FE 305 FOOD MICROBIOLOGY Foodborne Infection; Invasive Infection

Dr. Hüseyin BOZKURT

Foodborne Infections

Foodborne infections are diseases caused by microorganisms that multiply in the body after the consumption of food contaminated with pathogenic bacteria or viruses.

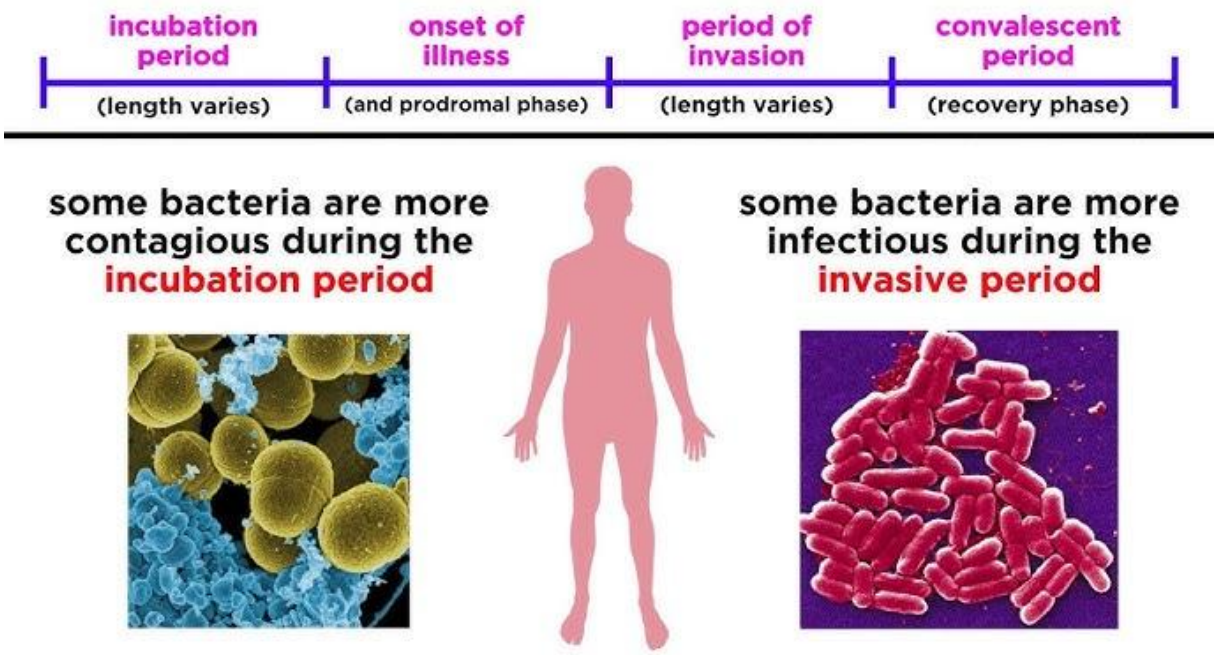
- The general characteristics of foodborne infections are:
  - living bacterial cells or virus particles are taken into the body with food;
  - the cells multiply in the intestine;
  - symptoms usually appear after 12–72 hours, but after days or weeks for some agents (e.g. *Listeria*, hepatitis A).



Foodborne Invasive Infections

Bacteria and viruses causing foodborne invasive infections:

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



Salmonella Infections

- Family Enterobacteriaceae; Gram-negative, mostly motile, facultatively anaerobic rods that produce gas from carbohydrates and polyhydric alcohols. *S.* Typhi does not produce gas from carbohydrates.
- The genus contains two species, *S. enterica* and *S. bongori*, and more than 2 600 serovars. Almost all human pathogenic serovars belong to *S. enterica* subsp. *enterica*; serovar names such as Typhimurium and Enteritidis are not species and are written in roman type.
- The somatic (O), capsular (Vi) and flagellar (H) antigens are used to group the serovars (Kauffmann–White–Le Minor scheme).
- It is mesophilic: optimum 35–37 °C (range about 5–47 °C), pH 6.5–7.5, minimum a_{vv} about 0.94. Growth is inhibited by 3–4% NaCl.
- Salmonellosis appears in two different clinical forms.
  - *S.* Typhi and *S.* Paratyphi cause typhoid and paratyphoid (enteric fever); humans are their only host.
  - They are invasive and cause septicaemia (they spread into the blood).
  - Body temperature rises to about 40 °C, and headache and pink “rose spots” on the chest and trunk are seen.
  - Constipation is common early; diarrhoea, sometimes bloody, may develop later in the disease.
  - The fatality rate is 10–20% in untreated patients and below 1% with antibiotic treatment.
  - The incubation period is usually 8–14 days (range 6–30 days), and the illness may last 3–4 weeks.

Salmonella Infections

- Paratyphoid resembles typhoid but is milder and shorter (1–3 weeks). Most other serovars cause gastroenteritis without septicaemia (non-typhoidal salmonellosis).
- The infective dose varies with the serovar, the food and the host.
  - For non-typhoidal salmonellosis it is usually 10^3–10^5 cells (as few as 10–100 in fatty foods);
  - for enteric fever (typhoid) it is about 10^5 cells.
- Humans and animals are the two main sources of *Salmonella*.
- Animals become infected from feed, pasture, streams and slaughterhouses.
- Some serovars are adapted to particular animal hosts.
- Poultry play a central role in spreading *Salmonella* in the human food chain.
- Eggs, especially duck eggs, are of particular importance; *S.* Enteritidis can be transmitted into the egg via the ovary.
- Besides farm animals, pets such as cats and dogs, and reptiles such as snakes and turtles, as well as frogs and wild birds, can be sources of *Salmonella*.
- *Salmonella* is frequently found in sewage and wastewater.

Typhoidal and Non-typhoidal Salmonella

Salmonella is ingested

Non-typhoidal (e.g. Enteritidis, Typhimurium)	Typhoidal (Typhi, Paratyphi)
Invades the intestinal mucosa stays mainly in the gut wall	**Crosses the epithelium via M cells** without much local inflammation
Acute inflammation neutrophils flood the mucosa	**Survives inside macrophages** carried to lymph nodes
Diarrhoea, cramps, fever after 6-72 h; lasts 4-7 days	**Blood, liver, spleen, gallbladder** fever 40 °C, rose spots after 8-14 days
Usually self-limiting risky for infants, elderly, immunocompromised	**Chronic carriers** gallbladder shedding for years - humans only

Hosts and vehicles

non-typhoidal: poultry, eggs, pork, many animals | typhoidal: only humans - water and food contaminated by patients or carriers

Salmonella Infections



Salmonella Infections

- A food matrix high in fat or protein gives *Salmonella* significant protection.
- Infection may then result from a very low dose of cells,
  - because such foods buffer the gastric acid and
  - fat speeds the passage of the food,
    - carrying *Salmonella* through the stomach to the intestine without injury.
    - Cells in such foods are also often in a dormant, more resistant physiological state.
- Outbreaks from chocolate, peanut butter, hamburgers, ice cream and potato crisps have been caused by as few as 10–100 cells per gram.
- Children are most often affected.
- Chocolate is probably contaminated
  - from the water circulation pipes and from added ingredients.
- Salmonellosis has also occurred in infants and children after eating salami sticks.
- These are made by traditional methods but with a very short manufacturing period,
- which is not long enough to destroy any *Salmonella* present in the meat.
- The surviving *Salmonella* can then cause salmonellosis.

