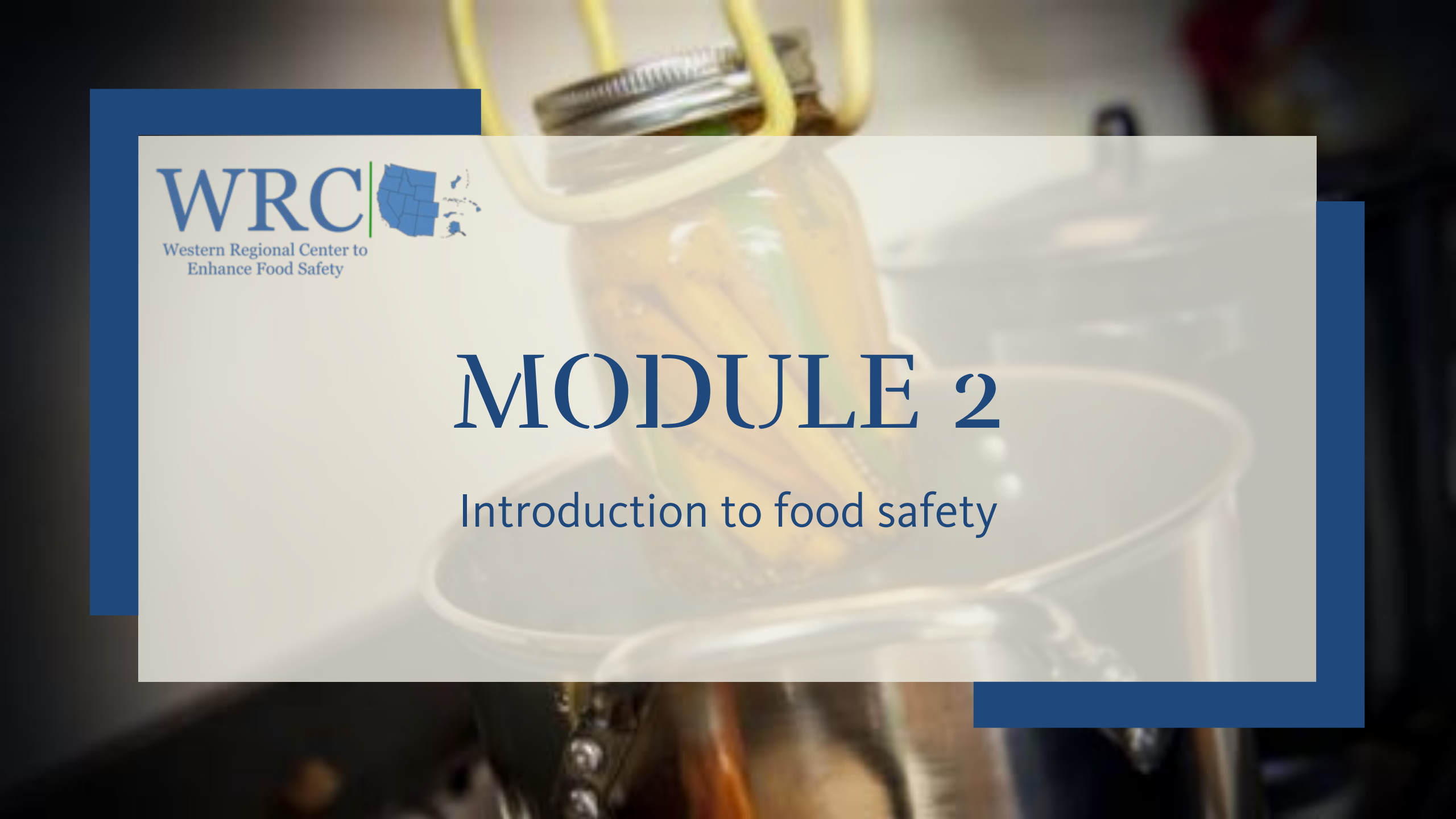

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# MODULE 2

## Introduction to food safety

# Learning objectives

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- Learn about microbiological contaminants in food and their sources.
- Review sources of contamination.
- Gain understanding of factors influencing microbial growth and survival.
- Introduce ways to control microbial hazards.

# Definitions

- Hazard
  - Any biological, chemical (including radiological), or physical agent that has the potential to cause illness or injury.
    - 21 CFR 117.3
- Known or reasonably foreseeable hazard
  - A biological, chemical (including radiological), or physical hazard that is known to be, or has the potential to be, associated with the facility or the food.

# Food Safety

- Food safety requires multisectoral and multidisciplinary approach
  - Foodborne disease and outbreaks result of complex issues
- Farm-to-fork chain
  - Pre-harvest, processing, distribution, retail, restaurants/catering, consumers

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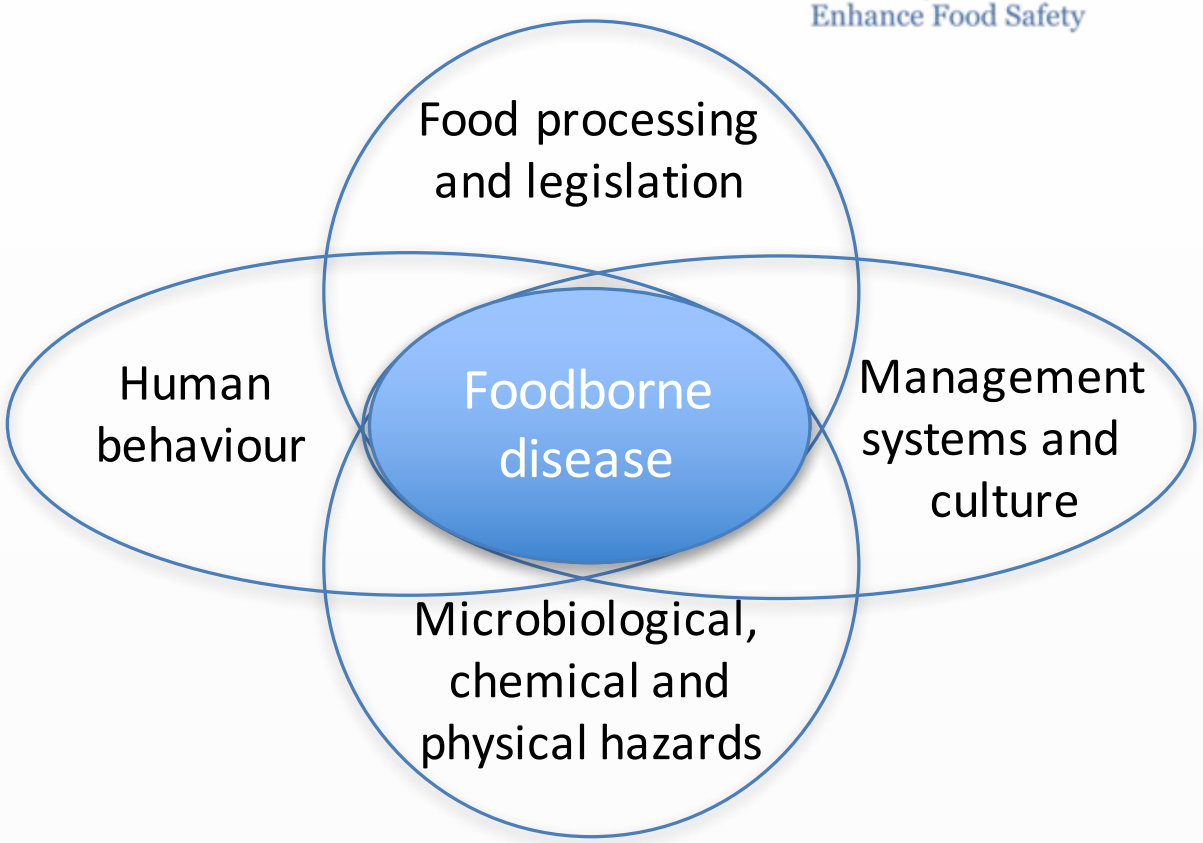


Figure 1. Multidisciplinary interplay within food safety. Adapted from Griffith, 2006. BFJ 108 (1), 6-15.

# Foodborne Illness in North America

Meat and poultry
22% of illnesses

Dairy and eggs
20% of illnesses

Produce
46% of illnesses

The top three commodities linked to the transmission of foodborne illness in North America

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# Biological agents cause more outbreaks

## Reported Foodborne Illness Outbreaks 2009–2013

| Hazard Type | Outbreaks | Illnesses | Hospitalizations | Deaths |
|---|---|---|---|---|
| Biological | 2,545 | 52,750 | 3,552 | 99 |
| Chemical | 163 | 663 | 67 | 5 |
| Physical | Not collected | | | |
| Unknown | 1,204 | 13,770 | 286 | 3 |

Adapted from: CDC Surveillance for Foodborne Disease Outbreaks, United States Annual Reports, 2009-10, 2011, 2012, 2013

FSPCA
FOOD SAFETY PREVENTIVE CONTROLS ALLIANCE

# Microbial hazards

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What are the microbial hazards?

