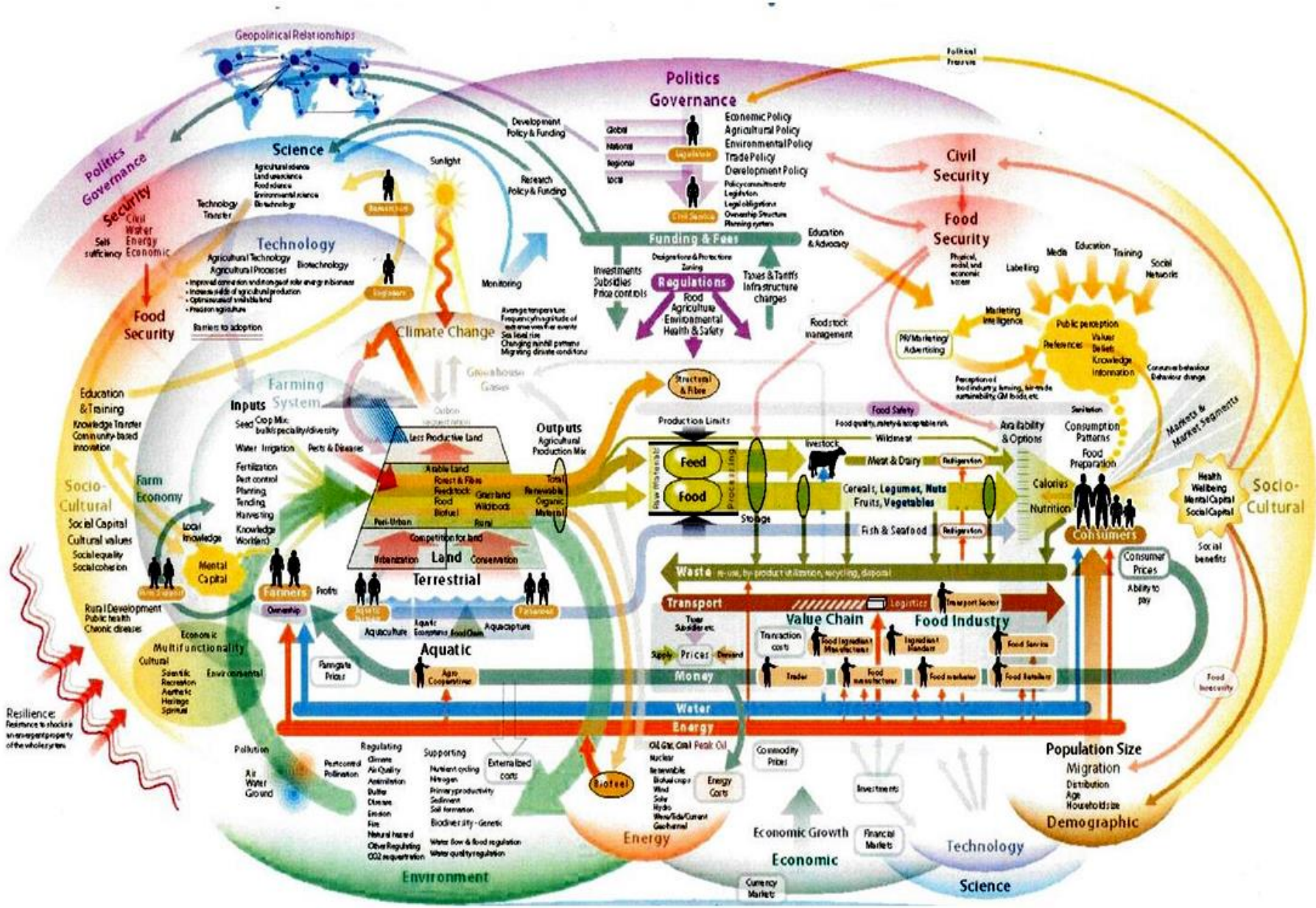
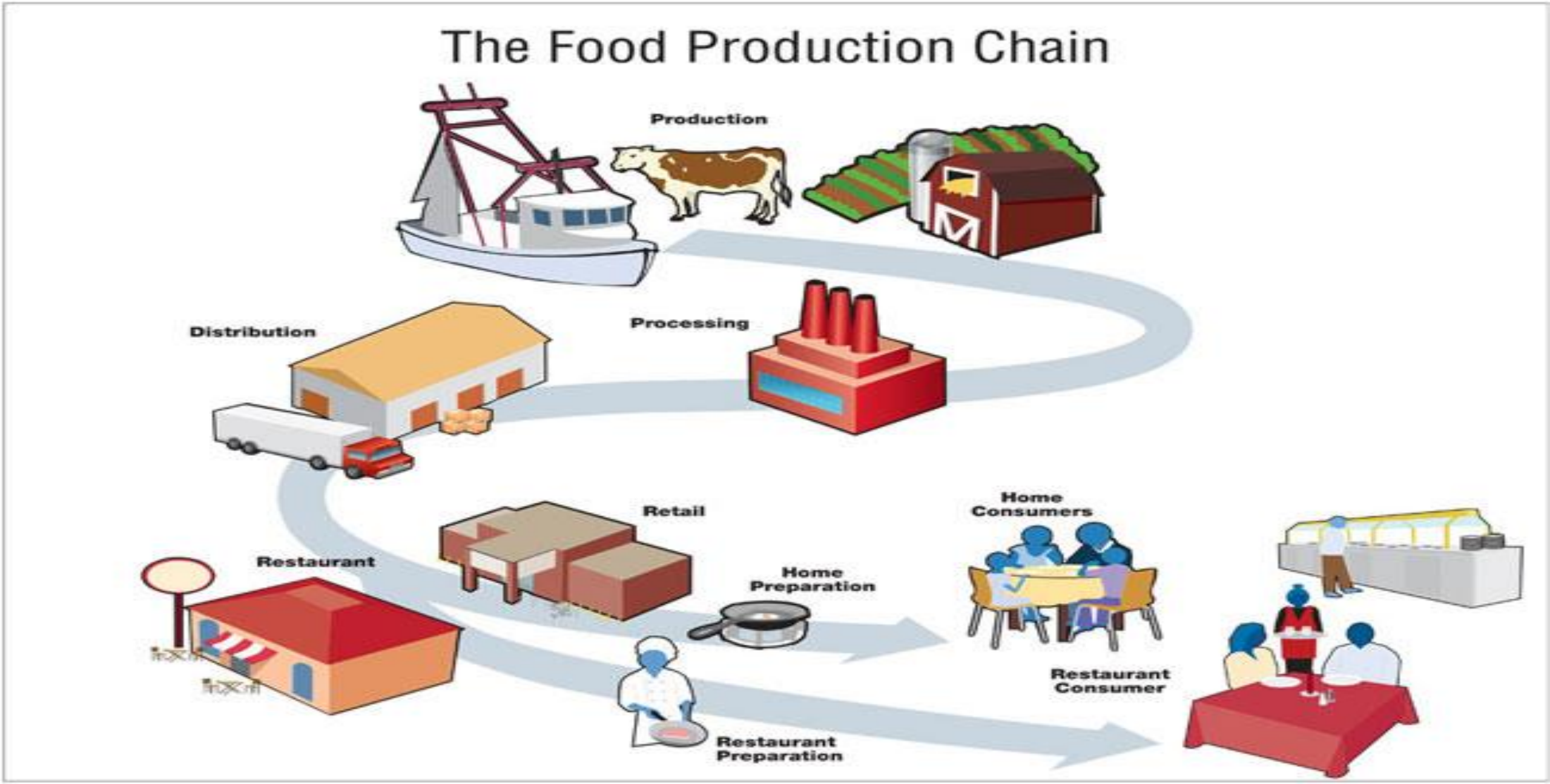
Microbes, food, and nutrition