Salmonella Infections Prevention and control

- Train commercial food handlers in food hygiene, and inform the public about *Salmonella* contamination and food poisoning.
- The factors most frequently associated with *Salmonella* outbreaks are:
  - poor personal hygiene;
  - poor supervision;
  - poor sanitation during food preparation and storage;
  - poor maintenance of equipment;
  - presence of rodents and flies;
  - holding food at warm temperatures for long periods;
  - slow cooling of large batches in the refrigerator;
  - using the same cutting boards for raw and cooked meat and poultry; and
  - poor cleaning of cutting boards and other utensils.
- Poultry, meat and hamburgers should be cooked thoroughly, with no pink colour in the middle.
- Raw or unpasteurised milk and dairy products should not be consumed.
- Milk should be pasteurised.
- Cross-contamination of foods should be avoided:
- raw meat should be kept separate from produce, cooked foods and ready-to-eat foods.
- Hands, cutting boards, counters, knives and other utensils should be washed thoroughly after handling raw foods.
- Hands should be washed before handling any food and between handling different foods.
- People with salmonellosis should not prepare food.
- Hands should be washed after contact with animal faeces,
- and immediately after handling reptiles, which are frequently associated with *Salmonella*.

Salmonella Infections

- In a *Salmonella* outbreak the course of the disease can differ:

  (1) acute salmonellosis;

  (2) salmonellosis without severe symptoms;

  (3) recovered patients who continue to shed the bacteria in their faeces for some time (convalescent carriers);

  (4) people who were exposed and carry the bacteria without ever showing symptoms (asymptomatic carriers).

- **General precautions:**
  - prevent contamination at the level of primary production;
  - prevent contamination and growth before and after heat treatment during processing;
  - education programmes.
  - *Salmonella* does not form a preformed toxin in food; live cells are needed. The lipopolysaccharide (endotoxin) of its cell wall contributes to the fever and inflammation.
  - The cells are not resistant to heat: pasteurisation of milk at 63 °C for 30 min or 72 °C for 15 s eliminates the *Salmonella* hazard.

Clostridium perfringens

- *C. perfringens* is a Gram-positive, non-motile rod that forms oval, subterminal spores and grows only under anaerobic conditions. Its spores vary in heat resistance: those of food-poisoning strains can survive boiling for 1–5 hours. A heat shock activates the spores so that they germinate into vegetative cells.
- Strains are classified by the major toxins they produce. Since 2018 seven toxinotypes (A–G) are recognised; the food-poisoning strains, which carry the enterotoxin gene (*cpe*), are now classified as type F (formerly type A).
- It is a mesophile with an unusually high optimum temperature, 43–45 °C; growth occurs between about 12 °C and 50 °C. The heat resistance of the spores of food-poisoning strains varies widely (D_{90} = 0.015–8.71 min).
- It grows between pH 5.0 and 8.3; the optimum is 6–7.
- It tolerates NaCl up to about 5%. Heating a medium containing nitrite produces an additional inhibitor of clostridia; this is called the Perigo effect, and NaCl and $NaNO_2$ act synergistically.
- The minimum a_{vv} for growth is 0.95–0.97, and 0.98 for sporulation.
- It is a fastidious bacterium that needs a very rich medium for good growth.

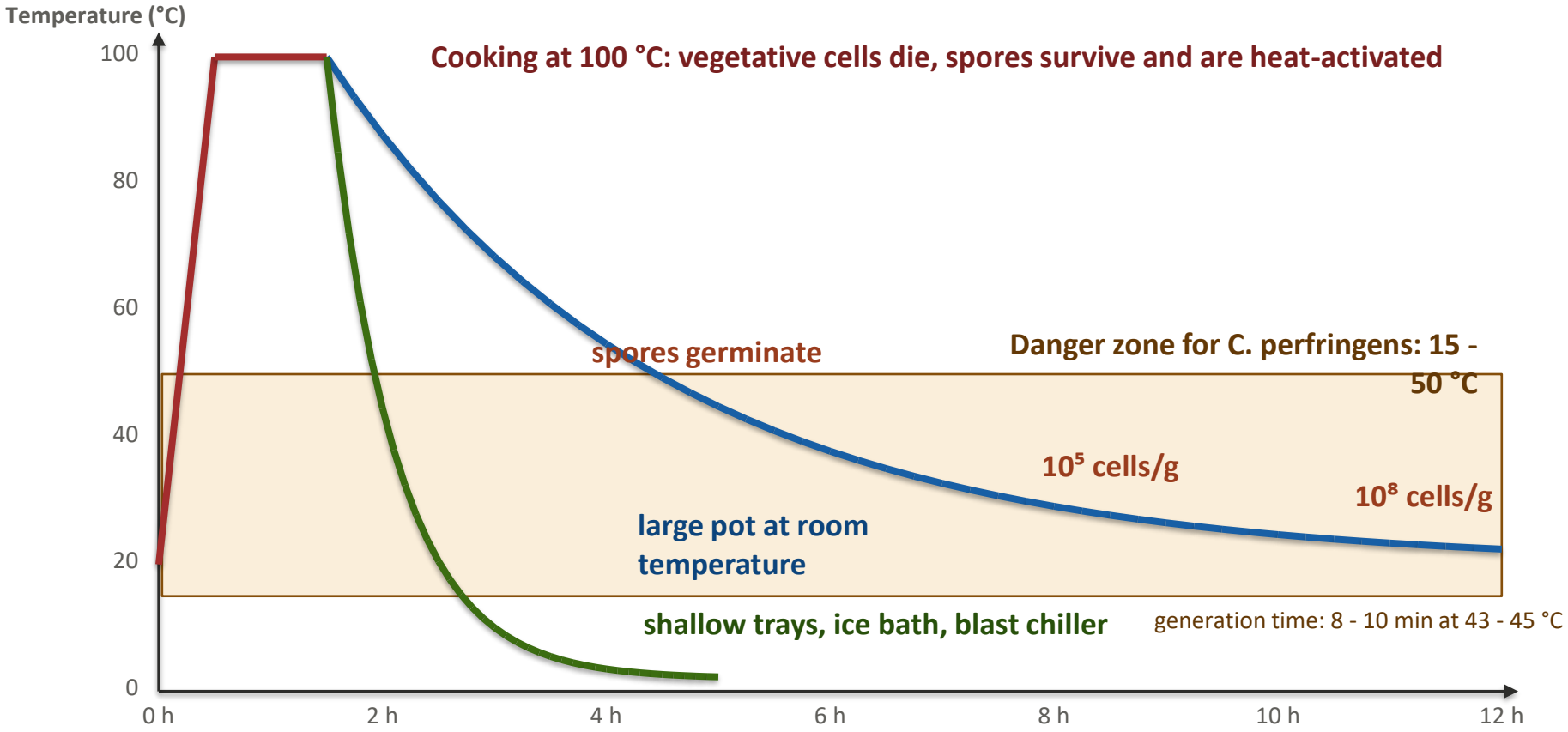
Clostridium perfringens

- Because it has a wide range of enzymes, it can meet some of its needs from polymeric substrates.
- Strictly anaerobic conditions (Eh about −200 mV) are required for growth to start.
- In a rich medium the generation time is only 8–10 minutes (7.1 minutes for some strains).
- The illness is a toxicoinfection: vegetative cells ingested with the food sporulate in the intestine and release an enterotoxin (CPE) when the mother cell lyses. CPE is heat-sensitive.
- If cooked meat, meat sauces and broths are cooled slowly or held for a long time between about 20 °C and 50 °C, the spores germinate and the cells multiply rapidly to dangerous numbers.
- Slicing and mincing raw meat for cooking, dirty work areas and equipment, and poor personal hygiene all make it easier for the organism to contaminate the food and multiply.

Clostridium perfringens

- The most important protection against *C. perfringens* poisoning is to cool cooked food quickly and in small portions.
- In food processing and catering, staff health and hygiene, correct preparation and storage of meat and hygienic drainage and sewerage systems are essential.
- Thorough cooking kills vegetative cells but does not destroy heat-resistant spores. Leftover food must be reheated to at least 74 °C before it is eaten.
- Food poisoning in humans is caused by the enterotoxin-producing strains, now called type F.
- The beta toxin of type C causes a different disease, enteritis necroticans (pig-bel), described in the highlands of Papua New Guinea after traditional pig feasts.
- The incubation period of *C. perfringens* food poisoning is 8–22 hours, usually about 12 hours.
- Large numbers of vegetative cells (usually more than 10^6 per gram of food) must be ingested to cause illness.
- In the intestine the cells sporulate; the enterotoxin is released when the cells lyse and acts on the intestinal epithelium.

