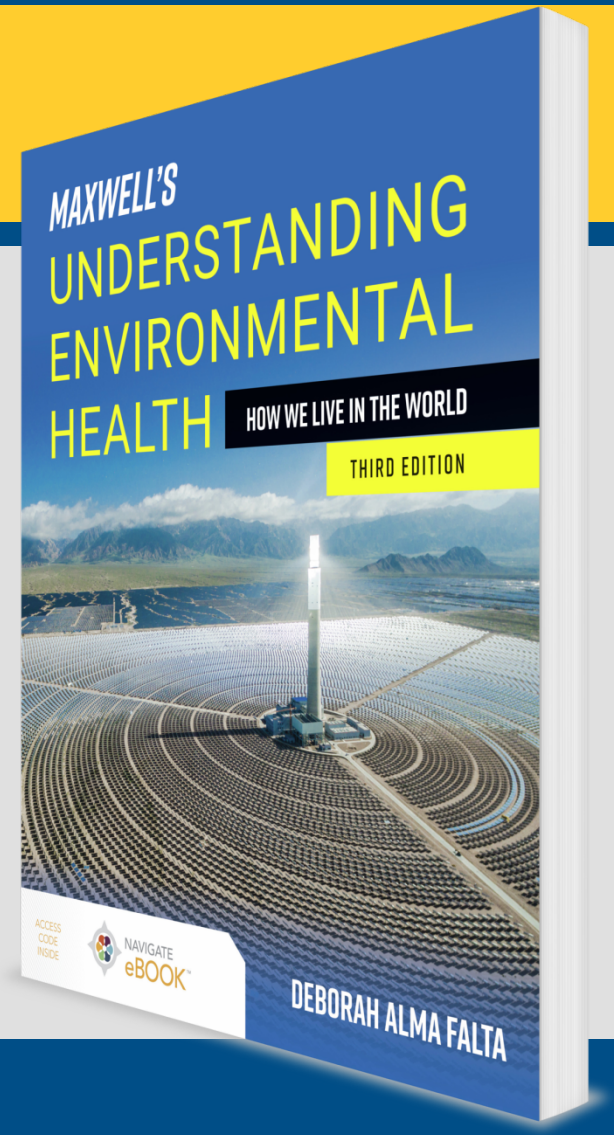
CHAPTER 4

Living with Nature



4.1 Infectious Disease

4.2 Poisons in Nature

4.3 Naturally Occurring Radiation

4.4 Natural Disasters

Introduction to Infectious Disease

- "Infectious disease" is host-centered concept
  - Human body is habitat and host to many organisms.
  - Associations that harm or bother us are *infectious diseases*; agents are *pathogens.*

Began to Think Infectious Diseases Were Only a Scourge of the Past

- Medical strides during late 19th and early 20th centuries, such as antibiotics and immunizations, reduced or eradicated much infectious disease.
- Public health measures such as improved sanitation and disinfection, plus improved food storage, also arrested the spread of pathogenic infectious agents.

However, Infectious Diseases are (Re-)Emerging as a Significant Cause of Human Morbidity and Mortality

- Why?
  - Decrease in funding for surveillance and infectious disease prevention infrastructure
  - Increasing urbanization overwhelming any improvements in sanitation "infrastructure"
  - Antibiotic resistance

Other Environmental Factors Associated with Observed Increases in Infectious Diseases

- Movement of the human population into endemic areas (due to wars, migration, and increasing urbanization)
- Ecological changes resulting from agricultural projects (deforestation, extension into endemic areas, irrigation methods, conversation of grasslands)
- Climate change

Other Reasons for Newly Emerging or Reemerging Infectious Diseases?

- New agents of infection (such as prions), some associated with new industrial processes
- Terrorism

Examples of Emerging Zoonoses and Their Contributing Factors

- Bacterial:
  - Escherichia coli O157:H7 (hemolytic-uremic syndrome)
    - Mass food-processing technology allowing contamination of meat
- Nonconventional agent:
  - Bovine spongiform encephalopathy
    - Changes in rendering process

Scope of Environmental Health Focus on Infectious Disease

- Environmental health does not typically address directly transmitted types of infectious diseases (STDs, colds, etc.)
- Rather, the focus is on infectious diseases that require on environmental mode of transmission (indirect)
  - Water or foodborne diseases
  - Zoonotic and vectorborne diseases

Zoonosis

- Refers to an infection or infectious disease transmissible under natural conditions from animals to humans
  - Sometimes animals get the diseases, but more often serve as non-affected reservoir
  - Reservoir: the source of an infectious agent

Methods for Transmission of Zoonoses

- Contact with the skin
- A bite or scratch from an animal
- Direct inhalation or ingestion
- The bite of an arthropod vector

Vector

- Defined as “an insect or any living carrier that transports an infectious agent from an infected individual or its wastes to a susceptible individual or its food or immediate surroundings.”
- ***NOTE: the actual agent is typically a pathogenic virus, bacterium, or protozoan!***

Types of Pathogenic Agents

The Transmission of Infectious Disease

The Body's Defense against Pathogens

Population-Level Impacts of Infectious Disease

Types of Pathogens (1 of 2)

- Worms: multicellular; parasitic
- Protozoa: unicellular; parasitic
- Bacteria: unicellular; most not parasitic
  - Aerobic vs anaerobic, or tolerate either
  - Some form spores
- Molds and yeasts: **single-celled fungi**
- Viruses: strand of DNA or RNA; parasitic
- Prions: abnormally shaped proteins found on nerve cells; cause degenerative brain diseases

