ENVIRONMENT

THE SCIENCE BEHIND THE STORIES

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Ch 14

Environmental Health and Toxicology

Part 2: Environmental Issues and the Search for Solutions

PowerPoint® Slides prepared by
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There are many types of environmental hazards

- **Environmental health** = assesses environmental factors that influence human health and quality of life
  - Natural and human-caused factors are both considered
- **Physical hazards** = occur naturally in our environment
  - Earthquakes, volcanoes, fires, floods, droughts
  - We can't prevent them, but we can prepare for them
  - We increase our vulnerability by deforesting slopes (landslides), channelizing rivers (flooding), etc.

Chemical and biological environmental hazards

- **Chemical** = synthetic chemicals such as pesticides, disinfectants, pharmaceuticals
  - Harmful natural chemicals also exist
- **Biological** = result from ecological interactions
  - Viruses, bacteria, and other pathogens
  - **Infectious** (**communicable**, or **transmissible**) **disease** = other species parasitize humans, fulfilling their ecological roles
  - We can't avoid risk, but we can reduce the likelihood of infection

Cultural environmental hazards

- **Cultural** = result from the place we live, our socioeconomic status, our occupation, our behavioral choices
  - Smoking, drug use, diet and nutrition, crime, mode of transportation

(a) Physical hazard

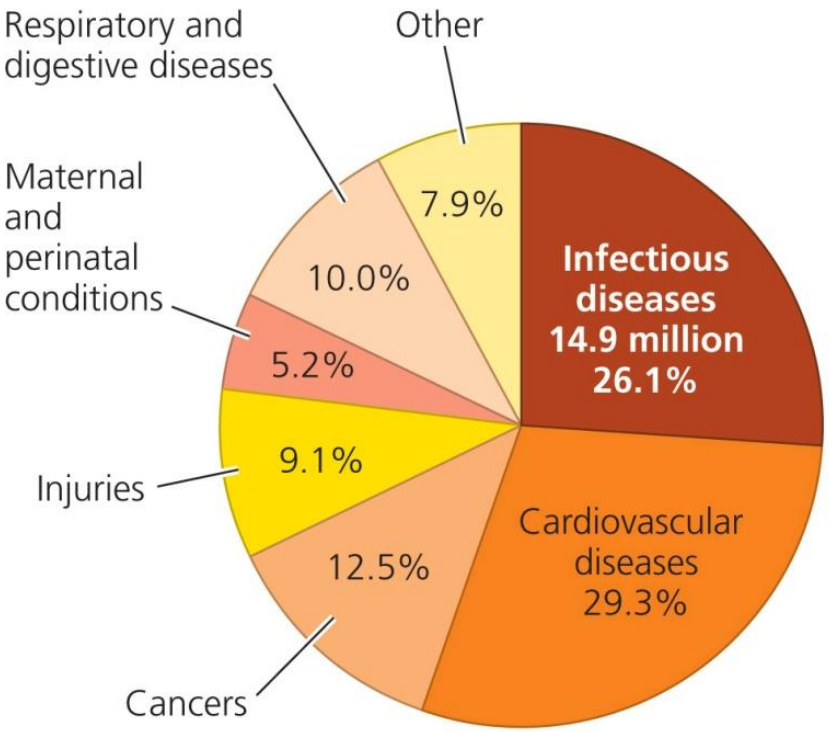
(b) Chemical hazard

(d) Cultural hazard

(c) Biological hazard

Disease is a major focus of environmental health

- Despite our technology, disease kills most of us
- Disease has a genetic and environmental basis
  - Cancer, heart disease, respiratory disorders
  - Poverty and poor hygiene can foster illnesses



(a) Leading causes of death across the world

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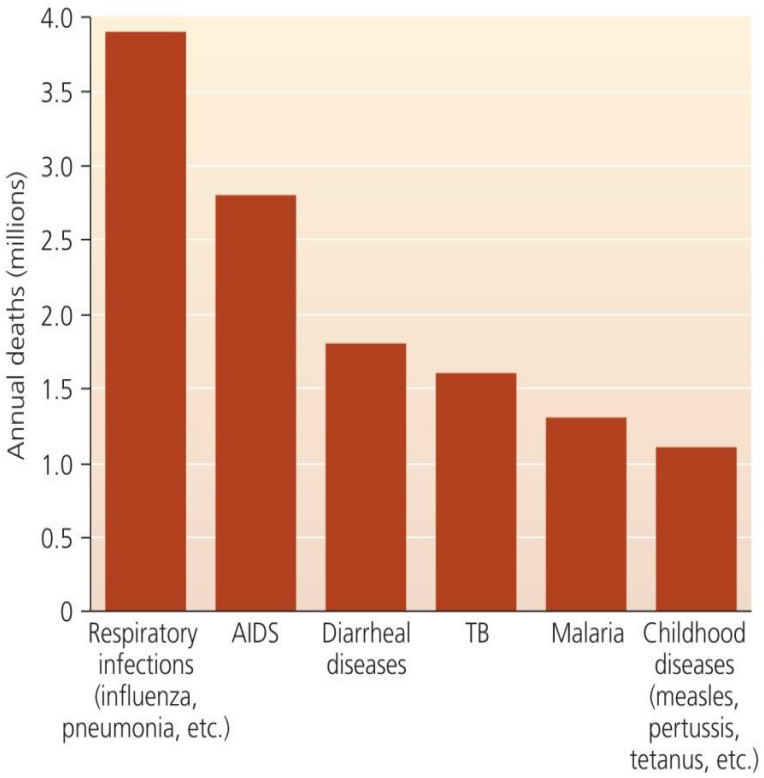
Infectious diseases kill millions



(b) Leading causes of death by infectious disease

- Infectious diseases kill 15 million people per year
  - Half of all deaths in developing countries
  - Developed countries have better hygiene, access to medicine, and money
- Tuberculosis, acquired immunodeficiency syndrome (AIDS), and the West Nile virus
- Climate change will expand the range of diseases

