



# Comparative genomics among dairy strains of *Streptococcus thermophilus* and *Streptococcus macedonicus*

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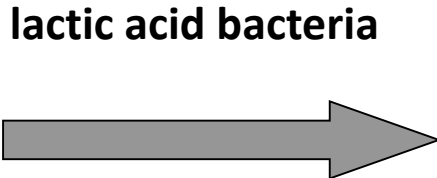
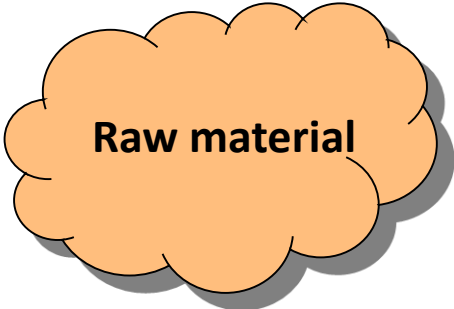
<sup>5</sup> CNRS UMR8204, F-59021 Lille, France

<sup>6</sup> Univ Lille de Nord France, F-59000 Lille, France

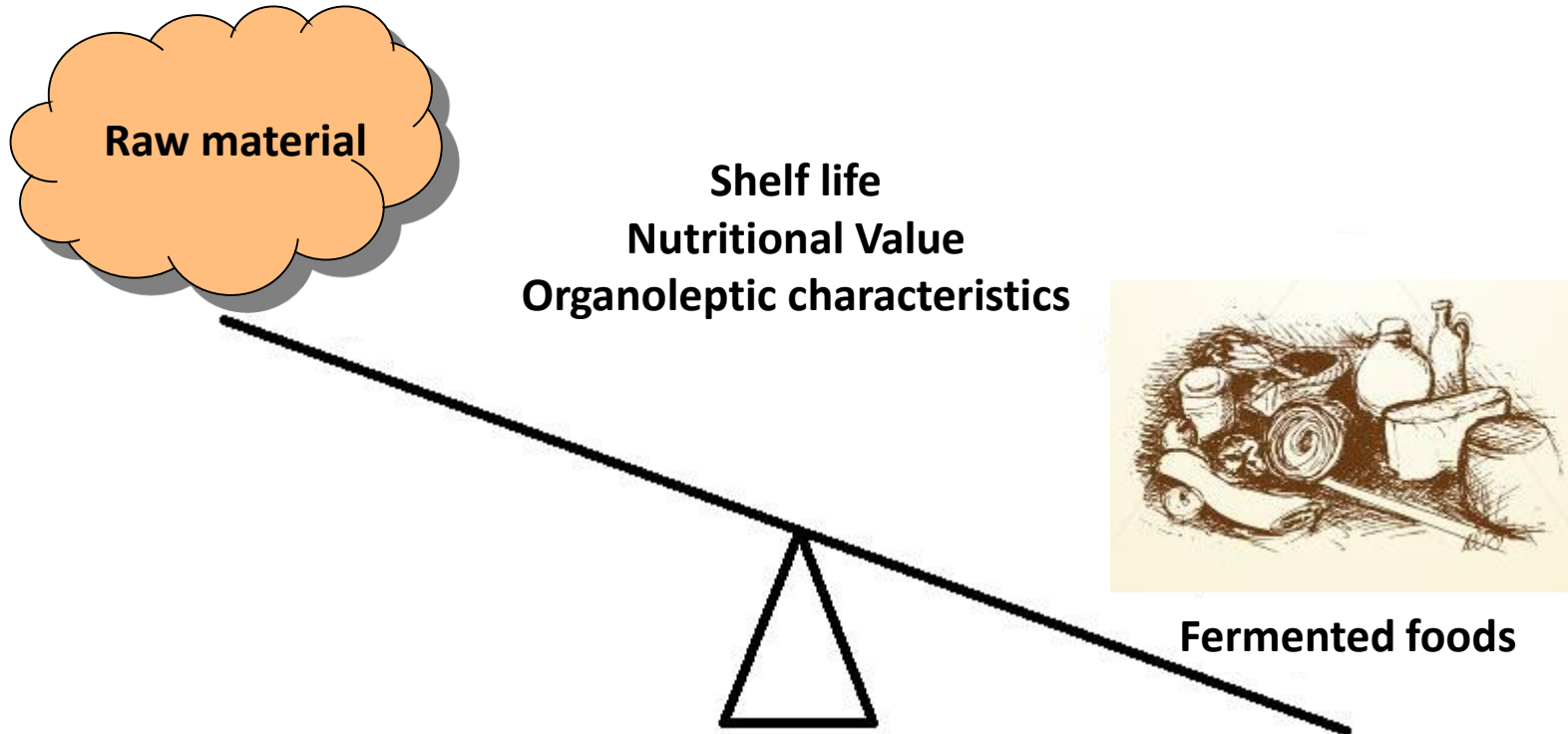
<sup>7</sup> Institut National de la Recherche Agronomique, UMR1319 Micalis, Domaine de Vilvert, Jouy-en-Josas, France



# Laying the background: Fermented foods and Microorganisms



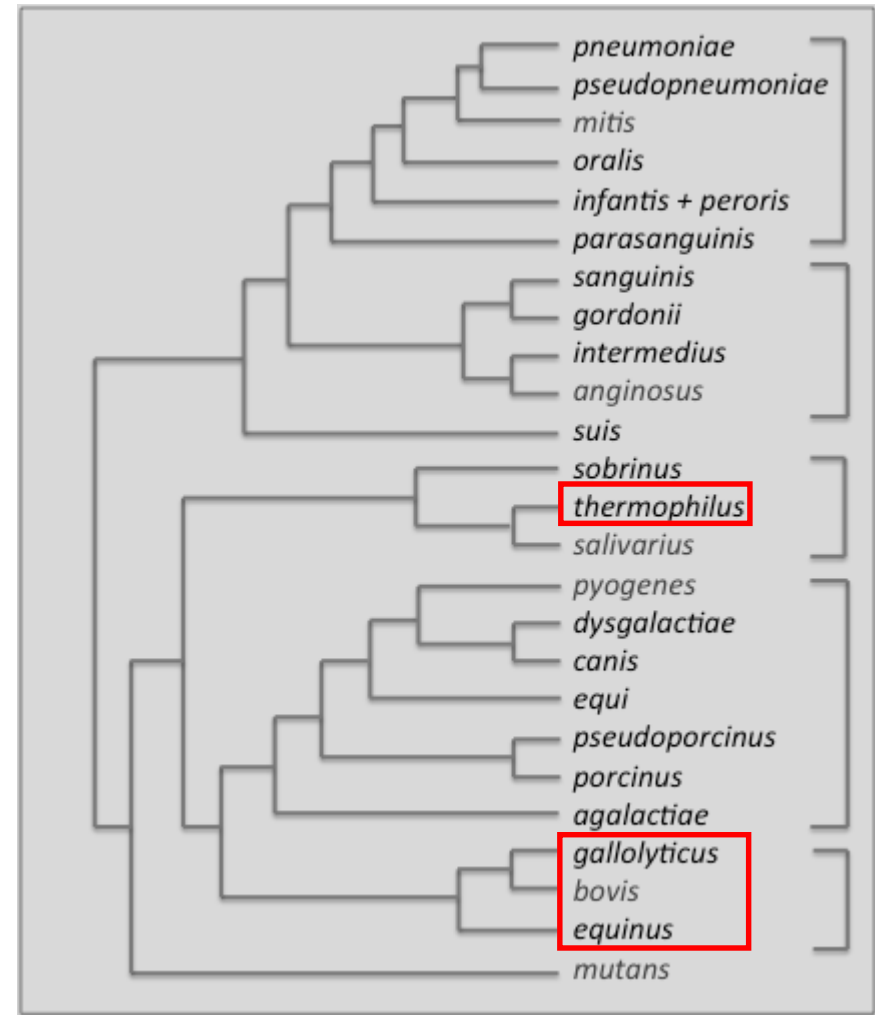
# Laying the background: Fermented foods and Microorganisms



**Fermented foods**

# Laying the background: Streptococci and Fermented foods

- *Carnobacterium*
- *Enterococcus*
- *Lactococcus*
- *Lactobacillus*
- *Leuconostoc*
- *Oenococcus*
- *Pediococcus*
- *Streptococcus*
- *Weissella*



