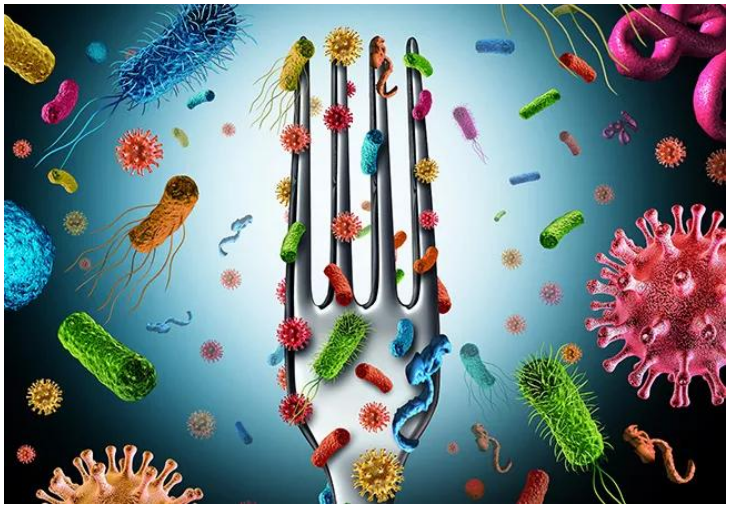
FE 305 FOOD MICROBIOLOGY
Foodborne Disease

Dr. Hüseyin BOZKURT

Foodborne Disease

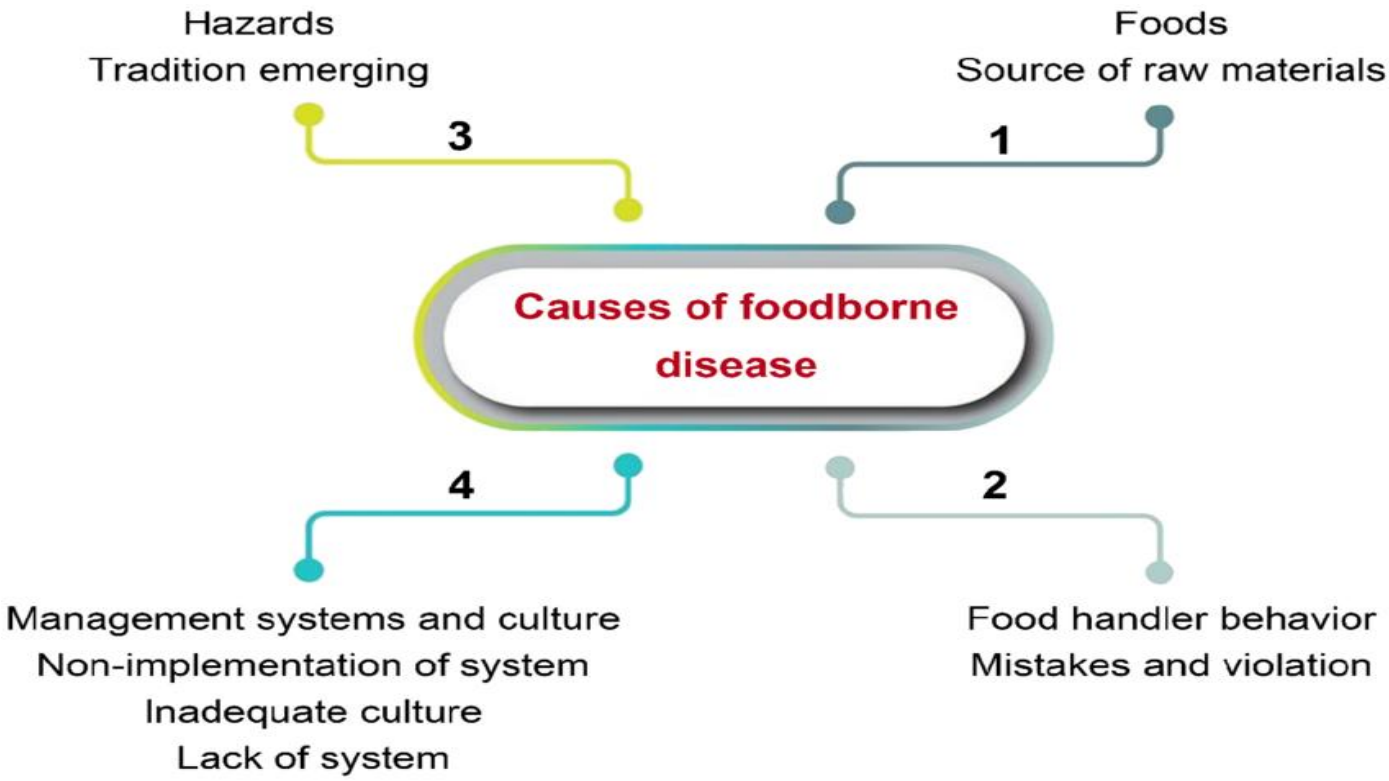
- The World Health Organization (WHO) defines foodborne disease as “a disease of an infectious or toxic nature caused by, or thought to be caused by, the consumption of food or water”.
- More than 250 foodborne diseases are known; they are caused by a wide range of bacteria, viruses, parasites, toxins, metals and prions.
- A foodborne disease outbreak is defined as the occurrence of a similar illness in two or more people after the ingestion of the same food or water containing a pathogen or its toxin.
- Foodborne diseases are among the most widespread health problems in the world.





