Risk, Toxicology, & Human Health

tutorial by Paul Rich

Outline

1. Risks & Hazards
   definitions, major types
2. Toxicology
   toxicity, dose–response curves
3. Biological Hazards
   diseases, controlling disease
4. Chemical Hazards
   mutagens, teratogens, carcinogens, bioaccumulation, hormone disrupters
5. Physical Hazards
   earthquakes, volcanoes, ionizing radiation, EM radiation
6. Risk Analysis
   how to estimate risk, major risks, managing risks

1. Risks & Hazards

Risk *is the possibility of suffering harm from a* ***hazard*** *that can cause injury, disease, economic loss, or environmental damage.*

- risk expressed as a probability;
- **risk assessment** involves using data, hypotheses, & models to estimate the probability of harm to human health, society, or the environment that may result from exposure to specific hazards;

Major Hazards

There are four major types of hazards:

- **cultural hazards,** such as unsafe working conditions, smoking, poor diet, drugs, drinking, driving, criminal assault, unsafe sex, & poverty;
- **chemical hazards** from harmful chemicals in air, water, soil, & food;
- **biological hazards** from pathogens, pollen & other allergens, & animals such as bees & poisonous snakes.
- **physical hazards**, such as noise, fire, tornadoes, hurricanes, earthquakes, volcanic eruptions, floods, & ionizing radiation;

Causes of Death

Tobacco use is the leading cause of preventable death (data from 1993).

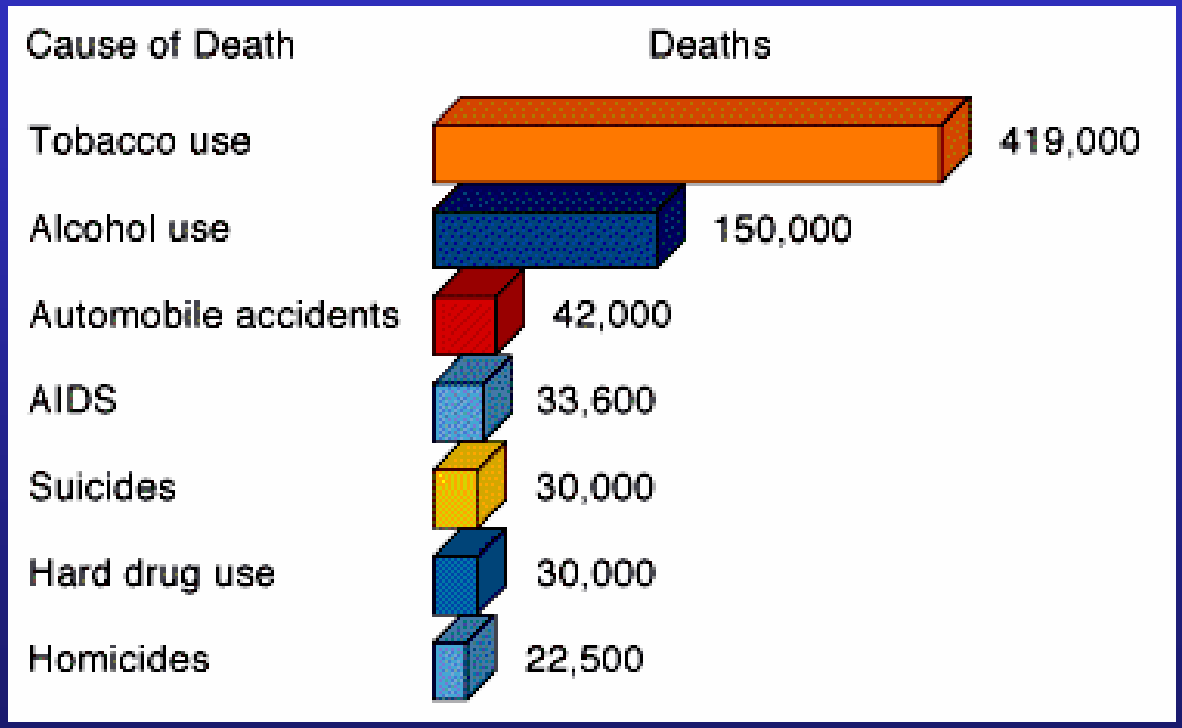


Fig.17–1

2. Toxicology

Toxicology *is the study of the adverse effects of chemicals on health.*

- **toxicity** is a measure of how harmful a substance is;
- the amount of a potentially harmful substance that is ingested, inhaled, or absorbed through the skin is called the **dose**;
- the resulting type & amount of damage to health are called the **response**;
- two types of responses:
  - **acute effect**: immediate or rapid harmful reaction, e.g., dizziness, rash, death;
  - **chronic effect**: permanent or long–lasting consequence, e.g., asthma, kidney damage, heart disease;

Determining Toxicity

Three methods of determining toxicity:

- case reports (usually to physicians) about health effects after exposure to a chemical;
- epidemiology, involving studies of populations exposed to certain chemicals or diseases
- laboratory investigations (usually with test animals);
  - **LD_{50}** is the median lethal dose, the amount of a chemical received that kills 50% of animals (usually rats or mice) in a test population (usually 60–200 animals) within a 14–day period;
  - a **poison** is legally defined as a chemical that has an **LD_{50}** of 50 milligrams or less per kilogram of body weight.

