

FE 305- FOOD MICROBIOLOGY

Introduction

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Introduction

- Substances that are consumed to provide the energy needed for the growth and development of living things, for their reproduction, for the building and repair of their tissues and for the metabolic activities of the cell are called “food”.
- **Food is everything that people eat and drink, apart from medicines, in order to survive and to meet their physiological needs.**
- Safe and healthy food is defined as “food that is physically, chemically and microbiologically safe and that contains nutrients in sufficient and balanced amounts”.
- Microorganisms have both beneficial and harmful effects in the food industry.
- The development of taste and aroma in foods and the production of fermented foods with microbial cultures are examples of their beneficial effects.
- Harmful microorganisms in foods can damage human health, cause poisoning and, in some cases, even death.
- They can also cause serious economic damage to a country through losses of product and time.

Introduction

- Long before Antonie van Leeuwenhoek described his “living animalcules” in the 1670s, many of the conditions that control microbiological spoilage had already been identified empirically.
- However, it was the emergence of microbiology as a science that moved food preservation from an art to a science, allowing foods to be processed, distributed and marketed with a high degree of confidence in both quality and safety.
- The scope of food microbiology is very broad and interfaces with virtually all subdisciplines of microbiology (public health microbiology, microbial genetics, fermentation technology, microbial physiology, etc.).
 - Areas in which food microbiologists currently provide critical insight include:
 - biofilm formation on food-contact surfaces and its control;
 - detection of low numbers of metabolically stressed (injured) microorganisms in complex food matrices;
 - predictive microbiology and quantitative microbial risk assessment (QMRA);
 - probiotics, prebiotics and the food and gut microbiome;
 - naturally occurring antimicrobials, bacteriophage applications and whole-genome sequencing (WGS)-based outbreak surveillance.

Milestones in Food Microbiology

6000 BC	●	Fermentation, drying and salting are used - without knowing why they work
1676	●	Leeuwenhoek sees “animalcules” through microscopes he built himself
1810	●	Appert preserves food in sealed, heated jars - the birth of canning
1857 - 64	●	Pasteur links fermentation and spoilage to microbes; pasteurisation
1895	●	van Ermengem isolates <i>Clostridium botulinum</i> from a ham
1922	●	Esty and Meyer lay the basis of the “botulinum cook” (12-D) for cans
1959 - 71	●	HACCP is developed by Pillsbury for NASA space food
1993	●	Jack in the Box STEC O157:H7 outbreak reshapes US meat safety rules
2011	●	German sprout outbreak (STEC O104:H4): about 3 800 cases, 53 deaths
2020s	●	Whole-genome sequencing links patients to foods almost in real time

Food and Microorganisms

- In nature there is a constant interaction between microorganisms, plants and animals.
- Microorganisms play a key role in many biogeochemical cycles (C, N, S, CO₂ and O₂ cycles).
- Through their enzymatic activities they cause the spoilage of many foodstuffs.
- A large number of pathogenic microorganisms cause infections in humans, animals and plants.
- The main function of microorganisms is to carry out the activities required to maintain their own life and generation. To do so, they perform the following basic reaction:

Organic compounds  Cell structures + Energy + Inorganic compounds

- The substances formed as a result of this reaction provide nutrients for plants, and plants in turn provide nutrients for animals.

Food and Microorganisms

- Foods are spoiled by the enzymatic activity of the microorganisms present in their natural flora and of those that contaminate them later.
- This has led people to think about how foods could be stored without spoiling.
- Fermentation and drying are the oldest methods of food preservation.
 - For example, acid-producing bacteria are used in pickles, vinegar and fermented dairy products;
 - alcoholic beverages such as beer and wine are the fermentation products of alcohol-producing yeasts.
- In the earliest ages people consumed raw foods; from about 6000–8000 BC onwards they began to preserve them by cooking, salting, drying, covering with oil and storing in snow.

Food and Microorganisms

- In those periods, preservation methods were based on trial and error, and it was not known that various diseases were transmitted to humans through food.
 - For example, during the ergotism (St Anthony's fire) epidemic of 944–945 AD in France, in which about 40 000 people died, it was not known that the cause was a toxin produced by the mould *Claviceps purpurea*.
- Saprophytic microorganisms cause spoilage in foods;
- pathogenic microorganisms cause foodborne infections and intoxications;
- some microorganisms play a beneficial role in the production of fermented meat products, yoghurt, beer and wine.
- The relationship between a food and its microorganisms is governed by two groups of factors:
 - intrinsic (internal) factors such as pH, water activity, redox potential, natural antimicrobial substances and the nutrients present in the food (protein, fat, carbohydrate, minerals, vitamins, etc.);
 - extrinsic (external) factors such as storage temperature, relative humidity and the gas atmosphere of the storage environment.

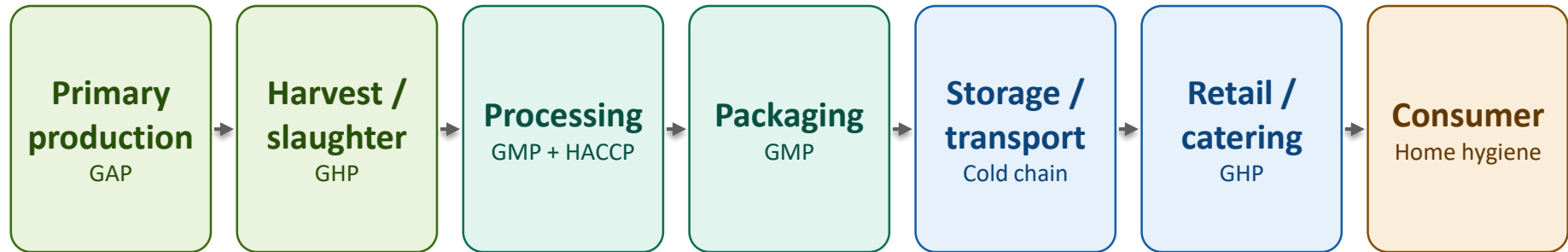
Nutrition and Food Security

- The world population passed 8 billion in November 2022 and reached about 8.2 billion in 2025; almost all of this growth occurs in developing and least-developed countries. More than half of the world's people now live in urban areas, and the urban population is expected to approach 5 billion by 2030.
- Such population growth and urbanisation require new approaches to food security and to food systems.
- At the same time, continuing innovations — improvements in plant and animal production and in extension services, the control of pre-harvest and post-harvest losses, effective food processing and distribution systems and new preservation technologies — aim to meet the nutritional needs of this ever-increasing population.
- As urbanisation increases, radical changes in food production and consumption and changes in food sources lengthen the food chain, allow new hazards to emerge and may increase the severity of existing hazards.
 - For this reason, a food safety approach must be applied in every country in order to protect both public health and the economy.