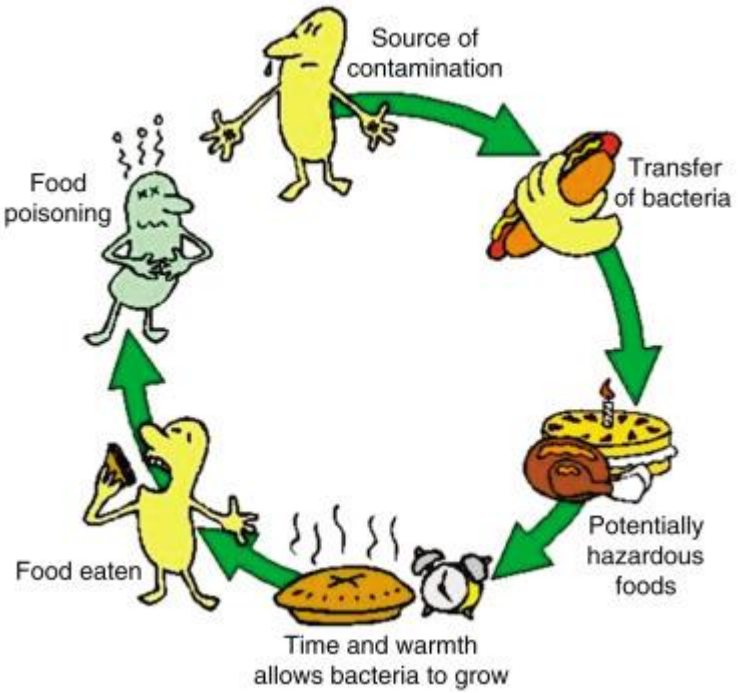
Foodborne Disease

- Foodborne diseases are caused
  - by the ingestion, with food, of pathogenic bacteria, viruses, parasites or fungi, or of the exotoxins and endotoxins they produce, whether these are present in the food from the start or contaminate it later;
  - or by the consumption of foods that contain naturally toxic substances or that have been contaminated with toxic substances.



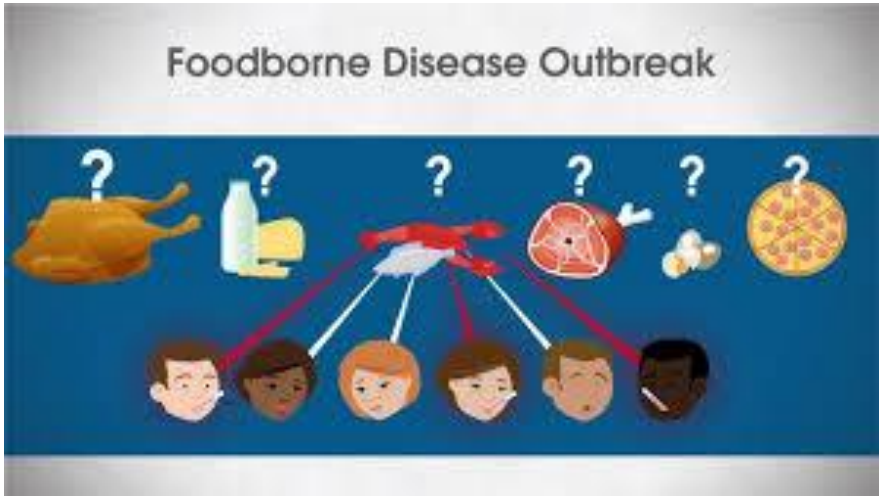
Foodborne Disease

- Although viruses (above all norovirus) cause most foodborne illnesses, most hospitalisations and deaths are caused by bacteria.
- According to the current CDC estimates, foodborne pathogens cause about 48 million illnesses in the USA each year,
  - with about 128 000 hospitalisations and 3 000 deaths.
- The USDA Economic Research Service estimates the annual cost of the 15 leading foodborne pathogens in the USA at more than US$ 17 billion.
- Illness is caused either by a toxin produced by the microorganism or by the reaction of the body to the microorganism itself.
  - The clinical picture ranges from mild gastroenteritis
  - to life-threatening neurological, hepatic and renal syndromes.



Foodborne Disease

- According to the WHO estimates published in June 2026, unsafe food causes about 866 million illnesses and 1.5 million deaths worldwide every year; children under five bear almost one third of these illnesses.
- Foodborne diseases are a public health problem that causes significant economic losses and reduces quality of life, in Türkiye as well as throughout the world.
- Because only a small fraction of cases are reported to the authorities, the true incidence is much higher than the recorded figures; national surveillance and whole-genome sequencing are improving the picture.



Foodborne Disease

Foodborne disease results from:

- the transmission by food of microorganisms that can cause disease,
  - such as botulism, dysentery, salmonellosis, campylobacteriosis, hepatitis A, listeriosis and staphylococcal food poisoning;
- the presence of toxic chemicals in foods, which may be
  - natural (e.g. cyanogenic glycosides in cassava), or
  - contaminants (e.g. toxic heavy metals, sanitisers, pesticides);
- the presence of physical agents in foods, such as glass splinters.

Foodborne Disease

- Diseases caused by the consumption of a food containing a pathogenic microorganism or its toxin are called foodborne microbial diseases.
- Foodborne microbial diseases are examined in three groups:
  - food infections,
  - food intoxications,
  - food toxicoinfections.

Foodborne Disease

- If the cause of the disease is the pathogen cell itself, the disease is called a foodborne infection.
- If the cause is a toxin secreted by the pathogen into the food, the disease is called a foodborne intoxication.
- If the food is only a carrier and the microorganism cannot multiply in it, the infection is called a passive foodborne infection (e.g. viruses, *Shigella*).
- If the pathogen multiplies in the food and the disease follows the ingestion of a sufficient number of cells, the infection is called an active foodborne infection (e.g. *Salmonella*).
- Intoxication results from the ingestion of toxins produced in the food by pathogenic bacteria or moulds.
  - The toxin must be present in the food in its active form.
  - Living cells are not required: the toxin formed in the food is sufficient to cause the disease.
  - Staphylococcal food poisoning is the most typical example of this group.

How Foodborne Microbial Diseases Arise

Pathogen in the food
click to follow each route

INTOXICATION	INFECTION	TOXICOINFECTION
grows in the food produces toxin in the food toxin is eaten live cells not needed onset 1 - 6 h, vomiting	live cells are eaten survive stomach acid attach and multiply in gut may invade tissue onset 12 - 72 h, diarrhoea, fever	many live cells are eaten sporulate or die in the gut release toxin there no tissue invasion onset 8 - 22 h, diarrhoea, cramps
S. aureus, *C. botulinum*, *B. cereus* (emetic)	*Salmonella*, *Campylobacter*, STEC, norovirus	*C. perfringens*, *B. cereus* (diarrhoeal), ETEC

Key question: where is the toxin made?
in the food = intoxication | by cells in the gut = infection or toxicoinfection

Foodborne Disease

- Food poisoning occurs in every country of the world and causes both health and economic problems.
- The most common contributing factors are:
  - poor general hygiene;
  - infected food handlers;
  - storage at ambient temperature;
  - consumption of raw foods;
  - use of contaminated ingredients;
  - contamination by infected persons;
  - cross-contamination;
  - use of contaminated equipment;
  - processing failures;
  - undercooking;
  - inadequate hot holding;
  - excessively long storage;
  - contamination during final preparation;
  - preparation of very large quantities of food;
  - use of leftovers;
  - inadequate reheating before reuse;
  - inadequate thawing.