Some Toxicity Ratings

Table 17–1

Toxicity Rating	LD_{50}	Average Lethal Dose	Examples
super toxic	< 0.01	less than 1 drop	nerve gases, botulism, mushroom toxins, dioxin
extremely toxic	< 5	less than 7 drops	potassium cyanide, heroin, atropine, parathion, nicotine
very toxic	5–50	7 drop to 1 teaspoon	mercury salts, morphine, codeine
toxic	50–500	1 teaspoon to 1 ounce	lead salts, DDT, sodium hydroxide, fluoride, sulfuric acid, caffeine, carbon tetrachloride
moderately toxic	500–5,000	1 ounce to 1 pint	methyl alcohol, ether, pehobarbital, amphetamines, kerosine, aspirin
slightly toxic	5,000–15,000	1 pint to 1 quart	ethyl alcohol, lysol, soaps
essentially nontoxic	> 15,000	more than 1 quart	water, glycerin, table sugar

Dose–Response Curves

Dose–response curves show the adverse effects of various doses of a toxic agent on a test population by plotting harmful effect as a function of dose.

The left dose–response curve shows increasing harmful effects with dose, & no dose is considered safe. The right example has a threshold, such that low doses are considered safe.

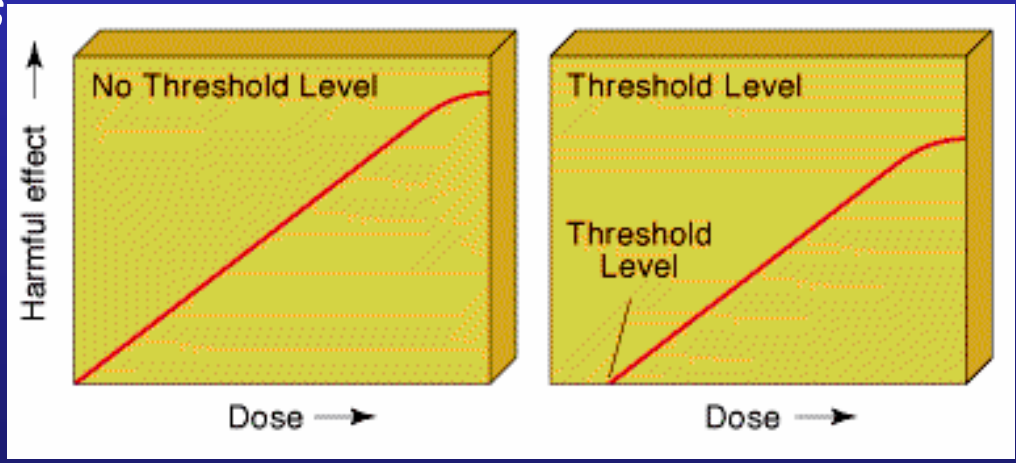


Fig.17–2

3. Biological Hazards

Biological hazards include both non-transmissible & transmissible diseases.

- Nontransmissible diseases are not passed from one person to another, e.g., cardiovascular disorders, most cancers, diabetes, emphysema, & malnutrition;
- Transmissible diseases are caused by bacteria, viruses, protozoa, or parasites, & can be passed from one person to another, e.g., colds, flus, hepatitis, sexually transmitted diseases, malaria;
- Some transmissible diseases are spreading over broad geographic areas as the result of human activity;
  - e.g., Lyme disease carried by ticks & spread by people is now widespread over North America.

Video: http://video.nationalgeographic.com/video/player/science/health-human-body-sci/health/virus-crisis-sci.html

Biological Hazards

Worldwide distribution of malaria today (red) and its projected distribution in 2046 (orange). If the world becomes warmer, as projected by current climate models, by 2046 malaria could affect 60% of the world's population.