Food Safety

- Adequate nutrition and a healthy life, which are among the most basic human needs, are only possible if food safety is ensured.
- The emergence of many new foodborne diseases worldwide has demonstrated the importance of food safety.
- Foodborne diseases have negative consequences for human health in both developed and developing countries.
- Food-related problems affect not only human health but also the economic and social structures of individuals, families, communities, industrial sectors and, ultimately, countries.
- On a global scale, the food trade provides foreign exchange to exporting countries, creates added value in the sector and makes a significant contribution to national income.
- Nevertheless, foodborne risks can cause serious health problems in every layer of society, as well as reduced work efficiency and economic losses.
- Modern food safety systems are based on the “farm to fork” approach, which is an effective way of reducing foodborne hazards.
 - Preventing foodborne hazards requires that every step of the food chain, from raw material to consumption, be examined carefully and that appropriate control measures be applied.

The Farm to Fork Chain



A hazard introduced at any step can travel the whole chain
control measures are therefore needed at every step, not only at the end

Food safety is managed by prerequisite programmes (GAP, GHP, GMP) on which HACCP is built. The chain is only as safe as its weakest link, so responsibility is shared by every actor from the field to the table.

Food Safety

- In recent years, the development of the food industry and the globalisation of the food trade have changed food production and distribution methods.
- Unlike in the past, foods and feed materials are produced by very different methods and can be delivered over very long distances in a very short time.
- In the same way, food-related problems can also spread rapidly to many points of consumption.
 - During the Belgian dioxin crisis of 1999, dioxin-contaminated feed from a single source was distributed to more than 1 500 farms within two weeks. Foods obtained from animals fed with this feed reached other regions, countries and even continents within a few weeks. The health and economic consequences of the dioxin crisis are still discussed today.
- New risks may always arise in the future.
- In developed countries, roughly half of all food expenditure is spent on food eaten outside the home.
 - When it is considered that a single contamination event can spread locally, nationally, regionally or even between continents, the importance of the subject becomes much clearer.
- Given the increase in urbanisation, food safety systems must be applied effectively and legal sanctions must be imposed on establishments that produce, store, distribute and serve food.

Food Safety

- Today the globalisation of the food trade offers consumers safe, high-quality and affordable foods that meet their expectations, and it has greatly increased the variety of foods available.
- Although many countries have made progress in making foods safer, millions of people still become ill every year as a result of consuming contaminated food.
- Consumers are now aware of the pathogenic microorganisms and chemical substances that may be present in the food supply and of the risks they cause.
- Innovations such as genetic engineering, new thermal and packaging technologies, the use of food additives, pesticides and veterinary drugs, and problems such as their residues and mycotoxins make food safety even more important.
- New technologies increase food production and diversity; however, they also raise questions about product safety and consumer acceptance.
- In order to reach sound conclusions, these issues should be evaluated in a participatory and transparent way, using internationally accepted methods.

Food Safety

- Food safety covers all the measures taken to eliminate the physical, chemical and biological hazards that may occur in food. In the narrow sense, safe food is:
 - food that, when prepared as intended, is suitable for consumption in terms of its physical, chemical and microbiological properties and that has not lost its nutritional value.
- A food that is harmful to human health causes abnormal changes when it is eaten, such as producing disease symptoms or aggravating existing disorders.
- All hazards affecting food safety arise from biological, chemical or physical contamination and from malpractice during production.
- For this reason, “food safety” can only be ensured if everyone involved in the food chain fulfils their responsibilities.
- Food safety and quality are managed by implementing food safety and quality assurance programmes (GHP, GMP, HACCP, ISO 22000) in the food industry.

Food Safety

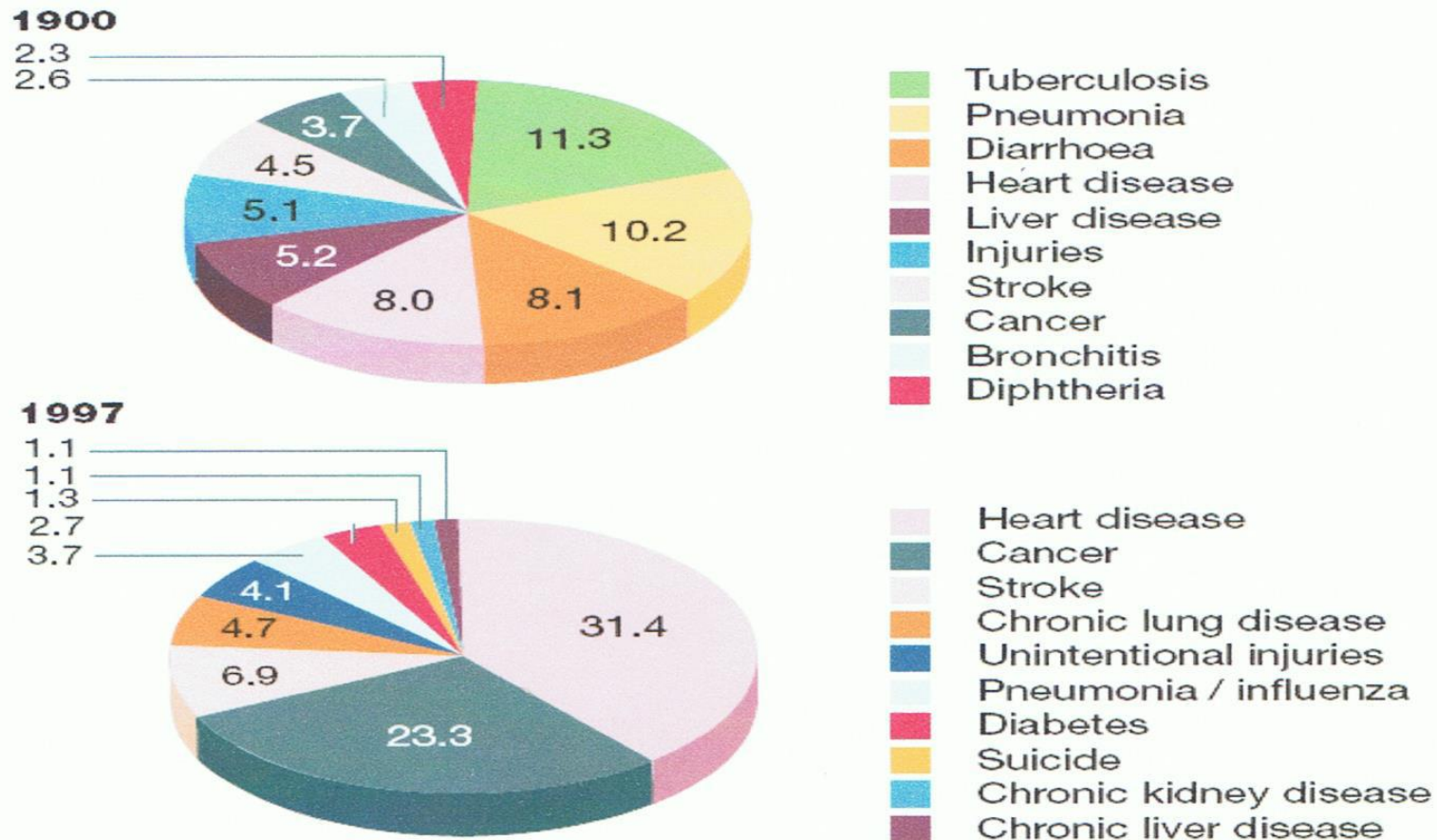


Figure 2 – The ten leading causes of death in the United States in 1900 and 1997. From “Changing Patterns of Infectious Disease”, Mitchell L. Cohen, Nature, Volume 406, 17 August, 2002, pp 762-767.

