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Ch. 17: Environmental health and toxicology

Ch. 17 in F/R text:

- mod 56 Human Disease
- mod 57 Toxicology and chemical risk
- mod 58 Risk Analysis

Module 56 Human Disease
Bacteria e.coli in produce/food: summary

- 1992 Jack in the box-CA, 700 infected, 3 died
- 2002 ConAgra beef, recalled 19 million pounds of beef
- 2005 California spinach
- 2015 Chipotle restaurant
- 2017 IM Healthy granola

Key terms:
Disease: impaired health
Infectious disease: caused by agents-"pathogens"
Acute (sharp) vs. chronic disease

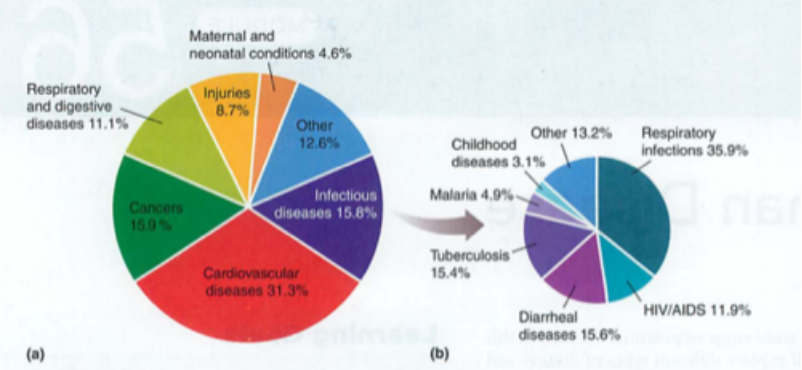


FIGURE 56.1 Leading causes of death in the world. (a) More than three-quarters of all world deaths are caused by diseases, including respiratory and digestive diseases, various cancers, cardiovascular diseases, and infectious diseases. (b) Among the world's deaths caused by infectious diseases, 94 percent are caused by only six types of diseases. *(Data from Global Health Estimates 2015: Deaths by Cause, Age, Sex, by Country and by Region, 2000-2015. Geneva, World Health Organization, 2016.)*

Click for full-size image

Note global rate of cardiovascular/heart disease (red), usually preventable
Pathways (vectors)
"Vector" in physics means magnitude and direction
In APES, we usually mean something (a "pathogen") that carries disease:

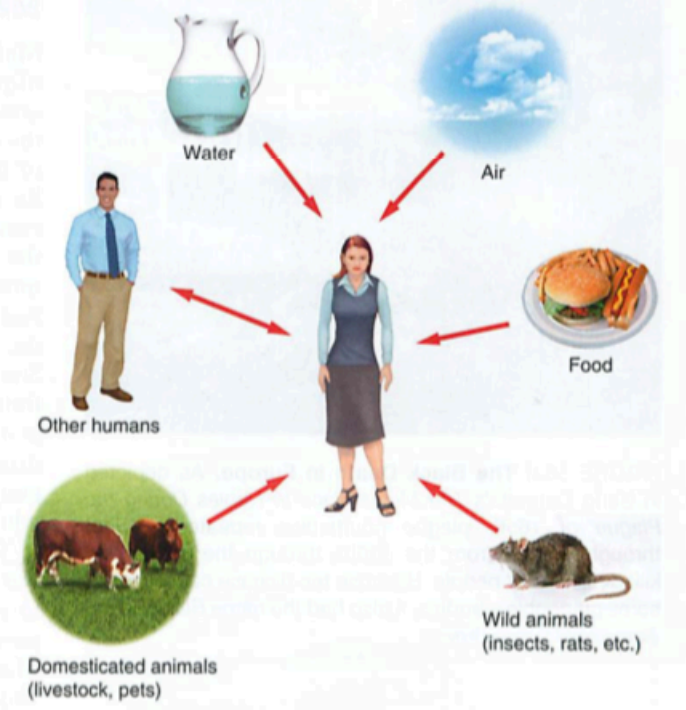


FIGURE 56.4 Pathways of transmitting pathogens. Pathogens have evolved a wide variety of ways to infect humans.

Epidemic: rapid increase in disease (think of epidermis, the top layer of your skin)
Pandemic: entire continent or world (COVID19)
Plague: bacterium from fleas (modern antibiotics can cure this if given in time)
Malaria: from the Spanish for "bad air", also why Buenos Aires is such a nice place. Plasmodium in blood, no cure, just cure for symptoms. Once you have it, you have it for life, and it can recur.
Tuberculosis: airborne bacterium (like in Les Miserables), very contagious, modern threat is from drug resistant TB, esp. in Russia (selling antibiotics for alcohol)
Emergent infectious diseases:

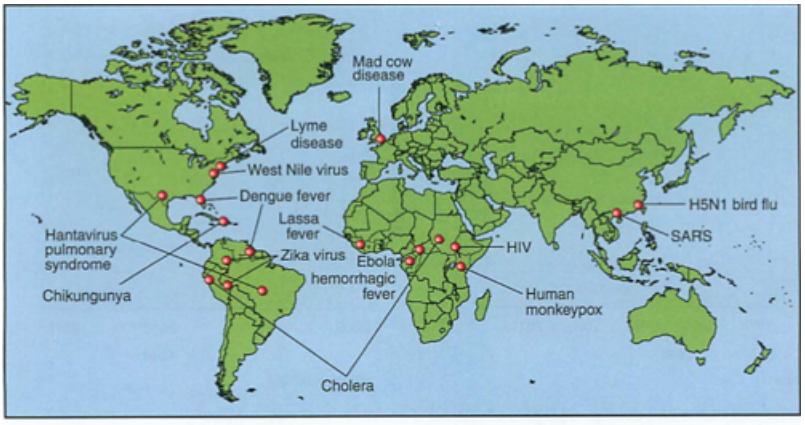


FIGURE 56.7 The emergence of new diseases. Since the 1970s, new diseases, or diseases that have been rare for more than 20 years, have been appearing throughout the world at a rate of approximately one per year. *(Data from https://www.niaid.nih.gov/sites/default/files/public%3A/images/news/main%20map.jpg.)*