Dr. Nick Coleman

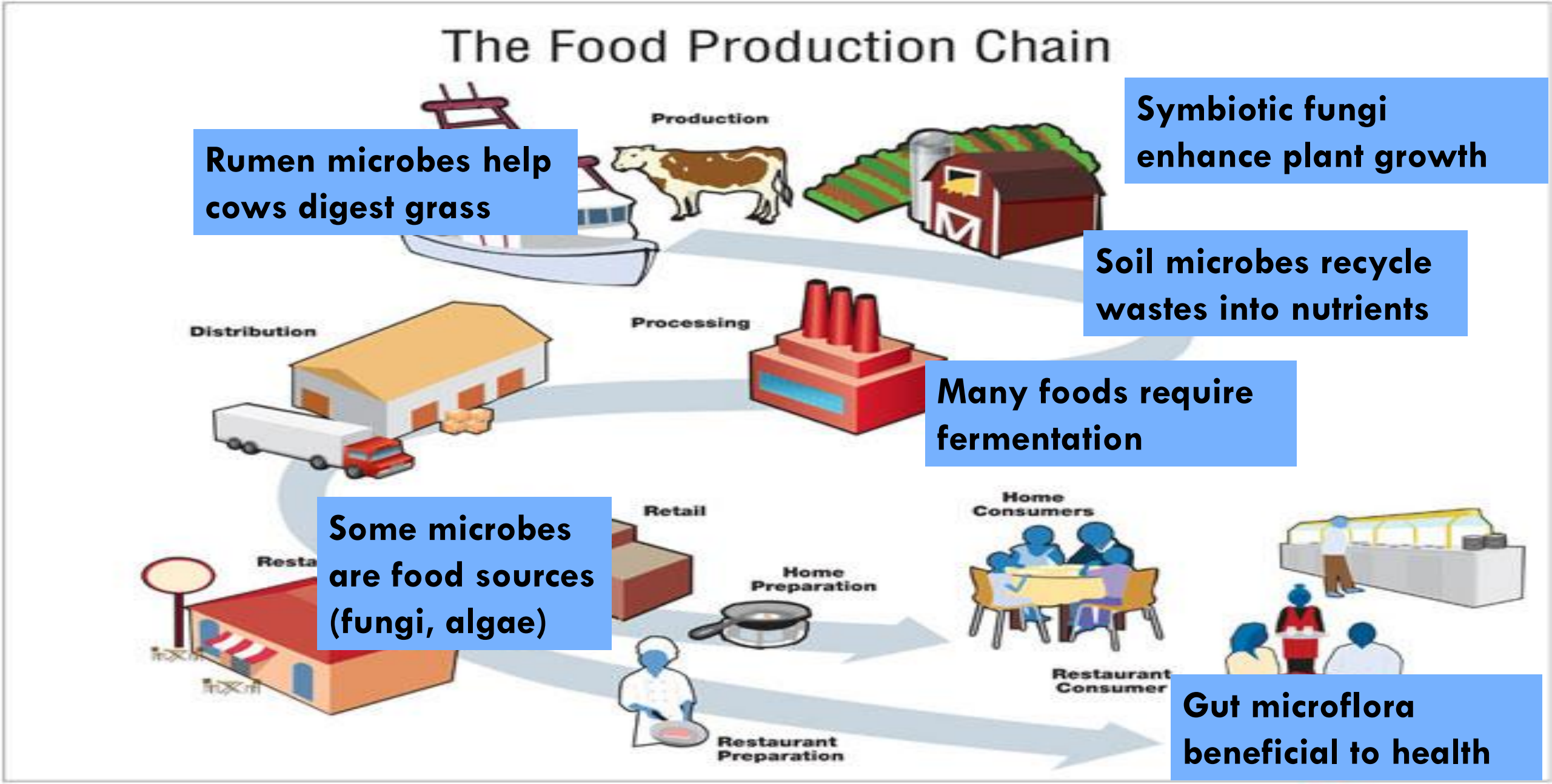
Our food supply is very complex



Microbes affect every point in food production



Microbes affect every point in food production for good…



Rumen microbes help cows digest grass

Symbiotic fungi enhance plant growth

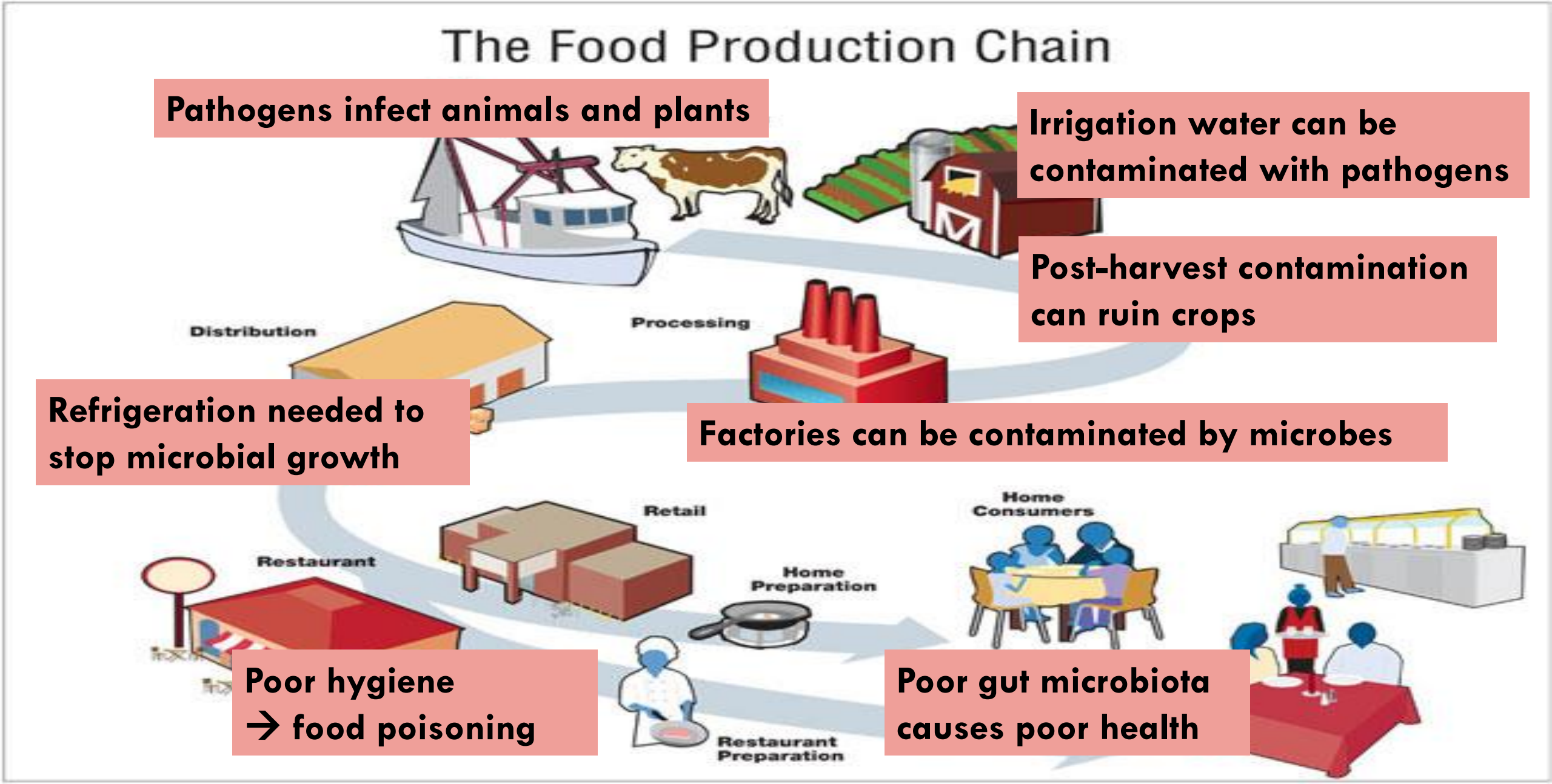
Soil microbes recycle wastes into nutrients

Many foods require fermentation

Some microbes are food sources (fungi, algae)

Gut microflora beneficial to health

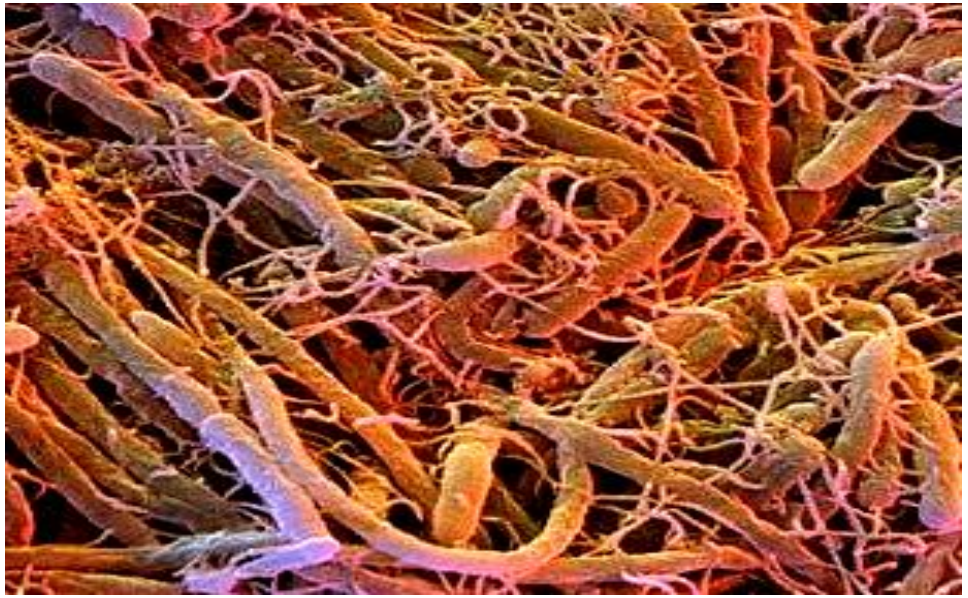
Microbes affect every point in food production and bad…



Enhancing food production - microbes in soil

Microbes maintain soil health by:

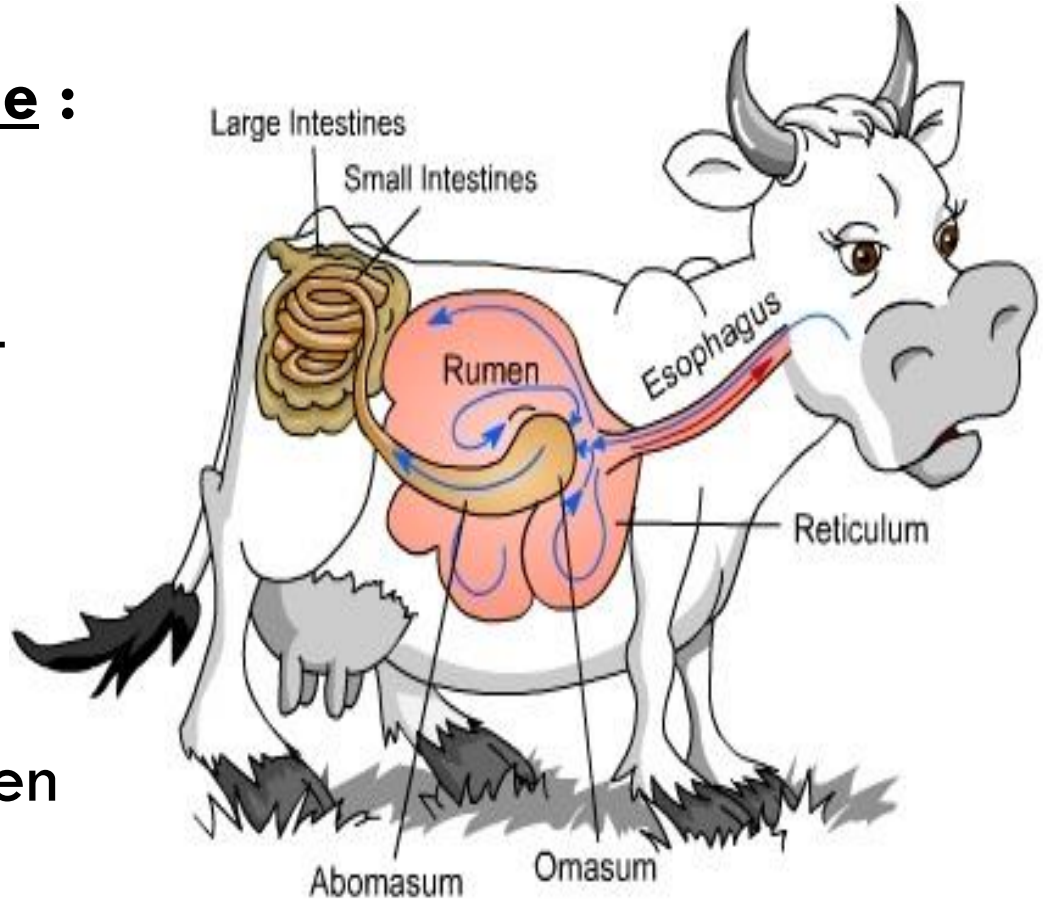
- Fixing nitrogen ($N_2 \rightarrow NH_4^+$)
- Breaking down organic wastes into inorganic nutrients
- Suppressing animal + plant pathogens
- Breaking down toxins e.g. pesticides



Enhancing food production - microbes in animals

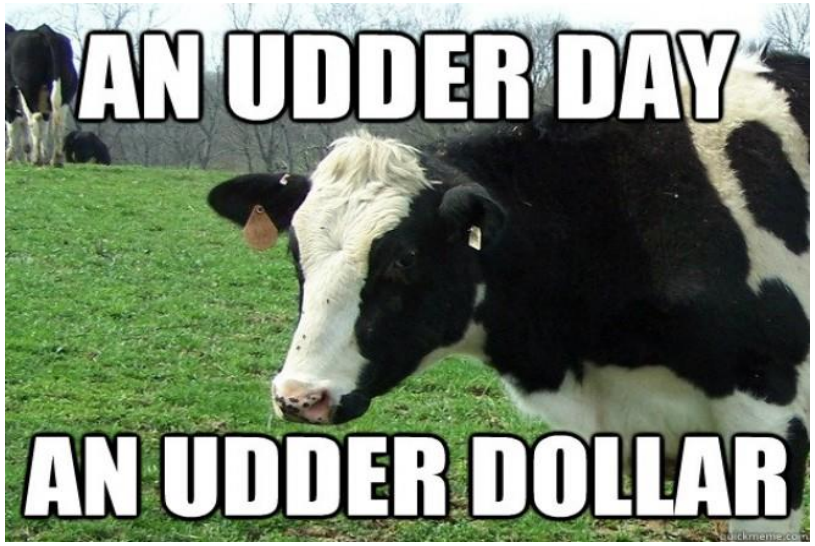
Microbes enable animals to digest <u>cellulose</u> :

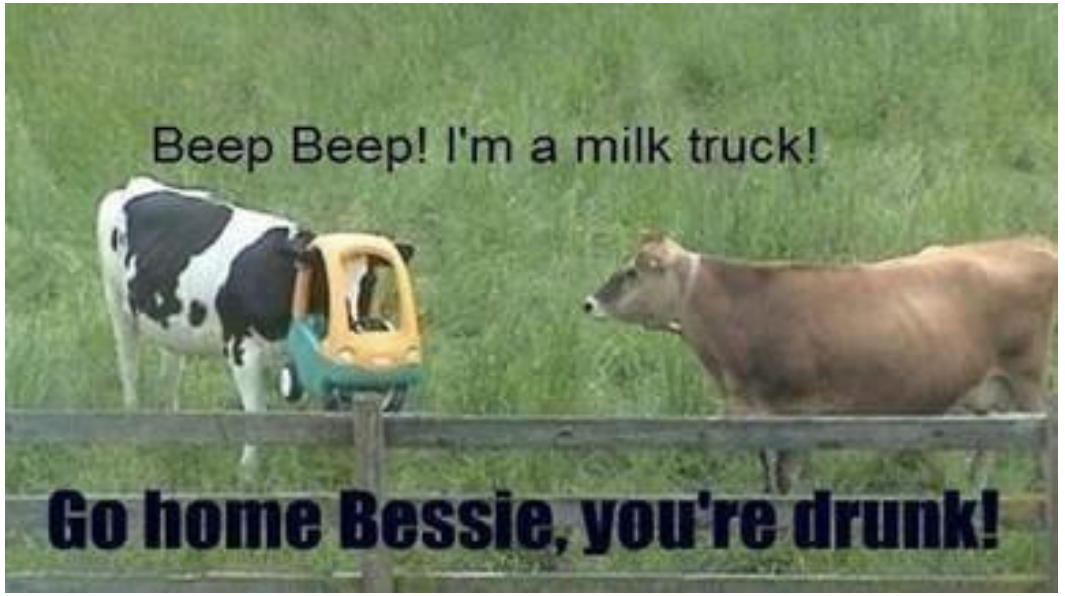
- Cellulose: a sugar polymer, abundant in plants, carbon-rich, but difficult to digest
- <u>Rumen</u> microbes break down cellulose → sugars → organic acids, CO_2 , CH_4
- Organic acids and microbial cells are then digested by animal as nutrients