Environmental health hazards exist indoors

- **Radon** = a highly toxic, radioactive gas that is colorless and undetectable
  - Can build up in basements
- **Lead poisoning** = from lead pipes
  - Damages organs; causes learning problems, behavior abnormalities, and death
- **Asbestos** = insulates, muffles sounds, and resists fire
  - **Asbestosis** = scarred lungs may cease to function

A recently recognized hazard

- **Polybrominated diphenyl ethers (PBDEs)** = has fire-retardent properties
  - Used in computers, televisions, plastics, and furniture
  - Persist and accumulate in living tissue
  - **Endocrine disruptors** = compounds that mimic hormones and interfere with the functioning of animals' endocrine (hormone) systems
  - Affect brain and nervous system development, and may cause cancer

Toxicology is the study of poisonous substances

- **Toxicology** = the study of the effects of poisonous substances on humans and other organisms
- **Toxicity** = the degree of harm a toxicant can cause
  - "The dose makes the poison" = toxicity depends on the combined effect of the chemical and its quantity
  - Analogous to pathogenicity or virulence = the degree of harm of biological hazards that spread disease
- **Toxicant** = any toxic agent

Environmental toxicology

- Deals with toxic substances that come from or are discharged into the environment
- Studies the health effects on humans, other animals, and ecosystems
  - Focus mainly on humans, using other animals as test subjects
  - Can serve as indicators of health threats
- Don’t forget, chemicals have given us our high standard of living

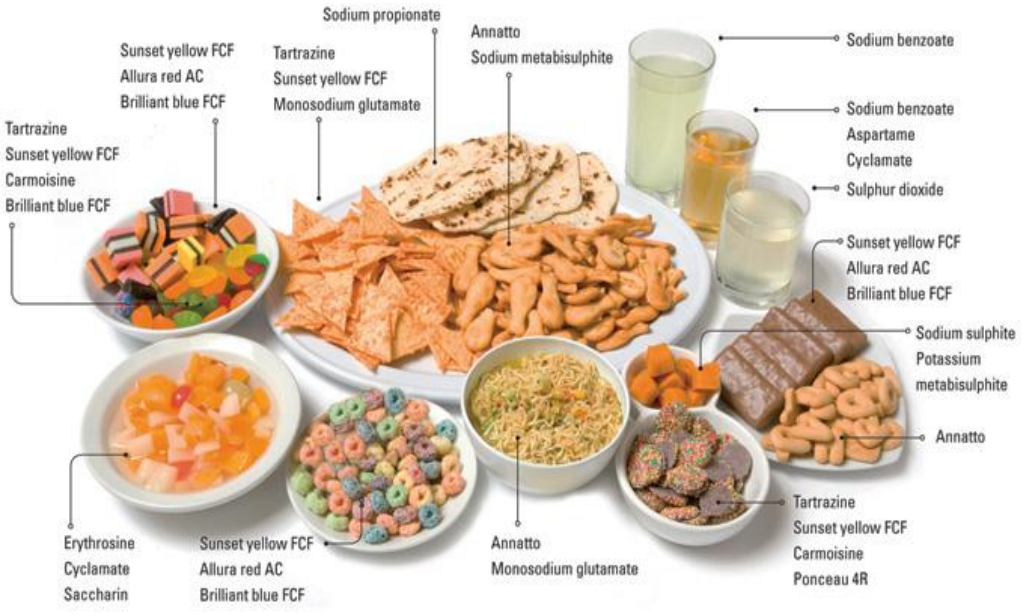
Toxic agents in the environment

- The environment contains countless natural chemicals that may pose health risks
- But, synthetic chemicals are also in our environment
  - Every human carries traces of industrial chemicals

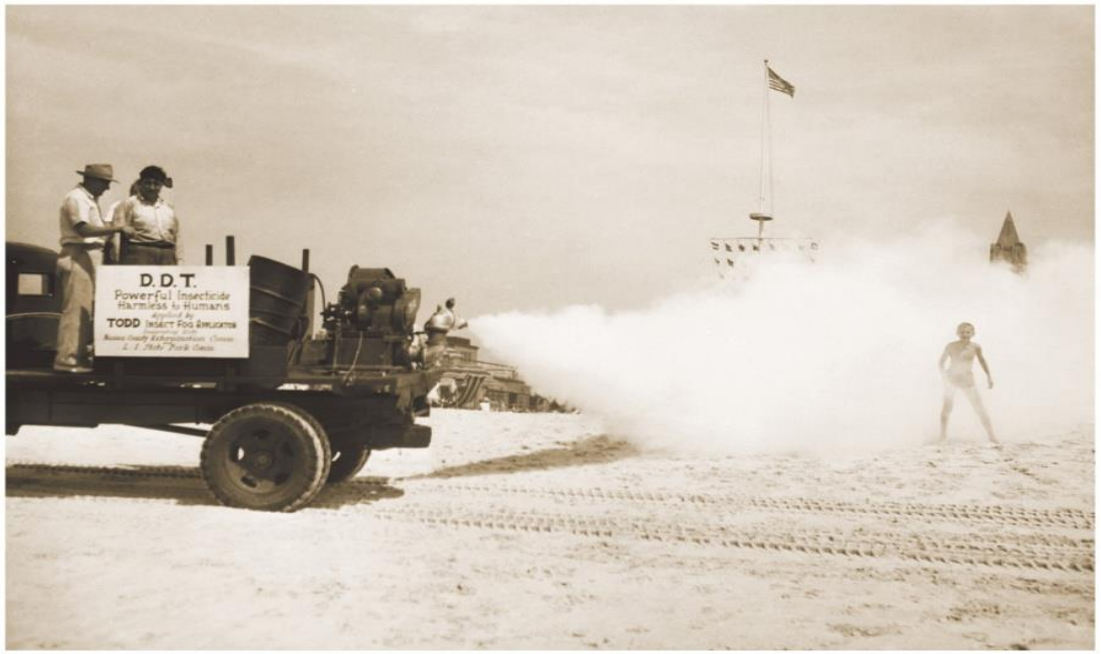
80% of U.S. streams contain at least trace amounts of 83 wastewater contaminants