Where do they come from?

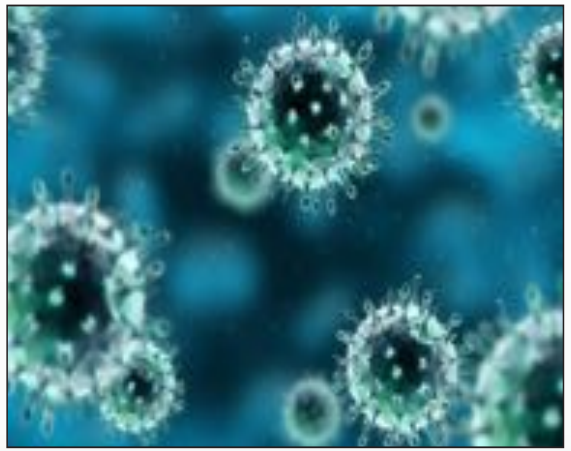
Why and how do they survive?

How do we prevent or control them?

# Biological or microbial hazards

- Pathogens
  - Organisms of concern because they can make people ill
  - Any agent that causes disease in humans, animals or plants
    - Bacteria, viruses, protozoans

*Listeria monocytogenes*
(Photo source: CDC, Jennifer Oosthuizen)



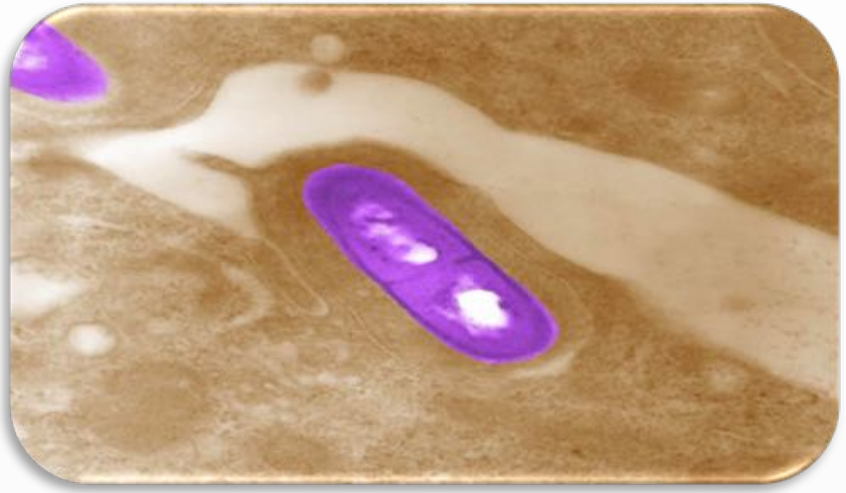
Enterovirus

*Giardia*

Meals et al., 2013. TechNotes 9 - National Nonpoint Source Monitoring Program.

# Environmental pathogens of concern in food processing environments

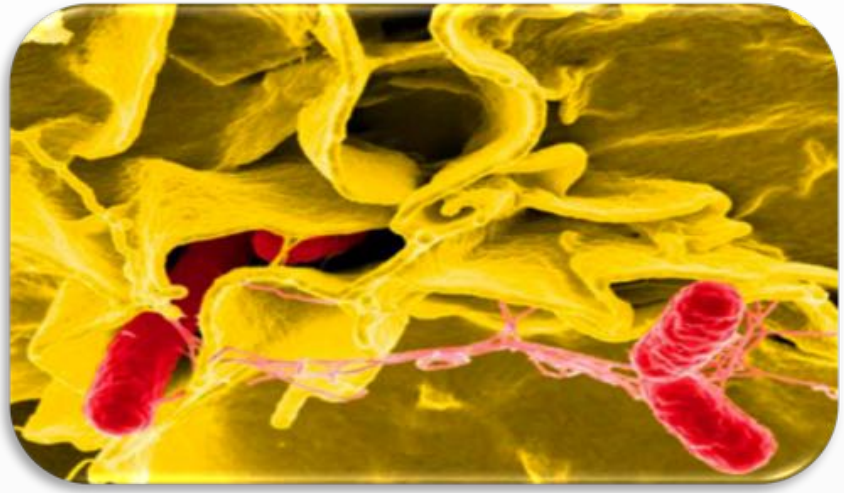
## Contaminant of concern in wet RTE environments



*Listeria monocytogenes*

Photo source: CDC, Dr. Balasubr Swaminathan; Peggy Hayes

## Contaminant of concern in dry RTE environments



*Salmonella* sp.

Photo source: CDC, National Institute of Allergy and Infectious Diseases (NIAID)

# Food processing environment

Western Regional Center to Enhance Food Safety

What are the microbial hazards?

**Where do they come from?**

Why and how do they survive?

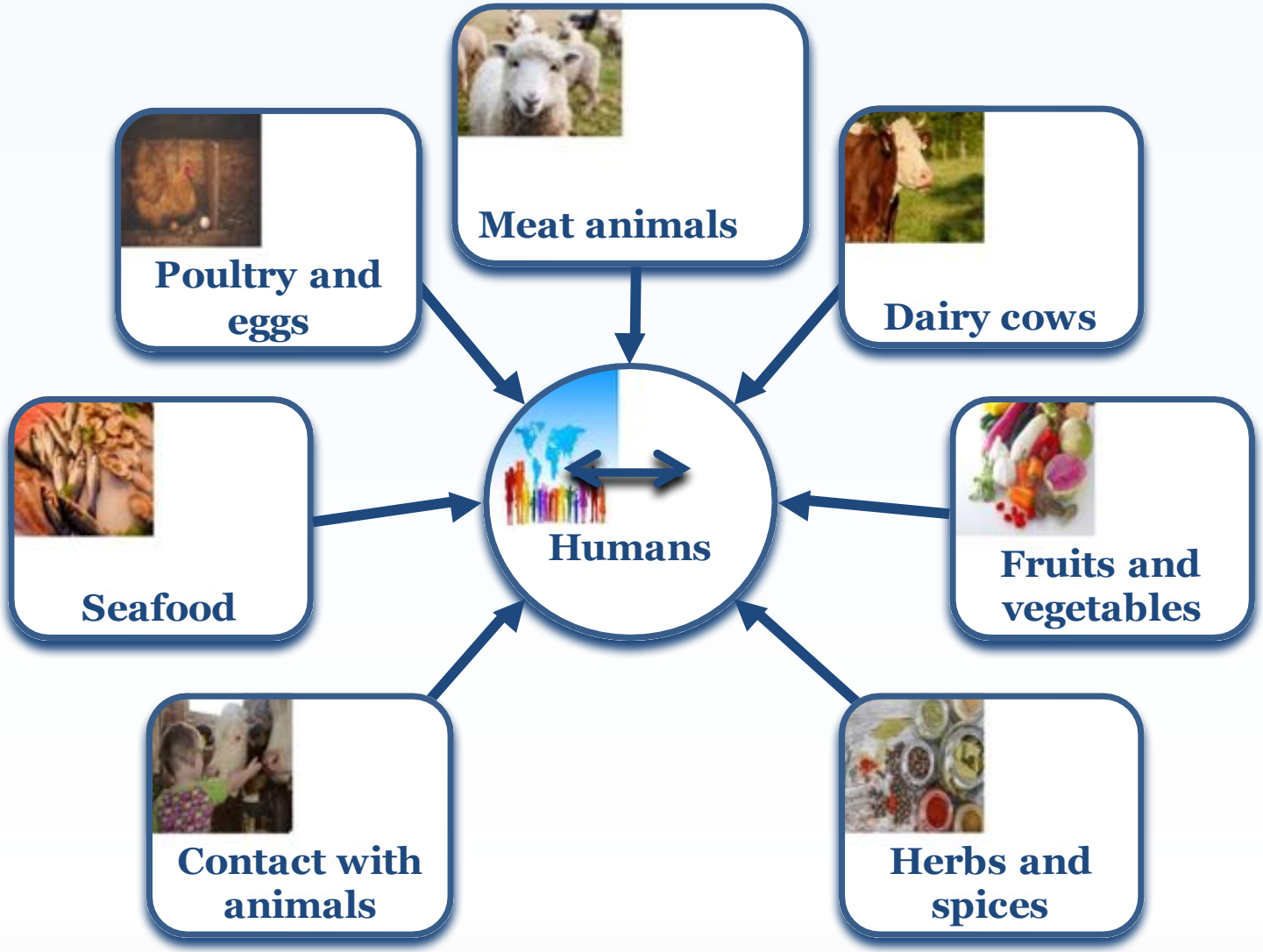
How do we prevent or control them?