Hazards in Foods

- The prerequisite for food safety is the use of safe raw materials. Foods must therefore be produced and prepared in establishments that provide, as a minimum, hygienic conditions and adequate technical facilities.
- Food-related hazards are divided into three classes:
 - **Physical hazards** are all kinds of foreign bodies (stone, soil, metal, glass, bone, wood, etc.) that are undesirable in foods, that affect consumer preference and that may cause injury.
 - **Biological hazards** – bacteria, viruses, parasites, moulds and naturally occurring toxins.
 - **Chemical hazards** – pesticide and veterinary drug residues, heavy metals, mineral oils, cleaning agents, process contaminants and allergens.

Hazards in Foods

Biological

Bacteria (*Salmonella*, *Listeria*)
Viruses (norovirus, HAV)
Parasites (*Taenia*,
Toxoplasma)
Moulds and mycotoxins
Natural toxins

Usually the highest risk

Chemical

Pesticide residues
Veterinary drug residues
Heavy metals
Cleaning agents, mineral oils
Process contaminants
Allergens

Often invisible and
cumulative

Physical

Stone, soil, glass
Metal, wood
Bone, shell
Jewellery, hair
Packaging fragments

Cause injury and complaints

All three must be controlled for a food to be safe
identify - assess - control at each step of the process

Hazards in Foods

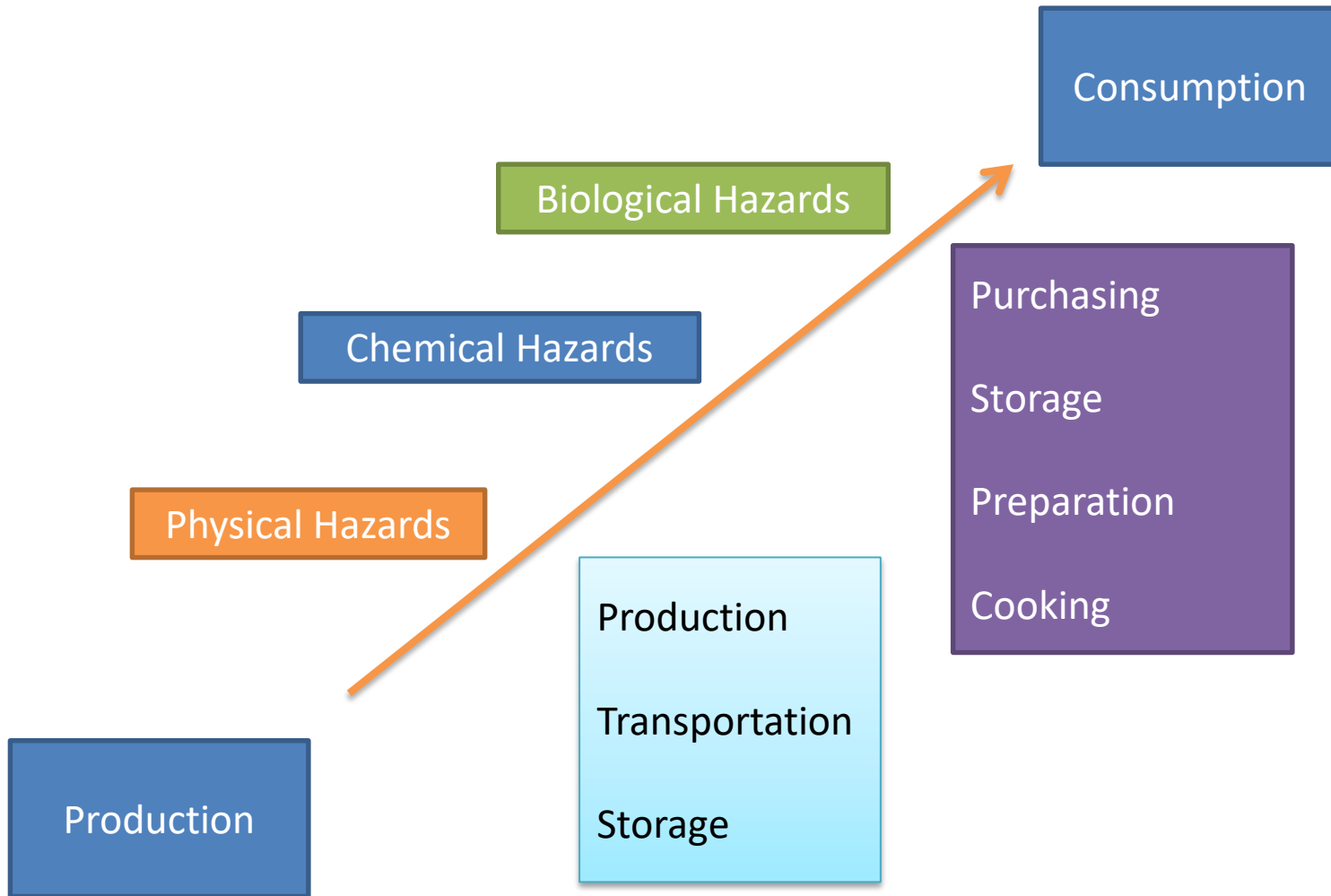
- **MICROBIAL HAZARDS rank first among foodborne risks and vary with many factors. They are important at many stages of production.**
 - Unless they are sterilised, foods naturally contain many microorganisms. When their number exceeds a certain limit, the food becomes unusable because of the changes that occur and it poses a risk to human health.
- The main **CHEMICAL HAZARDS** include residues of veterinary drugs and agricultural pesticides used incorrectly or excessively to increase yield in animal and plant production, chemicals transferred from environmental sources, and hazardous compounds formed during food processing (acrylamide, furan, PAHs, 3-MCPD esters, etc.).
 - Natural toxic components and allergens present in the composition of foods must also be considered within the scope of food safety. In addition, it is very important to ensure that food additives are of food grade, that they are used according to good manufacturing practice and that they are applied at the permitted levels.

Hazards in Foods

- Foods may contain hazards arising from raw materials, production methods and techniques and the hygiene practices of employees, as well as hazards arising from contamination with foreign substances (paint, machine oil, etc.).
- All these potential hazards must be kept under the control of management during production, purchasing, processing, distribution and sale.

Chemical Hazards	Source
Pesticides contamination	Raw material pesticide application
Detergents and disinfectants	Poor rinsing after cleaning
Packaging Chemicals	Chemical used in package film production
Contamination of product with oil	Machine oils used in equipment
Heavy metal contamination	Water, soil, environment
Residual pesticides	Application of pesticides
Nitrate, nitrite, urea	Water

Hazards in Foods



Important Microorganisms in Foods

- Microorganisms are commonly classified according to their morphological characteristics, their taxonomic position and their technological use.
- In food microbiology, a mixed approach that combines all three of these systems is generally used.
 - For example, broad groups such as bacteria, yeasts and moulds;
 - technological or physiological groups such as lactic acid bacteria, gram-positive cocci, spore formers and coliforms;
 - and the scientific binomial nomenclature (order, family, genus and species) are used together.
- According to their importance and their effects on foods and consumers, the microorganisms of interest in food microbiology are divided into three main groups:
 - spoilage microorganisms and microorganisms used technologically,
 - indicator microorganisms,
 - pathogenic and toxigenic microorganisms.

