

Chapter 2: Characteristics of predominant microorganisms in food

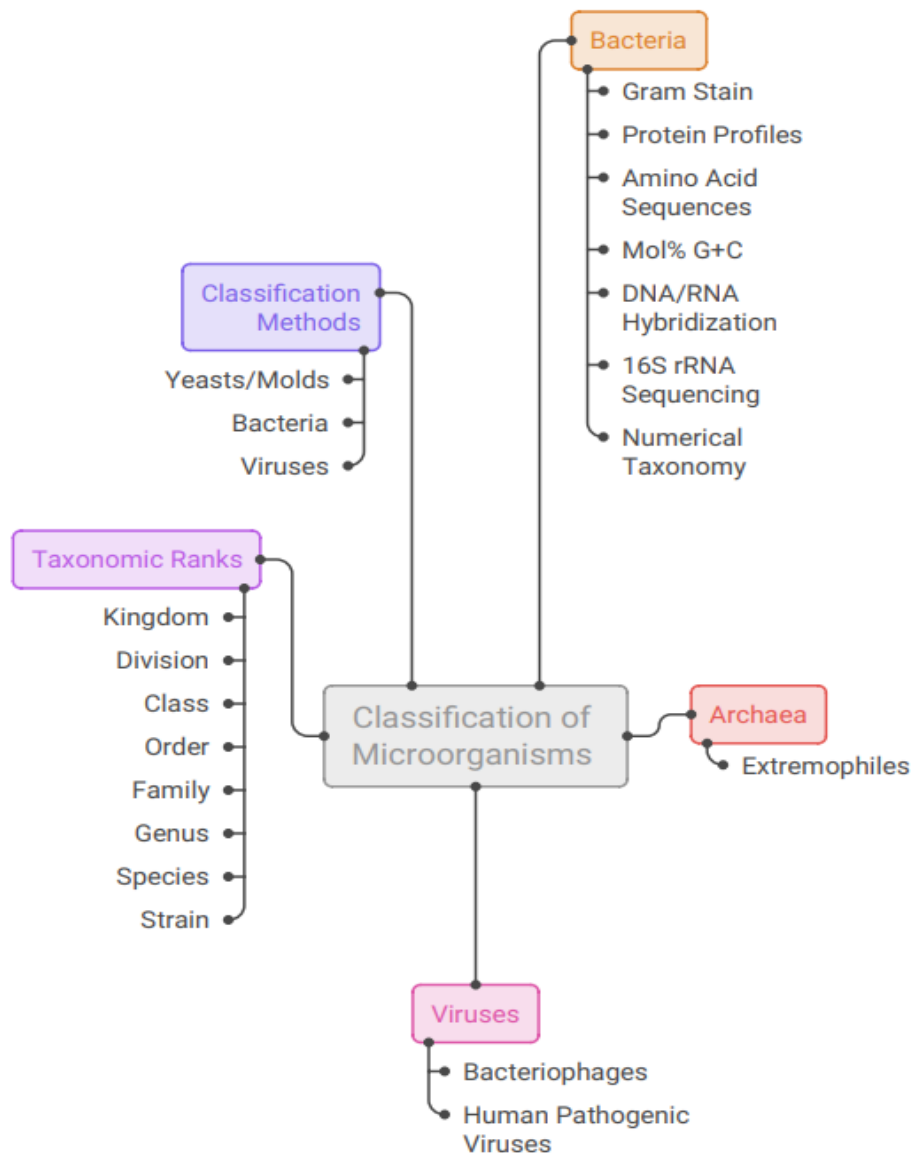
2.1. Introduction

- The main microbial groups in food are **bacteria, yeasts, molds, and viruses**.
- They are important because they can:
 - ✓ Cause foodborne diseases (mainly bacteria, some molds and viruses; not yeasts)
 - ✓ Cause food spoilage (bacteria, molds, yeasts; viruses cannot grow in food)
 - ✓ Be used to produce fermented foods and food ingredients (food-grade microorganisms)
- Bacteria are the most important group due to their ubiquity, rapid growth, and ability to grow under a wide range of conditions.

