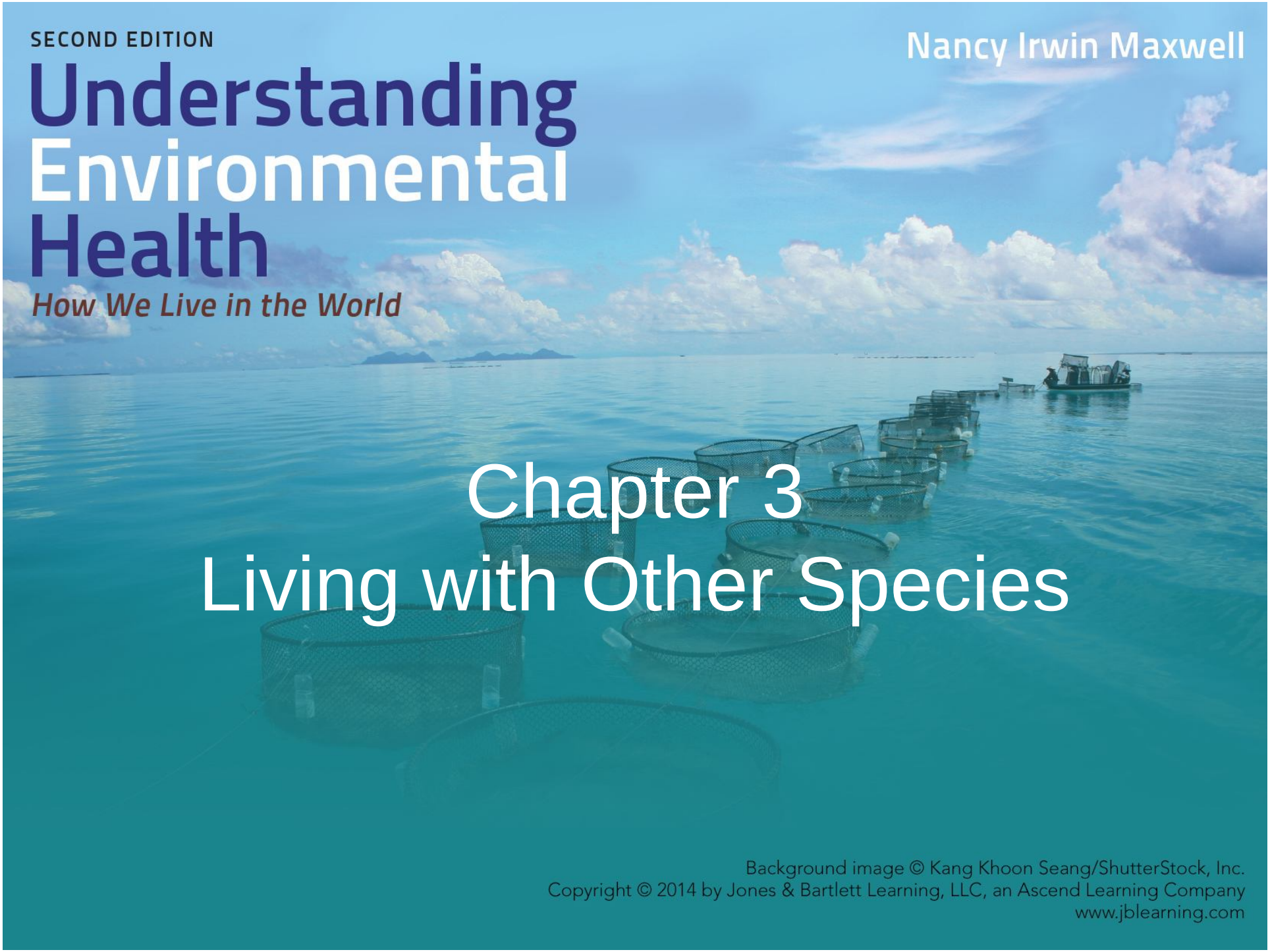


SECOND EDITION

Understanding Environmental Health

How We Live in the World

Nancy Irwin Maxwell

Chapter 3
Living with Other Species

3.1 Infectious Disease

3.2 Poisons in Nature

3.3 Allergy and Asthma

3.4 Natural Disasters

3.5 Naturally Occurring Radiation

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.*
  - Zoonosis—infectious disease transmissible to humans from other animals.

Types of pathogens

The Body's Defense against Pathogens

The Transmission of Infectious Disease

Population-Level Impacts of Infectious Disease

U.S. Regulatory Framework for Managing Infectious Disease Risk

Types of pathogens

- Worms—multicellular; parasitic
- Protozoa—unicellular; parasitic
- Bacteria—unicellular; most not parasitic
  - Aerobic vs anaerobic; or tolerate either
  - Some form spores
- Viruses—strand of DNA or RNA; parasitic
- Prions— abnormally shaped proteins found on nerve cells; cause degenerative brain diseases