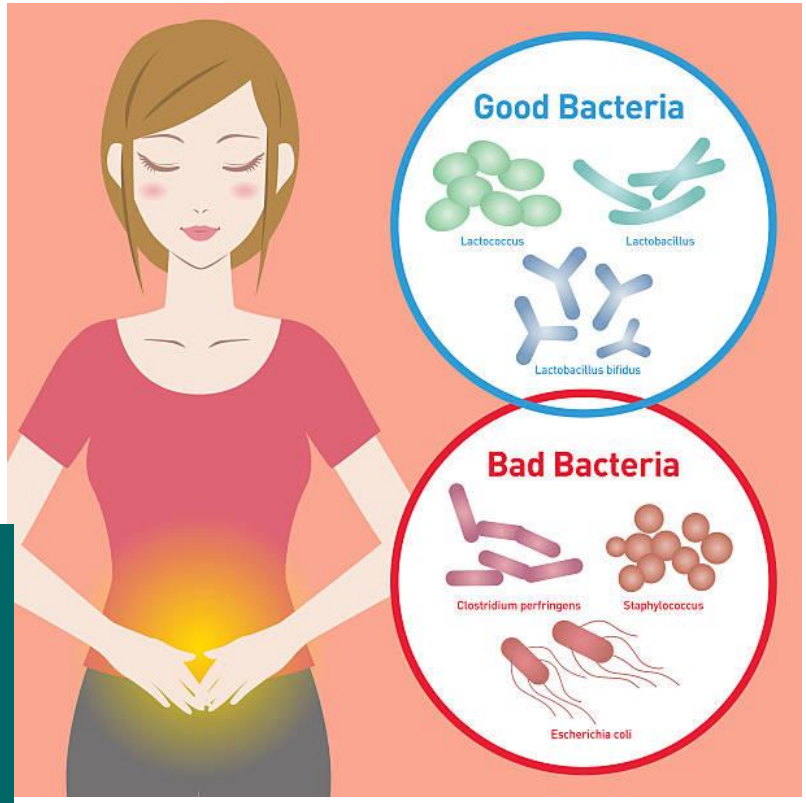
The Slow-Cooling Trap: Clostridium perfringens

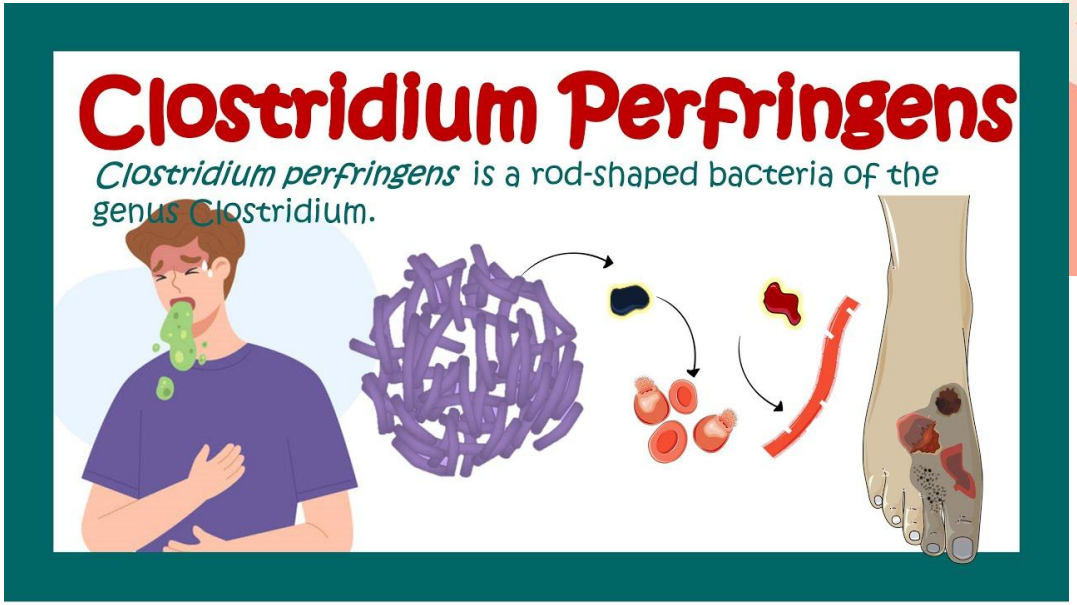


Rapid cooling rule (FDA Food Code)
from 57 °C to 21 °C within 2 hours,
then to 5 °C within a further 4 hours

After the meal (8 - 22 h)
>10^8 cells eaten - they sporulate in the gut,
release enterotoxin (CPE) - cramps, diarrhoea

Clostridium perfringens





Clostridium perfringens

- Symptoms of *C. perfringens* poisoning appear 8–22 hours (usually about 12 hours) after the food is eaten.
- The illness begins suddenly with severe abdominal cramps and watery diarrhoea, followed by weakness. Nausea, vomiting and fever are rare, and the illness usually lasts a day or less.
- The organism lives in the faeces of humans and animals, and in dust, soil and sewage. It is common in raw and cooked foods.
- The infective dose is reported to be more than 10^8 cells in total.
- The foods most often involved are boiled, roasted and stewed meat, poultry, gravies and meat sauces.
- Places where food is prepared and eaten in large quantities (canteens, catering, hospitals) are at particular risk.
- The main preventive measures are thorough cooking, rapid cooling, protection of the food from recontamination and hygienic tools and equipment.

Vibrio parahaemolyticus

- Gram-negative, motile, slightly curved rods of the family Vibrionaceae. It is halophilic, growing best at 3% NaCl.
- Many serotypes exist. Pathogenic strains produce the thermostable direct haemolysin (TDH) and the related TRH. Poorly cooked fish, crustaceans and mussels are the usual vehicles.
- The pathogenicity of strains is determined by the Kanagawa reaction on Wagatsuma agar (TDH production).
- Cases occur mainly in summer, in coastal areas, and especially after eating raw seafood.
- The optimum growth temperature is 37 °C; the range is 5–43 °C.
- The infective dose is 10^5–10^7 Kanagawa-positive cells.
- The disease is especially important in Japan and other Asian countries.
- Symptoms are nausea, vomiting, abdominal pain, mild fever, headache and diarrhoea, sometimes with bloody and mucous stools.
- The incubation period is 4–96 hours (usually 12–24 hours); recovery takes 2–5 days.
- The bacterium is sensitive to low temperatures; chilled storage reduces its numbers.

Yersinia enterocolitica

- *Yersinia pestis* and *Yersinia enterocolitica*, members of the family Enterobacteriaceae (now placed in Yersiniaceae), are two important human pathogens.
- *Y. enterocolitica* is widespread and psychrotrophic.
- Its optimum growth temperature is 28–32 °C, and it can grow at refrigeration temperature.
- It is found in sick and healthy animals, especially pigs, and in cats, dogs and foods. It causes enterocolitis and appendicitis-like pain (pseudoappendicitis), especially in children. Pathogenic strains produce a heat-stable enterotoxin (Yst) at temperatures below 30 °C.
- The incubation period is 24–36 hours, sometimes longer.
- Yersiniosis is usually self-limiting; septicaemia is rare, but its fatality rate is high in immunocompromised patients.
- Non-pathogenic strains may behave as opportunists in weakened hosts.
- It is most often isolated from raw pork, milk (raw and, after post-pasteurisation contamination, pasteurised), raw vegetables, eggs, sausages and lightly processed meat products.
- Control measures:
  1. raising animals free from *Y. enterocolitica*;
  2. hygiene during the transport, slaughter and processing of animals;
  3. staff training.

