Microbiology for Growers: Understanding Organisms and What Can be Done




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February 27th, 2025

Why are we even worrying about this?

Why Should We Care?

Every year

- 48 million case
- 325,000 peopl
- 3,000 deaths e
- Economic loss
  10-83 billion d

Why Should People take Care?

Every year foodborne illnesses result in an estimated:

- 48 million cases of foodborne illness
- 125,000 people hospitalized for foodborne illness
- 3,000 deaths each year.
- Economic losses between 10-83 billion dollars.

Scallan, E., et al. 2011

Foodborne Illness Linked to Produce

It has been estimated that harmful foodborne bacteria, viruses and parasites "pathogens" account for 47.8 million illnesses annually in the United States

(Scallan, 2011)

Foodborne Illness Linked to Produce

- Outbreaks linked to the consumption of fresh cut fruits and vegetables are increasing
- From 1973 to 1997, the % of outbreak-associated cases attributed to fresh produce increased
  - From <1% to 6%
  - Median size of these outbreaks doubled

(Sivapalasingam, 2004)

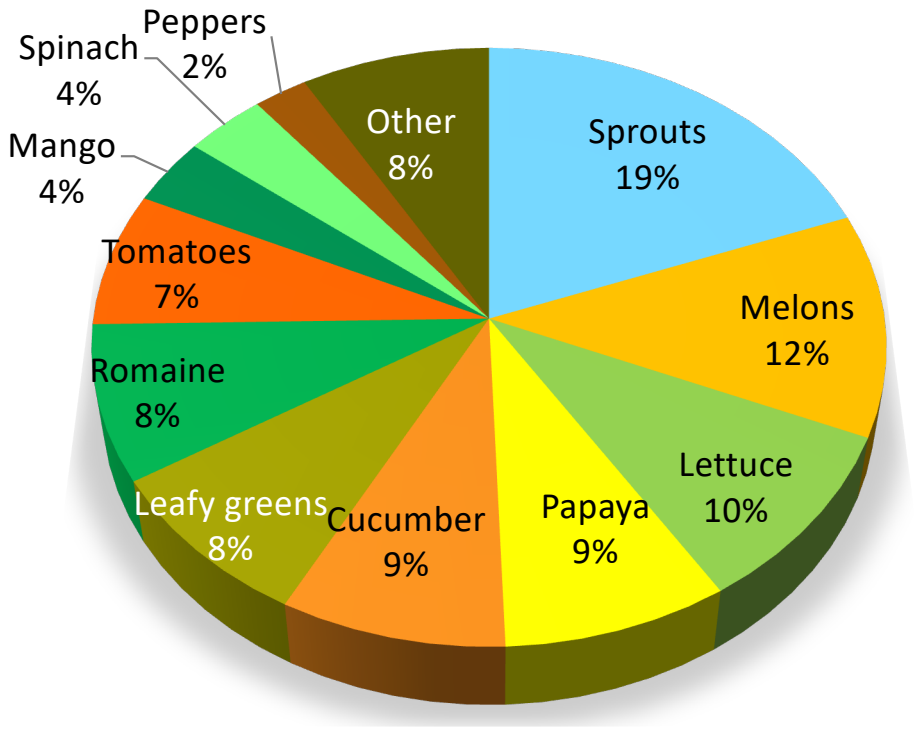
Foodborne Illness

	Food Category	QALY Loss*	Cost of Illness ($ Mil.)	Illnesses	Hospitalizations	Deaths
1	Poultry	14,744	2,462	1,538,468	11,952	180
2	Complex foods	7,518	2,078	3,001,858	11,674	189
3	Pork	7,830	1,894	449,322	4,334	201
4	Produce	6,171	1,404	1,193,970	7,125	134
5	Beef	5,766	1,338	760,799	4,818	131