Types of pathogens

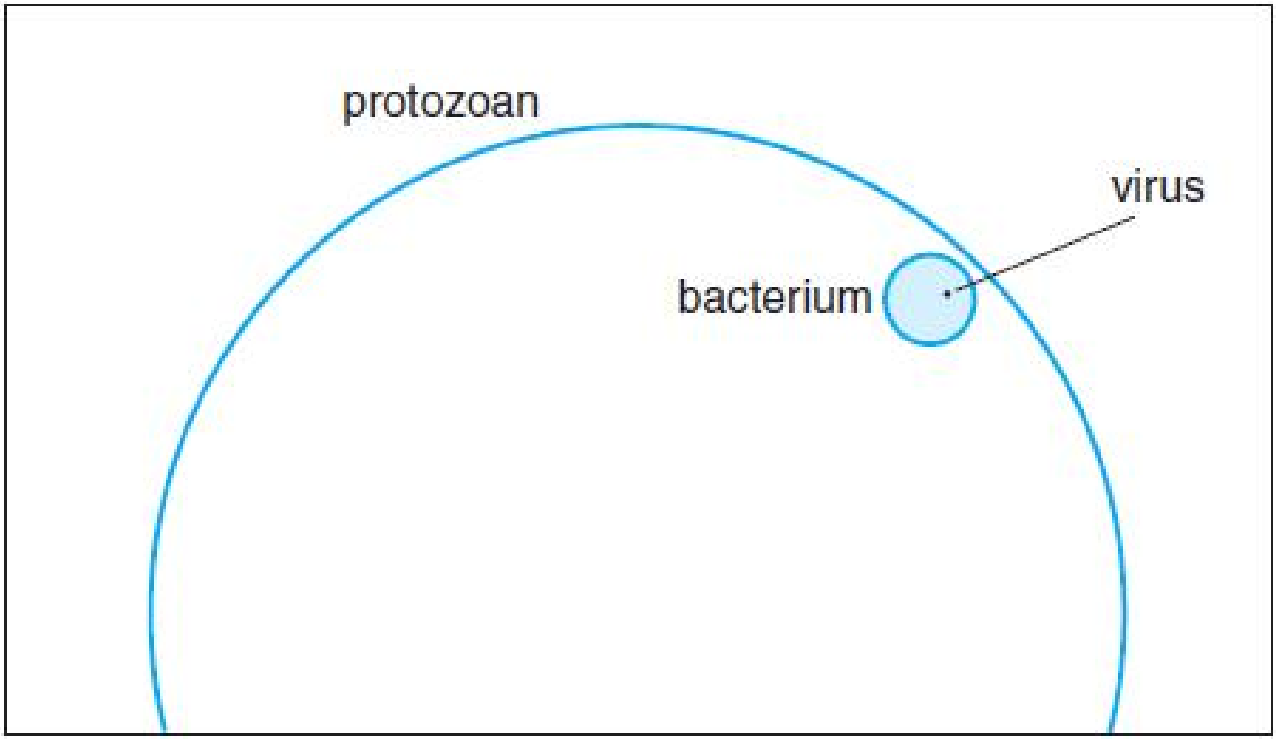


FIGURE 3.2 Approximate relative size of protozoan, bacterium, and virus.

Types of pathogens

The Body's Defense against Pathogens

The Transmission of Infectious Disease

Population-Level Impacts of Infectious Disease

U.S. Regulatory Framework for Managing Infectious Disease Risk

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

Types of Pathogens

The Body's Defense against Pathogens

The Transmission of Infectious Disease

Population-Level Impacts of Infectious Disease

U.S. Regulatory Framework for Managing Infectious Disease Risk

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

Evolution of strategies for managing transmission

- Vaccination (above) to prevent illness
- Antibiotics to treat illness
  - Populations of pathogens become resistant over time
  - Methicillin-resistant *Staphylococcus aureus* (MRSA)
- Pesticides (below) to control vectors

The transmission of infectious disease

- 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 by fomite
- Airborne transmission in aerosols (distinct from droplet transmission)