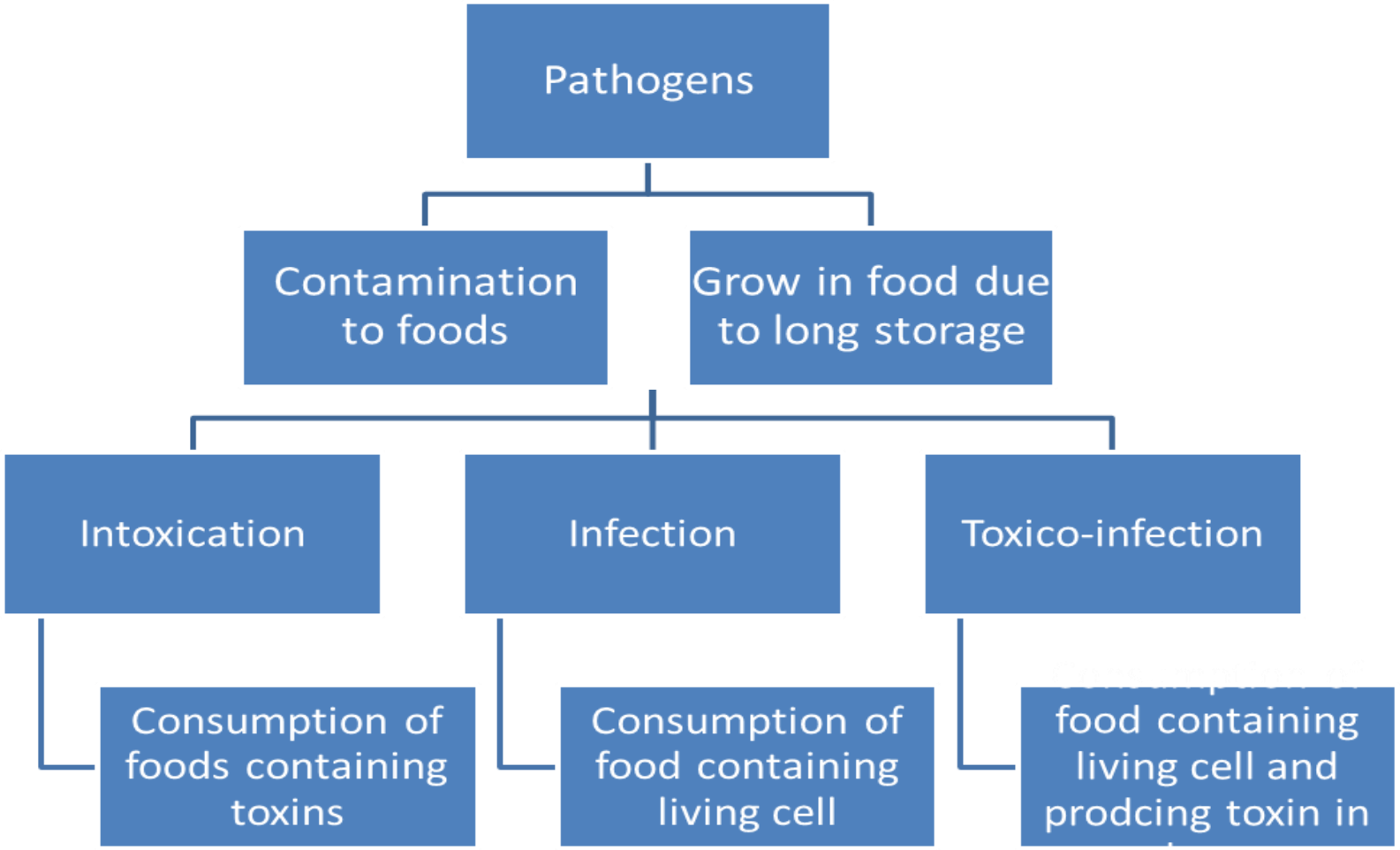
The Five Main Causes of Outbreaks

The US CDC and FDA identify five major risk factors behind outbreaks:

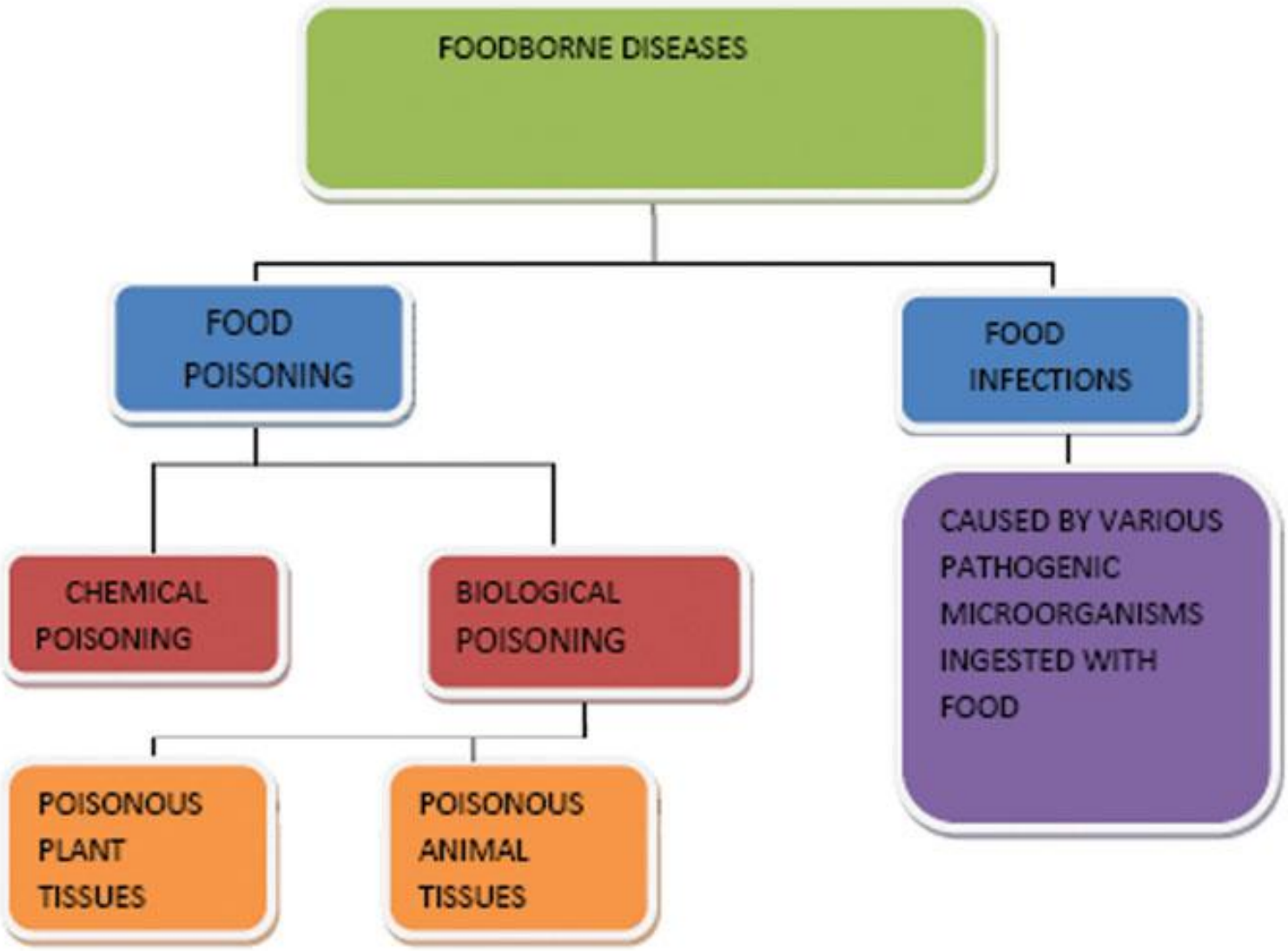
1	**Improper holding temperature**	slow cooling, food left at room temperature, hot holding below 63 °C
2	**Inadequate cooking**	core temperature not reached - especially poultry, eggs, minced meat
3	**Contaminated equipment**	cross-contamination from raw to cooked via boards, knives, slicers
4	**Food from unsafe sources**	raw shellfish, raw milk, unapproved suppliers, contaminated water
5	**Poor personal hygiene**	infected handlers, no hand washing - the main route for norovirus