Types of Pathogens (2 of 2)

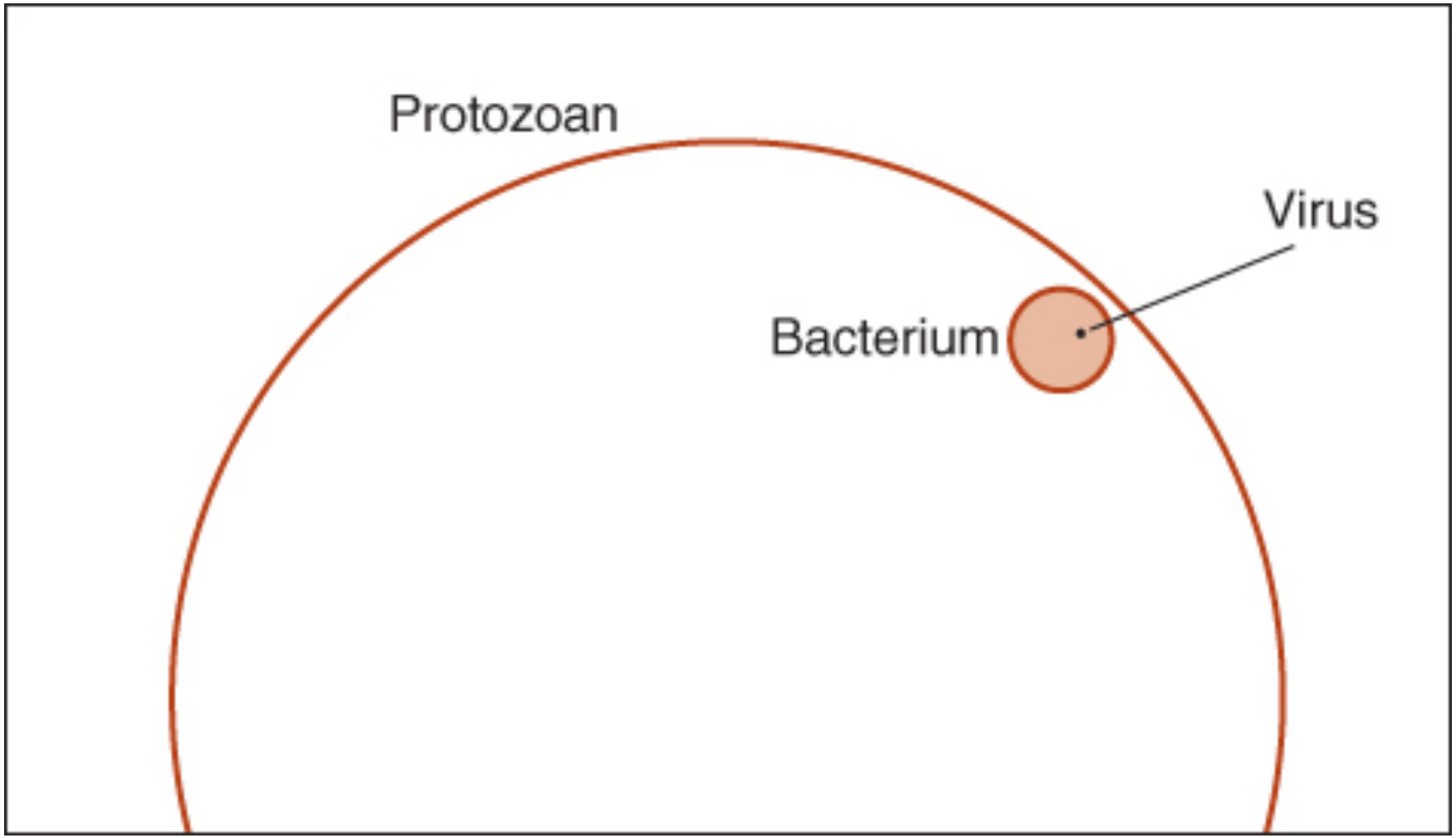


FIGURE 4.2 Approximate relative size of protozoan, bacterium, and virus.

Types of Pathogens

The Transmission of Infectious Disease

The Body's Defense against Pathogens

Population-Level Impacts of Infectious Disease

The Transmission of Infectious Disease (1 of 7)

- Transmission through closeness/contact
  - Droplet transmission: coughing, sneezing
    - Diphtheria, tuberculosis, pertussis, influenza, measles, mumps, rubella
  - Direct oral contact
    - Strep, herpes simplex-1, infectious mononucleosis
  - Transmission terms
    - Vector (“*to carry”):* a living transmitter of disease
    - Mechanical vector: items such as syringes
    - Fomite:an inanimate object that transmits disease
- Airborne transmission in aerosols (distinct from droplet transmission)

The Transmission of Infectious Disease (2 of 7)

- Fecal–oral transmission of diarrheal disease
  - Fecal–oral pathway: one person's infectious diarrheal disease becomes next person's disease of fecal origin
  - If sewage not well controlled, waterborne transmission dominates.

