

Foodborne Microbial Disease

Mommy - Do you remember Defne's birthday party which I couldn't attend yesterday? All my friends who attended the party had diarrhea afterwards and couldn't come to school today!

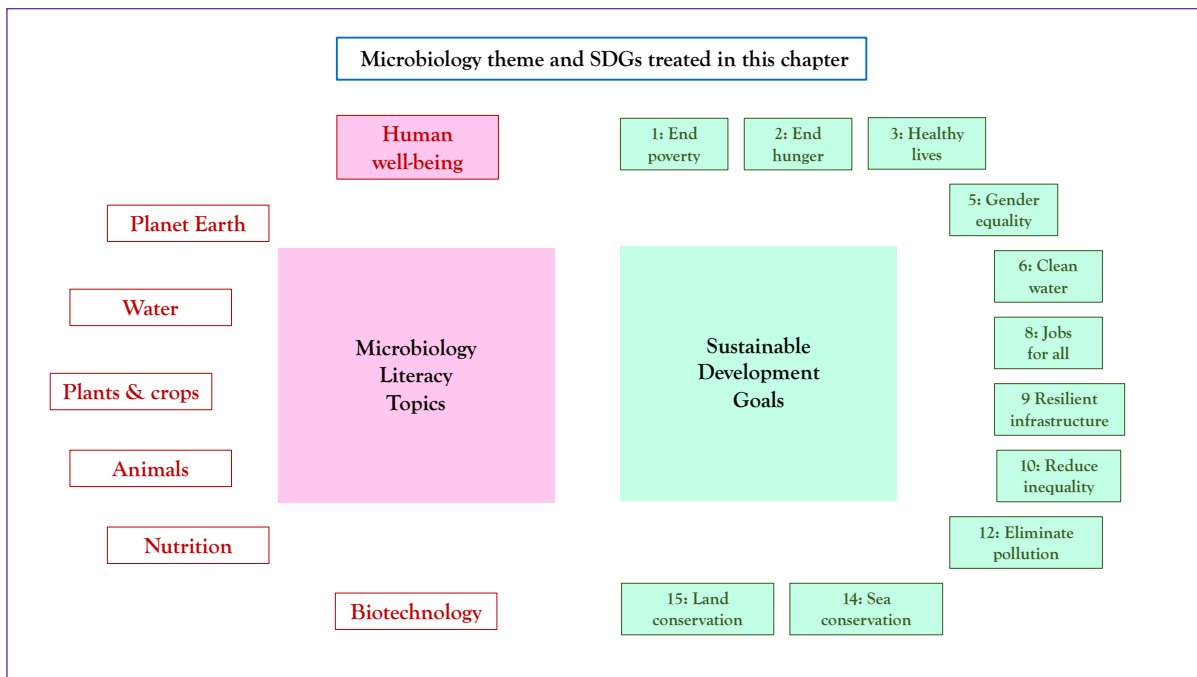


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Foodborne Microbial Disease

Storyline

Eating something delicious is a very pleasing action! This action is not only necessary for gaining energy for our daily activities and for growth, but also a social event, gathering people together. Consuming a birthday cake, ice-cream, hamburgers, seafood, fruits and vegetables makes us happy. On the other hand, foods can also be dangerous for our health in many ways that we can't even imagine. Inappropriate eating habits may lead to diseases such as obesity (putting on too much weight) and associated health problems, some foods may lead to allergies or intolerances, others may carry antimicrobial resistant microbes into our bodies, and yet others can transmit infectious agents, toxins, physical agents and chemicals leading to foodborne diseases (FBDs). The fact that we cannot see, taste or feel the presence of microorganisms or their toxins in the food, may render us defenseless against FBDs as we may not know if the food contains any harmful agents or not. Foodborne pathogens usually cause self-limiting gastrointestinal disease – tummy upsets that only last a short time – but some may cause more serious illnesses and associated side effects that make us ill enough to need to go to hospital. Some pathogens may even lead to death. Besides serious health consequences, FBDs have negative social, economic, and political outcomes.



The Microbiology and Societal Context

The microbiology: Definition and classification of FBDs; symptoms of FBDs; pathogens responsible for FBDs; transmission routes of FBDs and barriers; preventing FBDs; causes of FBDs and contamination of food; zoonotic FBDs; vulnerability to FBDs; transmissibility of FBDs; role of microbiota in protection against FBDs. *And peripherally for completeness of the storyline:* the food value chain; food safety and the future of FBDs. *Sustainability issues:* health; food and energy; economy and employment; environmental pollution; global warming.

Foodborne Microbial Disease: the Microbiology

1. ***FBDs are illnesses caused by biological, chemical and physical agents contaminating food or drink.*** FBDs are the result of ingesting food safety hazards naturally occurring or contaminating the food or drinks. A food safety hazard is anything in the food that can harm human health. These hazards can be biological agents (such as bacteria, viruses, parasites and fungi) or their toxins, chemicals (such as heavy metals, growth promoting hormones or antimicrobials and pesticides), or physical agents (such as fragments of glass or metal). Food or drinks (water, milk, fruit juices, etc.) can introduce these agents to our body.