# Microbial sources

- Diverse habitats (but overlapping!)
  - *Escherichia coli*
    - Soil and water, plants, GI tract, people
  - *Listeria* spp.
    - Soil and water, plants, people, animal feeds, animal hides
  - *Salmonella* spp.
    - GI tract, animal feeds

Jay et al., 2005. Modern Food Microbiology, 7th Ed. Springer. Pg.18-19.

# Sources of foodborne pathogens




Ray, 2013. pp. 34

# Sources of foodborne pathogens

- Understanding sources important for
  - Developing methods to control access of microorganisms to the food
  - Developing processing methods to destroy them/ suppress their growth
  - Determining the microbiological quality of food
  - Setting up microbiological standards and specifications of foods and food ingredients

# Sources of contamination in food processing environment

- Food processing environment is a complex and dynamic environment
- Potential contamination reservoirs…

RAW MATERIALS

*Recurring introduction of new microorganisms*

PERSONNEL

*Fecal (coliforms, enterococci, pathogens)*

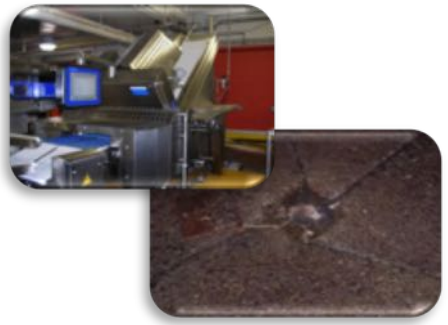
*Nasal, skin (*Staphylococcus aureus*), hair*

*Ill and asymptomatic employees (Viruses -Norovirus, Hepatitis)*

WATER

*Contaminated water*

*Inappropriate washing & aerosol spread*



PRODUCTION ENVIRONMENT

*Food contact surfaces (FCS)*

*Floors, drains, utensils*

*Production equipment – fork lifts, hydraulic hand lifts, mats etc.*

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Photo source:
https://pixnio.com (raw materials, personnel 2, water 2); http://weclipart.com/ (personnel 1); https://pixabay.com (water 1), BCFPA (production environment 1)

# Microbial hazards

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What are the microbial hazards?

Where do they come from?

Why and how do they survive?

How do we prevent or control them?

# Microbial growth

- Microorganisms grow or multiply in numbers when exposed to a favorable environment
- Growth can be associated with:
  - Food spoilage
  - Foodborne diseases
  - Food bioprocessing

- Growth affected by:
  - Food properties/ environment → intrinsic factors
  - Environment in which food is stored → extrinsic factors
  - Microorganism properties → implicit factors

## Intrinsic factors

Properties of a food product

- pH
- Water activity ($a_w$)
- Redox potential (Eh)
- Nutrient content
- Antimicrobial constituents
- Biological composition/ structures

## Extrinsic factors

Properties of storage environment that affect microbial survival/growth, external to the food

- Temperature
- Relative humidity
- Gases
- Microbiota competition

## Implicit factors

Properties of microorganisms themselves

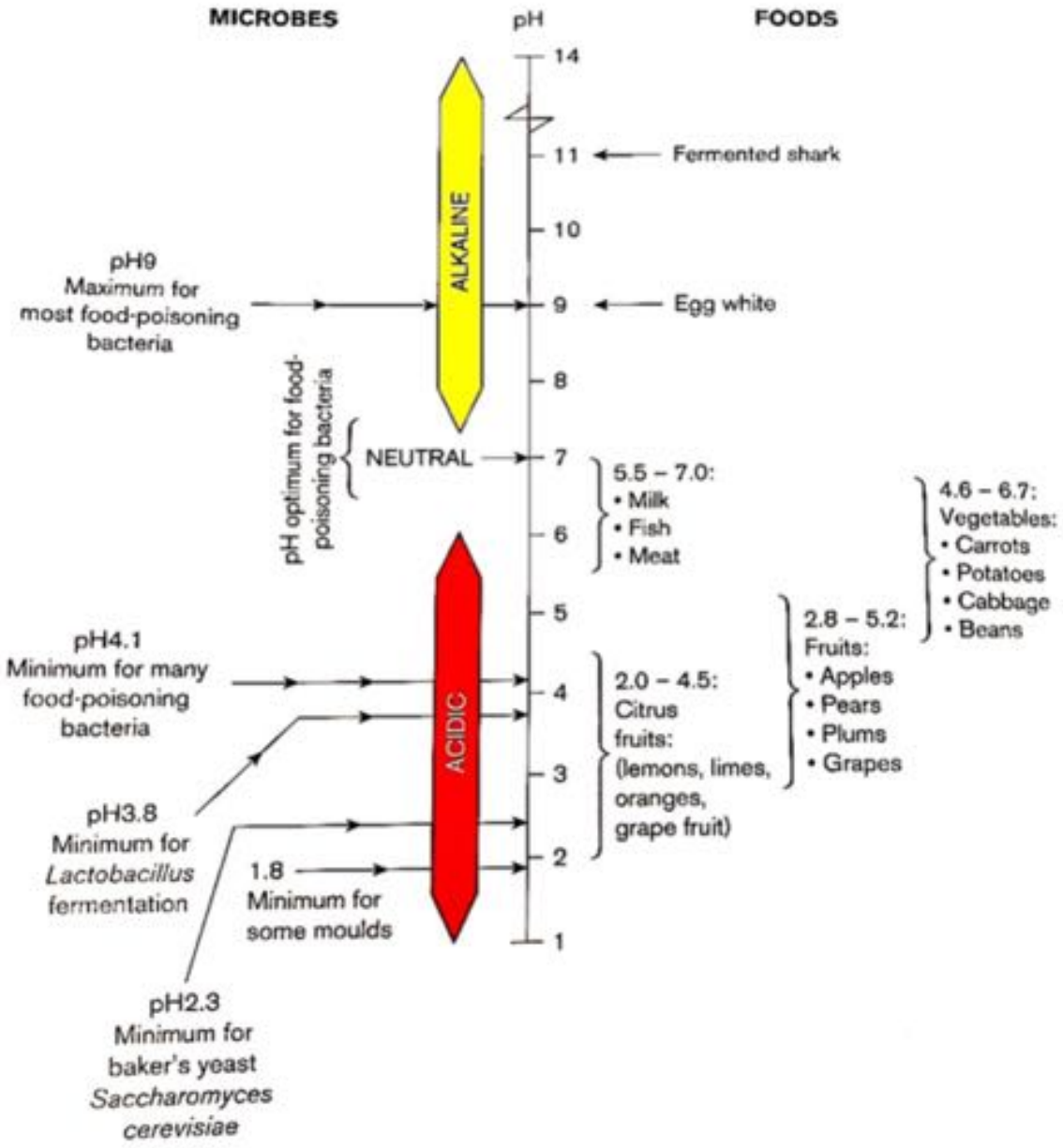
- Exponential phase cells killed more easily by heat, low pH and antimicrobials
- Preadaptation to stress
- Stress response mechanisms

# pH

A measure of food's acidity or alkalinity.

Foods with a pH less than 7.0 are acidic.

While a low pH may prevent bacterial growth, some pathogens can survive!

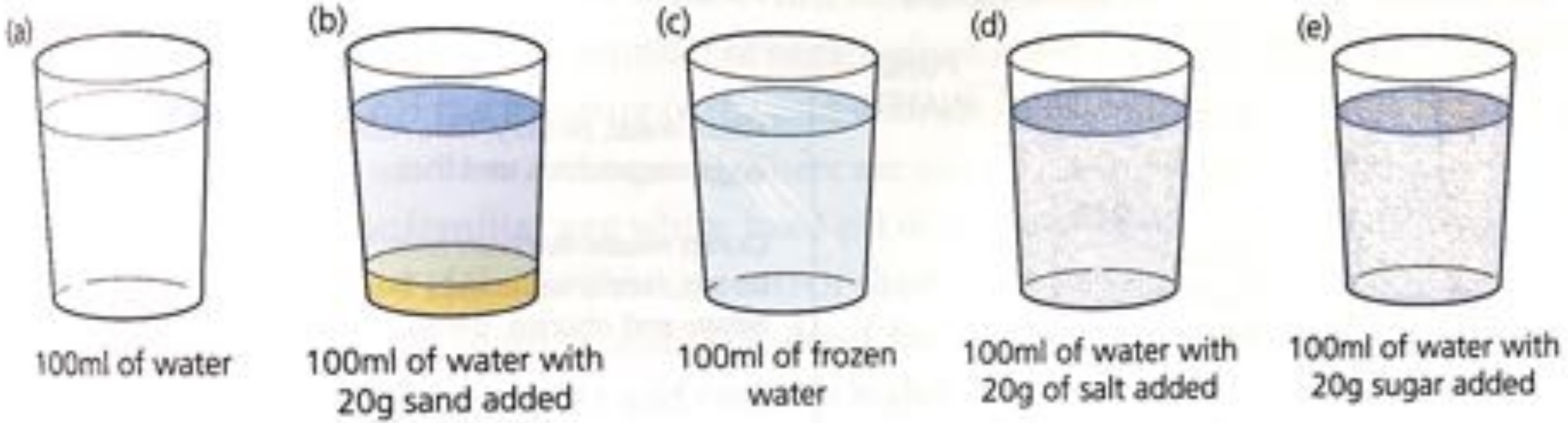



Roller, 2012. Essential Microbiology and Hygiene for Food Professionals. Pg. 131

# $a_w$

"A measure of the free moisture in a food and is the quotient of the water vapor pressure of the substance divided by the vapor pressure of pure water at the same temperature."

