DIVISION OF AGRICULTURE

RESEARCH & EXTENSION

University of Arkansas System

Introduction to Food Safety and Microbiology

Food Safety

Divided into causitive categories called “hazards”

- Biological Hazards - bacteria, molds, natural occurring toxins
- Chemical Hazards – chemicals like petroleum, herbicides, pesticides, heavy metals.
- Physical Hazards – glass, rocks, wood splinters

1990 vs 1997

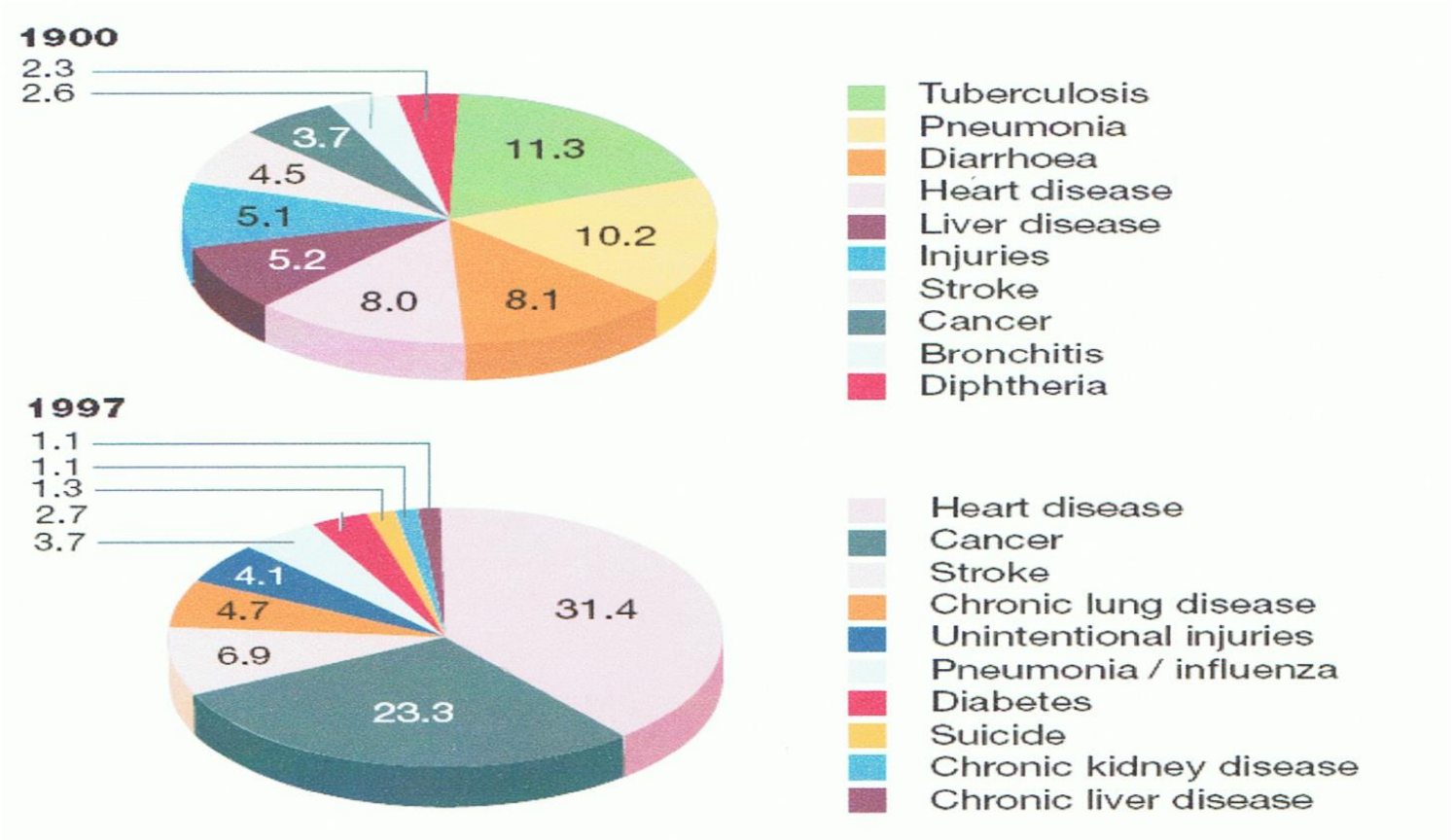
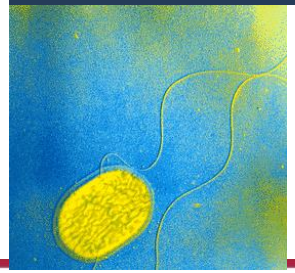


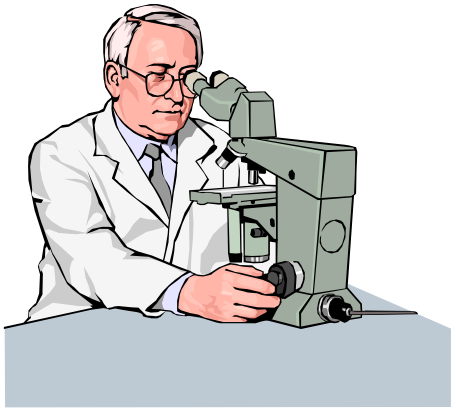
Figure 2 – The ten leading causes of death in the United States in 1900 and 1997. From "Changing Patterns of Infectious Disease", Mitchell L. Cohen, Nature, Volume 406, 17 August, 2002, pp 762-767.

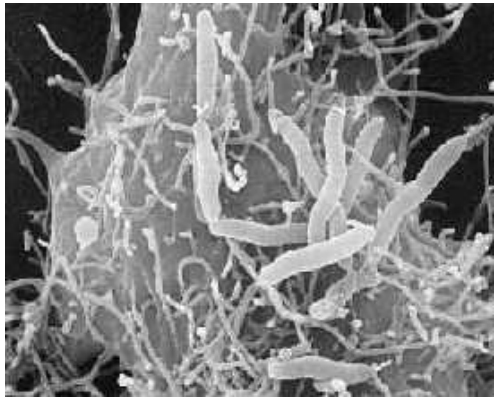
Food Microbiology

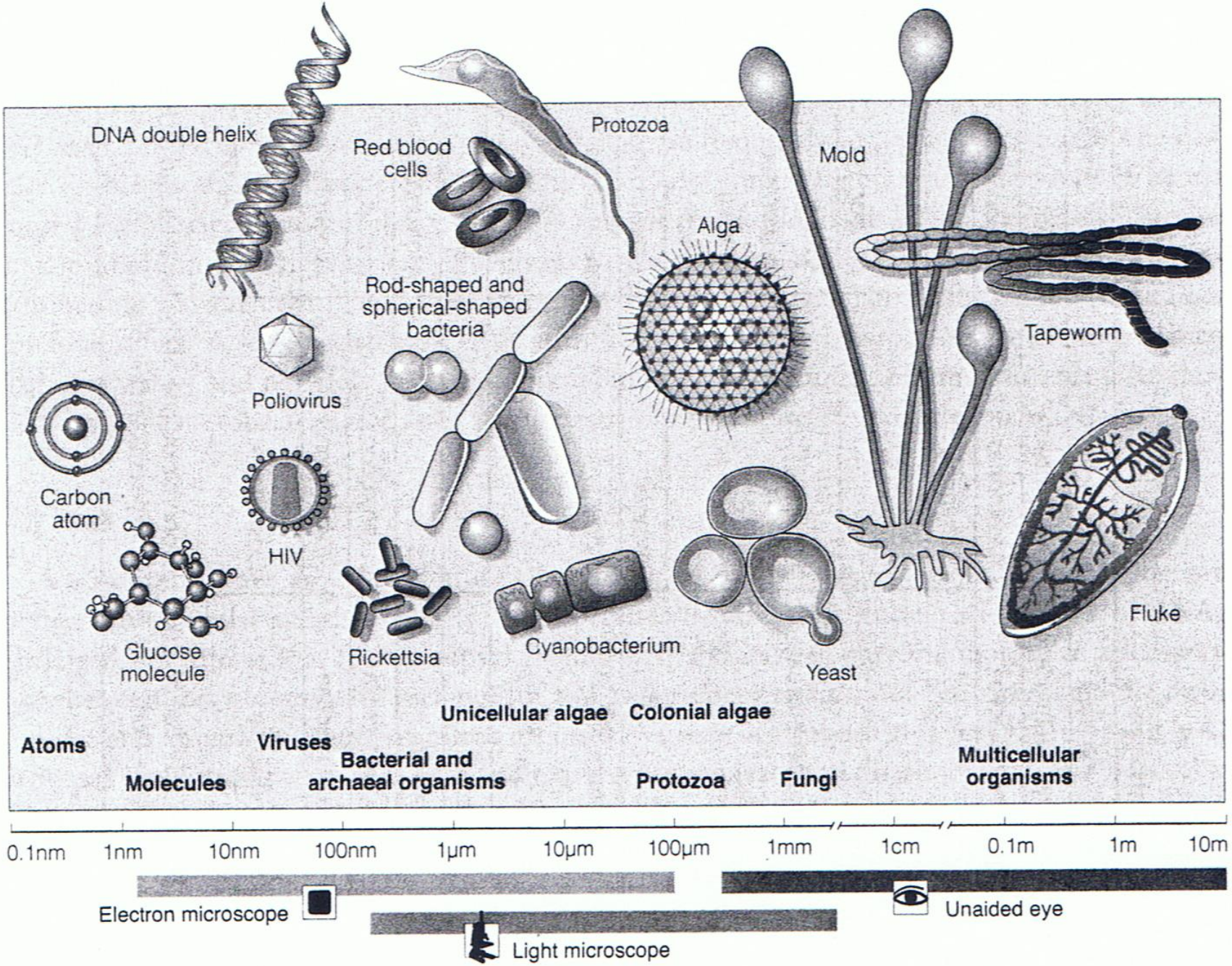


Definition

- Microorganisms: Organisms such as bacteria, parasites, viruses, yeasts, and molds
  - Usually too small to be seen by the naked eye