# Laying the background: Streptococci and Fermented foods

*S. thermophilus*

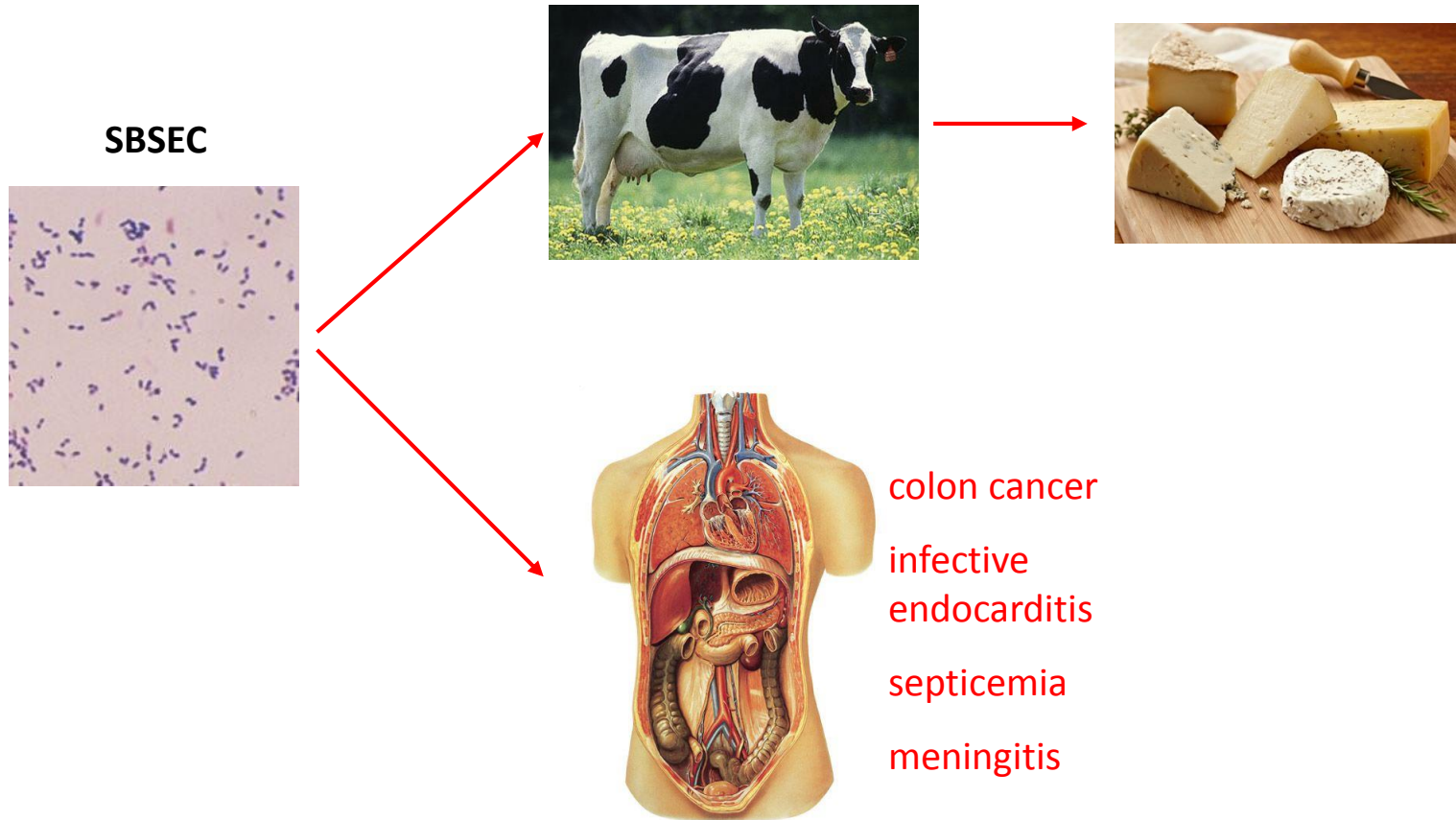


*S. macedonicus*  
*S. infantarius*



# Laying the background: Streptococci and Fermented foods

- Streptococci that can be found growing in milk belong to the *Streptococcus bovis*/*Streptococcus equinus* complex (SBSEC)

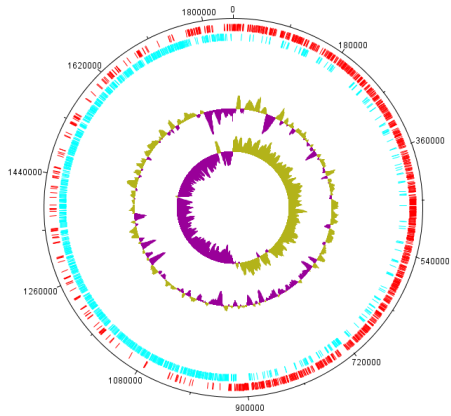


Herrera et al. Anaerobe 2009

- **Greek *Streptococcus thermophilus* ACA-DC 29**
- **French *Streptococcus macedonicus* 679**
- **Comparative genomics between strains of *S. thermophilus* and *S. macedonicus***



# Comparative genomics of *S. thermophilus*

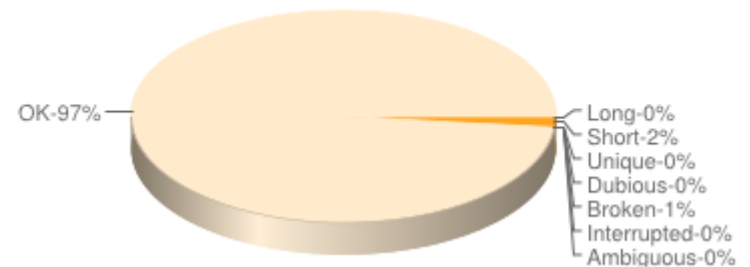


ACA-DC 29

- RAST
- BASyS
- FGenesB
- MetaGeneAnnotator
- **Manual curation**
- GenePrimp (**check**)

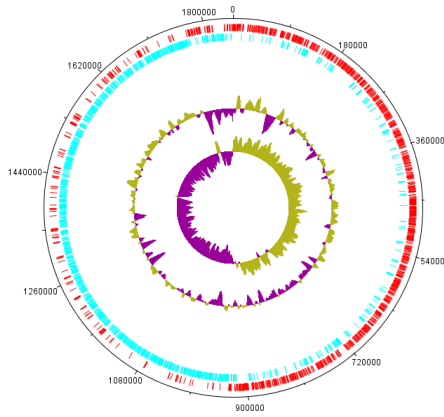
- 1990 CDS
- 15 rRNA
- 58 tRNA
- pseudogenes ?

## Gene prediction anomalies

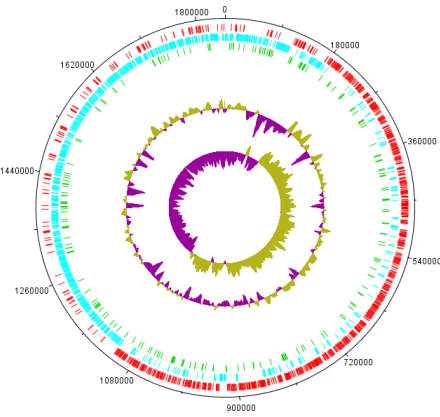




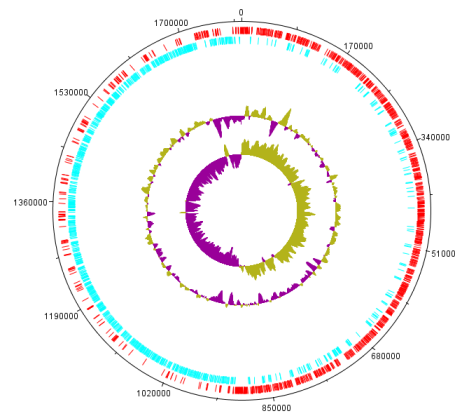
# Comparative genomics of *S. thermophilus*



