Chapter 13

Food Preservation and Safety

Objectives: After reading Chapter Thirteen, you should understand…

- General concepts associated with food spoilage and sources of food contamination.
- How spoilage of food is prevented.
- How high and low temperatures can be used to preserve the quality of foods.

<u>Food Spoilage </u>(not always caused by pathogens)

The story of Cornelius Vanderbilt and potato chips.

One third of all food produced in the world is lost to spoilage.

The majority is lost due to **microbial contamination**.

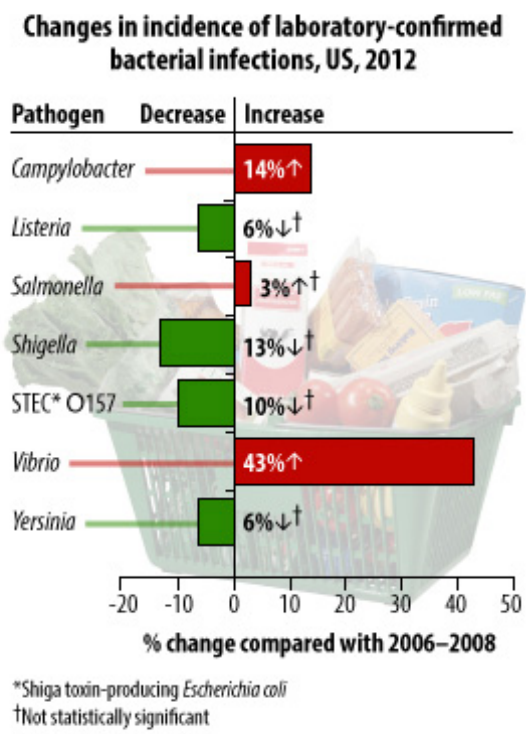
While microbial contamination results in economic losses, it also causes public health concerns, such as food poisoning.

Data from FoodNet, which monitors 15% of the US population, provide the best measure of trends in foodborne disease in the United States.

2012 data showed a lack of recent progress in reducing foodborne infections and highlight the need for improved prevention.

Campylobacter was the second most common infection reported in FoodNet (14.3 cases reported per 100,000 population). Incidence of infection was <u>14%</u> higher in 2012 compared with 2006–2008.

Although *Vibrio* infections are rare (0.41 cases reported per 100,000 population), the incidence of *Vibrio* infection was 43% higher in 2012 compared with 2006–2008.



Changes in incidence of laboratory-confirmed bacterial infections, United States, 2012 compared with 2006–2008

When food contamination is occurring, food microbiologists ask two general questions:

1. What microbes are contaminating the food?
2. How many microbes are there?

Why are these questions important?

How many microbes are acceptable in food?

It depends…consider "Ready-to-eat" foods - food ready for immediate consumption at the point of sale.

Can be raw or cooked, hot or chilled, and can be consumed without further heat-treatment including re-heating.

Criterion		**Microbiological quality** Colony-forming unit (cfu) per gram unless specified			
		Class A Satisfactory	**Class B Acceptable**	**Class C Unsatisfactory**	**Class D Unacceptable**
Aerobic colony count (ACC) [30°C/48hours]					
Food Category (see table next page)	1	$< 10^3$	$10^3 - < 10^4$	$\geq 10^4$	N/A
	2	$< 10^4$	$10^4 - < 10^5$	$\geq 10^5$	N/A
	3	$< 10^5$	$10^5 - < 10^6$	$\geq 10^6$	N/A
	4	$< 10^6$	$10^6 - < 10^7$	$\geq 10^7$	N/A
	5	N/A	N/A	N/A	N/A
Indicator organism (applies to all food categories)					
E. coli (total)		< 20	20 - < 100	≥100	N/A
Pathogens (apply to all food categories)					
Campylobacter spp.		Not detected in 25g	N/A	N/A	Present in 25g
E. coli O157		Not detected in 25g	N/A	N/A	Present in 25g
Salmonella spp.		Not detected in 25g	N/A	N/A	Present in 25g
V. cholerae		Not detected in 25g	N/A	N/A	Present in 25g
L. monocytogenes					
For food under refrigeration (excluding frozen food) or food intended for infants		Not detected in 25g	N/A	N/A	Present in 25g
For other ready-to-eat food		< 20	20 - < 100	N/A	≥ 100
V. parahaemolyticus		< 20	20 - < 100	$100 - < 10^3$	$\geq 10^3$
S. aureus		< 20	20 - < 100	$100 - <10^4$	$\geq 10^4$
C. perfringens		< 20	20 - < 100	$100 - <10^4$	$\geq 10^4$
B. cereus		$< 10^3$	$10^3 - < 10^4$	$10^4 - < 10^5$	$\geq 10^5$