Click for full-size image

AIDS/HIV: first seen in early 1980's (along with certain music and hair)
First showed up in babies, homosexuals and blood transfusion recipients
No known cure, but can be managed. Drugs are expensive, so this is still a threat in Sub Saharan Africa, among

other places.
HIV mutates to avoid the immune system, and folks usually die from opportunistic infections, like pneumonia

Ebola: Hemorrhagic fever, about 90% fatality rate, very contagious, from primates originally in Africa

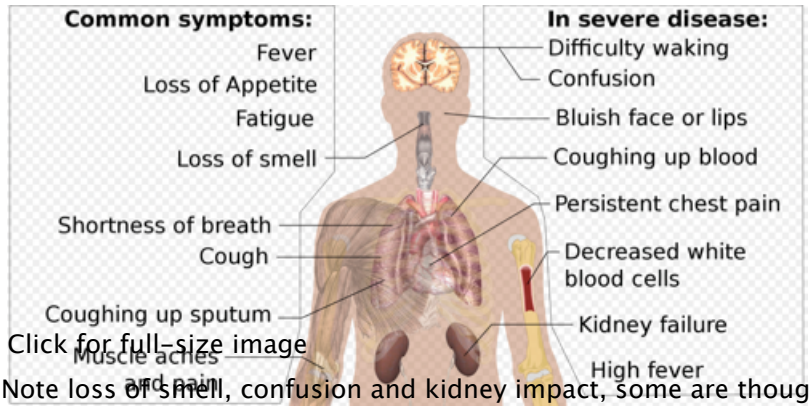
Mad Cow disease (bovine spongiform encephalopathy): "prion" protein pathogen, basically a toxic protein that survives cooking, originally found in UK, banned all beef from there for a certain time in 1996.
Caused by using ground up sick cows as feed for other cows (gross!)

Influenza A viruses:
Swine Flu, Bird Flu H5N1: both jumped from animals to humans (like Covid-19). If this jump is not human-to-human transmitted, then only a few humans die, if it jumps or mutates, then things get serious.
H5N1 refers to the histology (H) and nucleotides (N) in the virus, so we can discern it from others
18000 deaths in 2009 from swine flu

Coronaviruses:
SARS: Severe acute respiratory syndrome, 2002, 10% fatality rate, air transmission, coronavirus
All boarders from Asia were kept at HPA for the year due to this breakout in Asia
person to person transmission, 8000 infected, 10% fatality rate

MERS: another coronavirus in 2012, ME stands for Middle East, 34% fatality rate (!)

COVID-19: SARS-CoV-2: Coronavirus, airborne and contact on surfaces (perhaps through food), mutating now with "variants" with different internal and spike protein structures.
Named COVID for CoronaVirus
President Biden says by April 19, 2021 90% of you (over 16) will be vaccinated.
3.31.21 news: Pfizer vaccine 100% effective for kids 12-15
Vaccines are either binary or solo (Johnson and Johnson), based on testing not on structure
Vaccines prep the immune system by mimicking the spike proteins on COVID-19, one reason you have an immune response.
Deb Birx the COVID coordinator in 2020 now says 400,000 deaths could have been prevented with masking (disinformation)
#3 cause of death in 2020 behind CV disease and cancer
"Long COVID". patients have many long term challenges, some have seen vaccine improves their outcome even after exposure
Exposure impacts everything in the cardiovascular system, and kidneys, as it attacks the lining of blood vessels and the angiotensin pathway that regulates blood pressure
2 day latency period (no symptoms, asymptomatic)



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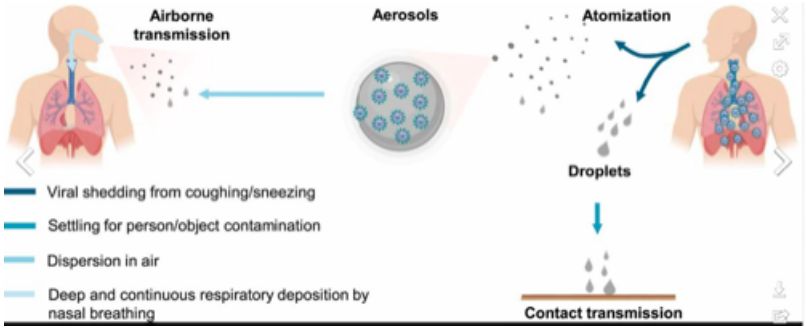
Note loss of smell, confusion and kidney impact, some are thought to be permanent

Fatality rate varies with age and pre-conditions, about 8% in early cases

Mechanism:



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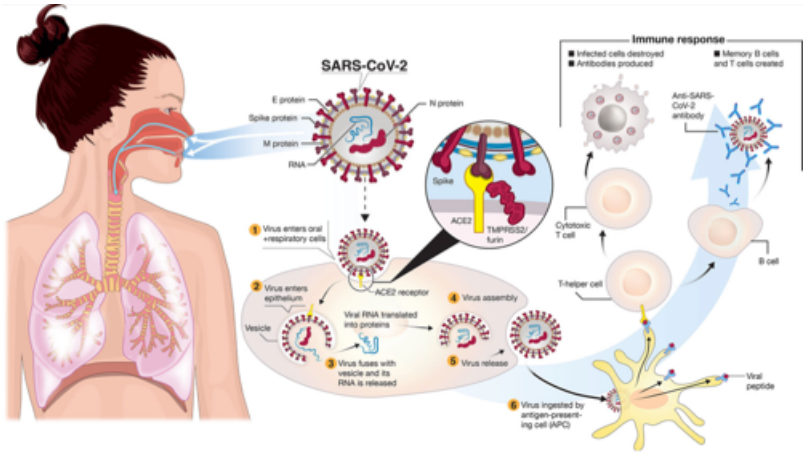

