*  
*Scopulariopsis*  
*Galactomyces*  
*Fusarium*  
*Penicillium*



Fungus alone  
*Staphylococcus*  
*Brevibacterium*  
*Brachybacterium*  
*Corynebacterium*  
*Arthrobacter*  
*Vibrio*  
*Pseudoalteromonas*  
*Halomonas*  
*Psychrobacter*  
*Serratia*  
*Pseudomonas*



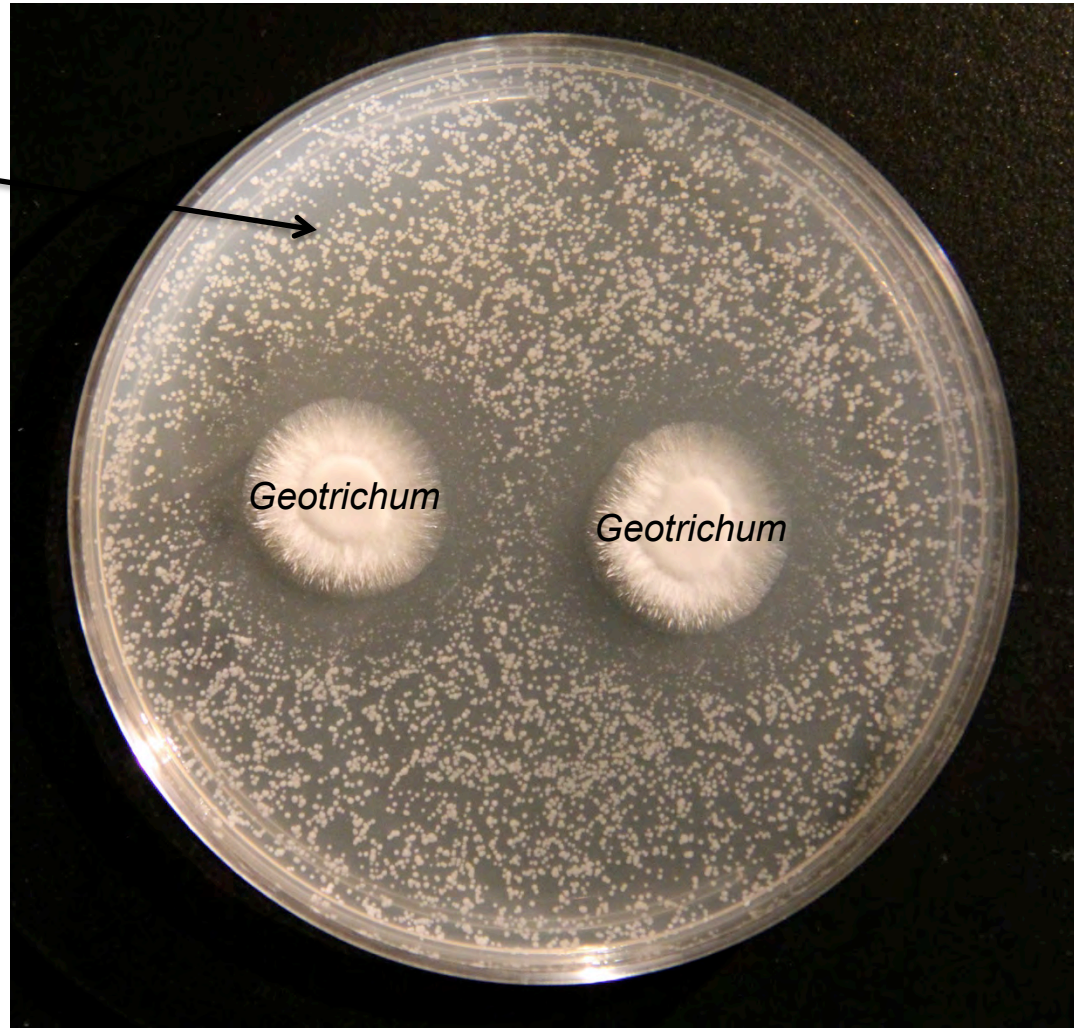
# Microbial Interactions: Killer Yeasts



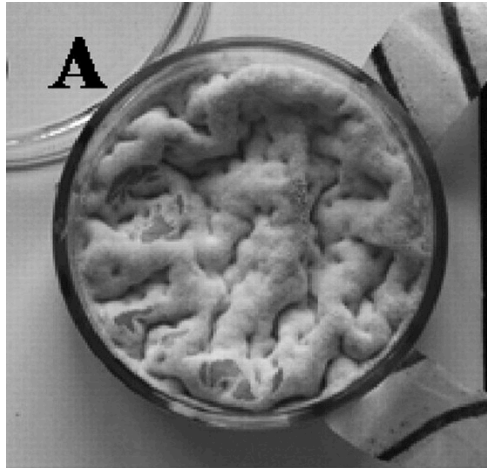
*Candida catenulata*, a yeast commonly found on the surface of blue cheeses with a natural rind, kills other yeast species