Important Microorganisms in Foods

Spoilage and technological

Psychrotrophs
Lipolytic
Proteolytic
Halophilic
Starter cultures
Probiotics

Indicator

Total viable count
Enterobacteriaceae
Coliforms
Faecal coliforms, *E. coli*
Enterococci
Yeasts and moulds

Pathogenic and toxigenic

Salmonella, *Campylobacter*
Listeria monocytogenes
STEC (O157:H7)
S. aureus, *B. cereus*
C. botulinum, *C. perfringens*
Toxigenic moulds

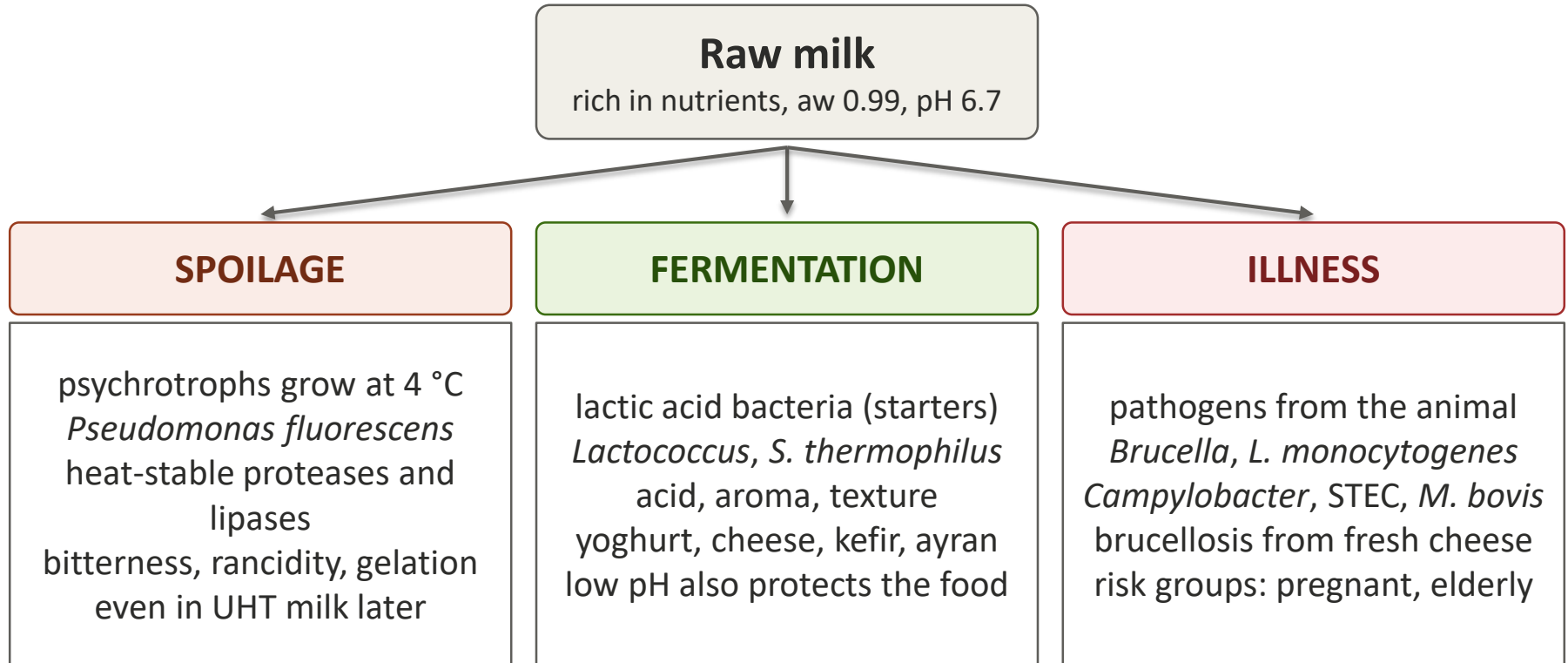
What each group tells us

Determine shelf life and the type of spoilage; some are used deliberately.

Show whether hygiene and processing were adequate; not pathogens themselves.

Cause infection or intoxication; controlled by process and temperature.

One Food, Three Fates: Raw Milk



Which microorganism wins decides the outcome

pasteurisation removes the pathogens and most spoilage flora;
a selected starter then makes sure the right organism takes over

Spoilage and Technologically Important Microorganisms

They are divided into the following groups according to some important characteristics:

1. Microorganisms growing in the cold (psychrotrophs)

- Most of these are in fact mesophilic microorganisms whose optimum growth temperature is 20–30 °C. However, because their generation time at low temperatures is still relatively short, they are able to grow at temperatures of about 7 °C and below, making liquid media turbid within 7–10 days or forming visible colonies on solid media in the same period. Bacteria form the largest part of this group, but yeasts and moulds are also included. For example:
 - Bacteria: *Acinetobacter*, *Aeromonas*, *Alcaligenes*, *Bacillus*, *Brochothrix*, *Chromobacterium*, *Clostridium*, *Flavobacterium*, *Listeria*, *Pseudomonas*, *Psychrobacter*, *Shewanella*, *Vibrio*, *Yersinia*, etc.
 - Yeasts: *Candida*, *Debaryomyces*, *Hanseniaspora* (formerly *Kloeckera*), *Kluyveromyces*, *Rhodotorula*, *Saccharomyces* and *Wickerhamomyces* (formerly *Hansenula*).
 - Moulds: *Botrytis*, *Cladosporium*, *Fusarium*, *Geotrichum* (teleomorph *Galactomyces*), *Penicillium*, *Sporotrichum*, etc.
- Whatever their taxonomic group, microorganisms growing at low temperatures cause spoilage in protein-rich chilled foods such as fish, red and poultry meat, milk and dairy products.

Spoilage and Technologically Important Microorganisms

2. Fat-degrading (lipolytic) microorganisms

- Microorganisms able to produce lipase and thus to hydrolyse fats are included in this group.
- Bacteria, yeasts and moulds are all represented. For example:
 - Bacteria: *Acinetobacter*, *Alcaligenes*, *Brevibacterium*, *Brochothrix*, *Kocuria* (formerly *Micrococcus*), *Pseudomonas*, *Serratia*, *Staphylococcus*, etc.
 - Yeasts: *Candida*, *Rhodotorula*, *Saccharomycopsis*, *Wickerhamomyces* (formerly *Hansenula*), *Yarrowia lipolytica*, etc.
 - Moulds: *Alternaria*, *Aspergillus*, *Cladosporium*, *Fusarium*, *Penicillium*, *Rhizopus*, etc.
- Microorganisms of this group cause spoilage in fat-containing or fat-rich foods such as dairy products, margarine, butter and edible oils.