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Others:
West Nile virus: in birds from mosquitoes, to humans, causes brain swelling
Lyme disease: from deer ticks, incidents are further north now due to global warming
Zika: pathogen causing babies brains to be damaged/small

Module 57 Toxicology
6 Main chemical toxins:
Neurotoxins-disrupt the nervous system, e.g. insecticides, lead, mercury
Carcinogens-cause cancer, e.g. dioxin, PCB, many others
Mutagens-cause mutations and often cancers, e.g. radon, asbestos, formaldehyde, tobacco
Teratogens-cause birth defects, e.g. mercury, thalidomide, alcohol
Allergens-cause allergic reactions, e.g. dust, pollen, animal dander
Endocrine disruptors-interfere with hormones, e.g. BPA

TABLE 57.1 Some chemicals of major concern

Chemical	Sources	Type	Effects
Lead	Paint, gasoline	Neurotoxin	Impaired learning, nervous system disorders, death
Mercury	Coal burning, fish consumption	Neurotoxin	Damaged brain, kidneys, liver, and immune system
Arsenic	Mining, groundwater	Carcinogen	Cancer
Asbestos	Building materials	Carcinogen	Impaired breathing, lung cancer
Polychlorinated biphenyls (PCBs)	Industry	Carcinogen	Cancer, impaired learning, liver damage
Radon	Soil, water	Carcinogen	Lung cancer
Vinyl chloride	Industry, water from vinyl chloride pipes	Carcinogen	Cancer
Alcohol	Alcoholic beverages	Teratogen	Reduced fetal growth, brain and nervous system damage
Atrazine	Herbicide	Endocrine disruptor	Feminization of males, low sperm counts
DDT	Insecticide	Endocrine disruptor	Feminization of males, thin eggshells of birds
Phthalates	Plastics, cosmetics	Endocrine disruptor	Feminization of males

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Note the **heavy metals** (mercury, lead, arsenic) the **artificial chemicals** (PVC, VC, Alcohol, phthalates) and the **pesticides** (atrazine, DDT).
Asbestos is a natural fiber, used in places that can cause cancer through inhalation in humans (insulation, flooring, etc.)
Radon occurs naturally, and concentrates in lower dwellings or in the lower lobes of your lungs.

Allergens: not usually taken seriously, but are often **synergistic** with toxins above (you may have some)
Endocrine disrupters: can interfere with growth, metabolism and others, often estrogens or similar
Can be hormone blockers or hormone copies (hormone mimicry)

Dose response studies: acute or chronic, seeks to find an LD50 or an ED50 (non-lethal)
LD50 means lethal to 50% of the test population
ED50 means non-lethal impact on 50% of the population

Test data is surmised to be linear, but often not so, e.g. drugs for the aged are not cleared by their liver/kidney as effectively, so blood levels of the drugs increase.
THC decay curve: if half life is 8 days, make a graph of dosing every 4 days

NOEL: no observed effect level-non-lethal impact
Bioaccumulation: A single organism, collecting in fat tissues (PCB, dioxins) or muscles (mercury)
Biomagnification: MANY organisms eaten by an apex predator, increasing the level of a toxin, e.g. you eating Ahi, getting mercury poisoning: See Jack Black and Sushi.
POPs: persistent organic pollutants (carbon based): note half lives

TABLE 57.2 The persistence of various chemicals in the environment

Chemical	Source	Half-Life
Malathion	Insecticide	1 day
Radon	Rocks and soil	4 days in air
Vinyl chloride	Industry, water from vinyl chloride pipes	4.5 days in air
Phthalates	Plastics, cosmetics	2.5 days in water
Roundup	Herbicide	7 to 70 days in water
Atrazine	Herbicide	224 days in wetland soils
Polychlorinated biphenyls (PCBs)	Industry	8 to 15 years in water
DDT	Insecticide	30 years in soil

n.b. roundup was recently banned in CA and EU, suspected of causing cancer
Module 58 Risk Analysis