# Microbial Interactions: Killer Yeasts

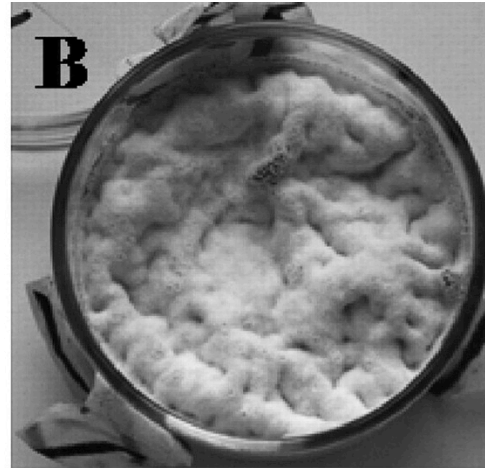
*Debaryomyces*  
(DH)



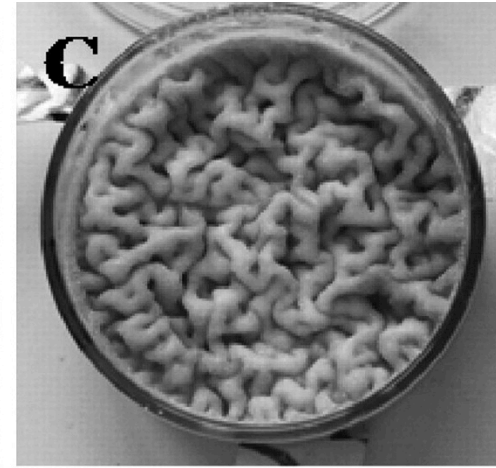
# Microbial Interactions: Altered aesthetics of Geo