N/A denotes "Not applicable"

Notice that high densities of microbes are tolerated, especially for Food Categories 3 and 4.

What foods might these be?

Why would ANY microbes be tolerated?

The number of microbes present, the composition of the food and the conditions under which the food is held impact the **shelf-life** of foods.

Non-perishable foods contain low numbers of microbes and will have a long shelf-life.
Examples?

Semi-perishable foods usually contain some moisture and will support microbial growth in time.
Examples?

Perishable foods present the most favorable conditions for microbial growth and will spoil in a short time (short shelf-life) if stored incorrectly.
Examples?

The number of microbes contaminating a given amount of a food item is called the **microbial load**.

Consumers assume that the microbial load in foods is quite low, but some foods carry a **high** load.

Yogurt, pickles, sauerkraut.

Even milk, following pasteurization, can contain as many as 1000 bacteria per ml.

e.g. **Acidophilus milk** – contains *Lactobacillus acidophilus* (bacteria), which are added *intentionally* at the factory to promote better food digestion, prevent some specialized tumors and (maybe) inhibit certain intestinal pathogens.

Where do the contaminating microbes come from?

Microbes in **air** can be deposited on food.

Poorly-washed crops can contain microbes from **soil** or **manure fertilizers**.

Shellfish, clams, oysters can concentrate microbes in their tissues as they filter **water**.

Remember *Karina brevis*, the red tide algae?

Rodents and insects can carry microbes to and from foods.

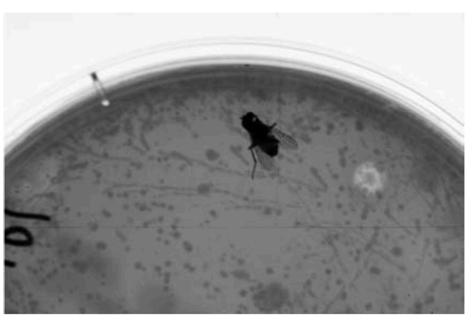


Fig. 1. Bacterial colonies obtained after placing an individual house fly on blood agar plate for 1 h followed by overnight incubation.

TABLE 1. IDENTIFICATION OF BACTERIA ISOLATED FROM WILD HOUSE FLIES (*MUSCA DOMESTICA*).

Bacteria Identification	Fatty acid SI[1]	16S rRNA sequence identity (%)	GenBank accession number[2]
Acinetobacter baumanni[3]	0.618	99	CP001172.1
Bacillus cereus	0.884	100	CP001177.1
Bacillus pumilus[3]	0.888	99	AE221329.1
Bacillus thuringiensis	0.845	99	AM778997.1
Cronobacter sakazakii[3]	0.879	N/R[5]	
Escherichia coli 0157:H7	0.814	99	CP001368.1
Methylobacterium persicinum[3]	N/I[4]	98	AB252202.1
Shigella dysenteriae	0.856	98	CP000034.1
Staphylococcus saprophyticus	0.799	99	AP008934.1
Staphylococcus sciuri[3]	N/I[4]	99	NR025520.1
Staphylococcus xylosus	0.772	99	G0222240.1

[1]SI = similarity index. Only samples with values over 0.500 are presented.
[2]best match by BLASTn.
[3]not previously identified in house flies.
[4]N/I: not identifiable by fatty acid analysis.
[5]N/R: not recovered for DNA analysis.