Very few chemicals have been thoroughly tested

- 100,000 chemicals are on the market today
  - 72,000 industrial
  - 8,700 food additives
  - 2,000 new chemicals introduced per year
- We don't know the effects, if any, they have

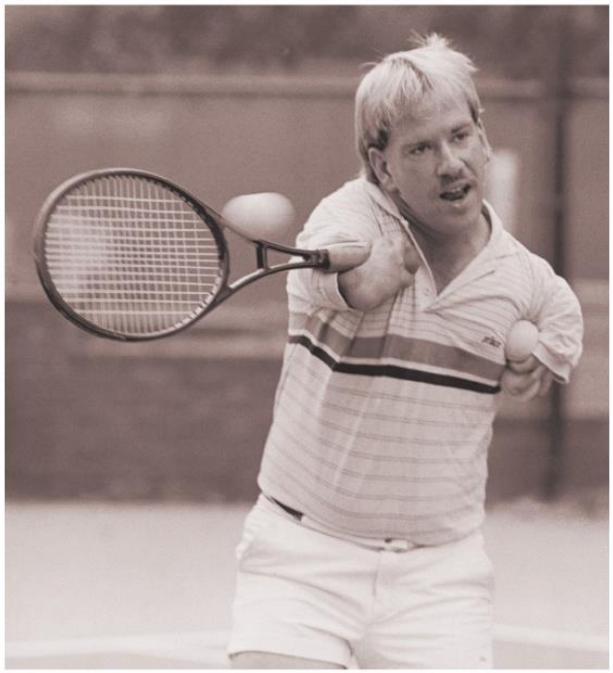


Silent Spring began public debate over chemicals



- Rachel Carson published *Silent Spring* in 1962
  - Brought together studies to show DDT risks to people, wildlife, and ecosystems
  - In the 1960s, pesticides were mostly untested and were sprayed over public areas, assuming they would do no harm
- The book generated significant social change

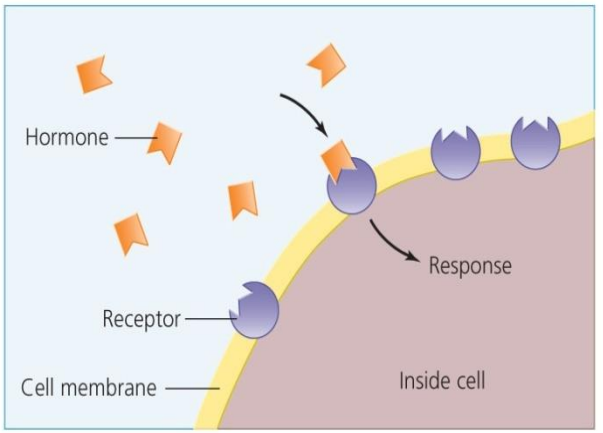
Types of toxicants



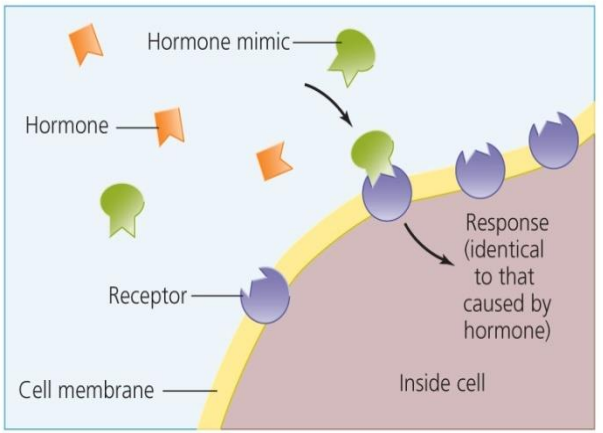
- **Carcinogens** = cause cancer
- **Mutagens** = cause DNA mutations
  - Can lead to severe problems, including cancer
- **Teratogens** = cause birth defects
- **Allergens** = over activate the immune system
- **Neurotoxins** = assault the nervous system
- **Endocrine disruptors** = interfere with the endocrine (hormone) system

Endocrine disruption may be widespread

- Theo Colburn wrote *Our Stolen Future* in 1996
  - Synthetic chemicals may be altering the hormones of animals
  - This book integrated scientific work from various fields
  - Shocked many readers and brought criticism from the chemical industry