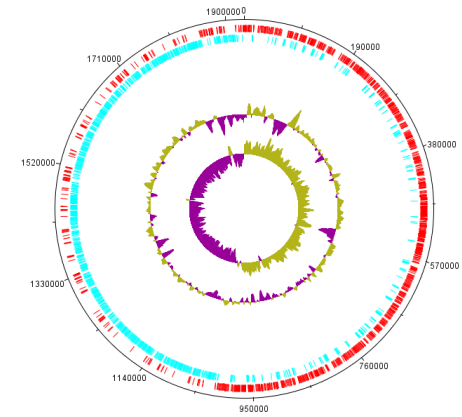
**ACA-DC 29**



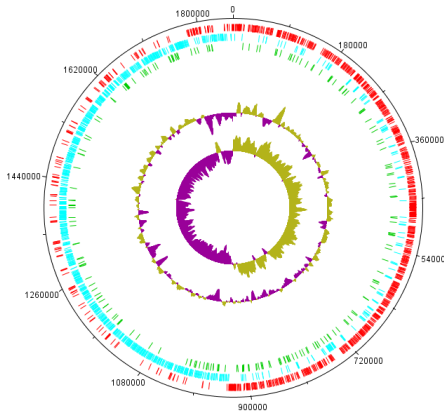
**ASCC 1275**



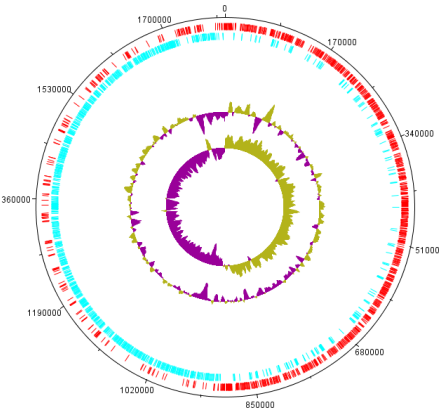
**CNRZ 1066**



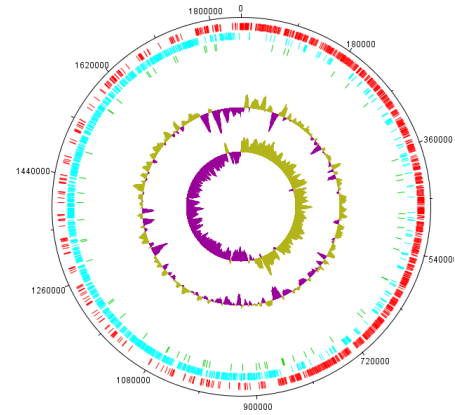
**JIM 8232**



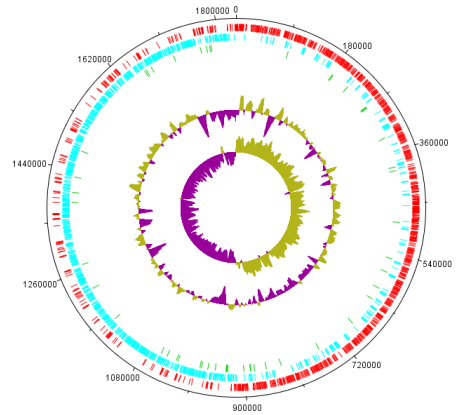
**LMD-9**



**LMG 18311**



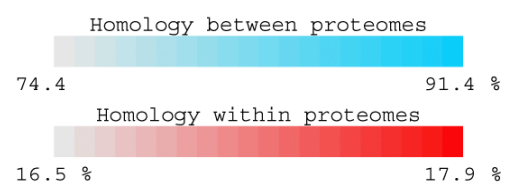
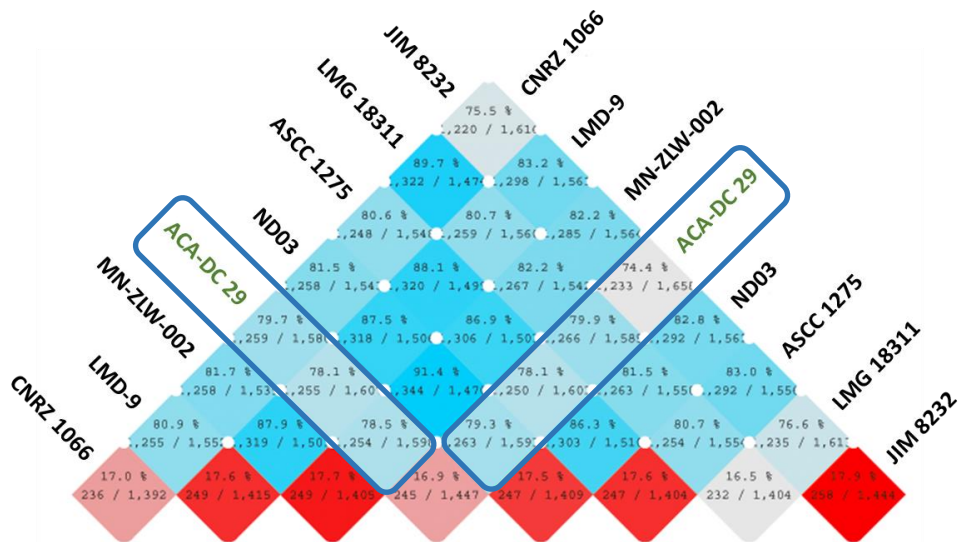
**MN-ZLW-002**



**ND03**



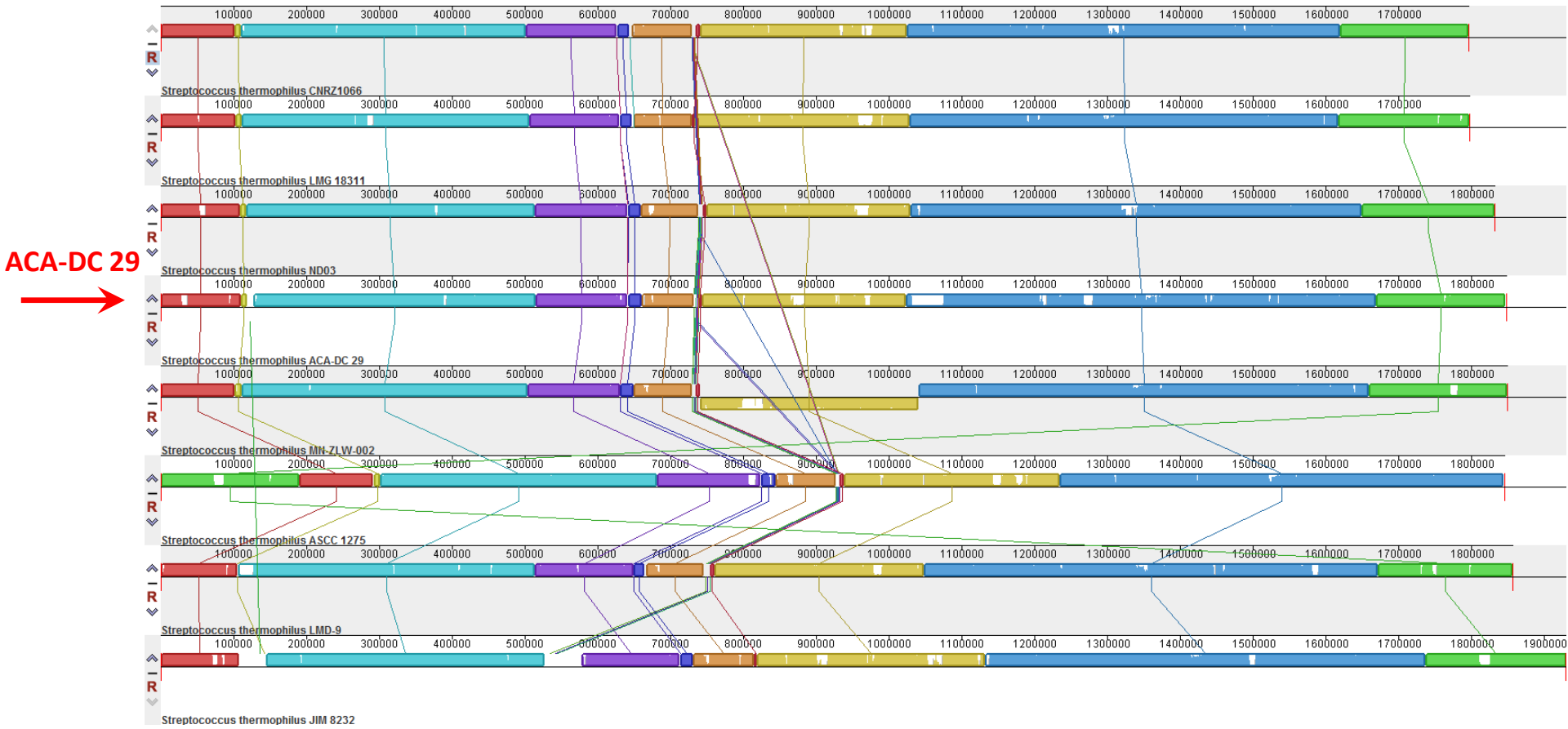
# Comparative genomics of *S. thermophilus*



	ACA-DC 29	ASCC 1275	CNRZ 1066	JIM 8232	LMD-9	LMG 18311	MN-ZLW-002	ND03
ND03	0.0%	7.5%	10.6%	8.3%	6.5%	10.4%	4.5%	0.0%
MN-ZLW-002	0.0%	7.0%	10.5%	8.5%	6.1%	9.8%	0.0%	4.3%
LMG 18311	0.0%	10.7%	5.8%	12.0%	10.3%	0.0%	9.7%	10.0%
LMD-9	0.0%	6.7%	11.2%	8.3%	0.0%	11.0%	6.7%	6.9%
JIM 8232	0.0%	10.5%	15.4%	0.0%	10.1%	14.5%	10.9%	10.5%
CNRZ 1066	0.0%	10.3%	0.0%	12.3%	9.8%	5.0%	9.6%	9.6%
ASCC 1275	0.0%	0.0%	11.0%	8.0%	6.0%	10.7%	6.9%	7.2%
ACA-DC 29	0.0%	13.6%	12.9%	14.8%	13.3%	12.5%	13.3%	12.7%

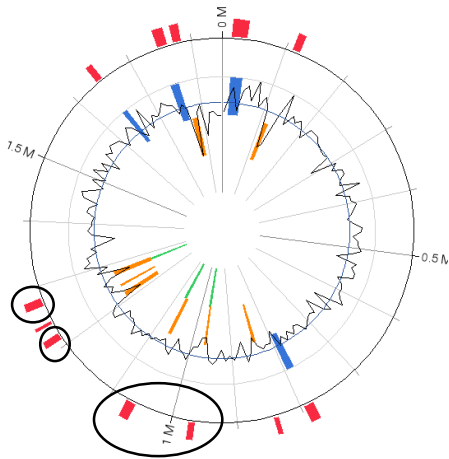
Fraction color scale: 0 (lightest green) to 14 (darkest green)