Batz 2011

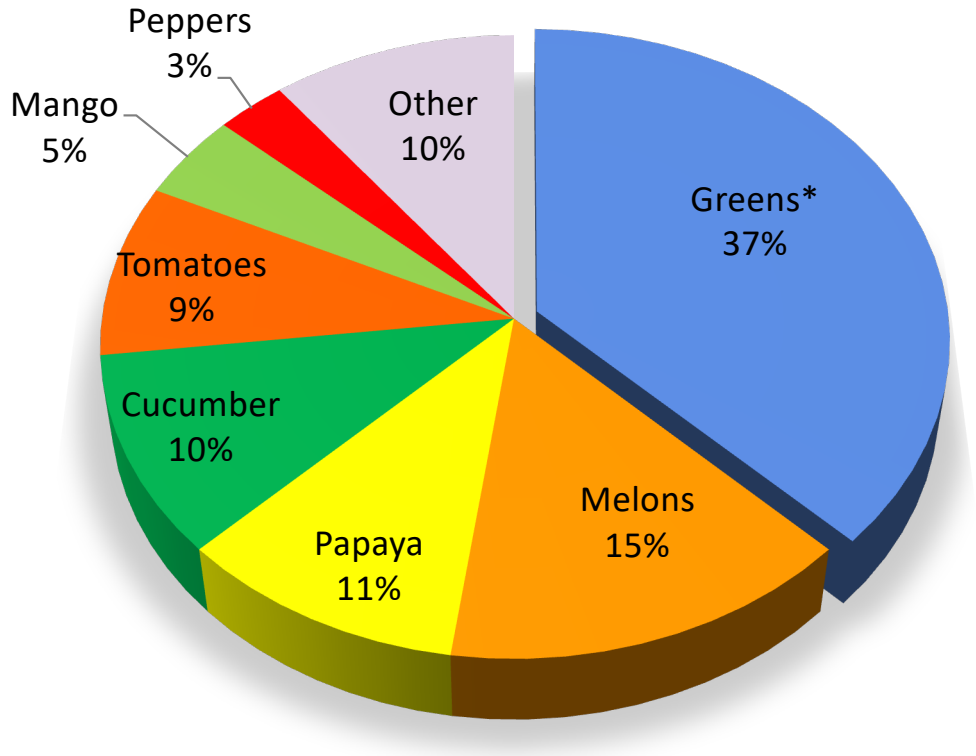
* Quality Adjusted Life Years

Multi-state Outbreaks (2010-2017)



Includes leafy greens not categorized as lettuce, Romaine, or spinach

Multi-state Outbreaks 2010-2017

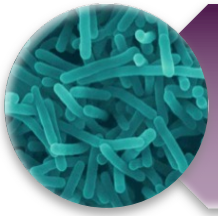


*Combining all greens into one category

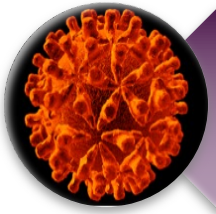

MICROBIOLOGY
REVIEW

Microbial Food Safety

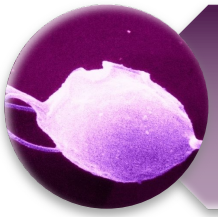
- There are three common types of biological hazards associated with food:



Bacteria (*E. coli, Salmonella, Shigella*, *Listeria*, etc.)



Viruses (Hepatitis A, Norovirus, Rotavirus)



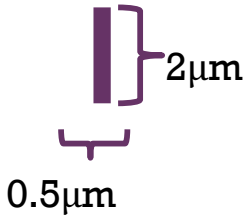
Parasites (Cyclospora, *Giardia*, *Cryptosporidium*, etc.)

Bacteria are sneaky, they like to hide

- Can you guess what this is a picture of?

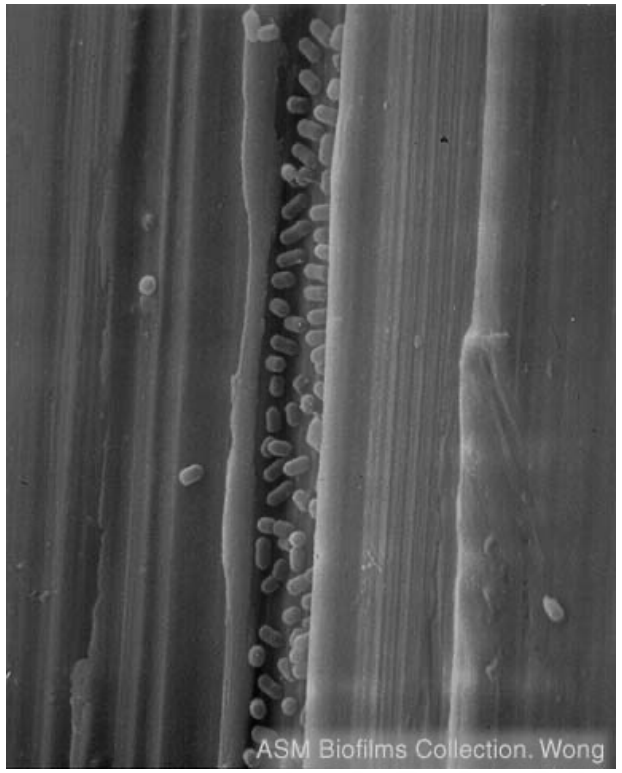
Polished stainless steel

- So how big are bacteria?



It would take 500 *E. coli* lined up end to end to equal 1 mm!