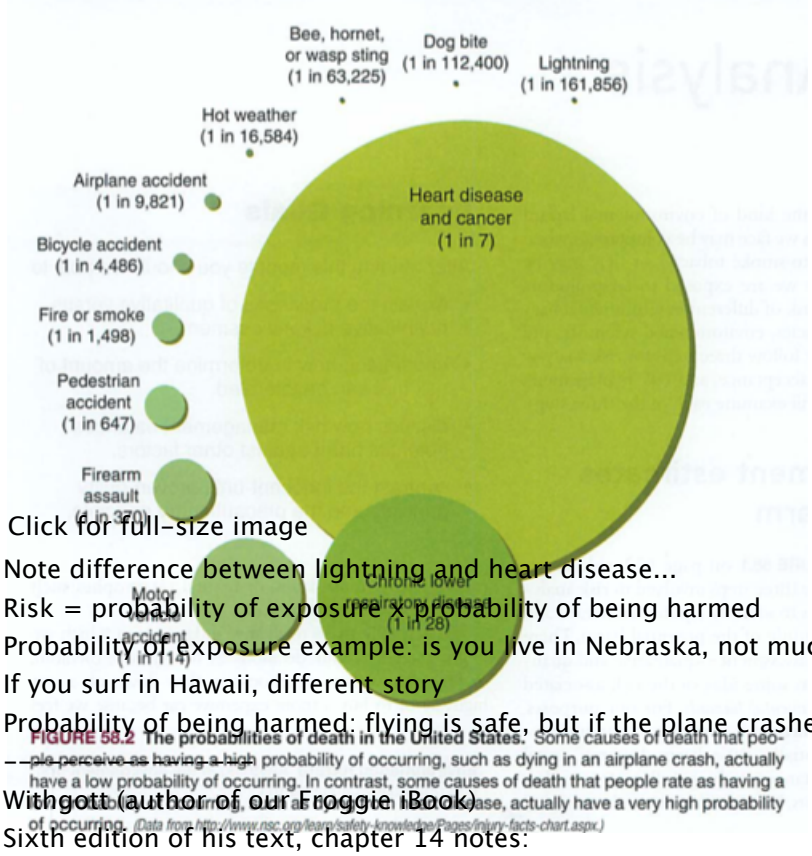

FIGURE 58.2 **The probabilities of death in the United States.** Some causes of death that people perceive as having a high probability of occurring, such as dying in an airplane crash, actually have a low probability of occurring. In contrast, some causes of death that people rate as having a low probability of occurring, such as dying from heart disease, actually have a very high probability of occurring. *(Data from http://www.nsc.org/lrs/statistics/prevstat/injury-facts-chart.aspx.)*

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Note difference between lightning and heart disease...

Risk = probability of exposure x probability of being harmed

Probability of exposure example: is you live in Nebraska, not much risk of sharks

If you surf in Hawaii, different story

Probability of being harmed: flying is safe, but if the plane crashes, fatality rate is around 100%

Withgott (author of our Froggie iBook)

Sixth edition of his text, chapter 14 notes:

withgott 14 health-toxicology.pdf

APES withgott 6e.14

BPA-bisphenol-A Water bottles, food, baby bottles, tupperware

Endocrine disruptors: what are they, how do they work?

BPA is an estrogen analog: https://en.wikipedia.org/wiki/Bisphenol_A

Hormone mimicry:

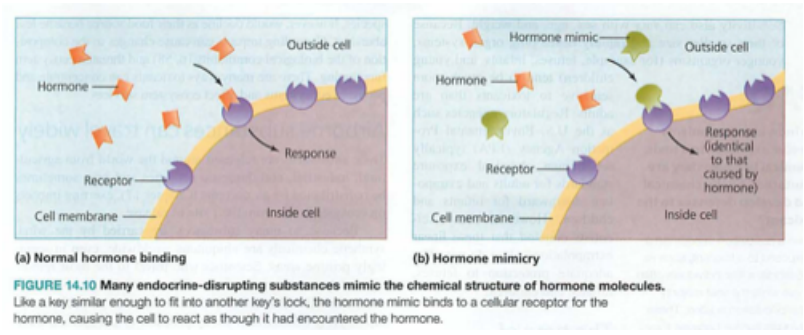

FIGURE 14.10 **Many endocrine-disrupting substances mimic the chemical structure of hormone molecules.** Like a key similar enough to fit into another key's lock, the hormone mimic binds to a cellular receptor for the hormone, causing the cell to react as though it had encountered the hormone.

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Possible impacts of hormone disruptors:

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4 Hazards:

- **Physical** e.g. UV radiation (DNA damage)
- **Chemical** e.g. drugs, pesticides, venoms, synthetic and natural
- **Biological** e.g. infectious diseases (vectors)
- **Cultural** e.g. smoking, COPD, seat belts, hang gliding, swimming with sharks

Non-infectious diseases: genetics + environmental factors, e.g. cancer, heart disease, obesity

Infectious diseases (ID): ebola, influenza, AIDS, SARS, Covid-19

These spread much faster due to air travel, trains, trucks (see AIDS in Africa, bubonic plague, SARS)

Kinshasa "AIDS highway" https://en.wikipedia.org/wiki/Kinshasa_Highway

Toxicology-chemical hazards

Radon: 226 mass, stays in lower lobes of the lungs, found in basements where Uranium ores are present (Colorado, Alaska)

Asbestos: fibrous non-burning insulating material, mined for ages as an insulator, tabletop, flooring, insulation. Fibers in the air cause asbestosis in the lungs, and various forms of lung cancer (carcinoma)

lead: used in many manufacturing processes, batteries, plumbing/solder, gasoline (yes, gasoline as tetra ethyl lead), causes brain retardation (see romans and lead), replaced in gasoline by MTBE, which causes cancer.

PBDE (polybrominated diphenyl ethers) fire retardants (e.g. TRIS), PBDEs are also hormone disrupters

Risk vs. reward (see malaria and DDT)

VOC in drinking water, also atomizers (like in some classrooms)

Heptachlor in green chop hawaii

EDB in water on Oahu (ant poison)

DDT-foggers in 1960's....

Toxins

Carcinogens-cause cancer, long term or short term

Mutagens-mutate you or your kids (reproductive DNA)

Teratogens-cause birth defects: fetal alcohol syndrome (huge in Russia), thalidomide

Neurotoxins-mercury and other heavy metals (Minamata Bay), many derived from insecticides

Allergens-airborne or food borne

Pathway inhibitors-endocrine disruptors, BPA, Phthalates (plastics)

Exposure can be acute (short) or chronic (long term)

Bioaccumulation-A single creature

Biomagnification–MANY trophic levels, **MANY** creatures (see below)