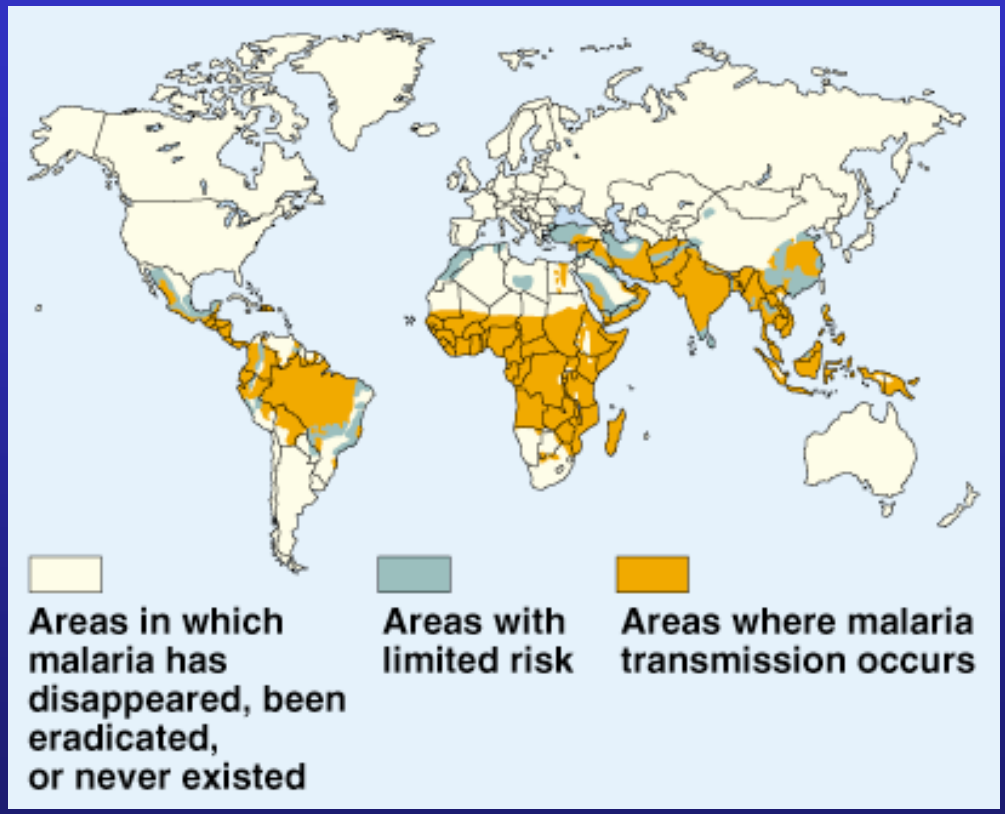


Fig. 17–10

Video: http://video.nationalgeographic.com/video/player/science/health-human-body-sci/health/malaria-sci.html

Biological Hazards

Generalized model of the epidemiological transition that may take place as countries become more industrialized.

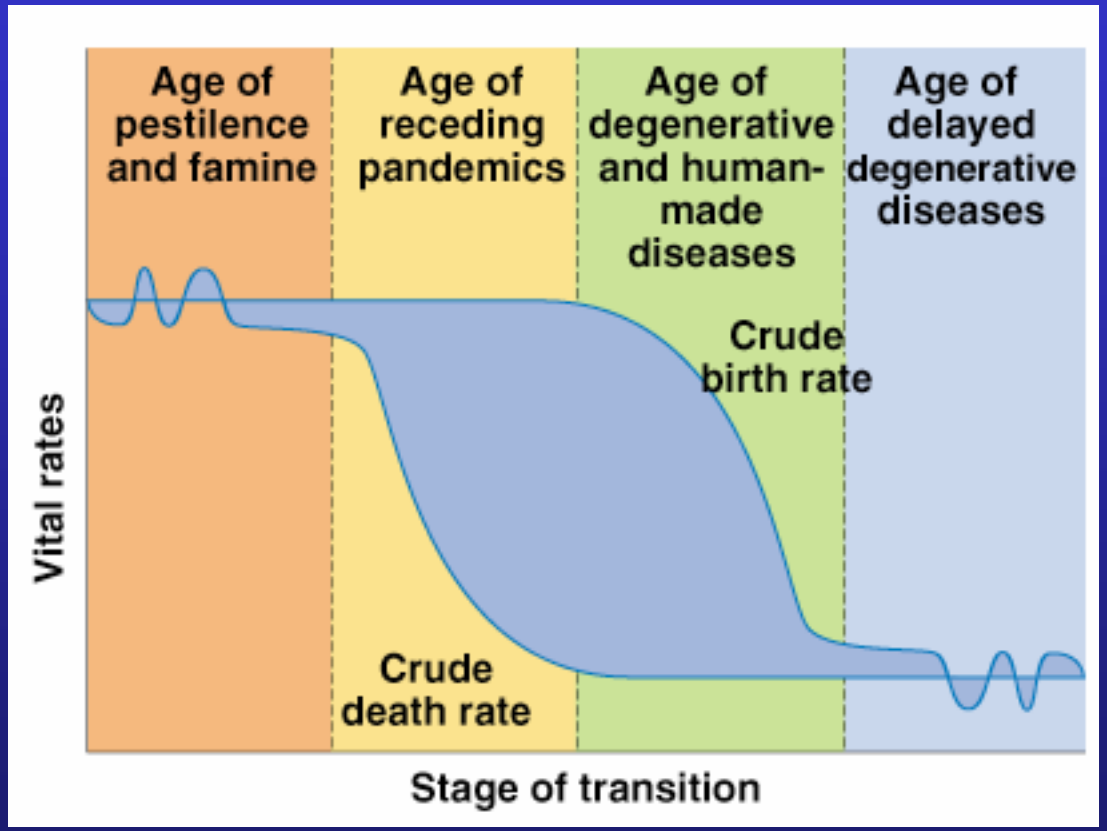


Fig. 17–12

Biological Hazards

What are some ways we reduce infectious diseases?