# Comparative genomics of *S. thermophilus*

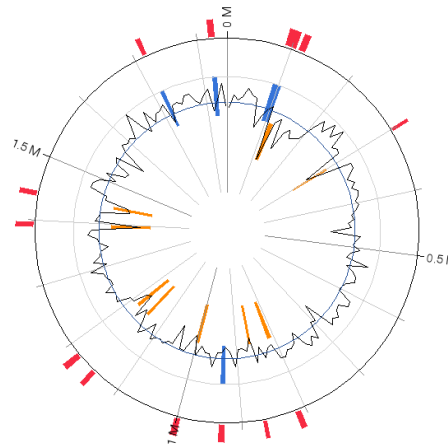


ACA-DC 29  
→

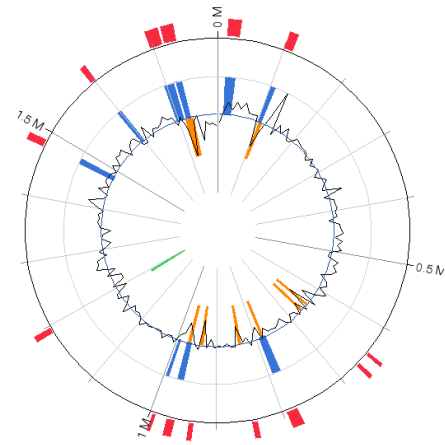
# Comparative genomics of *S. thermophilus*



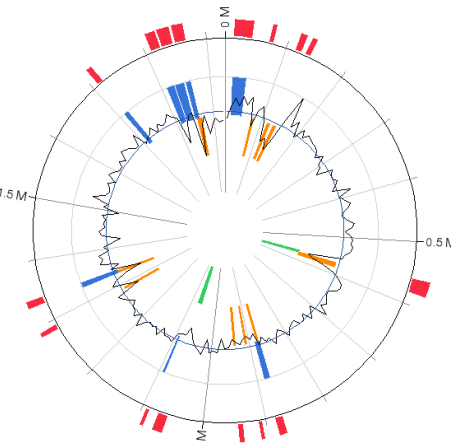
**ACA-DC 29**



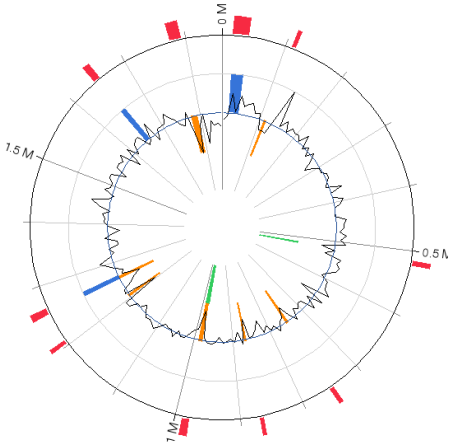
**ASCC 1275**



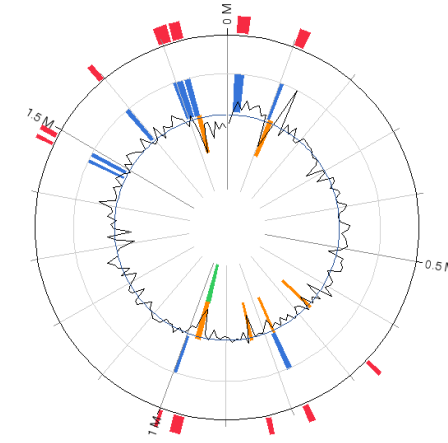
**CNRZ 1066**



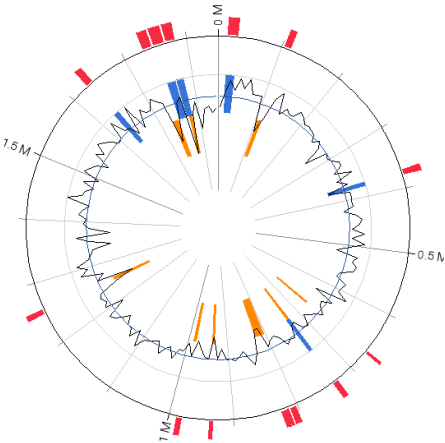
**JIM 8232**



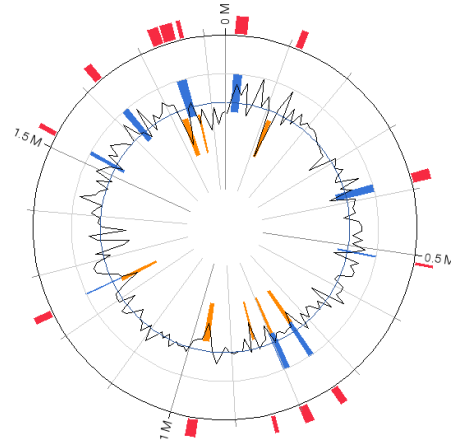
**LMD-9**



**LMG 18311**



**MN-ZLW-002**

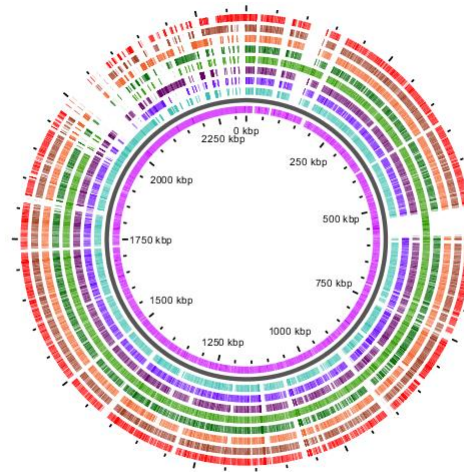


**ND03**



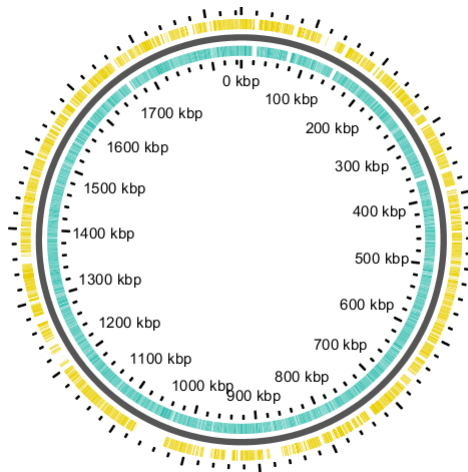
# Comparative genomics of *S. thermophilus*

*S. thermophilus* strains  
■ Pangenome

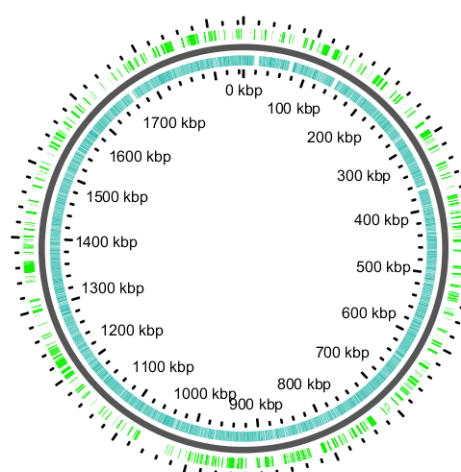


- ND03
- MN-ZLW-002
- LMG 18311
- LMD-9
- JIM 8232
- CNRZ 1066
- ASCC 1275
- ACA-DC 29
- Pangenome

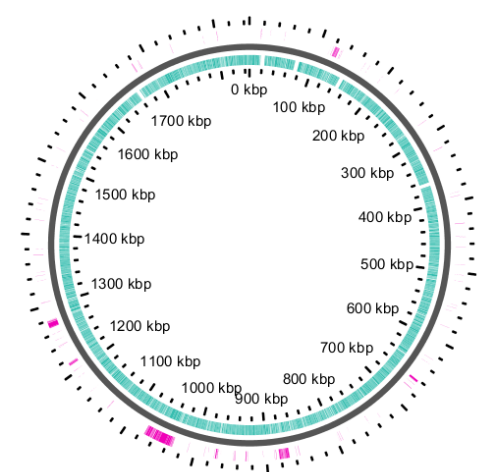
*S. thermophilus* ACA-DC 29  
■ Core genome