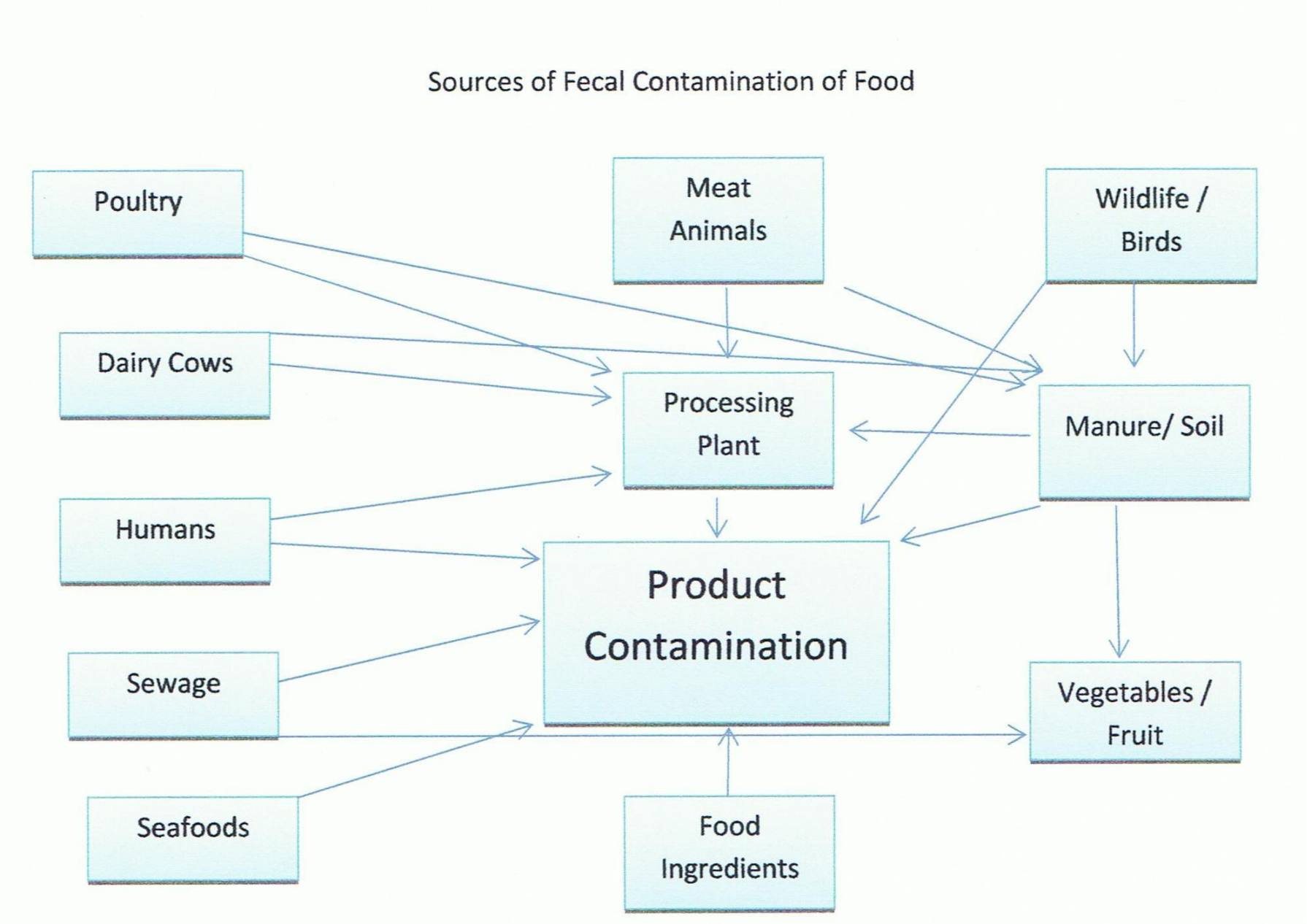





DNA double helix
Red blood cells
Protozoa
Mold
Alga
Rod-shaped and spherical-shaped bacteria
Tapeworm
Poliovirus
Carbon atom
HIV
Glucose molecule
Rickettsia
Cyanobacterium
Yeast
Fluke
Unicellular algae
Colonial algae
Atoms
Viruses
Molecules
Bacterial and archaeal organisms
Protozoa
Fungi
Multicellular organisms
0.1nm
1nm
10nm
100nm
1μm
10μm
100μm
1mm
1cm
0.1m
1m
10m
Electron microscope
Unaided eye
Light microscope

Where are microorganisms?

- Soil & Water
- Plants/Products
- Utensils/Equipment
- Gastrointestinal Tract
- Food Handlers
- Animal Feeds
- Animal Hides
- Air & Dust
- EVERYWHERE!


Sources of Fecal Contamination of Food
Poultry
Meat Animals
Wildlife / Birds
Dairy Cows
Processing Plant
Manure/ Soil
Humans
Product Contamination
Sewage
Vegetables / Fruit
Seafoods
Food Ingredients

Microorganisms in Food

Microorganisms are important in many different ways:

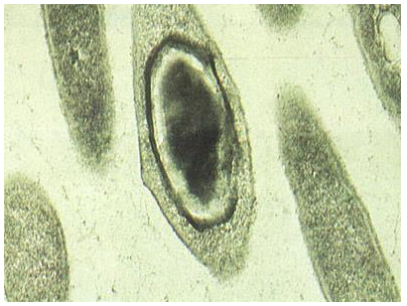
- *Pathogenic*, or disease causing, microorganisms can cause illness
- *Spoilage* microorganisms cause a food to smell, taste, and look unacceptable
- *Fermentation* microorganisms produce a desired food product
- Other microorganisms do nothing in foods

Bacterial Classifications

- Bacteria can be classified in a number of ways.

*Their shape-Round=cocci; Elongated=rods

Spores



- Sporeforming; Some rod shaped bacteria are sporeformers. This is a dormant stage in their life cycle. These spores have the ability to survive a wide range of environmental extremes. They can survive heating up to 212^0F and are resistant to most chemicals including sanitizing solutions. The most noteworthy sporeformer is Clostridium botulinum.

- Spores $\Rightarrow$ dormant state
  - Much more resistant to environmental stresses (heat, cold, chemicals)
- Vegetative state $\Rightarrow$ active state
  - More susceptible to inactivation

Temperature and Growth

- PSYCHROPHILE:

Grow from 1-20°C
EXAMPLES: *Pseudomonas*, *Flavobacterium*, *Alcaligenes*

- PSYCHROTROPHIC:

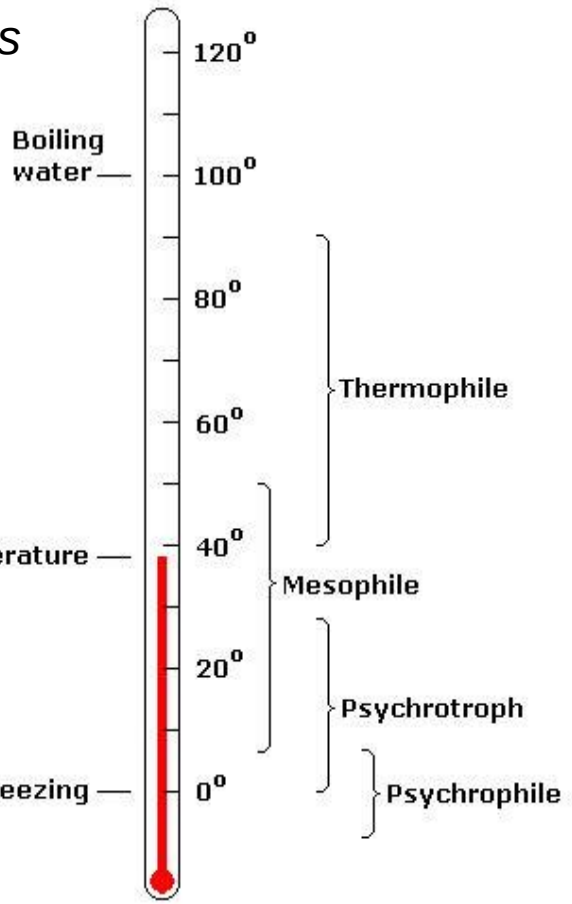
Grow best at 37°C, but can grow at refrigeration (3-7°C)
EXAMPLE: *Listeria monocytogenes*

- MESOPHILE:

Optimum temperature 20-40°C
Group containing most human pathogens
EXAMPLES: *E. coli, Salmonella, Clostridium botulinum*

- THERMOPHILE:

Optimum temp >45°C
EXAMPLE: *Bacillus stearothermophilus*



Low and High Temperatures

Low Temperatures

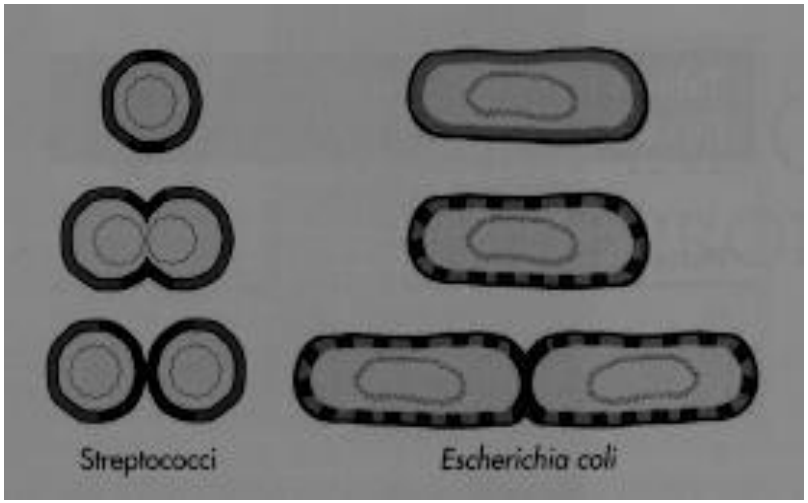
- Refrigeration (40-45^{o}F) slows or stops bacterial growth
- Freezing stops bacterial growth