CH_4 from ruminants → climate change ☹

Enhancing food production – microbes in animals

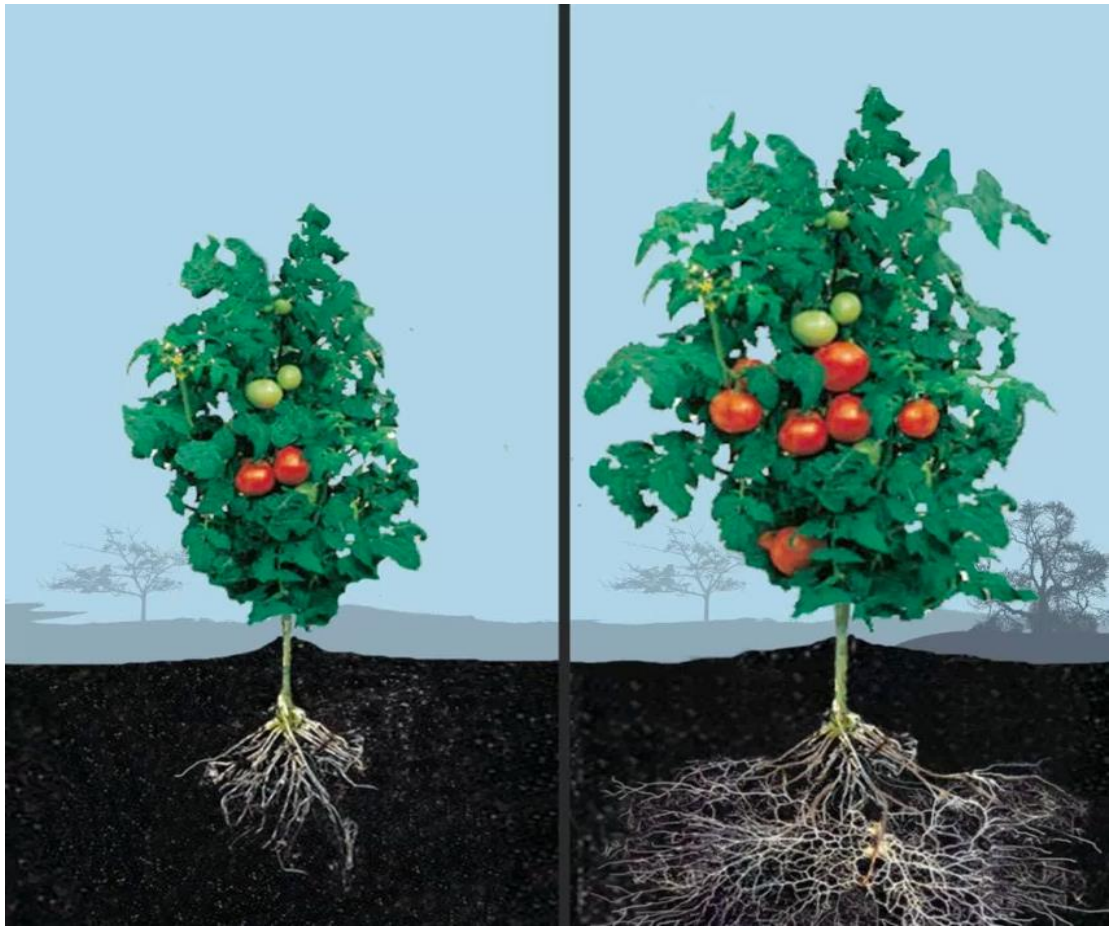




Enhancing food production - microbes in plants

Microbes promote plant growth via mutualism:

- Mutualism: ecological interaction where both partners benefit
- Mycorrhizal fungi (in most plants) enhance water + inorganic nutrient uptake, receive sugars from plant
- *Rhizobium* bacteria (in legume roots) fix nitrogen, receive sugars in return

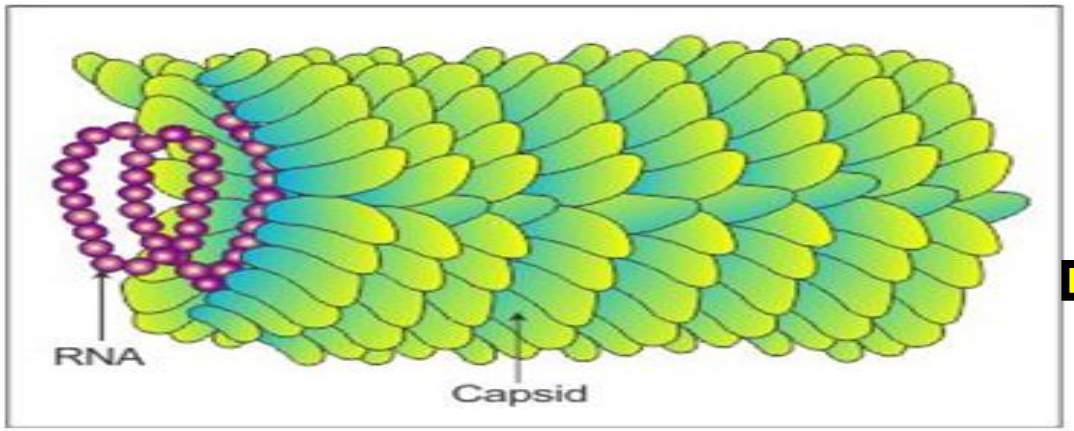


no mycorrhizal fungi

+ mycorrhizal fungi

Plant pathogens

- Just like humans and animals, plants are subject to diseases caused by microbial pathogens
- Fungi and viruses are the main problems
- Crop pathogens cause global losses of ~30% of total yield (approx. $1 trillion!)



Tobacco mosaic virus is simple (only 3 genes)

… but it can infect many crops !

Plant pathogens … emerging diseases

- Sigatoka fungi threaten the survival of bananas globally

  Why ?

- Modern Cavendish bananas are all grown from cuttings, not seed → genetically identical → ALL equally susceptible

- Need to apply fungicides 50x per year, and fungus is rapidly evolving resistance … sound familiar?

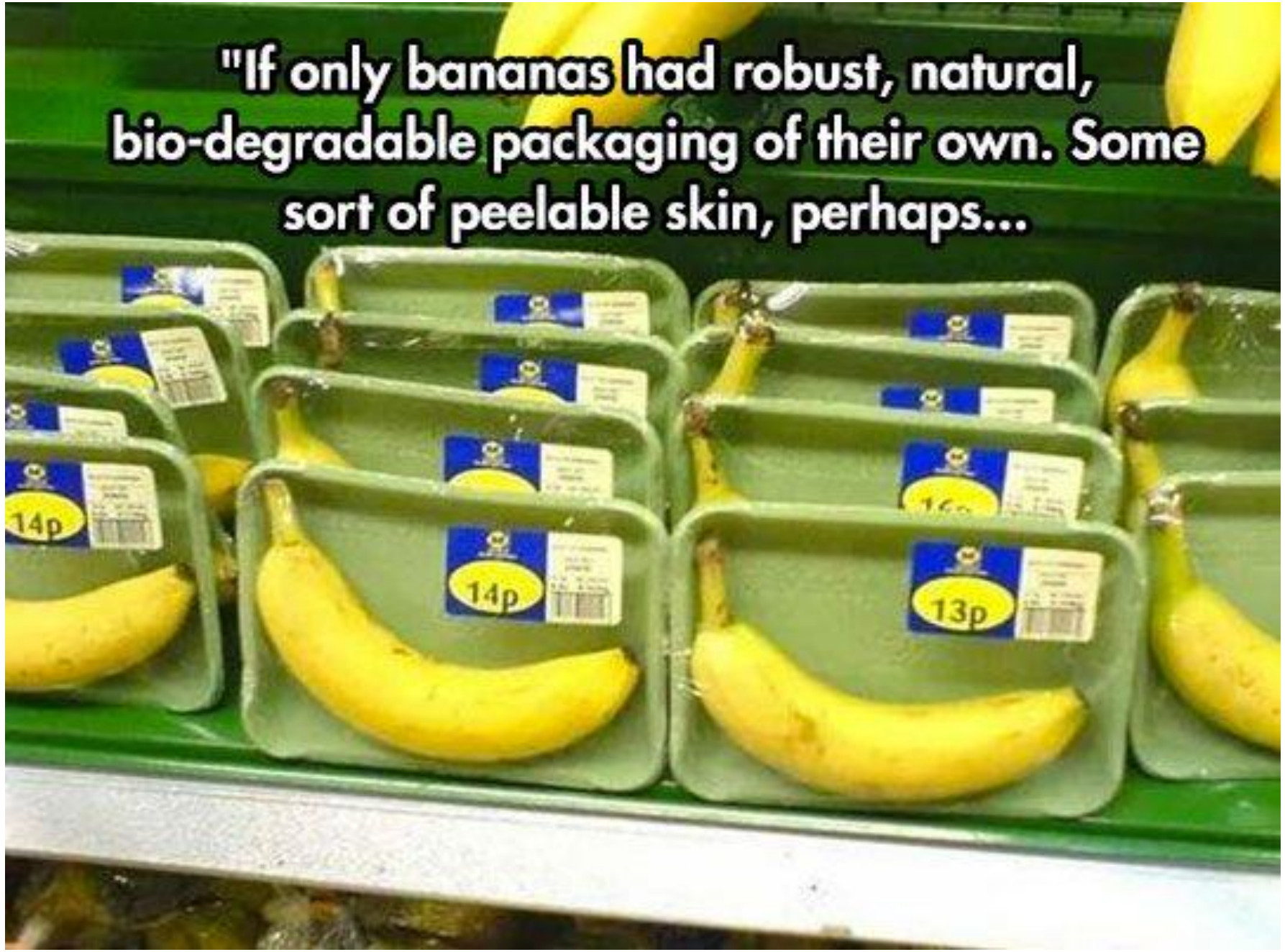
news

Bananas could be extinct in five years because of a fast-advancing disease

IF YOU love a good banana, you had better make the most of them because you might not be able to enjoy them much

Matthew Dunn @mattydunn11

news.com.au AUGUST 17, 2016 10:38AM


"If only bananas had robust, natural, bio-degradable packaging of their own. Some sort of peelable skin, perhaps...
14p
14p
13p

