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
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 transmission 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 transmission of disease, in a setting with no treatment of sewage or drinking water.
The transmission of infectious disease

– Some important foodborne pathogens

• 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
  – 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>
<thead>
<tr>
<th></th>
<th>Incidence per 100,000 Population</th>
<th>Case-Fatality Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salmonella</td>
<td>17.62</td>
<td>0.35</td>
</tr>
<tr>
<td>Campylobacter</td>
<td>13.58</td>
<td>0.13</td>
</tr>
<tr>
<td>Listeria</td>
<td>0.27</td>
<td>12.80</td>
</tr>
<tr>
<td><em>E. coli</em> 0157:H7</td>
<td>0.94</td>
<td>0.45</td>
</tr>
</tbody>
</table>

*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.

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.

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.

The transmission of infectious disease

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

<table>
<thead>
<tr>
<th>Transmitter of Disease</th>
<th>Is Transmitter a Living Organism?</th>
<th>Is Transmitter a Host Organism?</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fomite</td>
<td>no</td>
<td>no</td>
<td>handkerchief, toy</td>
</tr>
<tr>
<td>Mechanical vector</td>
<td>yes</td>
<td>no</td>
<td>housefly</td>
</tr>
<tr>
<td>Biological vector (vectorborne illness)</td>
<td>yes</td>
<td>yes</td>
<td>mosquito</td>
</tr>
</tbody>
</table>
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
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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
  - Respiratory infections (29%), diarrheal disease (20%), and HIV/AIDS (14%) are leading infectious causes of death

- Worldwide, 22% of all deaths in 2008
  - 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 $\rightarrow$ cell proliferation

- Known infectious causes of cancer account for $\sim$18% of cancers worldwide
  - 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**
  - 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
- 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

- 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\textsuperscript{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
  - \textit{Amanita phalloides} (the “death cap”)\textsuperscript{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
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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\textsuperscript{12}
  - 1962-2011: estimated 5 million deaths\textsuperscript{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

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

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

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

<table>
<thead>
<tr>
<th>Particle Ejected</th>
<th>Radioactive Isotope</th>
<th>Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Seconds</td>
</tr>
<tr>
<td>Alpha</td>
<td>Beta</td>
<td></td>
</tr>
<tr>
<td>x</td>
<td>Uranium-238</td>
<td></td>
</tr>
<tr>
<td>x</td>
<td>Thorium-234</td>
<td>24.10</td>
</tr>
<tr>
<td>x</td>
<td>Protactinium-234</td>
<td>1.17</td>
</tr>
<tr>
<td>x</td>
<td>Uranium-234</td>
<td>245,500</td>
</tr>
<tr>
<td>x</td>
<td>Thorium-230</td>
<td>75,400</td>
</tr>
<tr>
<td>x</td>
<td>Radium-226</td>
<td>1599</td>
</tr>
<tr>
<td>x</td>
<td>Radon-222</td>
<td>3.823</td>
</tr>
<tr>
<td>x</td>
<td>Polonium-218</td>
<td>3.04</td>
</tr>
<tr>
<td>x</td>
<td>Lead-214</td>
<td>26.9</td>
</tr>
<tr>
<td>x</td>
<td>Bismuth-214</td>
<td>19.7</td>
</tr>
<tr>
<td>x</td>
<td>Polonium-214</td>
<td>0.000164</td>
</tr>
<tr>
<td>x</td>
<td>Lead-210</td>
<td>22.6</td>
</tr>
<tr>
<td>x</td>
<td>Bismuth-210</td>
<td>5.01</td>
</tr>
<tr>
<td>x</td>
<td>Polonium-210</td>
<td>138.4</td>
</tr>
<tr>
<td></td>
<td>Lead-206 (stable)</td>
<td></td>
</tr>
</tbody>
</table>

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

- extremely low-frequency radiation (longest wavelength)
  - radio waves
  - microwaves
  - infrared radiation
  - visible light
  - ultraviolet radiation
  - X-rays
  - gamma radiation
  - cosmic radiation (shortest wavelength)

- nonionizing

- ionizing
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) $\times$ RBE = dose (Sieverts)
  - RBE of alpha $>$ RBE of beta $>$ RBE of gamma
### Table 3.8 An Example Showing the Relationship Between Dose in Grays and Dose in Sieverts for Alpha, Beta, and Gamma Radiation

<table>
<thead>
<tr>
<th>Type of Radiation</th>
<th>Description</th>
<th>Dose in Grays</th>
<th>Relative Biological Effectiveness (RBE)</th>
<th>Equivalent Dose in Sieverts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>2 protons + 2 neutrons</td>
<td>2</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Beta</td>
<td>1 electron</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Gamma</td>
<td>High-energy electromagnetic radiation</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

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

- High-level exposure $\rightarrow$ radiation sickness; frequently fatal
  - Death of cells in central nervous system, gastrointestinal tract, bone marrow

- High-level (and thus also low-level) exposure $\rightarrow$ 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