- Looks can be deceiving- need to rely on our practices



http://www.asmusa.org/edusrc/biofilms/hires/044h.jpg

Estimates of foodborne illness attributed to specific food commodities within the US 1998-2008

	Number (%) Illnesses				
	All agents	Bacterial	Parasitic	Viral	Chemical
Plants	4,939,155 (51.2)	1,171,874 (32.1)	69,023 (29.5)	3,635,505 (66.0)	62,753 (25.2)
Produce	4,438,970 (46.1)	989,550 (27.1)	69,023 (25.5)	3,332,983 (60.5)	47,414 (19.0)
Vegetables	3,274,822 (34.0)	750,290 (20.6)	1,277 (0.5)	2,505,325 (45.5)	17,931 (7.2)

Emerging Infectious diseases. Vol 19, No. 3, 2013

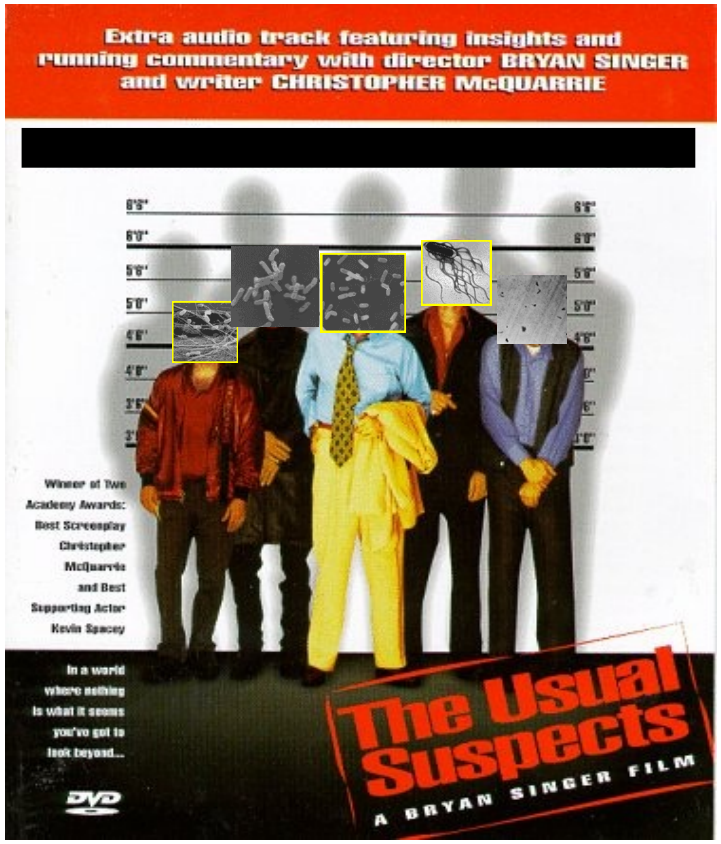
Estimates of foodborne illness attributed to specific food commodities within the US 1998-2008

	Number (%) Illnesses				
	All agents	Bacterial	Parasitic	Viral	Chemical
Fruits-nuts	1,164,148 (12.1)	239,261 (6.6)	67,746 (29.0)	827,657 (15.0)	29,483 (11.8)
Fungi	4,542 (0)	[illegible] (0)			3,857 (1.5)
Leafy	2,133,383 (22.1)	186,140 (5.1)	84 (0)	1,938,047 (35.2)	9,113 (3.7)
Root	347,359 (3.6)	96,375 (2.6)		249,744 (4.5)	1,240 (0.5)
Sprout	32,706 (0.3)	32,706 (0.9)			
Vine-stalk	756,831 (7.9)	434,384 (11.9)	1,193 (0.5)	317,534 (5.8)	3,721 (1.5)

Emerging Infectious diseases. Vol 19, No. 3, 2013

The Usual Suspects

- Bacteria
  - *Salmonella*
  - *Shigella*
  - *Campylobacter*
  - *E. coli* O157:H7
  - *Listeria monocytogenes*
- Viruses
  - Norovirus
  - Hepatitis
- Parasites
  - *Cyclospora*
  - *Cryptosporidium*



Salmonella

Disease Microorganism

Salmonellosis

Salmonella (bacteria)

Source of Illness

Raw produce sources implicated in outbreaks include melons, tomatoes, alfalfa sprouts and orange juice. Raw meats, poultry, milk and other dairy products, shrimp, frog legs, yeast, coconut, pasta, and chocolate are most frequently involved. Individuals carrying this organism but exhibiting no symptoms of illness could contaminate produce due to poor hygiene practices.

Symptoms

Non-typhoid Infections (gastroenteritis)

Onset: Generally 8-12 hours after eating.
Symptoms: Abdominal pain and diarrhea, and sometimes nausea and vomiting. Symptoms last a day or less and are usually mild. Can be more serious in older or debilitated people.