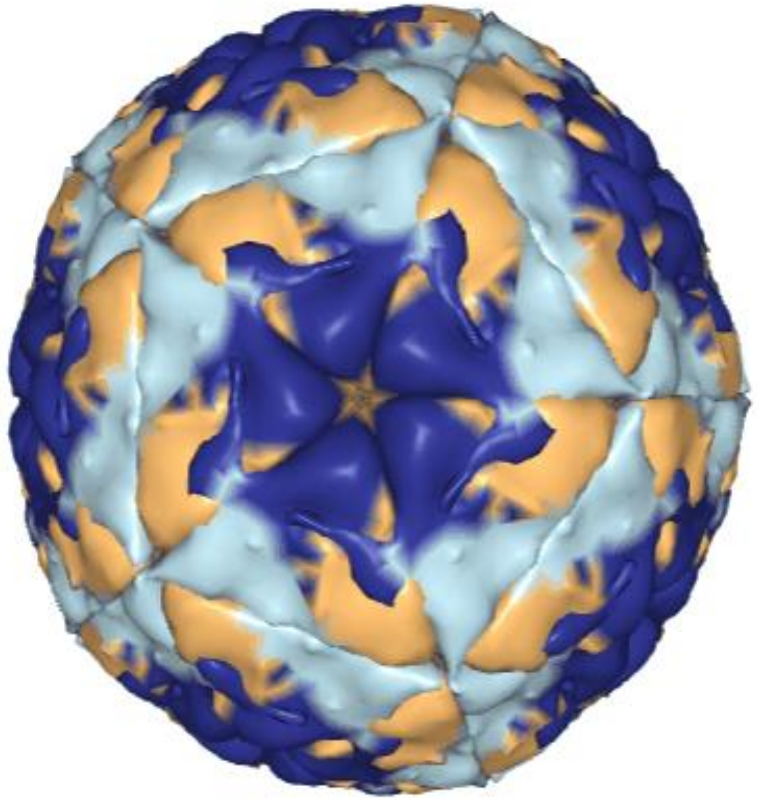
Animal pathogens

- Pathogens infecting animals inflict suffering, death, and massive economic losses (~20% of total production)
- Pathogens can be viruses, bacteria, fungi, or protists
- Modern agricultural practices can aggravate the microbial problems

'Foot and mouth' virus:
a devastating viral disease
infecting many farm animals

A devastating disease sits at Australia's doorstep

Foot-and-mouth disease is spreading across livestock in Bali and throughout Indonesia. If it were to reach Australia, the consequences would be devastating.



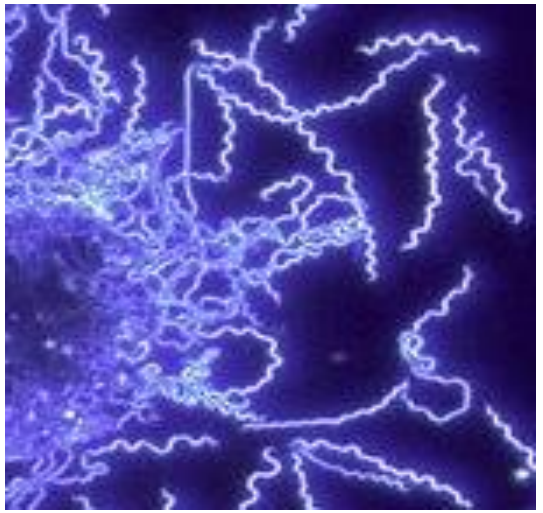
Animal pathogens: Foot-and-Mouth-Disease (FMD)

- Infects cows, pigs, sheep, goats … but not humans
- Huge economic losses. UK outbreak in 2001 resulted in cull of ~10 million animals, and cost £8 billion
- Cause of UK outbreak: pigs fed waste products incl. meat illegally imported from infected animals
- Poses many ethical and environmental issues in addition to economic problems

Zoonosis: human infection arising from animals

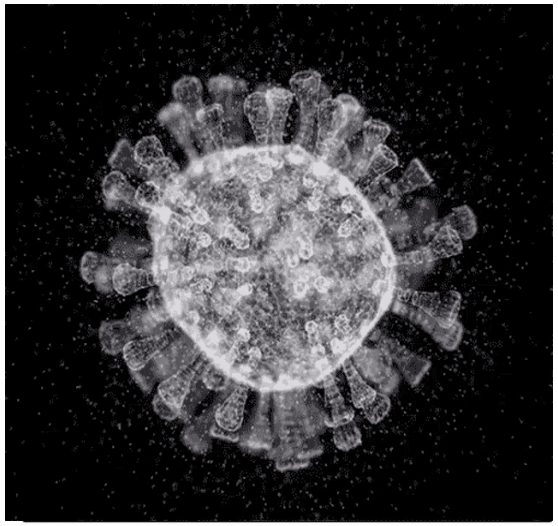
- Microbe may be pathogenic to <u>both</u> animal and human hosts (e.g. rabies virus) …or…
- Human pathogen may be <u>normal flora</u> for the animal (e.g. *Salmonella* bacteria in chickens) …or…
- Animal is a '<u>vector</u>' for disease e.g. animal ticks can carry *Borrelia* bacteria (Lyme disease)

Characteristic rash seen in 'Lyme Disease'



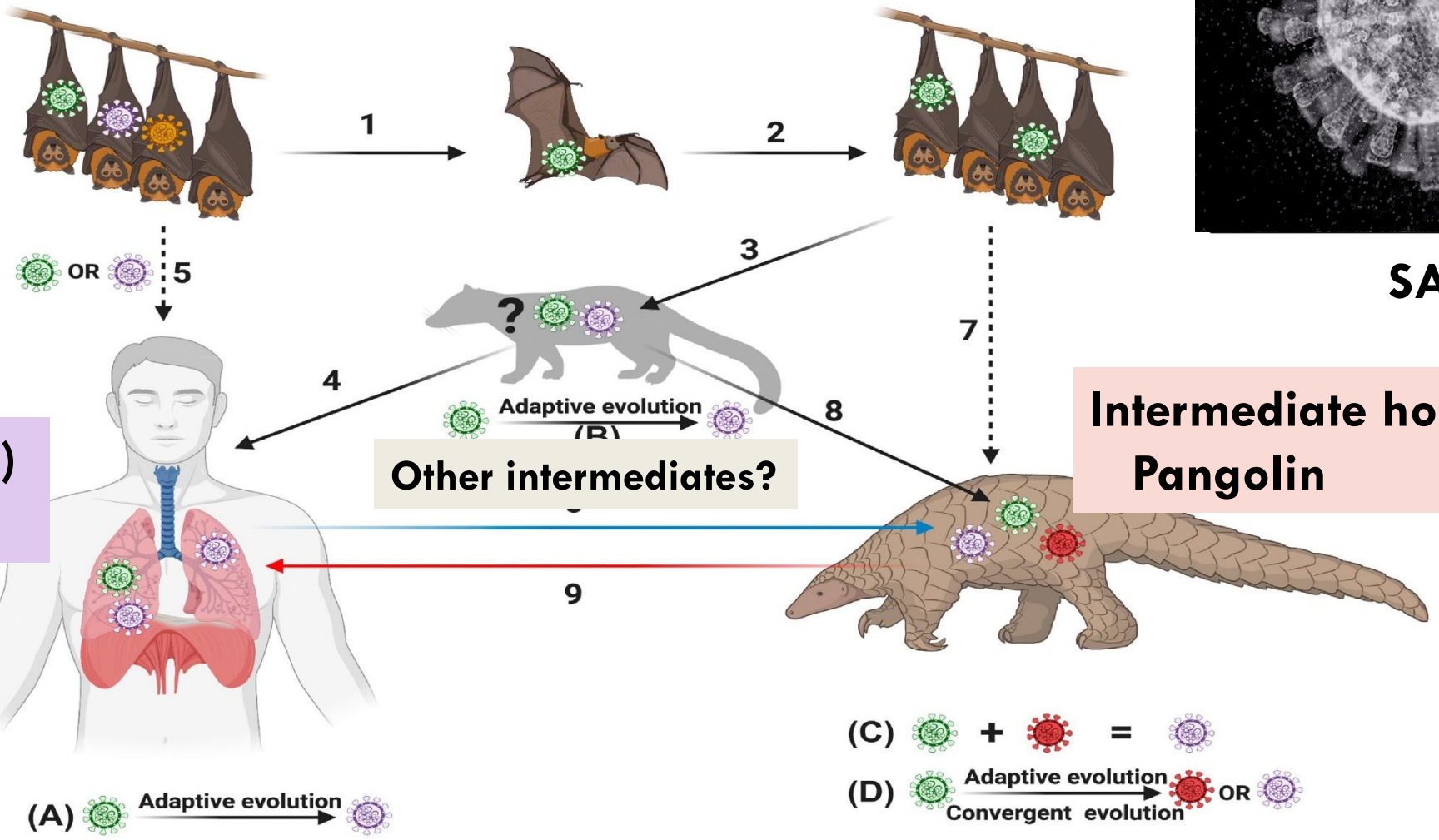
Zoonosis: human infection arising from animals

- The covid pandemic most likely had a zoonotic origin



SARS-CoV2

Original host:
Bat



Final host (?)
Human

Intermediate host:
Pangolin

Trends in Ecology & Evolution, March 2021, Vol. 36, No. 3

Enhancing food processing - Fermentation

- **"Fermentation"** has multiple meanings:
  - microbial transformation of foods by fungi or bacteria
  - anaerobic metabolism of sugars → alcohols, acids, CO_2
- Examples:
  - Beer
  - Wine
  - Bread
  - Kimchi
  - Yogurt
  - Cheese
  - Pickles

Fermented foods – beer production

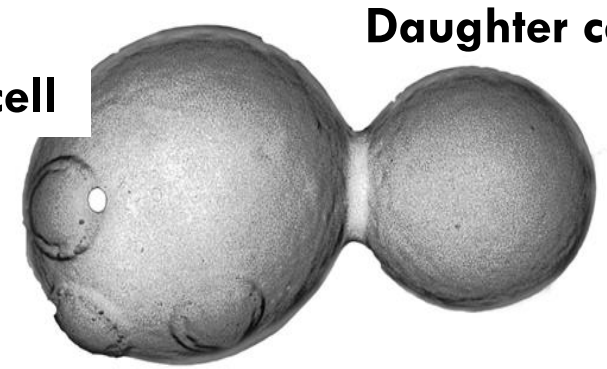
Barley: source of sugars to support fermentation

Hops: natural preservative, provide bitterness

Yeast: ferments sugars to alcohol and CO_2

The hero of beer production:

Saccharomyces (brewer's yeast)



Saccharomyces also makes wine, cider and other alcoholic beverages. And it makes bread rise. It's a wonder-bug!