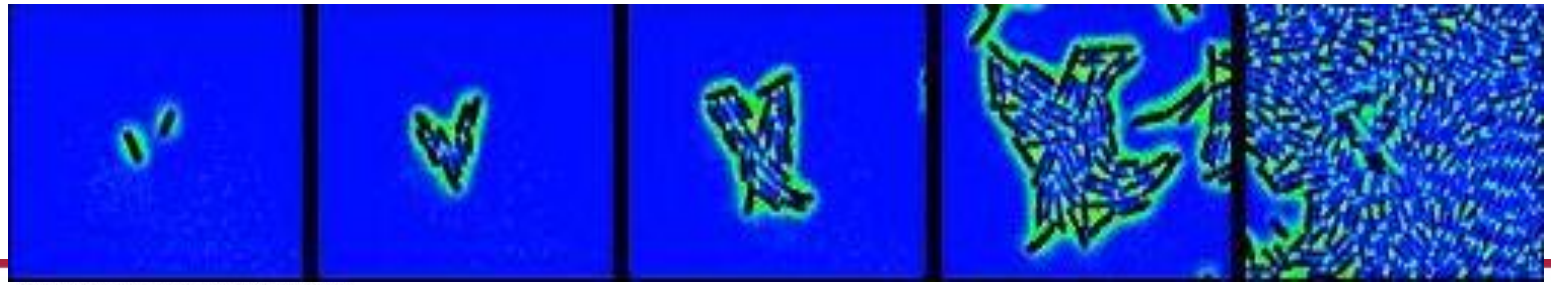
High Temperatures

- Heating (165^{o}F or higher) destroys bacteria for immediate service foods served in restaurants and homes.
- Thermal processing of shelf stable foods (180 - 250^{o}F) destroys bacteria for longer shelf-life foods – temperature dependent upon product acidity
- Low acid canned foods – inactivation of *C. botulinum*

Reproduction of Bacterial Cells

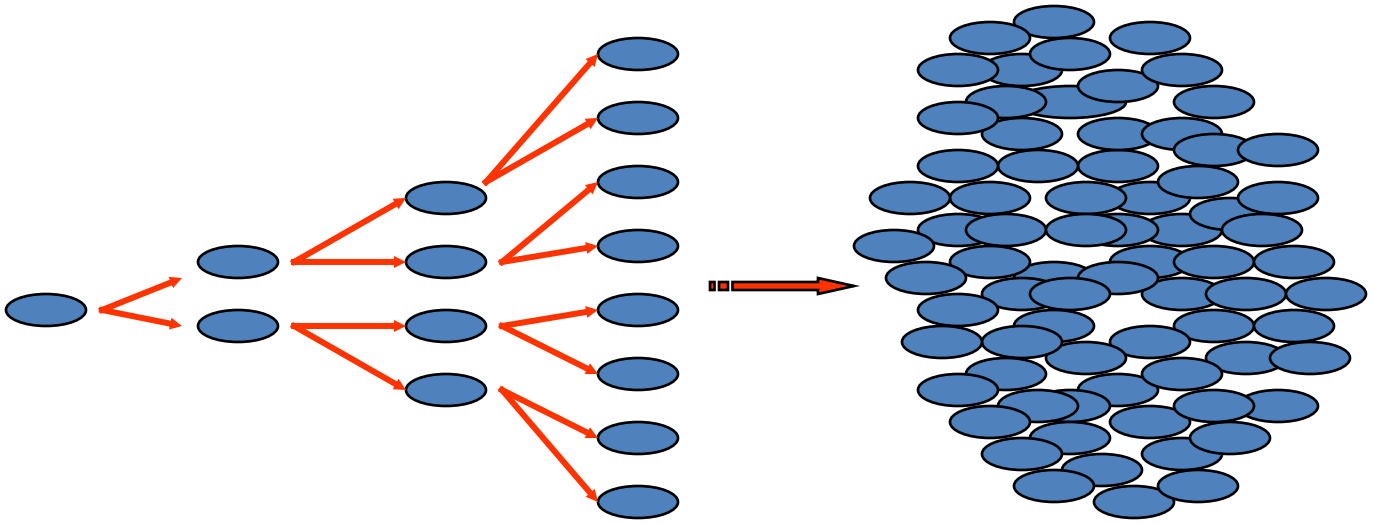
- Reproduced by division
- Referred to as “growth”
- Under optimum conditions a cell divides every 20-30 minutes





Growth of Bacteria

- Binary Fission



Controlling Growth

F – Food

A – Acidity

T – Temperature

T – Time

O – Oxygen

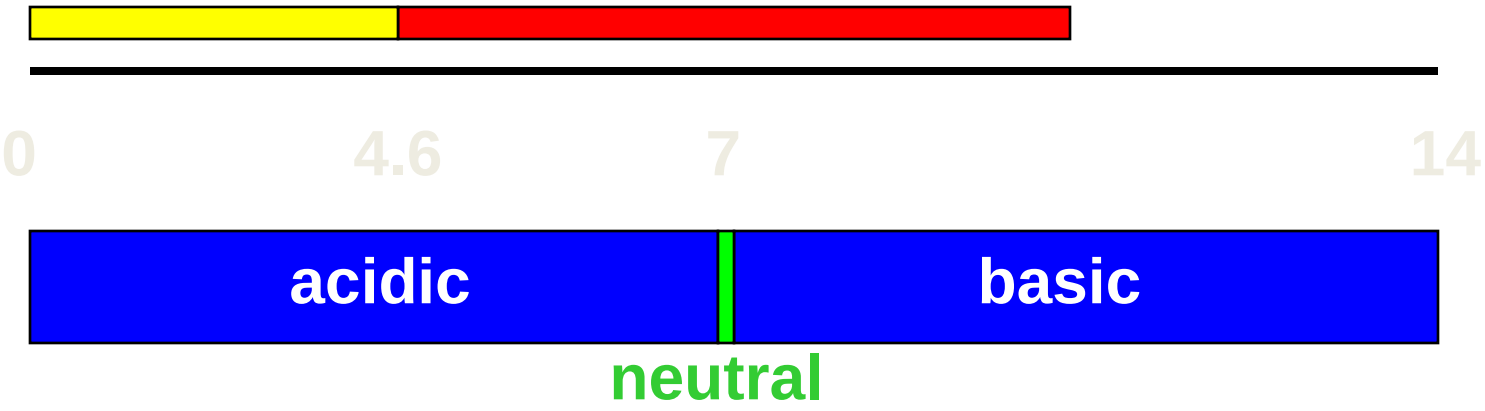
M – Moisture

Controlling Growth

Food – Nutrients Content

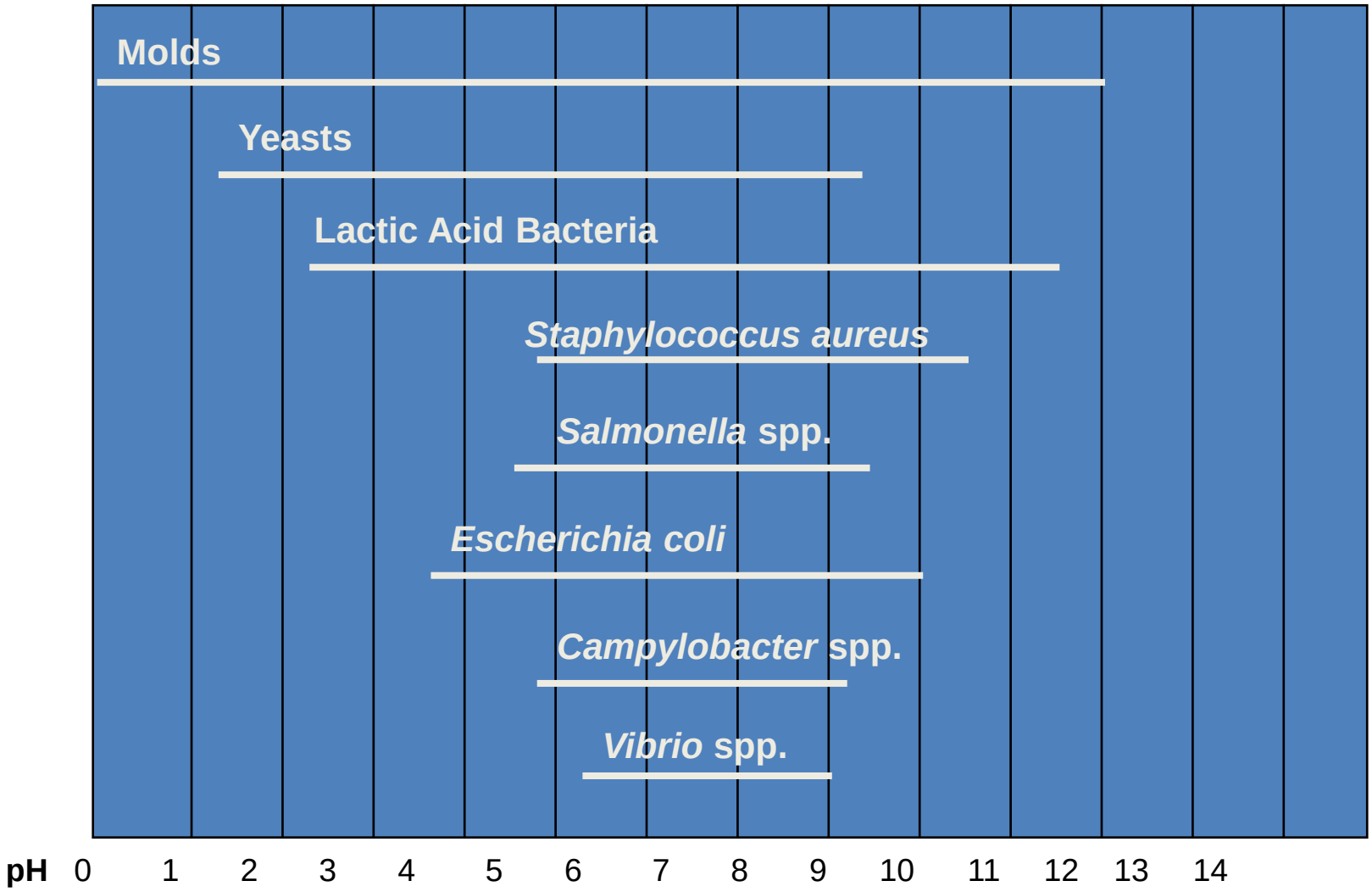
- For growth, microorganisms require the following:
  - Water
  - Source of energy
  - Source of nitrogen
  - Vitamins & related growth factors
  - Minerals