Shigella

Disease/Microorganism	Source of Illness	Symptoms
Shigellosis (bacillary dysentery) *Shigella* (bacteria)	Have been found in lettuce, green peas, milk, dairy products, poultry, and potato salad. Food becomes contaminated when a human carrier does not wash hands and then handles produce. Organisms multiply in food left at room temperature.	Onset: 1-7 days after eating. Symptoms: Abdominal cramps, diarrhea, fever, sometimes vomiting and blood, pus, or mucus in stool.

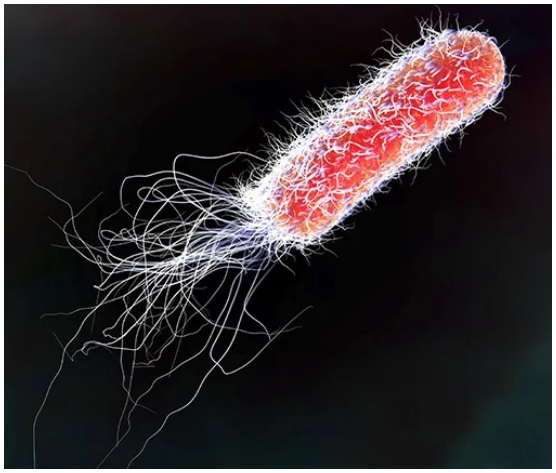
Facultative anaerobic. Found in intestines and feces of warm-blooded animals. Causes a toxin mediated foodborne infection. Accounts for 10% bacterial foodborne illnesses in the US.

E. coli O157:H7

Disease/Microorganism

Infection by *Escherichia coli* (bacteria) O157:H7

Syndrome (HUS)



Source of Illness

Illnesses associated with *E. coli* O157:H7 have been associated with unpasteurized apple juice and cider, ground beef, lettuce, salads, salmon and cheese.

Symptoms

Onset: From 8-44 (12-72) hours after consumption of contaminated food.

Symptoms: Fever, abdominal spasms, shivering, aqueous diarrhea, vomiting and dehydration.

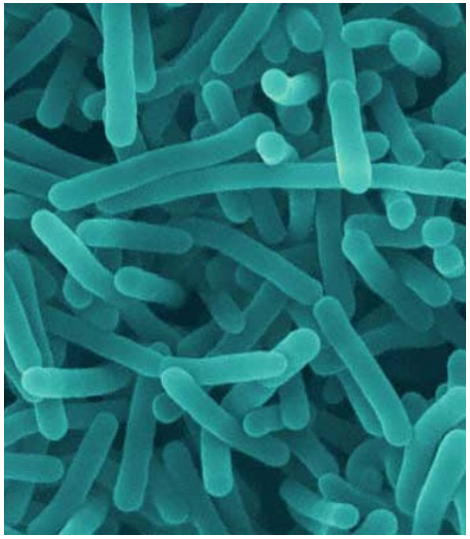
The mortality rate is very high. Leads to the occurrence of HUS in children.

Listeria monocytogenes

Disease/Microorganism

Listeriosis, meningitis encephalitis

Listeria monocytogenes (bacteria)



Source of Illness

Found in unpasteurized soft cheese, unpasteurized milk, seafood products, frozen cooked crabmeat, cooked shrimp and cooked surimi, coleslaw and raw produce. Listeria is much more resistant to heat, salt, nitrite, and acidity than many other micro-organisms. They survive and grow at low temperatures. Other potential sources of contamination include processing equipment, sewage and other inert surfaces.

Symptoms

Onset: From 7-30 days after eating, but most symptoms have been reported 48-72 hours after consumption of contaminated food.

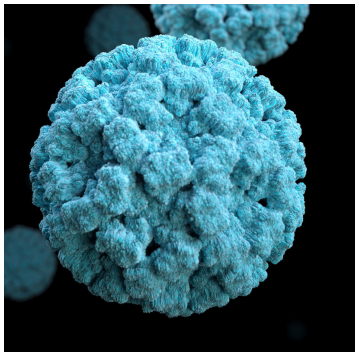
Symptoms: Fever, headache, nausea, and vomiting. Primarily affects pregnant women and their fetuses, newborns, the elderly, people with cancer, and those with impaired immune systems. Can cause fetal and infant death.