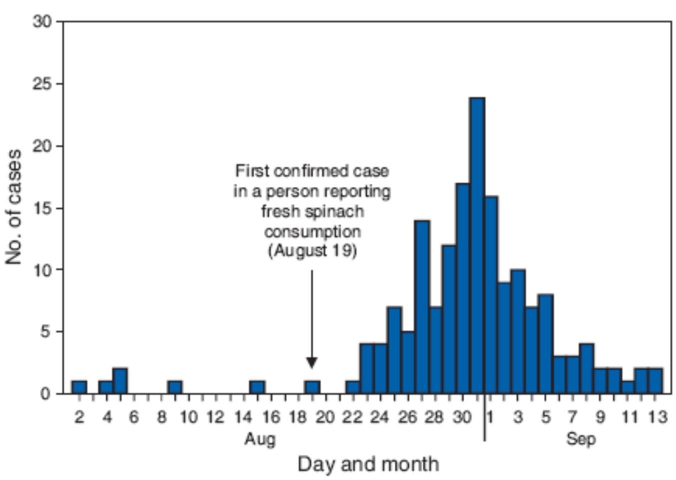
From: Butler et al: Pathogenic Bacteria Carried by House Flies

Perhaps the most important mechanism for food contamination is careless **human handling**.

e.g., meat processing – contents of animal intestines should not contact the meat (why?), but poor handling puts the food at risk of contamination.

Vegetable production – those grown organically (with manure fertilizers) should be thoroughly washed prior to distribution.

FIGURE 2. Number of confirmed cases (n = 171)* of *Escherichia coli* serotype O157:H7 infection, by date of illness onset — United States, August–September 2006



* Confirmed cases with known dates of illness onset reported as of 1:00 p.m. EDT on September 26, 2006.

Food contamination can be used as an act of **terrorism**.

1984 – Followers of the religious leader Bhagwan Shree Rajneesh sprayed a broth containing *Salmonella typhimurium* in dressings and vegetables in salad bars in Oregon, infecting 751 people.

The conditions for spoilage.

Food is essentially a **culture medium** for microbes. Therefore the principles that govern microbial growth in laboratory media and the environment, also govern growth in food.

<u>What parameters are important for food spoilage?</u>

Water – 18 – 20% *minimum* water content (this is why drying helps to preserve foods like potato chips).

pH – Most foods are slightly acidic, which can limit the number of bacteria that can contaminate the food (many still tolerate these conditions, though).

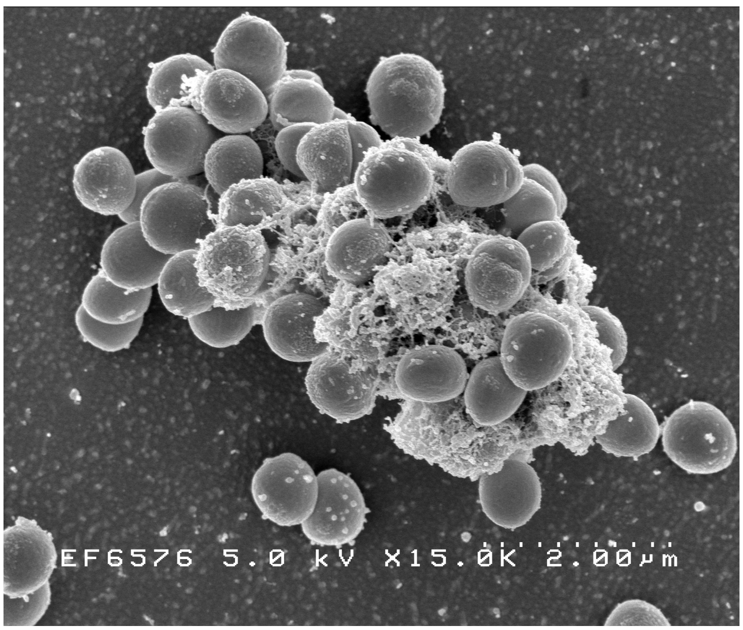
More acidic foods such as citrus fruits are spoiled by fungi, which grow well under acidic conditions.