Most outbreaks involve more than one of these factors at the same time

Foodborne Disease



Foodborne Disease Classification



Common Associations of Foodborne Pathogens

Epidemiology	Pathogens
Travel to a developing region	- Enterotoxigenic *E. coli* (ETEC) - *Salmonella* (e.g. *S.* Typhi) - *Shigella* (e.g. *S. dysenteriae*) - *Campylobacter* - *Entamoeba histolytica*
Consumption of raw or undercooked foods of animal origin	- *Salmonella* (e.g. undercooked eggs, meat, chicken) - *Campylobacter* (e.g. undercooked chicken, raw milk) - STEC O157:H7 (e.g. undercooked beef, hamburgers) - *Toxoplasma gondii* (e.g. undercooked pork and lamb) - *Trichinella spiralis* (e.g. undercooked pork, game) - *Yersinia enterocolitica* (e.g. undercooked pork, milk)
Exposure to untreated water	- *Shigella* (e.g. lakes contaminated with human faeces) - STEC O157:H7 (e.g. lakes contaminated with faeces) - *Cryptosporidium* (e.g. faecally contaminated water, including swimming pools; the oocysts are resistant to chlorine) - *Giardia* (e.g. faecally contaminated water)

Types of Food Poisoning

Types of Food Poisoning



Food poisoning comes from many sources, including bacteria, viruses, and fungi.



Listeria
fresh milk, unwashed produce



E. coli
fecal contamination



Campylobacter
undercooking, unhygienic kitchen



Salmonella
undercooking, poor hygiene



Staphylococcus
unrefrigerated food



Ciguatera
coral algae toxin



Shigella
human waste contamination



Botulism
damaged cans

Invasive Infections

- This type of foodborne disease results from
  - the ingestion of viable bacterial cells in sufficient numbers with the food,
  - their survival through the acidity of the stomach, and
  - their multiplication and colonisation in the intestinal lumen.
- The pathogen attaches to and colonises the epithelial surface,
  - which prevents it from being washed away by the rapid flow of the intestinal contents.
- Attachment is achieved by adhesins,
- and the fimbriae on the bacterial cell surface recognise and bind to specific receptor sites on the microvilli.

Invasive Infections

- Invasive infection is the intestinal inflammation caused when pathogenic microorganisms ingested with food spread into the intestinal tissue.
- Live microorganisms taken in with the food survive the acid of the stomach, enter the intestinal epithelial cells, multiply there and produce toxins.
- The number of living cells needed to cause the disease (the infective dose) varies with the species and the strain.
- As the epithelial cells are lysed, toxins are released into the intestinal lumen and the live microorganisms spread to neighbouring epithelial cells.
- In some cases the bacteria cross the intestinal barrier and spread to the lymph nodes, liver, brain and other organs, causing non-enteric (systemic) disease.