Food Acidity

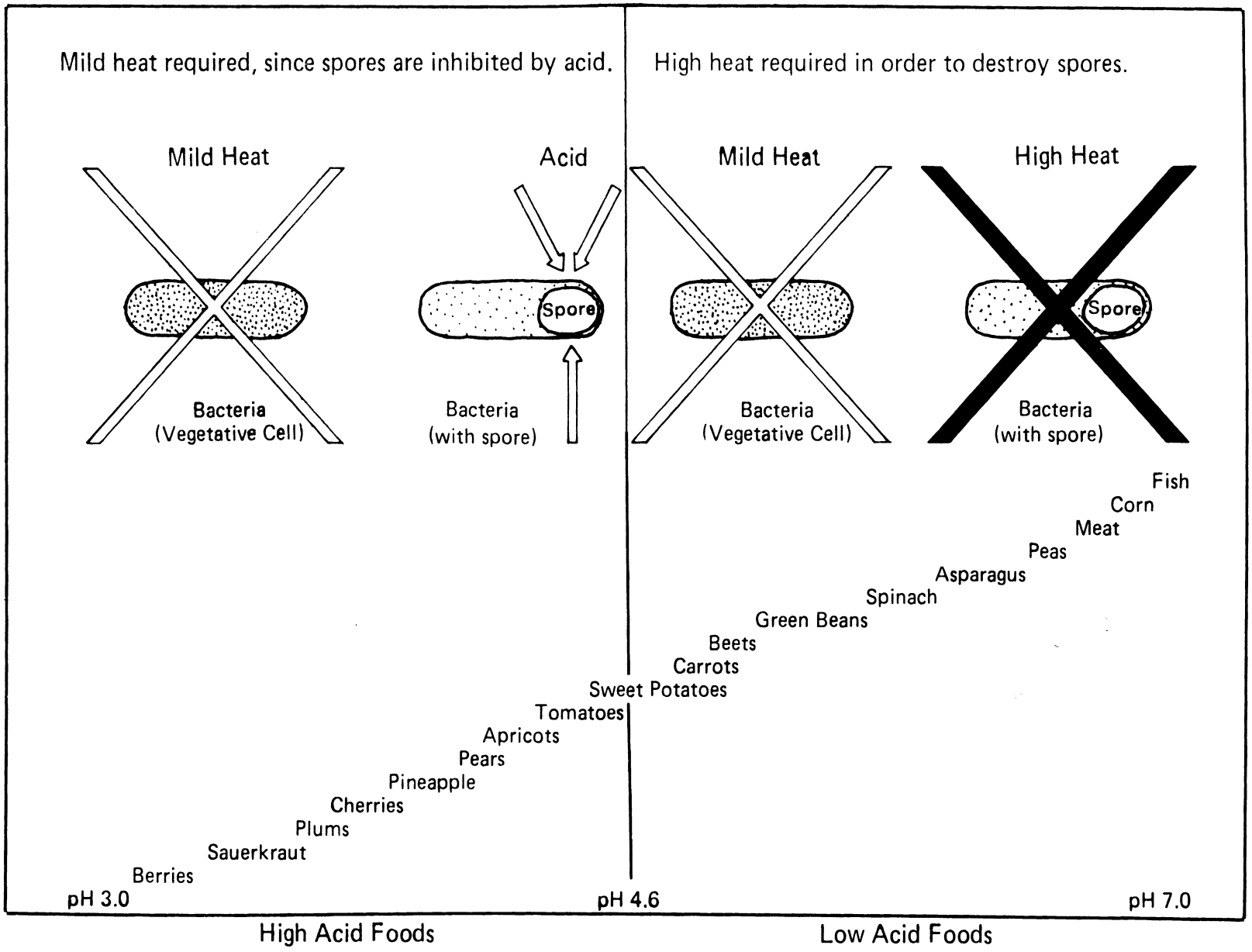


- Optimal pH for growth: 6.0 – 8.0
- Disease causing bacteria: 4.6 - 9.5
- Spoilage bacteria: 1.5 - 9.5

pH – Growth Range in Foods



Source: Jay, J.M. 1996. Modern Food Microbiology


Mild heat required, since spores are inhibited by acid.
High heat required in order to destroy spores.
Mild Heat
Acid
Mild Heat
High Heat
Spore
Spore
Bacteria
(Vegetative Cell)
Bacteria
(with spore)
Bacteria
(Vegetative Cell)
Bacteria
(with spore)
Fish
Corn
Meat
Peas
Asparagus
Spinach
Green Beans
Beets
Carrots
Sweet Potatoes
Tomatoes
Apricots
Pears
Pineapple
Cherries
Plums
Sauerkraut
Berries
pH 3.0
pH 4.6
pH 7.0
High Acid Foods
Low Acid Foods

Controlling Growth

T =Temperature

- Optimal Growth
  - Thermophiles – like hot conditions
  - Mesophiles – like warm conditions (around body temperature)
  - Psychrotrophs – can grow at refrigeration temperatures
- Most pathogens are mesophiles

Temperature Classifications

*Based on optimum temperature for growth;