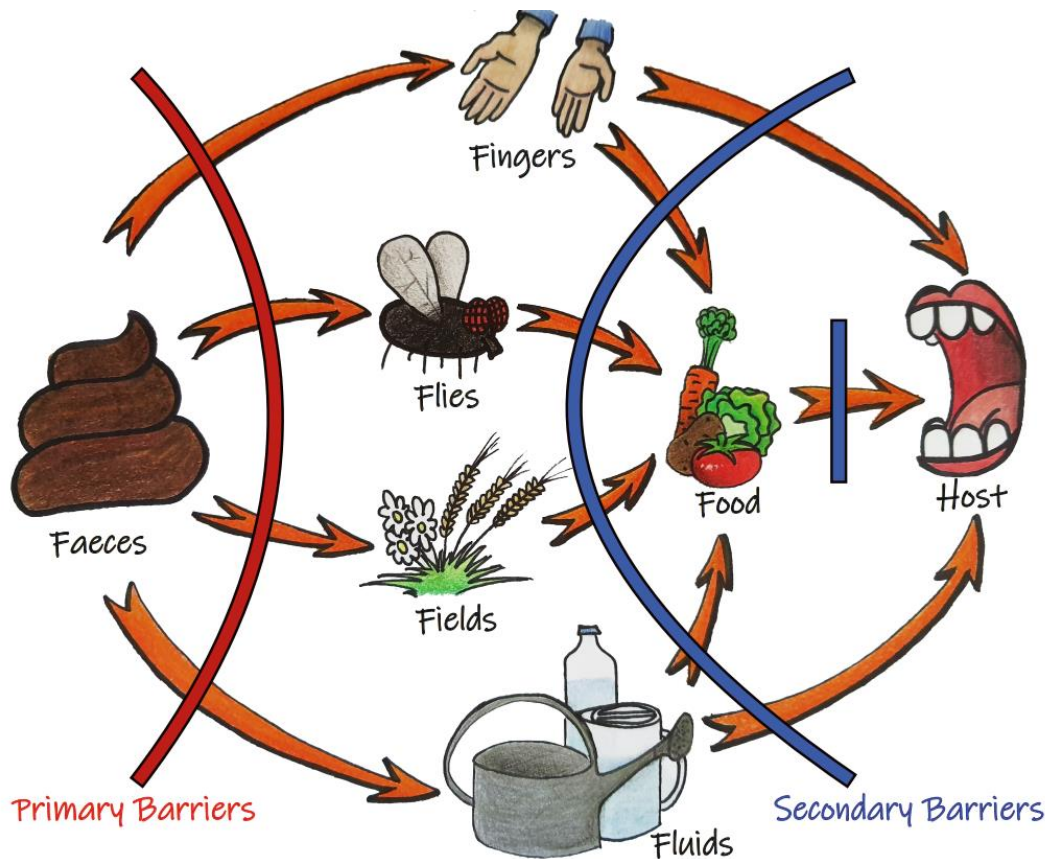
2. ***FBDs usually manifest with gastrointestinal symptoms, fever and aches, and neurological symptoms.*** Gastrointestinal symptoms associated with FBDs are vomiting and diarrhea, stomach ache and cramps. Neurological symptoms include difficulty in swallowing or speaking, dry mouth, fascial weakness on both sides of the face, blurred or double-vision, dropping eyelids, breathing difficulties, and paralysis.

3. ***Foodborne pathogens are microbes that cause FBDs.*** Many bacteria, viruses, parasites, fungi and prions can cause FBDs.

4. ***Bacteria and their toxins are the most common causes of FBDs.*** Bacteria or their toxic products (toxins) are the major causes of FBDs, so bacterial FBDs can be simply classified into two categories depending on whether the microorganism (foodborne disease) or its toxin (food poisoning) is the cause of the FBD. How quickly we feel ill – the incubation period or time from ingestion until symptoms occur – with food poisoning is much faster (hours) than with foodborne infections (days-weeks), because toxins act immediately, whereas an infection needs growth and multiplication of the microbe, which takes time. Although most foodborne pathogens are killed by cooking, many of the toxins are not. Some examples of bacteria causing FBDs include *Bacillus cereus*, *Campylobacter jejuni*, *Clostridium botulinum*, *Clostridium perfringens*, *Cronobacter sakazakii*, *Esherichia coli*, *Listeria monocytogenes*, *Salmonella* spp., *Shigella* spp., *Staphylococcus aureus*, *Vibrio* spp., *Yersinia* spp., *Brucella* spp., and *Mycobacterium tuberculosis/bovis*.