(a) Normal hormone binding



(b) Hormone mimicry

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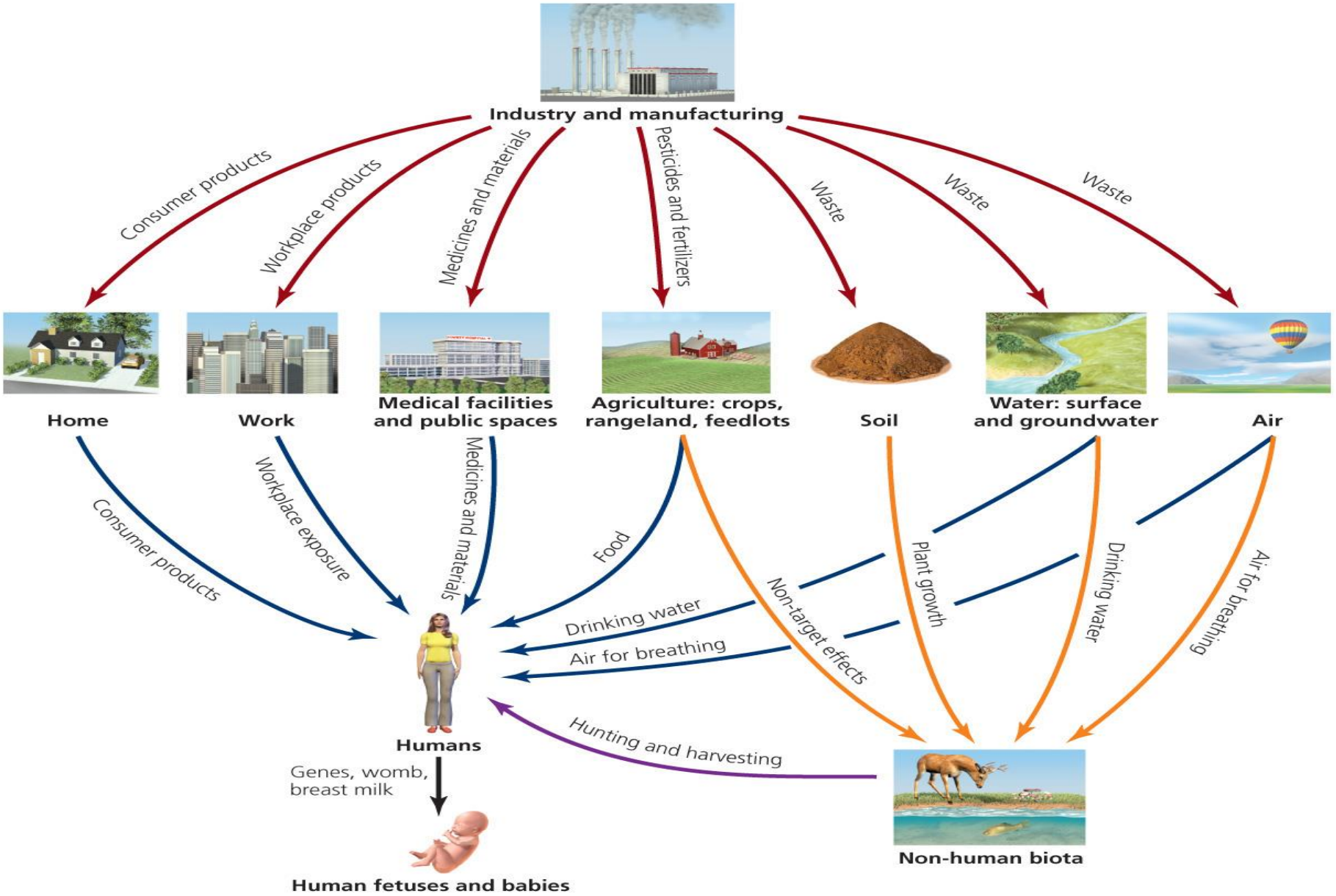
Toxins may concentrate in water

- Runoff carries toxins from large land areas to small volumes of surface water
- Chemicals can leach into the soil
- Chemicals enter organisms through drinking or absorption
  - Aquatic organisms are effective pollution indicators

Routes of chemical transport



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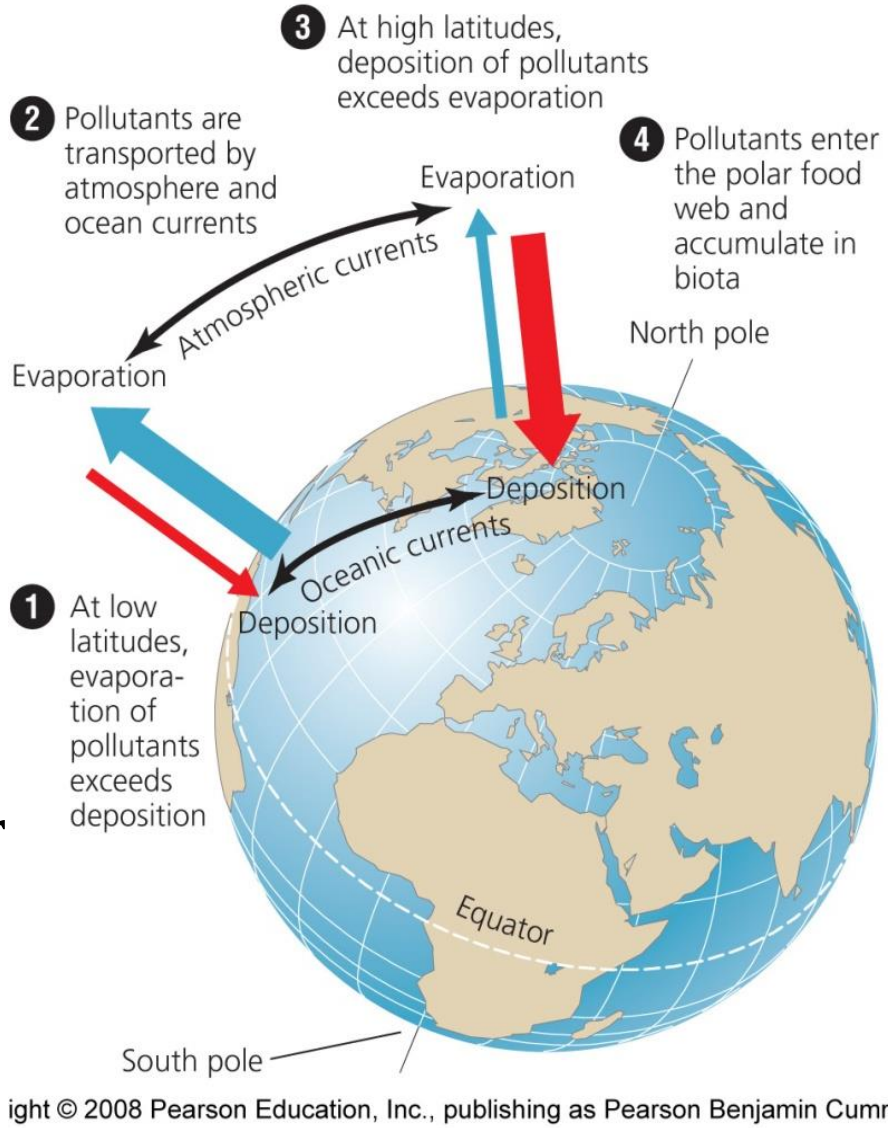
Airborne toxicants travel widely