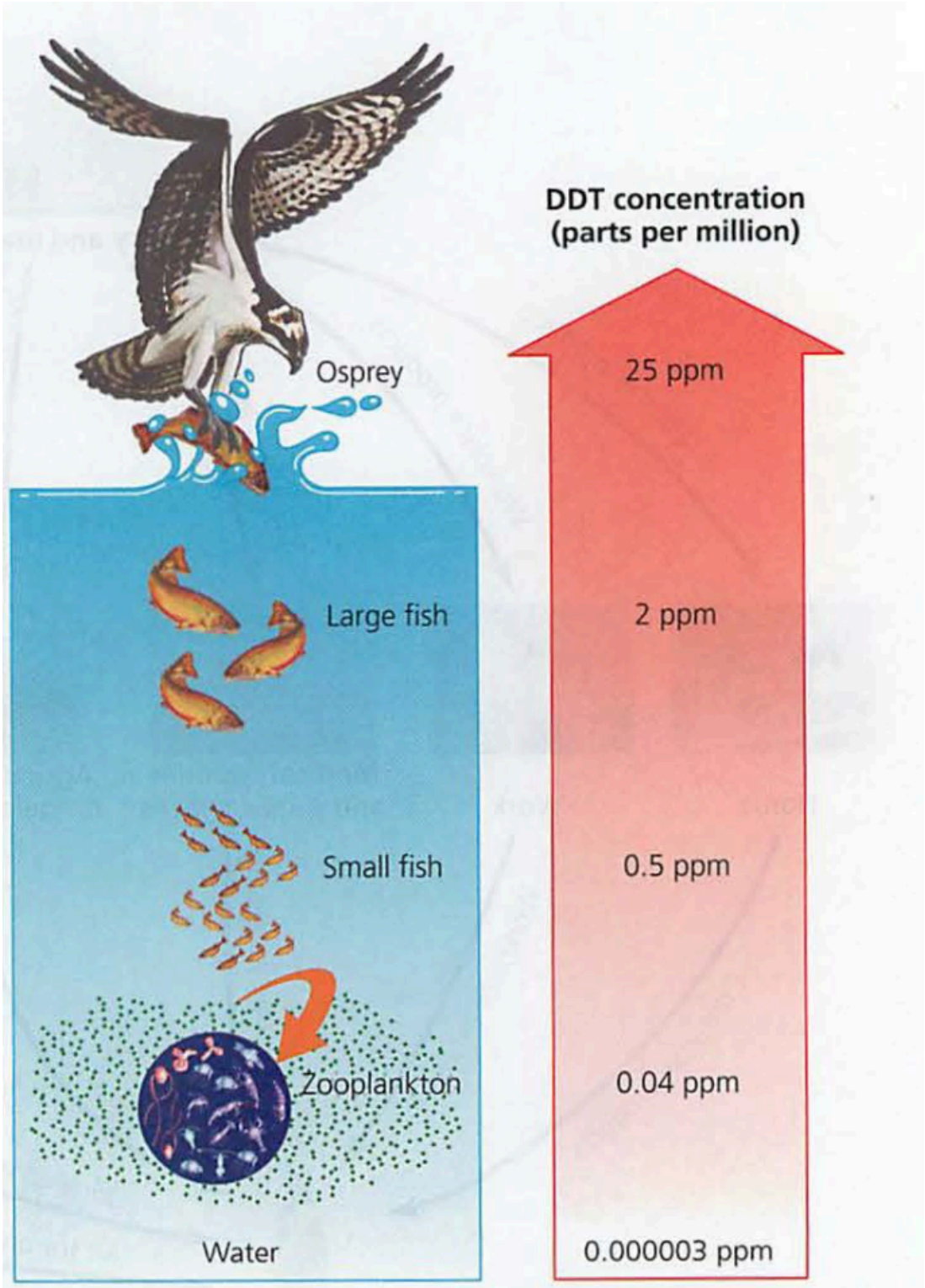


FIGURE 14.14 In a classic case of biomagnification, DDT becomes highly concentrated in fish-eating birds such as ospreys. Organisms at the lowest trophic level take in fat-soluble compounds such as DDT from water. As animals at higher trophic levels eat organisms lower on the food chain, each organism

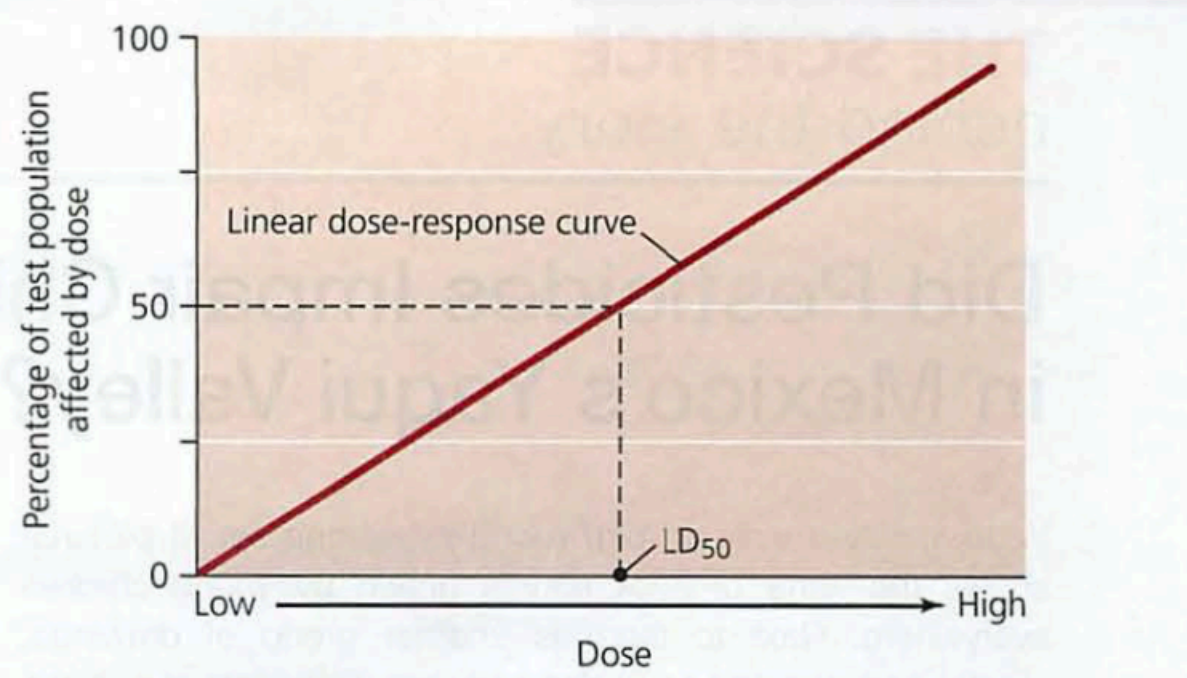
passes its load of toxicants up to its consumer, such that organisms on all trophic levels bioaccumulate the substance in their tissues.