2.2. Classification of microorganisms

- Originally grouped into five kingdoms; bacteria = prokaryotes, molds/yeasts = eukaryotic fungi.
- Later reclassified into Bacteria and Archaea (Archaea = extremophiles, not important in food microbiology).
- Viruses are not living cells and are not included in this classification.
- Taxonomic ranks: Kingdom → Division → Class → Order → Family → Genus → Species. (Species = basic taxonomic group; Strain = descendant of a single colony; one strain is designated as the type strain).
- Methods used for classification:
 - Yeasts/molds: morphology, reproduction, biochemical and metabolic patterns.
 - Bacteria: Gram stain, protein profiles, amino acid sequences, mol% G+C, DNA/RNA hybridization, 16S rRNA sequencing, numerical taxonomy.
 - Two strains are considered related if:
 - Mol% G+C difference < 10%
 - DNA homology $\geq 90\%$
 - 16S rRNA homology high
 - Numerical taxonomy score $\geq 90\%$
- Viruses are classified arbitrarily by disease type, nucleic acid content, and morphology.
 - Important in food: bacteriophages and human pathogenic viruses.

Classification of Microorganisms



2.3. Morphology and structure of microorganisms in foods

2.3.1. Yeasts and molds

- Eukaryotic: larger (20–100 µm) than prokaryotes (1–10 µm).
- Cell wall: rigid, carbohydrates; no mucopeptide.
- Plasma membrane: contains sterol.
- Cytoplasm: mobile, membrane-bound organelles (mitochondria, vacuoles).
- Ribosomes: 80S, attached to endoplasmic reticulum.
- DNA: linear, with histones, enclosed in nuclear membrane.
- Division: mitosis (asexual), meiosis (sexual).
- **Molds:** multicellular, filamentous, branched; cell wall = cellulose/chitin.
 - Hyphae → mycelium
 - Hyphae: nonseptate, septate-uninucleate, septate-multinucleate

- Reproductive hyphae form **exospores** (conidia or sporangium)
- **Yeasts:** unicellular, oval/spherical/elongated ($5\text{--}30 \times 2\text{--}10 \mu\text{m}$), nonmotile.
 - Cell wall: polysaccharides, proteins, lipids; scars from budding.
 - Well-defined nucleus.