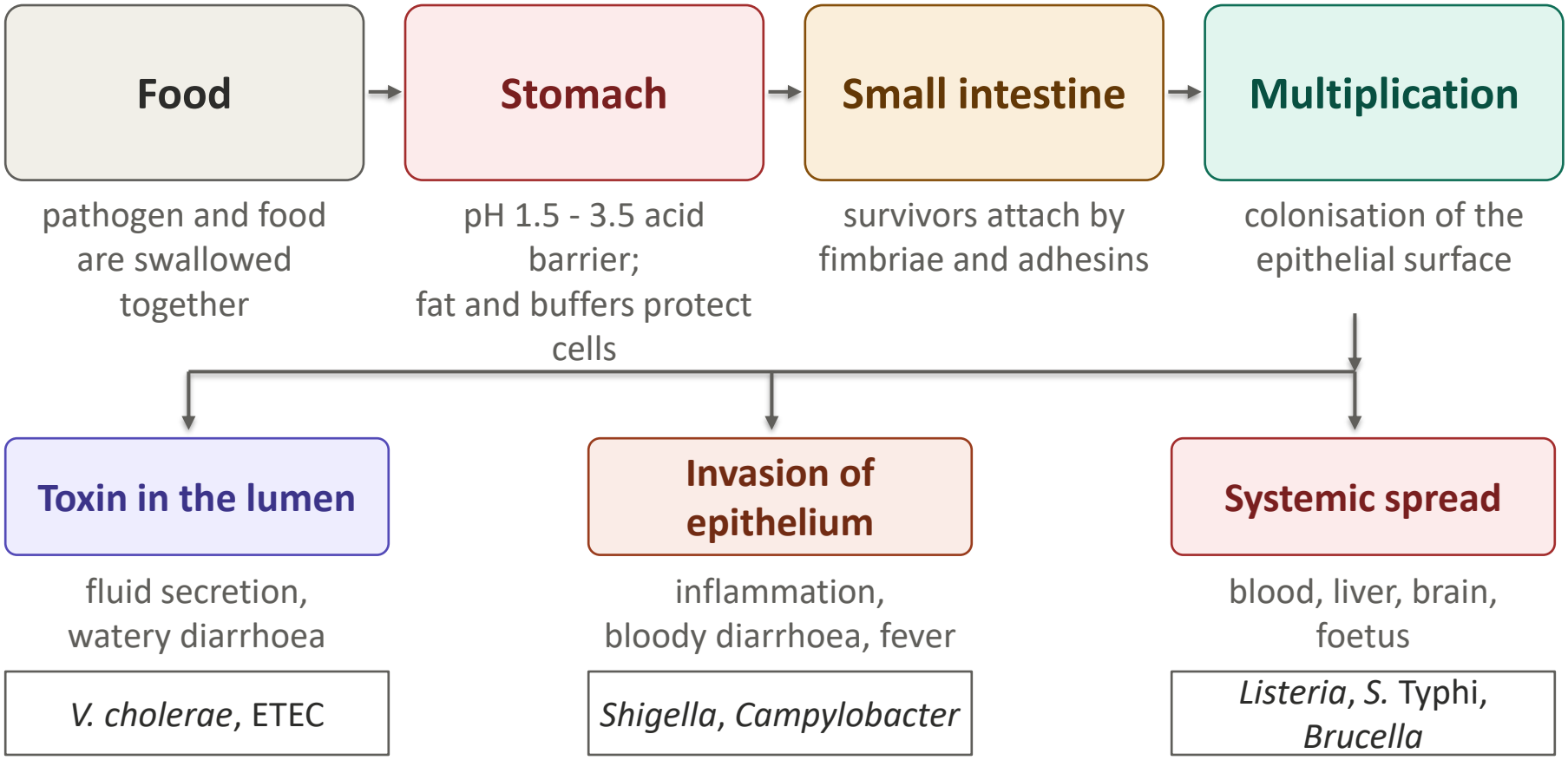
Invasive Infections

- Loss of the ability
  - to adhere to the intestinal wall
    - reduces the virulence of a pathogen and
  - its ability to cause illness.
- Once attached, the bacterial cells can multiply and produce a protein enterotoxin in the intestinal tract.
- The enterotoxin changes the flow of electrolytes and water across the mucosa into the intestinal lumen.
- *Vibrio parahaemolyticus*, *Vibrio vulnificus*, *Salmonella*, enteroinvasive *E. coli*, Shiga toxin-producing *E. coli*, *Campylobacter*, *Yersinia*, *Listeria*, *Shigella*, *Brucella* and enteric viruses are examples of agents of invasive infection.

Invasive Infections

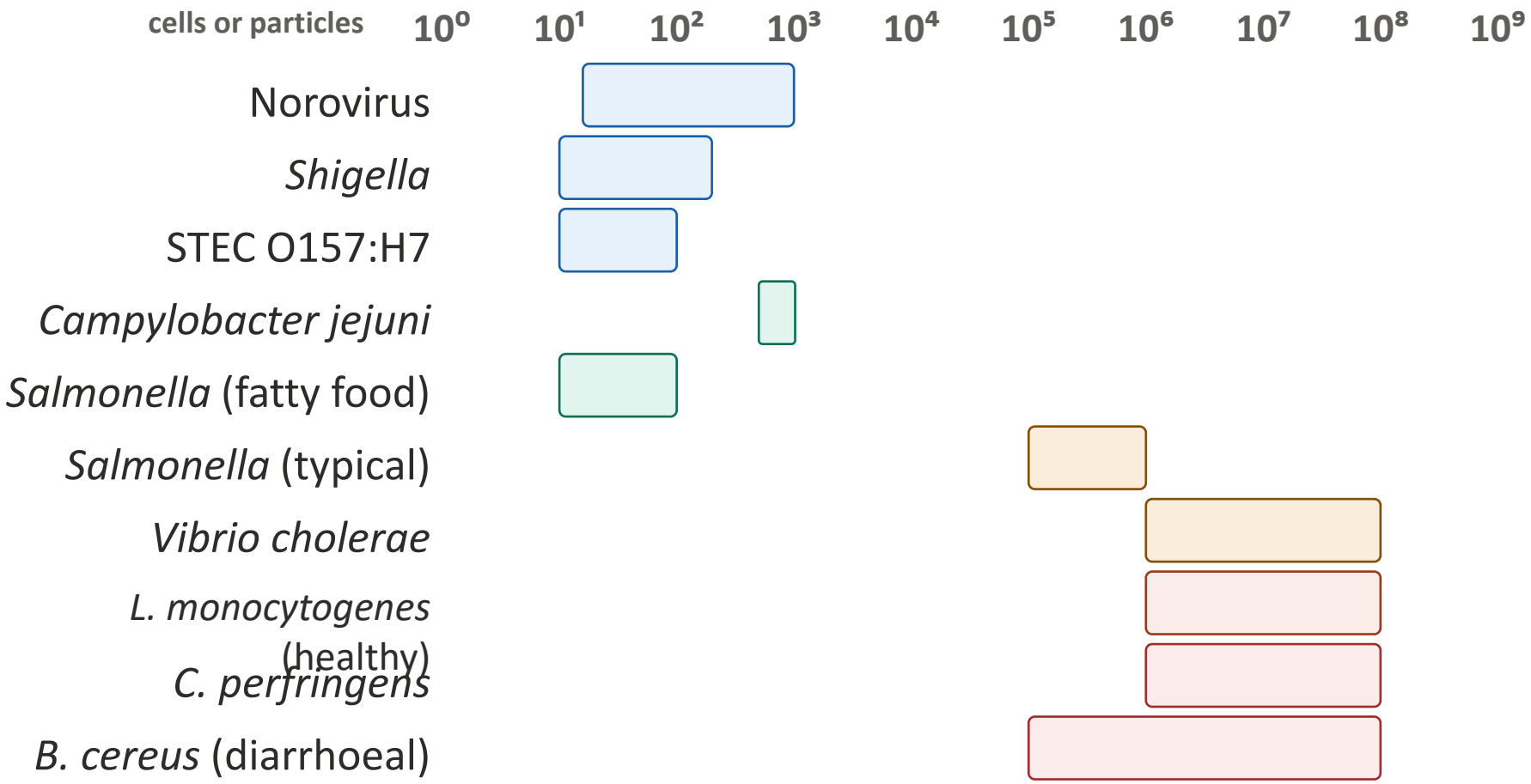
- The infective dose differs greatly between pathogens: 10–100 cells are enough for *Shigella* and STEC O157:H7, whereas most *Salmonella* serovars need 10^3–10^5 and *V. parahaemolyticus* 10^5–10^7 cells.
  - this allows enough cells to pass through the acid barrier of the stomach and reach the intestine.
- However, infection may also result from a low dose
  - if the food protects the pathogen during its passage through the stomach,
    - for example if it is high in fat or has a high buffering capacity.
  - Outbreaks of salmonellosis have been caused by foods such as chocolate and cheese containing 100 *Salmonella* cells per gram or fewer. For *Shigella*, STEC and norovirus, as few as 10–100 cells or particles may be enough.