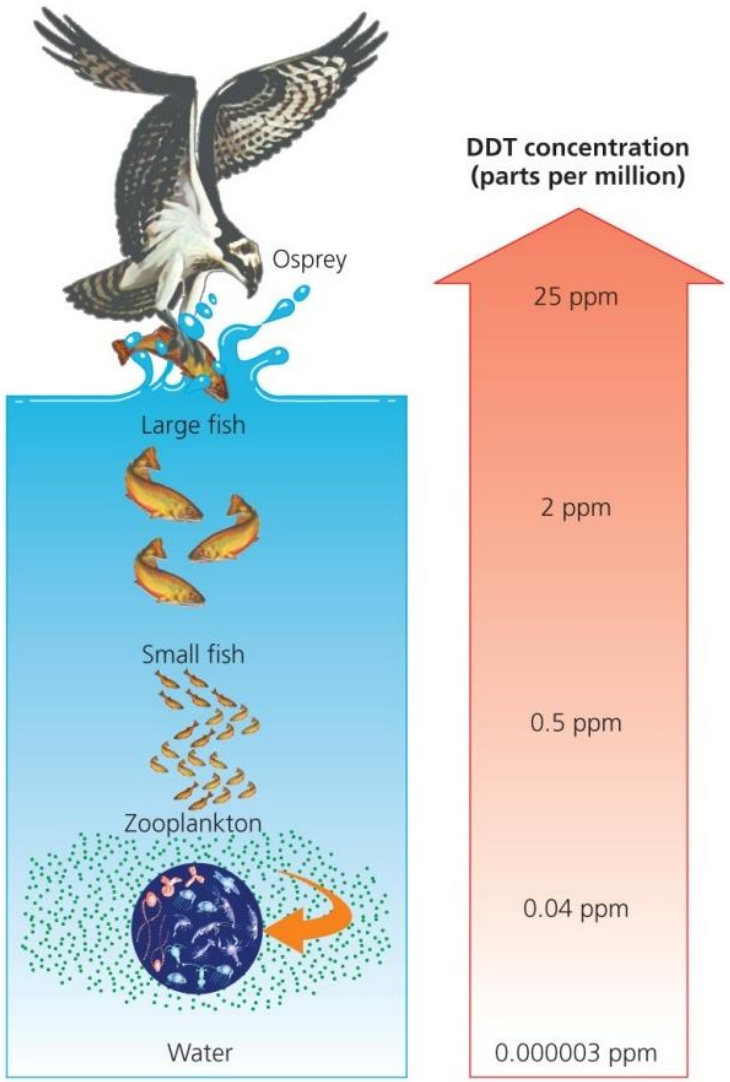
- Because chemicals can travel by air, their effects can occur far from the site of chemical use
- **Pesticide drift** = airborne transport of pesticides
- Synthetic chemical contaminants are found globally
  - They appear in arctic polar bears, Antarctic penguins, and people living in Greenland



Some toxicants persist for a long time

- Toxins can degrade quickly and become harmless
  - Or, they may remain unaltered and persist for decades
  - Rates of degradation depends on temperature, moisture, and sun exposure
- Persistent chemicals have the greatest potential for harm
- **Breakdown products** = toxicants degrade into simpler products
  - May be more or less harmful than the original substance
  - DDT degrades into DDE, which is also highly persistent

Toxicants can accumulate and biomagnify

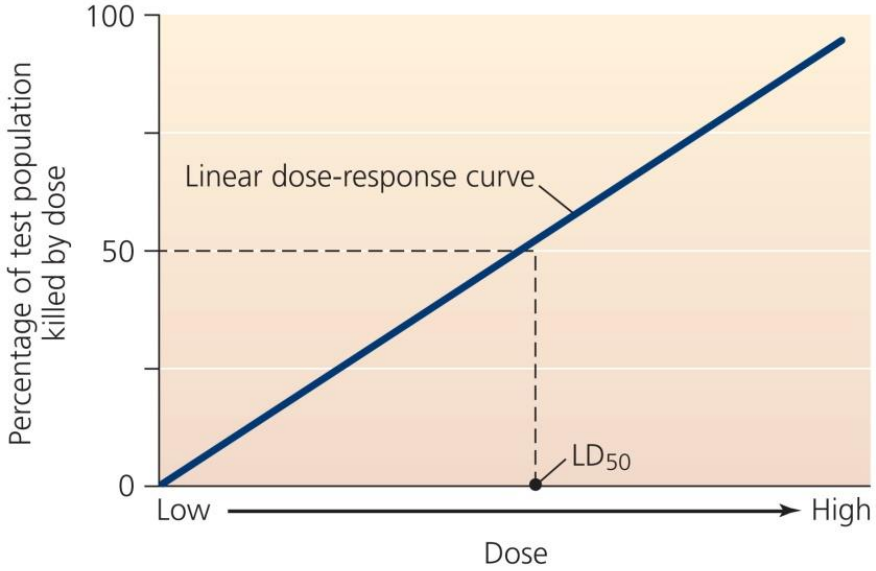


- Some toxicants can be excreted or metabolized
  - Fat-soluble toxicants are stored in fatty tissues
- **Bioaccumulation** = toxicants build up in animal tissues
- **Biomagnification** = toxicants concentrate in top predators
  - Near extinction of peregrine falcons and brown pelicans

Studying the effects

- **Case histories** = studying sickened individuals directly
  - Autopsies
  - Don't tell about future risks
- **Epidemiology** = large-scale comparisons between groups of people
  - Studies between exposed and unexposed people last for years
  - Yield accurate predictions about risk
- Animals are used as test subjects
  - Some people object to animal research
  - New techniques (human cell cultures, bacteria, etc.) may replace some live-animal testing