5. ***Many viruses, parasites, fungi or prions are also responsible for FBDs.*** About one third of FBDs are caused by viruses. The most frequently encountered viruses are rotavirus, norovirus, enteroviruses and hepatitis-A and -E viruses. The longest incubation period for foodborne infections is about 2-6 weeks for hepatitis viruses. Among the parasites that cause FBDs are *Entamoeba histolytica*, *Giardia histolytica*, *Cyclospora cayetanensis*, *Isospora belli*, *Microsporidium* spp., *Toxoplasma gondii*, *Trichinella spiralis*, *Trichuris trichura*, *Taenia saginata*, *Taenia solium*, *Fasciola hepatica*, *Diphyllobothrium* spp., and *Ascaris lumbricoides*. Fungi such as *Aspergillus* spp., *Candida* spp., and *Saccharomyces* spp. can also produce FBDs, especially in vulnerable people, such as those whose defenses are low because of other illnesses, or medicines they take for illnesses. Prions are not microbes but rather “rogue” proteins that cause some of our own proteins in the brain to form abnormal structures that cause diseases called progressive spongiform encephalopathies, such as variant Creutzfeldt Jacob Disease. The nature and frequency of FBDs can differ according to the place where we live or what we consume (our dietary habits). Knowing which foodborne pathogens are causing the biggest problems in which parts of the world can lead to targeted action by the government, the food industry and the public.

6. *Foodborne pathogens can be transmitted to humans via various routes.* FBDs may be transmitted through fecal-oral or inhalation routes, and fomites (contaminated inanimate objects). The 5F summarises the fecal-oral means of transmission of pathogens: Food, Flies, Fields, Fingers, Fluids. These 5F are the vehicles for the pathogens to reach and contaminate food and water.



The 5F Diagram and Barriers

Insects are well recognized vectors for foodborne pathogens. Their association with decaying matter, their ability to enter buildings and cohabitation with humans make flies, cockroaches and ants relevant for transmitting foodborne pathogens. House flies can carry pathogens through their body hairs and surface, through hairs on their feet, by regurgitating vomitus and by defaecating. The fact that a fly defecates every 4-5 minutes throughout the day shows their huge ability for transmission of pathogens all around. Indeed, the role of flies in the transmission of *Shigella* spp., which cause dysentery, from faeces to food under conditions of poor hygiene (such as field toilets) is well documented, owing to the fact that ingesting as low as 10 microbial cells are enough to establish an infection.

Aerosol transmission is another important way of pathogens to enter the food chain. Toilet bowls, for example, are considered as a source for environmental contamination by aerosols. The highest level of airborne microorganism concentration is shown to be achieved after the first flush. Sequential flushing causes further distribution of pathogens into the air, but the

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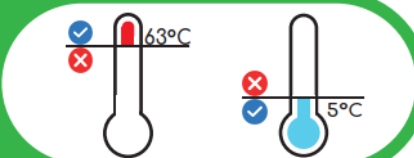


numbers decline after each flush. Flushing toilets with the covers closed can minimize airborne distribution of microorganisms.

Fomites are inanimate – non-living – objects, such as money or toys, that can harbor microorganisms and serve as a vehicle for spreading the germs. Foodborne pathogens such as *E. coli* and *Salmonella* spp. can survive on coins for about 10 days.

7. **Two types of barriers reduce transmission of FBDs.** Primary barriers, such as toilet usage and presence of healthy and functioning sewer systems, prevent the entry of pathogens into the environment. These barriers are the most effective interventions to prevent FBD transmission. Secondary barriers include factors that prevent pathogens in the environment from multiplying and reaching a new host. These barriers include measures to provide safe water, hygiene, and hand washing.

8. **FBDs are preventable.** Ensuring a safe national food and water supply and establishing strict and multi-point food-safety management systems are integral to the prevention of FBDs. These systems must cover every stakeholder and consumer from farm to fork. Coordination among different agencies responsible for human and animal health, agriculture, trade and others, is important for controlling FBDs.

FOOD SAFETY RULES

- 1 Be Clean, Be Healthy**
 - Wash your hands when necessary
 - Don't work with food if you are ill
 - Never touch ready-to-eat food without washing your hands
- 2 Keep it Cold, Keep it Hot**
 - Keep cold foods at 5°C or below
 - Keep hot foods at 63°C or above
- 3 Don't Cross-Contaminate**
 - Don't store raw foods over cooked or ready-to-eat foods
 - Never prepare ready-to-eat foods on the same surface as or with the same utensils used to prepare raw meat and poultry
- 4 Wash, Rinse and Sanitize**
 - Properly wash, rinse and sanitize all food contact utensils and equipment
- 5 Cook it & Chill it**
 - Cook food until it reaches a proper internal temperature.
 - Rapidly cool food to 5°C or below