We will discuss more uses for yeast in a later lecture

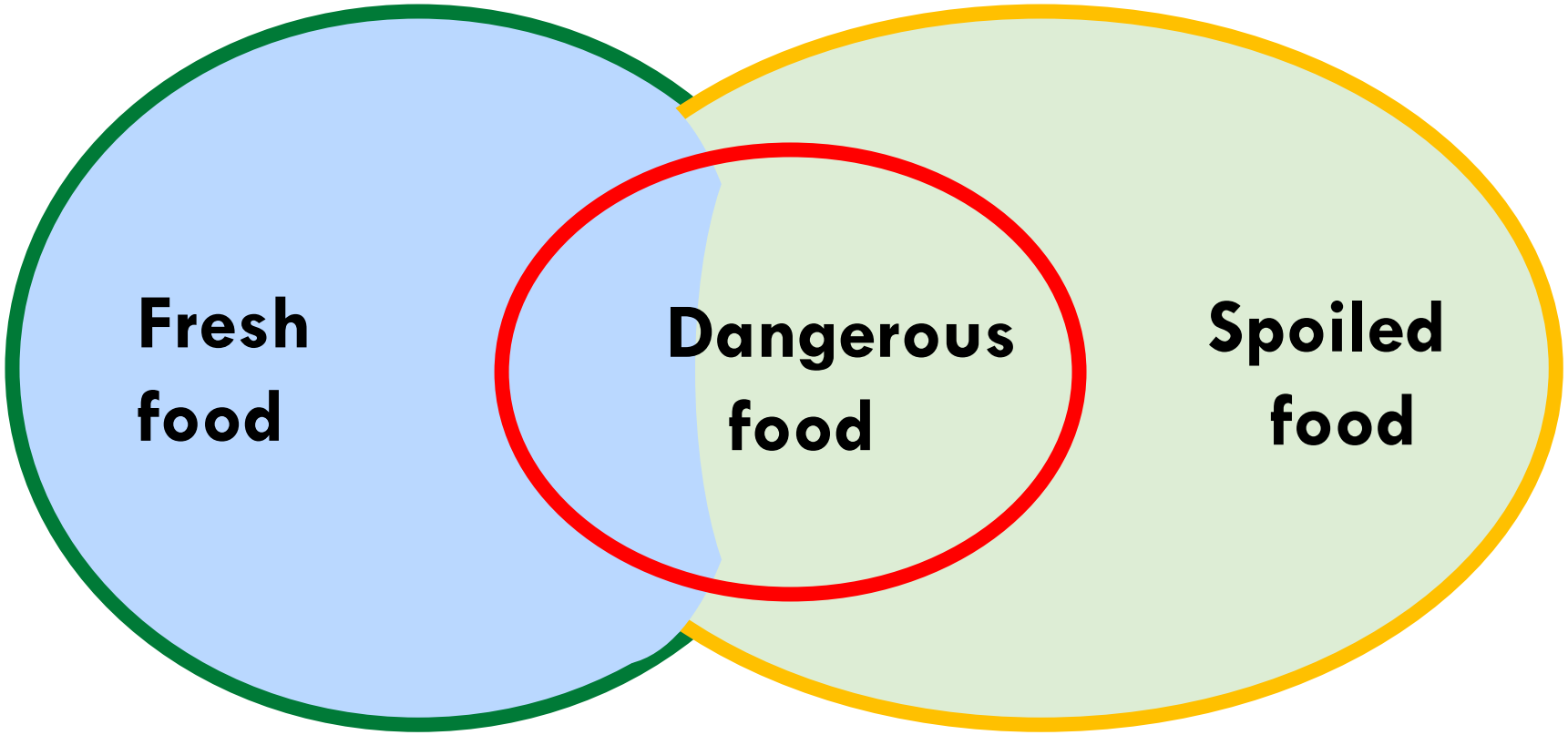
Microbial food spoilage

- Spoilage is due to the growth of fungi or bacteria, and/or due to enzymes that these microbes make and secrete
- Big economic problem: Approx. 20% of all food is lost to microbial spoilage… approx. $1 trillion

https://www.youtube.com/watch?v=tHC2MPU8hL0

- Spoilage prevention?
  - Refrigeration
  - Preservatives
  - Fermentation

Food spoilage vs. food 'poisoning'



- Food poisoning can occur from spoiled food or fresh food … different sets of microbes are responsible for spoilage vs. poisoning

Food ‘poisoning’ = Infection or Intoxication

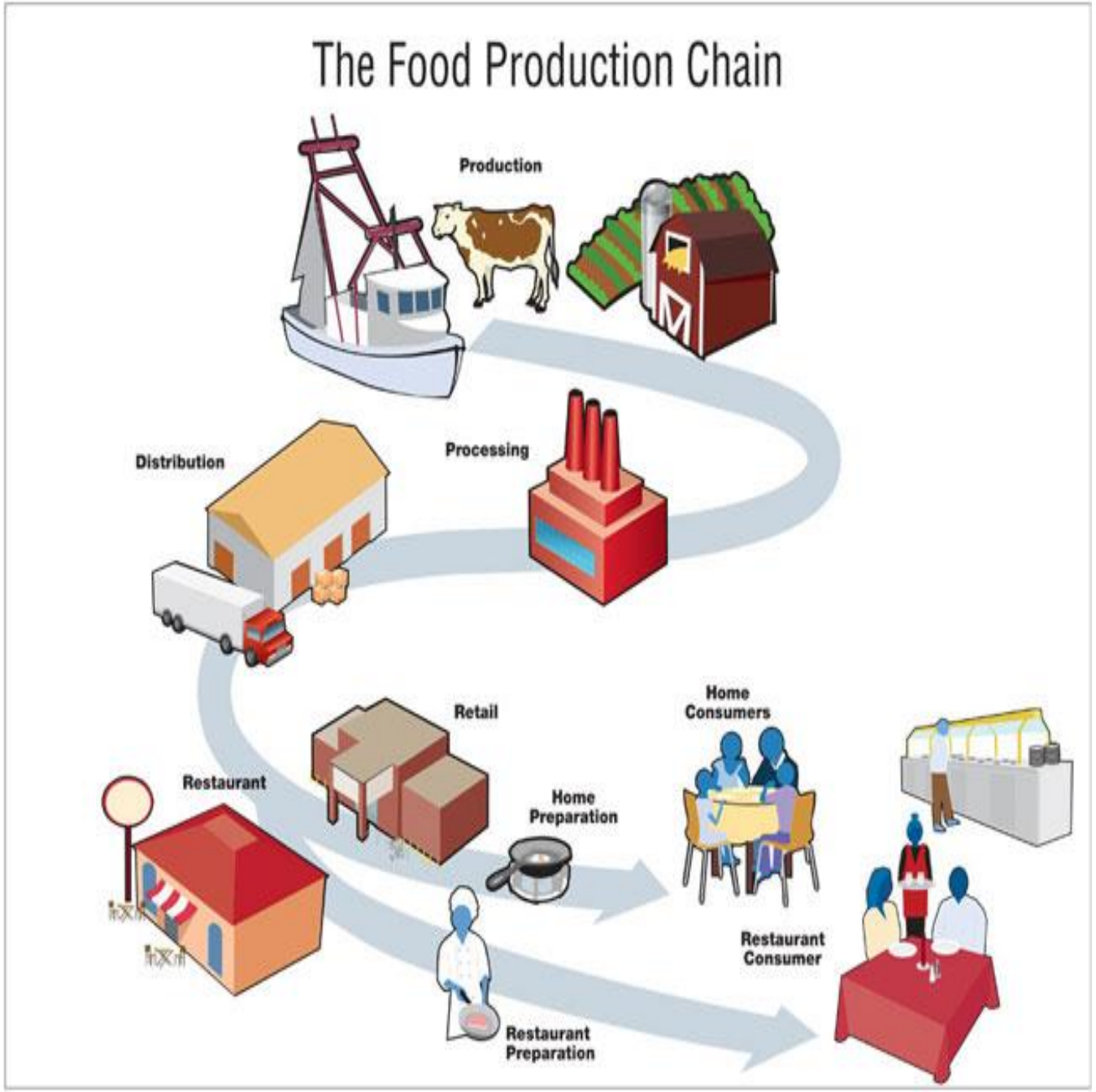
- **Food-borne infection:** microbes grow in gut
- **Food-borne intoxication:** microbes make toxins in food