Spoilage and Technologically Important Microorganisms

3. Protein-degrading (proteolytic) microorganisms

- As the name suggests, this is the group of microorganisms able to hydrolyse proteins.
- Many bacterial genera and species belong to this group, including *Acinetobacter*, *Aeromonas*, *Bacillus*, *Clostridium*, *Corynebacterium*, *Lactobacillus*, *Lactococcus*, *Moraxella*, *Proteus*, *Pseudomonas*, *Serratia* and *Staphylococcus*.
- On the one hand, the representatives of this group cause spoilage by changing the taste and odour of protein-containing foods; on the other hand, they contribute beneficially to the ripening of some cheese varieties and fermented meat products.
- In addition, some species are desirable microorganisms because they are used to produce the proteases employed in the food industry.

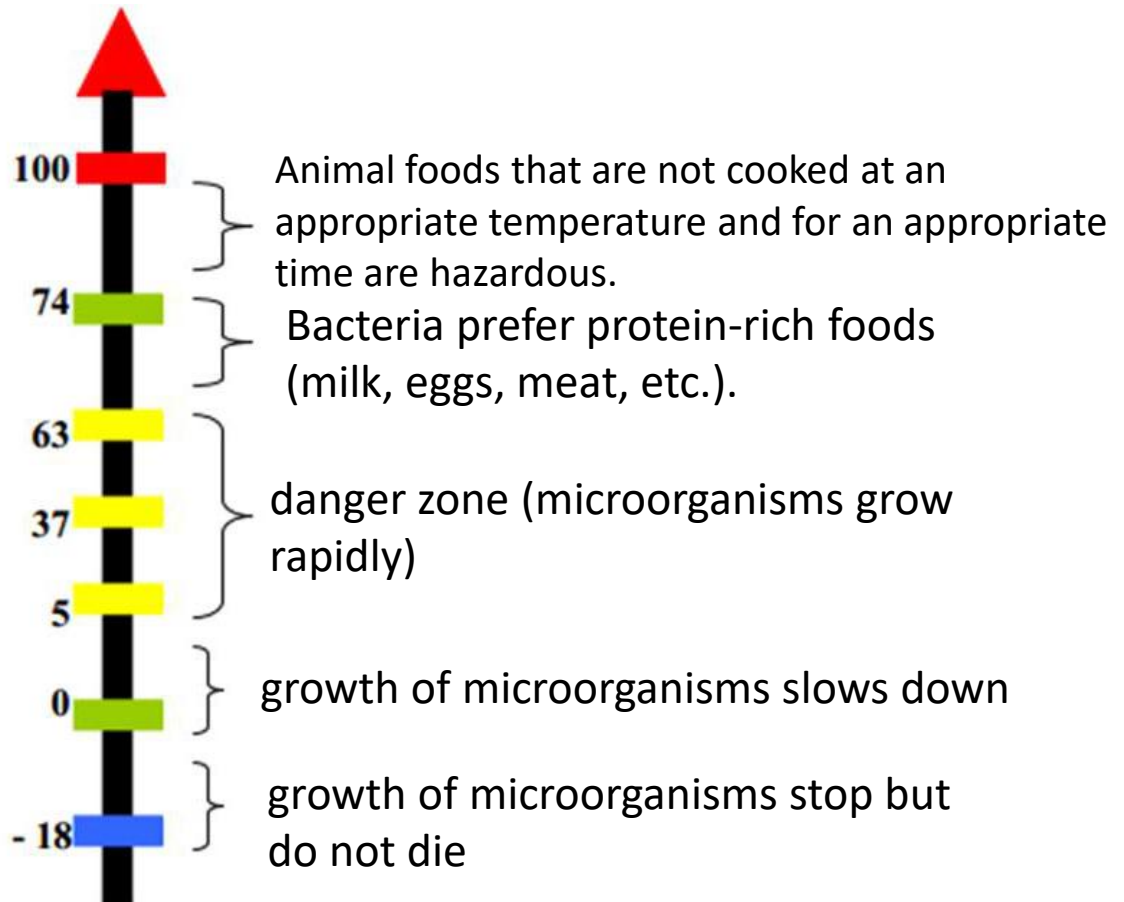
Spoilage and Technologically Important Microorganisms

4. Salt-loving (halophilic) microorganisms

- The microorganisms of this group either require salt for growth or are able to grow at high salt concentrations. For this reason they cause spoilage in foods preserved by salting. Bacteria, yeasts and moulds are all represented in the group.
 - According to the salt concentration at which they can grow, bacteria are divided into three groups: slightly halophilic (2–5% salt), moderately halophilic (5–20% salt) and extremely halophilic (20–30% salt).
 - Among the yeasts, some *Candida*, *Pichia* and *Debaryomyces hansenii* strains, as well as *Zygosaccharomyces rouxii*, can grow in media containing up to about 20–25% salt.
 - Among the moulds there are species that grow in media containing up to 20% salt, for example *Aspergillus halophilicus* and some xerophilic *Wallemia* species.
- The extremely halophilic bacteria of this group are *Halococcus* and *Halobacterium* species, which belong to the domain Archaea. They grow in salted foods such as salted fish and hides and cause colour changes (pink or red discoloration) as well as off-flavours and off-odours.

Microorganism–Temperature Relationship

- Animal foods that are not cooked at the appropriate temperature and time pose a danger.
- Bacteria like foods with protein (milk, eggs, meat, etc.).