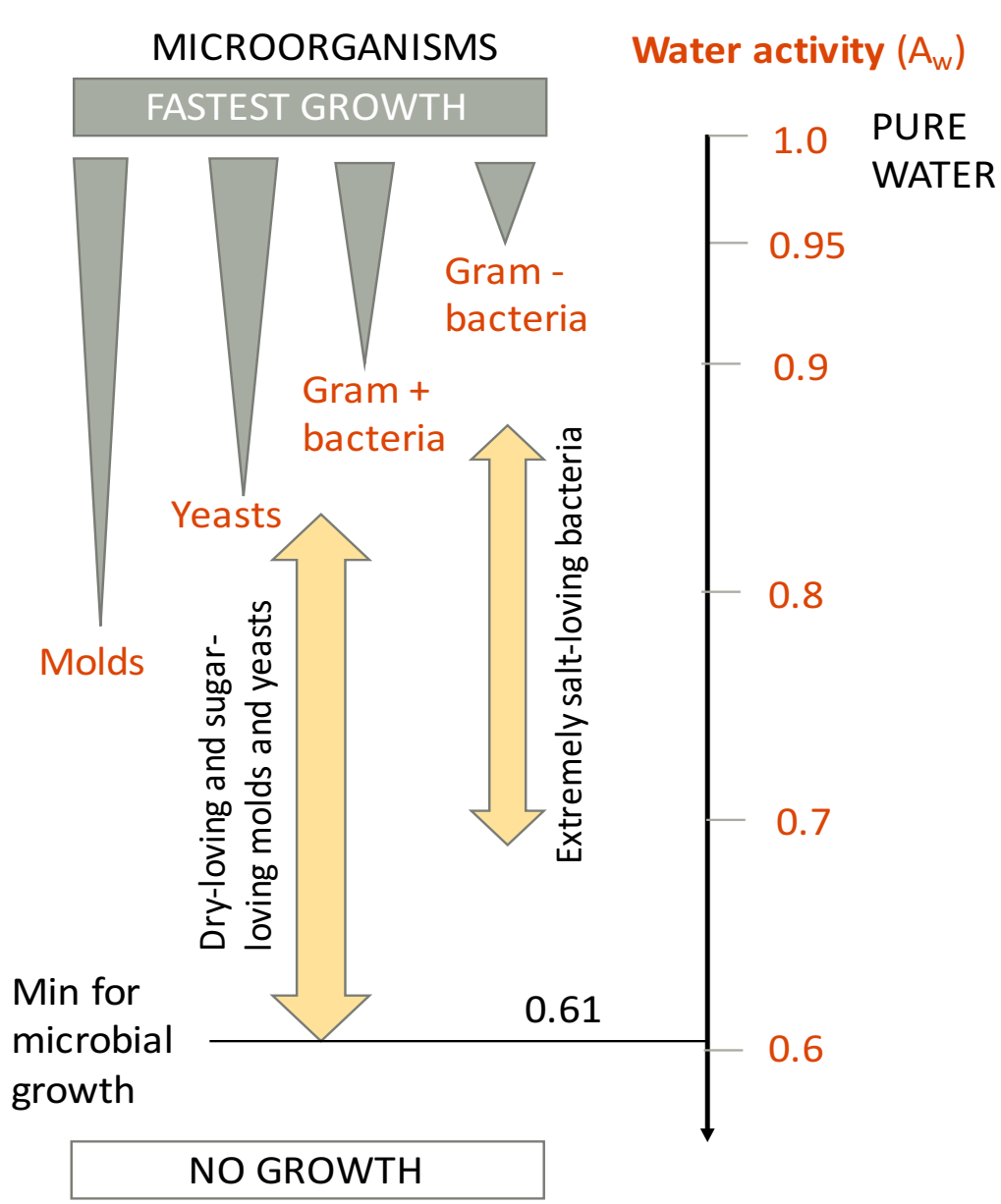
21 CFR 117.3




The availability of water for microbial growth.

Roller, 2012. Essential Microbiology and Hygiene for Food Professionals. Pg. 129

$a_w$




FOODS

Fresh meat, poultry, fish, milk, eggs, vegetables, fruit

Cured meats such as ham and bacon, fermented meats such as salami and chorizo, bread

Foods preserved by drying or addition of larger amounts of sugar or salt

- Mature cheeses
- Fruit conserves and jams
- Pickles and syrups
- Cakes
- Dried fruits
- Dried fish

Dehydrated foods

- flour, pasta, biscuits, crackers, cereals, dried soups, powdered milk, chocolate, sugar, honey

Roller, 2012. Essential Microbiology and Hygiene for Food Professionals. Pg. 130. Graphic adapted by J. Kovacevic.

# Redox potential (Eh)

- Ease with which an element or compound loses/gains electrons
- Unit is mV
  - Aerobes, +mV (oxidative)… $O_2$
  - Anaerobes, -mV (reductive)… $NO_3$, $SO_4$, hydrogen, lactate
- Microbes have different Eh niches