Dose response analysis: determining the dose to have some sort of immediate impact, usually on test animals, but can also be part of a "natural experiment" where something happens to a human or other population, not planned, but well documented.

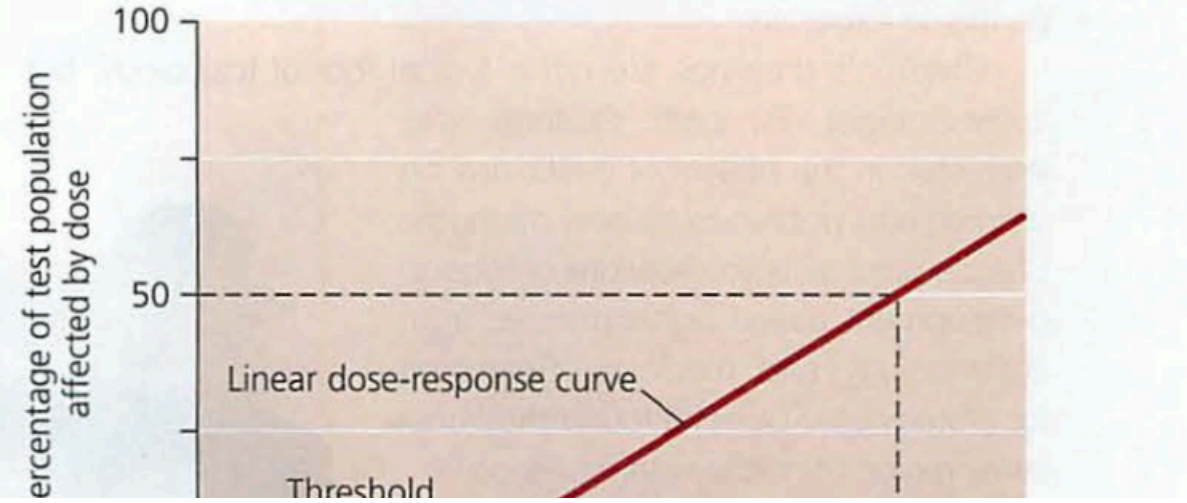
LD50 and ED50 (not the same)

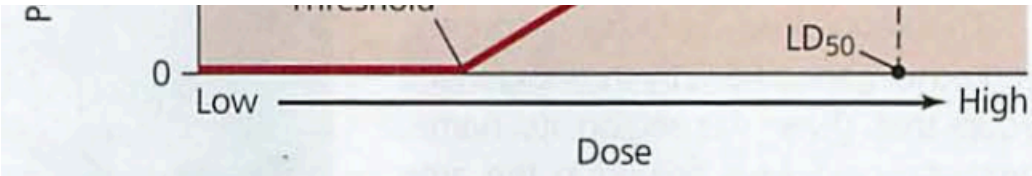
LD50 is the dose that **kills** 50% of the population, so LD50 means "lethal dose to 50%"

ED50 is the **effective** dose (ED) in a test, which can be good or bad: good might be aspirin, but usually it means amount to cause some non-lethal effect, like mice losing their hair.