2.3.2. Bacterial cells

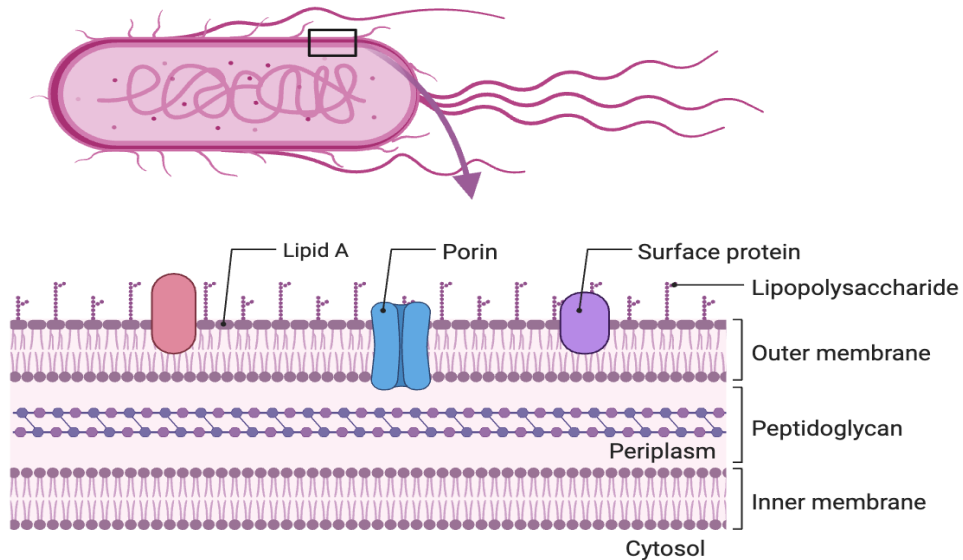
- Unicellular, $0.5\text{--}1.0 \times 2.0\text{--}10 \mu\text{m}$.
- Three morphological forms: cocci, bacilli, curved/comma.
- Can form clusters, chains, tetrads; motile or nonmotile.
- Prokaryotic features:
 - Rigid cell wall, plasma membrane, mesosomes
 - No membrane-bound organelles
 - 70S ribosomes
 - Circular DNA (no histones)
 - Binary fission
 - May have flagella, capsules, S-layer, pili, endospores
- **Gram-negative cell wall:**
 - Outer membrane (LPS, lipoprotein, phospholipids)
 - Middle membrane (thin peptidoglycan + periplasmic proteins)
 - Inner membrane (phospholipid bilayer)
 - Resistant to lysozyme, SDS, bile salts, penicillin
- **Gram-positive cell wall:**
 - Thick mucopeptide layers
 - Teichoic acids (wall and lipoteichoic)
 - Negatively charged; antigenic
 - May have surface layer protein (SLP)
 - Considered evolutionarily older

2.3.3. Viruses

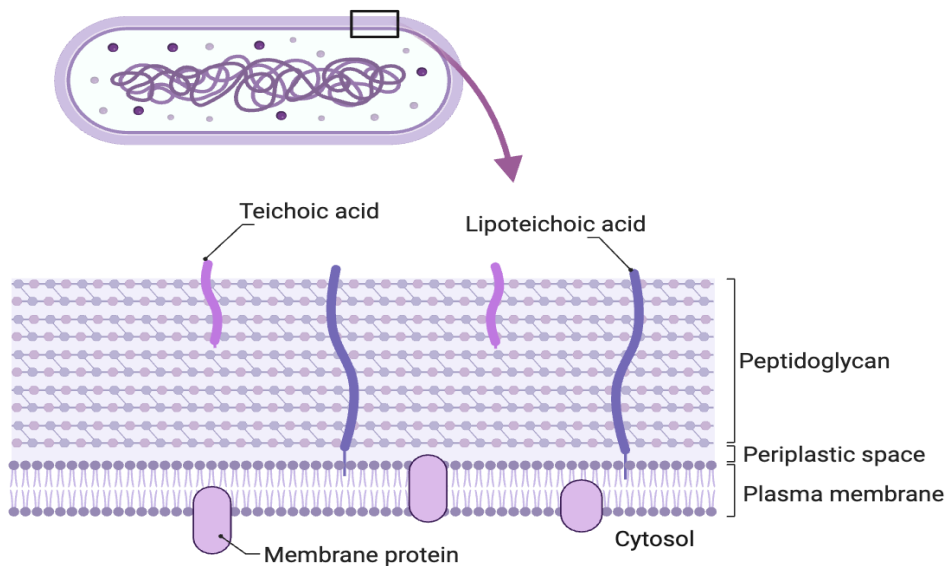
- Noncellular entities; nucleic acid (DNA/RNA) + proteins.
- Bacteriophages: head + tail; attach to host, inject nucleic acid, replicate, lyse cell.
- Human pathogenic viruses in food:

- Hepatitis A: small, naked, polyhedral, ssRNA, ~30 nm
- Norwalk-like viruses: ssRNA
- Difficult to detect in foods; involvement in foodborne disease likely underestimated.