Salmonella enterica
→ food-borne infection

Clostridium botulinum
→ food-borne intoxication

Food ‘poisoning’ risk factors

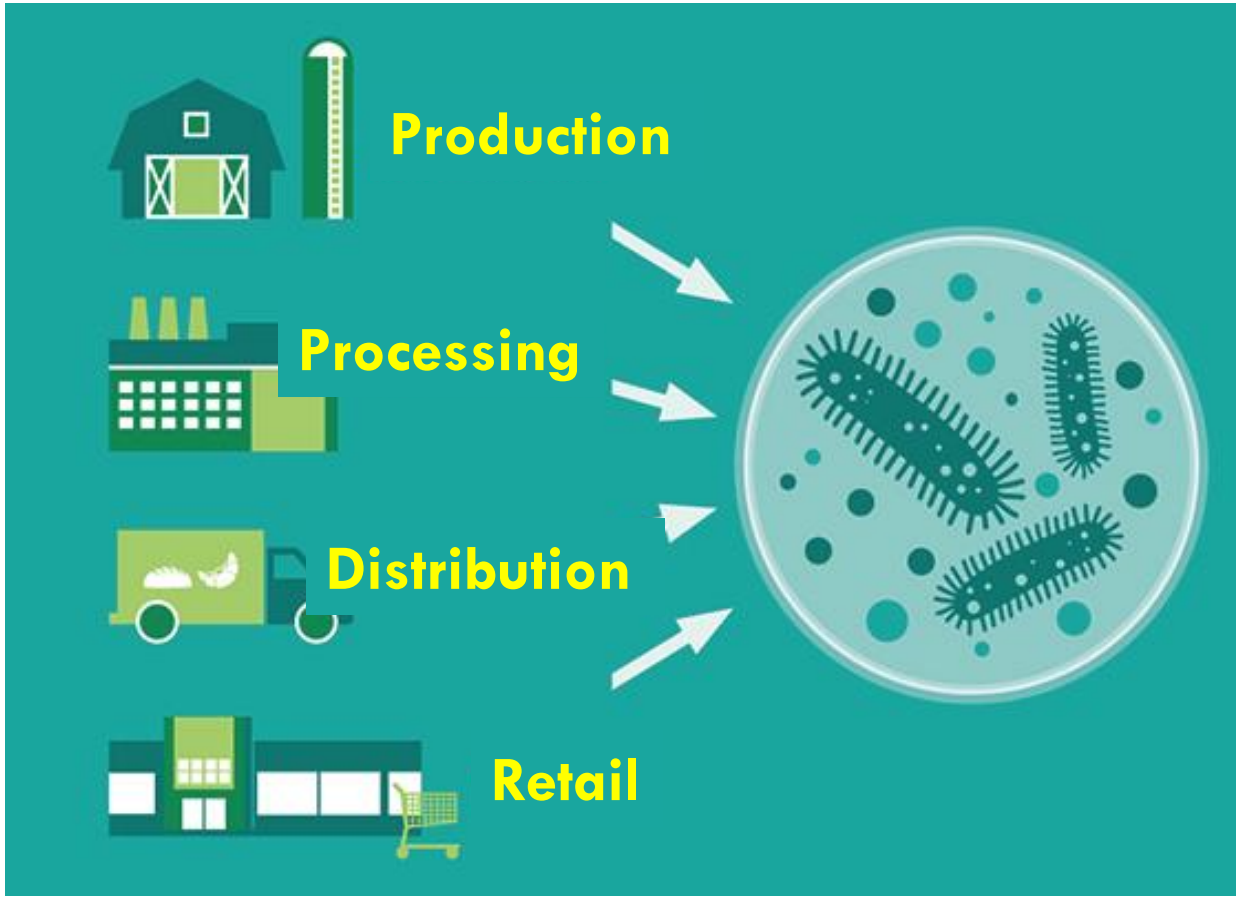
- **Origins of food**
  - determines types and numbers of microbes
- **Transport & Storage**
  - temperature?
  - time?
- **Preparation & human factors**
  - raw vs. cooked?
  - hygiene !



One Health concept in food production

- Maintaining a safe food supply depends on managing microbes at every stage in the production chain:

  - SOIL
  - PLANTS
  - ANIMALS
  - PEOPLE
  - FACTORY
  - KITCHEN

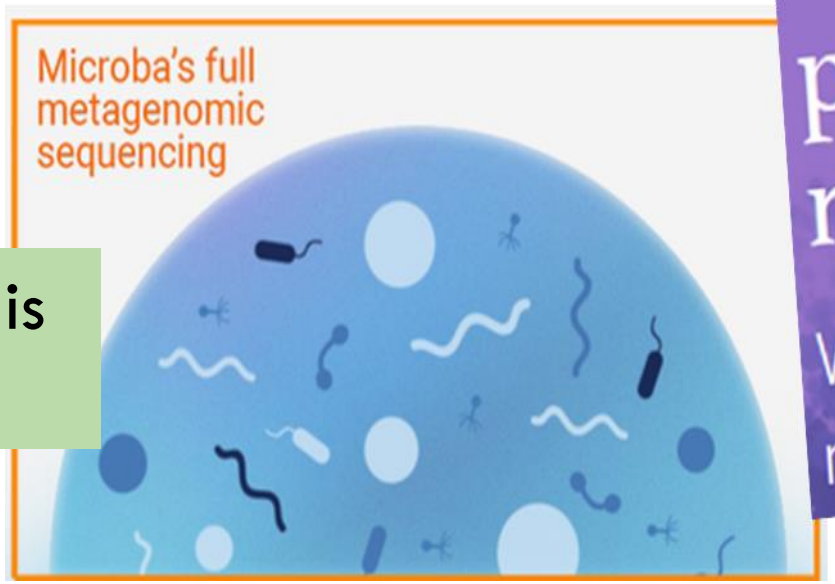


The human gut microbiome

- Gut microbes are the most important element of our normal flora – these are primarily BACTERIA

- Approx 40 trillion bacteria in gut microbiome; now considered a separate body 'organ'