Yersinia enterocolitica

- Yersiniosis is most common in cooler climates.
- Pathogenic strains produce a heat-stable enterotoxin and invasion factors that enable the cells to colonise the intestinal epithelium.
- Ingested viable cells must first survive the acidity of the stomach
  - before they reach the intestine.
- A high dose (about 10^7 cells) is generally required,
  - because gastric acid is an effective barrier to *Y. enterocolitica*.
- The cells attach to the intestinal epithelium through their invasion factors.
- Symptoms appear 24–36 hours after the viable cells are eaten.
- The main symptom is pain in the lower abdomen, with watery to mucoid diarrhoea, headache and mild fever.
- Vomiting is rare.
- The pain is strongest in the lower right abdomen and can be mistaken for appendicitis.
- The illness lasts 2–3 days and is self-limiting.
- Yersiniosis occurs mostly in children, especially those under seven years of age.
- The cells colonise the epithelial cells and show cytotoxic activity.

Pathogenic *E. coli*

- Pathogenic *E. coli* strains that cause gastrointestinal disease are classified into six groups (pathotypes) according to their virulence properties, mechanisms of pathogenicity, clinical syndromes and O:H serotypes:
  - enteropathogenic *E. coli* (EPEC),
  - enterotoxigenic *E. coli* (ETEC),
  - enteroinvasive *E. coli* (EIEC),
  - enterohaemorrhagic / Shiga toxin-producing *E. coli* (EHEC/STEC),
  - diffusely adherent *E. coli* (DAEC),
  - enteroaggregative *E. coli* (EAEC).

Pathotypes of Diarrhoeagenic E. coli

EPEC Enteropathogenic	**ETEC** Enterotoxigenic	**EIEC** Enteroinvasive
site: small intestine attaching and effacing lesions infant diarrhoea	site: small intestine LT and ST enterotoxins traveller's diarrhoea	site: large intestine invades like Shigella dysentery
EHEC / STEC Shiga toxin-producing	**EAEC** Enteroaggregative	**DAEC** Diffusely adherent
site: large intestine Shiga toxins Stx1, Stx2 bloody diarrhoea, HUS	site: small and large intestine stacked-brick adherence, biofilm persistent diarrhoea	site: small intestine diffuse adherence diarrhoea in children

Shiga toxin
absorbed into blood
→
Damages vessels
of kidney and brain
→
Haemolytic uraemic syndrome
anaemia + low platelets + kidney failure;
5-10% of STEC cases, mainly children under 5

The 2011 outbreak in Germany (sprouts, O104:H4) was caused by an EAEC strain that had acquired the Shiga toxin gene: about 3 800 cases, 855 with HUS and 53 deaths.

Pathogenic *Escherichia coli*

a) Characteristics of the organism

- A member of the Enterobacteriaceae: catalase-positive, oxidase-negative, fermentative, Gram-negative, mesophilic, motile, non-spore-forming, facultatively anaerobic short rod; a normal inhabitant of the human and animal intestine.
- Non-pathogenic *E. coli* is used as an index organism
  - for possible faecal contamination and the presence of enteric pathogens in food and water.
  - It is distinguished from other Enterobacteriaceae by sugar fermentation, biochemical and serological tests.
- Pathogenic strains are differentiated from non-pathogenic ones by their somatic (O, lipopolysaccharide), flagellar (H) and capsular (K) antigens and, today, by detecting their virulence genes.

Enteroinvasive *E. coli* (EIEC)

- EIEC strains cause dysentery-like diarrhoea.
- Like *Shigella*, they invade the epithelial cells of the large intestine (colon), multiply inside them and kill them.
- Most EIEC strains are non-motile, do not produce gas and do not ferment lactose within 48 hours.
- Their virulence depends on a large invasion plasmid (about 220 kb), closely related to that of *Shigella*.
- This plasmid encodes many outer-membrane proteins that are required for invasion,
  - including the secretion system and effector proteins that allow the bacteria to enter the host cell.

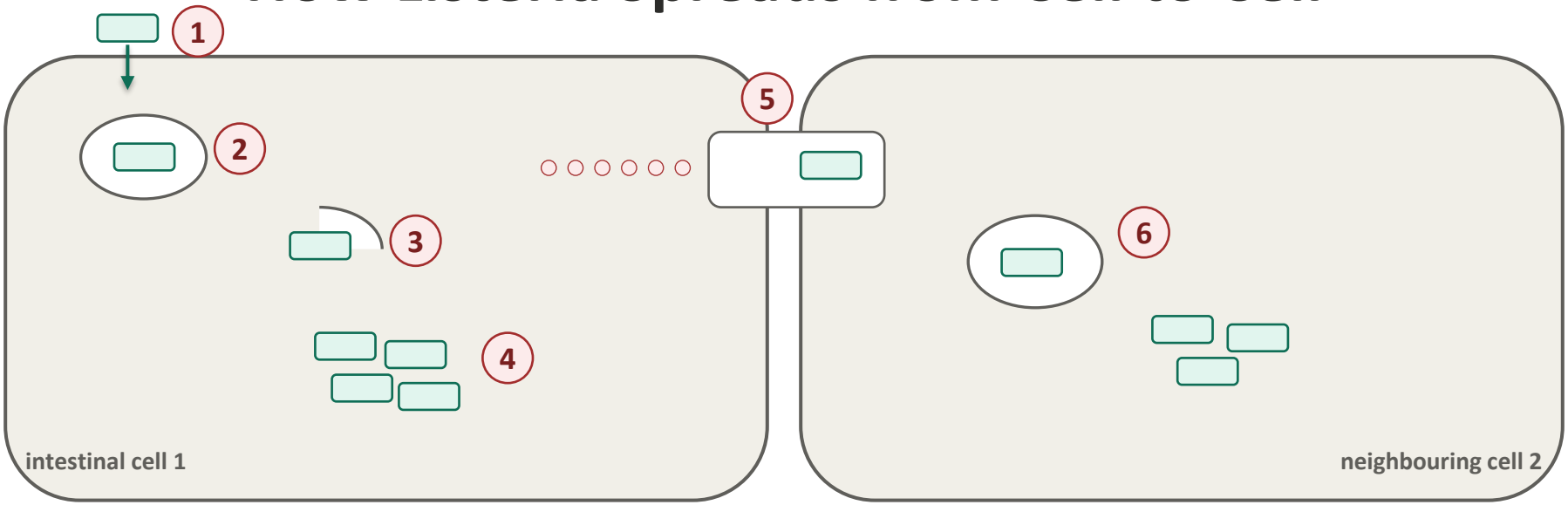
Listeria monocytogenes

- The genus *Listeria* now contains more than 20 species. The classical ones are *L. monocytogenes, L. ivanovii, L. innocua, L. welshimeri, L. seeligeri* and *L. grayi*. *L. monocytogenes* is the main human pathogen; *L. ivanovii* is mainly an animal pathogen and only rarely infects humans.
- *L. monocytogenes* is a Gram-positive, short, regular rod (0.4–0.5 µm wide and 0.5–2 µm long) that may form short chains. It has no capsule and no spores, is motile at 20–25 °C but not at 37 °C, is aerobic or facultatively anaerobic, grows between about −0.4 °C and 45 °C and has an optimum of 30–37 °C.
- *L. monocytogenes* is not demanding and is found in faeces, soil, water, milk, red and white meat and on green leafy vegetables.
- It can multiply at refrigeration temperature (4 °C) and in the presence of 10% NaCl; some studies report growth between −0.4 °C and 50 °C and at 12% NaCl.
- It grows best at neutral to slightly alkaline pH and can grow between pH 4.4 and 9.6.