- reduce overcrowding, unsafe drinking water, poor sanitation, inadequate health care systems, malnutrition, & poverty;
- increase funding for disease monitoring;
- sharply reduce antibiotic use to prevent evolution of resistant organisms;
- protect biodiversity as a means of reducing disease spread;
- increase research.

4. Chemical Hazards

What are toxic vs. hazardous chemicals?

- **toxic chemicals** are generally defined as substances that are fatal to over 50% of test animals (LD_{50}) at given concentrations.
- **hazardous chemicals** cause harm by
  - being flammable or explosive (e.g., gasoline);
  - irritating or damaging the skin or lungs (e.g., strong acids or alkalines such as oven cleaners);
  - interfering with or preventing oxygen uptake & distribution (e.g., carbon monoxide, CO);
  - inducing allergic reactions of the immune system (allergens).

Mutagens, Teratogens, & Carcinogens

- **mutagens** are agents, chemicals & radiation, that cause random mutations, or changes in the DNA;
- **carcinogens** are agents (chemicals, radiation, or viruses) that cause cancer;
  - over 100 types of cancer (depending on cells involved);
  - e.g., cigarette smoke.
- **teratogens** are agents (chemicals, radiation, or viruses) that cause birth defects;
  - e.g., PCBs, steroid hormones, heavy metals;

Bioaccumulation & Biomagnification

The pesticide DDT becomes increasingly concentrated high in the food chain because it is stored in fatty tissue & not easily broken down or excreted.

- **Bioaccumulation** results when the concentration of a chemical in specific organs or tissues is higher than would normally be expected.
- Biomagnification involves magnification of concentrations as they pass through the food chains & webs.