*Psychro=cold

*Meso = middle

*Thermo= warm

*Trophic =growing

*Duric=withstand

*Phil or philic-prefers or loves

Categories of Microbes Based on Temperature Range

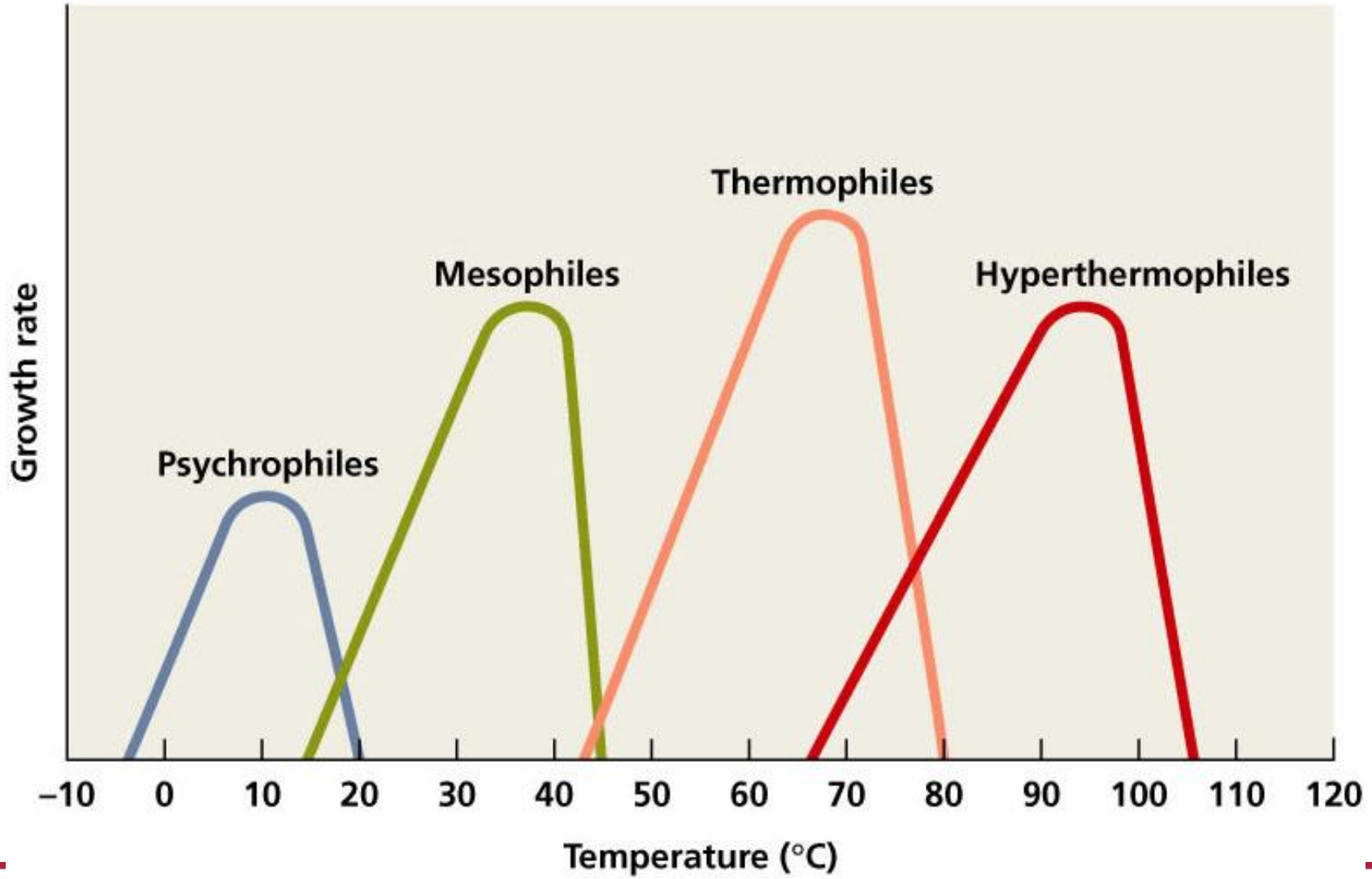
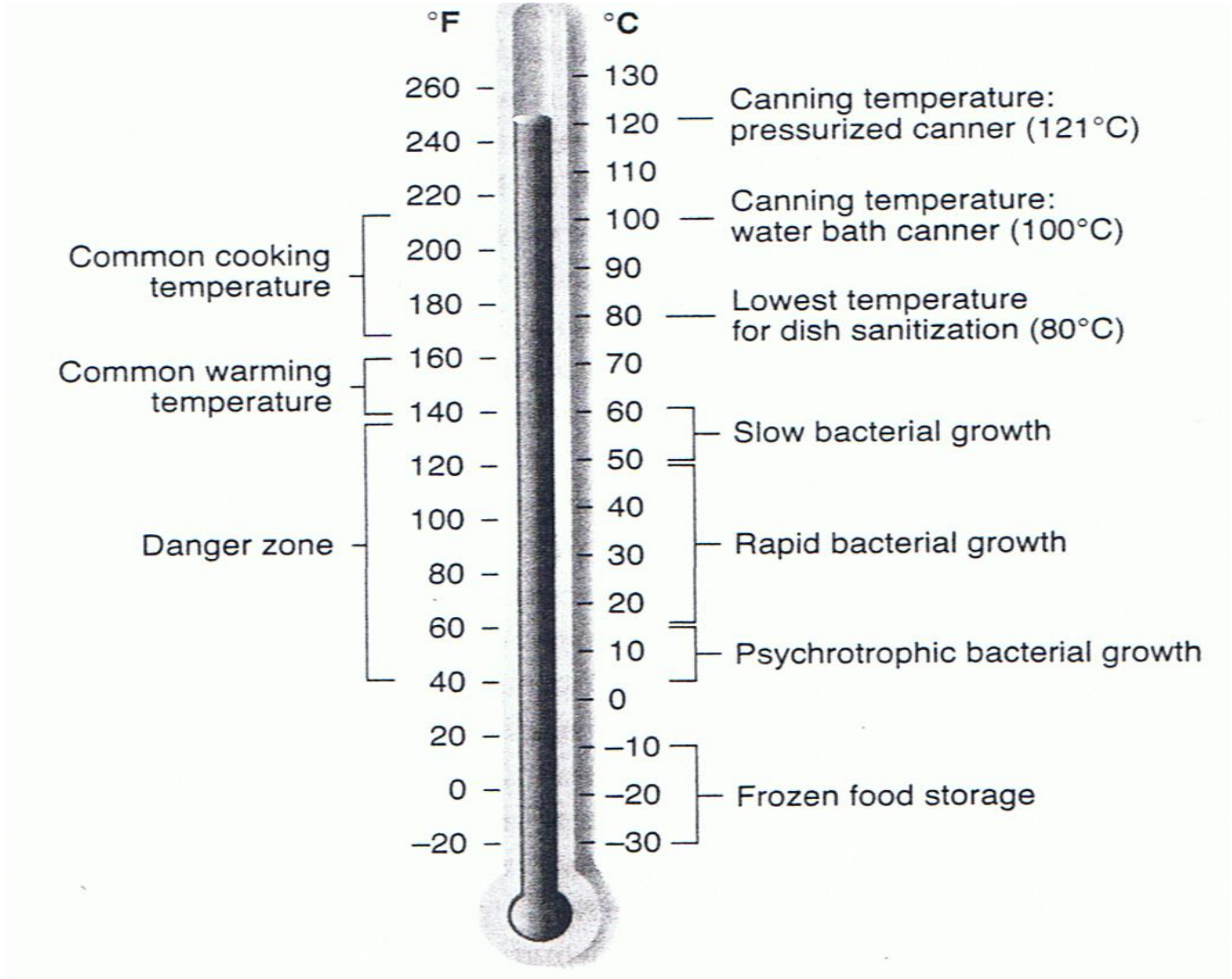
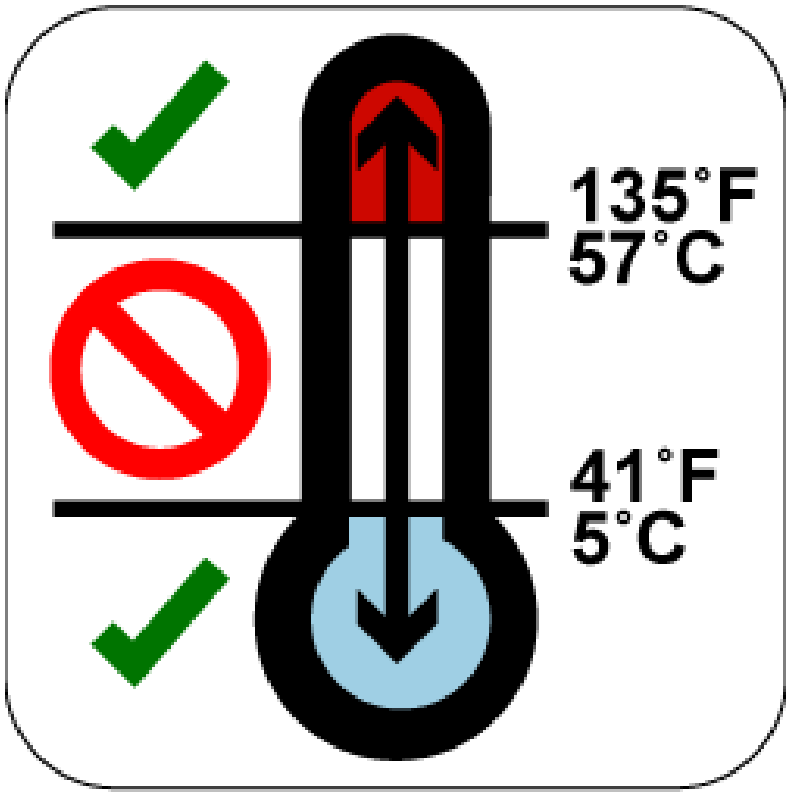


Image: Pearson Education Inc. (2004) publishing as Benjamin Cummings


°F
°C
260
240
220
200
180
160
140
120
100
80
60
40
20
0
–20
130
120
110
100
90
80
70
60
50
40
30
20
10
0
–10
–20
–30
Canning temperature: pressurized canner (121°C)
Canning temperature: water bath canner (100°C)
Lowest temperature for dish sanitization (80°C)
Slow bacterial growth
Rapid bacterial growth
Psychrotrophic bacterial growth
Frozen food storage
Common cooking temperature
Common warming temperature
Danger zone

Controlling Growth

Temperature Danger Zone



Controlling Growth

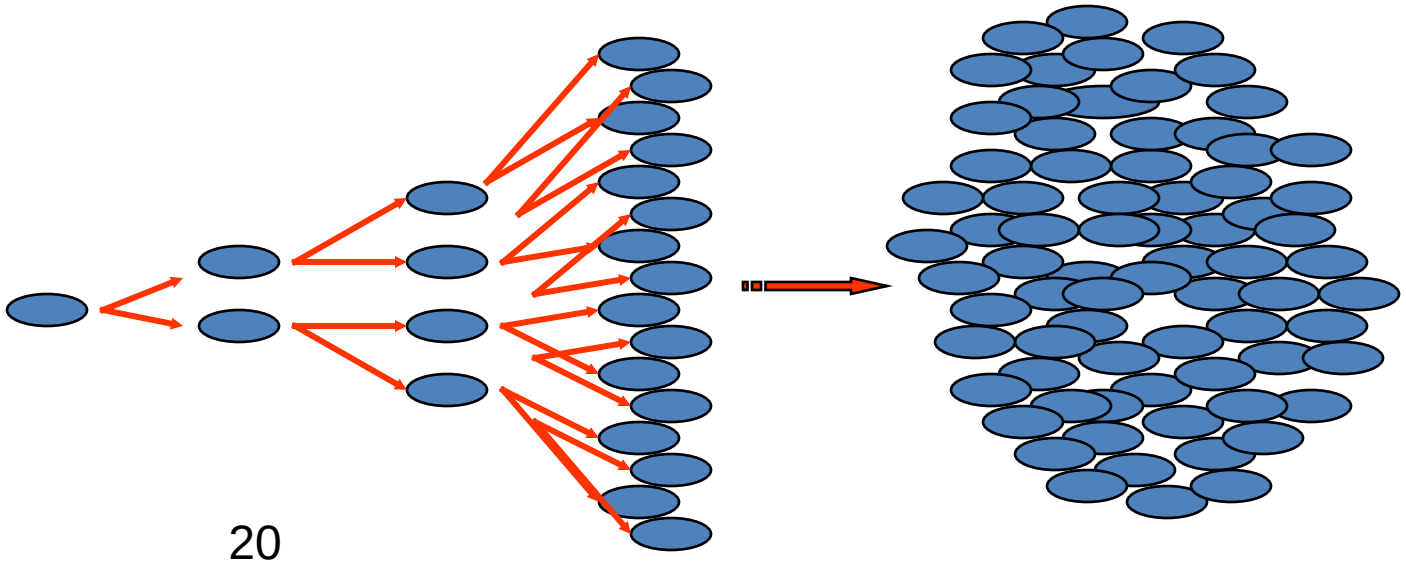
- Temperature lower than 41° F
  - Bacteria cease to multiply but do not die
  - Freezing can cause cell wall damage
- Temperature higher than 135 ° F
  - Bacteria die if heated for a sufficient time
  - Increased destruction with longer times and higher temperatures

Controlling Growth

TIME

- Under optimal conditions, some bacteria can double every 20 minutes.
- The colder the storage temperature, the longer the potential shelflife.
- Potentially hazardous foods should not remain in the danger zone (50-140^{0}F) for more than 4 hours during the entire food handling process.