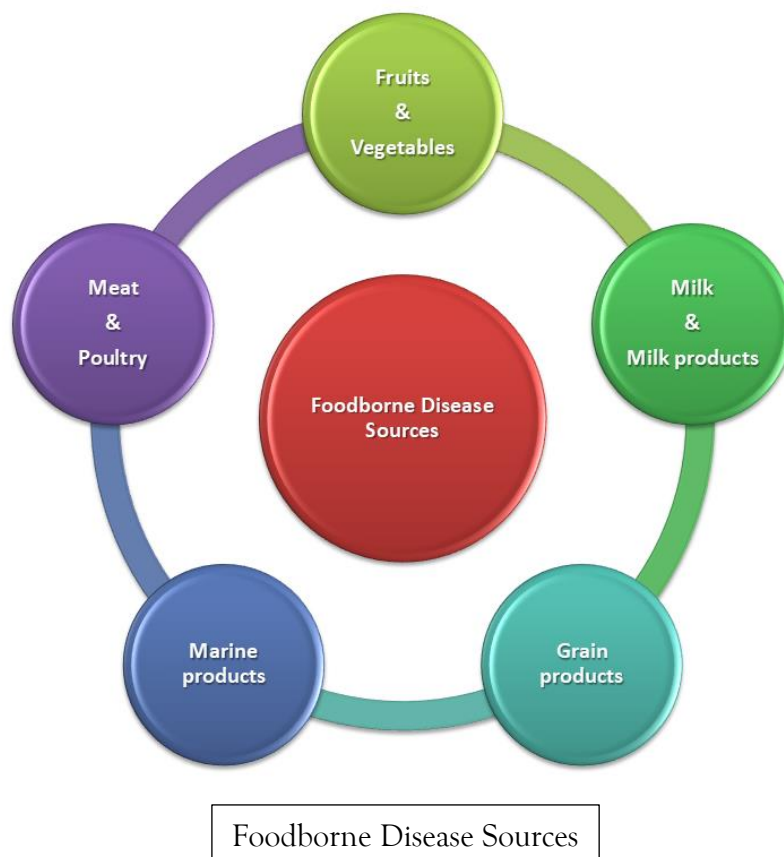
Food Safety Rules

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Surveying of food products in the food value chain, strictly complying with hygiene rules throughout the production, processing, packaging, and preparation steps, and applying food safety practices at home, such as hand washing, rinsing well with clean water, preventing cross-contamination in the kitchen (e.g. between meat and vegetables), maintaining cooking temperatures and proper storage, can protect end-users from FBDs.

9. *Some FBDs are vaccine-preventable.* Some FBDs, such as those caused by rotavirus or hepatitis-A infections, can be prevented by vaccination.

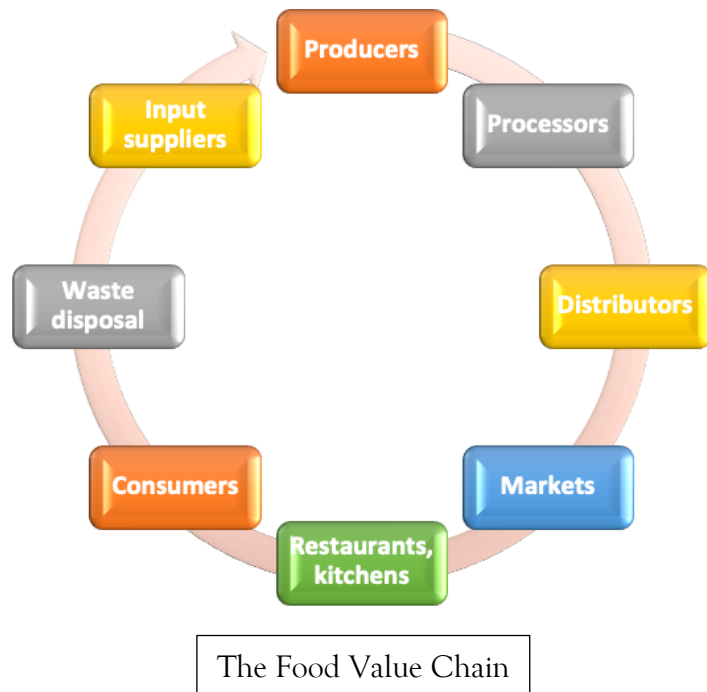
10. *Eating high-risk foods, raw/undercooked or improperly stored food are important causes of FBDs.* In the last 30 years nearly half of the known sources of foodborne pathogens have been meat and meat products. Consumers must be aware of high-risk foods (raw or undercooked meat, seafood and poultry, unpasteurized milk and milk products such as soft cheese, foods that contain raw/undercooked eggs, raw sprouts, hot dogs and deli meats, unpasteurized/refrigerated pates or meat spreads, improperly preserved rice, and honey [for infants under 12 months of age]). Using and drinking clean water and ice is also important for preventing FBDs, as many of the etiological agents can also be ingested by water or foods that come into contact with contaminated water. For babies who cannot consume mother milk, infant formulas should be prepared and stored safely. Food must be stored properly in order to prevent bacterial growth. Bacteria grow more rapidly at 4-63 °C, which is called the “danger zone”. Storing food below or over the danger zone can effectively inhibit growth of bacteria and their toxin production.



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11. *Food can become contaminated in various steps along the value chain.*

Contamination of food can occur from the environment where the plants are grown and harvested or animals are raised, during the production process such as transportation, processing and handling of food, and due to cross-contamination during preparation and serving of food or from people eating the food.



12. *Many FBDs are zoonotic.* Zoonotic diseases (or zoonoses) are diseases that are transmitted to humans from animals. Approximately 100 zoonotic pathogens whose source is manure from farm animals are reported. Examples to these pathogens include parasites (*Trichinella* spp. and *Cryptosporidium* spp.), bacteria (*Salmonella* spp., *Shigella* spp., Staphylococci, Clostridia, *Bacillus cereus*, *Campylobacter* spp., *Yersinia* spp., *L. monocytogenes*, and *E. coli*) and viruses (rotavirus and norovirus). The World Health Organization (WHO) expects an increase in viral zoonosis in the coming decades. This increase will most probably be the result of increased movement of people worldwide, the transport of exotic animals, human invasion/destruction of animal habitats that bring humans in closer contact with wild life and wild animal markets (as we have just seen in SARS-CoV-2), and changes in the eating habits of people.