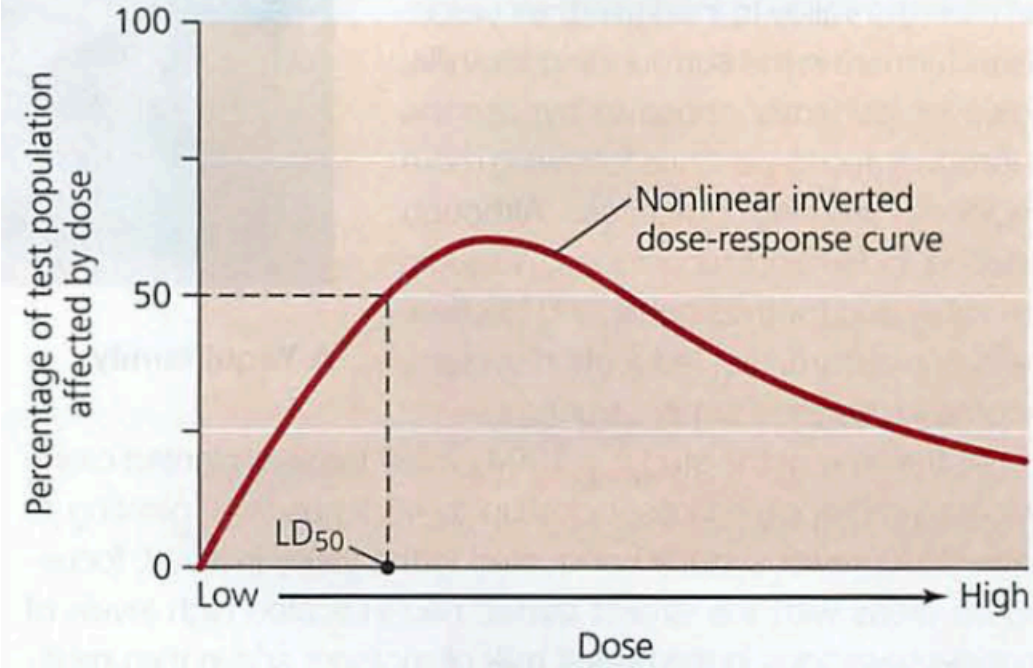


(a) Linear dose-response curve





(b) Dose-response curve with threshold

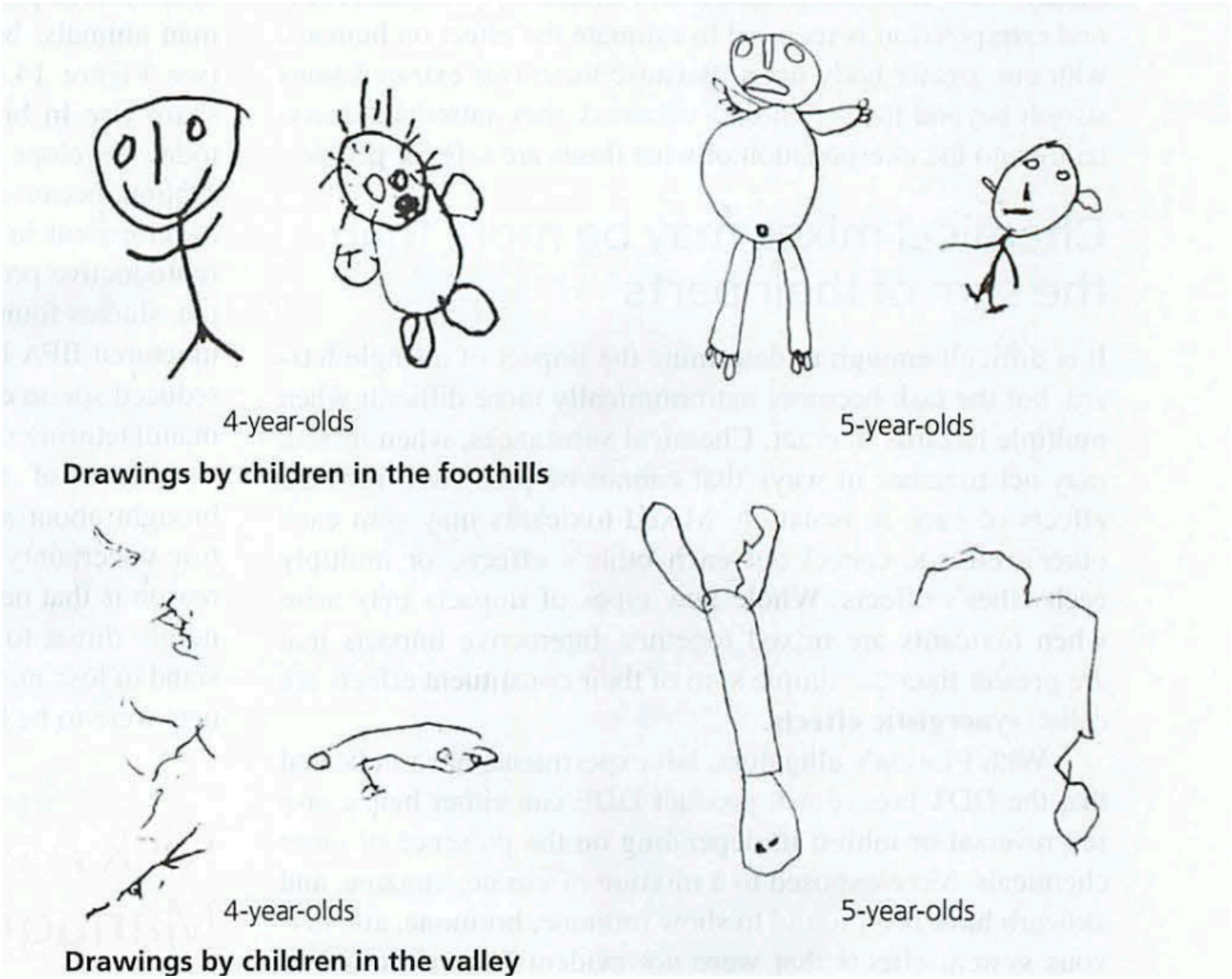


(c) Unconventional dose-response curve

FIGURE 14.17 Dose-response curves show that organisms' responses to toxicants may sometimes be complex. In a classic linear dose-response curve **(a)**, the percentage of animals killed or otherwise affected by a substance rises with the dose. The point at which 50% of the animals are killed is labeled the lethal dose–50, or LD_{50}. For some toxic substances, a threshold dose **(b)** exists, below which doses have no measurable effect. Some substances, in particular endocrine disruptors, show unconventional, nonlinear dose-response curves **(c)** that are U-shaped, J-shaped, or shaped like an inverted U.

Threshold dose (non linear)

Pesticide poisoning: Yaqui indians, PCB endocrine disruptors



Synergistic effects–combined impact greater than sum of separate impacts, e.g. Endocrine disruptors