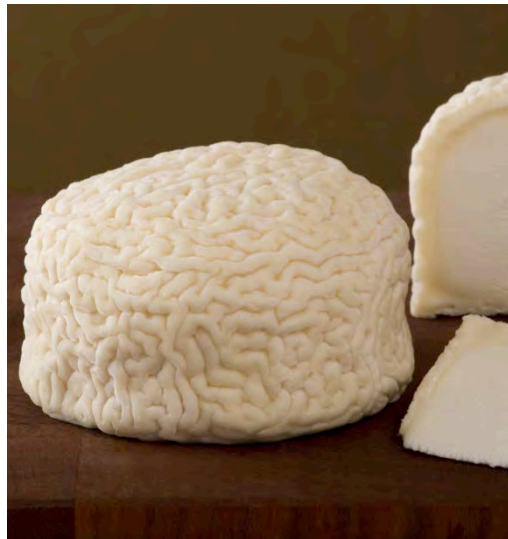
Geo alone



Geo + *Debaryomyces*

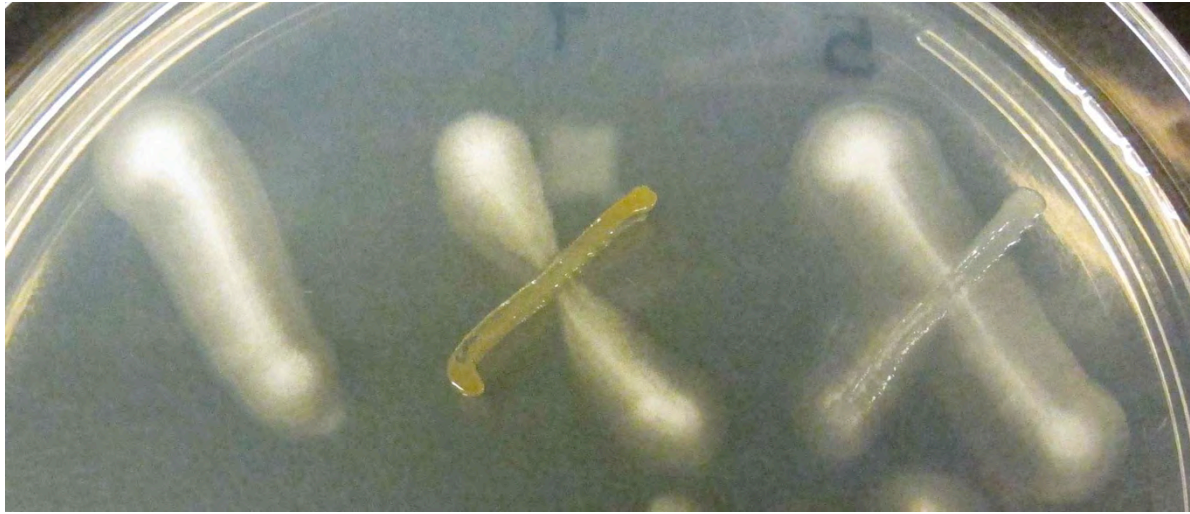


Geo + *Yarrowia*



Mounier *et al.* 2008, *AEM*

# Microbial Interactions: Case of the missing Geo rind...



Geo  
alone

Geo +  
*Pseudomonas*

Geo +  
*Staph*

# Microbial Interactions: Pigments from bacterial warfare



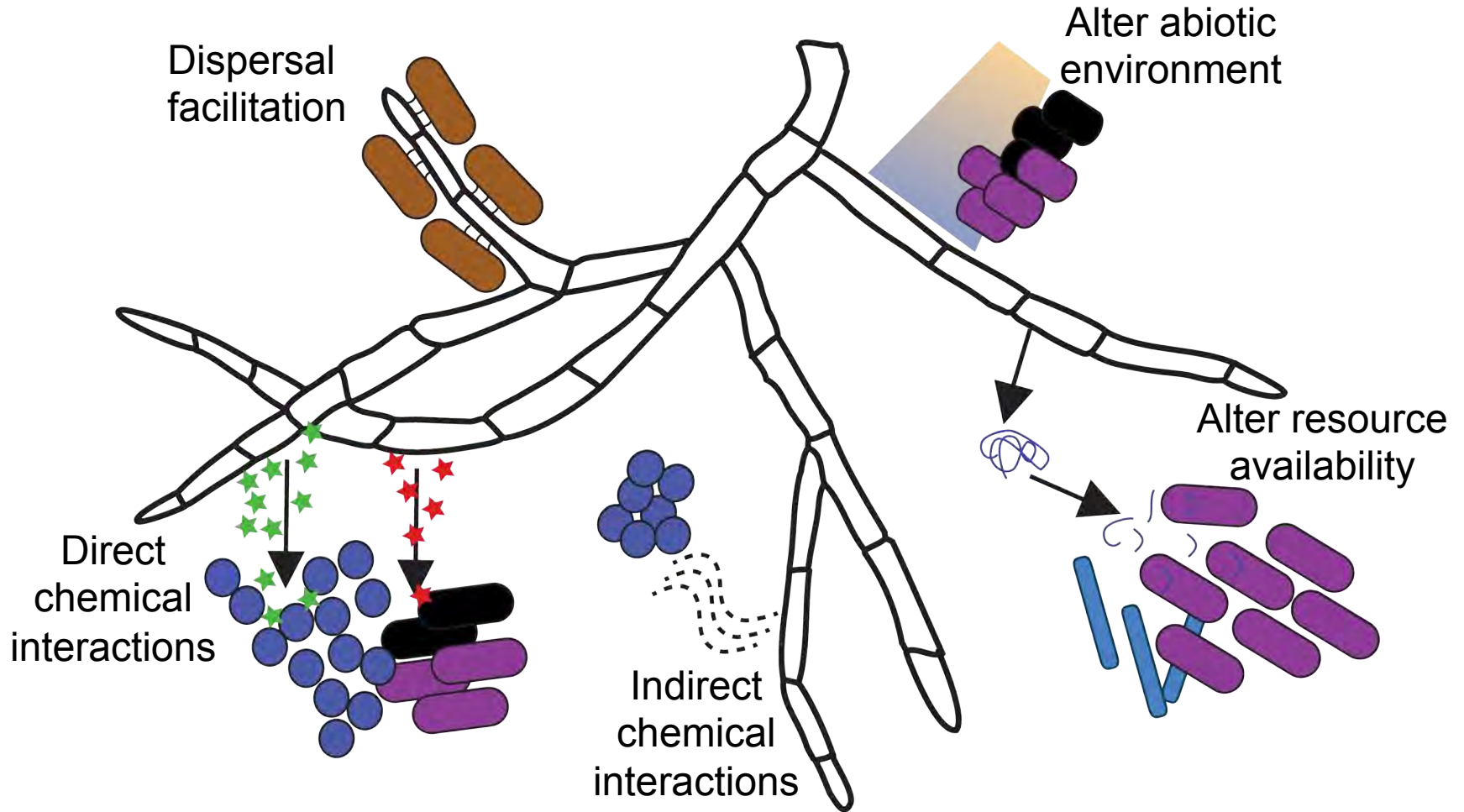
*Arthrobacter*  
alone

*Arthrobacter* +  
*Penicillium*

*Penicillium*  
alone



# Microbial interactions in cheese rinds



# Microbiology of Cheese Rinds

What is the microbial diversity of cheese rinds?

What are the design principles for cheese rinds?