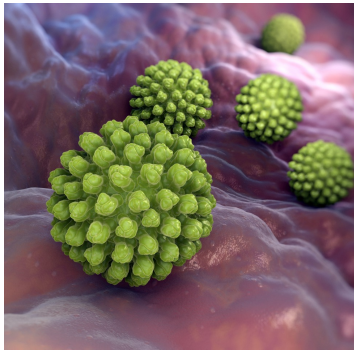
Viruses that have been reported as transmitted by foods include:

Hepatitis A (any food prepared with human contact, or contaminated water)

Norovirus (sewage, contaminated water, salad ingredients, clams and oysters)

Rotaviruses (sewage, contaminated water, salad ingredients, raw seafood)

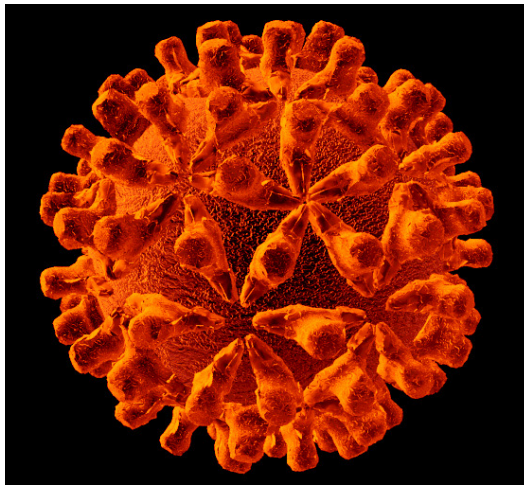




Hepatitis A

Disease/ Microorganism

Hepatitis A (virus)



Source of Illness

Outbreaks have been associated with raspberries, lettuce, mollusks (oysters, clams, mussels, scallops) and other foods that become carriers when untreated sewage pollutes them. Raw shellfish are especially potent carriers, since cooking does not always kill the virus.

Symptoms

Symptoms and Onset:

Begin with malaise, appetite loss, nausea, vomiting, and fever.

After 3-10 days patient develops jaundice with darkened urine.
Severe cases can cause liver damage and death.

Protozoa Most Commonly Associated With Human Infections

Protozoa most commonly associated with human infections include:

- Giardia (contaminated water, vegetables including carrots)
- Entamoeba (polluted waters, vegetables)
- Toxoplasma (raw meats, vegetables and fruits)
- Cryptosporidium (contaminated water, vegetables)
- Cyclospora (water, strawberries, raspberries and vegetables)

Okay, What Can We Do To Minimize the Risks?

- Focus on risk reduction, not risk elimination.
- Current technologies cannot eliminate all potential food safety hazards associated with fresh produce that will be eaten raw.
- Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables
- Good Agriculture Practices (GAPs)
- And as of 2016, we have the Produce Safety Rule

Enter FSMA

- Food Safety Modernization Act (FSMA)
- Effective Jan 4, 2011
- Biggest change since 1938
  - Federal Food Drug & Cosmetic Act

The Food Safety Modernization Act (FSMA)

- FSMA includes:
  - **Produce Safety Rule**
  - Preventive Controls for Human Food
  - Preventive Controls for Animal Food
  - Foreign Supplier Verification Programs
  - Accreditation of Third-Party Auditors/Certification Bodies
  - Sanitary Transportation of Human and Animal Food
  - Prevention of Intentional Contamination/Adulteration
- Focuses on the prevention of food safety issues and encompasses the entire food system

FDA FOOD SAFETY MODERNIZATION ACT

FSMA's New Food Safety Regulations; The Big 7

- Produce Safety Rule
- Preventive Controls for Human Food Rule
- Preventive Controls for Animal Food Rule
- Foreign Supplier Verification Rule
- Sanitary Transport Rule
- Protect Against Intentional Adulteration
- Third-Party Certification

Produce Safety Rule

Key Requirements

- Agricultural Water/Water quality: The final rule adopts the general approach to water quality proposed in the supplemental rule, with some changes.
- Biological Soil Amendments
- Sprouts
- Domesticated and Wild Animals
- Worker Training and Health and Hygiene
- Equipment, Tools and Buildings

On-going Issues with the Produce Safety Rule

- What is a farm?
- Biological soil amendments of animal origin BSAAO? This was left blank and remains blank to this day!!
- Water testing requirements. FDA had a plan in place and was to start regulating it in Jan 2022. They blew it up!!
- Domesticated and Wild Animals. We don't want animals in the fields contaminating our crops, yet you just can't go around wiping out wildlife, especially endangered species.

What is a farm?

[Code of Federal Regulations]
[Title 21, Volume 1]
[CITE: 21CFR1.227]

TITLE 21--FOOD AND DRUGS
CHAPTER I--FOOD AND DRUG ADMINISTRAT
DEPARTMENT OF HEALTH AND HUMAN SERVI
SUBCHAPTER A - GENERAL

PART 1 -- GENERAL ENFORCEMENT REGULATIONS

Subpart H - Registration of Food Facilities

General Provisions

Sec. 1.227 What definitions apply to this subpart?