The transmission of infectious disease

- 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

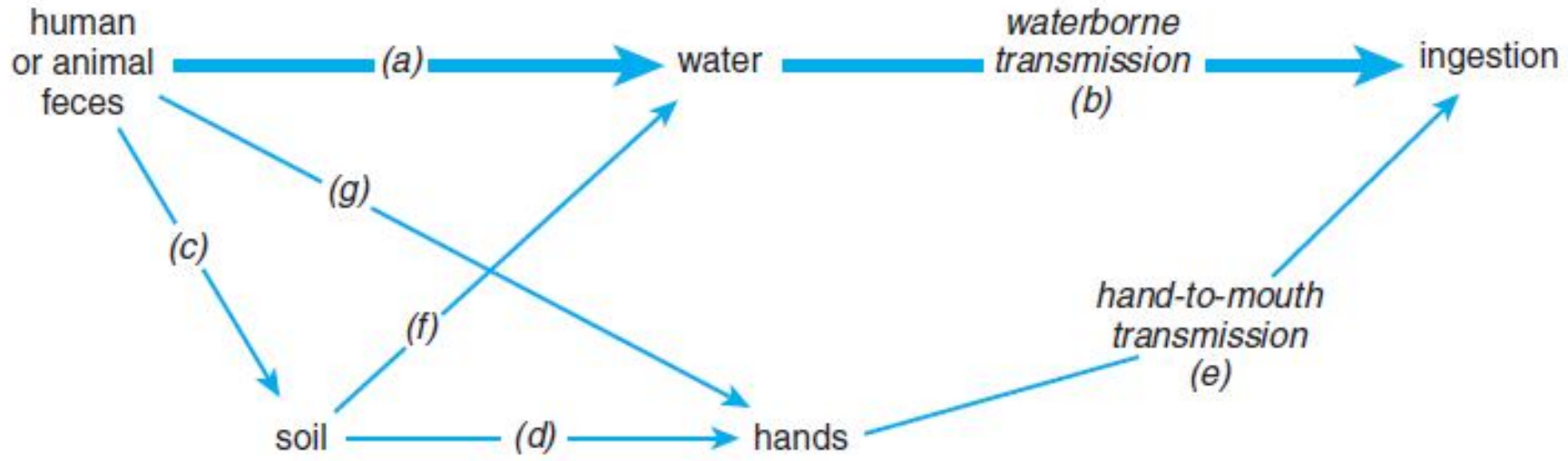


FIGURE 3.4 Fecal–oral transmission of disease via water, soil, and hands in a setting with no treatment of sewage or drinking water.

The transmission of infectious disease

- 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

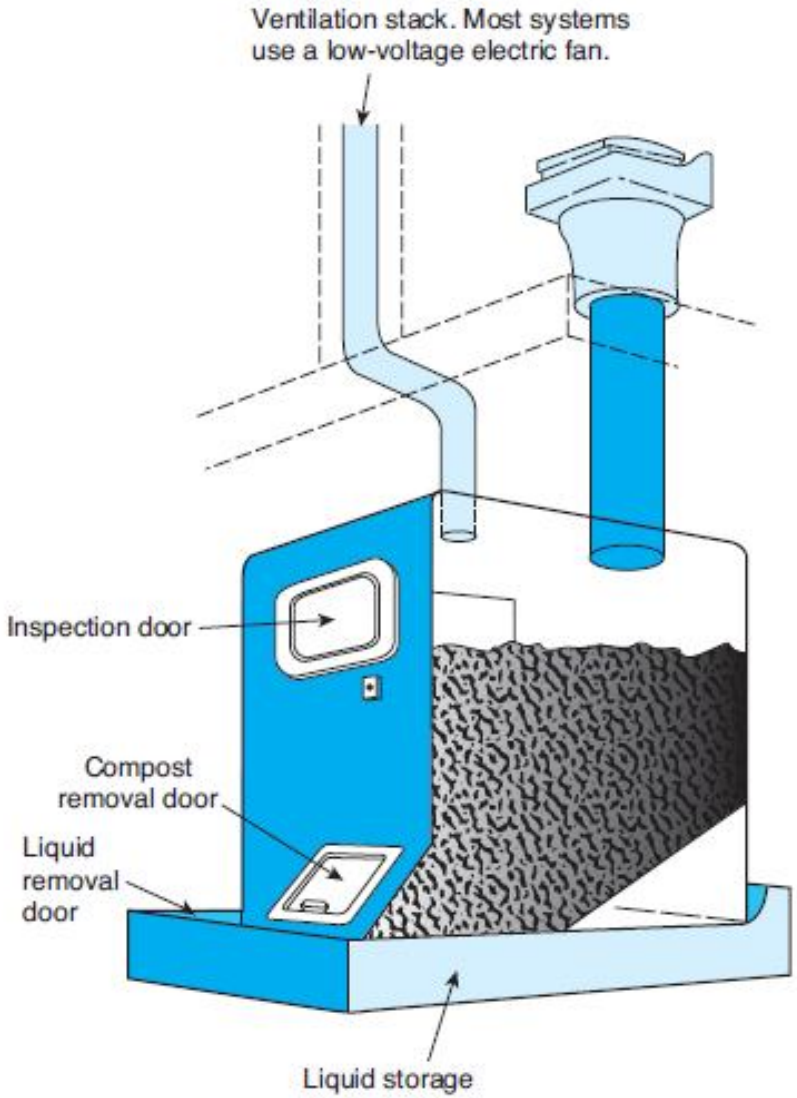


FIGURE 3.5 The design of the continuous composting toilet features a separate holding area for liquid waste, doors to inspect and remove compost and liquid, and a ventilation stack. When properly built and vented, a continuous composting toilet is odorless.

Source: Courtesy of ReSource Institute for Low-Entropy Systems (RILES).