Gram negative bacteria cell wall structure



Gram-Positive Bacteria Cell Wall Structure



2.4. Important microorganisms in food

2.4.1. Important mold genera

Genus	Key characteristics	Importance
<i>Aspergillus</i>	Septate hyphae, black conidia, xerophilic	Spoilage, mycotoxins (aflatoxin), food processing (<i>Asp. oryzae</i> , <i>Asp. niger</i>)
<i>Alternaria</i>	Septate, dark conidia	Tomato rot, rancidity in dairy, mycotoxins
<i>Fusarium</i>	Cottony growth, sickle-shaped conidia	Rot in citrus, potatoes, grains
<i>Geotrichum</i>	Septate, rectangular arthrospores, yeastlike	Dairy mold, equipment colonization
<i>Mucor</i>	Nonseptate hyphae, sporangiophores	Vegetable spoilage, fermentation, enzymes
<i>Penicillium</i>	Septate, blue-green brushlike conidia	Cheese production (<i>Pen. roquefortii</i> , <i>Pen. camembertii</i>), spoilage, mycotoxins (ochratoxin A)
<i>Rhizopus</i>	Aseptate, sporangiophores in sporangium	Fruit/vegetable spoilage, black bread mold

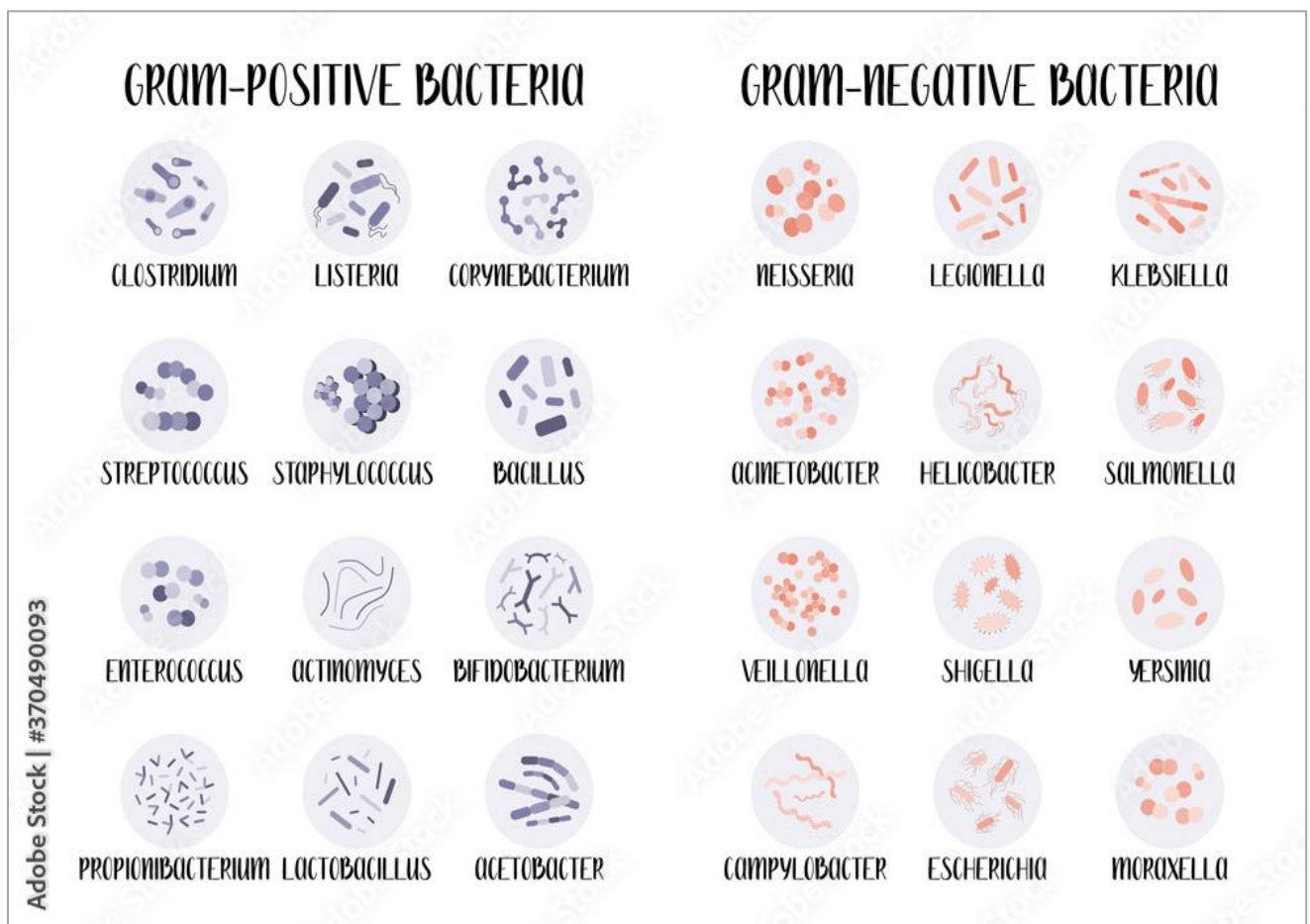
2.4.2. Important yeast genera

Genus	Key Characteristics	Importance
<i>Saccharomyces</i>	Round/oval/elongated	Baking, alcoholic fermentation, spoilage
<i>Pichia</i>	Oval to cylindrical, pellicles	Spoilage of beer, wine, brine; oriental fermentation
<i>Rhodotorula</i>	Pigment-forming	Discoloration of meat, fish, sauerkraut
<i>Torulopsis</i>	Spherical to oval	Spoilage of milk (ferments lactose), fruit juice concentrates
<i>Candida</i>	High acid/salt/sugar tolerance, pellicles	Rancidity in butter/dairy
<i>Zygosaccharomyces</i>	High-acid food spoilage	Sauces, ketchups, pickles, dressings

2.4.3. Important viruses

- **Foodborne disease:** Hepatitis A, Norwalk-like viruses, poliovirus, echovirus, Coxsackie virus.
- **Bacteriophages:**
 - Used for phage typing (*Salmonella*, *Staphylococcus aureus*)
 - Used for transduction (*E. coli*, *Lactococcus lactis*)
