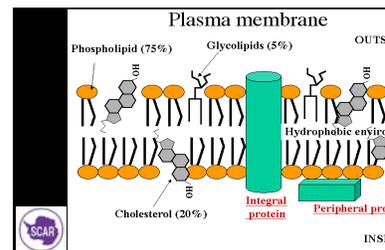
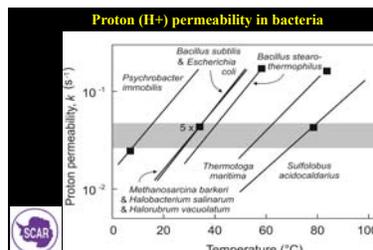
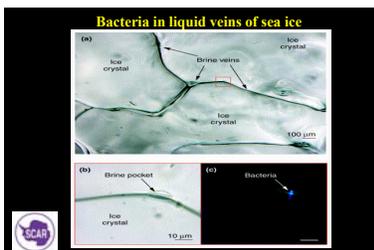
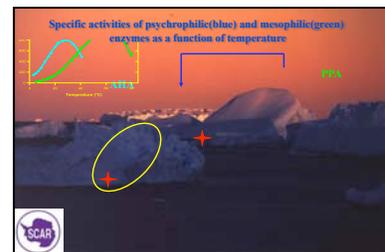
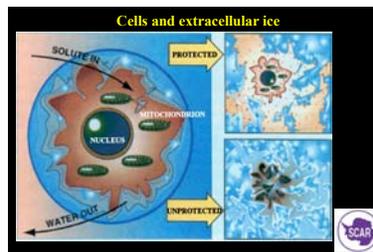


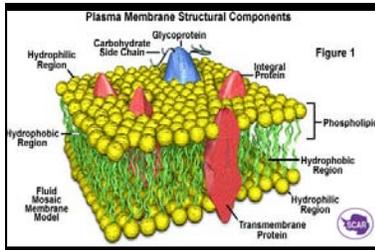
**How do psychrophiles maintain appropriate rate of reactions ?**

SCAR

**How do psychrophiles, living below 0°C, prevent freezing?**

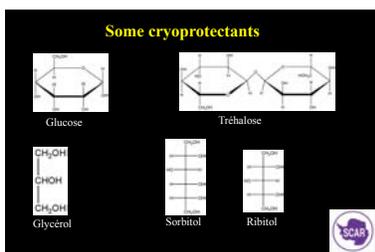
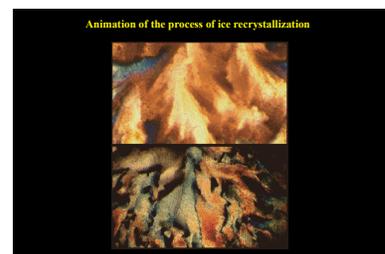
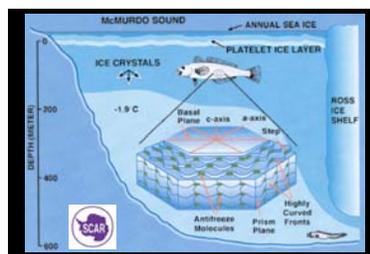
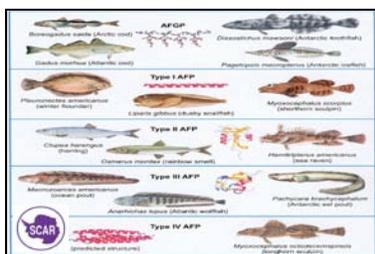
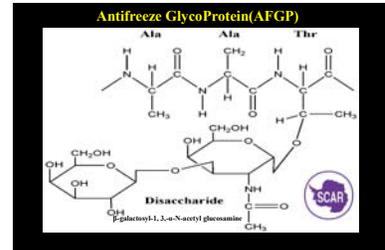
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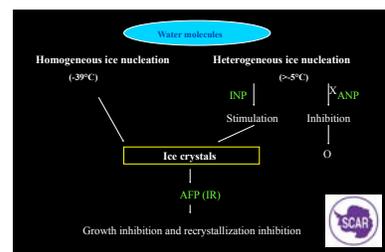