How can we use this knowledge to improve cheese quality?



# Identifying the causes of rind defects





# Finding novel species/strains to create new cultures



*Geotrichum candidum*



# Industrial cultures limit diversity of cheese flavors

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Antimicrobials  
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**Cultures**  
CHOOZIT™ Cheese Cultures  
FlavoGard®  
FloraFIT®  
HOLDBAC®  
HOWARU®  
Kefir-D cultures  
PROBAT™  
TEXEL® Meat Cultures

## CHOOZIT™ Cheese Cultures

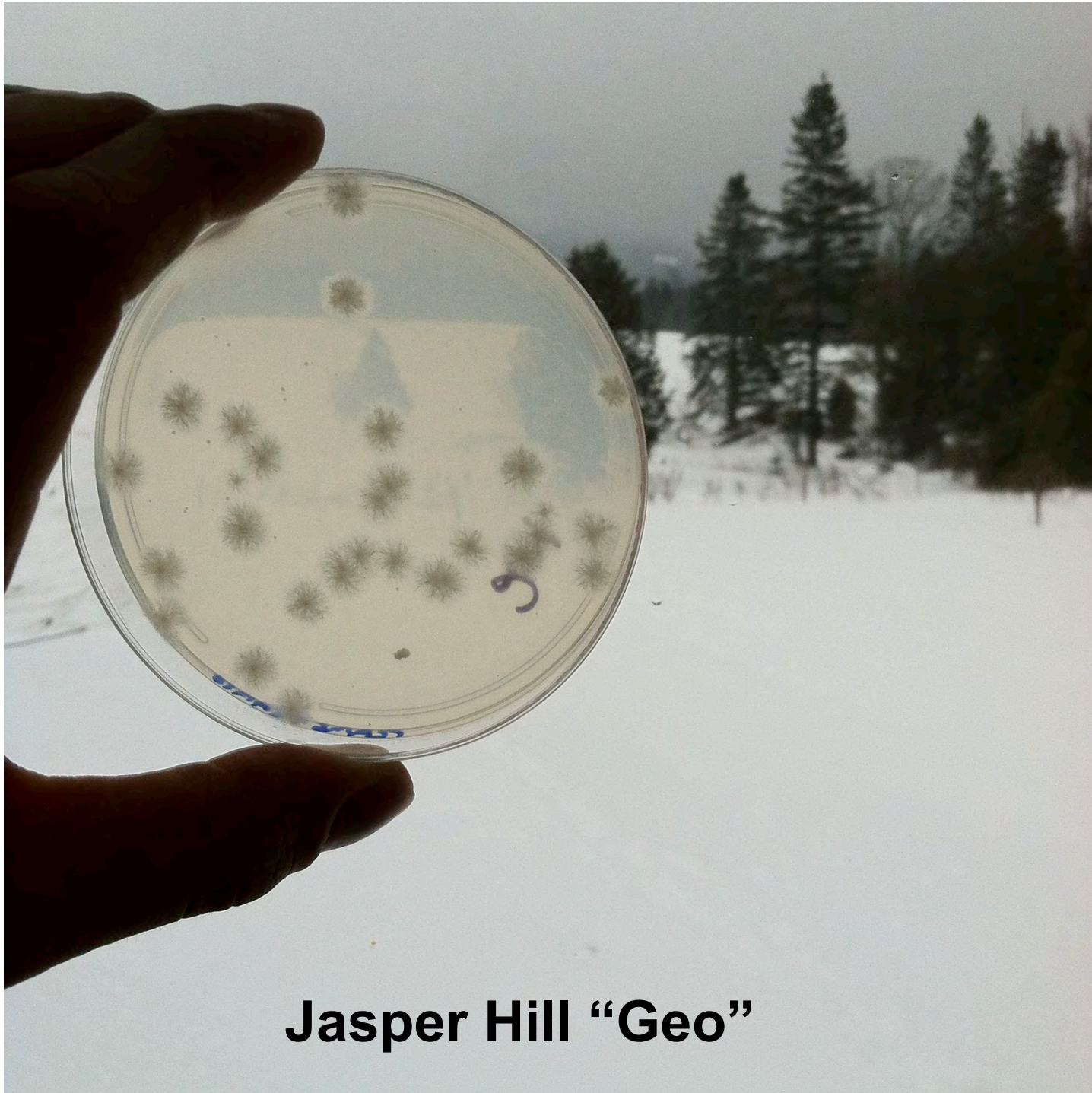
A comprehensive range of products for controlled acidification and for emphasizing and diversifying flavor profiles.

