



# Microbiology for Growers: Understanding Organisms and What Can be Done



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Food Science and Human Nutrition  
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+ Why are we even worrying about this?





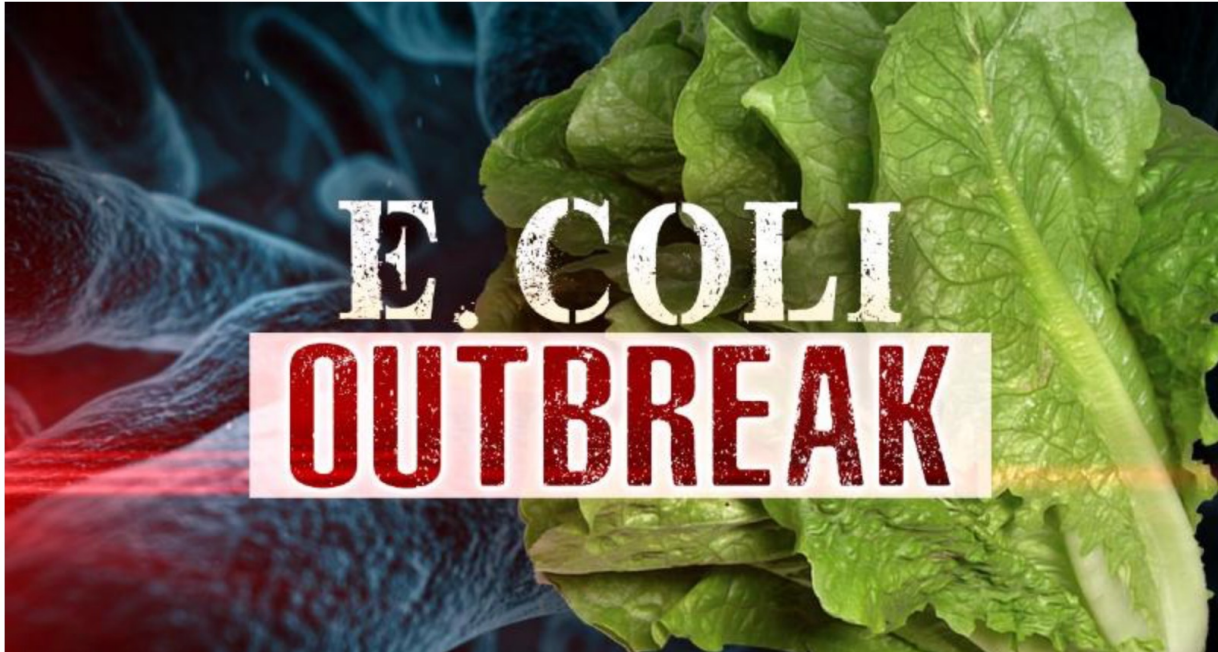


# Why Should We Care?

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Food Safety News  
**FDA: Romaine lettuce E. coli outbreak tied to nine more illnesses**



The daily... and are co... CDPH off...  
System healthy persons infected with *Salmonella* often experience fever, diarrhea (which may be bloody), nausea, vomiting and abdominal pain. In rare circumstances, infection with *Salmonella* can result in the organism getting into the...  
investigated by the Health Protection Agency. Photograph: Flickr International/AV...

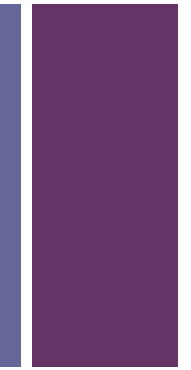
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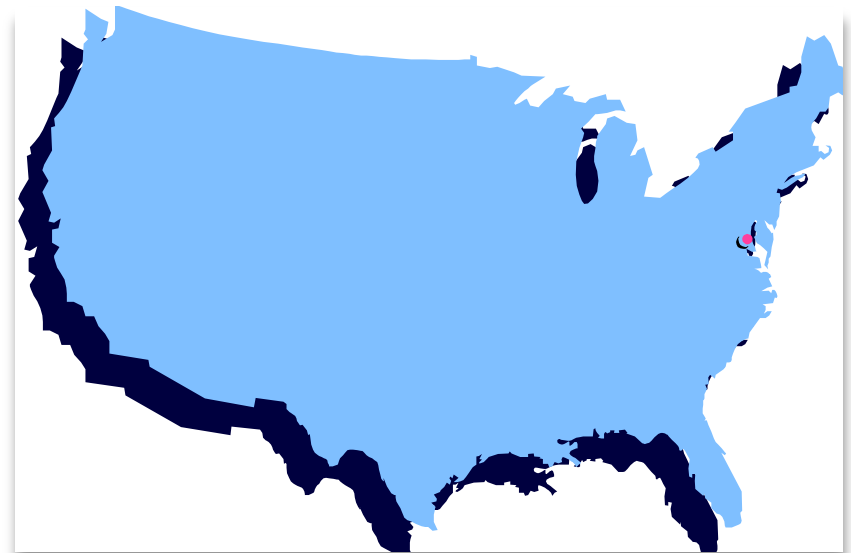


# + Why Should People take Care?

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.