The Transmission of Infectious Disease (3 of 7)

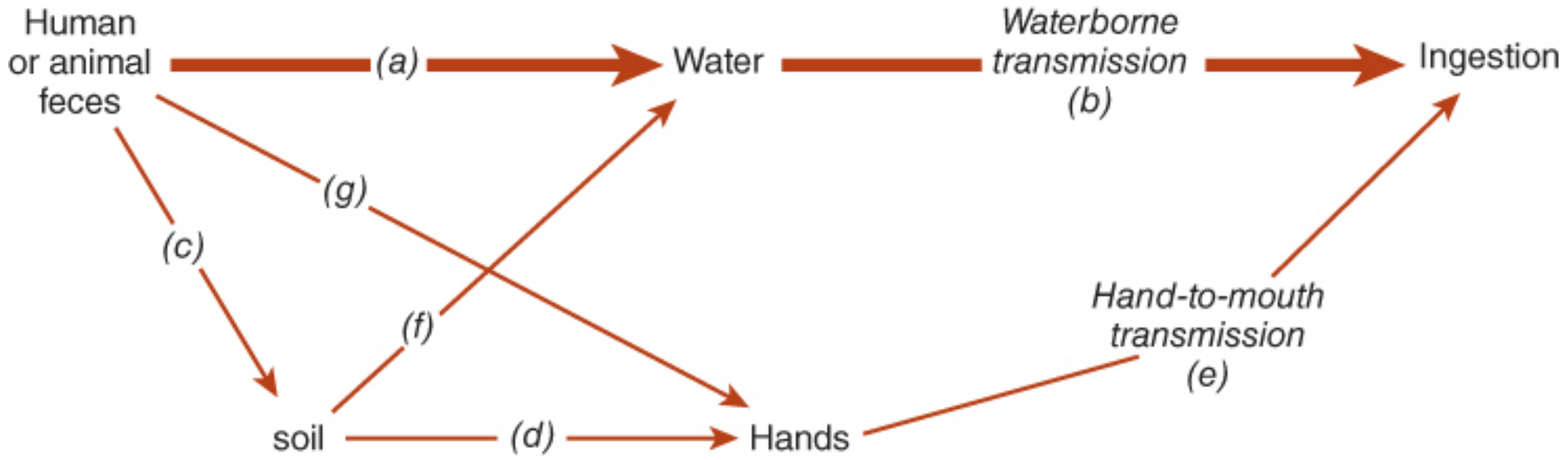


FIGURE 4.4 Fecal–oral transmission of disease via water, soil, and hands in a setting with no treatment of sewage or drinking water.

The Transmission of Infectious Disease (4 of 7)

- Fecal–oral transmission also via soil and by hand-to-mouth transmission
- Cholera, typhoid fever, dysentery; giardiasis, cryptosporidium (zoonoses); hepatitis A, Norwalk virus, polio
- Composting toilet as innovative approach to sanitation in less developed countries

Composting Toilet

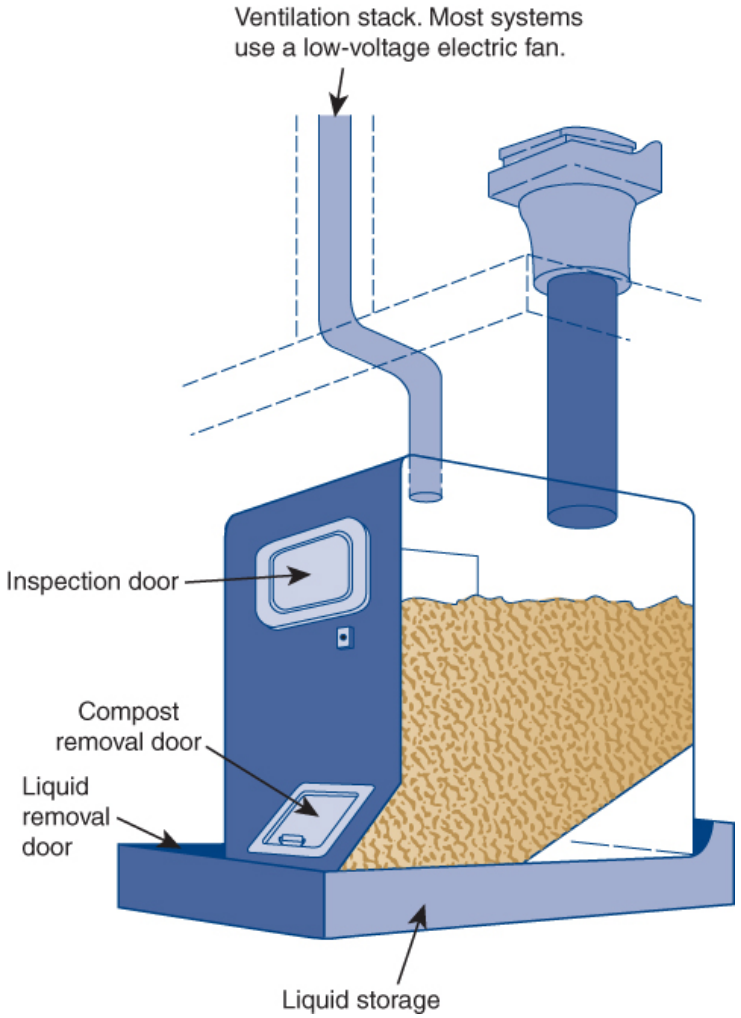


FIGURE 4.5 The design of the continuous composting toilet features a separate holding area for liquid waste, doors to inspect and remove compost and liquid, and a ventilation stack. When properly built and vented, a continuous composting toilet is odorless.

Courtesy of Clivusmultrum Incorporated.