*S. thermophilus* ACA-DC 29  
■ Accessory genome

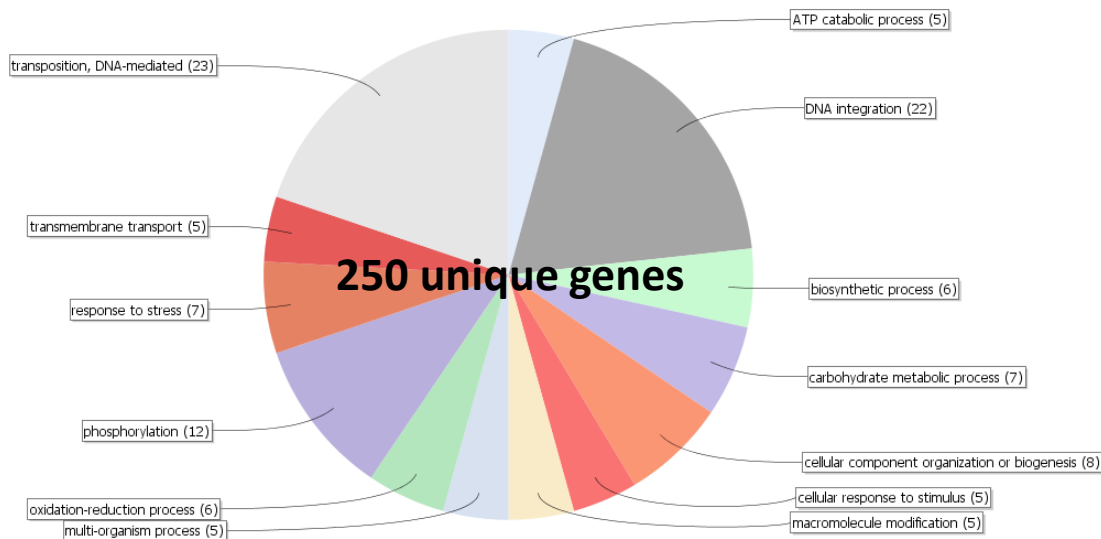


*S. thermophilus* ACA-DC 29  
■ Unique genome



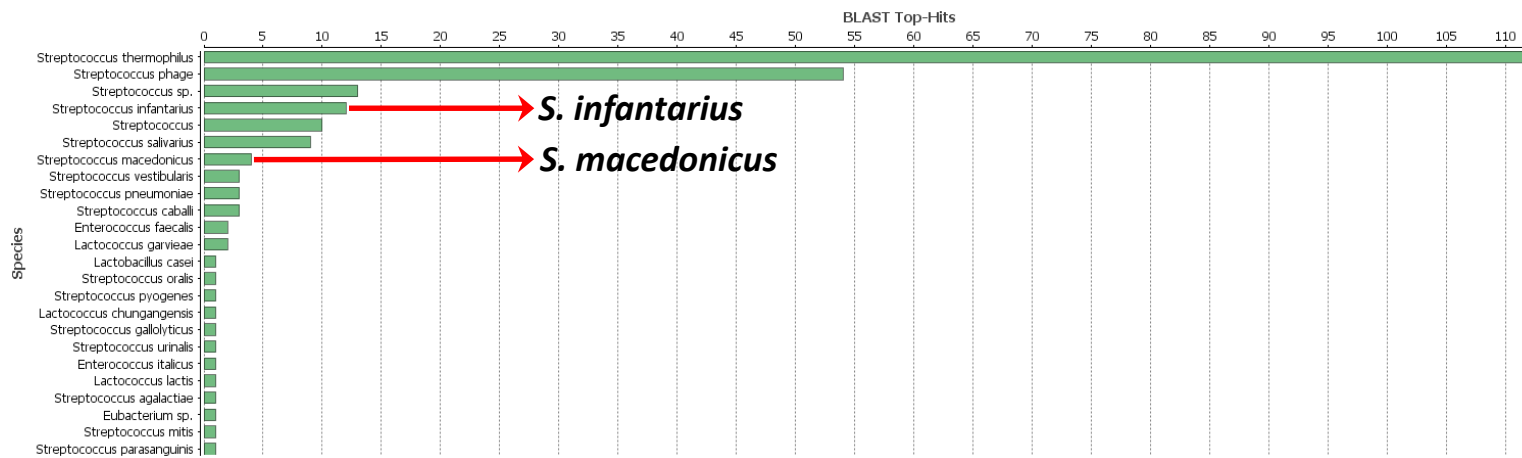
# Comparative genomics of *S. thermophilus*

## Biologic process distribution

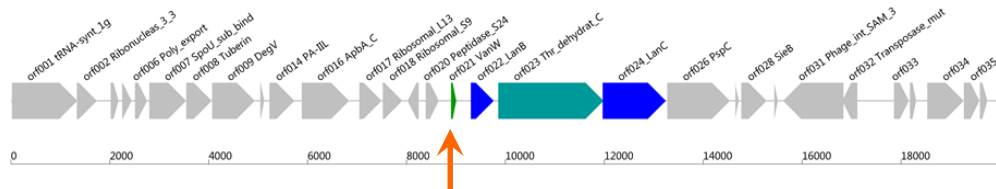


250 unique genes

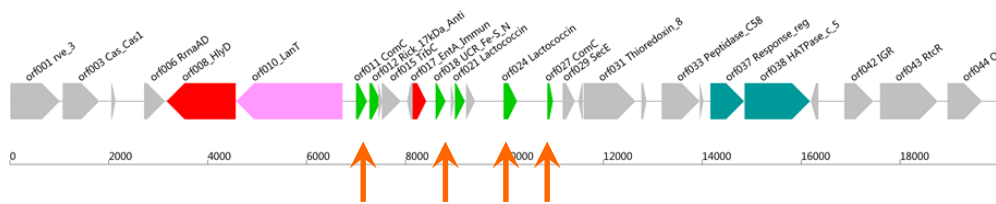
## Top hits species distribution



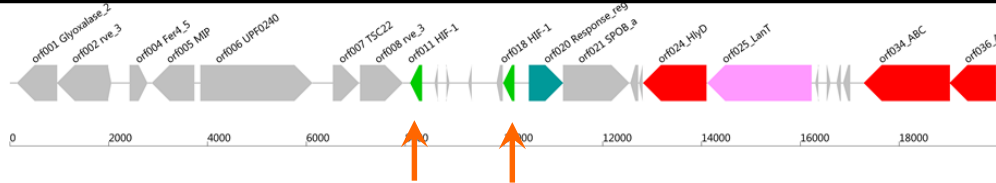
# Representative genomic traits of *S. thermophilus* ACA-DC 29 potentially involved in technological properties of starters



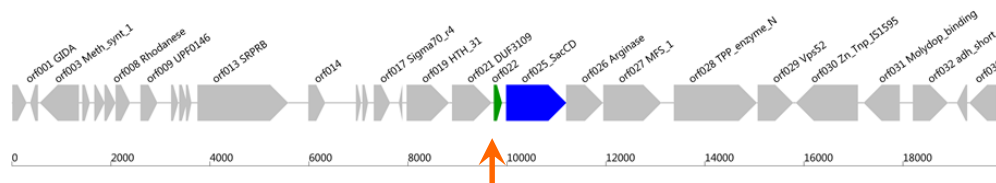
A. Lantibiotic



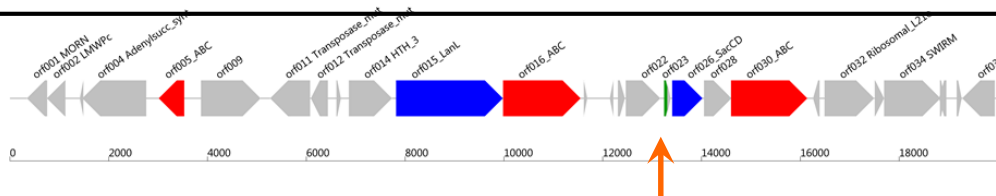
B. Unmodified



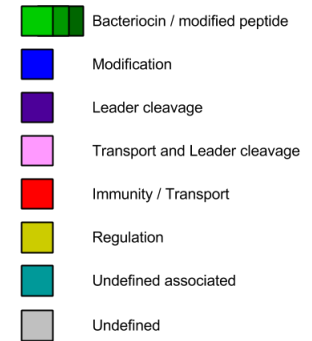
C. Unmodified



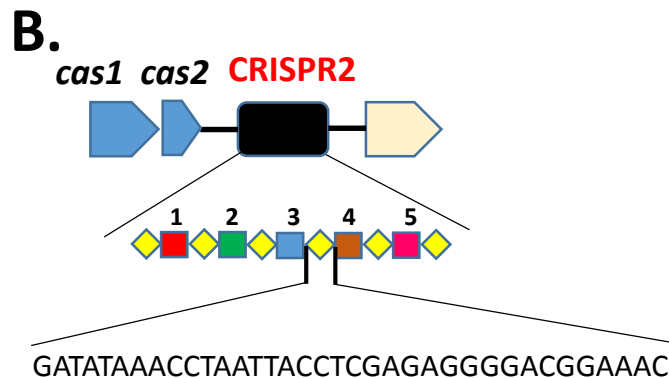
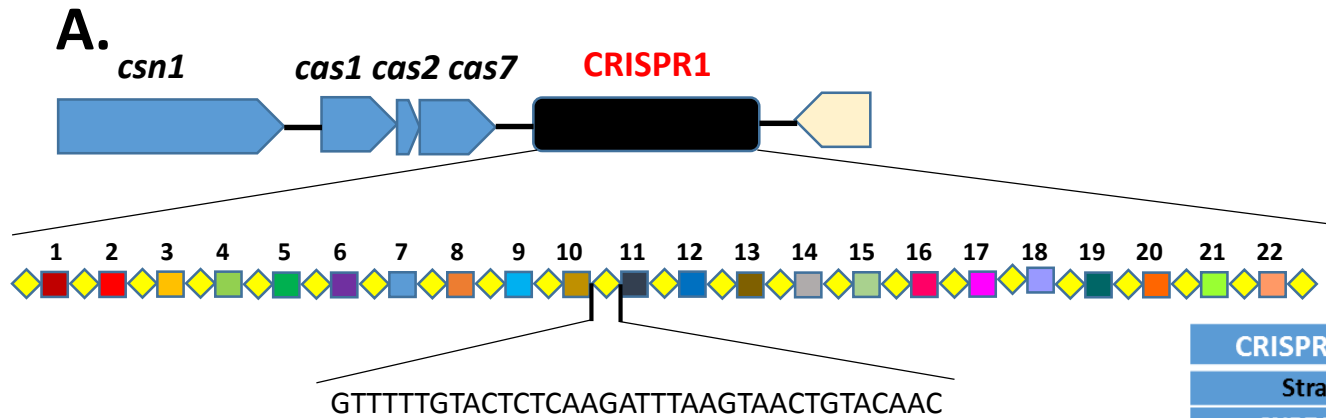
D. Sactipeptide