FOOD POISONING

INFOGRAPHIC ELEMENTS



SPOILED FOOD

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TREATMENT



LOREM IPSUM

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HOW TO PREVENT



WASH HANDS



FRESH FOOD

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DIZZINESS



NAUSEA



ABDOMINAL CRAMPS



FIVER



HEADACHE



DIARRHEA

WASH FRUITS AND VEGETABLES

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AVOID OUTDATED FOOD

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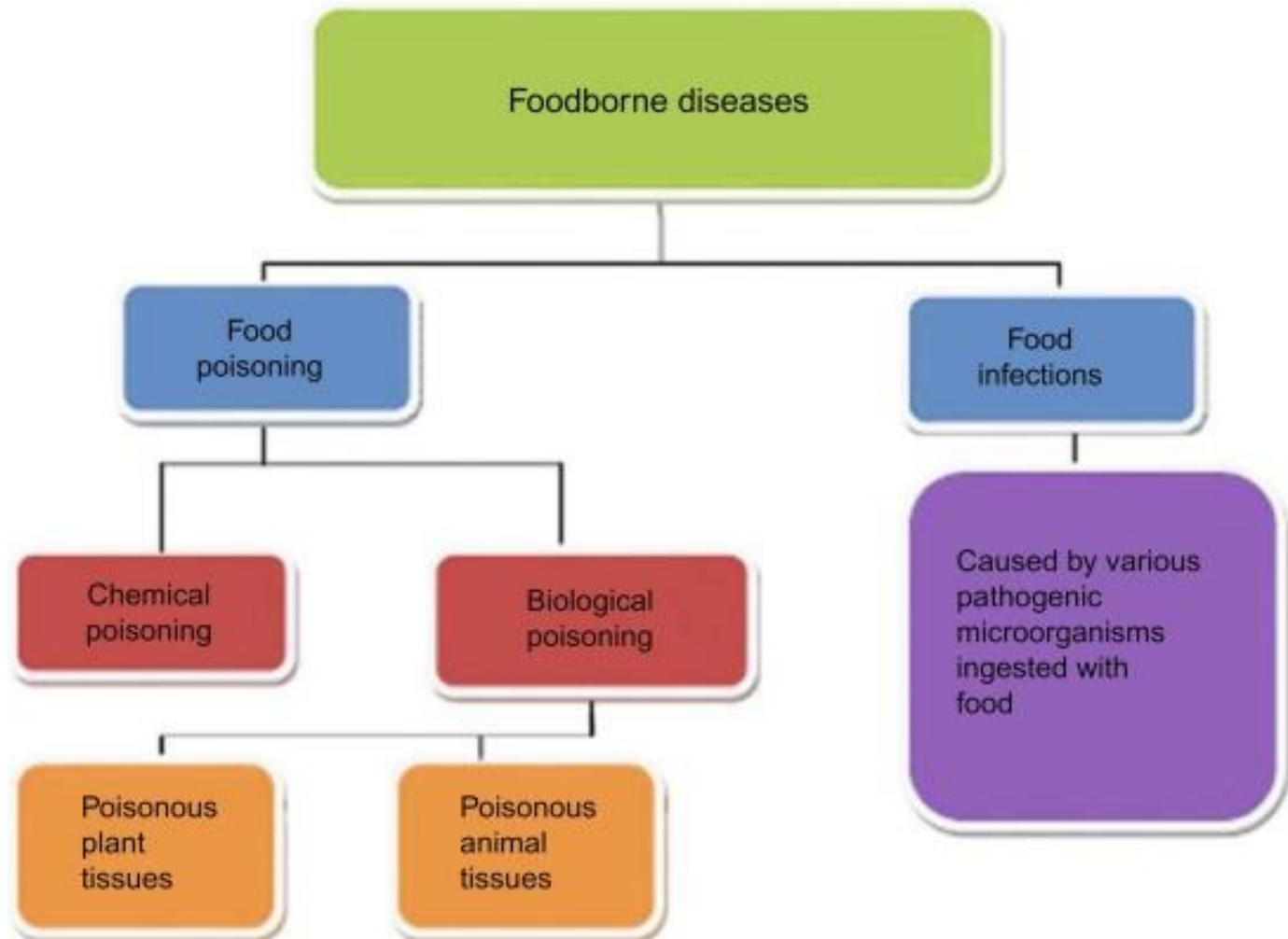
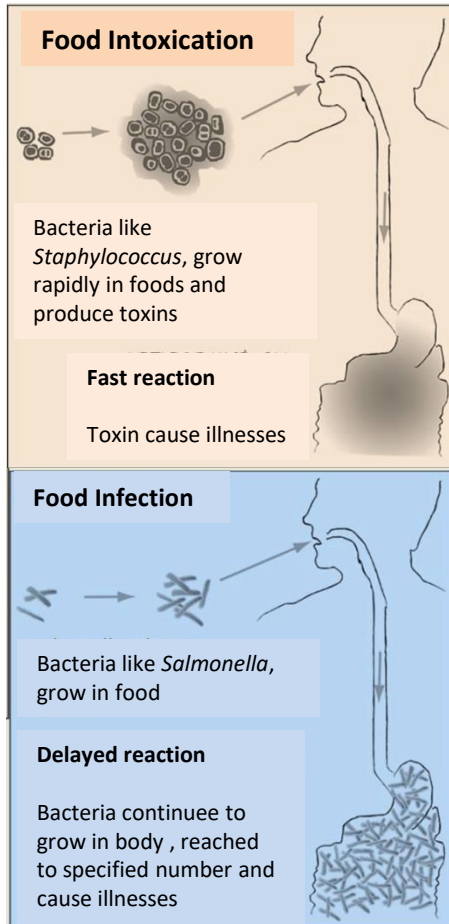
FOOD POISONING

- Food poisoning is an illness caused by eating foods that contain certain microorganisms or their toxins, poisonous animals or plants, or chemical contaminants.
- Foodborne poisonings and infections begin with severe pain in the stomach and intestines after the food has been eaten. The time between eating the food and the appearance of the first symptoms is called the incubation period of the disease.
- Both the incubation period and the severity of the symptoms differ from person to person. In general, the symptoms are nausea, vomiting, abdominal and intestinal cramps and painful diarrhoea. According to their causes, these illnesses can be divided into the following groups:
 - Overeating: eating too much may cause metabolic disturbances.
 - Inadequate eating: taking in smaller amounts of nutrients than required.
 - Food sensitivity: some food components cause allergy or intolerance in susceptible people.
 - Foodborne bacterial infection: pathogens originating from the raw material or from contamination cause illness.
 - Foodborne parasitic infestation: *Taenia* (tapeworm), *Trichinella*, *Toxoplasma*, etc.
 - Food poisoning (intoxication): illness caused by ingesting microbial toxins that are already present in the food.

FOOD POISONING

- Differences in the duration and severity of food poisoning are due to the following factors:
 - the type of microorganism causing the disease;
 - the number of bacteria and the toxin concentration in the food consumed (as the number of cells or the amount of toxin increases, the illness becomes more severe);
 - the susceptibility of the individual (the YOPI group — young children, the elderly, pregnant women and immunocompromised people — is at greater risk).
- Food poisonings are classified according to their origin and cause as follows:
 1. Bacterial food poisoning
 - a. Intoxication type
 - b. Infection type
 - c. Toxicoinfection type
 2. Poisoning caused by toxic animal and plant foods
 3. Poisoning caused by chemical substances

FOOD POISONING



Intoxication, Infection and Toxicoinfection

	Intoxication	Infection	Toxicoinfection
What is eaten	Preformed toxin in the food	Live cells of the pathogen	Live cells that then form toxin
Live cells needed?	No - toxin alone is enough	Yes - must reach infective dose	Yes - cells sporulate in the gut
Incubation period	Short: 1 - 6 hours	Long: 12 - 72 hours	Medium: 8 - 22 hours
Main symptom	Vomiting	Diarrhoea, fever	Diarrhoea, cramps
Example	<i>S. aureus</i> , <i>C. botulinum</i>	<i>Salmonella</i> , <i>Campylobacter</i>	<i>C. perfringens</i> , <i>B. cereus</i>
Effect of reheating	Toxin often survives	Cells are destroyed	Spores survive

FOOD POISONING

- In addition to microbial poisonings, the chemical hazards that pose a danger in foods can be divided into three categories:
 - Chemicals naturally present in the composition of the food, such as the phytohaemagglutinin (lectin) of raw kidney beans, the toxins of poisonous mushrooms and the tetrodotoxin of pufferfish (fugu).
 - Additives that may become hazardous to the consumer because of overdosing or of reactions with other food components, such as sodium nitrite (which may lead to the formation of nitrosamines), colouring agents, preservatives, pesticides and fungicides.
 - Chemicals transferred to the food because of technical errors during sowing, harvesting, transport and/or processing; for example packaging materials containing toxic substances, cleaning agents, metals dissolved from equipment and maintenance materials.