The Transmission of Infectious Disease (5 of 7)

- Non-fecal organisms also transmitted in water or soil
  - Guinea worm disease
  - Tetanus
- And via food (foodborne transmission)
  - Housefly as mechanical vector

The Transmission of Infectious Disease (6 of 7)

Transmission to food by mechanical vector

Transmission to food by water, soil, and hands

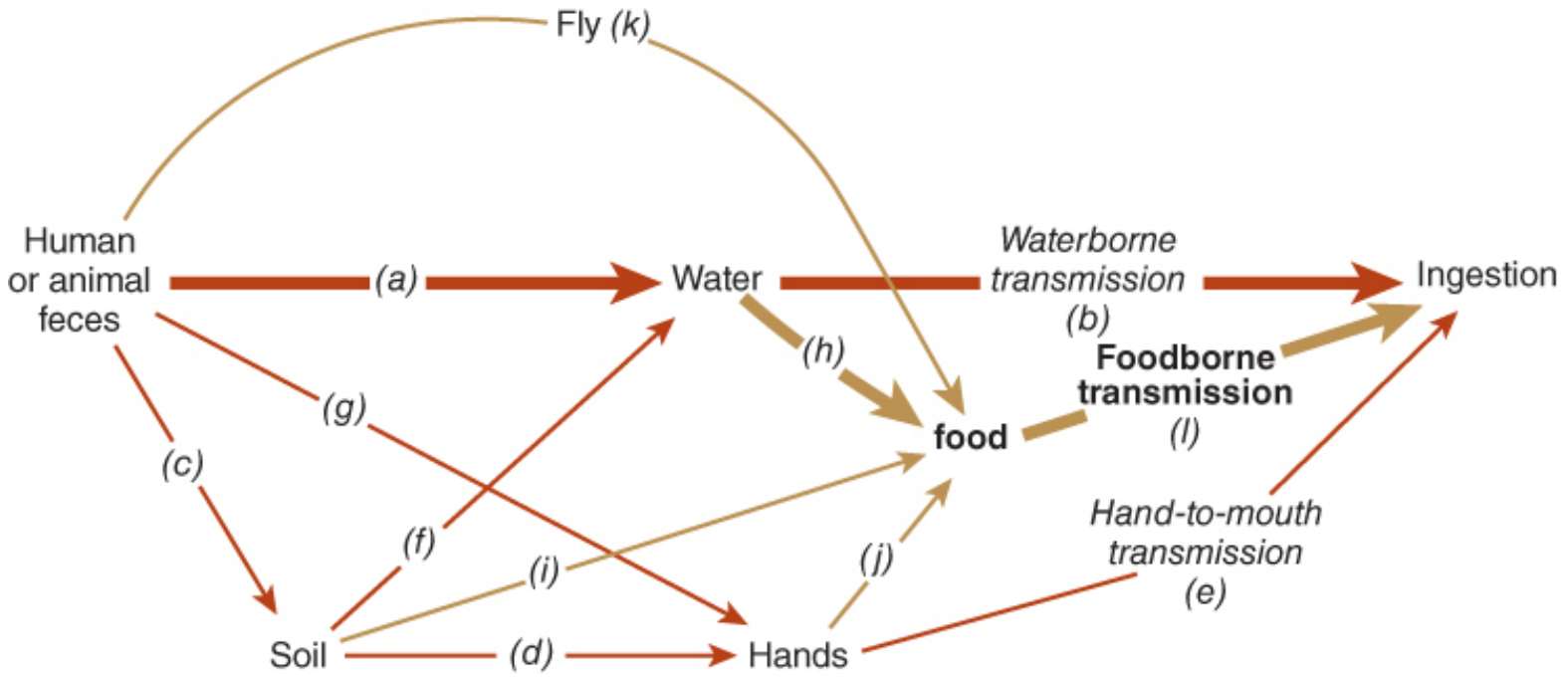


FIGURE 4.7 Addition of foodborne transmission to basic fecal–oral transmission of disease, in a setting with no treatment of sewage or drinking water.

The Transmission of Infectious Disease (7 of 7)

- Without sanitation, most foodborne illness is by fecal–oral pathway
- In the industrialized countries, some foodborne illness is of human-fecal origin
  - Shellfish contaminated by sewage
  - Inadequate handwashing in food preparation
- But most is from other sources:
  - Animal fecal pathogens, from slaughter
  - Pathogens in soil on food
  - Human skin
  - Mechanical vectors (flies, cockroaches)

Some Important Foodborne Pathogens (1 of 4)

- Illness may result directly from infection or from a bacterial toxin (intoxication)
- Non-typhoid Salmonella
  - Common in poultry feces; contaminate flesh
  - Typical scenario #1: poultry not cooked to high enough temperature
  - Typical scenario #2: cross-contamination after cooking
  - Common illness; gastrointestinal; rarely fatal

Some Important Foodborne Pathogens (2 of 4)

- *Campylobacter* species
  - Also common in feces of poultry
  - Common illness; gastrointestinal; rarely fatal
- *Listeria monocytogenes*
  - Widespread in environment; hardy
  - Septicemia, meningitis, reproductive effects[1]
  - Higher fatality rate

Some Important Foodborne Pathogens (3 of 4)

- *Escherichia coli (E. coli)* O157:H7[2]
  - May be in cattle intestines; contaminates meat during processing
  - Inadequate cooking, especially hamburgers; as few as 10 organisms can cause illness
  - Intoxication; bloody diarrhea; sometimes hemolytic uremic syndrome, death

Some Important Foodborne Pathogens (4 of 4)

Table 4.2 Estimated Overall Incidence and Case-Fatality Ratio* for Four Foodborne Illnesses in the United States in 2015

	Incidence per 100,000 Population	Case-Fatality Rate (%)
Campylobacter	17.12	0.2
Salmonella	16.63	0.4
E. coli 0157:H7	3.12	0.6
Listeria	0.23	12.9

*In infectious disease, the term *case-fatality rate* compares the number of deaths among reported cases to the number of reported cases, calculated as: (number of deaths/number of cases) × 100.