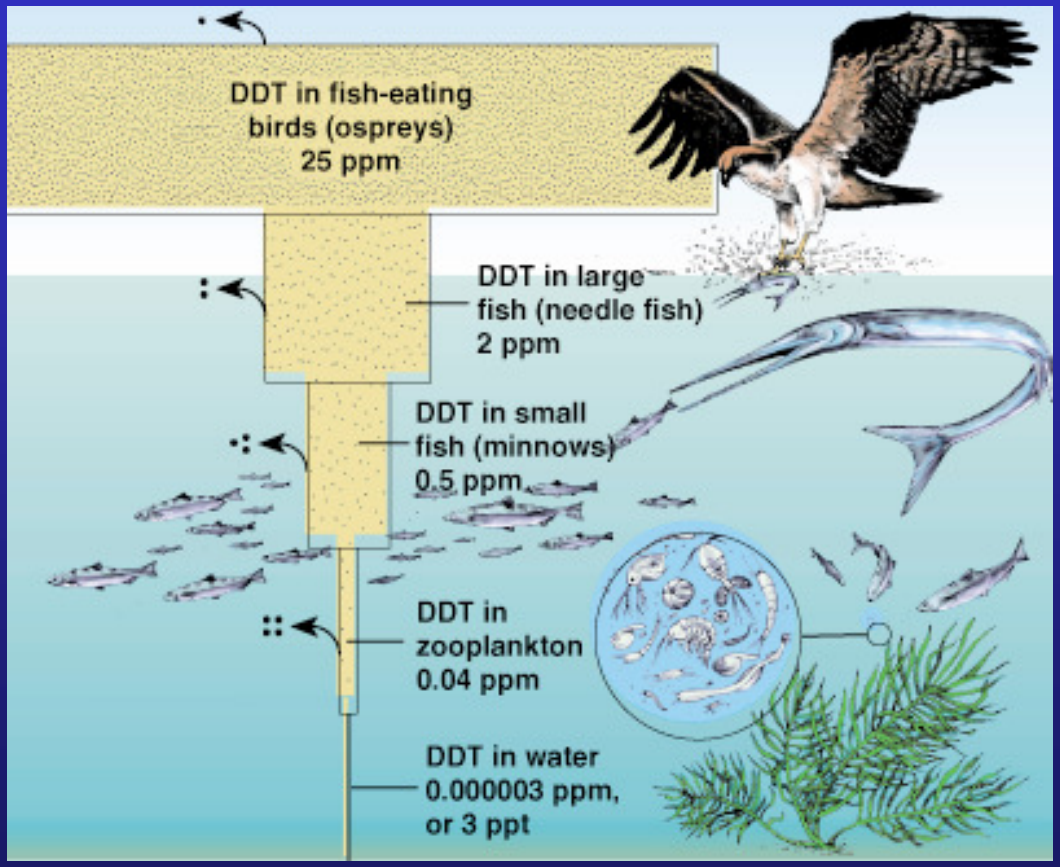


Fig.17–2

Hormone Disrupters

Each type of hormone has a unique molecular shape that allows it to attach to special receptors of cells (upper left). Hormone mimics, such as estrogen-like chemicals, attach to receptors & disrupt normal activity (upper right). Hormone blockers prevent hormones such as androgen from attaching to receptors (lower).

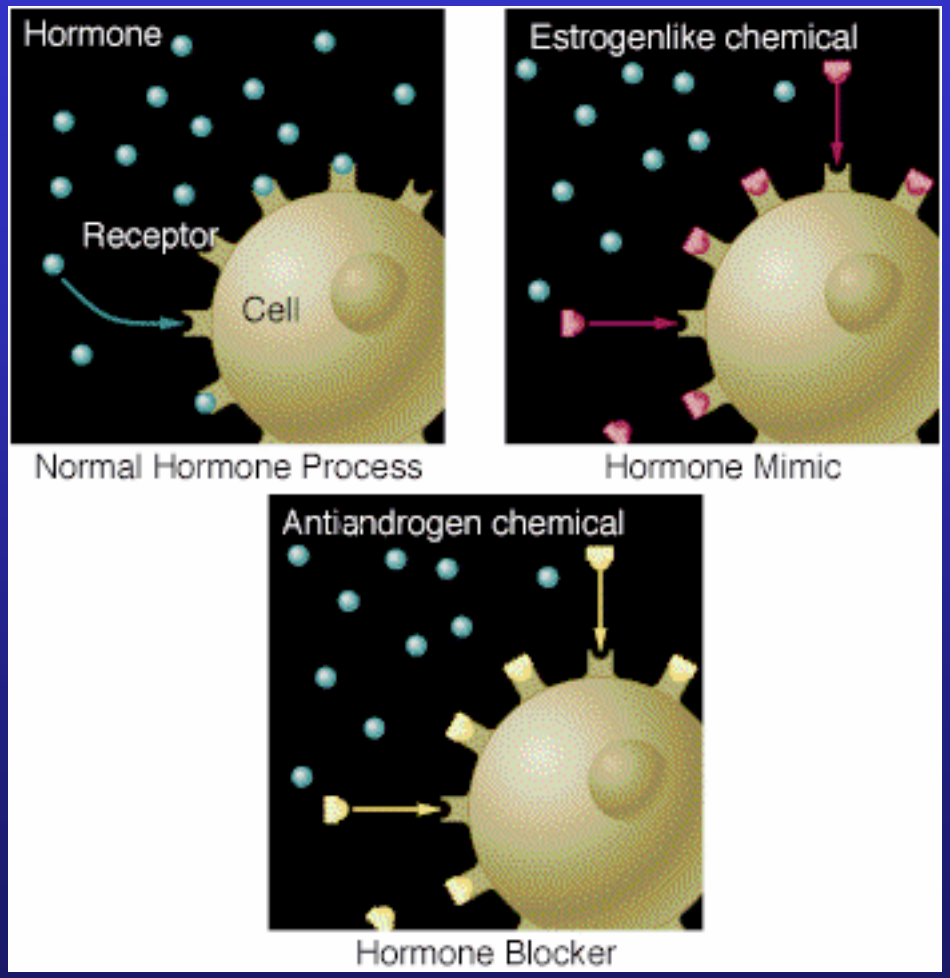


Fig.17–4

Hormone Disrupters

Hormones are molecules that act as messengers in the endocrine system to regulate various bodily processes, including reproduction, growth, & development. Hormone disrupters interfere with hormone function.

- So far 51 chemicals, many widely used, have been shown to act as hormone disrupters on wildlife, laboratory animals, & humans;
  - e.g., dioxins, certain PCBs, various chemicals in plastics, some pesticides, lead & mercury;
- 1997 study shows that sperm count of men in U.S. & Europe has declined 50%.

5. Physical Hazards

Earthquakes are among various types of natural physical hazards.

<u>Preventing loss</u>:

- understand where risk is high;
- establish building codes to regulate placement & design of buildings in high risk areas;
- determine if prediction is feasible.