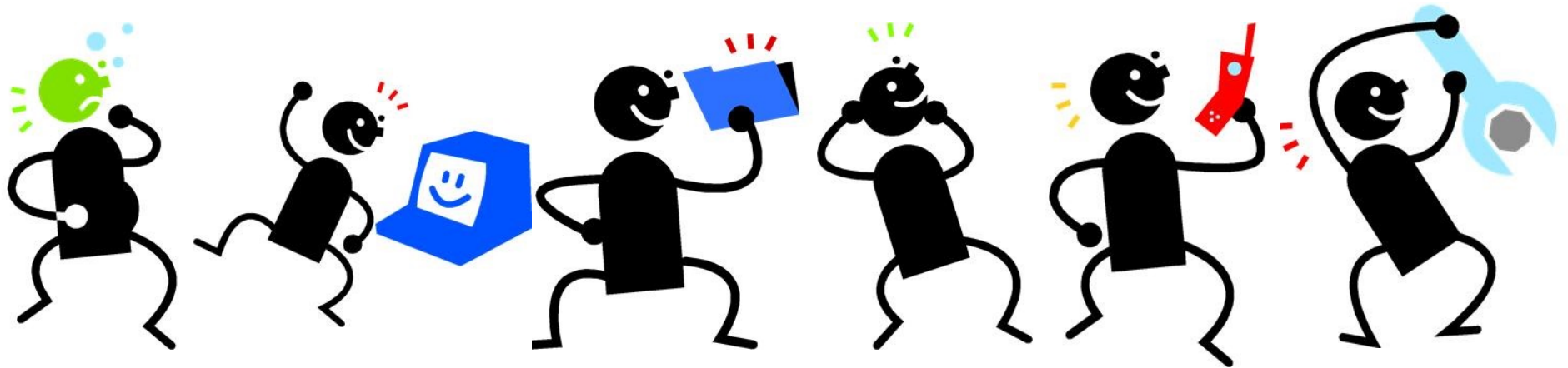
Scallan, E., et al. 2011



# + 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

## 1 Out of 6 People



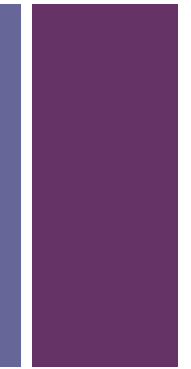
(Scallan, 2011)

# + Foodborne Illness Linked to Produce

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

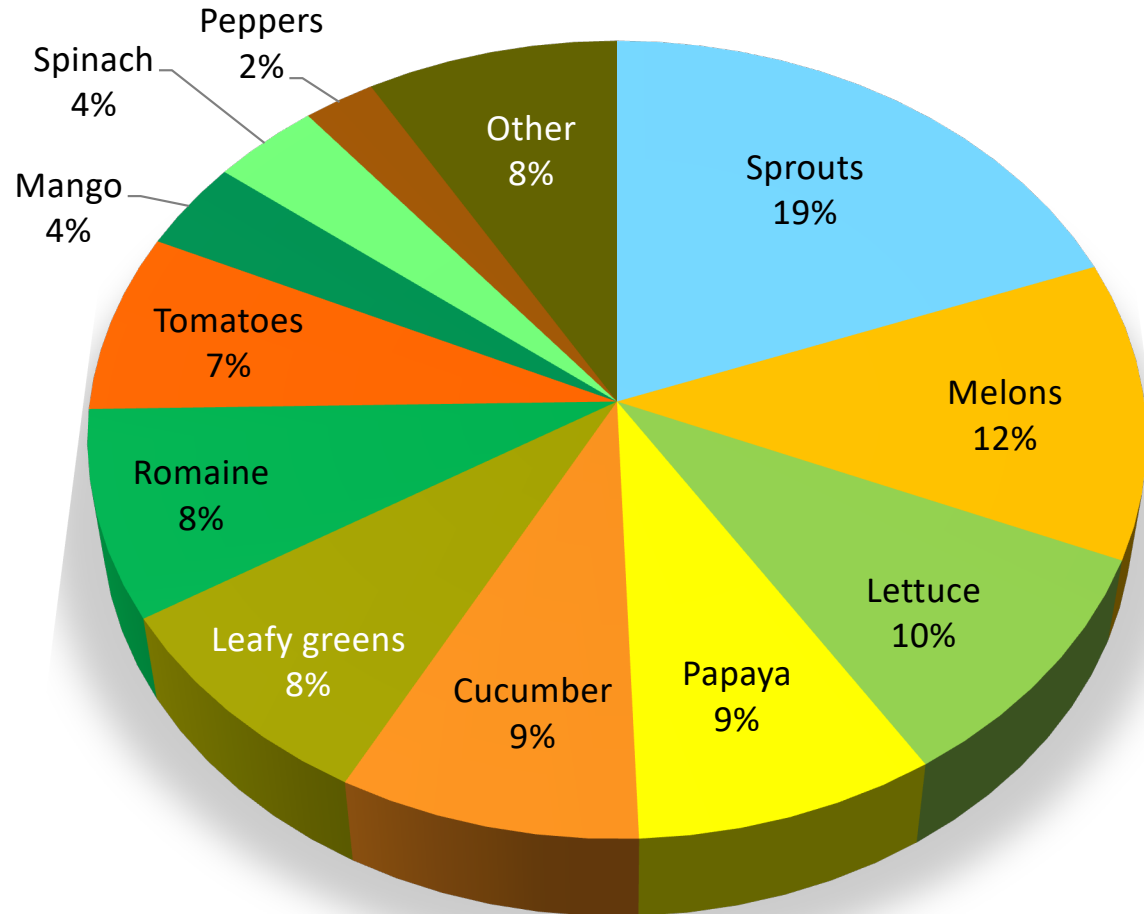
(Sivapalasingam, 2004)