Data from Centers for Disease Control and Prevention. Infection with Pathogens Transmitted Commonly Through Food and the Effect of Increasing Use of Culture-Independent Diagnostic Tests on Surveillance — Foodborne Diseases Active Surveillance Network, 10 U.S. Sites, 2012–2015, Available at: https://www.cdc.gov/mmwr/volumes/65/wr/mm6514a2.htm#T1_down Accessed June 25, 2020.

Vectorborne Transmission (1 of 2)

- Biological vector: host species that transmits disease to another host species
- Many vectors are arthropods (insects, arachnids).
- But mammals, such as rodents, can be vectors, too.

Vectorborne Transmission (2 of 2)

FIGURE 4.9 An *Aedes aegypti mosquito, the vector* for dengue fever, takes a blood meal from a human host.

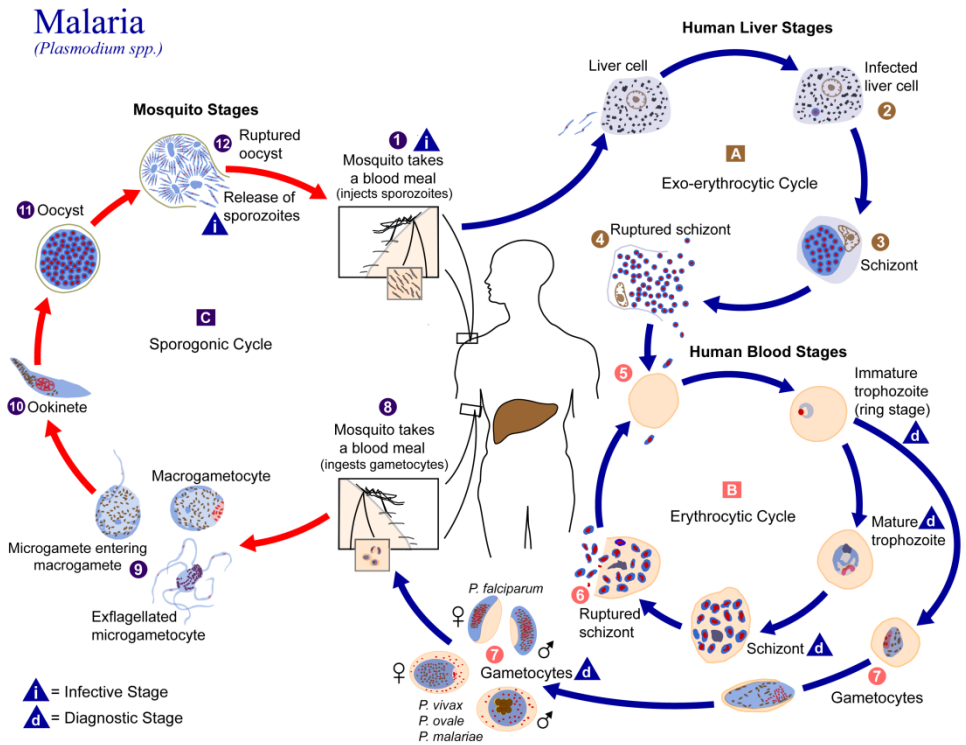
Courtesy of CDC Public Health Image Library. ID# 9252. Content providers CDC/Prof. Frank Hadley Collins, Dir., Cntr. for Global Health and Infectious Diseases, Univ. of Notre Dame. Available at: http://phil.cdc.gov/phil/home.asp. Accessed October 4, 2012.

FIGURE 4.10 The black-legged tick (*Ixodes scapularis), shown here on a blade of grass,* transmits Lyme disease among a number of mammalian hosts, including humans.

Courtesy of CDC Public Health Image Library. ID# 1669. Content providers CDC/Michael L. Levin, PhD. Available at: http://phil.cdc.gov/phil/home.asp.Accessed October 4, 2012

Malaria Transmission

- Transmission involves the complex life cycle of mosquitoes (the vector) and human hosts (with human liver and human blood stages).
- Transmitted through the bite of an infected mosquito of the *Anopheles* type



Plasmodium is a parasitic protozoan.

Source: Reprinted courtesy of the CDC Public Health Image Library. ID# 3405. Alexander J. da Silva, PhD, and Melanie Moser Content Providers. Available at: http://phil.cdc.gov/phil/details.asp. Accessed March 1, 2010.