Oxygen – Vacuum-sealed cans or bags will not support the growth of aerobic bacteria (but will allow for the growth of anaerobes, like *Clostridium botulinum*, which causes **???**).

Temperature – Your refrigerator (4° C) is cold enough to greatly slow the growth of most pathogens, but a bowl of potato salad left out in the sun at a picnic is the perfect temperature for microbial growth.

Physical structure – Steak will spoil more slowly than hamburger because bacteria have a more difficult time penetrating the steak. Bacteria can easily penetrate and be protected by the loose structure of hamburger.

Salt – Elevated salt will inhibit many microbes due to decreased osmotic potential. The staphylococci (e.g., *S. aureus*) actually thrive under these conditions and are often contaminants of ham.



Staphylococci colony in the presence of salt crystals. Note that the bacteria are not imploding, as would be expected with non-tolerant bacteria.

The foods…

Meats

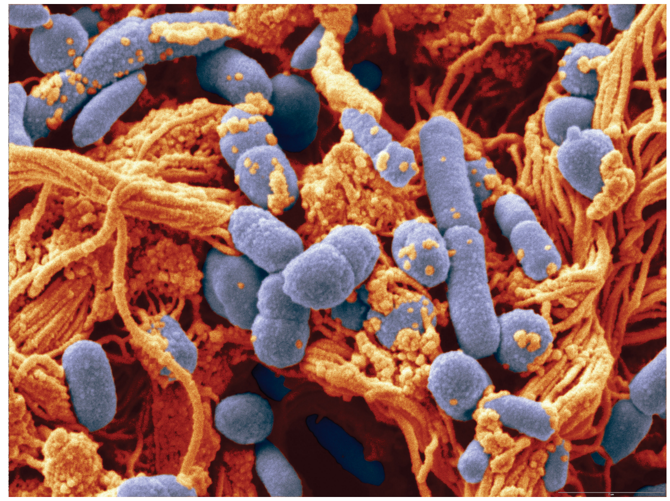
Spoilage of meat should be expected simply because of the nature of the food.

Cannot be pasteurized.
Full of nutrients that support the growth of microbes.
The numerous steps in processing allow many opportunities for contamination.

Sloppy harvesting of the meat.
Contaminated cutting boards and conveyor belts in the meat plant.
Improper holding temperatures.
Slow distribution to stores.

An early indication of spoilage is the loss of red color and the appearance of a brown color and a surface slime.

Spoiled ground beef (left).



Bacterial contamination of beef.

Seafood

Refrigeration is effective at limiting the growth of microbes that contaminate meats such as ground beef, but not fish. **Why?**

Therefore **freezing** is preferred.

Shellfish, in particular are of concern because they are **filter-feeders**.

Some shellfish can filter between thirty and sixty times their volume in water in one hour.

A medium sized clam (50 cm^3 volume) can filter as much as 3000 mls per hour (just under one gallon per hour).

If the water contains pathogenic bacteria, algae or viruses, these organisms can be accumulated in the shellfish tissue and eaten by the consumer.

Cholera (*Vibrio cholera*), brevotoxin poisoning (*Karina brevis*), hepatitis A (hepatitis A virus), typhoid fever (*Salmonella typhi*).

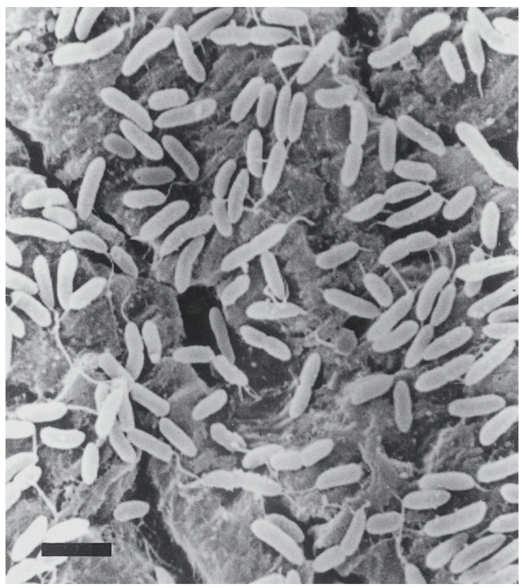
Fish **spoils faster** than other meats because the tissue is looser and microbes can more easily penetrate it.

