

Source	Use
Psychrophiles	
Alkaline phosphatase Proteases, lipases, cellulases and amylases Lipases and proteases Proteases Polyunsaturated fatty acids Various enzymes b-galactosidase Ice nucleating proteins Ice minus microorganisms Various enzymes (e.g. dehydrogenases) Various enzymes (e.g. oxidases) Methanogens	Molecular biology Detergents Cheese manufacture and dairy production Contact-lens cleaning solutions, meat tenderizing Food additives, dietary supplementsc Modifying flavors Lactose hydrolysis in milk products Artificial snow, ice cream Frost protectants for sensitive plants Biotransformations Bioremediation, environmental biosensors Methane production

Extremophiles and their uses in Biotechnology

Source	Use
Hyperthermophiles	
DNA polymerases Alkaline phosphatase Proteases and lipases Lipases, pullulanases and proteases Proteases, Amylases, a-glucosidase, pullulanase and xylose/glucose isomerases Alcohol dehydrogenase Xylanases Lenthionin S-layer proteins and lipids Oil degrading microorganisms Sulfur oxidizing microorganisms Hyperthermophilic consortia	DNA amplification by PCR Diagnostics Dairy products Detergents Baking, brewing, amino acid production from keratin Chemical synthesis Paper bleaching Pharmaceutical molecular sieves Surfactants for oil recovery Bioleaching, coal, waste gas desulfurization Waste treatment and methane production

Source	Use
Alkaliphiles	
Proteases, cellulases, xylanases, lipases and pullulanases Proteases Elastases, keritinases Cyclodextrins Xylanases and proteases Pectinases Alkaliphilic halophiles Various microorganisms	Detergents Gelatin removal on X-ray film Hide dehairing Foodstuffs, chemicals and pharmaceuticals Pulp bleaching Fine papers, waste treatment and degumming Oil recovery Antibiotics
Acidophiles	
Sulfur oxidizing microorganisms Microorganisms	Recovery of metals and desulfurication of coal Organic acids and solvents

Source	Use
Halophiles	
Bacteriorhodopsin Polyhydroxyalkanoates Rheological polymers Eukaryotic homologues Lipids Compatible solutes Nucleases, amylases, proteases G-linoleic acid, b-carotene and cell extracts Microorganisms Microorganisms Membranes	Optical switches and photocurrent generators Medical plastics Oil recovery Cancer detection, screening anti-tumor drugs Liposomes for drug delivery and cosmetic packaging; Heating oil Protein and cell protectants in a variety of industrial uses, e.g. freezing, heating Flavoring agents Health foods, dietary supplements, food coloring, feedstock Fermenting fish sauces and modifying food textures and flavors Waste transformation and degradation, e.g. hypersalines Surfactants for pharmaceuticals