13. *Some foodborne pathogens are also bioterror agents.* The United States Center for Disease Control (CDC) divides bioterrorism agents into three categories, depending on their ease of spread and the severity of illness they cause. Category A agents are the highest risk as they can be easily disseminated, transmitted from human-to-human, and result in high morbidity and mortality. Agents in Category B are the second highest priority agents, which are moderately easy to disseminate and result in moderate morbidity and low mortality. Category C agents include emerging pathogens which can be used as bioterror agents in the future. Food safety threats such as *Salmonella* spp. and *E. coli* O157:H7, and water safety threats such as *V. cholera* and *C. parvum*, as well as *Brucella* spp. and staphylococcal enterotoxin B, are classified in the Category B of bioterrorism agents.

14. *Some people are more vulnerable to FBDs.* People with physiological impairment of the immune system (pregnant women, neonates, elderly, and malnourished), primary or acquired immunodeficiencies (such as AIDS), autoimmune diseases, diabetics, transplant recipients, cancer patients, patients receiving immunosuppressive/immunomodulatory drugs, or using drugs impairing physical barriers (i.e., drugs inhibiting gastric acid production, or anti-diarrheic drugs that reduce gastrointestinal motility), people with defects of iron metabolism, cirrhosis or other liver diseases are more vulnerable to FBDs. FBDs cause higher morbidity (disease) and, mortality (death) in these vulnerable groups.

15. *There is heterogeneity in the transmission of FBDs from infected individuals to susceptible hosts.* It was historically believed that infected individuals had equal chances of infecting susceptible contacts, and that each contact was more or less equally likely to become infected. However, superspreading has been described for many pathogens and in many host species, including humans, animals and plants. Some individuals who create more secondary contacts than others (increased host-host interaction) are called superspreaders. Individuals who shed larger amounts of pathogen than others (increased host-pathogen interaction) are called supershedders.



Mary Malon was born in Ireland in 1869 and emigrated to the USA in 1884, where she worked for wealthy families before settling into her career as a cook. As a healthy carrier of *Salmonella typhi*, she was proven to be responsible for infecting at least 125 people, including five who died. She was forced into quarantine on two separate occasions for a total of 26 years and was offered the option of removal of her gallbladder, which she refused. She died alone in 1938. Her autopsy revealed the presence of stones in her gallbladder.

16. *A healthy intestinal microbiota plays a major role in protecting against FBDs.* The “microbiota” is the collection of microorganisms living within our body or on our body surfaces without causing us harm. The microbes within our intestine help to maintain our healthy state by producing vitamins, interfering with pathogens, and building our immune system. The most likely source of new microorganisms entering our gastrointestinal microbiota is the food we eat from the time of birth until death. So we can say that the food we eat controls our health: You are what you eat. The microbiota fight against pathogens in food by producing antimicrobial substances, by depleting nutrients from the environment, by occupying receptors on the intestinal surfaces that the pathogens must bind to in order to colonise us and/or invade us via the intestine.

17. *In future, foodborne diseases will occur more frequently than before.* The association between consumption of food and human diseases has long been recognized. The WHO alerts us to the fact that foodborne diseases will occur much more frequently in the future. In the European Union (EU) a total of 4362 foodborne and waterborne outbreaks were reported by the 26 member states in 2015. Changes in farming practices and eating habits, as well as global trade and climate change, are expected to increase the global burden of FBDs in the future.

18. *Food safety is a shared responsibility of all nations and every sector along the value chain.* According to the WHO, 31 foodborne pathogens are responsible for about 600 million cases of FBDs (i.e. affecting one in ten of the world population), and 420.000 deaths every year. 40% of all cases, and 125.000 deaths are in children below five years of age. Diarrheal diseases constitute more than half of the global burden of FBDs. The risk is higher in low-middle income countries due to food preparation with unsafe water, poor hygiene, inadequate conditions in food production and storage, lower levels of literacy and education, and inadequate food safety legislation. To keep our food safe, we need a high-level commitment to food safety practices on a political, financial and scientific level. Access to a sufficient amount of safe and nutritious food is a basic requirement of everyone. Unsafe food causes significant economic costs at both individual and national level. Unsafe food annually costs about US \$95.2 billion in lost productivity and US \$15 billion in related medical expenses in low-middle income countries. A large proportion of these costs may be reduced by adapting appropriate preventive measures that improve food safety from farm to fork.

Apart from personal suffering, consuming unsafe food impedes socioeconomical development, overloads healthcare systems, damages trade, tourism, and economy in all countries. Countries which are not able to meet international food safety standards lose the economic opportunities of the international food market, further hampering sustainable development. In order to reduce the burden of FBDs, a globally harmonized reporting system must be established and data sharing must be accelerated. Governments must not only invest more in food safety but also invest more strategically in foundational knowledge, human resources, and infrastructure. Governments must realize the interaction between food safety, human health and environmental protection, and must ensure reliable and effective enforcement of regulation. In order to prevent human diseases due to consumption of contaminated food, timely and committed multi-national and multi-sectoral action, integrated under the One Health approach covering human, veterinary and plant health, is mandatory.