Food has the meaning given in section 201(f) of the Federal Food, Drug, and Cosmetic Act:

(1) Except for purposes of this subpart, it does not include:

(i) Food contact substances as defined in section 409(h)(6) of the Federal Food, Drug, and Cosmetic Act; or

(ii) Pesticides as defined in 7 U.S.C. 136(u).

(2) Examples of food include: Fruits, vegetables, fish, dairy products, eggs, raw agricultural commodities for use as food or as components of food, animal feed (including pet food), food and feed ingredients, food and feed additives, dietary supplements and dietary ingredients, infant formula, beverages (including alcoholic beverages and bottled water), live food animals, bakery goods, snack foods, candy, and canned foods.

Harvesting applies to farms and farm mixed-type facilities and means activities that are traditionally performed on farms for the purpose of removing raw agricultural commodities from the place they were grown or raised and preparing them for use as food. Harvesting is limited to activities performed on raw agricultural commodities, or on processed foods created by drying/dehydrating a raw agricultural commodity without additional manufacturing/processing, on a farm. Harvesting does not include activities that transform a raw agricultural commodity into a processed food as defined in section 201(gg) of the Federal Food, Drug, and Cosmetic Act. Examples of harvesting include cutting (or otherwise separating) the edible portion of the raw agricultural commodity from the crop plant and removing or trimming part of the raw agricultural commodity (*e.g.*, foliage, husks, roots or stems). Examples of harvesting also include cooling, field coring, filtering, gathering, hulling, shelling, sifting, threshing, trimming of outer leaves of, and washing raw agricultural commodities grown on a farm.

(1) *Domestic facility* means any facility located in any State or Territory of the United States, the District of Columbia, or the Commonwealth of Puerto Rico that manufactures/processes, packs, or holds food for consumption in the United States.

(2) *Foreign facility* means a facility other than a domestic facility that manufactures/processes, packs, or holds food for consumption in the United States.

Farm means:

(1) Primary production farm. A primary production farm is an operation under one management in one general (but not necessarily contiguous) physical location devoted to the growing of crops, the harvesting of crops, the raising of animals (including seafood), or any combination of these activities. The term "farm" includes operations that, in addition to these activities:

. all processed food used in such activities is
der the same management, or is processed food
definition; and

uch activities is consumed on that farm or another farm under the same

processing of food that is not consumed on that farm or another farm
ent consists only of:

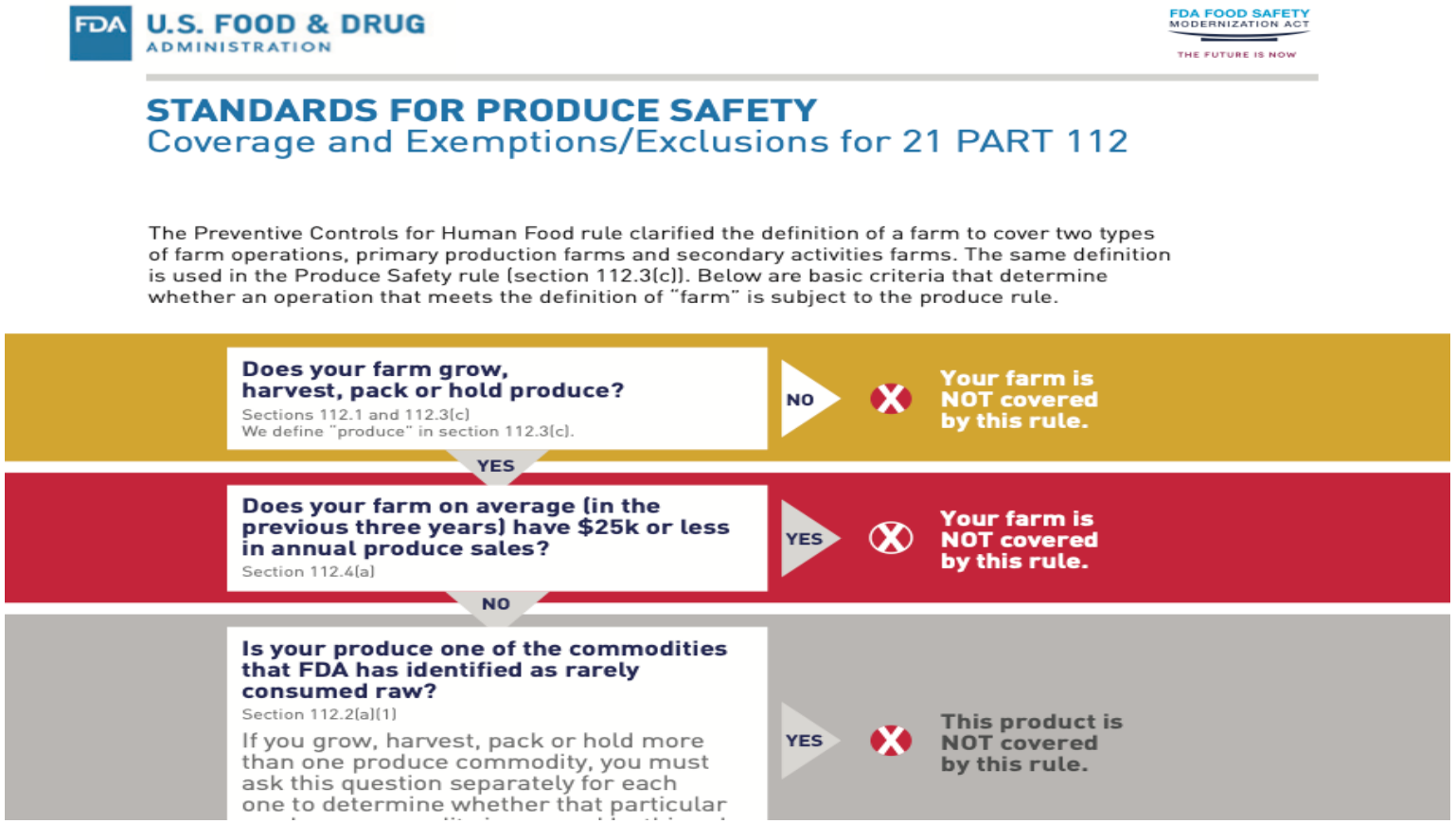
g raw agricultural commodities to create a distinct commodity (such as
pes to produce raisins), and packaging and labeling such commodities,
ufacturing/processing (an example of additional manufacturing/processing