The Journey of a Pathogen Through the Body



At every stage most of the ingested cells are lost - which is why the infective dose of many pathogens is high, and why a fatty or buffering food can lower it.

Infective Doses of Foodborne Pathogens



A low infective dose means that even a lightly contaminated food, or a single infected handler, can cause an outbreak. Values are approximate and vary with strain, food and host.

Infection

- Infection-type disease results from the ingestion of the vegetative cells of pathogenic bacteria, or of viruses, with food or water.
- Living cells must be present in the food at the time of consumption.
- Even when present in low numbers, they can settle in the intestine, multiply under suitable conditions and cause disease.
  - Salmonellosis, shigellosis, infection with Shiga toxin-producing *E. coli* (STEC/EHEC), norovirus gastroenteritis and hepatitis A are examples of this group.

Toxicoinfections

- In this type of disease, too, the causative agent is a pathogenic microorganism.
- Unlike in invasive infections, however, the symptoms
  - are caused by toxins released in the intestine: either large numbers of spore-forming bacteria ingested with the food sporulate in the intestine and release their toxin, or the ingested cells multiply in the intestine, die in large numbers and release toxins on lysis.

Toxicoinfections

- This type of foodborne disease results from the ingestion of large numbers of viable bacteria with food or water.
  - The cells must survive the stomach and reach the intestine.
  - In the intestine the cells multiply and die, but they do not invade the epithelial cells.
  - Spore-forming bacteria sporulate in the intestine and then lyse;
    - in doing so they release toxins that produce the symptoms.
    - The toxins cause fluid secretion and diarrhoea.
- Common symptoms are diarrhoea and abdominal cramps, sometimes with fever.
- Enterotoxigenic *E. coli*, *Bacillus cereus* (diarrhoeal type), *Clostridium perfringens*, *Vibrio cholerae*, *Aeromonas hydrophila* and *Plesiomonas shigelloides* can cause toxicoinfection.

Toxicoinfections

- In toxicoinfection, the disease results from toxins formed in the digestive tract after the ingestion, with food or water, of large numbers of living pathogenic cells, which then sporulate, colonise and die there.
  - Examples of this group are *Clostridium perfringens* gastroenteritis, *Bacillus cereus* diarrhoeal gastroenteritis and enterotoxigenic *E. coli* gastroenteritis.