Also, fish gills often trap microbes and keep them close to the body of the fish.

Poultry and Eggs

Contamination in eggs usually results from contamination that originated in the bird that laid the egg.

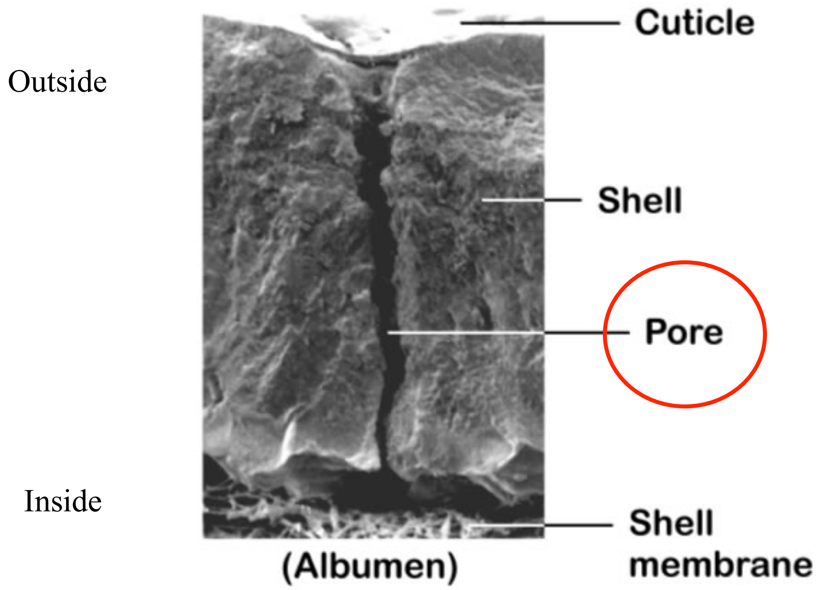
Salmonella spp. is a frequent contaminant (causes salmonellosis in humans– ~seven days of GI distress)



SEM of unidentified flagellated bacteria growing on the skin of a chicken carcass (Bar = 2 μm)

Commonly infects the birds and causes disease, but it easily transmitted to the eggs as well.

Eggs are normally sterile when laid, but the cuticle, shell and shell membrane can be penetrated by bacteria from the bird.



Microscopic cross-section of an egg shell (Lucore, 1994).

Proteus spp. (bacteria) can cause black rot of eggs when they break down the **amino acid** cysteine to produce hydrogen sulfide gas.

Why would there be a lot of amino acids in eggs?

Milk and Dairy Products

Milk is extremely nutritious…for humans **AND** microbes.

It is a solution of fats, proteins, carbohydrates, vitamins and minerals.

It has a neutral pH (7.0)

Milk's composition is closely connected with its propensity for spoilage:

- **87% water**
- **5% protein**
  Casein and lactalbumin.
- **5% carbohydrates**

  The major carbohydrate is lactose (sometimes called "milk sugar"), which is rarely found elsewhere.

Lactose is a disaccharide that is not digestible by many bacteria (those that can are usually harmless).

However, milk spoilage occurs when *Lactobacillus* or *Streptococcus spp*. that survive pasteurization multiply and ferment the lactose.

The acids that develop during fermentation, curdle the casein (the protein structure is altered), producing a **sour curd**.

While undesirable for milk, this fermentation is a necessary first step in the production of **cheese**.

- **3% fat** (butterfat)

When bacteria digest this fat into fatty acids, the milk or butter becomes sour (rancid).

Where do the organisms that contaminate milk originate?