Listeria monocytogenes

- *L. monocytogenes* grows best under reduced oxygen with 5–10% CO_2; its growth slows in atmospheres with 80–100% CO_2. It requires biotin, riboflavin, thiamine and some amino acids.
- The minimum a_{vv} for growth is 0.92 with NaCl (about 0.90 with glycerol).
- Its somatic (O) and flagellar (H) antigens divide the strains into 13 serotypes: 1/2a, 1/2b, 1/2c, 3a, 3b, 3c, 4a, 4ab, 4b, 4c, 4d, 4e and 7.
- Serotypes 4b, 1/2a and 1/2b cause more than 95% of human listeriosis cases.
- Although mesophilic (optimum 30–37 °C), it is psychrotrophic and multiplies in the refrigerator; growth has been reported down to −0.4 °C.
- The infective dose is not known precisely; it is estimated at 10^3–10^6 cells, and lower for high-risk groups.
- Invasive listeriosis causes miscarriage and stillbirth, meningitis, septicaemia and, rarely, endocarditis.
- The elderly, newborns, pregnant women and immunocompromised patients are the risk groups.
- THE CASE FATALITY RATE IS ABOUT 20–30% - THE HIGHEST OF ALL COMMON FOODBORNE INFECTIONS.

How Listeria Spreads from Cell to Cell



1. Attachment and entry - internalins InlA and InlB bind host receptors
2. Enclosed in a membrane vacuole inside the cell
3. Escape - listeriolysin O (LLO) dissolves the vacuole membrane
4. Multiplication free in the cytoplasm
5. ActA builds an actin tail that pushes the bacterium into cell 2
6. Escapes again and repeats - never exposed to antibodies

Why this makes Listeria so dangerous

hidden inside cells, it crosses the intestinal, blood-brain and placental barriers: septicaemia, meningitis, miscarriage and stillbirth - case fatality 20-30%

Listeria monocytogenes

L. monocytogenes is

- widely distributed in the environment (soil, sewage, water and decaying vegetation) and
- is associated with
  - surface waters,
  - decaying vegetables, soil, sewage, silage, seafood and raw vegetables (fresh-cut vegetables, potatoes, tomatoes, lettuce),
  - meat, meat products, poultry and eggs,
  - raw and pasteurised milk, dairy products and the dairy plant environment, where it persists in drains and biofilms.

- Non-invasive listeriosis causes mild fever, abdominal pain, nausea, vomiting, chills and diarrhoea.
- The incubation period of invasive listeriosis is long: from 1 day to 70 days (median about 1–4 weeks).
- The case fatality rate of invasive listeriosis is about 20–30%;
  - it is highest in newborns and in elderly and immunocompromised patients.

Listeria monocytogenes

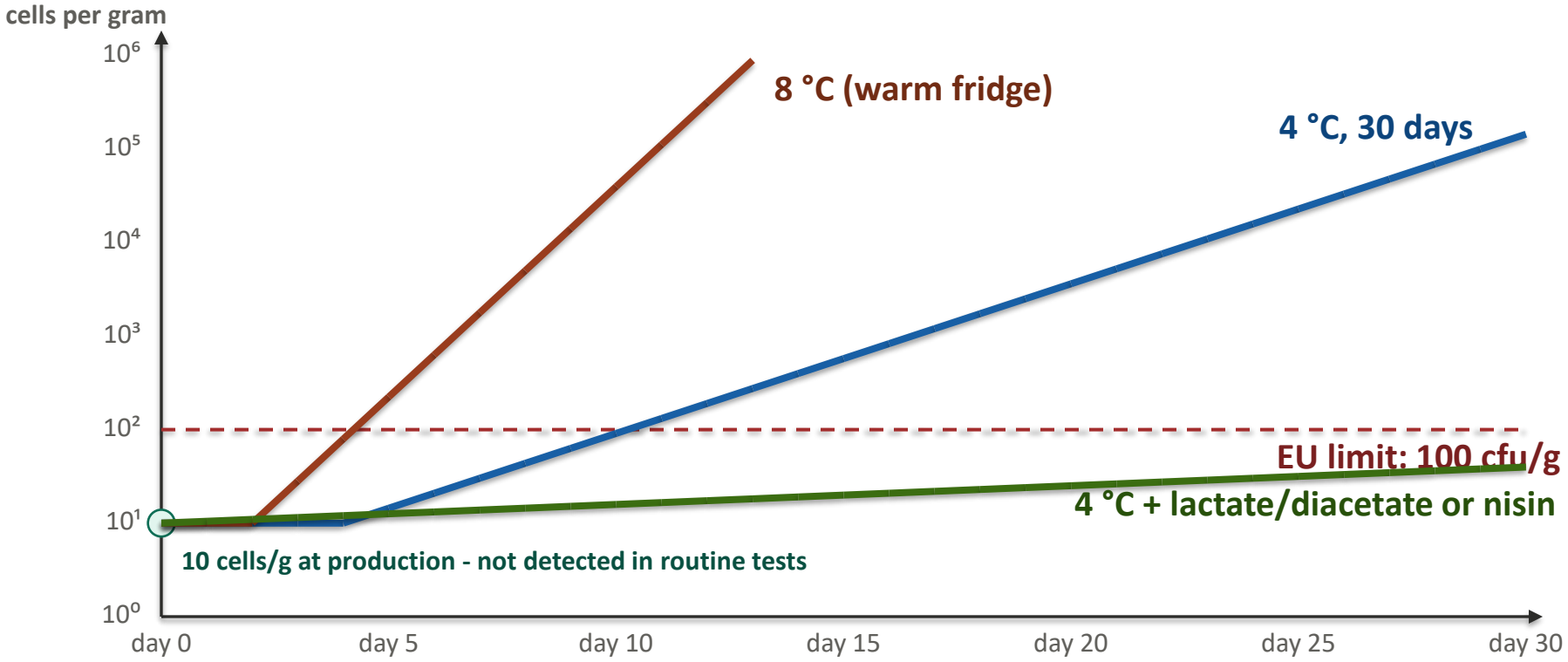
Prevention and control

- Sanitisers (acid-anionic detergents, quaternary ammonium compounds, iodophors, peroxide and chlorine)
  - reduce *L. monocytogenes* populations by at least 99.999% (5 log) on clean surfaces; cells in biofilms are more resistant.
- A number of natural compounds and food additives inhibit *L. monocytogenes*:
  - the lactoperoxidase system (in milk),
  - lysozyme (in milk and egg white),
  - lactoferrin (in milk) and
  - free fatty acids (in milk).
- Nisin from *Lactococcus lactis*, pediocins from *Pediococcus acidilactici* and *P. pentosaceus*, other LAB bacteriocins and *Listeria*-specific bacteriophages
  - inhibit or kill *L. monocytogenes*.

Listeria monocytogenes

- General recommendations to reduce the risk of listeriosis:
  - do not drink raw or unpasteurised milk;
  - do not eat dairy products made from raw milk;
  - keep raw and cooked foods separate at all times;
  - wash hands, knives and all food-contact surfaces (cutting boards, etc.) after handling raw foods;
  - wash fruit and vegetables thoroughly before eating;
  - cook all raw foods of animal origin, and leftovers, thoroughly;
  - keep hot food hot (above 60 °C);
    - do not keep food at room temperature for more than 2 hours;
  - reheat leftovers and ready-to-eat foods until steaming hot before eating;
  - keep cold food cold (at or below 4 °C) and observe use-by dates;
  - refrigerate food in small portions so that it chills rapidly;
  - pregnant women should avoid soft cheeses, pâtés and cold smoked fish.

Listeria in Chilled Ready-to-Eat Foods



EU criterion for RTE foods that support growth (Reg. 2024/2895, in force since 1 July 2026)

If the producer can prove - by challenge tests or predictive models - that the level stays below 100 cfu/g until the end of shelf life, the 100 cfu/g limit applies.

Otherwise: not detected in 25 g throughout the whole shelf life, not only at the factory gate.

Aeromonas hydrophila

- A Gram-negative, non-spore-forming, facultatively anaerobic, motile rod of the family Aeromonadaceae (formerly placed in Vibrionaceae).
- Growth temperature 0–42 °C, optimum about 28 °C.
- It causes gastroenteritis in humans.
- It affects people of all ages but is more common in the elderly and in children.
- The commonest symptoms are vomiting and watery diarrhoea, ranging from cholera-like to dysentery-like illness.
- It also causes skin and soft-tissue infections, septicaemia, arthritis, meningitis, peritonitis, endocarditis and respiratory and gynaecological infections.
- The infective dose is not well established; figures of 10^2–10^9 cells per g or ml have been reported.
- It is found mainly in water and wastewater, and has also been isolated from fish, shellfish and various animals.
- Because it is psychrotrophic, refrigeration alone does not prevent its growth.