E. Sactipeptide



# Representative genomic traits of *S. thermophilus* ACA-DC 29 potentially involved in technological properties of starters



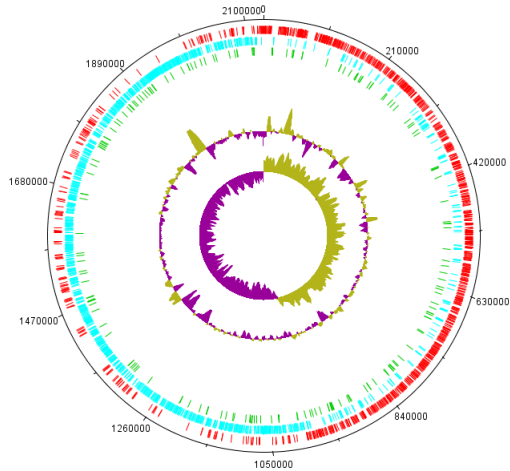
CRISPR arrays of <i>S. thermophilus</i> strains		
Strain	CRISPR	Spacers
CNRZ1066	1	40
LMG 18311	3	32
		4
		3
ND03	2	35
		19
MN-ZLW-002	2	29
		25
ASCC 1275	3	31
		11
		11
LMD-9	2	15
		7
JIM 8232	2	41
		16



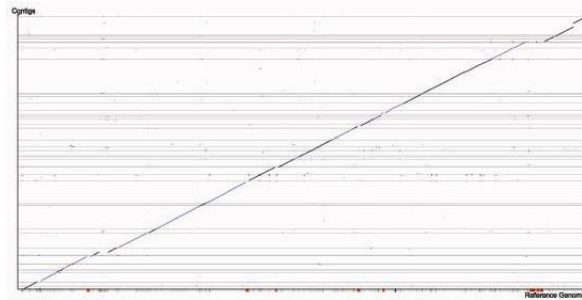
- **Greek *Streptococcus thermophilus* ACA-DC 29**
- **French *Streptococcus macedonicus* 679**
- **Comparative genomics between strains of *S. thermophilus* and *S. macedonicus***



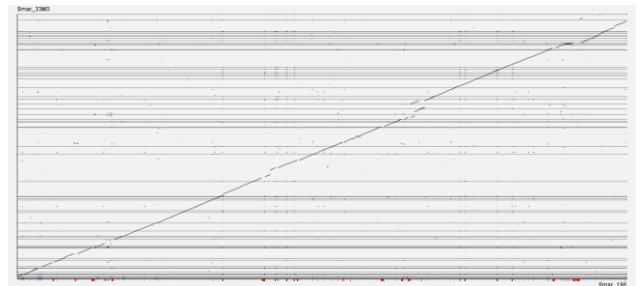
# Comparative genomics of *S. macedonicus*



ACA-DC 198

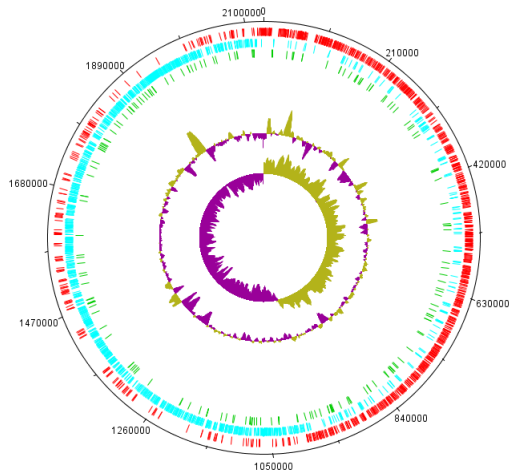


679 vs ACA-DC 198

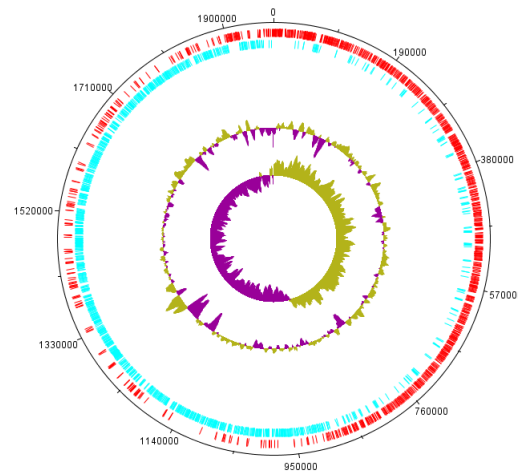


33MO vs ACA-DC 198

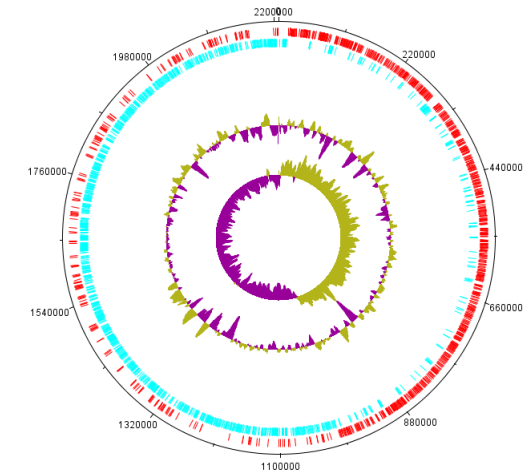
# Comparative genomics of *S. macedonicus*



**ACA-DC 198**

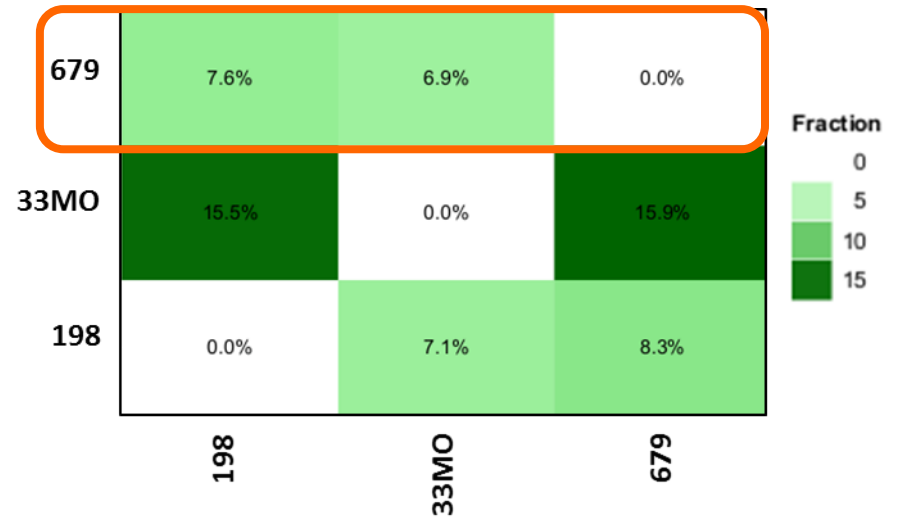
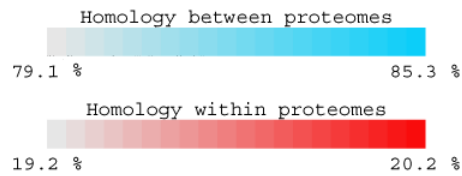
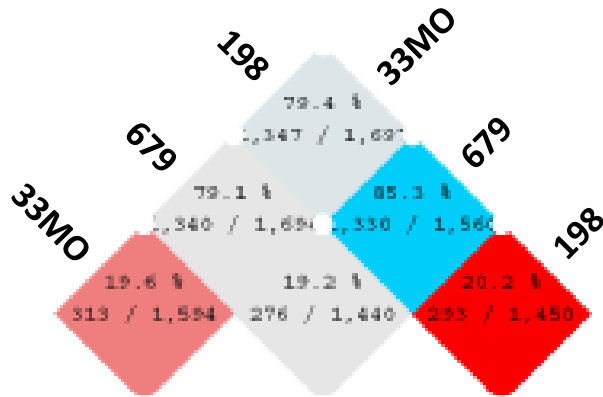