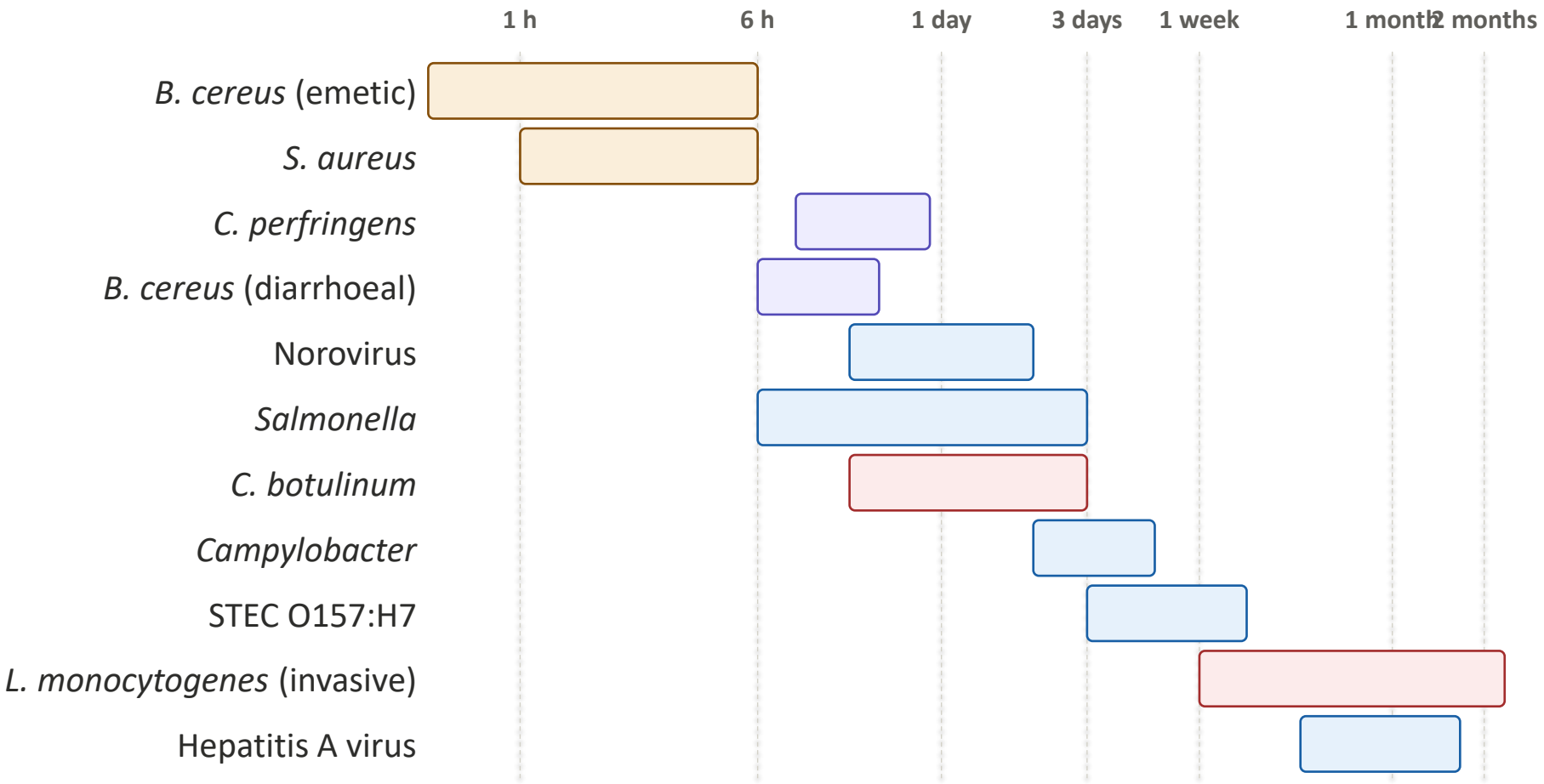
Intoxication

- When the causative agent is a microbial toxin, the foodborne illness is called an intoxication.
- In this case the pathogenic microorganism multiplies in the food and produces its toxin there.
- Symptoms appear when this toxin is consumed with the food.
- Such diseases can occur even when no live microorganisms remain in the food: the cells may be inactivated after producing the toxin (for example by reheating), while the heat-stable toxin remains active.

Intoxication

- Foodborne intoxication is caused by the consumption of food containing previously formed toxins.
- Toxigenic microorganisms
  - multiply in foods and
  - produce toxins under suitable conditions.
- The toxins cause gastrointestinal or systemic disorders.
- Viable microorganisms need not be present in the food at the time of consumption.
- *S. aureus*, *B. cereus* (emetic type), *C. botulinum*, toxigenic moulds, poisonous mushrooms and biogenic amines can cause intoxication.

Incubation Periods of Foodborne Illnesses



Short incubation (hours) points to a preformed toxin; long incubation (days to weeks) points to an infection. Amber = intoxication, purple = toxicoinfection, blue = infection, red = life-threatening.

Foodborne Diseases

Invasive infections

- *Salmonella* (other than *S.* Typhi and *S.* Paratyphi)
- *Vibrio parahaemolyticus*
- Enteroinvasive *E. coli* (EIEC)
- Shiga toxin-producing *E. coli* (STEC/EHEC)
- *Listeria monocytogenes*
- *Yersinia enterocolitica*
- *Brucella abortus* / *B. melitensis*
- *Shigella dysenteriae*
- *Campylobacter*
- *Coxiella burnetii*
- Norovirus, hepatitis A virus
- Hepatitis E virus
- Enteroviruses
- Parasites

Toxicoinfections

- *Clostridium perfringens*
- *Bacillus cereus* (diarrhoeal)
- *Vibrio cholerae*
- Enteropathogenic *E. coli* (EPEC)
- Enterotoxigenic *E. coli* (ETEC)
- *Plesiomonas shigelloides*
- *Clostridioides difficile*
- *Aeromonas hydrophila*

Intoxications

- *S. aureus*
- *Bacillus cereus* (emetic)
- *C. botulinum*
- Mycotoxins
- Plant toxins
- Algal toxins

Food Poisoning



Foodborne Disease

Pathogen	*Type*	*Foods Implicated*	*Causes*	*Symptoms*
Bacillus cereus	Bacteria	Cooked rice, corn, potatoes	Temperature abuse, improper cooking	Diarrhea, cramps
Botulism	Bacteria	Canned vegetables, baked potatoes in aluminum foil, herb or garlic infused oils	Foods held at warm temperatures	Double or blurred vision, slurred speech, difficulty swallowing, muscle weakness
Ciguatera	Bacterial Toxin	Large reef fish, barracuda, grouper, red snapper, eel, amberjack, sea bass, and Spanish mackerel	Toxin concentrated in the viscera and organs of fish	Nausea, vomiting, diarrhea, muscle pain, numbness, tingling, abdominal pain, dizziness, and vertigo
Clostridium perfringens	Bacteria	Meat, poultry, foods held in danger zone	Improper cooling of cooked foods, Foods held in danger zone	Diarrhea, cramps, headaches, chills
Campylobacter jejuni	Bacteria	Poultry, contaminated water	Improperly cooked foods, cross-contamination	Diarrhea, cramps, headache, nausea
Cryptosporidium parvum	Parasite	Contaminated water, fresh produce	Improper hand washing	Diarrhea, cramps, nausea
Escherichia coli	Bacteria	Raw/undercooked ground beef, raw milk, alfalfa sprouts, unpasteurized fruit juices, dry-cured salami, lettuce, game meat, cheese curds	Undercooked meats, cross-contamination, unpasteurized fruit juices, infected food handlers	Hemorrhagic colitis, hemolytic uremic syndrome
Hepatitis A	Virus	Ready-to-eat foods, shellfish, fresh green onions, contaminated water	Improper hand washing, Handling food with bare hands, Infected workers, Infected shellfish	Fever, physical weakness, nausea, abdominal pain, jaundice
Listeriosis	Bacteria	Vegetables, unpasteurized milk, raw meat, ready-to-eat foods, deli meats	Unpasteurized milk, improperly cooked foods, cross-contamination	Meningitis Septicemia, miscarriage
Norwalk Virus	Virus	Raw oysters and shellfish, contaminated water and ice, ready-to-eat foods	Inadequate treatment of sewage, infected food handlers	Nausea, vomiting, diarrhea, abdominal cramps
Salmonellosis (Salmonella)	Bacteria	Meat, poultry, egg or dairy products	Improper cooking, cross-contamination, infected food handlers	Nausea, diarrhea, abdominal pain, fever, headache, chills
Shigellosis	Bacteria	Contaminated food and water	Improper hand washing, infected workers,	Diarrhea, fever, abdominal pain
Staphylococcus	Bacterial Toxin	Custards, ham, poultry, eggs, potato salad, cream sauces, sandwich fillings	Improperly refrigerated foods, unsafe food handling practices, food handlers with open cuts and sores	Vomiting, diarrhea, abdominal cramps
Vibrio	Bacteria	Raw, partially cooked oysters	Undercooked oysters, infected oysters	Diarrhea, cramps, nausea, vomiting, fever, chills
Yersiniosis	Bacteria	Raw milk, chocolate milk, water, pork, raw meats	Unpasteurized milk, undercooked foods, cross-contamination	Enterocolitis (mimics acute appendicitis)

Some Causes of Foodborne Disease

- Ignoring the storage conditions of food, for example not keeping it cold;
- insufficient cooking or reheating;
- not cooling cooked food quickly;
- cross-contamination;
- insufficient or incorrect thawing of frozen foods;
- keeping food too long before it is eaten;
- eating raw foods that should not be eaten raw;
- holding food that is to be served hot below 63 °C;
- inadequate cleaning and hygiene;
- contamination of food after cooking;
- use of poor-quality raw materials;
- consumption of raw foods (raw milk, raw fish, etc.);
- preparing food in large quantities;
- infections transmitted by staff;
- employment of carriers;
- using foods beyond their shelf life.