# + 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

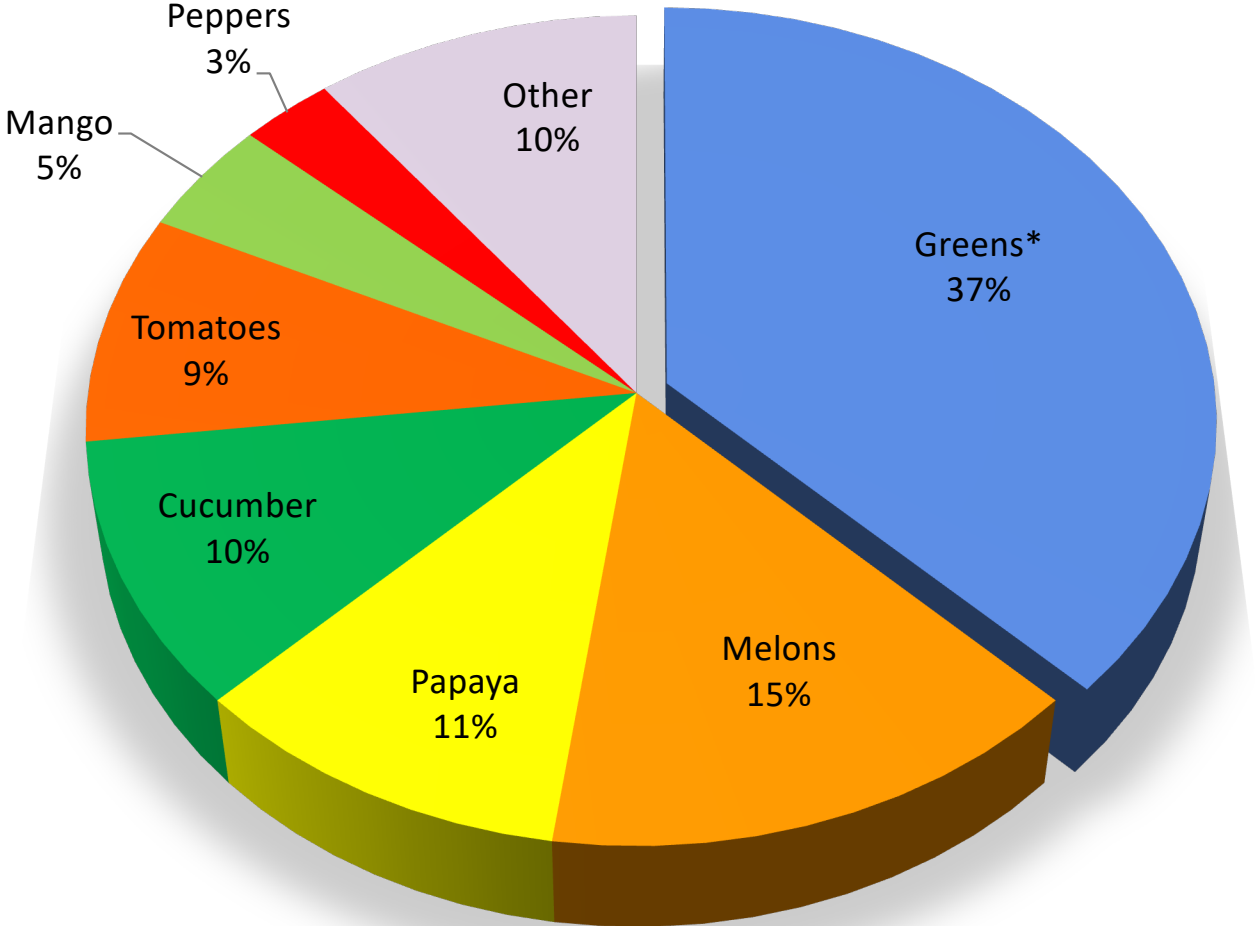
# Multi-state Outbreaks (2010-2017)