The transmission of infectious disease

- 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

Transmission to food by mechanical vector

Transmission to food by water, soil, and hands

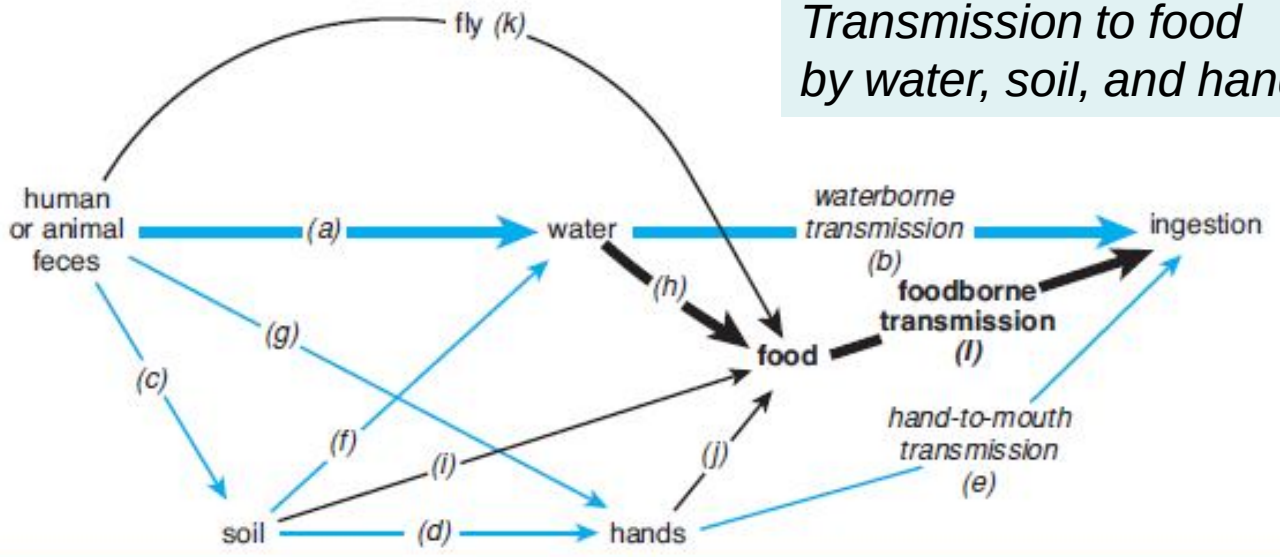


FIGURE 3.8 Addition of foodborne transmission to basic fecal–oral transmittion of disease, in a setting with no treatment of sewage or drinking water.

The transmission of infectious disease

- 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)

The transmission of infectious disease

- Basic levers for food safety
  - Time and temperature: "Keep it hot, or keep it cold, or don't keep it."
  - Temperature: danger zone is 40ºF to 140ºF
  - Time: lag phase and log phase in growth of bacterial population