**679**



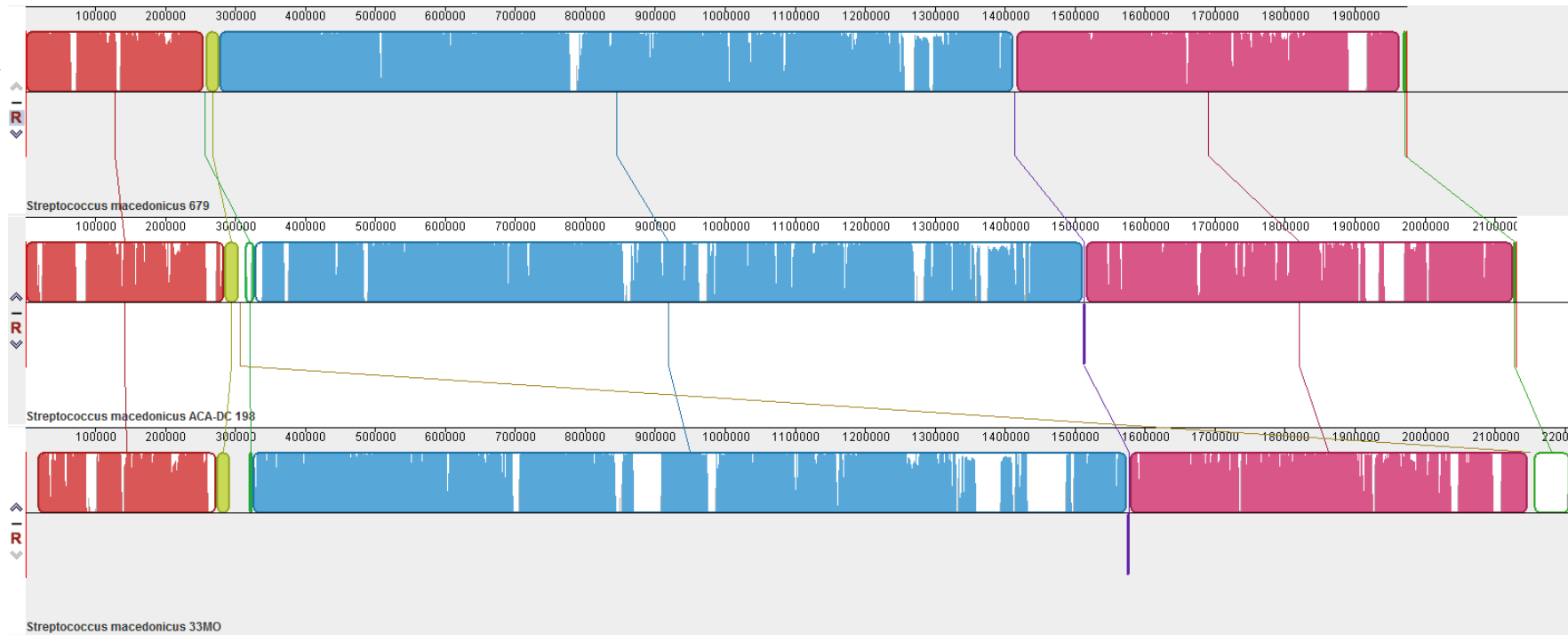
**33MO**

# Comparative genomics of *S. macedonicus*

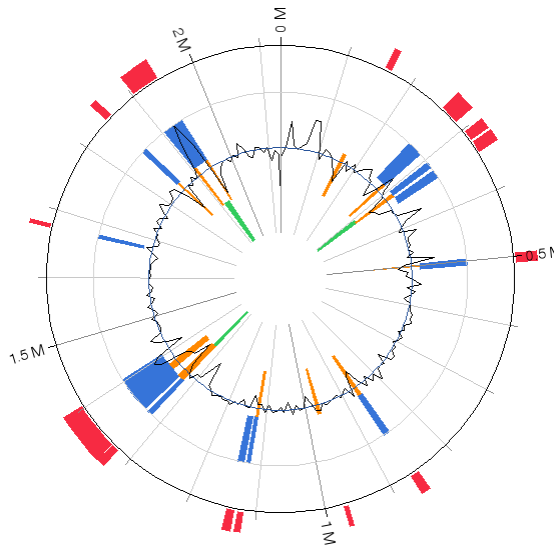


# Comparative genomics of *S. macedonicus*

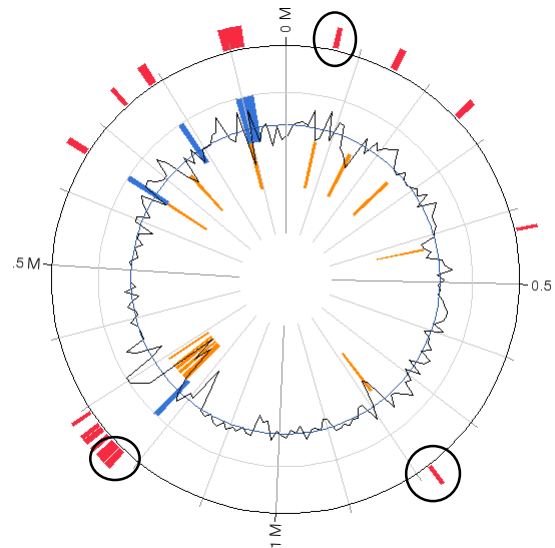
679



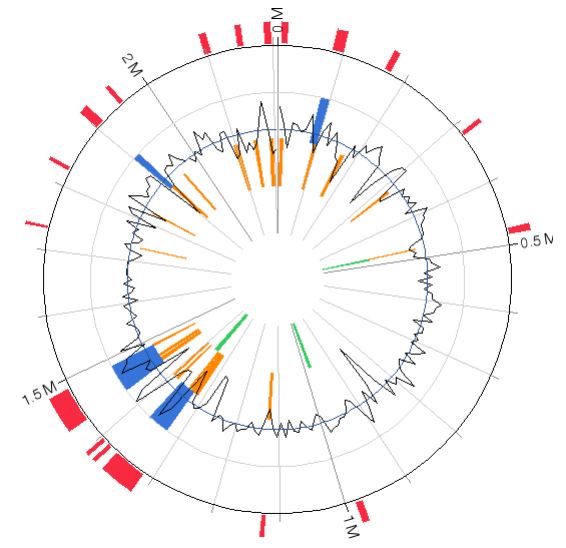
# Comparative genomics of *S. macedonicus*



**ACA-DC 198**



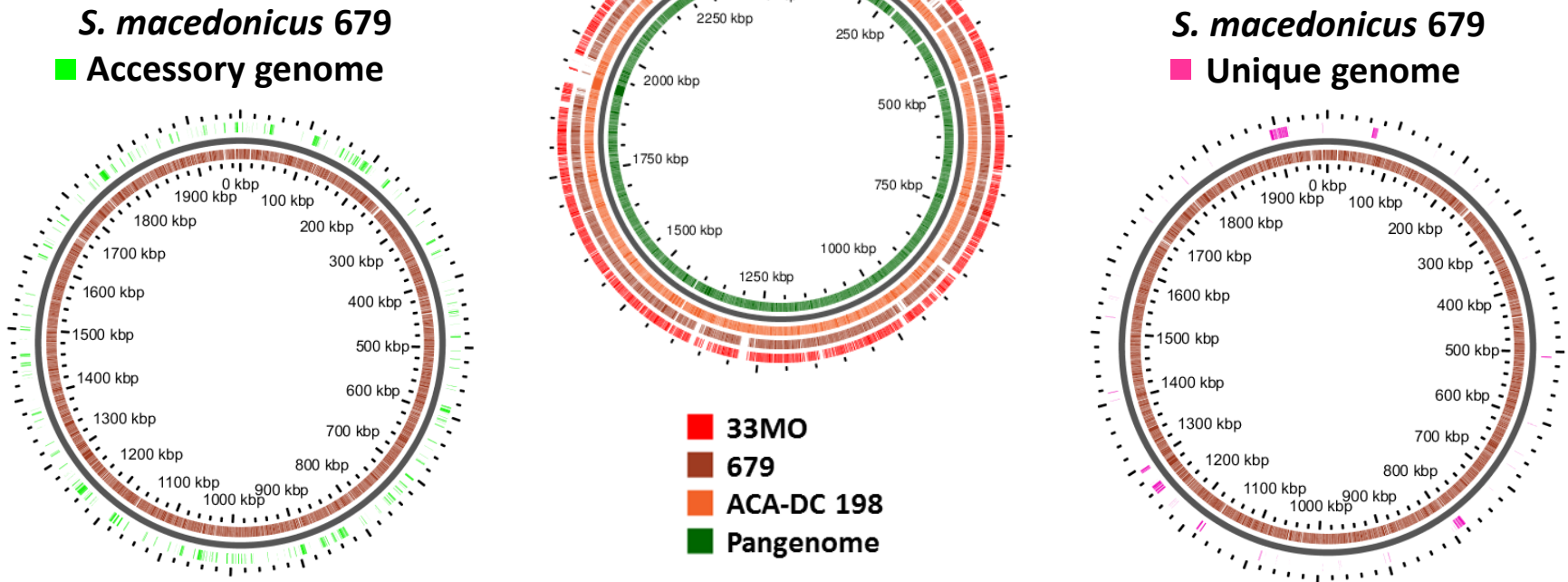
**679**



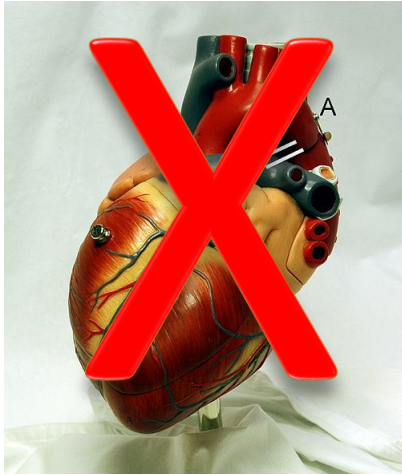
**33MO**

# Comparative genomics of *S. macedonicus*

## *S. macedonicus* pangenome



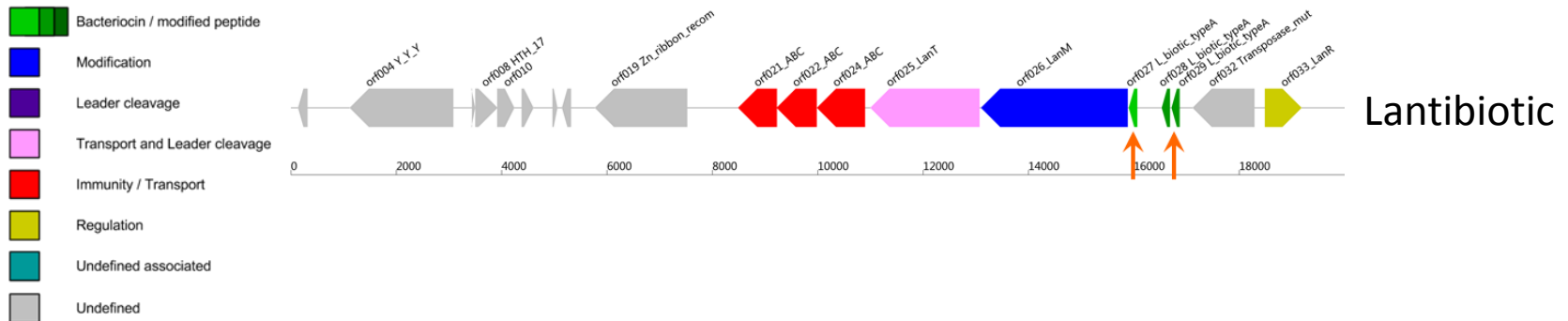
# Representative genomic traits of *S. macedonicus* 679 potentially involved in technological properties of starters