pulate the ripening of raw agricultural commodities (such as by treating
gas), and packaging and labeling treated raw agricultural commodities,
ufacturing/processing; and

eling raw agricultural commodities, when these activities do not involve
ng/processing (an example of additional manufacturing/processing is

es farm. A secondary activities farm is an operation, not located on a
m, devoted to harvesting (such as hulling or shelling), packing, and/or
tural commodities, provided that the primary production farm(s) that
r raises the majority of the raw agricultural commodities harvested,
the secondary activities farm owns, or jointly owns, a majority
ary activities farm. A secondary activities farm may also conduct those
allowed on a primary production farm as described in paragraphs (1)(ii)
nition.

What is a farm?



FSMA Produce Safety Rule

- The first-ever mandatory federal standard for growing, harvesting, packing, and holding of fresh produce
- Some growers may be eligible for an exemption or excluded based on:
  - Commodities grown but rarely consumed raw
  - Processing activities that include a 'kill step'
  - Based on average annual produce sales
  - Also, average annual food sales and sales to 'qualified end users'
- Ultimately, all growers should understand and take action to reduce food safety risks on the farm

So what can you do? Multiple Hurdles

- Sampling doesn't work, you need to establish where you can minimize risk.
- Once established, some control or intervention can be put in place to lower the risk of failure at that point.
- The theory is the more "torturous" the path, the hard to get through.