The transmission of infectious disease

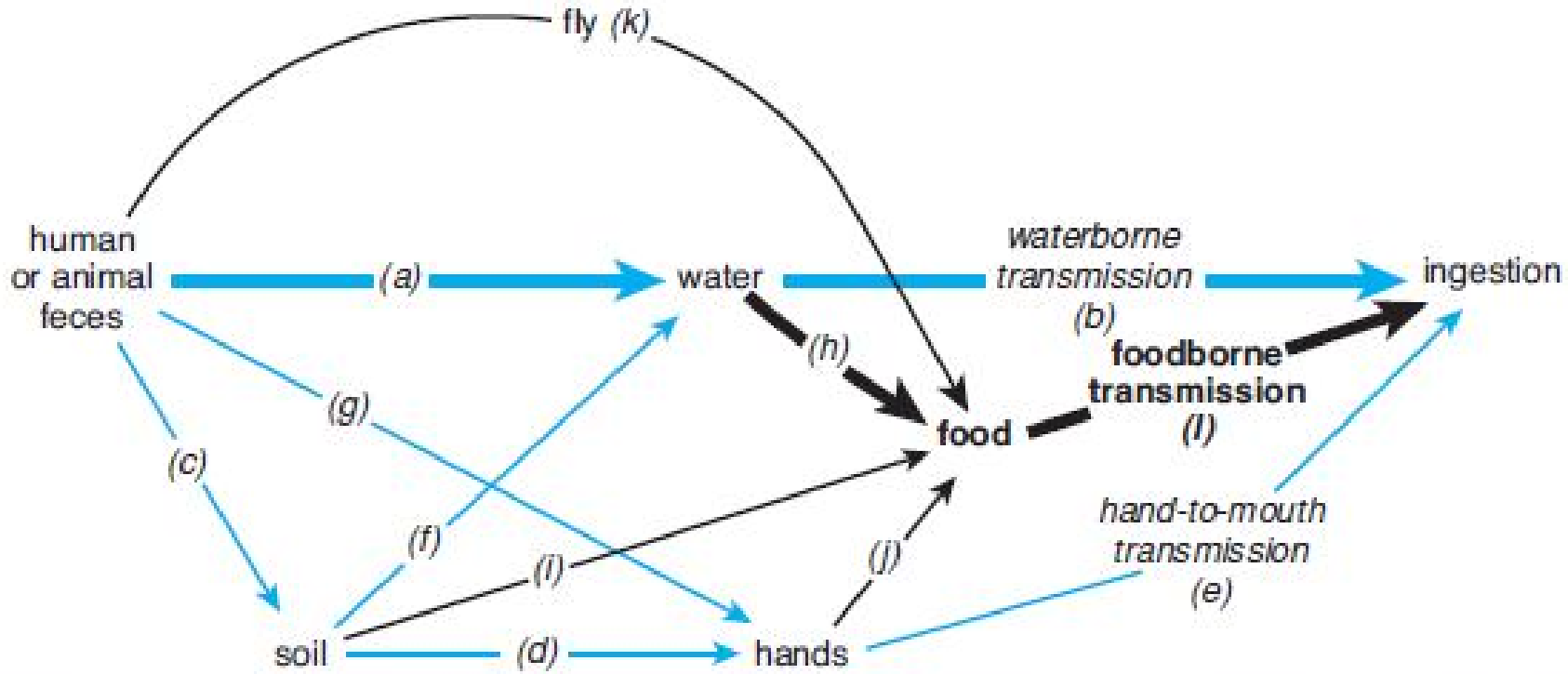


FIGURE 3.8 Addition of foodborne transmission to basic fecal–oral transmittion of disease, in a setting with no treatment of sewage or drinking water.

The transmission of infectious disease

- Some important foodborne pathogens[1]
  - 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

The transmission of infectious disease

- *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

The transmission of infectious disease

- *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

The transmission of infectious disease

Table 3.2 Estimated Overall Incidence and Case-Fatality Ratio* for Four Foodborne Illnesses in the United States in 2010

	Incidence per 100,000 Population	Case-Fatality Ratio
Salmonella	17.62	0.35
Campylobacter	13.58	0.13
Listeria	0.27	12.80
E. coli 0157:H7	0.94	0.45

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

Source: CDC, FoodNet Facts and Figures—Incidence of laboratory-confirmed bacterial and parasitic infections in 2010 (Table 3b), Available at: www.cdc.gov/foodnet/PDFs/Table3b.pdf. Accessed November 11, 2012; CDC, FoodNet Facts and Figures—Number of deaths and case fatality ratio (CFR) in 2010, by pathogen (Table 13), Available at: www.cdc.gov/foodnet/PDFs/Table13.pdf . Accessed November 11, 2012.

The transmission of infectious disease

- *Staphylococcus aureus* (staph)
  - Human skin; sores and cuts; poor handwashing
- *Clostridium botulinum* (botulism poisoning)
  - Widespread in soil, anaerobic, spore-forming
  - Potentially fatal neurotoxin; denatured by adequate heating
- Scombroid poisoning[3]
  - Bacteria acting on amino acids in food
  - Toxin not denatured by heat or cold
  - Blood pressure, headaches, GI illness

The transmission of infectious disease

- Vectorborne transmission
  - Biological vector: host species that transmits disease to another host species
  - Many vectors are arthropods (insects, arachnids) →
  - But mammals can be vectors, too
- Summary: vectors and fomites

The transmission of infectious disease

FIGURE 3.11 An *Aedes aegypti* mosquito, the vector for dengue fever, takes a blood meal from a human host.

Source: Reprinted 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.

The transmission of infectious disease

FIGURE 3.12 The black-legged tick (*Ixodes scapularis*), shown here on a blade of grass, transmits Lyme disease among a number of mammalian hosts, including humans.

Source: Reprinted 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.

The transmission of infectious disease

Table 3.3 Comparison of Fomite, Mechanical Vector, and Biological Vector

Transmitter of Disease	Is Transmitter a Living Organism?	Is Transmitter a Host Organism?	Example
Fomite	no	no	handkerchief, toy
Mechanical vector	yes	no	housefly
Biological vector (vectorborne illness)	yes	yes	mosquito

The transmission of infectious disease

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

The transmission of infectious disease

- The special case of DDT
  - Organochlorine, identified in 1930s
  - Widely used for mosquito control for 20 years before persistence appreciated
  - Widely banned after wildlife effects and human risk appreciated
  - But targeted use for mosquito control in some less developed countries with high malaria rates is approved by WHO

The transmission of infectious disease

- A complex web of transmission
  - Distinctions among modes of transmission may be blurred
  - Potential for use of pathogens as weapons by terrorists
  - (Re-)emerging infectious diseases
    - HIV/AIDS, H5N1 influenza, Ebola hemorrhagic fever, SARS, prion diseases, dengue fever, hantavirus, *E. coli* O157:H7, drug-resistant malaria

Types of pathogens

The Body's Defense against Pathogens

The Transmission of Infectious Disease

Population-Level Impacts of Infectious Disease

U.S. Regulatory Framework for Managing Infectious Disease Risk

Global Patterns of Infectious Disease Mortality

- Total ~12.3 million deaths in 2008[4]
  - Respiratory infections (29%), diarrheal disease (20%), and HIV/AIDS (14%) are leading infectious causes of death
- Worldwide, 22% of all deaths in 2008[4]
  - Highest in Africa (53%), Southeast Asia (27%), and Eastern Mediterranean (25%)

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 ~18% of cancers worldwide[5]
  - Liver (hepatitis B and C viruses, liver fluke)
  - Cervix (human papilloma virus)
  - Stomach (*Helicobacter pylori* bacterium)
- Higher percentage in lower-income countries