Growth of Bacteria



20 minutes

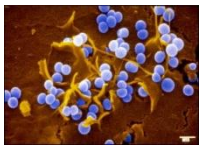
40 minutes

80 minutes

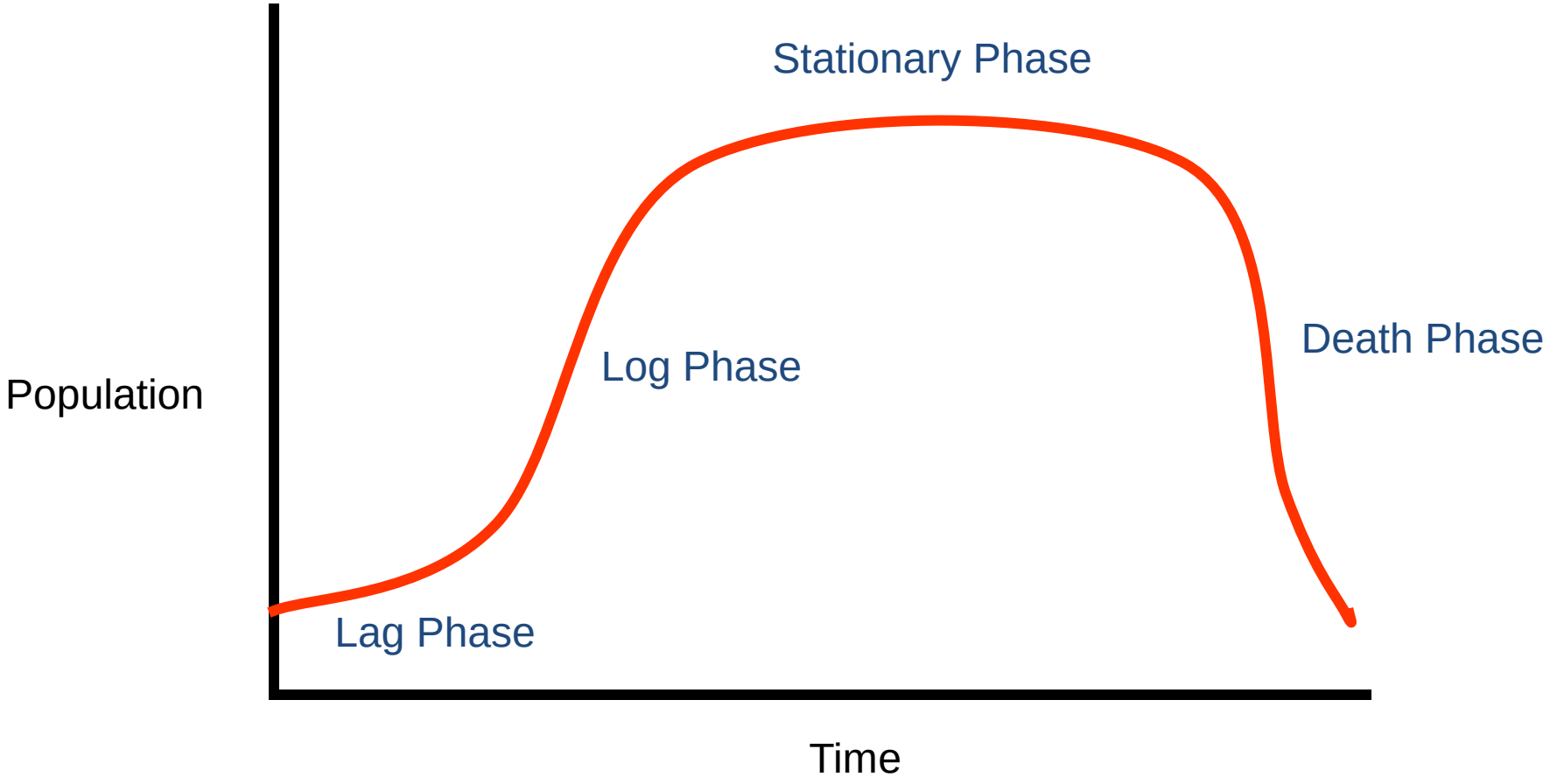
Four hours

Under optimal conditions. ~500 million!

Generation Time Under Optimal Conditions *(at 37°C)*

Organism	Generation Time *(min)*	
Bacillus cereus	28	
Escherichia coli	12.5	
Staphylococcus aureus *(causes many infections: toxic shock syndrome one example)*	27-30	
Mycobacterium tuberculosis *(agent of Tuberculosis)*	792 – 932	

Bacterial Growth Phases



O = Oxygen

Based on oxygen requirements;

Aerobic-Need oxygen to grow

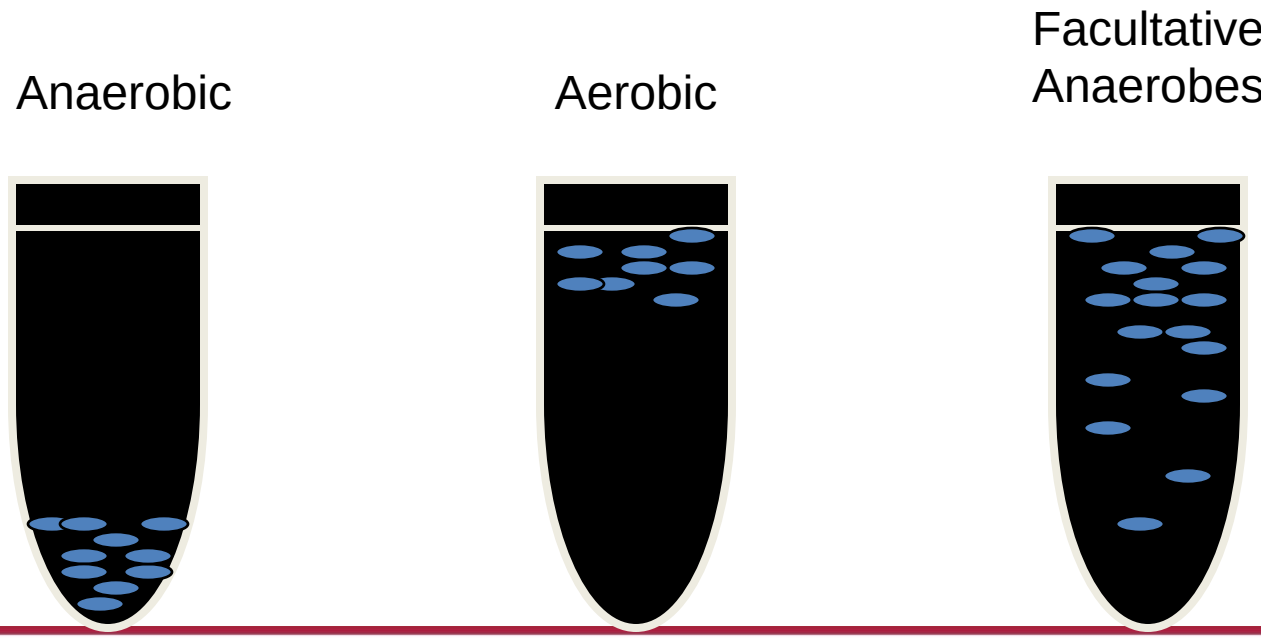
Anaerobic-Can grow only if oxygen is absent

Facultative-Can grow with or without oxygen.

Controlling Growth

Oxygen

- Tolerance to oxygen in the surrounding environment



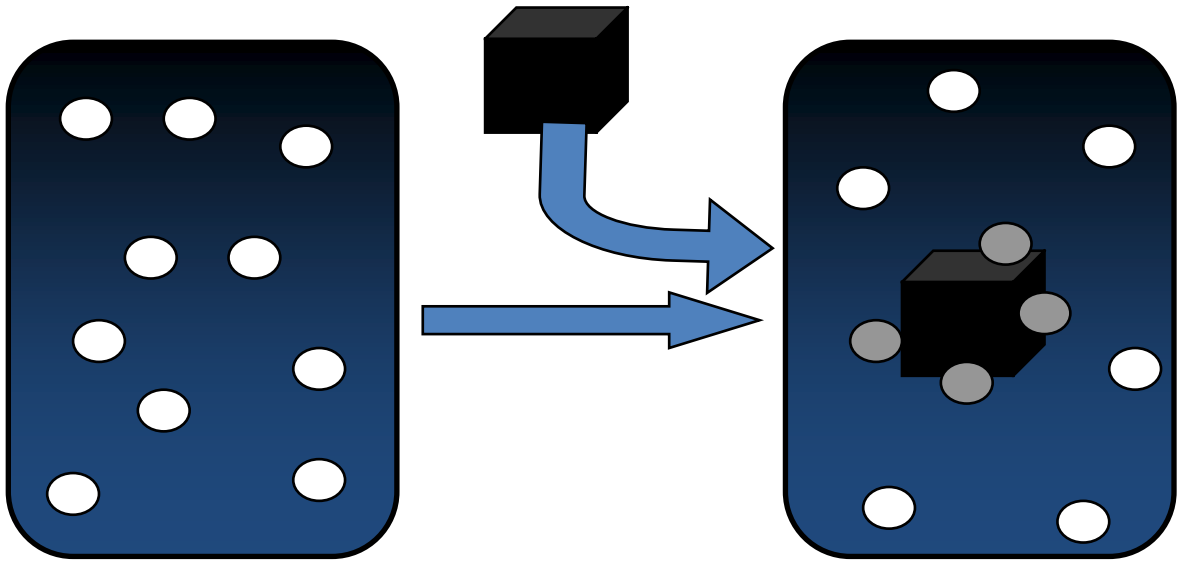
Controlling Growth

Moisture – Water Activity

- Water Activity (a_w) is the measure of "free" water available to the microorganism for growth

Water Activity

- A_w is affected by the presence of solutes (sugars and salts)

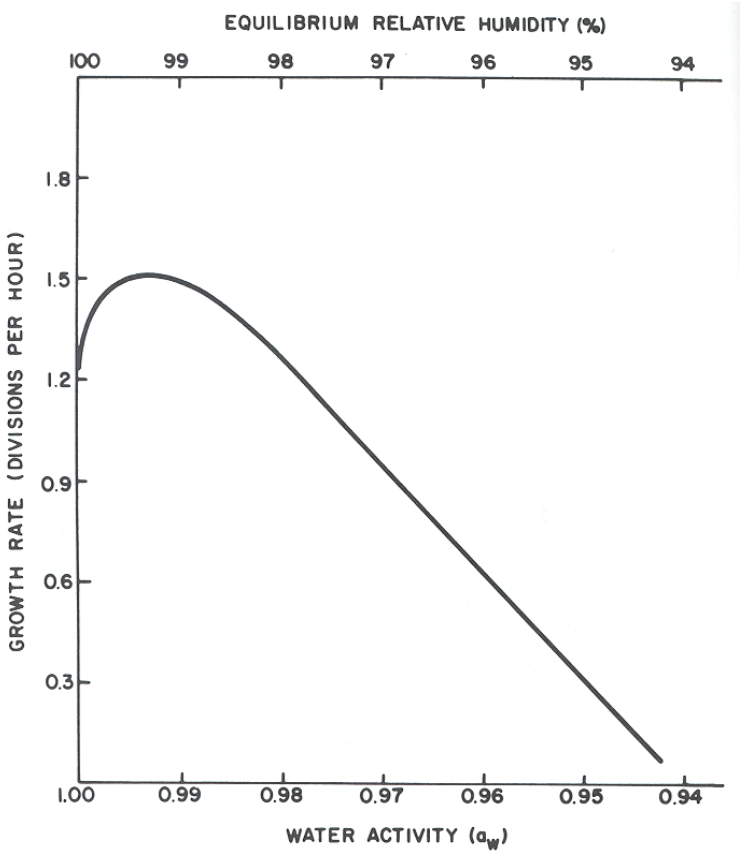


- Lowering a_w will reduce the ability for microorganisms to grow

Water Activity

Moisture in a food system that is available for microbial growth and chemical reactions – the relative humidity of a food