PASSIVE FOOD INFECTIONS: *Vibrio cholerae*

- *V. cholerae* is a non-spore-forming, short, comma-shaped, facultatively anaerobic rod of the family Vibrionaceae, motile by a single polar flagellum.
- It grows between 13 and 42 °C, with an optimum at 37 °C. It is alkali-tolerant and grows between pH 6 and 10; alkaline peptone water is used for its enrichment.
- It is not an obligate halophile, but it grows at NaCl concentrations up to 6%; above this no growth occurs.
- *V. cholerae* is divided into more than 200 serogroups on the basis of its O antigen; strains agglutinated by the O1 antiserum are called serogroup O1.
- Toxigenic strains of serogroups O1 and O139 cause epidemic cholera.
- Cholera may be asymptomatic or mild, but its typical symptom is very severe, watery “rice-water” diarrhoea.

Vibrio cholerae Infection

- Rapid and severe dehydration occurs, with abdominal cramps.
- A patient may lose several litres of fluid a day; without rehydration, the dehydration can be fatal within hours.
- The incubation period is from a few hours to 5 days, usually 2–3 days.
- The infective dose is about 10^8–10^9 cells in water, but much lower (10^3–10^6) when the cells are protected by food or when gastric acid is neutralised.
- Patients and some healthy carriers shed 10^2–10^9 cells per gram of faeces; humans are the most important source of epidemics.
- Most cholera outbreaks are caused by faecally contaminated water; outbreaks caused by seafood have also been reported.
- The bacterium survives for a long time in seawater (7–285 days) and on crustaceans (15–45 days), depending on the conditions.
- Oral rehydration therapy is the key treatment and reduces mortality to below 1%.

Campylobacter jejuni Infection

- *Campylobacter* species are Gram-negative, curved or spiral, microaerophilic, motile rods of the family Campylobacteraceae.
- *Campylobacter* causes illness similar to salmonellosis and shigellosis, and in many countries it is now the leading cause of bacterial gastroenteritis.
- In the European Union, campylobacteriosis has been the most frequently reported zoonosis every year since 2005.
- The incubation period is usually 2–5 days.
- It is associated mainly with foods of animal origin, above all poultry.
- The pathogenic species of *Campylobacter* are:
  - *C. fetus*, which causes systemic disease in humans;
  - *C. jejuni* and *C. coli*, which cause gastroenteritis.

Campylobacter jejuni Infection

- *C. jejuni* is thermotolerant: it grows at 30–45 °C with an optimum at 42 °C (the body temperature of birds), and at pH 6.5–7.5.
- It does not grow below 30 °C and is quickly killed by heating.
- It dies at room temperature, but survives for weeks in food, water and faeces at refrigeration temperature (4 °C).
- The infective dose is very low (about 500 cells).
- It is microaerophilic and capnophilic (it needs about 5% O_2 and 10% CO_2).
- It is very sensitive to salt, drying and freezing.
- Its source is animals; it reaches humans through meat, milk and water. It does not multiply in food, but a few hundred cells are enough to cause disease. Being microaerophilic, it survives in vacuum packs.
- *C. jejuni* invades the intestinal mucosa and causes enterocolitis. Rarely it spreads further; its most serious complication is Guillain–Barré syndrome, an acute paralysis that follows about 1 in 1 000 infections.
- Symptoms are fever, abdominal pain, diarrhoea (sometimes bloody), nausea, vomiting and headache. The incubation period is 2–5 days, occasionally up to 10 days.

From Chicken to Patient: Campylobacter

1	**Broiler gut**	10^6 - 10^9 cells per gram in the caeca at 42 °C; the bird stays healthy
2	**Slaughter**	defeathering and evisceration spread it - most carcasses become contaminated
3	**Storage and retail**	does not grow below 30 °C, but survives for weeks in the refrigerator
4	**Kitchen**	washing raw chicken splashes it; boards and hands carry it to salads
5	**Consumer**	about 500 cells are enough - enterocolitis after 2 - 5 days

Rare but serious
Guillain–Barré syndrome: acute paralysis after about 1 in 1 000 infections

Control points
on-farm biosecurity, carcass chilling or freezing, no washing of raw chicken, thorough cooking

Mycobacterium tuberculosis and *M. bovis* Infection

- Acid-fast, non-spore-forming, aerobic rods of the family Mycobacteriaceae.
- They are usually transmitted by the respiratory route, but *M. bovis* is also transmitted by raw milk.
- They cause disease without producing toxins.
- By inhalation, the infective dose may be only a few cells;
- by ingestion, several million cells are needed.
- Treatment requires months of combined antibiotic therapy (at least 6 months).
- Pasteurisation of milk and tuberculin testing of cattle have made milk-borne tuberculosis rare; drug-resistant tuberculosis is, however, increasing.

Shigella Infection

- The agents of shigellosis are divided into four serogroups: A, *S. dysenteriae*; B, *S. flexneri*; C, *S. boydii*; and D, *S. sonnei*.
- They cause bacillary dysentery. It is not a true food poisoning: the food only acts as a vehicle. Milk, water, vegetables and fruit and ready-to-eat foods (salads, egg dishes, etc.) are important.
- *Shigella* is pathogenic only for humans and higher primates. It is transmitted by direct contact, through food or through faecal contamination. After ingestion it passes through the stomach and small intestine and settles in the mucosa of the large intestine, where it multiplies and causes local inflammation.
- The bacteria survive for a long time in contaminated foods: up to about 170 days in milk and flour, a few hours in faeces and at very low pH, and about a week at 20 °C and pH 3.2.
- Even very small numbers can cause infection (infective dose 10–100 cells).

Shigella Infection

- The vehicle of infection can rarely be identified.
- The incubation period is 1–7 days (usually 1–3 days). The main symptoms are fever, severe abdominal pain, diarrhoea, vomiting, exhaustion and mucous and bloody stools.
- *S. dysenteriae* type 1 produces Shiga toxin; *Shigella* species also possess endotoxin and several enterotoxins.
- Shiga toxin can damage the kidneys and nervous system and may lead to haemolytic uraemic syndrome.
- Many strains are resistant to antibiotics and can cause severe epidemics. The *S. dysenteriae* type 1 epidemic of 1968–1970 in Central America caused more than 10 000 deaths.
- These diseases, generally called shigellosis, are also known as bacillary dysentery.

Coxiella burnetii Infection

- A small, Gram-negative, obligately intracellular coccobacillus.
- It is killed by pasteurisation (62.8 °C for 30 min or 71.7 °C for 15 s); the time–temperature standards for milk pasteurisation were in fact set to destroy this organism.
- It causes Q fever.
- The incubation period is 2–3 weeks; fever is followed by malaise, loss of appetite and muscle pain.
- Bacteraemia (bacteria in the bloodstream) occurs during the febrile period.
- In chronic cases, cough, chest pain, liver damage and endocarditis are seen.
- Cattle, sheep and goats are its main reservoirs. Humans are usually infected by inhaling contaminated dust and aerosols, less often by raw milk; ticks transmit it between animals.

Brucella Infection

- *Brucella* species (family Brucellaceae) are Gram-negative, aerobic, catalase- and oxidase-positive, non-motile, non-spore-forming short coccobacilli that live as facultative intracellular parasites.
- They cause abortion and infertility in animals, and brucellosis (Malta fever, undulant fever) in humans.
- *B. melitensis* is found in sheep and goats, *B. abortus* in cattle and *B. suis* in pigs; all can be transmitted to humans.
- The incubation period is usually 2–4 weeks (range 5 days to several months).
- They grow aerobically, and many strains need increased CO_2 (5–10%) for optimum growth;
  - no growth occurs under strictly anaerobic conditions.
- The bacteria can penetrate the mucous membranes of the pharynx and tonsils and colonise bones, joints, the nervous system and the genital organs.