**Contact us**  
Send us an e-mail

### Key benefits

- Easy to use cultures for direct inoculation
- Provide controlled acidification profiles
- Offer comprehensive range of textures, flavors and colors

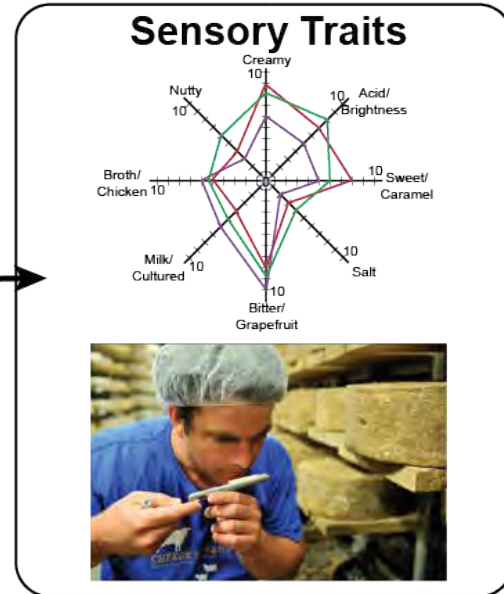
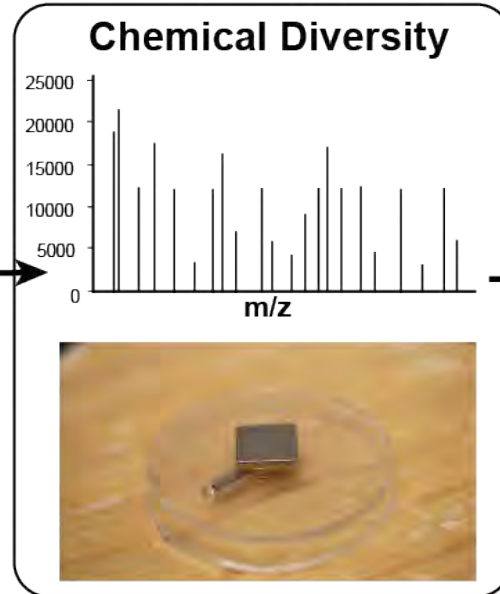
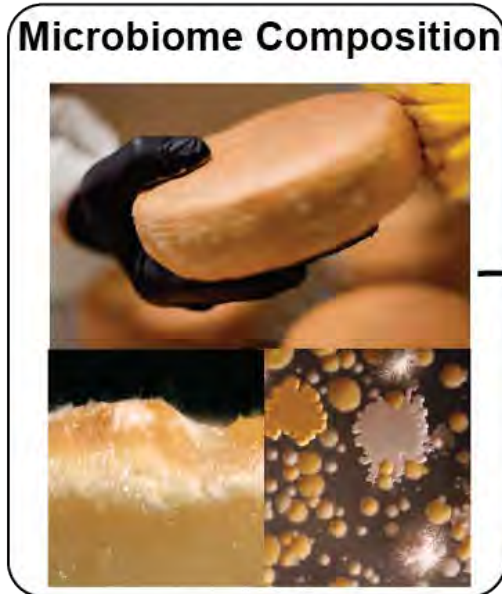
Product	Benefit	Application
CHOOZIT DVI lactic cultures	Texture and flavor development	All cheese types
CHOOZIT FLAV	Flavor development	Hard and semi-hard cheese
CHOOZIT PC	Flavor formation Color and appearance	White mold cheese, soft blue cheese and whey cheese
CHOOZIT P. Roqueforti	Flavor formation Color and appearance	Blue cheese
CHOOZIT Geotrichum	Flavor formation Color and appearance	Red smear cheese, soft cheese
CHOOZIT Yeasts	Flavor formation Color and appearance	Mix and smear cheese, soft cheese
CHOOZIT Brevibacteria	Colour formation from bright red to cream orange	Red smear cheese