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



# Multi-state Outbreaks 2010-2017



\*Combining all greens into one category

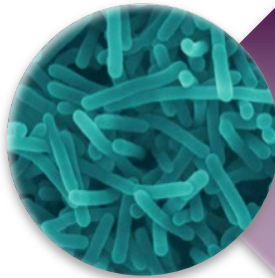


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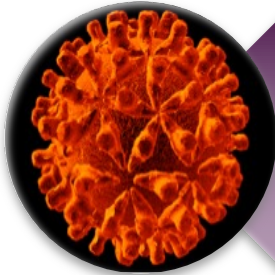


# Microbial Food Safety

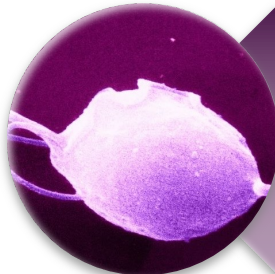
- There are three common types of biological hazards associated with food:



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



Viruses (Hepatitis A,  
Norovirus, Rotavirus)

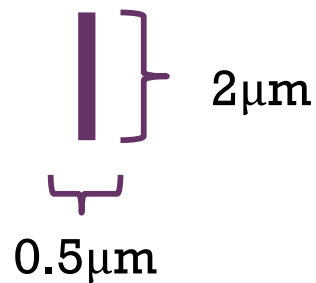


Parasites (*Cyclospora*,  
*Giardia*, *Cryptosporidium*,  
etc.)

# + Bacteria are sneaky, they like to hide

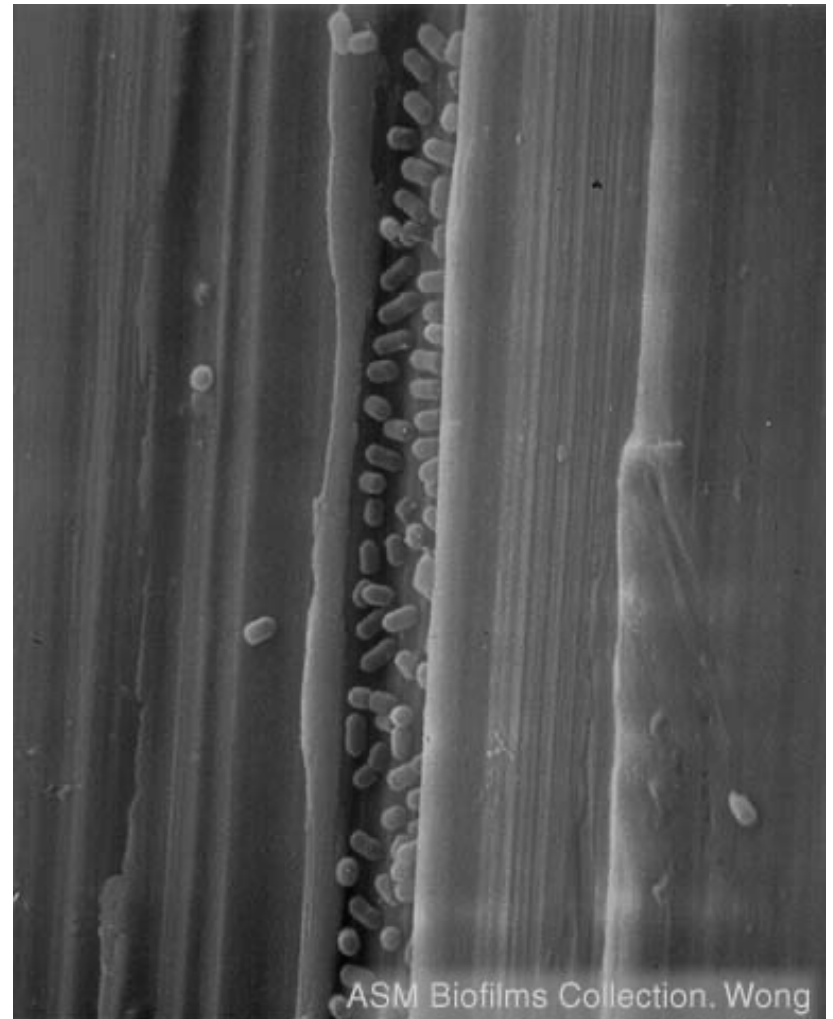
- Can you guess what this is a picture of?  
Polished stainless steel

- 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



+ 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)