Brucella Infection

- *Brucella* survives for a long time in milk, dairy products (e.g. cheese, cream) and raw meat.
- Brucellosis is associated with the consumption of undercooked meat, raw milk and dairy products made from raw milk,
  - such as cream and fresh cheese; in Türkiye unpasteurised fresh cheese is a typical source.
- *Brucella* is killed by normal milk pasteurisation, so pasteurised milk and products made from it carry no risk.
- Raw milk and some fresh products made from it can cause foodborne brucellosis.
- *B. melitensis* and *B. suis* are more readily transmitted to humans, and cause more severe disease, than *B. abortus*.
- There are no specific symptoms. The first symptoms of the acute form are fever, sweating, chills, weakness, pain in the body, especially in the back and joints, and weight loss.
- Some patients (10–15%) develop complications, one of which is osteomyelitis (inflammation of the bone).
- The chronic form lasts more than a year, with recurrent fever, various pains, depression and insomnia.
- Vaccination of animals and adequate heat treatment of animal products are the main control measures.

Brucella Infection

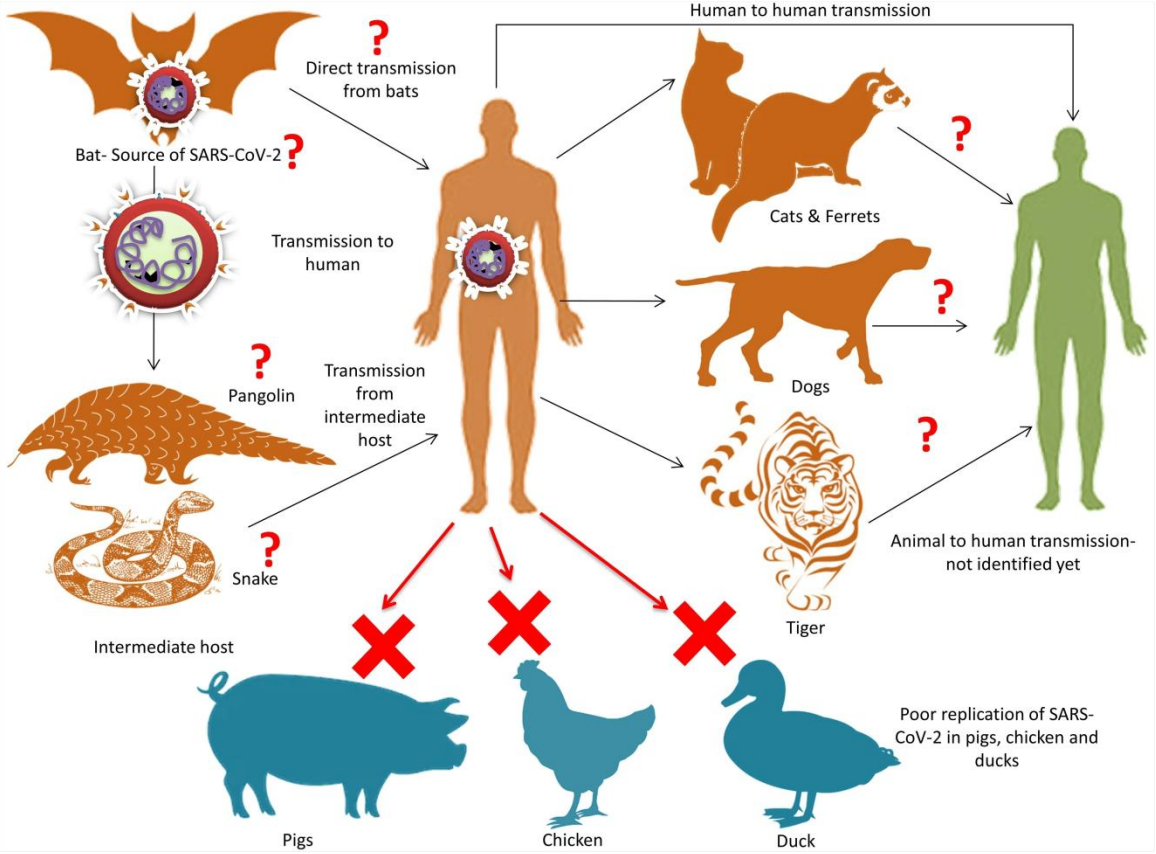
Prevention and control

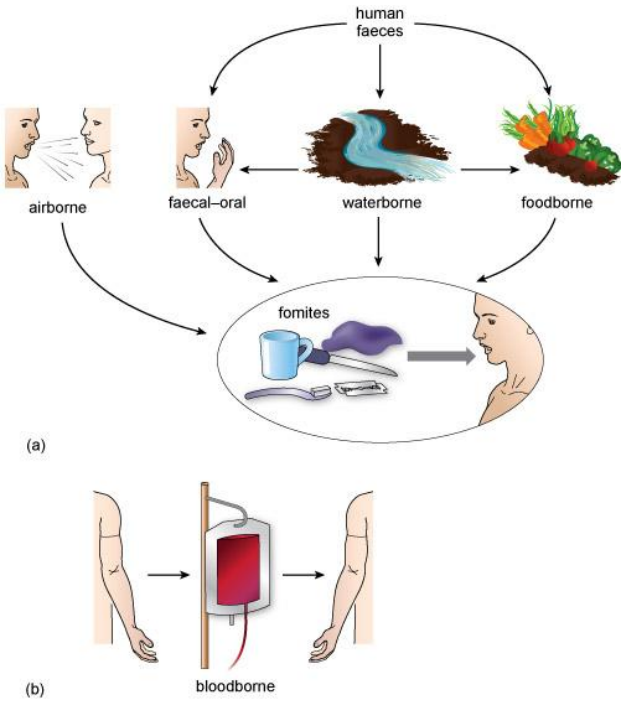
- Control measures include:
  - pasteurisation of milk;
  - manufacture of dairy products from pasteurised milk;
  - proper sanitation to prevent recontamination after pasteurisation;
  - an effective HACCP system in the dairy industry;
  - thorough cooking of all kinds of meat;
  - disinfection of
  - utensils and clothing by exposure to 1% phenolic disinfectant or chloramine for 30 min;
  - surfaces with a chlorine-based disinfectant;
  - educating the public not to consume untreated milk or dairy products made from unpasteurised milk;
  - serological testing of livestock to identify and remove infected animals.

Viral Infections

- The foodborne viruses that cause disease in humans are enteric viruses; the most important are:
  - Norovirus: the leading cause of foodborne illness worldwide (see the following slides).
  - Hepatitis A virus (infectious jaundice): transmitted by the faecal–oral route; shellfish, frozen berries and foods handled by infected workers are the most important vehicles. The incubation period is 15–50 days (average 28 days).
  - Enteroviruses (poliovirus, Coxsackie and ECHO viruses): the incubation period is usually 3–5 days; symptoms are fever, vomiting, diarrhoea, abdominal pain and headache. Poliomyelitis (5–35 days) has been almost eradicated by vaccination.
  - Hepatitis E virus and avian influenza A (H5N1)