Infectious disease as a cause of cancer

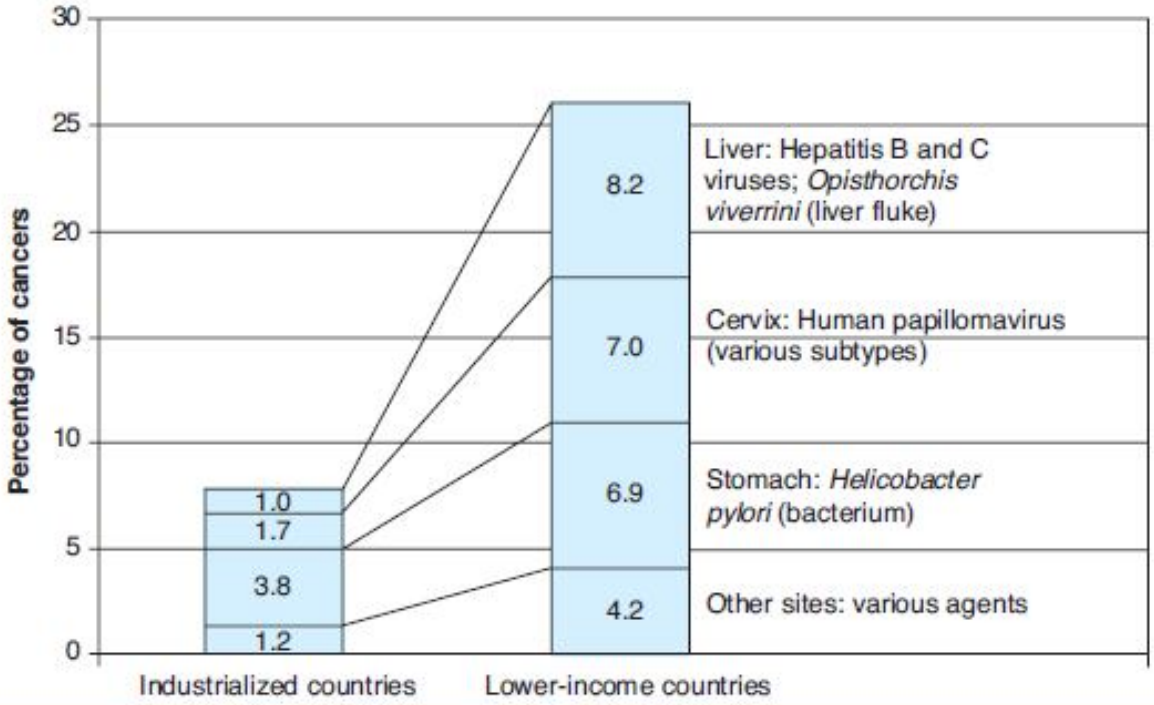


FIGURE 3.15 Percentage of cancers caused by infectious agents in industrialized and lower-income countries.

Source: Data from Parkin DM. The global health burden of infection-associated cancers in the year 2002. *Int J Cancer.* 2006;118:3030–3044, Table XI.

Types of pathogens

The Body's Defense against Pathogens

The Transmission of Infectious Disease

Population-Level Impacts of Infectious Disease

U.S. Regulatory Framework for Managing Infectious Disease Risk

US 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

3.1 Infectious Disease

3.2 Poisons in Nature

3.3 Allergy and Asthma

3.4 Natural Disasters

3.5 Naturally Occurring Radiation

Poisons in nature

- Contact with animals that use poison in self-defense or to subdue prey[7]
  - Venomous snakes, scorpions,

    spiders
  - Stingrays, scorpionfishes
- Consumption of natural toxins inherent in plant or animal tissue
  - Castor beans (ricin)
  - Pufferfish (neurotoxins)

FIGURE 3.14 A World War II era soldier demonstrates the application of DDT to U.S. army personnel.

Source: Reprinted courtesy of CDC Public Health Image Library. ID# 2620. Content provider: CDC. Available at: http://phil.cdc.gov/phil/home.asp. Accessed October 4, 2012.

Poisons in nature

- 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

- Consumption of toxin (aflatoxin) produced by mold, mostly on grains in storage, especially corn, peanuts[8,9,10]
  - 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")[11]

3.1 Infectious Disease

3.2 Poisons in Nature

3.3 Allergy and Asthma

3.4 Natural Disasters

3.5 Naturally Occurring Radiation

Allergy and asthma

- Allergen: foreign but harmless substance that elicits immune response (allergy)
  - First exposure → sensitization
  - Later exposures → allergic rhinitis
  - In asthmatic, later exposures→ asthma attack
- Asthma: chronic immune illness
  - Bronchi chronically inflamed and prone to sudden constriction
  - Asthma attack: increased inflammation, bronchoconstriction, overproduction of mucus
- Root causes and rising prevalence not well understood

3.1 Infectious Disease

3.2 Poisons in Nature

3.3 Allergy and Asthma

3.4 Natural Disasters

3.5 Naturally Occurring Radiation

Natural disasters

- 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

Table 3.6 A Snapshot of Four Recent Natural Disasters

Type of Disaster, Location	Year	Setting	Number Killed	Number Affected*	Affected/Killed
Tsunami, Indian Ocean/Indonesia	2004	Less developed country	226,096	2,321,700	10
Hurricane (Katrina), United States	2005	More developed country	1833	500,000	273
Earthquake, Haiti	2010	Less developed country	222,570	3,700,000	17
Earthquake and tsunami, Japan	2011	More developed country	20,319	405,719	20

*In need of assistance in the form of food, water, shelter, sanitation, or emergency medical care.