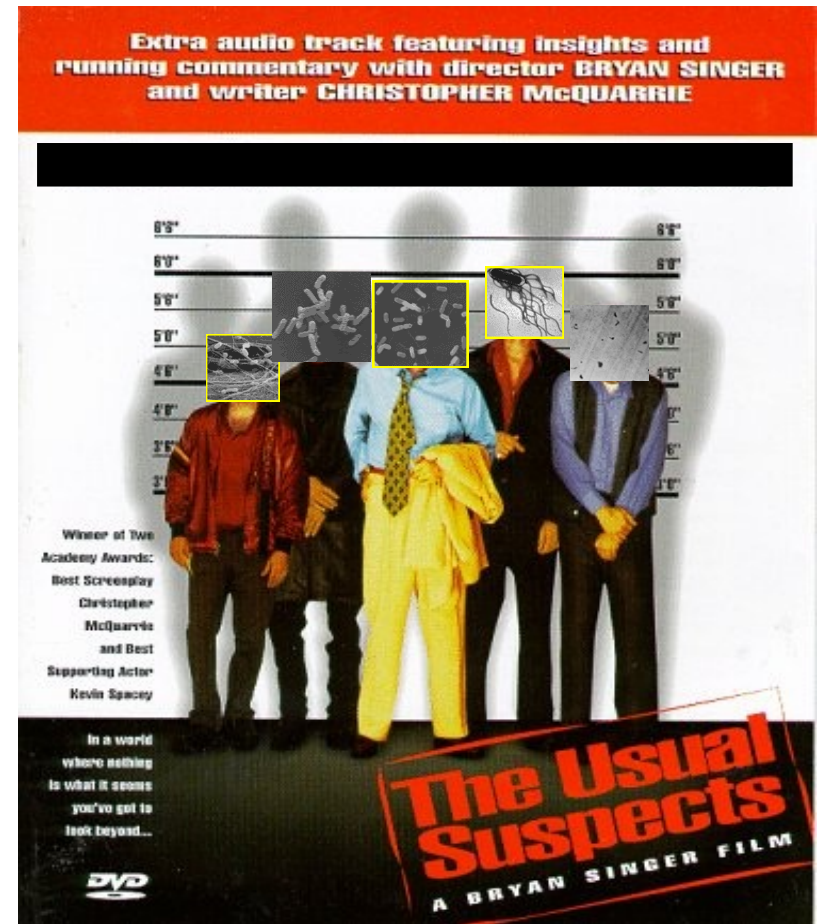
## + Estimates of foodborne illness attributed to specific food commodities within the US 1998-2008

	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)	686 (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)



# The Usual Suspects

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



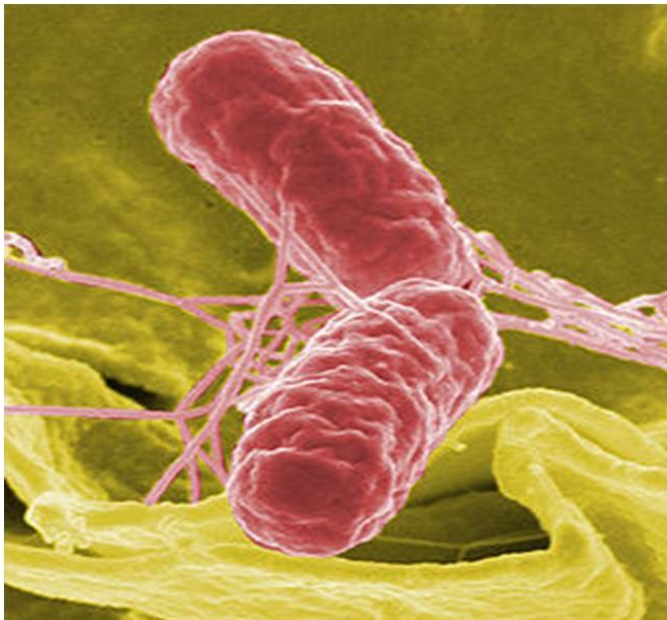
# Salmonella



## 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.

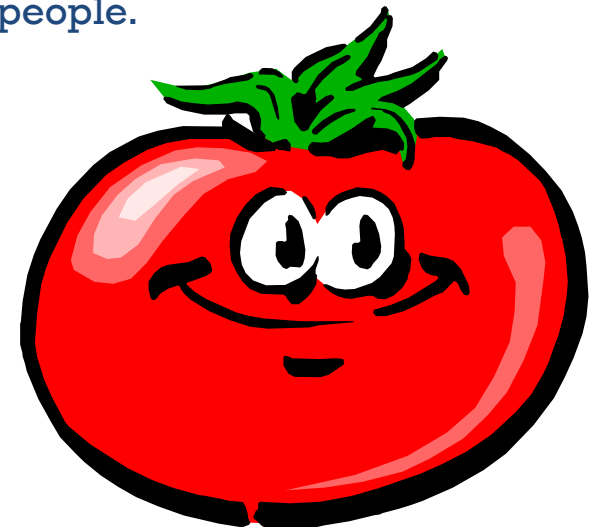
## Symptoms

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)  <i>Shigella</i> (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

Hemolytic Uremic 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.