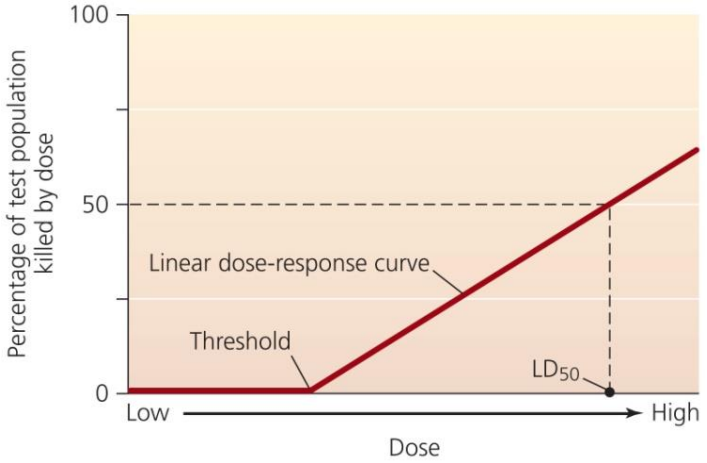
Dose-response analysis



(a) Linear dose-response curve

- **Dose-response analysis** = measuring how much effect a toxicant produces at different doses
  - Animal testing
  - **Dose** = the amount of toxicant the test animal receives
  - **Response** = the type or magnitude of negative effects of the animal
  - **Dose-response curve** = the plot of dose given against response

Dose response curves



(b) Dose-response curve with threshold

- **LD_{50}/ED_{50}**= the amount of toxicant required to kill (affect) 50% of the subjects
- **Threshold** = the dose level where certain responses occur
  - Organs can metabolize or excrete low doses of a toxicant
  - Some toxicants show a J-shaped, U-shaped, or inverted curve
- Scientists extrapolate downward from animal studies to estimate the effect on humans
  - Regulatory agencies set allowable limits well below toxicity levels in lab studies

Individuals vary in their responses to hazards

- Different people respond differently to hazards
  - Affected by genetics, surroundings, etc.
  - People in poor health are more sensitive
  - Sensitivity also varies with sex, age, and weight
  - Fetuses, infants, and young children are more sensitive
- Standards for responses are set by the Environmental Protection Agency (EPA)
  - Often, standards are not low enough to protect babies

The type of exposure affects the response

- **Acute exposure** = high exposure for short periods of time to a hazard
  - Easy to recognize
  - Stem from discrete events: ingestion, oil spills, nuclear accident
- **Chronic exposure** = low exposure for long periods of time to a hazard
  - Hard to detect and diagnose
  - Affects organs gradually: lung cancer, liver damage
  - Cause and effect may not be easily apparent

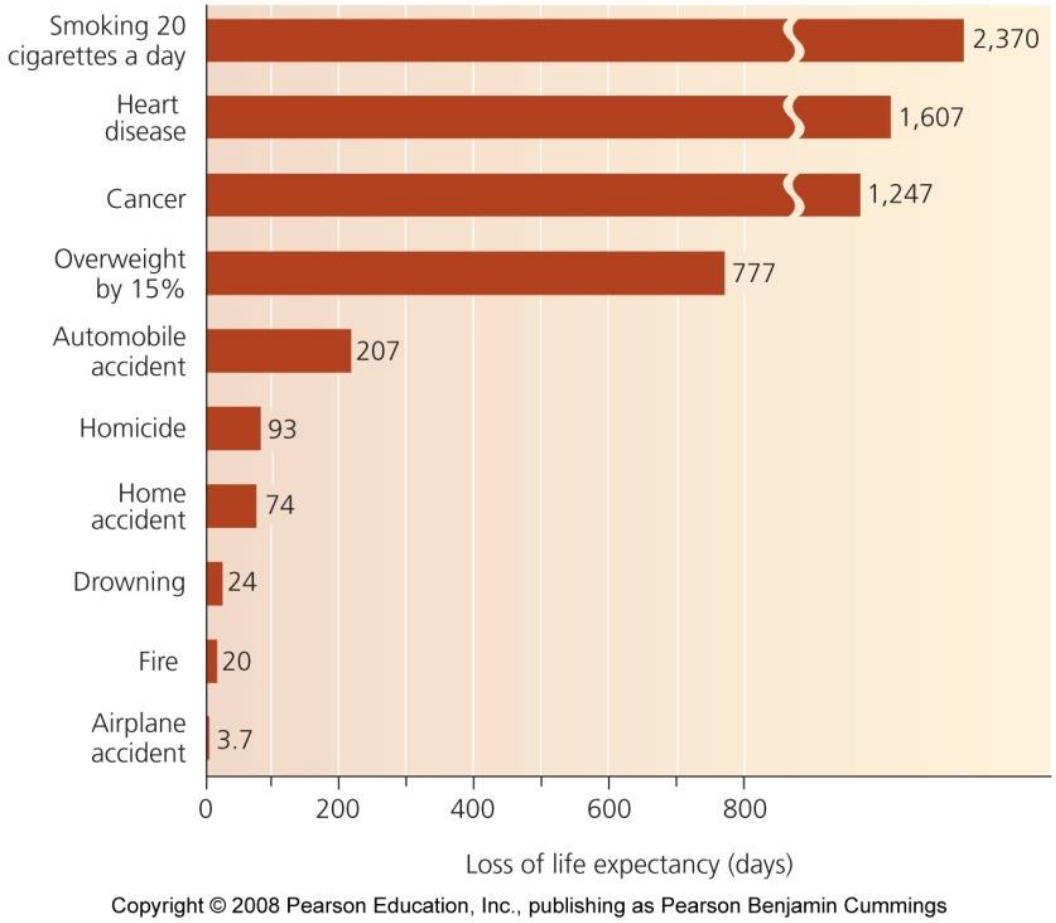
Mixes may be more than the sum of their parts