**General properties of enzymes from psychrophiles**

- High specific activity at low and moderate temperatures
- High thermostability - Flexible structure

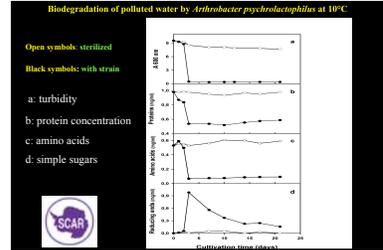
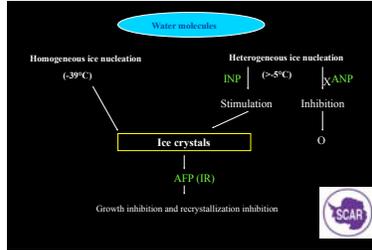


- Effects of cryoprotectants**
- 1- They depress the freezing point of water
  - 2- They prevent cell dehydration when extracellular ice is present
  - 3- They protect proteins against cold denaturation



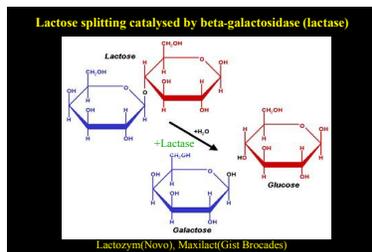
### Effects of ice-nucleating proteins

- 1-Ice is confined in the extracellular space
- 2-The formation of ice is controlled by the organism (time)
- 3-At the same time production of cryoprotectants
- 4-Some water is lost contributing to decrease the freezing point in the intracellular space

### Psychrophiles and cold-active enzymes in Biotechnology

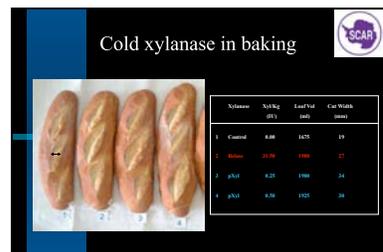
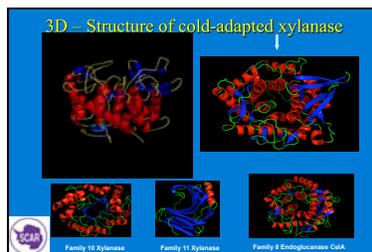
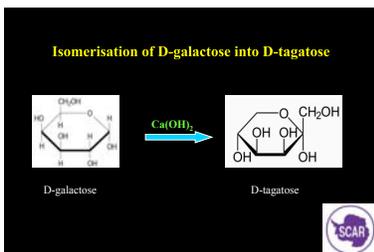
Applications	Advantage	Involved enzymes
Detergents	Washing at low temperature	Protease, lipase, amylase, cellulase, oxygenase
Food industry	Improved taste and aroma of fermentation products (cheese, wine)	Fermentation and ripening enzymes
	Lactose hydrolysis	$\beta$ -galactosidase
	Juice clarification and yield of extraction	Pectinase, cellulase
	Wine fermentation	Protease
Organic synthesis	Stable and heat-sensitive compounds, organic phase synthesis	Protease, lipase, glyceryl-hydrolyase, etc
Molecular biology	Mild inactivation, ligation, PCR	Various enzymes
	Low temperature	Ligation, carry-over in PCR
Textiles	Improved quality due to mild heat treatment for dyeing, biopolishing and stone washing of fabrics	Amylase, laccase, cellulase
Environment	In situ bioremediation of organic pollutants and hydrocarbons	Various hydrolases, mono- and dioxygenases, dehydrogenases
	Biogas production	Psychrophilic anaerobic digestion

### Tests in milk at 5 °C

Lactose + H<sub>2</sub>O  $\xrightarrow{\beta\text{-galactosidase}}$  D-glucose + D-galactose  
D-galactose + NAD<sup>+</sup>  $\xrightarrow{\text{Gal-DH}}$  lactonolactose + NADH + H<sup>+</sup>

	$\beta$ -galactosidase (mg/l)	Fresh [D-galactose] (mg/l)	[Lactose] hydrolysed (mg/l)
<i>P. halophilus</i>	0.778	0.135	0.256
Maxilact	0.770	0.049	0.093



### Acknowledgments

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