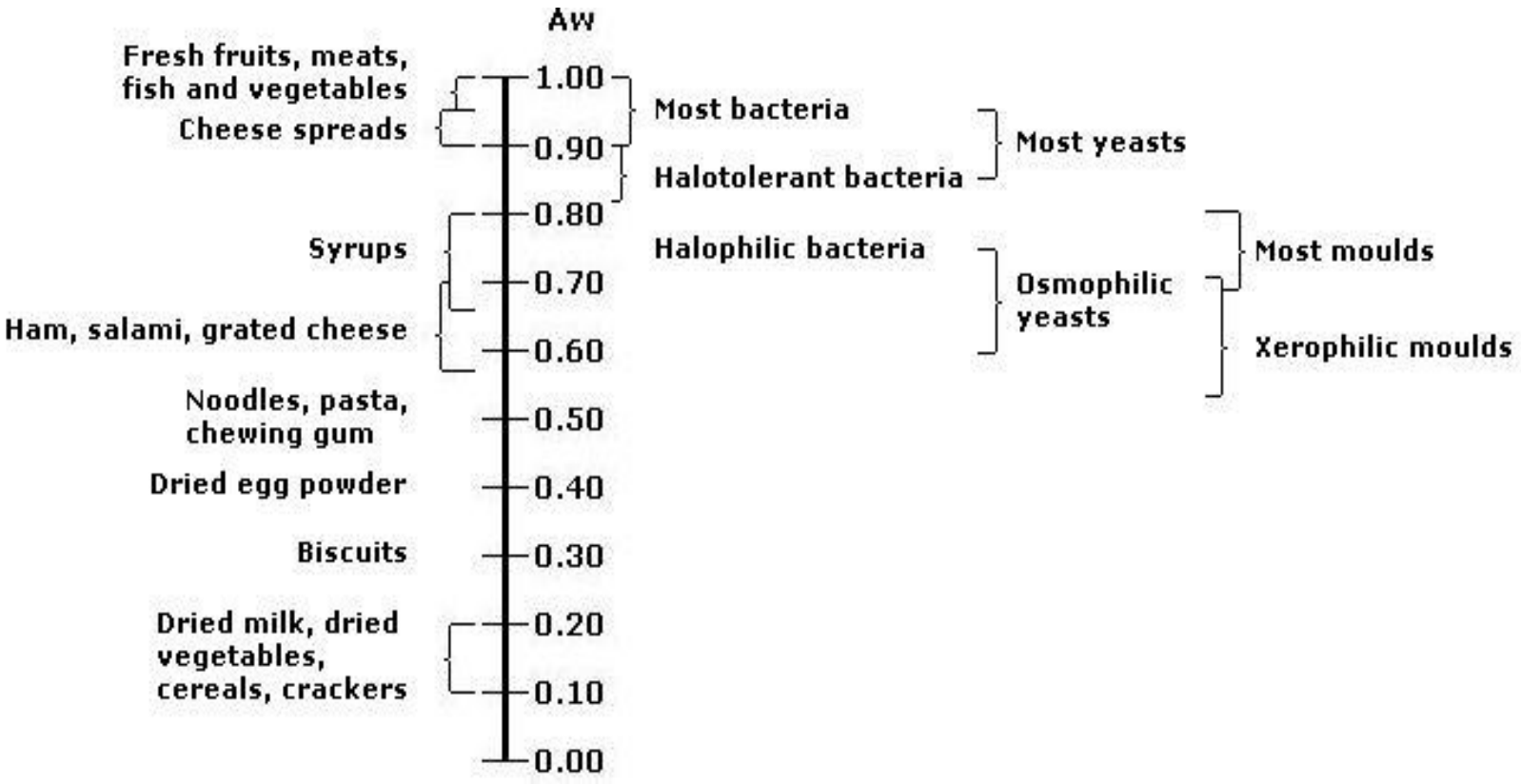
- 0.98 - 0.995 most foods.
- 85 -.995 for disease causing organisms range .
- 60 - .995 for spoilage organisms



WATER ACTIVITY

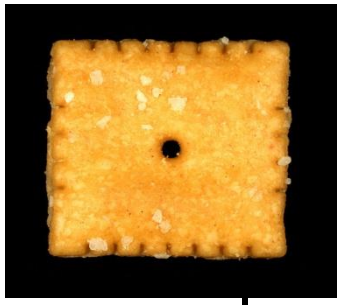
Aw/	Microorganism	Foods
1.0-0.95	Bacteria	Meat, fish, sausage, milk
0.95-0.91	Bacteria	Moist cheeses, cured meat (ham), fruit juice conc
0.91-0.87	Yeasts	Fermented sausages (salami), dry cheeses, margarine
0.87-0.80	Molds	Juice conc, syrups, flour, fruit cakes, honey, jellies, preserves
0.30-0.20	No microorganisms proliferate	Cookies, crackers, bread crusts

Water Activity: Foods and Microbial Growth



Controlling Growth

Water Activity of Common Foods




0.5 0.75 1.0




Controlling Growth

SUMMARY:

- Microorganisms can grow on food and in the environment under the right conditions
- Remember F-A-T-T-O-M
  - Food, Acidity, Temperature, Time, Oxygen, and Moisture

Interventions

Interventions – Combined Effects

"Hurdles Concept"

Predictive microbiology
The study of interactive effects of factors effecting microbial growth

- Additive effects
- Synergistic effects
- Antagonistic effects

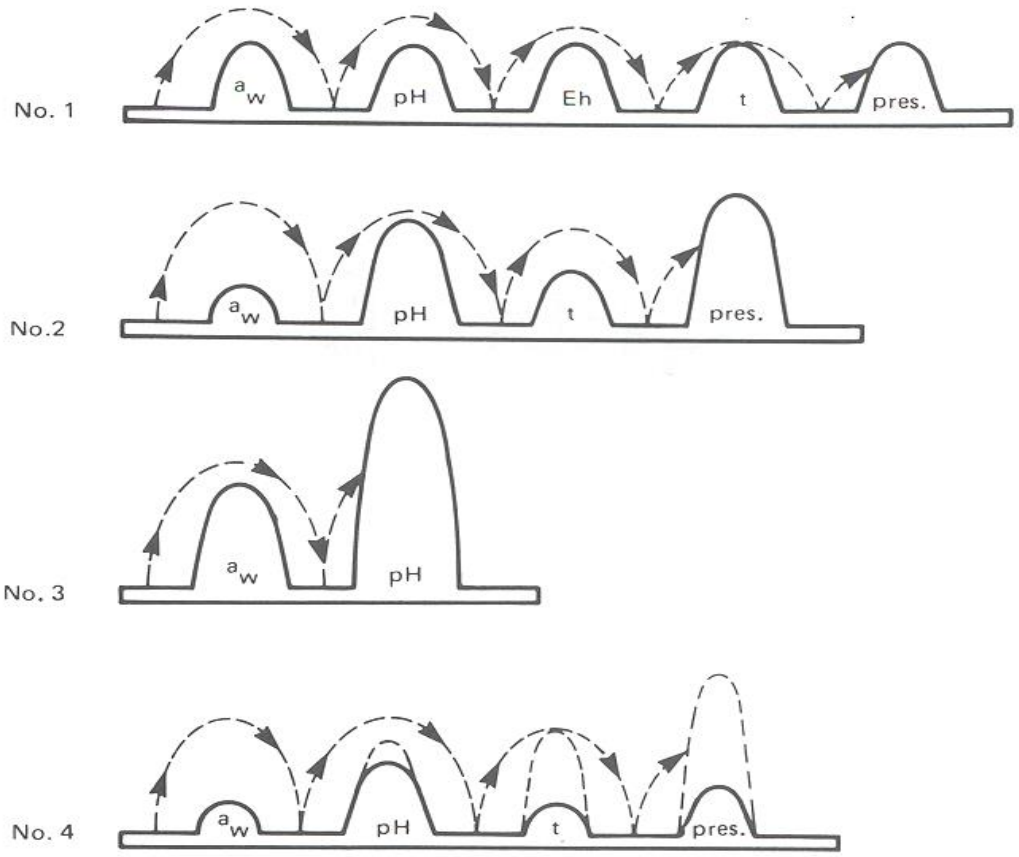


Fig. 4.1 Hurdle effect, illustrated using four food products as example. (*From Leistner 1978.*)

Food Industry Interventions

Ingredients

- Have good specifications and control of incoming ingredients

Process

- Have an adequate thermal process to destroy microorganisms
- Have an adequate packaging system to protect your product

After Processing

- Have control of distribution and a system for tracking and recalling
- Provide necessary information for consumers (labeling)

Farm to Fork Food Safety and Quality Programs

- HACCP, GMPs, Sanitation

Ingredient Control

- Specifications for ingredient make-up, quality, physical and microbial contaminant levels
  - » Letter of guarantee
  - » Certificate of analysis