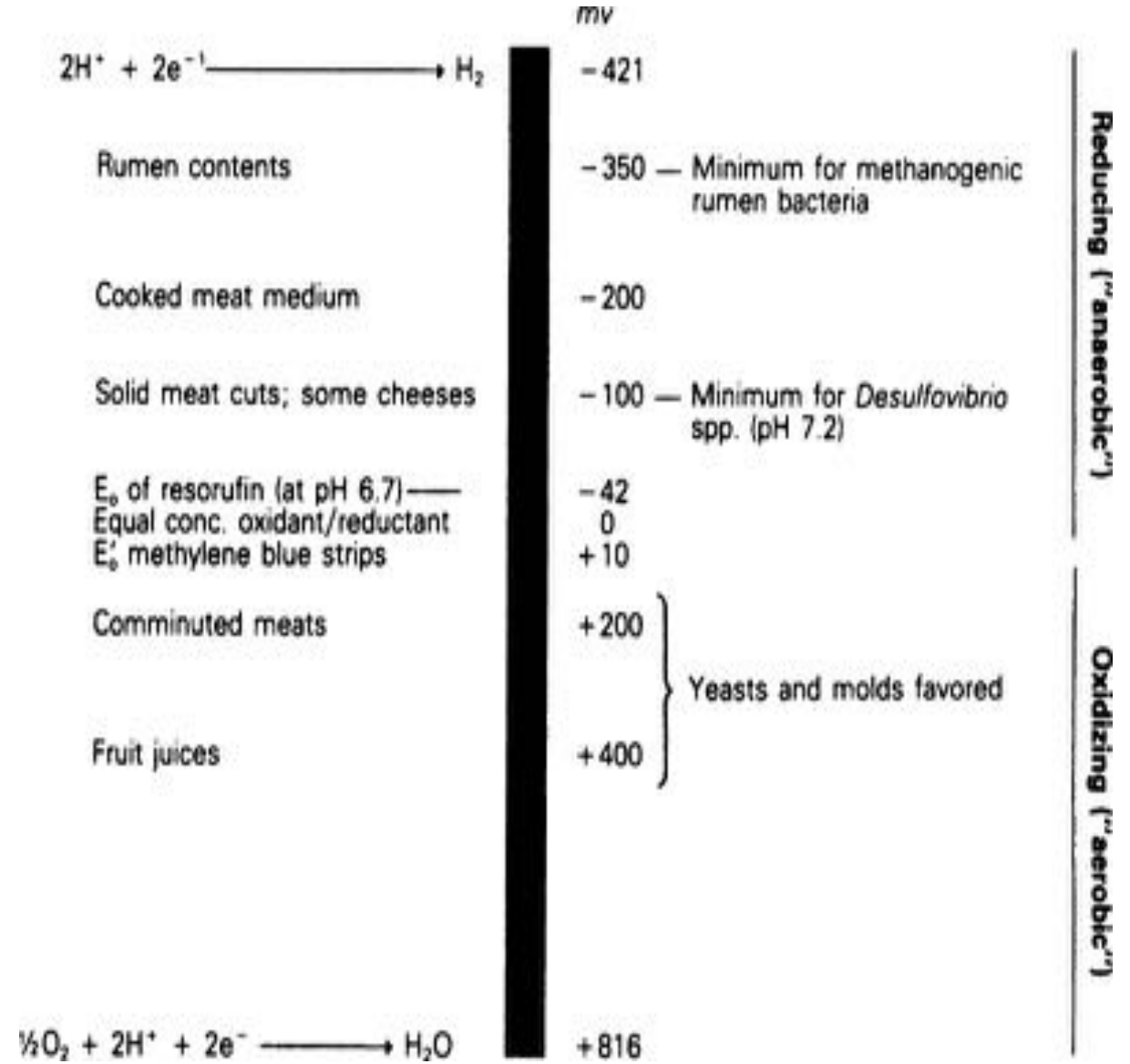
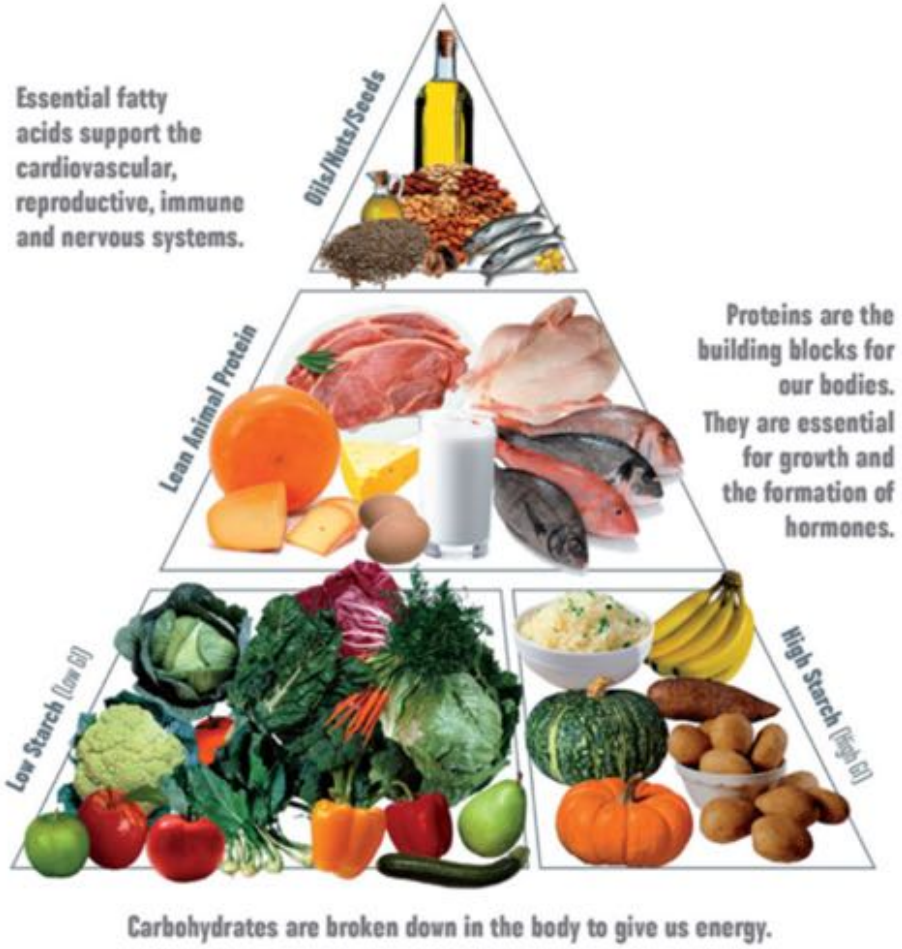



**Figure 3–3** Schematic representation of oxidation–reduction potentials relative to the growth of certain microorganisms.

Jay et al. 2005. Modern Food Microbiology, 7th Ed. Springer. pg.50.

# Intrinsic factors

- Nutrient content




- Antimicrobial constituents
  - Naturally occurring antimicrobial compounds
  - **Plants**: Eugenol (cloves), allicin (garlic), cinnamic aldehyde (cinnamon), thymol (sage, oregano)
  - **Dairy**: Lactoperoxidase, lactoferrin
  - **Eggs**: lysozyme, ovotransferrin

# Intrinsic factors: Biological composition

- Biological structures
  - Protective covering that prevent microorganisms from gaining entry to growth promoting tissues underneath
    - Once compromised, protective effect is minimized
- Examples
  - Nut shells
  - Eggs
  - Fruit skins/peels
  - Animal hides

## Intrinsic factors

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## Extrinsic factors

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- Gases
- Microbiota competition

## Implicit factors

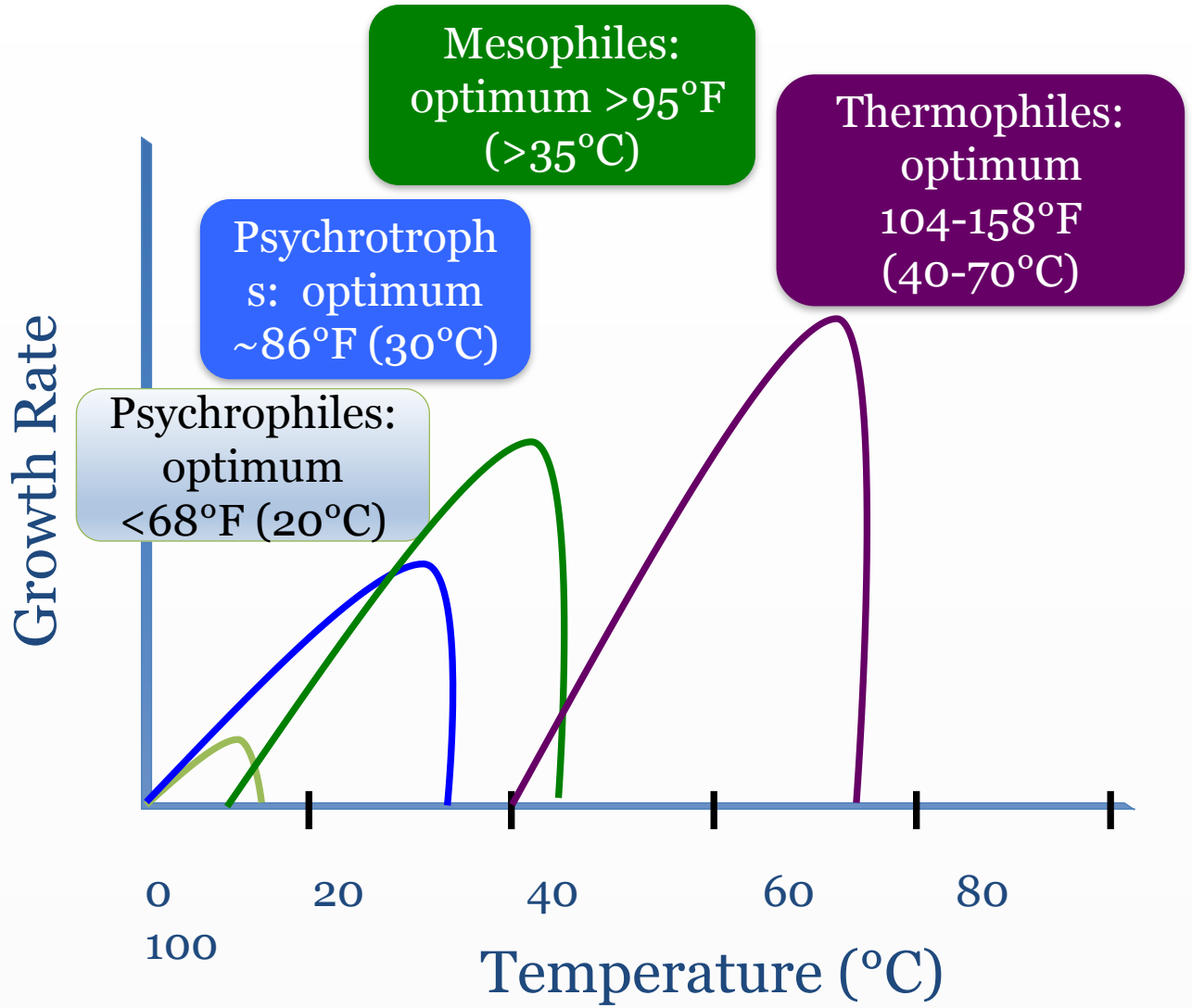
Properties of microorganisms themselves

- Exponential phase cells killed more easily by heat, low pH and antimicrobials
- Preadaptation to stress
- Stress response mechanisms

# Temperature

- Storage temperatures selective or inhibitory for different microbes
  - Abusive temperatures may negatively influence product microbes
  - Temperature can affect product quality

    e.g., bananas




FDA, 2012. "Bad Bug Book".
Graphic source: Kovacevic, J.