Mortality rate is very high.

Leads to the occurrence of Hemolytic Uremic Syndrome (HUS) in children.





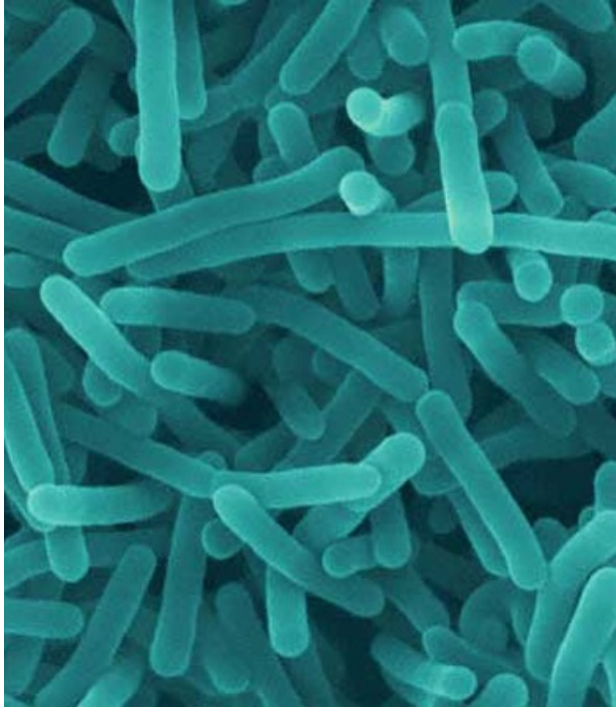
# *Listeria monocytogenes*



## **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 (imitation shellfish), 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.

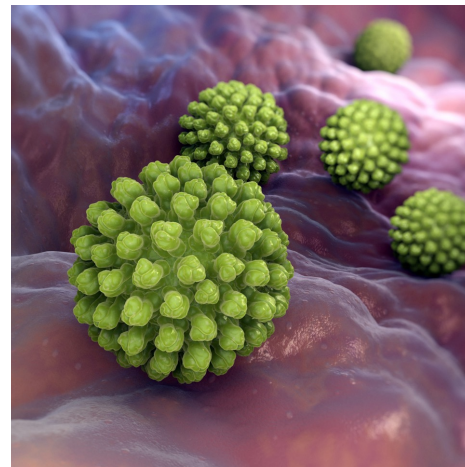
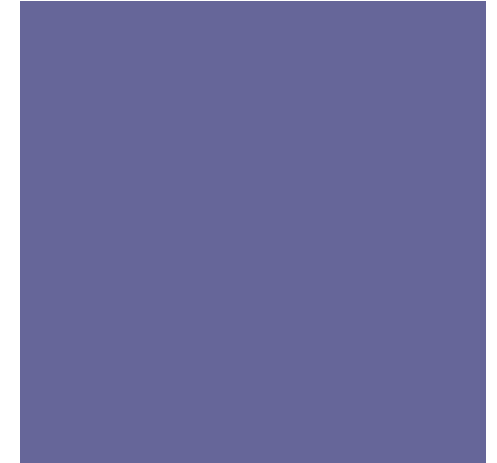
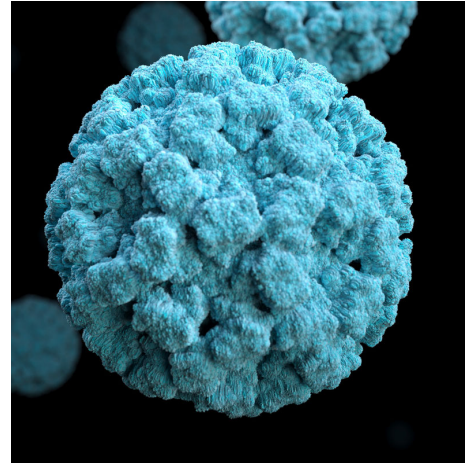


Viruses that have been reported as transmitted by foods include:

**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)**

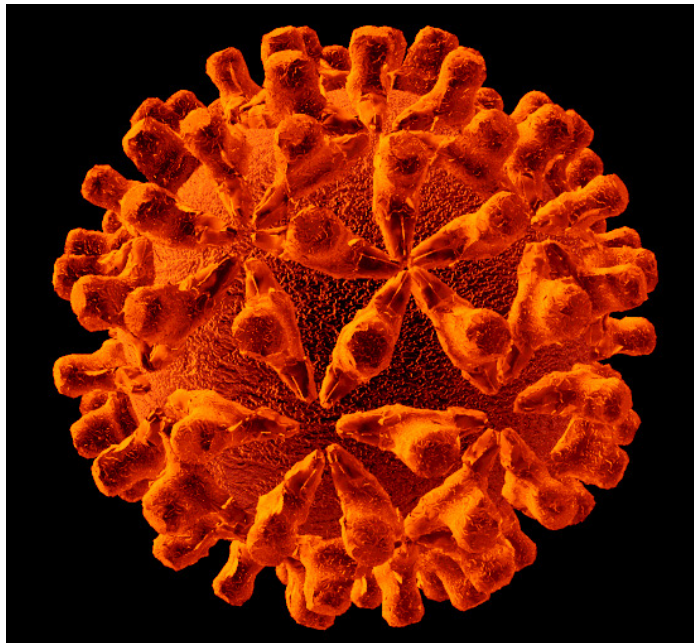


# Hepatitis A



## 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





# 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

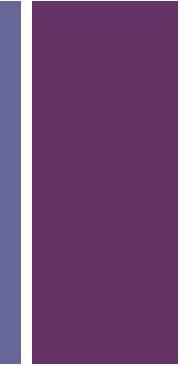
- What is a farm?
- Biological soil amendments of animal origin  
BSAAO? This was left blank and remains blank to this day!!
- Water testing requirements. FDA had a plan in place and was to start regulating it in Jan 2022. They blew it up!!
- Domesticated and Wild Animals. We don't want animals in the 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]

(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 is located outside the United States.

*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.

operation under one management in one or another farm under the same management.

located on that farm or another farm.

to constitute a distinct commodity (such as by treating and labeling such commodities, without additional manufacturing/processing).

raw agricultural commodities (such as by treating and labeling such commodities, without additional manufacturing/processing).

when these activities do not involve additional manufacturing/processing.

is an operation, not located on a farm (including an operation for shelling, packing, and/or primary production) on a farm(s) that produces raw agricultural commodities harvested, owned, or jointly owned, a majority of the activities farm may also conduct those activities described in paragraphs (1) (ii).



# What is a farm?



## STANDARDS FOR PRODUCE SAFETY Coverage and Exemptions/Exclusions for 21 PART 112

The Preventive Controls for Human Food rule clarified the definition of a farm to cover two types of farm operations, primary production farms and secondary activities farms. The same definition is used in the Produce Safety rule (section 112.3(c)). Below are basic criteria that determine whether an operation that meets the definition of “farm” is subject to the produce rule.

**Does your farm grow, harvest, pack or hold produce?**

Sections 112.1 and 112.3(c)  
We define “produce” in section 112.3(c).

NO



**Your farm is NOT covered by this rule.**

YES

**Does your farm on average (in the previous three years) have \$25k or less in annual produce sales?**

Section 112.4(a)

YES



**Your farm is NOT covered by this rule.**

NO

**Is your produce one of the commodities that FDA has identified as rarely**

# + 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

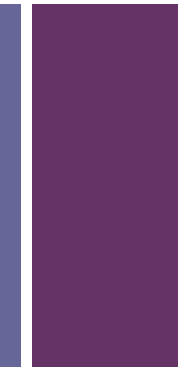




# So what can you do?

## 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 harder 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

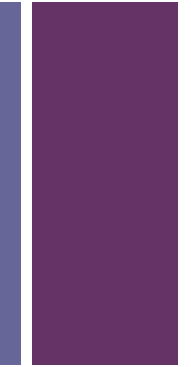
A vertical bar on the right side of the slide, consisting of a thin blue line on the left and a wider purple block on the right.