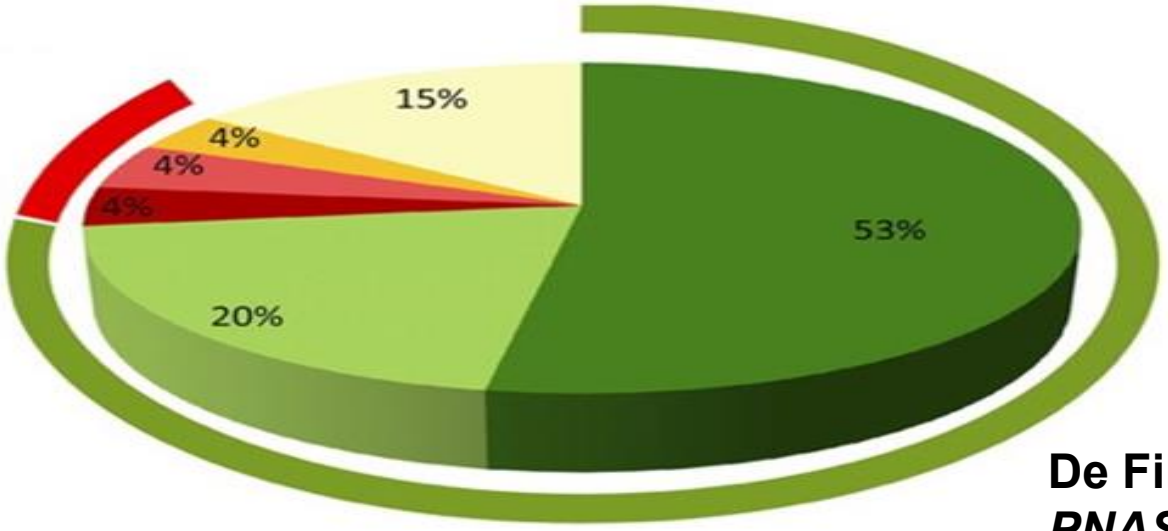
Microbiome analysis is now big business



Gut microbiome depends on diet

High fibre diet

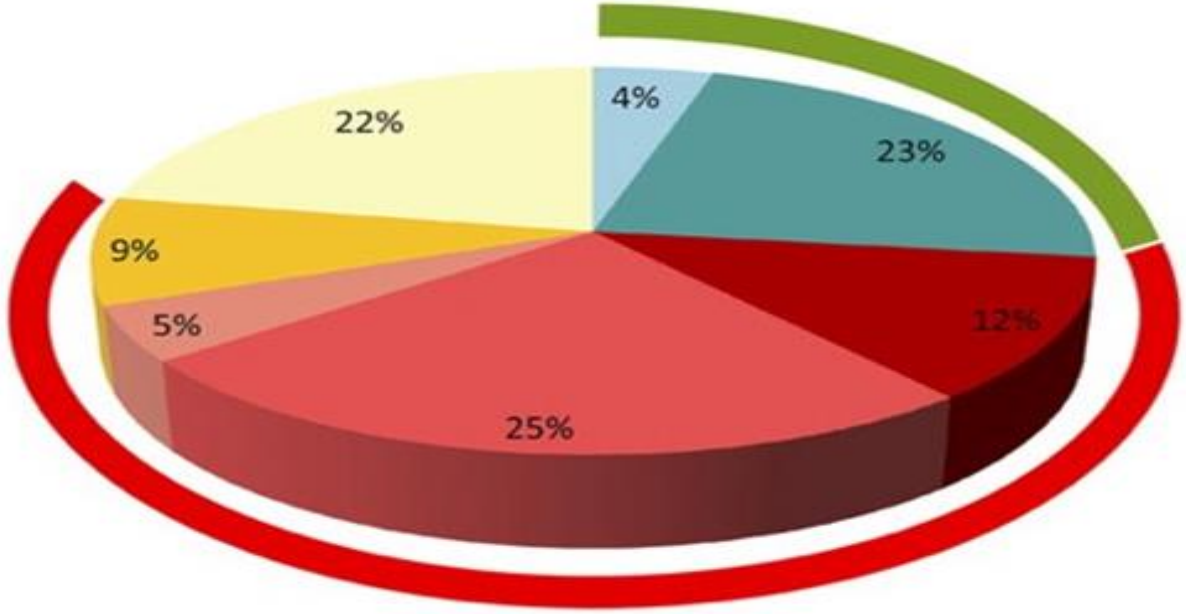
↑ Bacteriodetes



De Filippo et al (2010)
PNAS 107:14691-14696

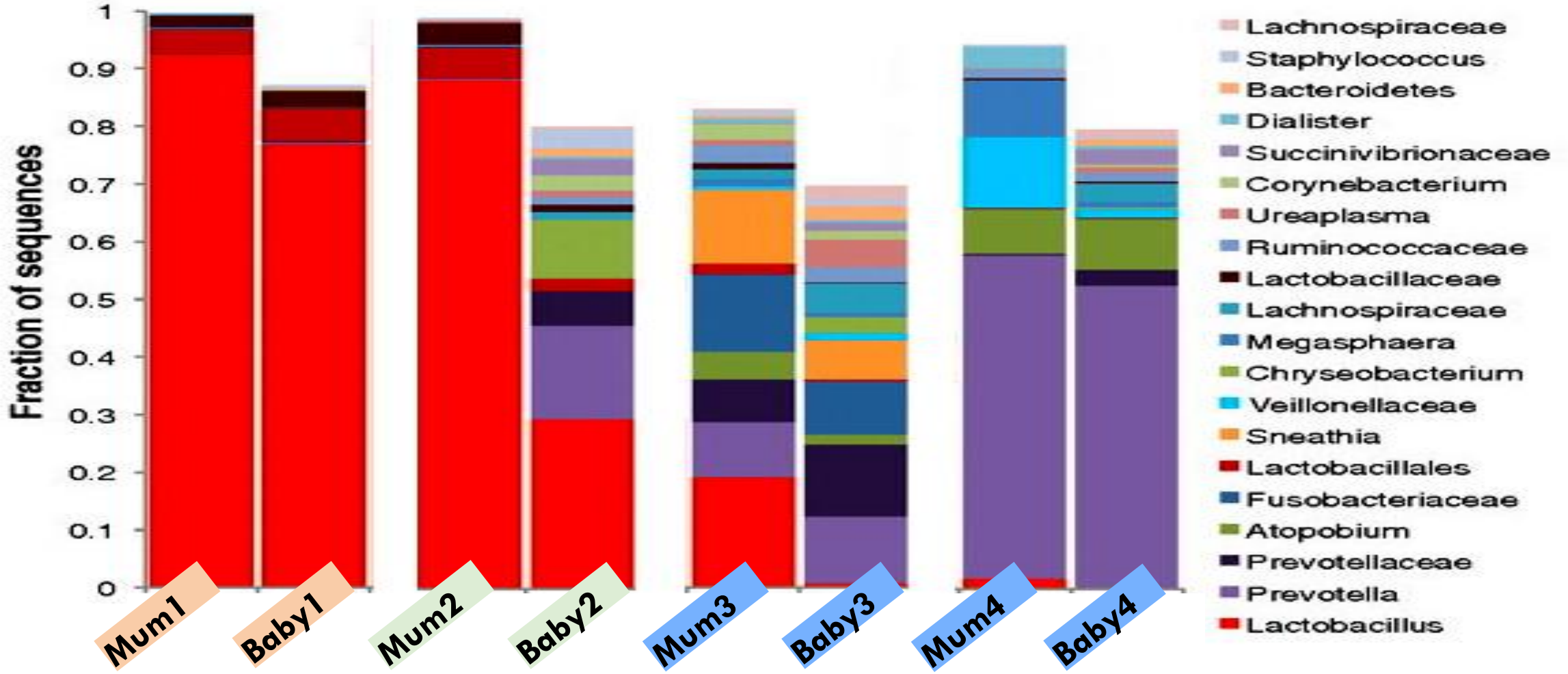
High protein & fat diet

↑ Firmicutes



… and other factors … your Mum matters !

DNA sequencing of PCR-amplified ribosomal genes “Culture-independent analysis”

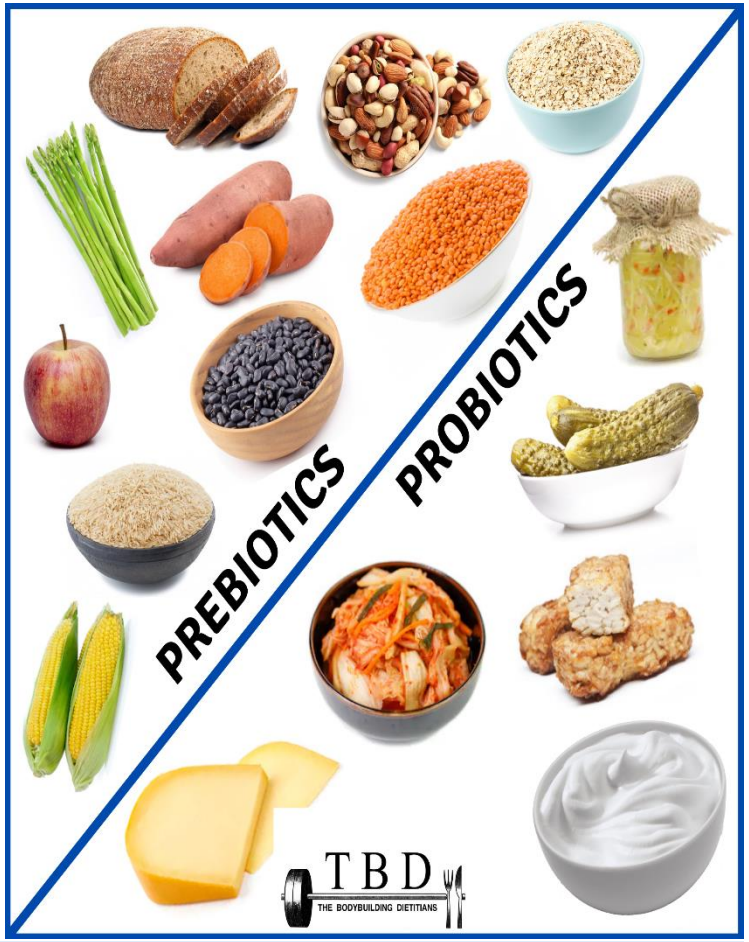


Dominguez-Bello et al (2010) PNAS 107:11971-11975

How does our gut microbiome influence us?

- Healthy microbiome important for:
  - Proper food digestion
  - Resistance to pathogens
  - Immune functioning
  - Mental health

- "Bad" microbiome linked to:
  - Allergies
  - Type 2 diabetes
  - Cancer
  - Obesity



Impact of antibiotics / probiotics / prebiotics on the human microbiome is controversial

Gut microbiome and obesity?

- Animal studies show :
  - Obese mice have a distinct gut microbiome
  - Transplanting 'obesity-associated' microbes makes germ-free mouse obese

Vol 444| 21/28 December 2006| doi:10.1038/nature05414 nature

An obesity-associated gut microbiome with increased capacity for energy harvest

Peter J. Turnbaugh[1], Ruth E. Ley[1], Michael A. Mahowald[1], Vincent Magrini[2], Elaine R. Mardis[1,2] & Jeffrey I. Gordon[1]

PNAS

Obesity alters gut microbial ecology

Ruth E. Ley†, Fredrik Bäckhed†, Peter Turnbaugh†, Catherine A. Lozupone‡, Robin D. Knight§, and Jeffrey I. Gordon†¶

- What about humans? … the jury is still out…