# Relative humidity and gases

- The amount of water vapor present in air expressed as a % of the amount needed for saturation at the same temperature
- $a_w$ of food is influenced by RH of storage environment

## Low moisture foods

- $a_w$ less than 0.6 must be kept dry, as they will pick up moisture from air in high RH
- Surface spoilage susceptible foods need low RH storage

## High moisture foods

- Low RH storage can decrease food quality due to physical/chemical changes

- To counteract low RH negative effects upon quality, gases can be added
  - Modified atmosphere packaging (MAP)

High: >70% $O_2$, 20-30% $CO_2$, $N_2$

Low: <10% $O_2$, 20-30% $CO_2$, $N_2$

Photo source: G. Mondini
http://www.gmondini.com/gallery/map

# Microbiota competition

- Microorganisms compete with each other for nutrients and space
  - Produce a variety of antimicrobial compounds (e.g. lactic acid bacteria)
    - Bacteriocins, hydrogen peroxide, organic acids (**lactic acid**)
    - Improve product quality/safety
  - Bacteriophage
    - Listeriaphage used to destroy *Listeria monocytogenes* in food production environments/in food

    e.g. Listex

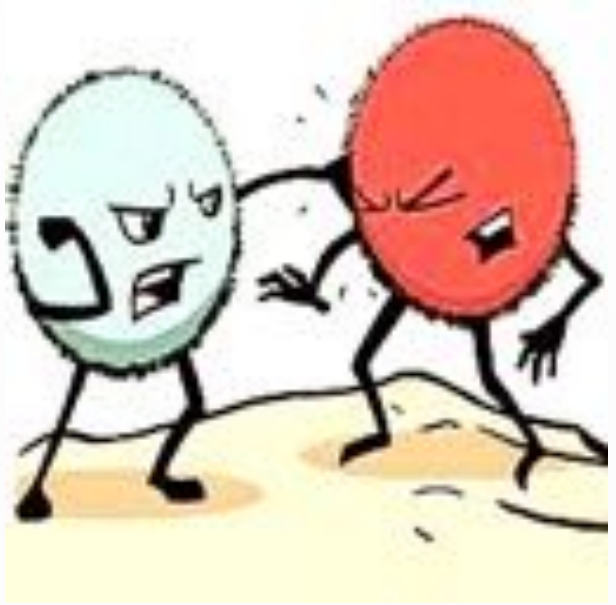


Image source: http://www.doctorbhatia.com/wp-content/uploads/2011/05/f-bacteria-fight.jpg

## Intrinsic factors

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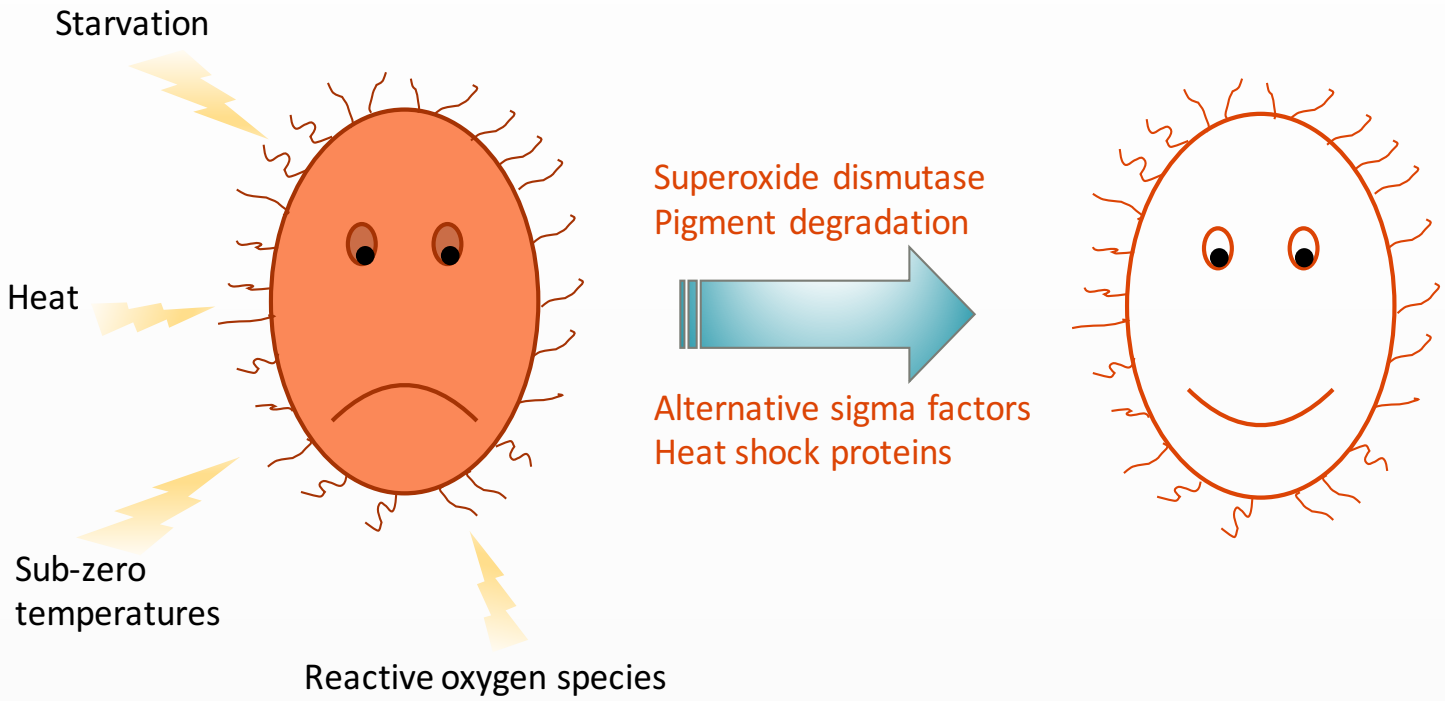
- Preadaptation to stress
- Stress response mechanisms

# Implicit factors

- Properties of microorganisms

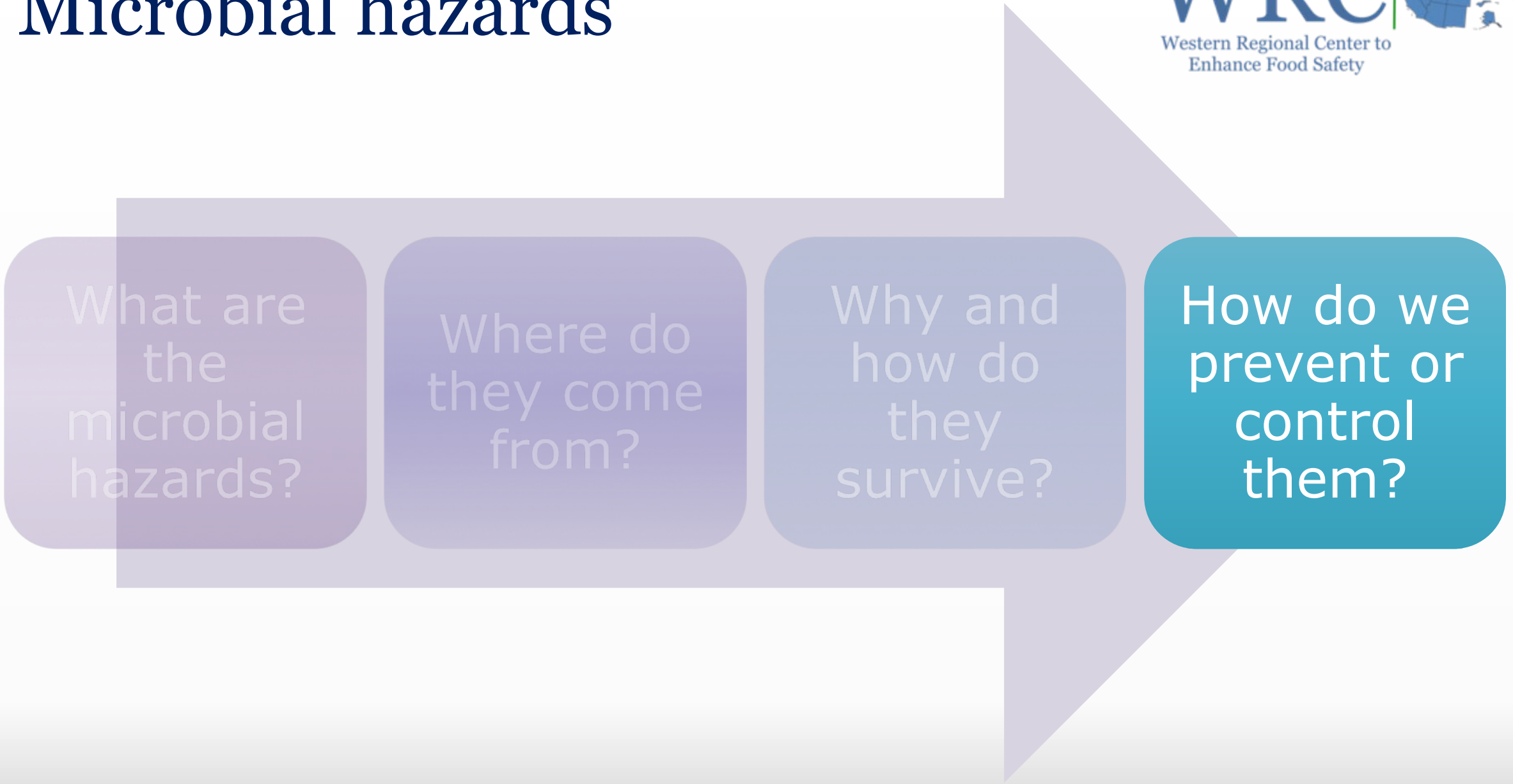
Microorganism are commonly exposed to damaging elements in food processing environments.