**catch  
22**





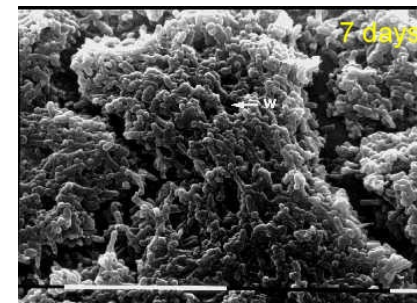
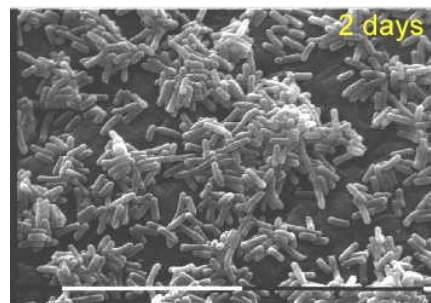
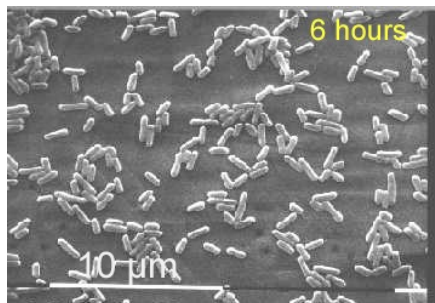
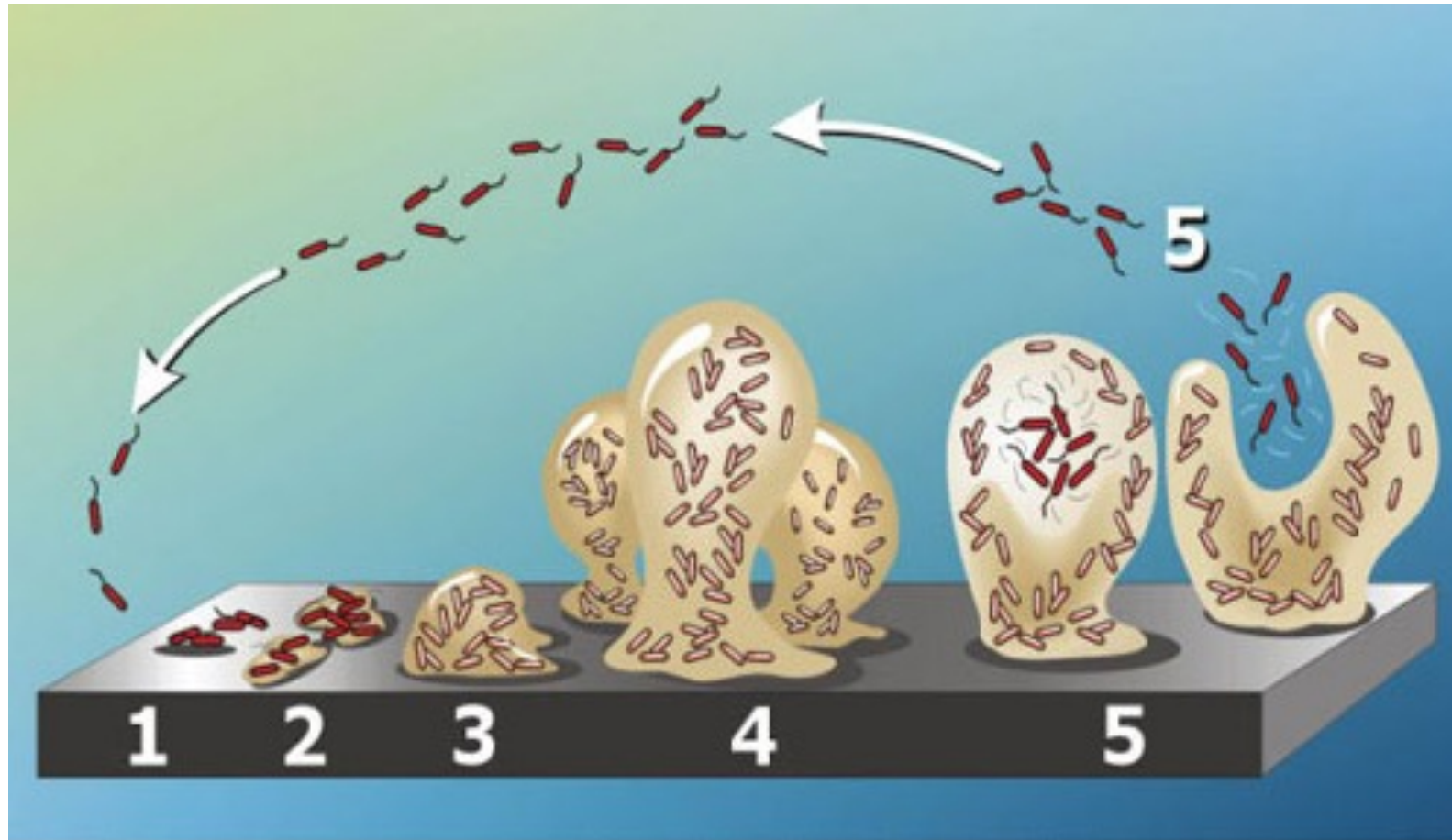
# What Happened in Colorado?



- 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
  - Conveyor Belt Material
  - Tomatoes





# Frequently Asked Questions

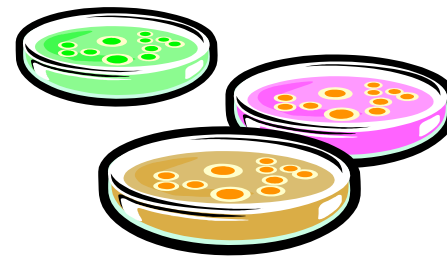
# Is a high total plate count bad?

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.

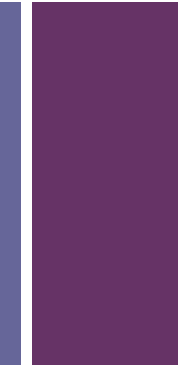


**I use chlorine in my wash process, shouldn't that kill all the pathogens?**

Yes and no. In a perfect world, if chlorine or most any other disinfectant used on foods come in contact with a pathogen, they 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, insulated 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, multiply hurdles can increase the safety of any system
- PSR is a preventive systems
- Need to understand the regs to properly implement a successfully food safety program