Risk probability: perception vs. reality

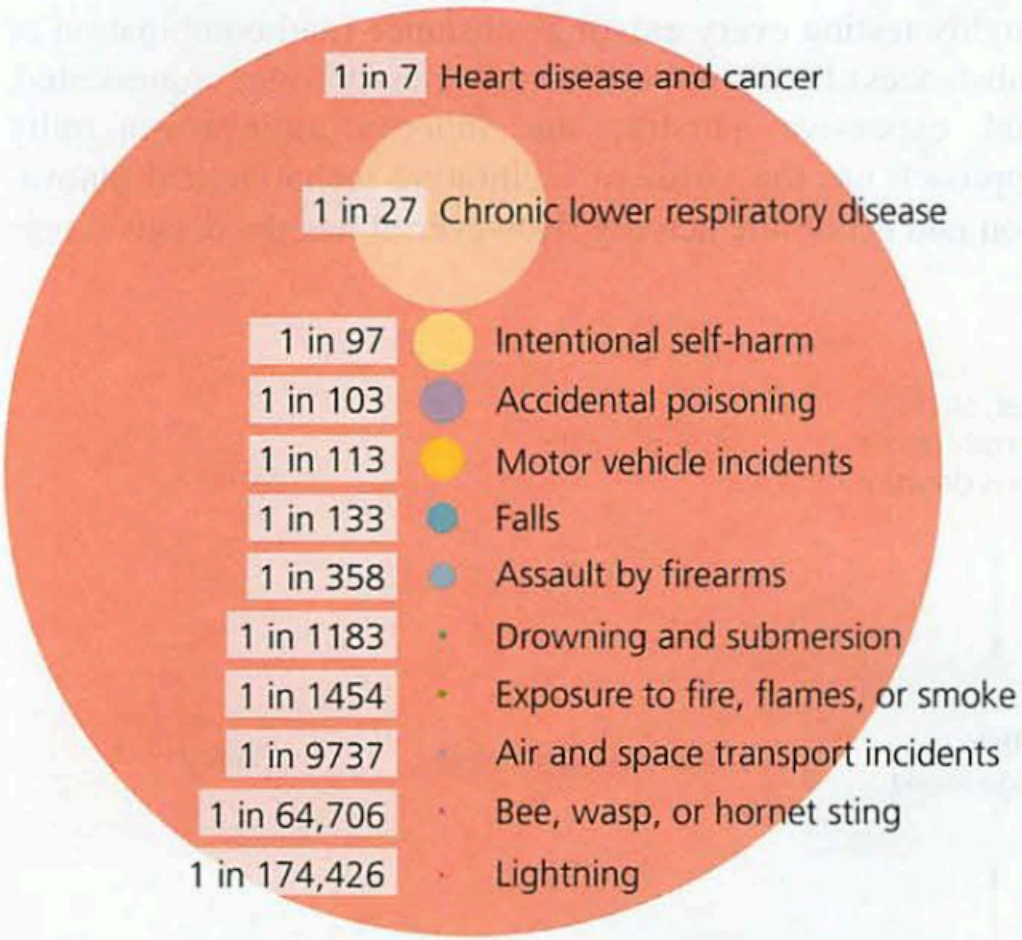


FIGURE 14.18 Our perceptions of risk do not always match the reality of risk. Listed here are several leading causes of death in the United States, along with a measure of the risk each poses. The larger the area of the circle in the figure, the greater the risk of dying from that cause. *Data are for 2013, from* Injury Facts, 2016. *Itasca, IL: National Safety Council.*

Regulation: Innocent until proven guilty vs. precautionary principle

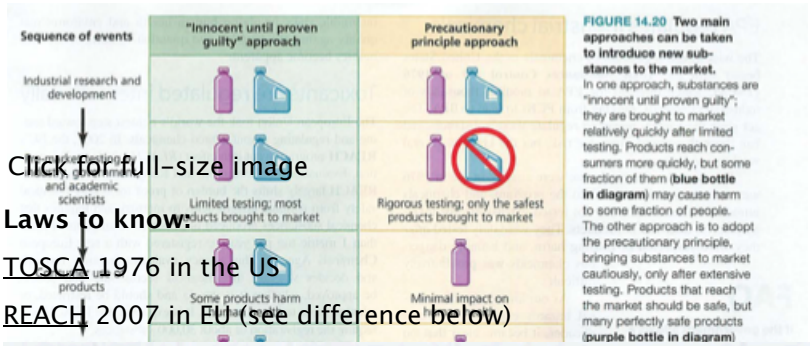


FIGURE 14.20 Two main approaches can be taken to introduce new substances to the market. In one approach, substances are "innocent until proven guilty"; they are brought to market relatively quickly after limited testing. Products reach consumers more quickly, but some fraction of them (**blue bottle in diagram**) may cause harm to some fraction of people. The other approach is to adopt the precautionary principle, bringing substances to market cautiously, only after extensive testing. Products that reach the market should be safe, but many perfectly safe products (**purple bottle in diagram**)

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Laws to know:

TOSCA 1976 in the US

REACH 2007 in EU (see difference below)

TABLE 14.2 American vs. European Approaches to Chemical Regulation

TSCA (UNITED STATES)	REACH (EUROPEAN UNION)
• Government bore burden of proof to show harm	• Industry bears burden of proof to show safety
• Few data on new chemicals were required from industry	• More data on new chemicals are required from industry
• Chemicals in use before 1976 were not regulated	• Chemicals in use before 1981 bear scrutiny like that directed toward newer chemicals
• Prioritizing problems was hampered by lack of data	• Problems are prioritized using data on risk
• Industry was allowed to keep trade secrets from the public	• Database will allow public access to chemical information

Source: Adapted from Schwarzman, M.R., and M.P. Wilson, 2009. New science for chemicals policy. *Science* 326: 1065–1066.

12 POPs: persistent organic pollutants: review for AP exam:

TABLE 14.3 The "Dirty Dozen" Persistent Organic Pollutants (POPs) Targeted by the Stockholm Convention

TOXICANT	DESCRIPTION	TOXICANT	DESCRIPTION
Aldrin	Insecticide to kill termites and crop pests	Furans	By-product of processes that release dioxins; also present in commercial mixtures of PCBs
Chlordane	Insecticide to kill termites and crop pests	Heptachlor	Broad-spectrum insecticide
DDT	Insecticide to protect against insect-spread disease; still applied in some countries to control malaria	Hexachloro-benzene	Fungicide for crops; released by chemical manufacture and processes that release dioxins and furans
Dieldrin	Insecticide to kill termites, textile pests, crop pests, and disease vectors	Mirex	Household insecticide; fire retardant in plastics, rubber, and electronics
Dioxins	By-product of incomplete combustion and chemical manufacturing; released in metal recycling, pulp and paper bleaching, auto exhaust, tobacco smoke, and wood and coal smoke	PCBs	Industrial chemical used in heat-exchange fluids, electrical transformers and capacitors, paints, sealants, and plastics
Endrin	Pesticide to kill rodents and crop insects	Toxaphene	Insecticide to kill crop insects and livestock parasites

Data from United Nations Environment Programme (UNEP), 2001.

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