Relevance for Sustainable Development Goals and Grand Challenges

Foodborne diseases relate to several SDGs, including

- **Goal 1. End poverty in all its forms everywhere** (*end poverty, improve socioeconomical status, improve the possibility to attain safe food for all*). Poverty is a major risk factor for FBDs individually, within household, and nationally. FBDs are most frequently seen in low-middle income countries and people living in poverty. At the same time, FBDs are a major factor causing and maintaining poverty. Costs of illness, lost days of work, catastrophic complications caused by FBDs such as paralysis, brain damage and even death, also contribute to the increase in the number of people living in poverty. Poverty is a major factor decreasing the ability of poor people to reach safe food. High costs of safe and processed food compel poor people to buy supplies from domestic markets with low prices. Foods sold in informal sectors are more frequently a source of FBDs (i.e., brucellosis caused by consumption of unpasteurized milk). Unsafe food is usually sold at a lower price or may not be sellable at all, which may cause financial loss for every stakeholder in the value chain. Pathogens causing FBDs may not only cause losses in livestock but also cause reduction in crop productivity.

- **Goal 2. End hunger, achieve food security, improve nutrition and promote sustainable agriculture** (*end hunger and malnutrition, increase agricultural productivity*) Unsafe food may result in

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reduced food availability due to destruction of food. Illnesses caused by foodborne pathogens may directly lead to malnutrition or can worsen the nutritional status indirectly. Achieving food security by means of controlled production and processing increase the costs of safe foods, which are already less available for poor people struggling with hunger. These high costs lead to the consumption of unsafe foods or food replacements which may lead to other health problems such as malnutrition, obesity, and even cancer.

- **Goal 3. Ensure healthy lives and promote well-being for all at all ages** (*improve health, reduce preventable disease and premature deaths*) Foodborne diseases are important contributors to the global health burden of preventable disease, and are comparable to the major infectious disease killers malaria, HIV/AIDS and tuberculosis. They are associated with high health costs, and physiological and mental distress which negatively affect our health and wellbeing. FBDs are also related to other diseases which threaten our health, such as malnutrition and stunting, reduced effectiveness of vaccines and even premature death. Concerns about food safety may also shift diets in directions that affect health. Meat, fresh fruits and vegetables are necessary for the growth and development of children. Supplying safe food and water is essential for wellbeing.

- **Goal 5. Achieve gender equality and empower all women and girls** (*achieve gender equality, empower women economically and socially*) Women have a major role in food production, processing, preparation and distribution. As food production and distribution systems develop, women may fall out of these systems which may lead to a decrease in their income and power. Pregnant women are more vulnerable to FBDs, and taboos around food consumption nutritionally disadvantage more women than men.

- **Goal 6. Ensure availability and sustainable management of water and sanitation for all** (*assure safe drinking water, improve water quality, reduce pollution, protect water-related ecosystems, improve water and sanitation management*). Many FBDs can be transmitted by contaminated water or food which comes in contact with contaminated water. Infected animals and humans may contaminate water, which in turn may contaminate field crops. The large amount of water used for production and processing of food may limit the availability of clean water for other purposes such as sanitation and drinking. Wastewater is often high in nutrients, so it may be used for agricultural purposes after being safely decontaminated.

- **Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all** (*promote economic growth, productivity and innovation, enterprise and employment creation*). FBDs have high costs which negatively impact economic growth. Foodborne pathogens result in lost value from exports and lost opportunities in the international market if standards are not met. Many people working in agriculture and food sectors are at increased risk of developing FBDs, and people with FBDs working in these sectors can contaminate food, leading to loss of value. Investment in the control of FBDs such as brucellosis, salmonellosis, etc. has economic benefits that outweigh the serious consequences of these infections. In developing countries, most of the food production and distribution is in the informal sector which provides employment to millions of people. Development of agri-food sectors may exclude these people from the markets, but on the other hand may provide new opportunities for smallholders.

- **Goal 9. Build resilient infrastructure, promote sustainable industrialization and foster innovation** (*improve infrastructure, promote sustainable food chain*). Extended and complex food value chains increase the risk of FBDs. Infrastructure is an important factor in attaining food safety. Improvements of transport can reduce FBDs by decreasing the transportation time and keeping food at low temperatures for longer times. Improved infrastructure increases the market

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orientation of farmers and decreases the use of agricultural inputs which protect food for longer periods.

- **Goal 10. Reduce inequality within and among countries** (*reduce inequalities, reduce social stigmatization*). FBDs induce the worsening of inequalities as vulnerable populations such as the young, the old, the pregnant, the malnourished and the immunosuppressed are more susceptible to FBDs. Some foodborne diseases, such as tuberculosis and cysticercosis/taeniasis (tapeworm infections) may result in social stigmata and disapproval.