- We can't determine the impact of mixed hazards
  - They may act in ways that cannot be predicted from the effects of each in isolation
- **Synergistic effects** = interactive impacts that are more than or different from the simple sum of their constituent effects
  - Mixed toxicants can sum, cancel out, or multiply each other's effects
  - New impacts may arise from mixing toxicants

Risk assessment

- **Risk** = the probability that some harmful outcome will result from a given action
  - Exposure to environmental health threats doesn't automatically produce an effect
  - Rather, it causes some probability (likelihood) of harm
- Probability entails
  - Identity and strength of threat
  - Chance and frequency that an organism will encounter it
  - Amount of exposure to the threat
  - An organism's sensitivity to the threat

Perceiving risks



- Everything we do involves some risk
- We try to minimize risk, but we often misperceive it
  - Flying versus driving
- We feel more at risk when we cannot control a situation
  - We fear nuclear power and toxic waste, but not smoking or overeating

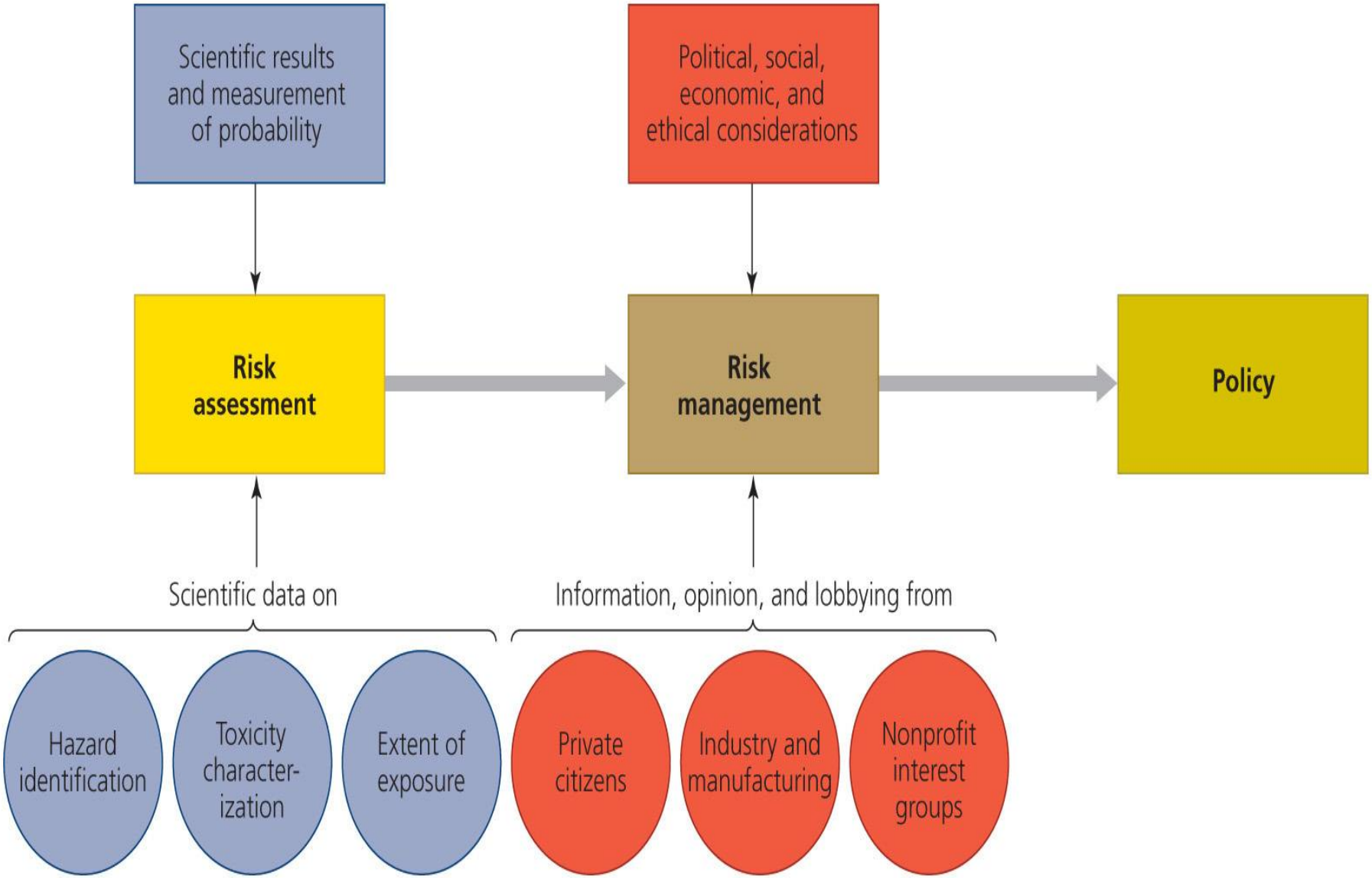
Analyzing risk quantitatively

- **Risk assessment** = the quantitative measurement of risk and the comparison of risks involved in different activities or substances
  - It is a way of identifying and outlining problems
- Several steps:
  - Scientific study of toxicity
  - Assessing an individual or population's likely extent of exposure to the substance, including frequency, concentrations, and length of exposure
- Studies are often performed by industry-associated scientists, which may undermine the study's objectivity

Risk management

- Combines decisions and strategies to minimize risk
- Scientific assessments are considered with economic, social, and political needs and values
- Developed nations have federal agencies to manage risk
  - The U.S. has the Centers for Disease Control (CDC), the EPA, and the Food and Drug Administration (FDA)
- Comparing costs and benefits is hard
  - Benefits are economic and easy to calculate
  - Health risks (costs) are hard-to-measure probabilities of a few people being affected