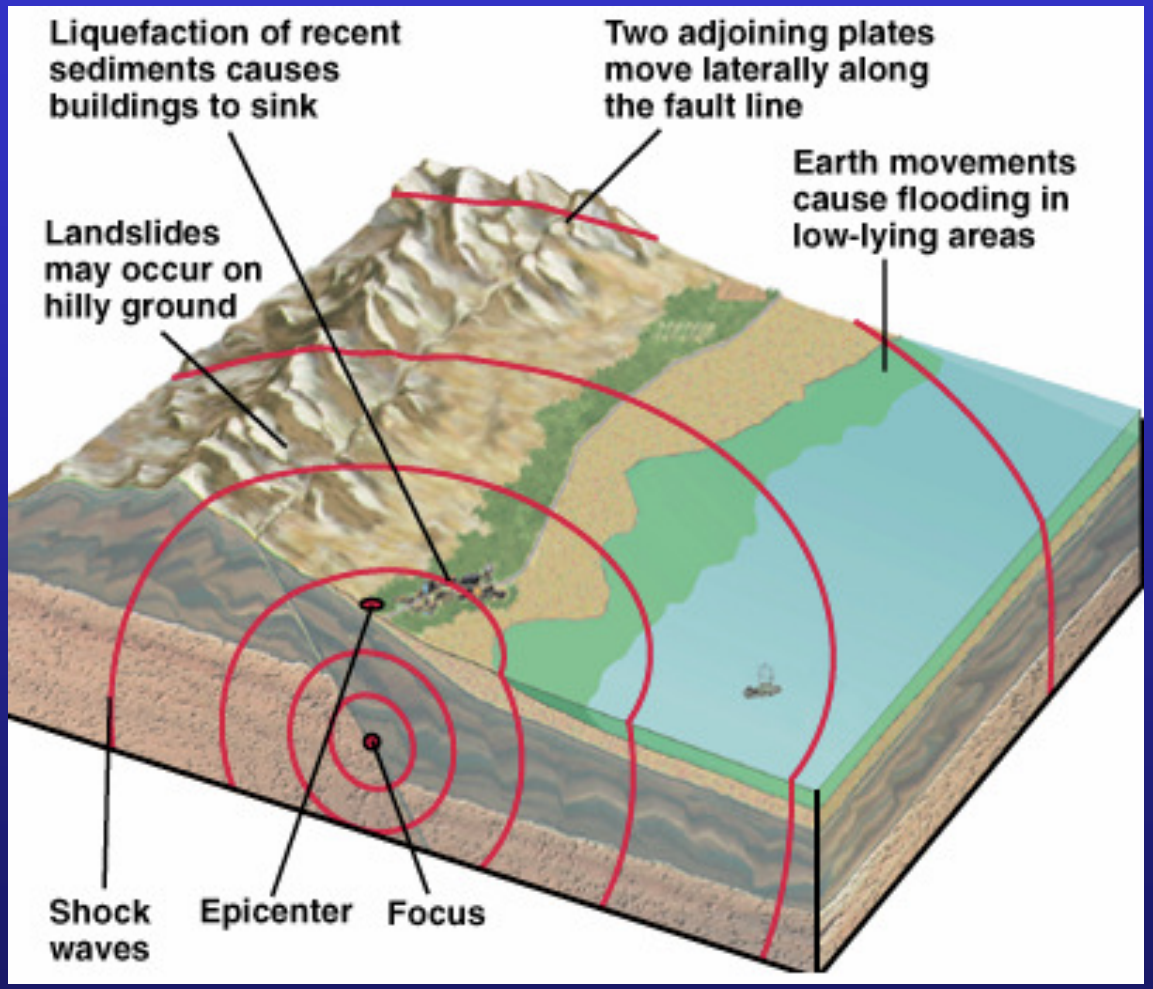
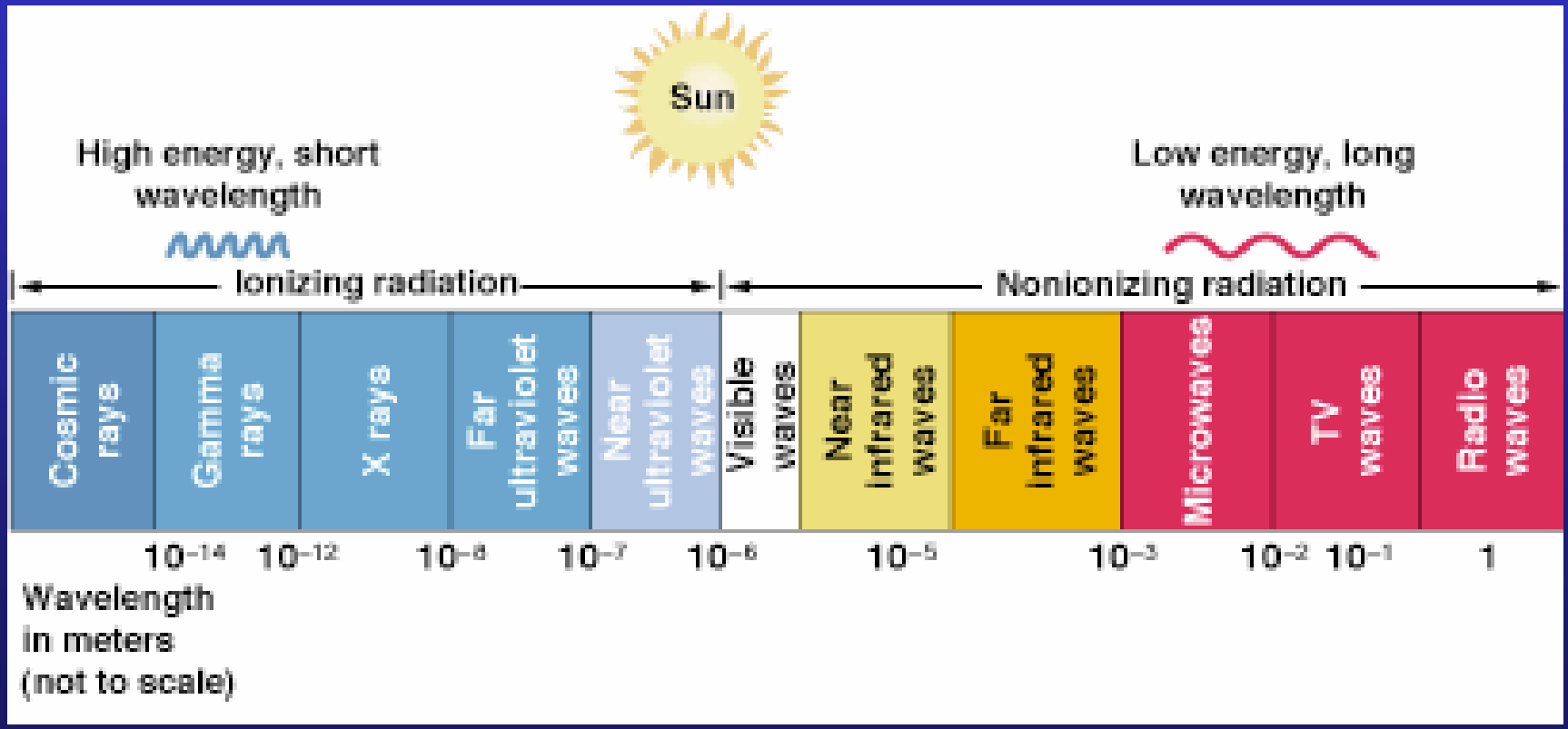