Infectious Agents of Malaria

- *Plasmodium falciparum*
  - Most deadly
- *Plasmodium vivax*
- *Plasmodium ovale*
- *Plasmodium malariae*

Malaria

- A disease found in more than 100 countries, with more than 40% of the world's population at risk
- Endemic regions include Central and South America, Africa, India, Southeast Asia, the Middle East, and Oceania.
- Global direct economic costs incurred by malaria are estimated to be in the billion of U.S. dollars
- The direct costs include those for treatment and prevention of the disease (e.g., medicine, hospitalization, and pesticide use).
- Lost productivity, lost earnings, and negative impacts upon travel and tourism
- Annual death toll for malaria was more than 1 million persons, and in 2017 there were half a million deaths globally from malaria
- Controlling malaria *pits* environmentalists versus public health practitioners! (to be further discussed in Chapter 5)

Arboviruses

- A group of viral diseases that are most frequently acquired when blood-feeding arthropod vectors infect a human host
- Arboviral disease symptoms may include acute central nervous system illness with fever or rash, and may progress to hemorrhagic fevers or polyarthritis
- Recent arbovirus diseases include Dengue fever, West Nile Virus, (re-emerging) Yellow fever, Chikungunya, and Zika

Prevention of Vectorborne Transmission

- Prevent human contact with vectors
  - Clothing, screens, and nets
  - Insect repellents
- Reduce vector population
  - Modifications to the environment
  - Release of (genetically modified) sterile male insects to reduce reproduction
  - Pesticides (to be discussed in Chapter 5)

Zoonotic Diseases may Involve a Complex Web!

- Consider the complex web of interactions between humans and other living species for the transmission of Lyme disease or anthrax!

Types of Pathogens

The Transmission of Infectious Disease

The Body's Defense Against Pathogens

Population-Level Impacts of Infectious Disease

The Body's Defense Against Pathogens

- Immune system distinguishes "self" from "foreign."
  - Active immunity: on first exposure to antigen, body produces antibodies
- Vaccination
  - Antigen preparation: active immunity
  - Antibody preparation: passive immunity
- Herd immunity: practical protection
  - If enough members of a group are immune, hard to maintain chain of infection

Evolution of Strategies for Managing Transmission of Disease

- Segregation of sick or exposed persons
  - Isolation: the separation of persons who have an infectious illness[5]
  - Quarantine: the separation of persons who have been exposed to an infectious agent[5]
- Sanitation: misguided but beneficial
- Antibiotics to treat illness
  - Populations of pathogens become resistant over time
  - Methicillin-resistant *Staphylococcus aureus* (MRSA)

Types of Pathogens

The Body's Defense Against Pathogens

The Transmission of Infectious Disease

Population-Level Impacts of Infectious Disease

Global Patterns of Infectious Disease Mortality

- Total 7 million deaths globally from infectious diseases in 2016[29]
  - Burden of death from respiratory infections (40% of infectious disease deaths), diarrheal disease (20%), HIV/AIDS (14%), tuberculosis (18%), and malaria (7%)

Infectious Disease as a Cause of Cancer

- Infection can increase cancer risk
  - E.g., chronic irritation → cell proliferation
- Known infectious causes of cancer account for ~15% of cancers worldwide[31]
  - Liver (hepatitis B and C viruses, liver fluke)
  - Cervix (human papilloma virus)
  - Stomach (*Helicobacter pylori* bacterium)
- Higher percentage in lower-income countries

U.S. Regulatory Framework for Managing Infectious Disease

- Vaccination
  - CDC develops guidelines; states implement
- Isolation and quarantine[6]
  - Nationally, CDC; states within their borders
- Surveillance by CDC of listed infectious diseases; data collected by states
- Regulation of food supply, and treatment of sewage and drinking water, are also important.

4.1 Infectious Disease

4.2 **Poisons in Nature**

4.3 Naturally Occurring Radiation

4.4 Natural Disasters

Poisons in Nature (1 of 3)

- Contact with animals that use poison in self-defense or to subdue prey
  - Venomous snakes, scorpions, spiders
  - Stingrays, scorpionfishes
- Consumption of natural toxins inherent in plant or animal tissue
  - Castor beans (ricin)
  - Pufferfish (neurotoxins)

Poisons in Nature (2 of 3)

- Consumption of plant or animal tissue containing accumulated natural toxins
  - Paralytic shellfish poisoning
  - Ciguatera poisoning
- Consumption of fungal toxins found on food plants in the field
  - Ergot (mycotoxin)

Poisons in Nature (3 of 3)

- Consumption of toxin (aflatoxin) produced by mold, mostly on grains in storage, especially corn, peanuts
  - Potent carcinogen: hepatocellular carcinoma, most common primary liver cancer worldwide
  - Synergistic effect with hepatitis B exposure
  - Together account for most hepatocellular carcinoma in high-risk regions
- Consumption of natural toxins in mushroom (fungus) tissue
  - *Amanita phalloides* (the “death cap”)

4.1 Infectious Disease

4.2 Poisons in Nature

4.3 Naturally Occurring Radiation

4.4 Natural Disasters

Radiation Basics

Radiation Health Impacts and Exposures

Electromagnetic Spectrum

- Energy in wave form; wavelength varies
- Shorter wavelength = higher energy
- Radiation: energy traveling as particles or waves