Preventing Foodborne Disease

- The symptoms of food poisoning vary greatly from country to country and from person to person. The differences in duration and severity are due to:
  - the type of microorganism causing the disease;
  - the susceptibility and general resistance of the individual;
  - the concentration of bacteria or toxins in the food consumed.
- Microorganisms in food are controlled for two main purposes:
  - to delay or completely prevent microbial spoilage, and
  - to prevent diseases transmitted to humans by food.
- Four basic principles are applied to control microorganisms; the different food preservation methods have been developed from them.

WHO Five Keys to Safer Food

1	Keep clean	wash hands before and during preparation clean surfaces; keep pests out
2	Separate raw and cooked	separate knives and boards for raw food store raw below cooked in the refrigerator
3	Cook thoroughly	core temperature at least 70 °C reheat until steaming hot
4	Keep food at safe temperatures	do not leave cooked food over 2 h at room temperature refrigerate below 5 °C; hot-hold above 60 °C
5	Use safe water and raw materials	choose fresh, wholesome food wash fruit and vegetables; avoid expired food

Five simple messages that link directly to the causes of outbreaks on the previous slides.

Four Basic Principles for Controlling Microorganisms in Food

1. Preventing contamination
2. Removing microorganisms
    i. Washing
    ii. Trimming and sorting
    iii. Centrifugation
    iv. Filtration
3. Inhibiting microbial growth
    i. Chemical preservatives
    ii. Low-temperature storage
    iii. Reducing water activity
    iv. Controlled and modified atmosphere storage
    v. Antagonism between microorganisms (biopreservation)
4. Killing microorganisms
    i. Thermal treatments
    ii. Irradiation
    iii. Sterilant gases
    iv. High-pressure processing
    v. Combined (hurdle) methods

Four Principles for Controlling Microorganisms

PREVENT keep them out	REMOVE take them away	INHIBIT stop them growing	KILL destroy them
hygienic design GHP, GMP, sanitation personnel hygiene clean water, packaging	washing trimming and sorting centrifugation filtration (0.2 µm)	chilling and freezing low aw, low pH preservatives, MAP biopreservation	pasteurisation sterilisation irradiation high pressure

cheapest, gentlest → **most severe, most change to the food**

In practice they are combined

prevention first; then the mildest combination of hurdles that makes the food safe

1. Preventing Contamination

- Because microorganisms are found everywhere in nature, it is almost impossible to prevent the contamination of foods completely (except in some special cases).
- However, contamination can be minimised by controlling its potential sources.
- Both
  - the number and
  - the type of the microorganisms in a food matter.
- Microbial contamination is prevented or controlled by sanitation practices.
- Sanitation → all the activities carried out to prevent or minimise microbial contamination along the chain from raw material production or harvest to the consumer.

2. Removing Microorganisms

- One way of controlling microorganisms in food is to remove
  - those present in the natural flora of the food, or
  - those that contaminate it later.
    - Washing, sorting, centrifugation and filtration are used for this purpose.

a. Washing: applied especially to fruits and vegetables to be eaten fresh. Washing removes a large part of the microorganisms and their spores from the surface.

- It also increases the effectiveness of the heat treatments applied later.

b. Trimming and sorting: used in fruit and vegetable processing. Removing mouldy fruits and vegetables prevents the contamination of sound ones (and reduces mycotoxin levels).

2. Removing Microorganisms

c. Centrifugation: not very effective for removing microorganisms.

- It is applied mainly to milk (bactofugation), to remove foreign particles and some of the bacteria and spores suspended in it.

d. Filtration: the most effective method for removing microorganisms.

- Microorganisms are retained according to the pore size of the filter.
  - For example, filters with a pore size of 0.2 µm retain bacteria, yeasts and moulds but not viruses; microfiltration is used for milk, beer, juices and water.

3. Inhibiting Microbial Growth

a) Preservation with chemical preservatives: substances that are not natural constituents of the food but are added to it during

- processing,
- storage or
- packaging.

} Chemical substances added at these stages are called additives.

b) Additives are substances that give foods their desired appearance, taste and other properties, protect them or enrich their nutritional value.

Some chemical preservatives

- ✓ **Sodium or calcium propionate**
- ✓ Sodium benzoate
- ✓ Sorbic acid and sorbates
- ✓ Sulphur dioxide (SO_2) and sulphites
- ✓ Formaldehyde (not permitted in foods)
- ✓ Ethylene oxide (banned for food use in the EU)
- ✓ Sodium nitrite

b) Low-Temperature Storage

Cold storage:

- all chemical reactions slow down at low temperature;
- the activity of the microorganisms in the food slows down; and
- the undesirable changes that may occur in the food also slow down.

Frozen storage:

- foods to be kept for a long time are frozen.
- Freezing slows down the natural enzymes and chemical reactions of the food and stops microbial growth completely at −18 °C; the microorganisms are not killed, however, and resume growth after thawing.
- Freezing and thawing can change the physical structure of some foods.

c) Reducing Water Activity

- Free water is the basic requirement for microbial activity and for enzymatic and chemical reactions in foods.
- Water can be removed physically, or its availability limited by adding solutes such as salt and sugar.
- Drying is one of the oldest methods used for this purpose.

4. Killing Microorganisms

Microorganisms are killed for many reasons:

1. to destroy the agents of disease in humans, animals and plants and so prevent infections and their spread;
2. to prevent the spoilage of foods;
3. to make media and other environments free from microorganisms;
4. to obtain pure cultures and prevent their contamination;
5. to prevent the contamination of materials and tools;
6. to prevent the spread and transmission of disease agents.