Fig.17–5

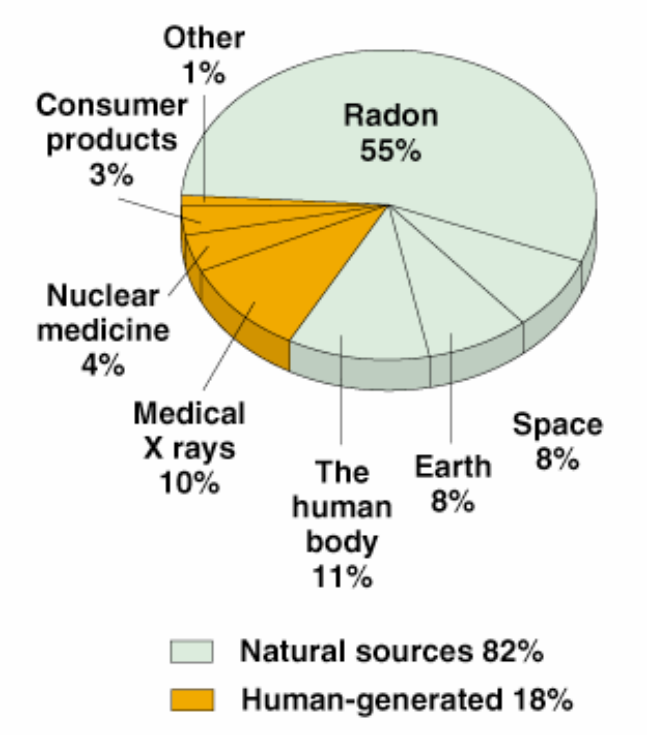
Video: http://nationalgeographic.com/video/player/environment/environment-natural-disasters/earthquakes/earthquake-101.html

Physical Hazards

Ionizing radiation, a form of electromagnetic radiation, has enough energy to damage body tissues. Examples include X rays & ultraviolet radiation, & various types of radiation emitted by radioactive isotopes.



Physical Hazards



Each year people are exposed to some radiation from natural or background sources, as well as from human–caused exposure.

- background sources include about 82% of the exposure;
- human–caused exposure include medical X rays (10%), nuclear medicine (4%), & consumer products (3%);
- harmful effects include burns, miscarriages, eye cataracts, & certain cancers;
- serious accidents, such as at the Chernobyl reactor, can release large quantities of radiation, far above background levels.