- **Goal 12. Ensure sustainable consumption and production patterns** (*achieve sustainable production and use/consumption practices, reduce waste production/pollutant release into the environment, attain zero –waste lifecycles, inform people about sustainable development practices*) There are complex interactions between dietary composition, dietary sustainability and FBD risk. Increasing the consumption of fresh and locally produced vegetables would reduce non-communicable diseases, and lower environmental costs. On the other hand, locally-traded, locally-produced food that is not subject to national safety controls, may lead to an increase in uncontrolled waste containing biohazardous agents such as microorganisms and toxins and an increase in FBDs. Decreasing consumption of animal food has health benefits for developed countries by decreasing hypercholesterolemia and obesity and associated problems, but may worsen the nutritional status of people living in developing countries, as animal protein is very important for the body and cognitive development of children. Animal food is associated with a higher environmental footprint.

- **Goal 14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development** (*reduced pollution of marine systems by toxic chemicals/agricultural nutrients/microorganisms/wastes like plastics, develop mitigation measures for acidification, enhance sustainable use of oceans and their resources*). Fish is an important and cheaper dietary protein source, especially for poor people. Fish meal is also used as a dietary supplement for livestock and these systems may result in water pollution that can lead to eutrophication and hypoxic water conditions. Fish is also highly vulnerable to contamination by toxic chemicals and microorganisms, thus may be a risk for animals and people that consume fish.

- **Goal 15. Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss** (*insufficient food supply, decrease in biodiversity*) The decrease of agricultural areas may lead to insufficient food supply and an increase in costs for safe food which may increase the tendency to buy unsafe food sold in domestic markets. Overuse of livestock and bushmeat can reduce biodiversity and ecosystem resilience.

Potential Implications for Decisions

FBDs have individual, community and national consequences not only health-related, but also social and economic. Preventing FBDs have major impacts on each of them.

1. Individual

- a. Weighing up the various microbial and non-microbial factors and aligning them with personal convictions (do the personal preferences outweigh the risks of consuming the desired food?)

- b. Is there a lower-risk option? (Preferring meat/poultry cooked to a safe internal temperature instead of raw/undercooked meat/poultry; preferring pasteurized milk/milk products instead of raw/unpasteurized milk/milk products; preferring foods that contain

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pasteurized eggs instead of foods containing raw/undercooked eggs; preferring well washed fresh fruits and vegetables instead of unwashed fresh fruits and vegetables, etc.)

c. Improving individual health literacy (buying from safe producers, reading the contents and expiry dates of packaged and canned food, being able to discriminate between fresh and dated fish/meat/fruits/vegetables, etc.)

d. Hand hygiene practices (awareness of the importance and necessity of social hand washing in preventing FBDs)

e. Employing hygiene and good cooking/proper storage practices during the preparation and serving of food to decrease cross contamination (microbial pathogens can be introduced directly from contaminated food/food products that are improperly processed, prepared and served, insufficiently cooked or inadequately stored, or from cross contamination of food from kitchen utensils and food preparation surfaces)

f. Education about food safety and improvement of consumer willingness to pay for food safety to develop safer food chains

g. *Non microbial parameters: The financial cost of buying safe/processed food, health risks of consuming processed food instead of meat/poultry/fresh fruits and vegetables, such as obesity, food allergies, and even cancer*

2. Community policies

a. Local environmental consequences of raising livestock (pollution of soil, local water sources with faeces)

b. Direct and indirect health costs associated with FBDs

c. *Non-microbial parameters: support of local producers and local markets, improving their consistence to meet food safety regulations*

3. National policies relating to FBDs

a. Testing food workers for the carriage of foodborne pathogens (infected food workers can be asymptomatic and can contaminate food or food contact surfaces, or infect other food workers – remember ‘Typhoid Mary’. On the other hand, food workers may also be the victim of FBDs as an occupational hazard)

b. Building up a sustainable food value chain which is profitable throughout all of its stages (economic sustainability), has benefits for society (social sustainability) and has a positive impact on the natural environment (environmental sustainability). The food value chain must have multiple check-points from farm to fork so that, if one barrier fails, other barriers may be strong enough to prevent the FBDs

c. Improving research and investment in food and water safety, foundational knowledge, human resources and infrastructure.

d. Improving coordinated action across multiple sectors involving human and animal health, and environmental protection.

e. Implementing and supervising the adaptation to food safety standards, setting up regulations and applying sanction

f. Healthcare economics of FBDs and associated consequences

g. Environmental pollution

h. Ensuring safe drinking water supplies

i. Greenhouse gas production due to raising livestock and global warming

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- j. Sequestration of agricultural land otherwise used for food and renewable production.
- k. *Non-microbial parameters: subsidizing the high cost for processed and safe food so that people of lower socioeconomic status can also reach them, economical support and control of domestic markets and improving their standards*

Pupil Participation

1. *Class discussion of the issues associated with FBDs*

2. *Pupil stakeholder awareness*

- a. FBDs have many negative consequences for the SDGs and reaching some SDGs may have negative impact on the burden of FBDs. Which of these are most important to you personally/as a class?
- b. Can you think of anything that might be done to reduce the negative consequences of FBDs, especially in the food value chain?
- c. Can you think of anything you might personally do to reduce the burden of FBDs?