FOODBORNE ILLNESSES



Salmonellosis

Identification - The most common food borne illness caused by many species of bacteria. It causes acute onset of head ache, fever, abdominal pain, diarrhea, nausea with occasional vomiting. Incubation period is 6-72 hours usually between 12-36 hours.

Reservoir - Exists in domestic and wild animals including poultry, pigs, cattle, rodents and pets such as baby chicks and ducklings, truffles, iguanas, dogs and cats.

Transmission - Ingestion of the organism in food obtained from infected animals or contaminated by feces from infected animals or peoples. Epidemics are traced to contaminated vegetables and fruit, eggs, processed meat, undercooked poultry products, raw milk and dairy products and foods prepared by infected food personnel.



Campylobacter Enteritis

Identification - An enteric disease caused by Campylobacter jejuni or C. coli accompanied by malaise, diarrhea, bloody stools, abdominal pain, fever, nausea, and vomiting. Symptoms may occur 2-5 days after exposure and persist for a week.

Reservoir - Poultry, cattle and other animals such as puppies, kitten, other pets, swine, sheep, rodents and birds. Most raw poultry is contaminated with

Campylobacter. **Transmission** - Ingestion of the organisms in undercooked meat, contaminated water and food, raw milk, farm animals, pets, infective dose is low. Person to person transmission is possible but not common.



Listeriosis

Identification - A disease which causes meningitis and/or septicemia in newborns and adults that is caused by L. monocytogenes. In pregnant women it causes fever and miscarriage or stillbirths. An asymptomatic woman can transmit the disease to the fetus. High risk populations include neonates, elderly, immunocompromised, pregnant women, alcoholics, diabetics.

Reservoir - Soil, silage, forage, and water. Animal reservoirs include infected wild and domestic animals. Up to 10% of the healthy people have L. monocytogenes in their feces but do not have symptoms.

Transmission - Ingestion of contaminated foods such as soft cheeses, raw milk, vegetables, ready to eat meats and pates. In neonatal infections, the bacteria is transmitted by the mother in utero or from passage through the birth canal.



Staphylococcal Food Intoxication

Identification - It is not an infection but is caused by the enterotoxins produced by Staphylococcus aureus. The disease is characterized by abrupt (30 minutes to 4 hours) and violent onset of vomiting, severe nausea, cramps, and prostration. Illness lasts a day or two. These enterotoxins are resistant to boiling or thermal processing.

Reservoir - Humans. About 25% of the population carries this bacteria. Occasionally cows with infected udders, dogs and fowl.

Transmission - Ingestion of food containing the enterotoxin. The food becomes contaminated first with the bacteria via the food handlers' hands. At room temperature, the bacteria multiply and produce the enterotoxin. Can be found in improperly handled or stored salad dressings, custards, sliced meat, meat products, meat sandwiches, unprocessed cheese.



E Coli O157:H7

Identification - Causes acute diarrhea with no fever. Incubation period is 2 to 10 days, most commonly 3-4 days. Diarrhea may be mild to severe with no blood or almost entirely blood. About 8% of people having diarrhea caused by this organism progress to hemolytic uremic syndrome (HUS). Infectious dose is very low. Children under 5 are at greatest risk for developing HUS.

Reservoir - Cattle are the primary reservoir although it is also found in deer. Humans can serve as the reservoir for

person to person transmission. **Transmission** - Fecal/oral or the ingestion of food contaminated with ruminant feces. Serious outbreaks have been associated with petting zoos, beef, hamburger, melons, spinach, lettuce, salmons, apple cider, alfalfa sprouts, and unpasteurized milk. Person to person transmission occurs in families, custodial care facilities, and day care centers. Water borne transmission comes from drinking and recreational water

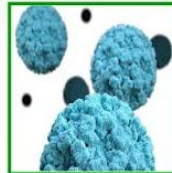


Giardiasis

Identification - A protozoan infection that may be either asymptomatic, cause acute self-limiting diarrhea, or chronic, frequent diarrhea with cramps, bloating and incomplete absorption of fats and vitamins eventually leading to fatigue and weight loss. In severe giardiasis there may be reactive arthritis and damage to the duodenal and jejunal mucosal cells. Median incubation is 7-10 days.

Reservoir - Humans and possibly beavers and other wild and domesticated animals.

Transmission - Localized outbreaks occur from the ingestion of food and water contaminated with protozoan cysts. Typical chlorination of drinking water is not enough to destroy the cysts. Unfiltered, contaminated recreational water can be a source. Person to person transmission occurs from transfer of cysts from infected people particularly in day care centers and institutions.



Norovirus

Identification - A viral infection that causes mild to moderate gastrointestinal illness with nausea, vomiting, diarrhea, abdominal pain, headache, malaise, and low grade fever. Usually lasts for 1-3 days.

Reservoir - Humans are the only known reservoir.

Transmission - Fecal/oral through ingestion of contaminated food, water or shell fish. Also contact with infected fomites.

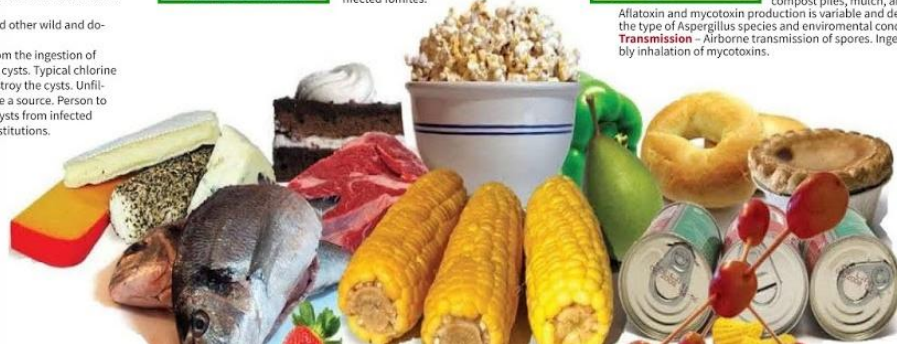


Aflatoxin Intoxication

Identification - Liver cancer caused by food contaminated with certain species of Aspergillus fungi. As the fungi grow, they produce aflatoxins and other mycotoxins that contaminate the food. Incubation period for fungal growth may be 2 days to 3 months.

Reservoir - Aspergillus fungal species are ubiquitous and exist worldwide particularly in decaying plant material, compost piles, mulch, and leaf piles.

Aflatoxin and mycotoxin production is variable and depends upon the type of Aspergillus species and environmental conditions. **Transmission** - Airborne transmission of spores. Ingestion and possibly inhalation of mycotoxins.



Microbial Hazards

- The hazards caused by foodborne pathogenic microorganisms have been known for many years.
 - The risks of milk-borne tuberculosis and salmonellosis were recognised at the beginning of the twentieth century, and these products were brought under control by pasteurisation;
 - botulism in hermetically sealed low-acid canned foods was controlled by applying a heat process above 100 °C (the botulinum cook, $F_0 \geq 3$ min at 121 °C).
- Despite the progress made in food science and technology, foodborne diseases and deaths are still reported in all countries, and the trend for some microbial pathogens continues to increase.
- Food safety problems cause preventable illness and death as well as heavy economic losses.
- According to the WHO estimates published in June 2026 (covering the period 2000–2021), unsafe food causes about 866 million illnesses and 1.5 million deaths worldwide every year.
 - Although children under five years of age make up only 9% of the world population, they account for almost one third of all foodborne illnesses.
 - The African and South-East Asian regions together account for nearly three quarters of all foodborne illnesses and for 60% of the related deaths.