 - Cause fermentation failure in lactic acid bacteria starter cultures
 - Phages isolated for *Lactococcus*, *Streptococcus*, *Leuconostoc*, *Lactobacillus*; none for *Pediococcus* yet
 - Genetic engineering for phage resistance

2.4.4. Important bacterial genera



A. Gram-negative aerobes

- *Campylobacter*: microaerophilic, helical, foodborne pathogen
- *Pseudomonas*: psychrotroph, major spoilage bacteria
- *Xanthomonas*: plant pathogen, xanthan gum production
- *Acetobacter*: oxidizes ethanol to acetic acid, vinegar production, spoilage
- *Gluconobacter*: similar to *Acetobacter*, fruit spoilage
- *Acinetobacter*: strictly aerobic, soil/water/sewage
- *Moraxella*: coccoid, mucous membranes
- *Alteromonas*: marine, psychrotroph, fish/meat spoilage
- *Flavobacterium*: yellow colonies, psychrotroph, milk/meat spoilage

- *Alcaligenes*: motile, protein-rich food spoilage
- *Brucella*: animal/human pathogen, foodborne brucellosis
- *Psychrobacter*: psychrotroph, fish/meat/poultry

B. Gram-negative facultative anaerobes

- *Citrobacter*, *Escherichia*, *Enterobacter*, *Klebsiella*: coliforms, sanitation indicators
- *Edwardsiella*: cold-blooded animals, fresh water
- *Erwinia*: plant pathogen, plant product spoilage
- *Hafnia*: intestinal contents, food spoilage
- *Morganella*: intestinal contents, potential pathogen
- *Proteus*: highly motile, swarming, food spoilage
- *Salmonella*: >2000 serovars, major foodborne pathogen
- *Shigella*: human/primate intestine, foodborne disease
- *Serratia*: pigmented colonies, food spoilage
- *Yersinia*: psychrotroph, foodborne outbreaks (*Y. enterocolitica*)
- *Vibrio*: marine/freshwater, pathogens (*V. cholerae*, *V. parahaemolyticus*, *V. vulnificus*) and spoilage (*V. alginolyticus*)
- *Aeromonas*: water environment, potential foodborne pathogen
- *Plesiomonas*: fish/aquatic animals, potential foodborne pathogen