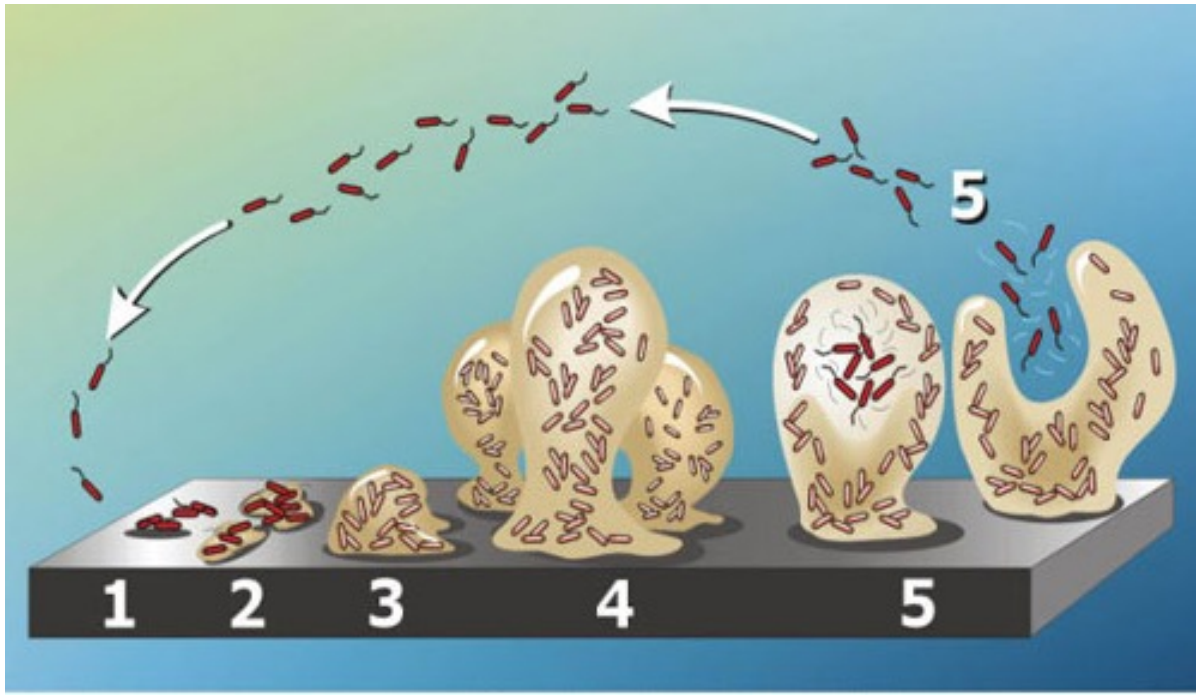
Catch-22

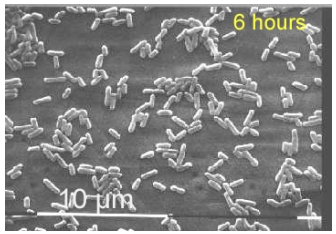
- Here is the "Catch-22"
  - We all want safer food…
  - We start testing…
  - The food quality increases…
  - Now you need to test more to continue to improve because the organisms are harder to find…
  - Testing now becomes less effective.
- This is where programs like PSR, PCHF, and GAPs were implemented

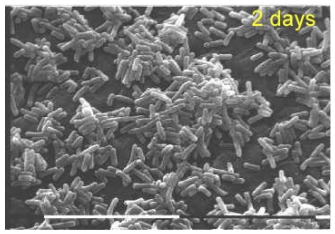
What Happened in Colorado?

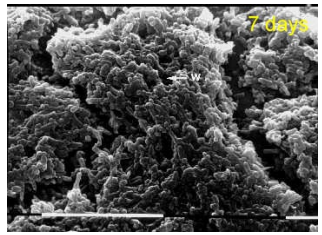
- Biofilms are collections of microscopic organisms which have attached themselves to a surface (and each other) in the interests of survival.
- Biofilms are found everywhere
- A biofilm is characterized by the sticky adhesive substance (a matrix of extracellular polymeric substance (EPS)) secreted by its members.
- This substance becomes a supportive matrix, pulling the colonists together and protecting them from the outside world.
- Attracts more organisms as it grows and provides anchoring points.

The Making of A Biofilm









Survival of Pathogens on Packinghouse Surfaces

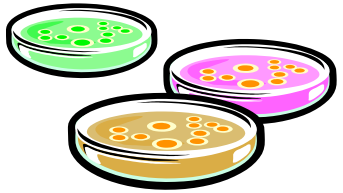
- Laboratory testing
  - Stainless Steel
  - PVC
  - Wood
  - Sponge Rollers
  - Conveyer Belt Material
  - Tomatoes

Frequently Asked Questions

Is a high total plate count bad?

Freshness of a product is sometimes judged by the total number of bacteria present. The tests are sometimes called:

- Total plate count (TPC)
- Aerobic plate count (APC)
- Heterotrophic plate count (HPC)



This test doesn't tell you if any pathogens are present, thus high plate count doesn't mean someone will get sick. Some products have naturally high plate counts (i.e., spouts, seafood). In these cases, plate counts can't be used as an absolute measure of freshness.

Is my product that is positive for *E. coli* going to make people sick?

E. coli is a natural part of the human gut flora. Usually, small amounts of *E. coli* in food won't make people ill. Certain strains, such as *E. coli* O157:H7 are very pathogenic. In general, the level of *E. coli* in a food product is a measure of contamination. *E. coli* is a good indicator organism; if it is present, then there is an increased risk of other fecal pathogens being present.

I use chlorine in my wash process, shouldn't that kill all the pathogens?

Yes and no. In a perfect world, if chlorine or almost any other disinfectant used on foods comes in contact with a pathogen, it should be killed. The problem is we don't live in a perfect world. Organic loading on the food or contact surface competes for active chemistry. Some bacteria, especially spores, are or can become resistant to certain disinfectants. Biofilms can develop, forming a protective layer that insulates the bacteria from a disinfectant. Lastly, some bacteria are hard to reach.

Summary

- Foodborne illness is prevalent
- Produce is problematic as it is frequently eaten raw
- There are several common foodborne pathogens of concern
- New regulations are designed to be proactive
- The more, the merrier, multiple hurdles can increase the safety of any system
- PSR is a preventive system
- Need to understand the regs to properly implement a successful food safety program