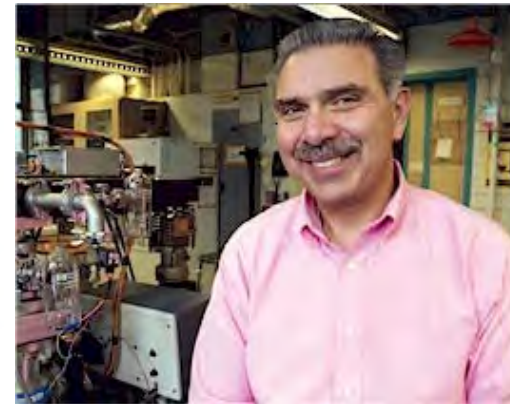
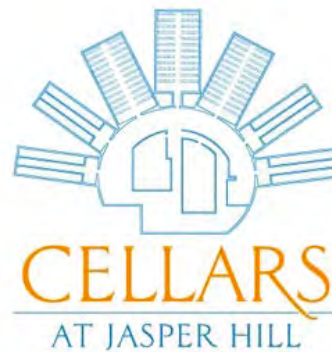
**Jasper Hill "Geo"**



# Tufts University Sensory & Science Center (TUSSC)



**Kehler Brothers**  
Jasper Hill Farm



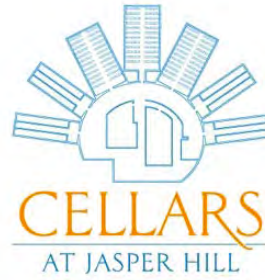
**Al Robbat**  
Chemistry, Tufts

<http://as.tufts.edu/tussc/>

# The New York Times

## Small Cheese Makers Invest in a Stinky Science

By LARISSA ZIMBEROFF FEB. 6, 2017



# Microbiology of Cheese Rinds

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# Learn more about cheese rind microbiology at...

## MicrobialFoods.org

Microbial  
Foods.Org

digesting the science of fermented foods

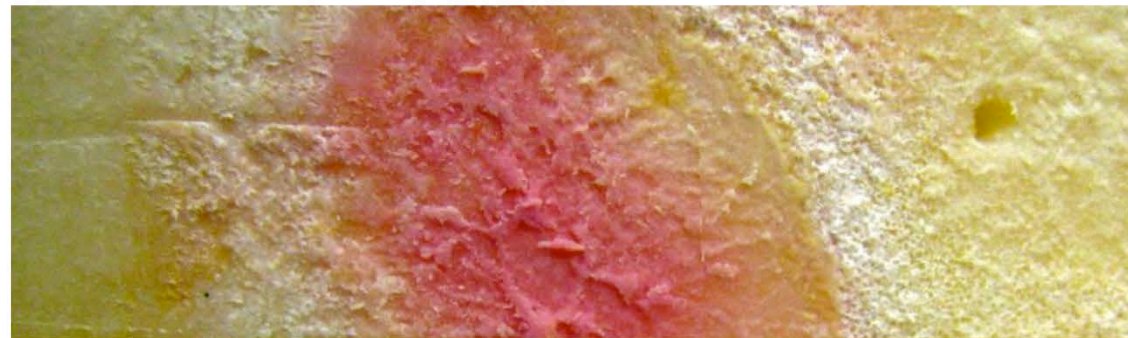
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Featured Profile



The effects of red pepper powder on kimchi fermentation  
by [Bronwen Percival](#)

When making fermented vegetables, we often add different kinds or amounts of spices. Their impacts on flavor may be obvious, but what do these spices do at the microbial level? A recent study took a careful look at how the addition of red pepper changes the course of microbial development in kimchi. [Click here to view the full story.](#)



### What causes cheese to turn pink?

Various attributes of a cheese, including both flavor and appearance, contribute to the final quality of the product. During the production of some cheeses, microbial processes can cause strange quality defects, often with colorful outcomes. Researchers in University College in Cork, Ireland identified the microbial culprit behind a notorious pink cheese defect. In this [Science Digested](#), Adam Shutes from the [Boston Cheese Cellar](#) explains what they found.

[\[click to view the full story\]](#)