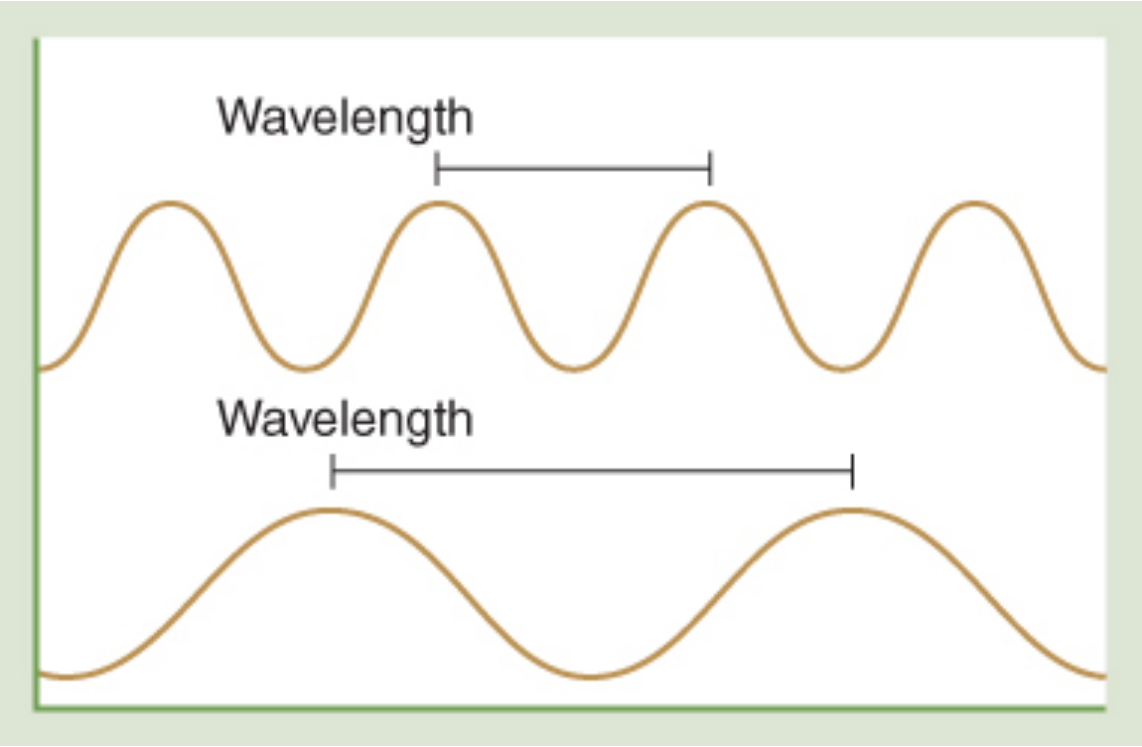


FIGURE 4.13 Electromagnetic radiation of shorter and longer wavelengths.

Radioactive Decay (1 of 3)

- Radioactive decay: a source of radiation
  - Some chemical isotopes are unstable (radioactive)
  - They achieve a more stable configuration by ejecting part of nucleus (radioactive decay)
  - Ejected particles:
    - Alpha particle = 2 protons + 2 neutrons
    - Beta = 1 electron (and neutron → proton)

Radioactive Decay (2 of 3)

- With change in number of protons, one element decays into different element
- Decays occur in characteristic series
- Each element has characteristic half-life
- In decay chain of uranium-238, radon and daughters are of special concern

Radioactive Decay (3 of 3)

Table 4.3 The Decay Chain of Uranium-238

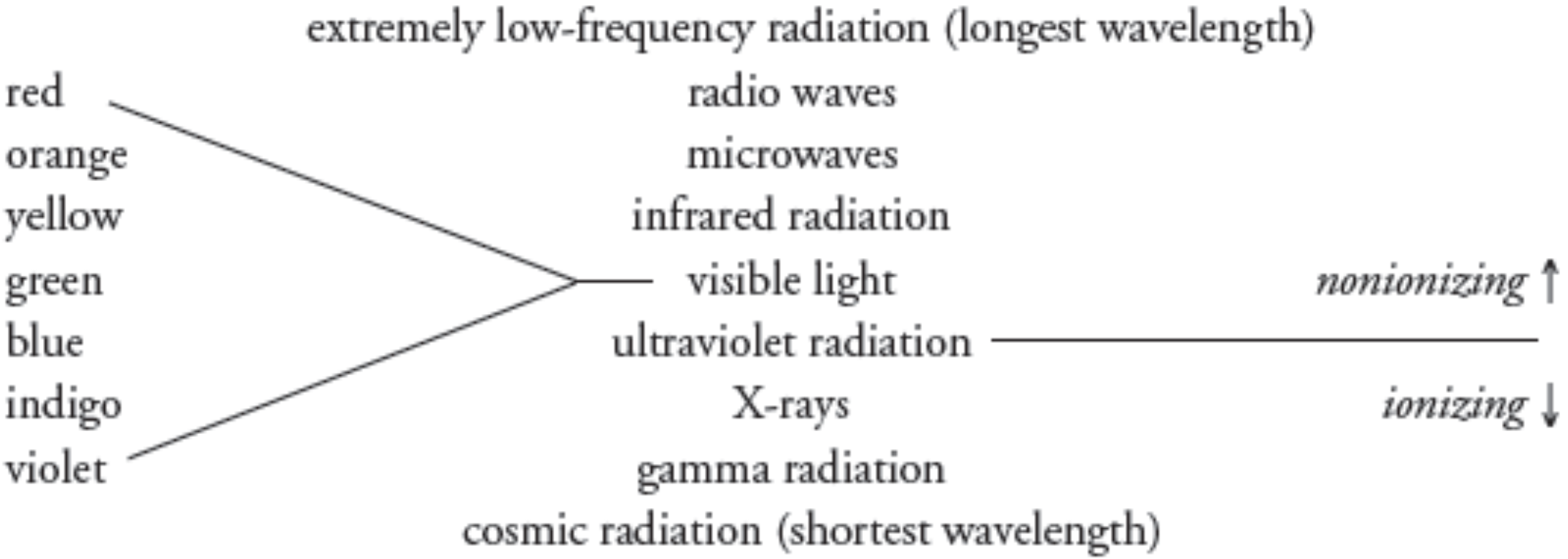
Particle Ejected			Half-life			
Alpha	Beta	Radioactive Isotope	Seconds	Minutes	Days	Years
X		Uranium-238				4.47 billion
	X	Thorium-234			24.10	
	X	Protactinium-234		1.17		
X		Uranium-234				245,500
X		Thorium-230				75,400
X		Radium-226				1,599
X		Radon-222			3.823	
X		Polonium-218		3.04		
	X	Lead-214		26.9		
	X	Bismuth-214		19.7		
X		Polonium-214	0.000164			
	X	Lead-210				22.6
	X	Bismuth-210			5.01	
X		Polonium-210			138.4	
		Lead-206 (stable)				