Global Burden of Foodborne Disease

WHO estimates published in June 2026, covering the period 2000 - 2021

866

million illnesses
every year worldwide

1.5

million deaths
every year worldwide

1 in 3

cases in under-5s
though they are only 9% of
people

310

billion US\$ lost
productivity in 2021 alone

Where the illness is

Africa and South-East Asia together account for almost three quarters of all foodborne illnesses and 60% of the related deaths.

What causes the deaths

Biological hazards cause most of the illnesses, but chemical hazards caused 73% of the deaths in 2021 - mainly arsenic (42%) and lead (31%).

These figures supersede the earlier estimate of 600 million illnesses and 420 000 deaths published in 2015. The total burden has fallen since 2000, but regional inequalities have not.

Microbial Hazards

- The economic cost of foodborne illness caused by microbial and chemical hazards is very high:
 - WHO estimates that foodborne diseases caused about US\$ 310 billion of lost productivity in 2021; when adjusted for differences in the cost of living between countries, this figure rises to about US\$ 647 billion.
 - According to the World Bank, unsafe food costs low- and middle-income economies about US\$ 110 billion per year in lost productivity and medical expenses.
 - In the United States, the Economic Research Service of the USDA estimates the annual cost of the 15 leading foodborne pathogens at more than US\$ 17 billion.
 - The US Centers for Disease Control and Prevention (CDC) estimates that foodborne pathogens cause about 48 million illnesses, 128 000 hospitalisations and 3 000 deaths each year in the USA alone.
- Outbreaks caused by organisms such as Shiga toxin-producing *Escherichia coli* (STEC), *Salmonella* and *Listeria monocytogenes* create serious food safety problems and consumer concern.
- Although the ecology of the organisms that cause food poisoning is largely known, their control cannot always be fully achieved.
 - Inadequate or incorrect production techniques, the difficulty of controlling hazards in agricultural production and processing, and the fact that foods are excellent growth media for microorganisms all contribute to this situation.
 - Problems caused by microorganisms show an increasing trend, and antimicrobial resistance among foodborne pathogens is also increasing.

Microbial Hazards

- Over the past few decades many microorganisms have been recognised as potential causes of foodborne illness.
 - For example, *Listeria monocytogenes*, *Clostridium perfringens*, *Campylobacter jejuni*, *Vibrio parahaemolyticus*, *Yersinia enterocolitica*, Shiga toxin-producing *Escherichia coli* (STEC, e.g. O157:H7), *Cronobacter sakazakii* (formerly *Enterobacter sakazakii*) and norovirus have been identified as agents of foodborne disease.
- Changes in food production, processing, preparation, storage and packaging have both changed the hazards relevant to food safety and created new ways in which they emerge.
 - For example, *Listeria monocytogenes* and *Clostridium botulinum* have become important because of changes in processed and packaged (chilled, vacuum- and modified-atmosphere packed) foods.
- The effective prevention and control of such microorganisms requires the application of GAP at the primary production stage and the implementation of GHP, GMP and HACCP systems during food processing, supported by whole-genome sequencing-based surveillance.

Microbial Hazards

- Mycotoxins are toxic, carcinogenic, mutagenic and teratogenic secondary metabolites produced by certain moulds.
- The most important mycotoxins are the aflatoxins, ochratoxin A, fumonisins, patulin, zearalenone and the trichothecenes (deoxynivalenol, T-2 toxin).
- Nuts and dried fruits such as hazelnuts, pistachios, peanuts, walnuts, almonds and dried figs, as well as maize and other cereals, red pepper and spices, are susceptible to mycotoxin contamination.
- The aflatoxins are the most intensively studied mycotoxins; aflatoxin B₁ is classified by IARC in Group 1 (carcinogenic to humans) and its relationship with liver cancer has been clearly demonstrated.
- Almost all products of plant origin are good substrates for fungal growth, which may be followed by mycotoxin contamination of raw materials intended for food and feed use.
- It is well known that aflatoxin B₁ ingested with contaminated feed is metabolised by dairy animals and excreted into milk as aflatoxin M₁.

The Major Mycotoxins

Mycotoxin	Produced by	Foods at risk	Main health effect
Aflatoxin B1, M1	<i>A. flavus</i> , <i>A. parasiticus</i>	Nuts, maize, dried figs, milk	Liver cancer - IARC group 1
Ochratoxin A	<i>A. ochraceus</i> , <i>P. verrucosum</i>	Cereals, coffee, wine, raisins	Kidney damage, carcinogenic
Fumonisin	<i>F. verticillioides</i>	Maize and maize products	Oesophageal cancer, neural defects
Deoxynivalenol	<i>F. graminearum</i>	Wheat, barley, maize	Vomiting, immune suppression
Zearalenone	<i>F. graminearum</i>	Maize, wheat	Oestrogenic effects
Patulin	<i>P. expansum</i>	Apples and apple juice	Gastrointestinal damage

Mycotoxins are heat-stable and are not destroyed by normal cooking or pasteurisation, so control must be preventive: drying, correct storage and sorting of the raw material.

Food Microbiology

Food microbiology deals mainly with the microbiological quality of foods and with the control of microorganisms in foods.

- New technologies used in food production, processing, distribution, storage and consumption constantly introduce new problems.
- These problems cannot be solved with existing microbiological knowledge alone.
 - Food microbiology studies these problems and develops effective solutions to them.

Food Microbiology

- Knowledge of food microbiology should include:
 - food spoilage;
 - foodborne diseases;
 - the effective control of microorganisms;
 - the bioprocessing (fermentation) of foods;
 - the fundamentals of microbial physiology,
 - metabolism and genetics;
 - the development of rapid and effective methods for detecting spoilage and pathogenic microorganisms;
 - the development of desirable microbial strains for food production;
 - the production of fermented foods of better quality;
 - the production of enzymes and food additives;
 - the development of methods for removing bacteria and biofilms from foods and equipment surfaces;
 - the development of methods for the effective control of spoilage and pathogenic microorganisms in foods.

Food Microbiology

A student who has completed a course in food microbiology (both lectures and laboratory) should be able to:

- determine the microbiological quality of foods;
- evaluate the use of ingredients in food production;
- identify the sources of microorganisms contaminating foods;
- determine the microbial groups involved in spoilage and in foodborne disease;
- design correct procedures to control spoilage and pathogenic microorganisms in foods;
- apply new techniques in food processing;
- apply this knowledge to overcome new problems;
- design effective sanitation procedures for the control of spoilage and pathogen problems in food processing areas;
- use desirable microorganisms in the production of fermented foods;
- design methods for producing better starter and probiotic cultures for fermented foods;
- apply national and international food regulations and standards.