3. *Exercises*

- a. When and how should we wash our hands?
- b. What do you think you can do to prevent FBDs in your kitchen? In your community? In your country? Globally?
- c. What are the primary and secondary barriers that prevent FBDs?
- d. Which foods are safer to eat outside? How can you replace safer foods with risky ones?
- e. How do you think the intestinal microbiota can protect us from foodborne pathogens?
- f. Do you think there are any rules for refrigeration of foods? What do you think they may be?
- g. What are the spoilage signs of meat/poultry/fish/milk/eggs/fruits/vegetables?
- h. What is the danger zone? Why is it important to keep food out of the danger zone?
- i. If pathogenic bacteria can double in every 20 minutes, how many bacteria would there be if the food containing one bacterium were kept at room temperature for six hours? Ingesting how many bacteria do you think is enough to get infected with *Salmonella*? *Shigella*? *Campylobacter*? *E.coli*? *Yersinia*?
- j. What do you know about shelf life terminology? Shelf life? Sell by? Best by/best before? Use by? Expiration date?
- k. Is typhoid Mary a victim or an enemy? Was she a superspreader or supershedder? Do you think the outbreaks she caused could have been prevented? How?
- l. What does “Food safety is a shared responsibility?” mean?

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The Evidence Base, Further Reading and Teaching Aids

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Glossary

5F: Five routes responsible for fecal-oral transmission of pathogens (Food, Flies, Fields, Fingers, Fluids).

Aerosol transmission: Transmission of pathogens by infectious aerosols which are able to suspend in the air.

Antimicrobial resistance: The ability of microorganisms to resist the killing effect of antimicrobial agents.

Biodiversity: The variety of living species on earth which include plants, animals, and microorganisms.

Bioterror=bioterrorism: Intentional use of microorganisms to sicken or kill humans, livestock or crops.

Decontamination: The process of cleansing an object or surface to eliminate microorganisms and other hazardous materials such as chemicals, and radioactive substances.

Eutrophication: Over enrichment of water with minerals and nutrients that result in depletion of oxygen and excessive growth of algae.

Fomites: inanimate objects, such as a dish, doorknob, or article of clothing, especially their surfaces, that may be contaminated with infectious agents and serve in their transmission

Food allergy: Abnormal immune response to certain foods which cause allergic symptoms such as hives, itchiness, trouble breathing, vomiting, diarrhoea, etc.

Food intoxication= Food poisoning: Illness that results from ingesting microorganism- or toxin-contaminated food

Food safety hazard=Foodborne hazard: Any agent (biological, chemical or physical) in the food that can cause adverse health consequences for consumers.

Food safety rules: Basic procedures such as cleaning, separating, cooking and chilling of food to keep it safe from food safety hazards.

Food safety standards: The formal documents which are implemented by authorities and enforced by the law that include the requirements that foods or food processors have to comply to keep food safe for human health.

Food safety legislation: Legislation that is designed to protect consumers from foods and from misleading information that can harm human health.

Food security: (As defined by the UN Committee on World Food Security) The ability of all people at all times to have physical, social and economic access to sufficient, safe, and nutritious food which meets their food preferences and dietary needs for an active and healthy life.

Food value chain: A series of activities that create and build value at every stage from production to consumption of food.

Foodborne disease=Foodborne microbial disease=Foodborne infection: Diseases caused by eating food contaminated with biological, (bacteria, viruses, parasites, fungi, or prions), chemical, and physical agents.

Fomite: Inanimate objects that can transfer microorganisms to new hosts when contaminated with or exposed to infectious agents.

Hepatitis: Inflammation of the liver which can be caused by infectious agents such as viruses or toxins.

High risk foods: Foods that have a tendency to spoil as a result of improper cooking methods or unsuitable storage conditions.

Immune system: The host defense system comprising many organs, tissues, cells and proteins that protect body against foreign substances such as infectious agents or cancer cells.

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Immunodeficiency: The inability of the immune system to fight against foreign substances such as infectious agents and cancer.

Incubation period: The time between contacting with the infectious agent and the emergence of symptoms.

Inequality: The difference in social status, wealth or opportunity between people or groups.

Microbiota: Communities of microorganisms that colonize human body without giving harm.

Morbidity: The condition of being ill, diseased or unhealthy.

Mortality: The condition of being dead.

Obesity: A medical condition due to accumulation of excess body fat.

Primary barriers: Barriers that prevent the entry of pathogens into the environment.

Receptor: Chemical structures (proteins) that receive and transduce signals into biological systems.

Secondary barriers: Barriers that prevent pathogens in the environment from multiplying and reaching a new host.

Supershedder: Individuals who shed larger amounts of pathogen than others.

Superspreader: Individuals who create more secondary contacts than others.

Toxin: A poisonous substance produced by living cells or organisms.

Vaccination: Administration of specific but safe antigenic components of microorganisms to the body to induce protective immune response against infection.

Vulnerable people: People who are more susceptible to being physically or emotionally wounded.

Wastewater: Any water that has been contaminated by human use.

Zoonoses: Infections that are transmitted to humans from animals.