Most studies indicate that there is no safe dose of ionizing radiation.

Physical Hazards

Is non-ionizing electromagnetic radiation harmful?

- we don't know;
- concern that electromagnetic fields (EMFs) from electrical appliances (e.g., microwave ovens, hair dryers, electric blankets, computer & TV monitors) may increase risk of some cancers, miscarriages, birth defects, & Alzheimer's disease;
- many respected scientists say that a statistical link has between established;
- however, the evidence is still not conclusive.

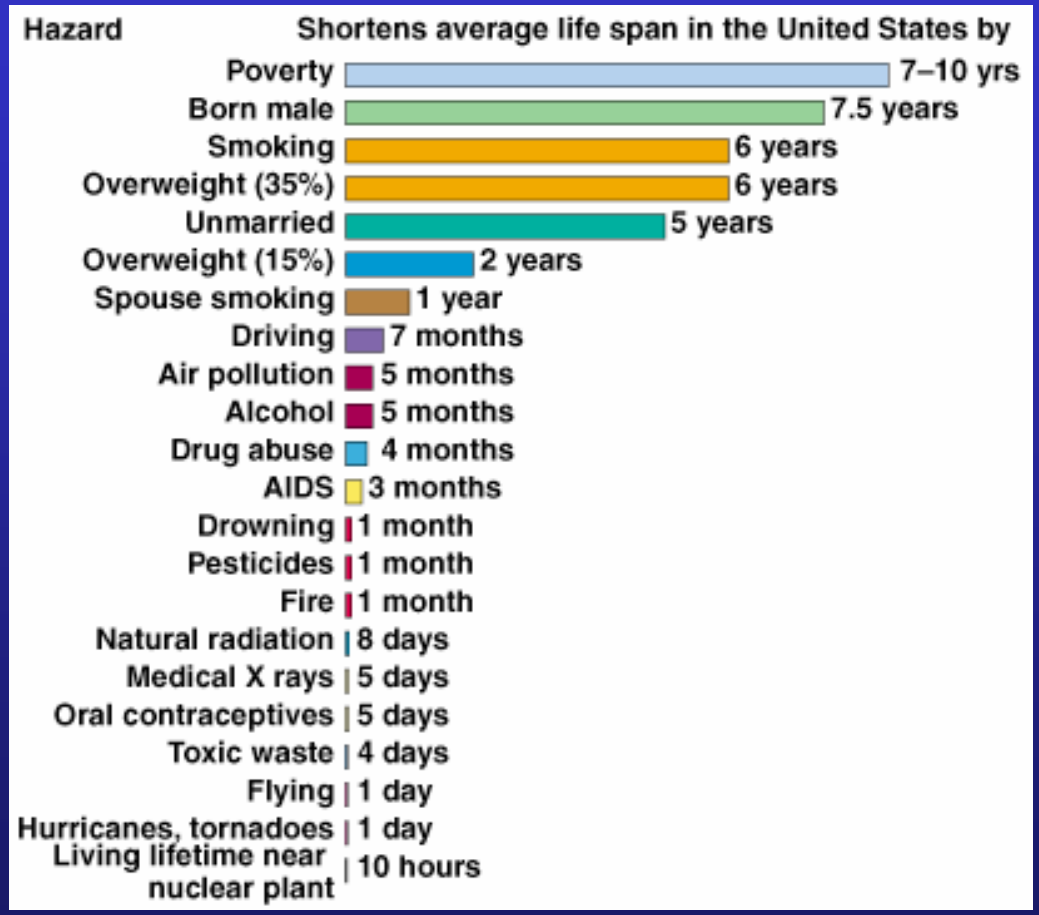
6. Risk Analysis

Risk analysis *involves identifying hazards & evaluating associate risks (risk assessment), ranking risks (comparative risk analysis), determining options (risk management), & informing decision makers & the public (risk communication).*

- **risk assessment** estimates probabilities associated with different types of hazards;
- **comparative risk analysis** summarizes the greatest ecological & health risks (see Fig. 17–13).

Greatest Risks to Humans in the U.S.

- poverty poses the greatest risk (shortens lifespan by 7–10 years);
- smoking & being overweight pose the next greatest risk (each shortens lifespan by 6 years);
- being born male poses a greater risk than being female (shortens lifespan by 7.5 years);
- being unmarried is associated with risk (shortens lifespan by 5 years);
- other significant risks in the U.S. include second–hand smoke, driving, air pollution, alcohol use, & drug abuse.



Risk Analysis

What are the limitations of risk assessment?

- inaccuracy of models;
- inadequate data;
- bias because of who does the analyses;

Major questions?

- Which risks are worth evaluating?
- How reliable are analyses?
- How much risk is acceptable?
- How much will it cost to reduce each risk?
- How can a risk management plan be communicated?