Source: Centre for Research on the Epidemiology of Disasters, Emergency Events Database (EM-DAT). Available at: www.emdat.be. Accessed March 21, 2012.

3.1 Infectious Disease

3.2 Poisons in Nature

3.3 Allergy and Asthma

3.4 Natural Disasters

3.5 Naturally Occurring Radiation

Radiation Basics

Radiation Exposures and Health Impacts

Radiation & radioactive decay

- Radiation—energy traveling as particles or waves
- 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

- 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

Table 3.7 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				1599
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)				

Source: Data 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.

Electromagnetic radiation

- Energy in wave form; wavelength varies
- Shorter wavelength → higher energy
- Gamma radiation: short-wavelength electromagnetic radiation; often released with alpha or beta particle
- Electromagnetic spectrum: all EM radiation, in order of wavelength

Electromagnetic radiation

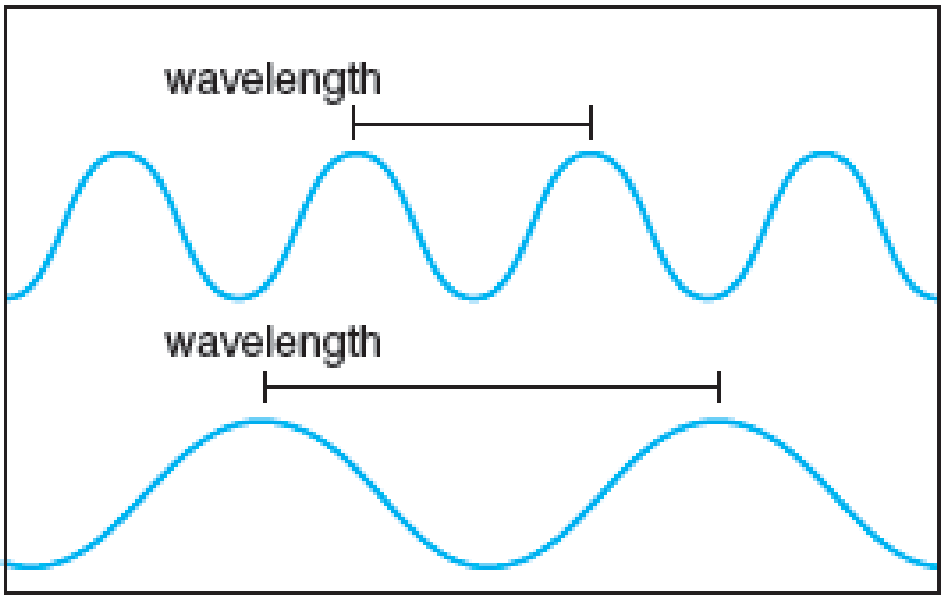
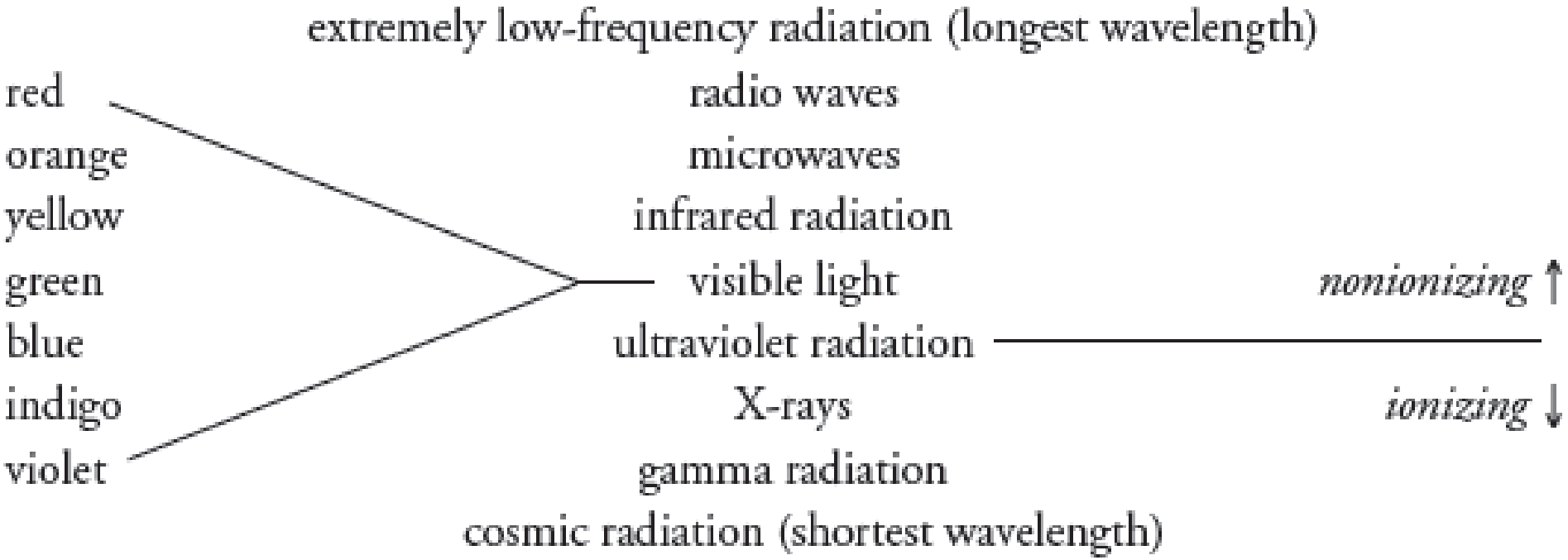