- Extra lactose operon
- Proteolytic system



# Representative genomic traits of *S. macedonicus* 679 potentially involved in technological properties of starters



CRISPR arrays of <i>S. macedonicus</i> strains		
Strain	CRISPR	Spacers
679	1	11
ACA-DC 198	1	49
33MO	2	3
		36

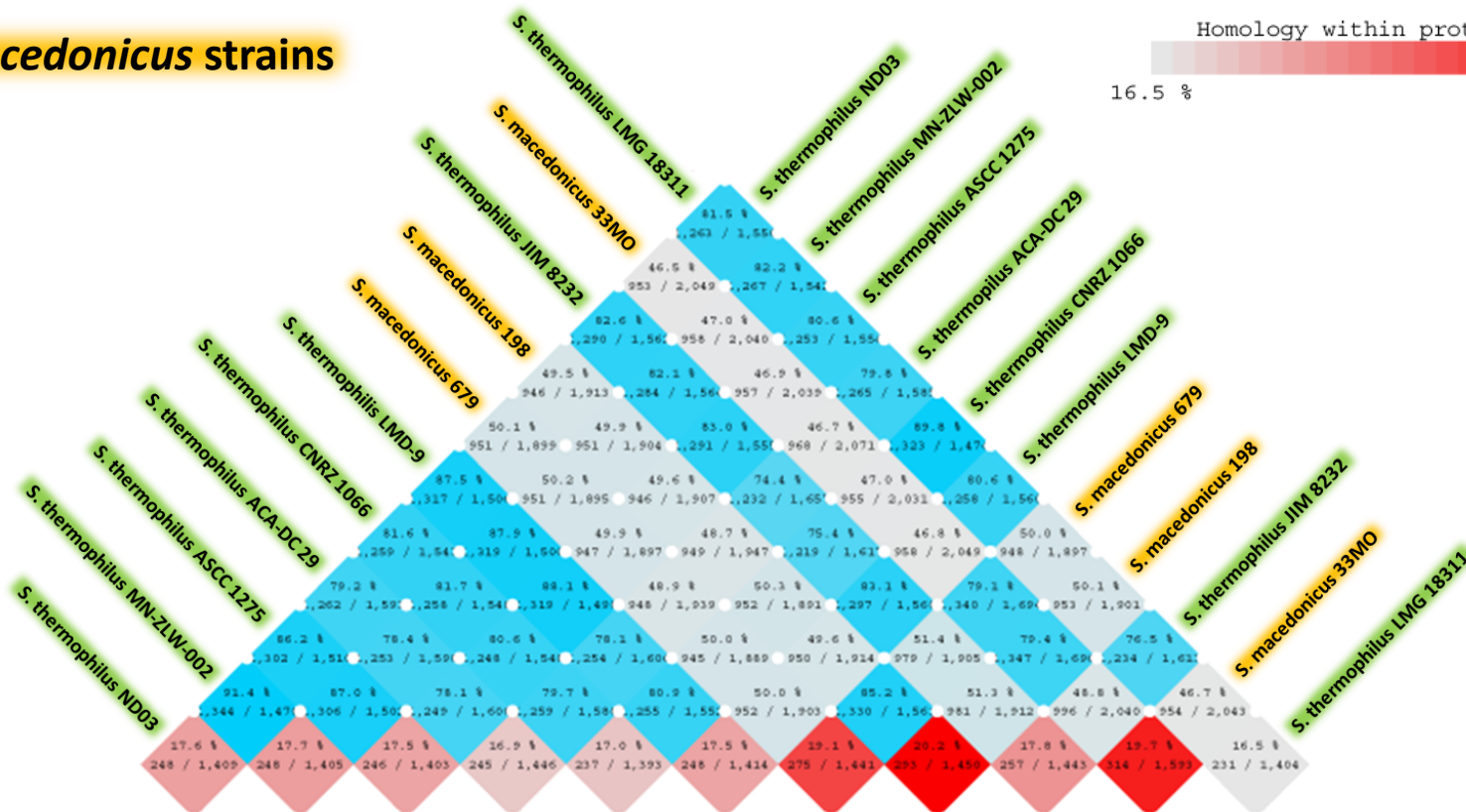
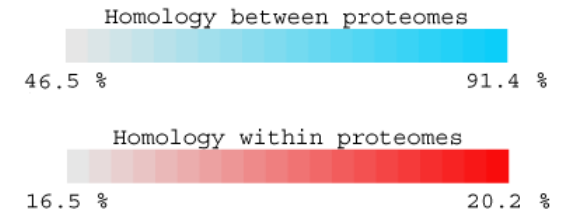
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# Comparative genomics between strains of *S. thermophilus* and *S. macedonicus*

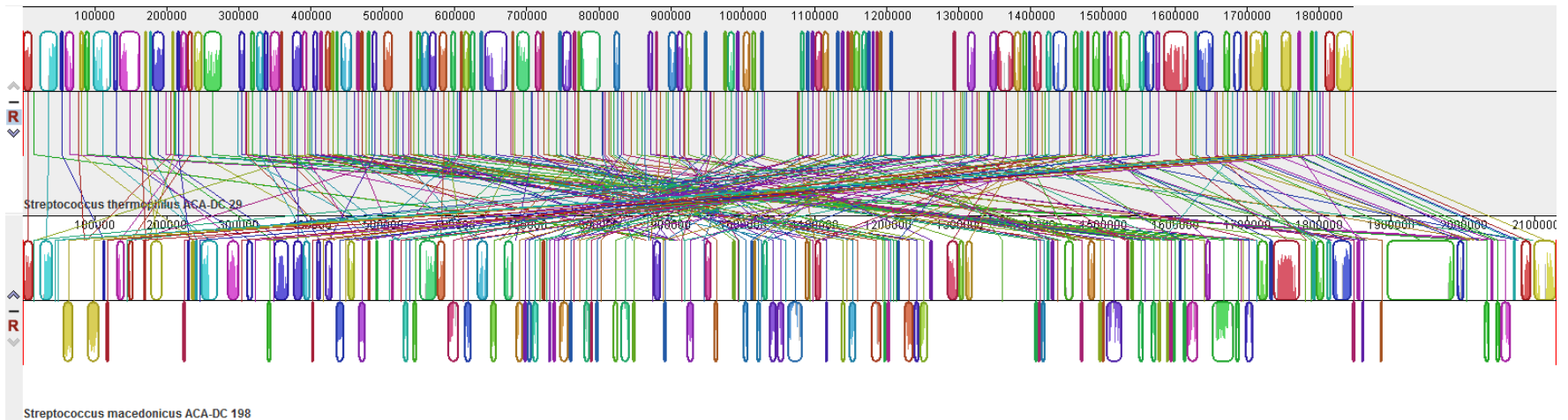
*S. thermophilus* strains

*S. macedonicus* strains



# Comparative genomics between strains of *S. thermophilus* and *S. macedonicus*

*S. thermophilus* ACA-DC 29



*S. macedonicus* ACA-DC 198

# Comparative genomics between strains of *S. thermophilus* and *S. macedonicus*

- *S. macedonicus* ACA-DC 198 carries in its CRISPR spacers that may confer resistance to known phages of *S. thermophilus*
- *S. macedonicus* ACA-DC 198 carries genes potentially acquired by horizontal gene transfer from *S. thermophilus* (e.g. type III RM system)
- *S. thermophilus* ACA-DC 29 carries genes potentially acquired by horizontal gene transfer from *S. macedonicus*

**data not shown**

# Conclusions

- Both *S. thermophilus* and *S. macedonicus* species include very closely related strains
- Sequencing of more strains is necessary since unique genes can always be found in their genomes
- *S. thermophilus* and *S. macedonicus* are diverge species but they both present traits of adaptation to the milk environment
- Both *S. thermophilus* and *S. macedonicus* seem to have been adapted to the milk environment using similar strategies



**The present work was cofinanced by the European Social Fund  
and the National resources EPEAEK and YPEPTH  
through the Thales project**



Thank you for your attention