C. Rickettsias

- *Coxiella*: obligate intracellular, heat resistant, Q fever from unpasteurized milk

D. Gram-positive cocci

- *Micrococcus*: aerobe, skin, spoilage
- *Staphylococcus*: clusters, 10% NaCl tolerance, *S. aureus* foodborne disease, *S. carnosus* fermented sausages
- *Streptococcus*: pairs/chains, *S. pyogenes* pathogen, *S. thermophilus* dairy fermentation
- *Enterococcus*: intestinal origin, sanitation indicator, spoilage, heat resistant
- *Lactococcus*: dairy fermentation, bacteriocins
- *Leuconostoc*: heterolactic, fermentation, spoilage (gas formation), bacteriocins
- *Pediococcus*: tetrads, fermentation, spoilage of alcoholic beverages, bacteriocins
- *Sarcina*: packets of 8+, plant/soil/feces, spoilage

E. Gram-positive, endospore-forming rods

- *Bacillus*: aerobe/facultative anaerobe, heat-resistant spores, foodborne disease (*B. cereus*), spoilage (*B. coagulans*, *B. stearothermophilus*), enzymes (*B. subtilis*)
- *Sporolactobacillus*: microaerophilic, homolactic, spores less heat resistant
- *Clostridium*: anaerobe, heat-resistant spores, pathogens (*C. botulinum*, *C. perfringens*), spoilage (*C. tyrobutyricum*), enzymes

E. Gram-negative, endospore-forming rods

- *Desulfotomaculum*: thermophilic, anaerobic, H₂S production, canned food spoilage

F. Gram-positive, nonsporulating regular rods

- *Lactobacillus*: homo-/heterolactic, fermentation, probiotics, spoilage, bacteriocins

- *Carnobacterium*: meat/fish, heterofermentative, bacteriocins
- *Brochothrix*: meat, homofermentative, vacuum-packaged meat spoilage
- *Listeria*: psychrotroph, *L. monocytogenes* foodborne pathogen

G. Gram-positive, nonsporeforming irregular rods

- *Corynebacterium*: curved rods, spoilage, glutamic acid production
- *Brevibacterium*: cheese aroma (*B. linens*, *B. casei*), fish spoilage
- *Propionibacterium*: pleomorphic, Swiss cheese fermentation, propionic acid
- *Bifidobacterium*: gut microbiota, probiotics

2.5. Important bacterial groups in foods

Group	Description	Examples
Lactic acid bacteria	Produce large amounts of lactic acid	<i>Lactococcus</i> , <i>Leuconostoc</i> , <i>Pediococcus</i> , <i>Lactobacillus</i> , <i>S. thermophilus</i>
Acetic acid bacteria	Produce acetic acid	<i>Acetobacter aceti</i>
Propionic acid bacteria	Produce propionic acid, dairy fermentation	<i>Propionibacterium freudenreichii</i>
Butyric acid bacteria	Produce butyric acid	<i>Clostridium butyricum</i>
Proteolytic bacteria	Hydrolyze proteins (extracellular proteinases)	<i>Micrococcus</i> , <i>Staphylococcus</i> , <i>Bacillus</i> , <i>Clostridium</i> , <i>Pseudomonas</i> , <i>Alteromonas</i> , <i>Flavobacterium</i> , <i>Alcaligenes</i> , <i>Enterobacteriaceae</i> , <i>Brevibacterium</i>
Lipolytic bacteria	Hydrolyze triglycerides (extracellular lipases)	<i>Micrococcus</i> , <i>Staphylococcus</i> , <i>Pseudomonas</i> , <i>Alteromonas</i> , <i>Flavobacterium</i>
Saccharolytic bacteria	Hydrolyze complex carbohydrates	<i>Bacillus</i> , <i>Clostridium</i> , <i>Aeromonas</i> , <i>Pseudomonas</i> , <i>Enterobacter</i>
Thermophilic bacteria	Grow at $\geq 50^{\circ}\text{C}$	<i>Bacillus</i> , <i>Clostridium</i> , <i>Pediococcus</i> , <i>Streptococcus</i> , <i>Lactobacillus</i>