They battle these conditions through sophisticated set of cellular stress responses.

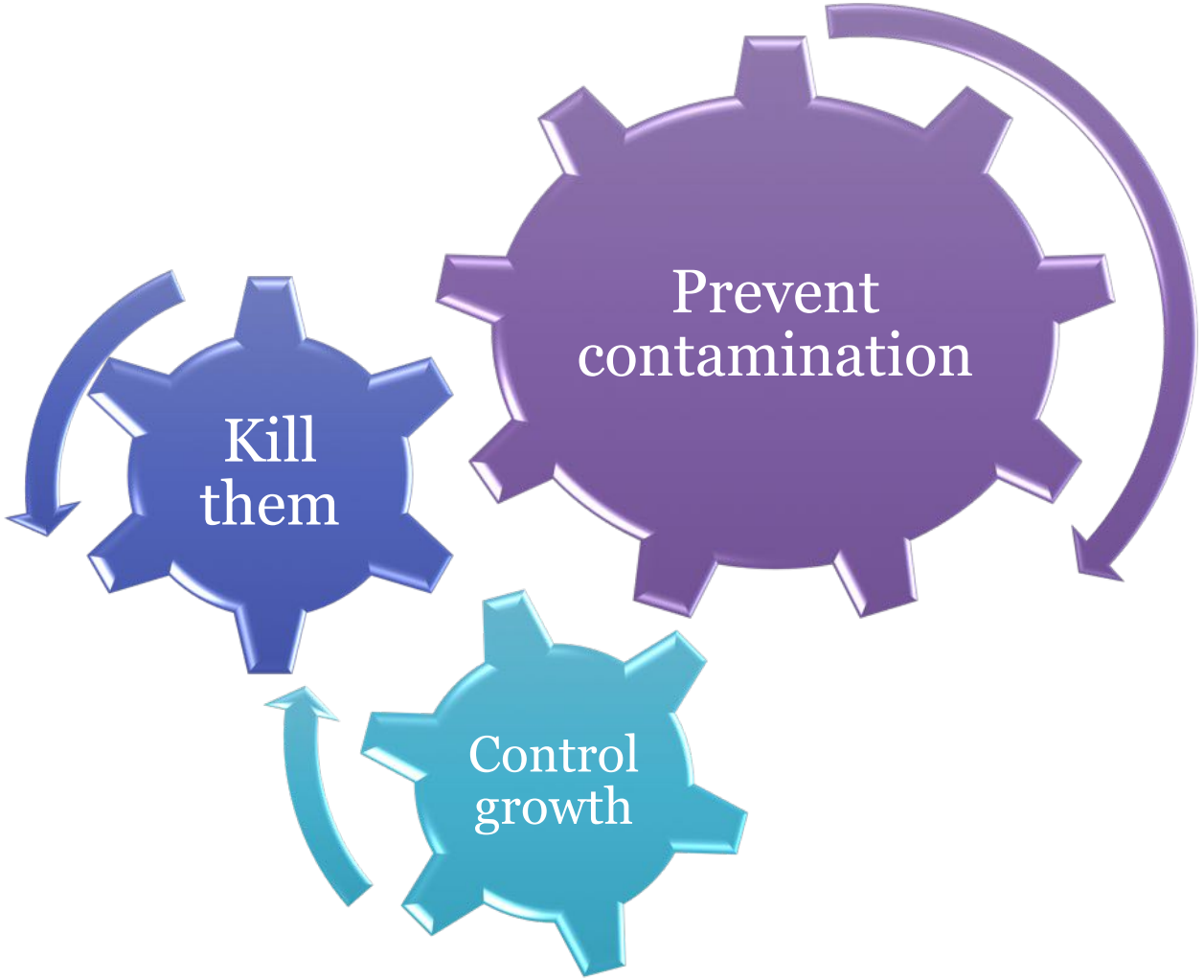



Adapted from Adrienne Dolberry. 7.343 MIT. OpenCourseWare, https://ocw.mit.edu.

# Microbial hazards



# Potential control methods for bacteria



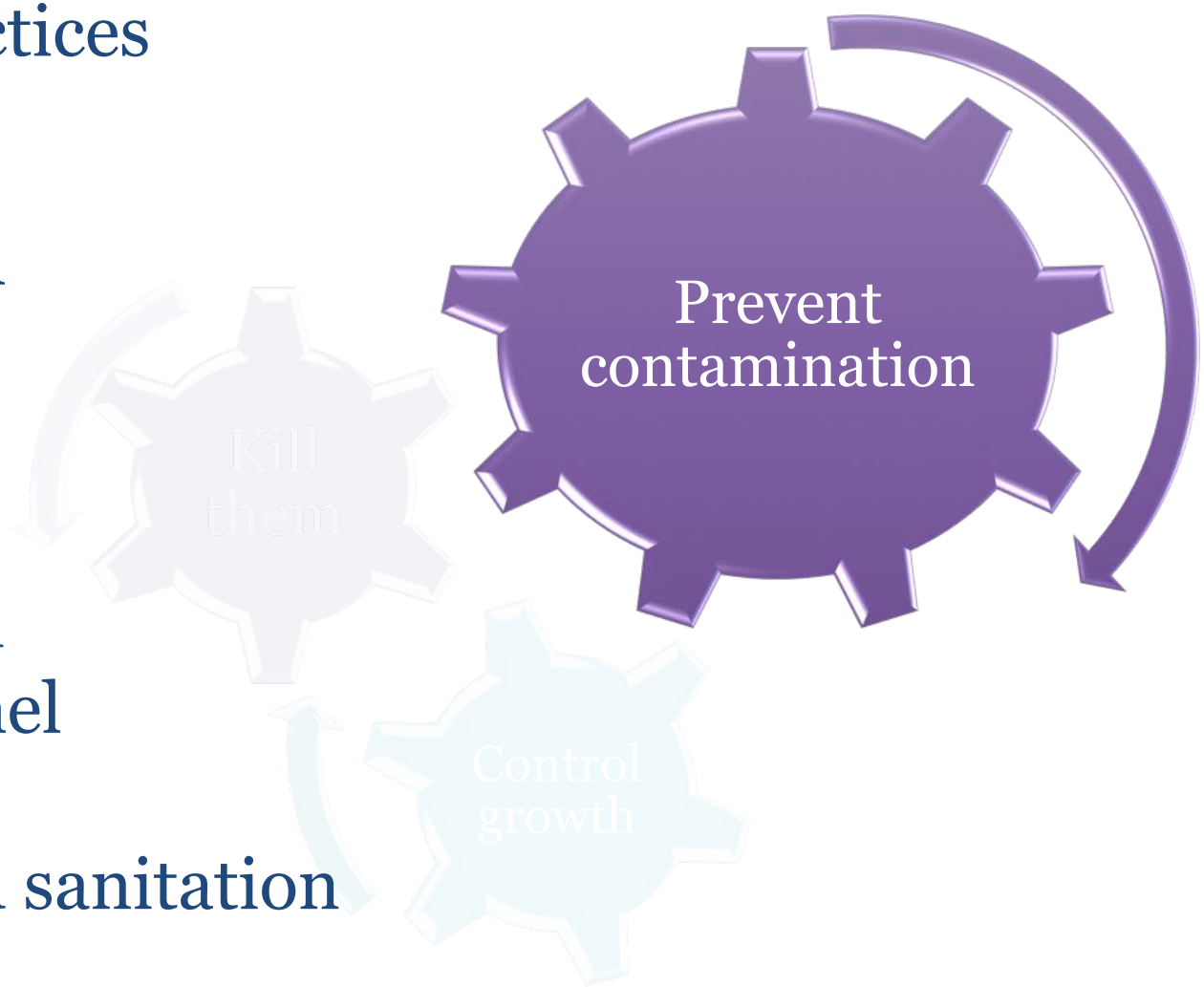
# Potential control methods for bacteria