Reproduced from Holden N. Table of the isotopes. In: Lide D, ed. *CRC Handbook of Chemistry and Physics*. 84th (2003–2004) ed. Boca Raton, Fla: CRC Press; 2003: 11-50–11-197.

Ionizing and Non-ionizing Radiation (1 of 2)

- Functional distinction: ionizing radiation is radiation that, when it strikes matter, has enough energy to knock an electron out of orbit, creating an ion.
- Ionization can lead to damage to cells.
- Alpha, beta, and gamma radiation are all ionizing.

Ionizing and Non-ionizing Radiation (2 of 2)



Measuring Exposure to Ionizing Radiation (1 of 3)

- Grays: intensity of exposure (energy delivered per gram of tissue)
- Impact of dose in Grays depends on
  - Relative biological effectiveness (RBE; damage per unit of energy delivered)
  - Dose (Grays) x RBE = dose (Sieverts)
  - RBE of alpha > RBE of beta > RBE of gamma

Measuring Exposure to Ionizing Radiation (2 of 3)

Table 4.4 An Example Showing the Relationship Between Dose in Grays and Dose in Sieverts for Alpha, Beta, and Gamma Radiation

Type of Radiation	Description	Dose in Grays	Relative Biological Effectiveness (RBE)	Equivalent Dose in Sieverts
Alpha	2 protons + 2 neutrons	2	10	20
Beta	1 electron	2	5	10
Gamma	High-energy electromagnetic radiation	2	1	2

Measuring Exposure to Ionizing Radiation (3 of 3)

- Internal: alpha, beta, gamma are hazards
- External: larger particles penetrate less

Table 4.5 Key Characteristics of Alpha, Beta, and Gamma Radiation

Type of Radiation	Description	Internal Hazard?	External Hazard?	Effective Shielding	Examples of Emitters
Alpha	2 protons+ 2 neutrons	Yes	No	Dead skin cells, paper	Uranium-238, radon and progeny
Beta	1 electron	Yes	Yes	Aluminum, plastic	Strontium-90, iodine-131
Gamma	High-energy electromagnetic radiation	Yes	Yes	Lead, concrete	(Often accompanies alpha or beta)

Radiation Basics

Radiation Health Impacts and Exposures

Biological Effects of Ionizing Radiation

- High-level exposure → radiation sickness; frequently fatal
  - Death of cells in central nervous system, gastrointestinal tract, bone marrow
- High-level (and thus also low-level) exposure → increased risk of cancer
  - Leukemia; breast, thyroid, ovary, bladder, lung, colon, liver, stomach, and nonmelanoma skin cancer

Natural Sources of Exposure to Radiation

- Nonionizing UV-A and UV-B radiation in sunlight
- Cosmic radiation (ionizing) from outer space
- Inhalation of radon
  - Gas, therefore mobile
  - Short-lived; rapid series of radioactive decays[14]

Human Health Impacts of Naturally Occurring Radiation

- Ionizing radiation
  - Increased risk of cancers listed previously
- Nonionizing UV radiation
  - Skin cancer (squamous and basal cell carcinomas, malignant melanoma)
  - Cataracts
  - Immune suppression

4.1 Infectious Disease

4.2 Poisons in Nature

4.3 Naturally Occurring Radiation

4.4 Natural Disasters

Natural Disasters (1 of 2)

- Biggest killers: droughts, earthquakes and tsunamis, storms and floods
  - 1912–1961: estimated 16 million deaths[12]
  - 1962–2011: estimated 5 million deaths[12]
- May create industrial hazards
  - Fukushima nuclear power plant
- Tabulating deaths and other impacts can be difficult in less-developed countries.
- Recent events

Natural Disasters (2 of 2)

Table 4.6 A Snapshot of Four Natural Disasters

Type of Disaster, Location	Year	Setting	Number Killed	Number Affected*
Tsunami, Indian Ocean/ Indonesia	2004	Less developed country	226,096	2,321,700
Hurricane (Katrina), United States	2005	More developed country	1,833	500,000
Earthquake, Haiti	2010	Less developed country	222,570	3,700,000
Earthquake and tsunami, Japan	2011	More developed country	20,319	405,719

*In need of assistance in the form of food, water, shelter, sanitation, or emergency medical care.
Data from Centre for Research on the Epidemiology of Disasters. Emergency Events Database (EM-DAT). Available at: www.emdat.be. Accessed March 21, 2012.