Psychrotrophic bacteria	Grow at $\leq 5^{\circ}\text{C}$	<i>Pseudomonas</i> , <i>Alteromonas</i> , <i>Alcaligenes</i> , <i>Flavobacterium</i> , <i>Serratia</i> , <i>Bacillus</i> , <i>Clostridium</i> , <i>Lactobacillus</i> , <i>Leuconostoc</i> , <i>Carnobacterium</i> , <i>Brochothrix</i> , <i>Listeria</i> , <i>Yersinia</i> , <i>Aeromonas</i>
Thermotolerant bacteria	Survive pasteurization	<i>Micrococcus</i> , <i>Enterococcus</i> , <i>Lactobacillus</i> , <i>Pediococcus</i> , <i>Bacillus</i> (spores), <i>Clostridium</i> (spores)
Halotolerant bacteria	Survive high salt ($\geq 10\%$)	<i>Bacillus</i> , <i>Micrococcus</i> , <i>Staphylococcus</i> , <i>Pediococcus</i> , <i>Vibrio</i> , <i>Corynebacterium</i>
Aciduric bacteria	Survive low pH (< 4.0)	<i>Lactobacillus</i> , <i>Pediococcus</i> , <i>Lactococcus</i> , <i>Enterococcus</i> , <i>Streptococcus</i>
Osmophilic bacteria	Grow at high osmotic pressure	<i>Staphylococcus</i> , <i>Leuconostoc</i> , <i>Lactobacillus</i>
Gas-producing bacteria	Produce CO_2 , H_2 , H_2S	<i>Leuconostoc</i> , <i>Lactobacillus</i> , <i>Propionibacterium</i> , <i>Escherichia</i> , <i>Enterobacter</i> , <i>Clostridium</i> , <i>Desulfotomaculum</i>
Slime producers	Synthesize polysaccharides	<i>Xanthomonas</i> , <i>Leuconostoc</i> , <i>Alcaligenes</i> , <i>Enterobacter</i> , <i>Lactococcus</i> , <i>Lactobacillus</i>
Spore formers	Produce spores	<i>Bacillus</i> , <i>Clostridium</i> , <i>Desulfotomaculum</i>
Aerobes	Require oxygen	<i>Pseudomonas</i> , <i>Bacillus</i> , <i>Flavobacterium</i>
Anaerobes	Cannot grow in oxygen	<i>Clostridium</i>
Facultative anaerobes	Grow with or without oxygen	<i>Lactobacillus</i> , <i>Pediococcus</i> , <i>Leuconostoc</i> , enteric pathogens, some <i>Bacillus</i> , <i>Serratia</i> , coliforms
Coliforms	Sanitation index	<i>Escherichia</i> , <i>Enterobacter</i> , <i>Citrobacter</i> , <i>Klebsiella</i>
Fecal coliforms	Sanitation index	<i>Escherichia coli</i>
Enteric pathogens	Cause gastrointestinal infection	<i>Salmonella</i> , <i>Shigella</i> , <i>Campylobacter</i> , <i>Yersinia</i> , <i>Escherichia</i> , <i>Vibrio</i> , <i>Listeria</i> , hepatitis A, others