FIGURE 3.17 Electromagnetic radiation of shorter and longer wavelengths.

Ionizing and non-ionizing radiation

- 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



Measuring exposure to ionizing radiation

- Grays: intensity of exposure (energy delivered per gram of tissue)
- Impact of dose in Grays depends on
  - Relative biological effectiveness (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

Table 3.8 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

- Impact of dose in Grays also depends on whether exposure is internal or external
  - Internal: alpha, beta, gamma are hazards
  - External: larger particle penetrates less

→

Measuring exposure to ionizing radiation

Table 3.9 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)

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[13]
  - Leukemia; breast, thyroid, ovary, bladder, lung, colon, liver, stomach, and nonmelanoma skin cancer

Radiation Basics

Radiation Exposures and Health Impacts

Natural sources of exposure to radiation

- Non-ionizing 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 above
- Non-ionizing UV radiation
  - Skin cancer (squamous and basal cell carcinomas, malignant melanoma)[15]
  - Cataracts[16]
  - Immune suppression[17]

References

1. US Food and Drug Administration. *Foodborne Pathogenic Microorganisms and Natural Toxins Handbook, 2006.* Available at: http://vm.cfsan.fda.gov/~mow/intro.html. Accessed March 20, 2007.
2. US Centers for Disease Control and Prevention. *Escherichia coli* O157:H7. Available at: http://www.cdc.gov/ncidod/dbmd/diseaseinfo/escherichiacoli_g.htm. Accessed March 24, 2007.
3. US Food and Drug Administration. *Foodborne Pathogenic Microorganisms and Natural Toxins Handbook: Scombrotoxin.* Available at: http://www.cfsan.fda.gov. Accessed May 25, 2006.
4. World Health Organization. Causes of Death 2008 Summary Tables. May 2011. Available at: www.who.int/gho/mortality_burden_disease/global_burden_disease_DTH6_2008. xls. Accessed March 19, 2012.
5. Parkin DM. The global health burden of infection-associated cancers in the year 2002. *Int J Cancer.* 2006;118:3030–3044.
6. US Centers for Disease Control and Prevention. *Fact Sheet: Isolation and Quarantine, 2004.* Available at: http://www.cdc.gov/NCIDOD/dq/sars_facts/isolationquarantine.pdf. Accessed July 15, 2006.
7. Russell FE. Toxic effects of animal toxins. In: Klaassen CD, ed. *Casarett and Doull's Toxicology: The Basic Science of Poisons.* 5th ed. New York, NY: McGraw-Hill; 1996:801– 839.
8. Kotsonis FN, Burdock GA, Flamm WG. Food toxicology. In: Klaassen CD, ed. *Casarett and Doull's Toxicology: The Basic Science of Poisons.* 5th ed. New York, NY: McGraw-Hill; 1996:909–949.
9. Yu MC, Yuan J-M. Environmental factors and risk for hepatocellular carcinoma. *Gastroenterology.* 2004;127:S72–S78.
10. Omer RE, Kuijsten A, Kadaru AMY, Kok FJ, Idris MO, El Khidir IM, et al. Population attributable risk of dietary aflatoxins and hepatitis B virus infection with respect to hepatocellular carcinoma. *Nutr Cancer.* 2004;48(1):15–21.
11. Norton S. Toxic effects of plants. In: Klaassen CD, ed. *Casarett and Doull's Toxicology: The Basic Science of Poisons.* 5th ed. New York, NY: McGraw-Hill; 1996:841–853.
12. World Health Organization, Centre for Research on the Epidemiology of Disasters. Emergency Events Database (EM-DAT) [data]. Available at: http://www.emdat.be/.Accessed April 30, 2012.
13. National Academy of Sciences. *Biological Effects of Ionizing Radiation (BEIR) VII: Health Risks from Exposure to Low Levels of Ionizing Radiation.* Washington, DC: National Academies Press; 2005.
14. 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.
15. Armstrong BK, Kricker A. The epidemiology of UV induced skin cancer. *J Photoch Photobio*. 2001;B:8–18.
16. McCarty CA. A review of the epidemiologic evidence linking ultraviolet radiation and cataracts. *Dev Ophthalmol*. 2002;35:21–31.
17. Sleijffers A, Garssen J, Van Loveren H. Ultraviolet radiation, resistance to infectious diseases, and vaccination responses. *Methods*. 2002;28:111–121.