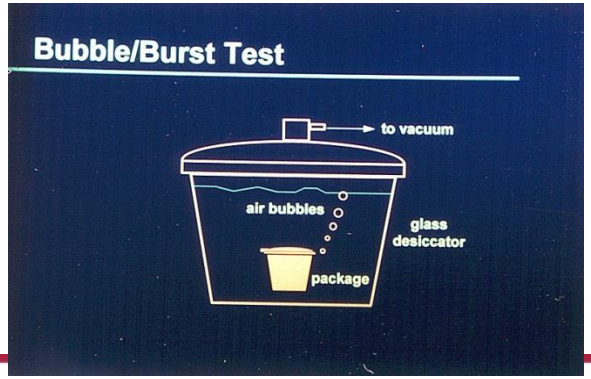
Thermal Processing Control

Thermal Processing

- Cooking
- Pasteurization
- Commercial sterility (shelf-stable) processes
  - Retort systems, aseptic processing, and hot filling

Package Integrity

- Measurements are made to insure the package is of good sanitary quality and can maintain a hermetic seal (such as visual inspections and torque measurements for your containers)



Thermal Processing Control

Low acid foods (pH>4.6, Aw>.85)

- Should have a process to eliminate 1,000,000,000,000 spores of *Clostridium botulinum*
- Examples: Most meat, vegetable, and dairy products
- Process often at 230^{o}F or above (retorts, aseptic processing)

Acidified foods (pH altered to ≤4.6, Aw>.85)

- Not required to have a process to eliminate *Clostridium botulinum*
- Examples: Pickled products, mayonnaise
- Process often 180 - 205^{o}F (pasteurization, hot filling)

High acid foods (pH ≤4.6, Aw>.85)

- Not required to have a heat process.
- Examples: sliced oranges, condiments
- Process often 180 - 205^{o}F (pasteurization, hot filling)

Pathogens

General Roles of Microorganisms

- Commensal
  - ubiquitous
  - harmless or beneficial
- Spoilage
  - Cause food to become inedible due to changes in color, flavor, odor, appearance or texture.
  - Grow to high levels and break down food components
  - Commensal organisms that have reached high populations (10^5-10^7 CFU/g)
  - Different products have different spoilage flora

General Characteristics of Microorganisms

- Beneficial
  - Used as an aid in producing desirable characteristics in food
- Pathogens
  - Cause foodborne illness
  - Microorganisms that are usually associated with the presence of pathogens are called “Indicators”. Most E coli do not cause illness.

Food Safety vs. Food Quality

- Food safety controls HAZARDS to the consumer.
  - A foodborne hazard is a biological, chemical, or physical property that may cause a food to be unsafe for human consumption
- Food quality controls deterioration of food to an unacceptable state

Foodborne Illness

- Foodborne illness in the United States is associated with:
  - 46 million illnesses a year
  - 325,000 hospitalizations a year
  - 3,000 deaths a year
  - A loss of $10-83 billion in pain & suffering, reduced productivity, and medical costs

Common Foodborne Pathogens

Bacteria

- *E. coli* 0157:H7
- *Salmonella* spp.
- *Staphyloccus aureus*
- *Listeria monocytogenes*
- *Campylobacter jejuni*
- *Shigella* spp.

Viruses

- Norovirus
- Rotovirus
- Hepatitis A

Parasites

- *Cryptosporidium parvum*
- *Giardia lamblia*
- *Cyclospora*

80-90% of Foodborne Illnesses from Bacteria come from just 4 Bacteria

- Campylobacter
- Salmonella
- Clostridium perfringens
- Staphylococcus aureus

Illness Mechanisms

- Infection
  - Microorganisms are ingested and then cause illness
- Intoxication
  - Toxins are produced by the pathogen, usually in the food. When food is consumed, illness occurs.
  - Even if microorganisms are killed, toxin can still remain the food

Bacterial Pathogens of Concern

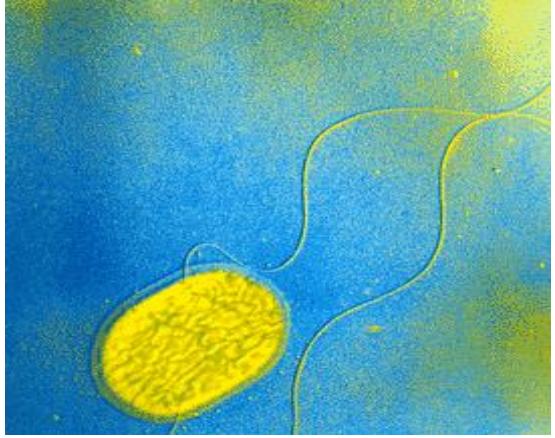
- *E. coli* O157:H7
- *Salmonella*
- *Listeria*
- *Campylobacter*
- *Staphylococcus aureus*
- *Clostridium botulinum*

Which Bacteria are Responsible?

Pathogen	Cases	Deaths
Campylobacter jejuni	4,000,000	200-1000
Salmonella	2,000,000	500-2000
Stapylococcus aureas	1,500,000	1200
Escherichia coli O157:H7	725,000	100-200
Clostridium spp.	10,000	100
Listeria monocytogenes	1500	250-500

E. coli O157:H7

- Hemorrhagic colitis
- Cause: infection
- Incubation: 2-4 days
- Symptoms: diarrhea (blood), HUS, TPP
- Contaminant: milk, meat, fruits, vegetables, water



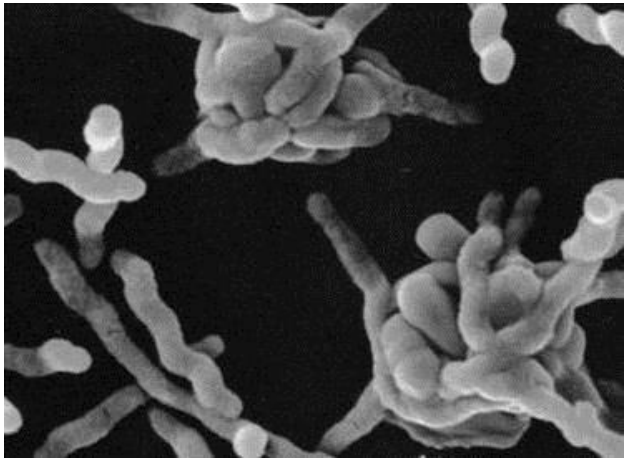
Salmonella

- Salmonellosis
- >2000 strains, 10 = foodborne illness
- Cause: infection
- Incubation: 6-48 hours
- Symptoms: nausea, fever, diarrhea, arthritis
- Contaminant: milk, meat, eggs

Listeria monocytogenes

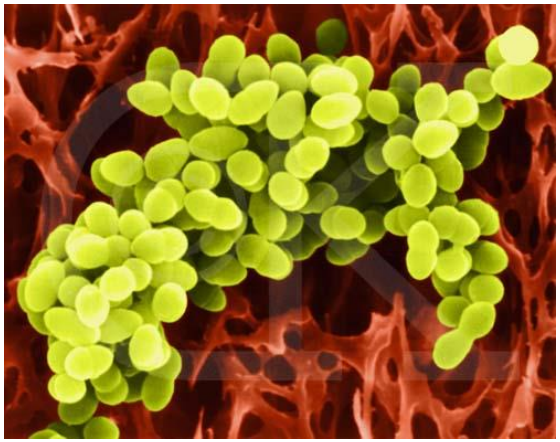
- Listeriosis
- Cause: infection
- Incubation: 2 days - 3 weeks
- Symptoms: vomiting, diarrhea
    - meningitis, septicemia, miscarriage
- Contaminant: vegetables, milk, cheese, meat, seafood

Campylobacter jejuni



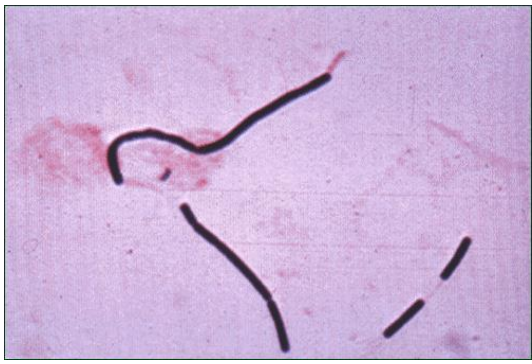
- Campylobacteriosis
- Cause: infection
- Incubation: 2 - 5 days
- Symptoms: nausea, fever, diarrhea (blood)
- Contaminant: milk, meat, water

Staphylococcus aureus



- Staphyloenterotoxicosis
- Cause: intoxication
  - (1 mg toxin = 100,000 cfu/g)
- Incubation: 1-6 hours
- Symptoms: nausea, fever, diarrhea
- Contaminant: milk, meat, eggs

Clostridium botulinum



- Botulism
- Cause: intoxication (spores - neurotoxin)
- Incubation: 18 -36 hours
- Symptoms: weakness, vertigo
    - difficulty in speaking, swallowing, breathing
- Contaminant: pH >4.6, low oxygen foods

Prevention of Foodborne Illness

1) Cook- Cook all meat, poultry and eggs to at least 160F. Other than spore-forming bacteria, all bacteria, parasites and viruses are killed quite easily with heating to 160F.
2) Avoid Cross-Contamination- Do not cross-contaminate one food with another. Keep raw food totally separated from cooked product. Clean utensils and work areas etc in between working raw and cooked product. Constantly be thinking of how microorganisms get from raw to cooked products.

Prevention of Foodborne Illnesses

3) Chill Foods- Keep foods cold. After cooking, chill foods as rapidly as possible. Remember that cooking has destroyed most of the bacteria but spore formers, that are resistant to cooking may become very active and can proliferate rapidly.

4) Cleaning-Wash fruits and vegetables and all foods possible. In addition, continually wash work areas. Use only treated or tested water.

Prevention of Foodborne Illnesses

5) Personal Hygiene- People working with foods should wash their hands regularly, wear hairnets, plastic gloves etc. In addition, food handlers should not work with food if they have a boil, open sores or feel sick themselves

Spoilage Organisms

- Bacterial (hundreds of bacteria cause spoilage)
  - *Erwinia, Pseudomonas, Flavobacteria, & Enterobacter* spp.
  - Lactic acid bacteria

- Fungal
  - *Penicillium, Aspergillus, Fusarium,* and *Candida*

CONCLUSIONS

- Food Microbiology is huge area
- FATTOM
- Pathogens – Food Safety
- Spoilage microorganisms – costly