Transmission of Viruses to Humans through Food



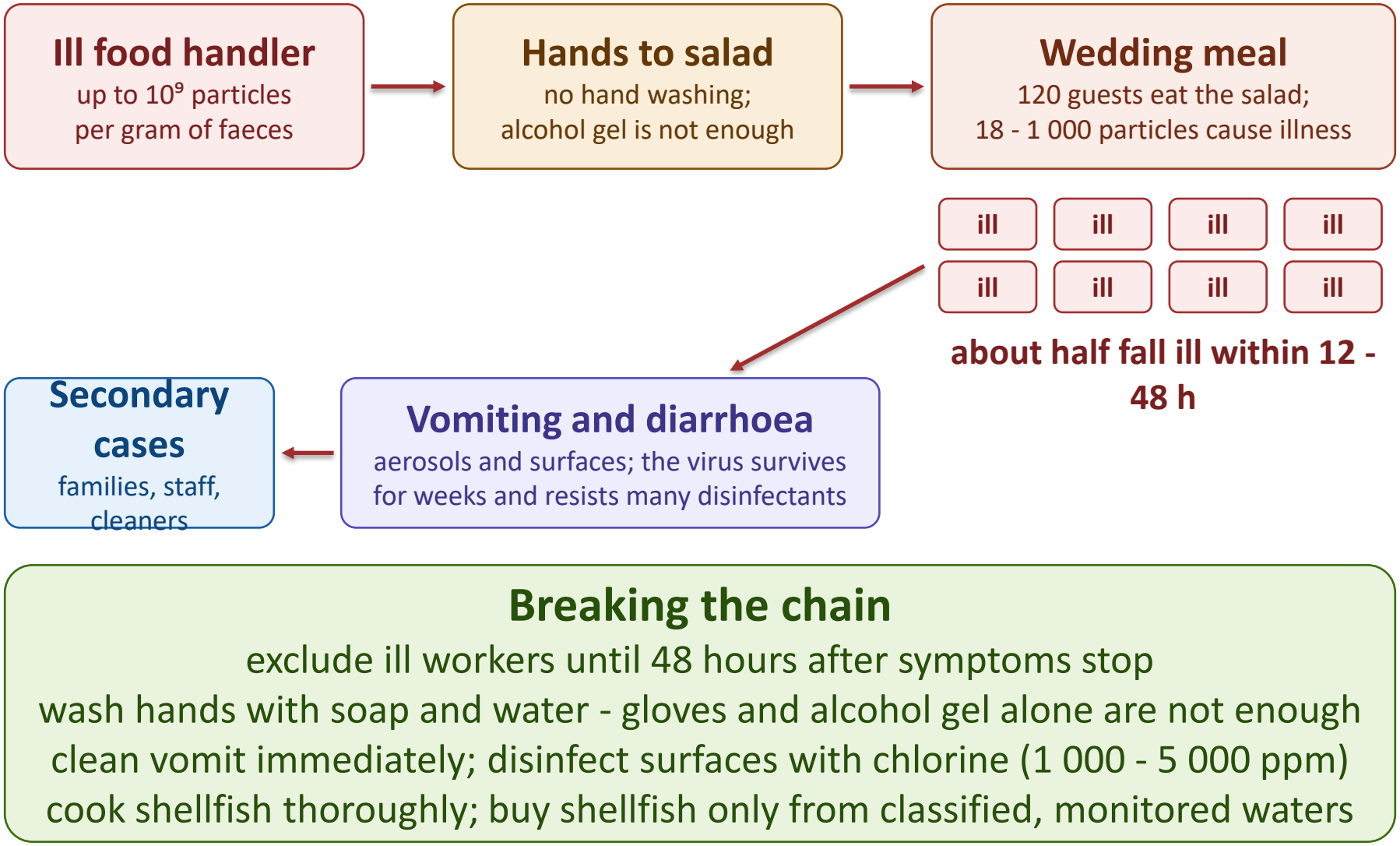


Viral infections

Norovirus (NoV)

- Norovirus causes about one fifth of all cases of acute gastroenteritis worldwide and is the leading cause of foodborne illness. Cases occur all year round but peak in the winter months (“winter vomiting disease”). It is transmitted by the faecal–oral route: through contaminated food and water, from person to person and from contaminated surfaces. Outbreaks are caused by foods such as shellfish, salads, cream products, sandwiches, frozen berries and ice. The infective dose is very low (about 18–1 000 particles), and a patient may shed billions of particles per gram of faeces. Symptoms appear after 12–48 hours; the main ones are vomiting and diarrhoea, sometimes followed by fever, muscle pain and headache. The virus resists many disinfectants and alcohol hand gels, so hand washing with soap and water, food hygiene and the exclusion of ill workers for 48 hours after recovery are the most effective preventive measures.

Norovirus: Anatomy of an Outbreak



Breaking the chain

exclude ill workers until 48 hours after symptoms stop

wash hands with soap and water - gloves and alcohol gel alone are not enough

clean vomit immediately; disinfect surfaces with chlorine (1 000 - 5 000 ppm)

cook shellfish thoroughly; buy shellfish only from classified, monitored waters

Foodborne Viruses: Why They Are Different

They cannot grow in food	the food is only a vehicle - numbers never increase, so the dose eaten is the dose contaminated
The infective dose is tiny	about 18 - 1 000 norovirus particles; a patient sheds up to 10^9 per gram of faeces
They are tough	survive freezing, drying, acid pH and weeks on surfaces; alcohol gels are poorly effective
Indicator bacteria do not predict them	*E. coli* may be absent while norovirus is present - shellfish waters are the classic example
They cannot be cultured routinely	detection is by RT-PCR (ISO 15216), which cannot say whether the particle is still infectious

The three that matter

Norovirus: the leading cause of foodborne illness worldwide; 12 - 48 h; short, violent
Hepatitis A: 15 - 50 days; jaundice; vaccine
Hepatitis E: undercooked pork and game

What actually controls them

exclude ill workers until 48 h after recovery
hand washing with soap; gloves are not enough
shellfish from classified waters; heat 90 °C/90 s (depuration does not remove norovirus)

Viral infections

Hepatitis A (HAV)

- Hepatitis A virus infects the liver and causes jaundice. The virus is shed in faeces and reaches humans through contaminated water and food. Shellfish grown in polluted waters, frozen berries, raw vegetables and foods handled by infected workers are the most important sources; it is also spread by contact with patients and carriers. The disease appears on average 28 days (15–50 days) after exposure. Symptoms include malaise, fever, loss of appetite, nausea, vomiting, dark urine, pale stools and jaundice. To prevent HAV transmission:
  - hygiene rules should be observed;
  - hands should be washed with soap and water;
  - food handlers should be monitored and, where appropriate, vaccinated;
  - food should be clean and thoroughly cooked (the virus is inactivated at 85 °C for 1 min);
  - well or tank water should be chlorinated;
  - vaccination is highly effective; the HAV vaccine was added to the childhood vaccination schedule in Türkiye in 2012.

Viral infections

Avian influenza

- Avian influenza (bird flu) is caused by influenza A viruses, such as H5N1, that infect poultry and wild birds. Humans are infected mainly through close contact with infected birds and contaminated surfaces.
  - Cases have occurred mainly among poultry workers, their families and staff involved in culling, and after visits to live bird markets. Sustained human-to-human transmission has not been observed, so it has not caused large human epidemics. Since 2024, H5N1 has also been found in dairy cattle in the USA, with high virus levels in raw milk; pasteurisation inactivates it. Symptoms are fever above 38 °C, malaise, cough, sore throat and sometimes diarrhoea; the incubation period is 2–5 days.
  - To prevent bird flu:
  - poultry meat and eggs should be thoroughly cooked (at least 70 °C in all parts), and raw milk should not be consumed;
  - hygiene rules should be observed when handling raw poultry.

Antimicrobial Resistance in the Food Chain

1	**Farm**	antibiotics used for treatment, and in some countries still for prevention or growth
2	**Selection**	resistant bacteria survive and multiply in the animal gut; resistance genes sit on plasmids
3	**Food**	resistant *Salmonella* and *Campylobacter*, ESBL-producing *E. coli*, LA-MRSA on meat
4	**The consumer**	infection with a resistant strain, or transfer of the gene to our own gut flora
5	**Environment**	manure and waste water spread the genes back to soil, water and crops

Why it concerns food microbiology

resistance is not a property of the food but of the bacteria we allow to reach it; cooking destroys the bacteria, but not the genes they have already passed on

What is being done

EU banned antibiotic growth promoters (2006) and routine prophylactic use (2022)
EU-wide monitoring of resistance in animals and food; prudent use and biosecurity on farm

One Health

Human medicine, veterinary medicine and the food chain share the same resistance problem; the food microbiologist sits exactly where the three meet.