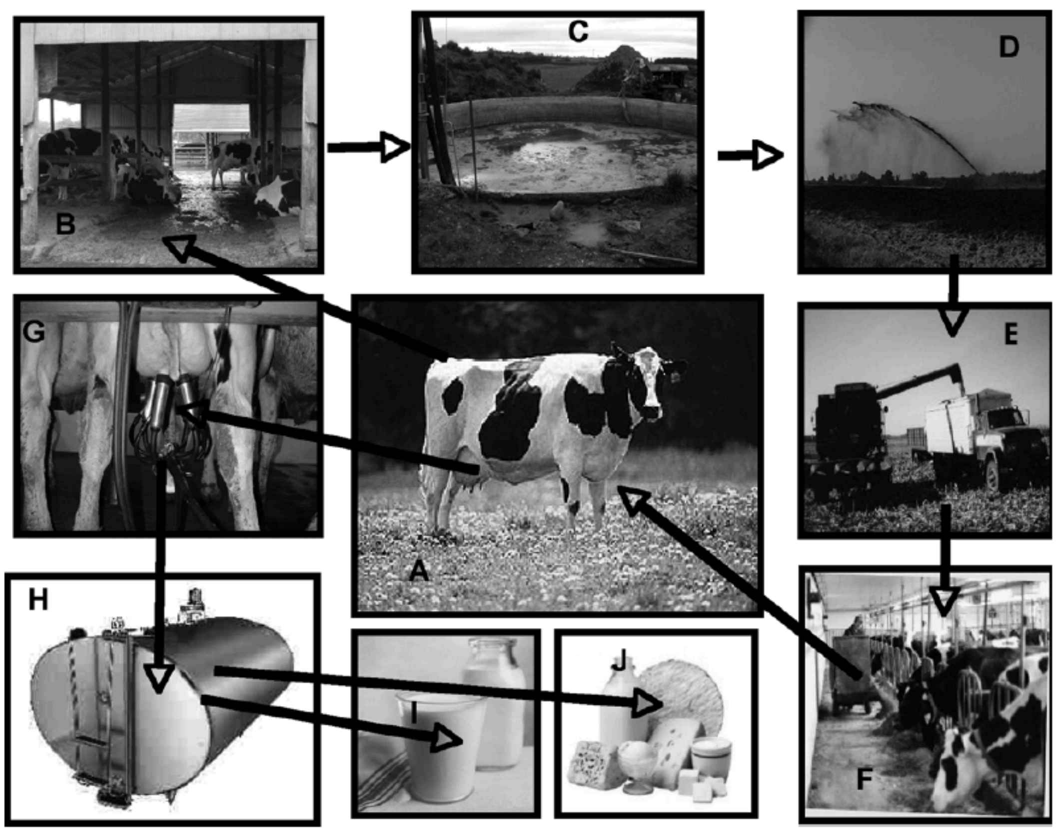


FIG. 2. Cycling of foodborne and veterinary pathogens in the dairy farm environment and their transfer to milk. (A) Amplification of the pathogen in the cow. (B) Dissemination in the immediate environment of the cow via feces. (C) Accumulation of feces on the dairy. (D) Spreading cow manure onto croplands. (E) Crops become contaminated with pathogens. (F) Contaminated feed consumed by cows. (G) Milk can become contaminated with pathogens during milking. (H) Pathogens enter bulk tank milk. (I,J) Unpasteurized milk, cheese, and other dairy products made from unpasteurized milk consumed by humans.

In the cow's udder, milk is sterile, but bacteria from these sources can colonize the ducts leading from the udder.

> The mammary glands of cows (and humans) can become inflamed due to a bacterial infection called mastitis. During a mastitis infection, very high numbers of bacteria (often staphylococci) can be in the udder and in the milk.

Soilborne *Lactobacillus* and *Streptococcus spp*. can be also acquired along with other pathogens such as *Listeria monocytogenes, Escherichia coli* O157:H7 and *Campylobacter jejunii* (bacteria), which can cause severe diarrhea in humans.