Proper hygiene practices

Preventing cross contamination from raw to ready-to-eat

Preventing contamination from equipment, personnel

Proper cleaning and sanitation



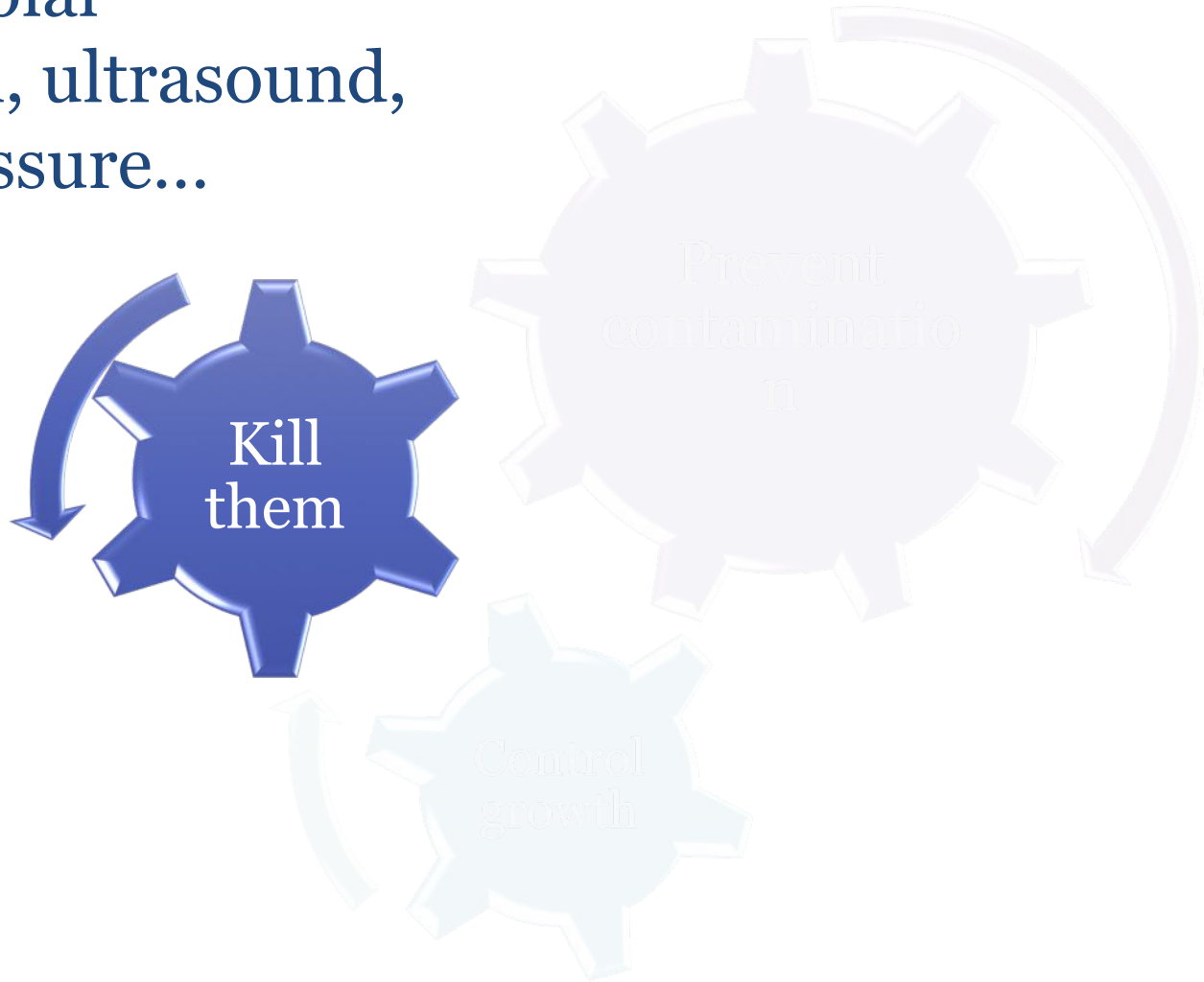
# Potential control methods for bacteria

Heat, acid, antimicrobial chemicals, irradiation, ultrasound, pulsed light, high pressure…

Conditions influence rate of kill

- Time,
- temperature, food composition…

Models can predict inactivation

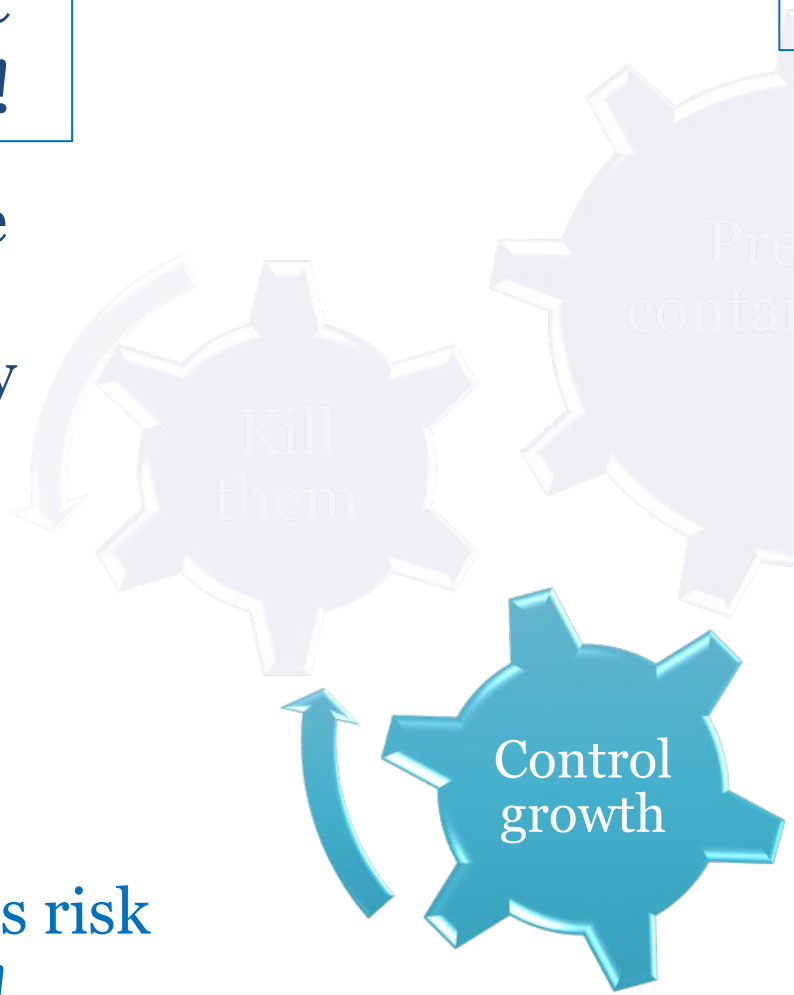


# Potential control methods for bacteria

## Understand intrinsic and extrinsic factors!

Food – a nutrient source
Temperature and time
pH – acidity or alkalinity measure
Water
Proper atmosphere
Microbial competition
Preservatives

Reducing growth reduces risk but may not eliminate it!




## Apply hurdle concept

Multiple factors are combined to control food microorganisms

Temp, $a_w$, pH, Eh, antimicrobials

Can lead to milder processing, increasing fresher food product availability

Gas packaging, bioconservation, bacteroicins, ultrahigh pressure treatment, edible coatings

# Potential control methods for bacteria

Understand intrinsic and extrinsic factors!

Apply hurdle concept

**Validate processes are adequate to kill microorganisms/prevent growth!**

# Summary

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- Foods and food processing environments may become contaminated with pathogens found in nature, animals, humans and various sources
- Two common pathogens of concern in food processing environments are *Listeria monocytogenes* (wet environment) and *Salmonella* spp. (dry environment)
- Microbial growth and survival is affected by intrinsic, extrinsic and implicit factors
- Potential controls for microbiological hazards include: preventing contamination, killing microorganisms through processing, controlling growth of microorganisms through manipulation of growth conditions (intrinsic/extrinsic factors)