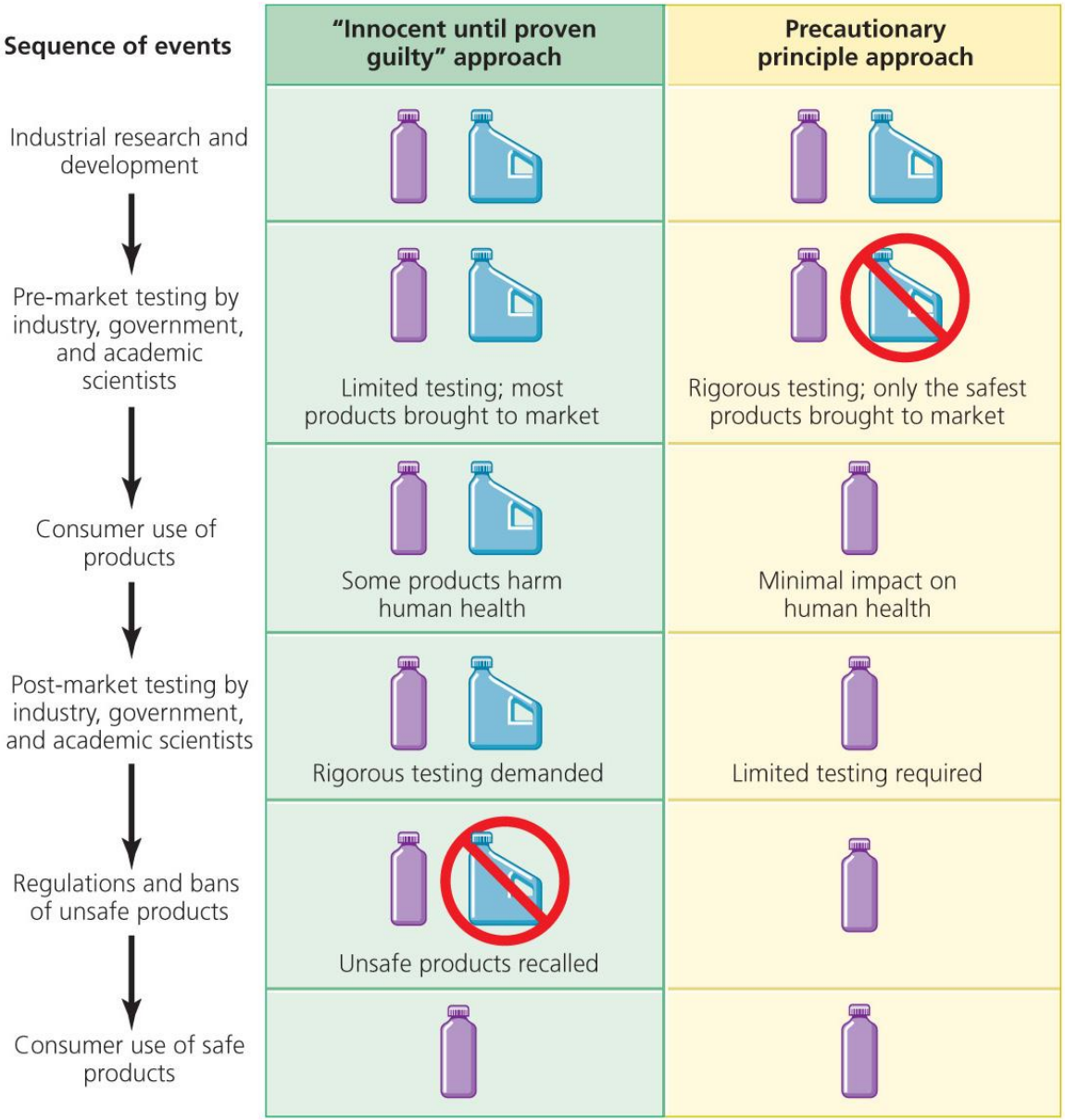
The process of risk management



Approaches to determining safety

- **Innocent until proven guilty approach:** product manufacturers must prove a product is safe
  - Benefits: not slowing down technological innovation and economic advancement
  - Disadvantage: putting into wide use some substances that may later on turn out to be dangerous
- **Precautionary principle approach:** the government, scientists, and the public are required to prove a product is dangerous
  - Assume substances are harmful until they are proven harmless
  - Identifies troublesome toxicants before they are released
  - But, this may impede the pace of technology and economic advance

Two approaches for determining safety



The EPA regulates many substances

- Federal agencies apportion responsibility for tracking and regulating synthetic chemicals
  - FDA: food, food additives, cosmetics, drugs, and medical devices
  - EPA: pesticides
  - Occupational Safety and Health Administration (OSHA): workplace hazards
- Many public health and environmental advocates fear it isn't enough
  - Many synthetic chemicals are not actually tested
  - Only 10% have been tested for toxicity
  - Fewer than 1% are government regulated

International regulation

- Nations address chemical pollution with international treaties
- **Stockholm Convention on Persistent Organic Pollutants (POPs)** was ratified by 140 nations in 2004
  - Ends the release of the 12 most dangerous POPs (the dirty dozen)
- EU's Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Program
  - Aims to evaluate and restrict dangerous chemicals while giving industries a streamlined regulatory system
  - It will cost the chemical industry 2.8 – 5.2 billion euros (U.S. $3.8 – 7.0 billion), but will save more than 10 times that in health benefits

The "Dirty Dozen"

aldrin [1]
chlordane [1]
dichlorodiphenyl trichloroethane (DDT)[1]
dieldrin[1]
endrin[1]
heptachlor[1]
hexachlorobenzene [1,2]
mirex[1]
toxaphene[1]
polychlorinated biphenyls (PCBs) [1,2]
polychlorinated dibenzo-p-dioxins[2](dioxins)
polychlorinated dibenzofurans[2] (furans)

1-Intentionally Produced.
2-Unintentionally Produced - Result from some industrial processes and combustion.