© Don Kohlbauer / Zuma Press

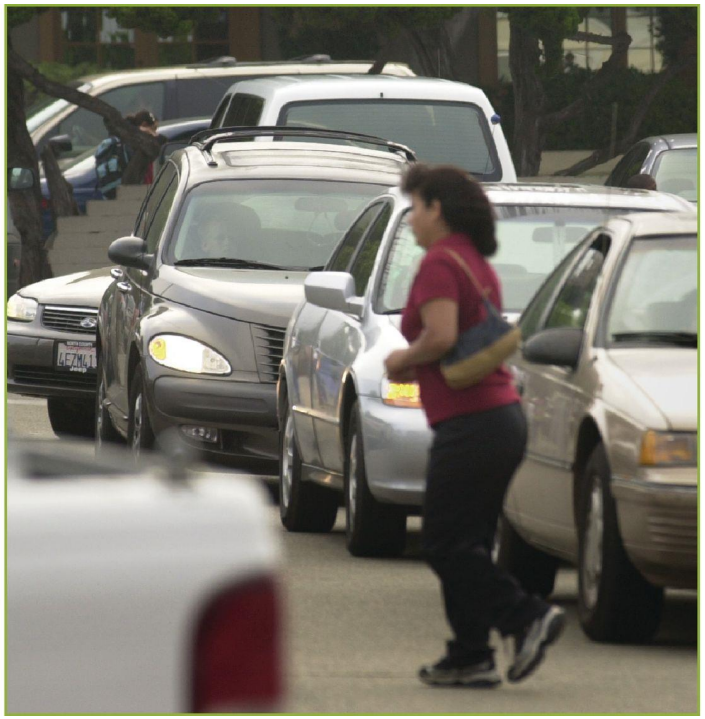
7 Human Health and Environmental Toxicology

Overview of Chapter 7

- Human Health
  - In developed countries
  - In developing countries
- Environmental Pollution and Disease
  - Environmental Contaminants
  - Endocrine Disrupters
- Determining Health Effects of Pollutants
- Ecotoxicology
- Risk Assessment

Humans and the environment are interacting

- Children driven to school instead of walking
  - How does this behavior change the environment?
  - How does this behavior change the children?
- Human health and activity affects the environment
- Environmental health affects human health



© Don Kohlbauer / Zuma Press

Human Health

- Two indicators of human health
  - Life expectancy - how long people are expected to live
  - Infant mortality - how many children die before age of 1 year per 1,000 live births
- Vary greatly between countries
  - Developed countries
    - Infant mortality-Japan 0.26%
  - Developing countries
    - Zambia 7%

Hierry Falise / Getty Images

Health in Highly Developed Countries

- Health is generally good in these countries
- Average life expectancy
  - Men = 75 years
  - Women = 80 years
- Leading causes of death in US (chronic)
  - Cardiovascular disease, Cancer, Lung Disease
- Premature deaths caused by lifestyle
  - Poor diet, Lack of exercise, Smoking, Obesity

Health in Highly Developed Countries

- Body mass index (BMI)

$$BMI = (Weight \times 703) \div Height^2$$

- Weight in pounds, height in inches
- Underweight >18.5
- Healthy weight 18.5 – 24.9
- Overweight 25-29.9
- Obese >30
- Does not account well for muscular people

Health in Developing Countries

- Biggest problems
  - Malnutrition, unsafe water, poor sanitation
- Life Expectancy
  - Overall is 65 years
  - Very poorest developing countries = 45 years
    - Due to AIDS epidemics
- Childhood mortality is high
  - Diarrheal diseases
  - Malnutrition
  - Malaria
  - AIDS/HIV

Robert Caputo/Aurora Photos, Inc.

Table 7.1 Ten Facts on the Global Burden of Disease

1. Around 6.6 million children under the age of five died in 2012.
2. Cardiovascular diseases are the leading causes of death in the world.
3. HIV/AIDS is the leading cause of death in Sub-Saharan Africa.
4. Population aging is contributing to the rise in cancer and heart disease.
5. Lung cancer is the most common cause of death from cancer in the world.
6. Complications of pregnancy account for almost 15% of deaths in women of reproductive age worldwide; 99% of these are in developing countries.
7. Mental disorders such as depression are among the 20 leading causes of disability worldwide.
8. Hearing loss, vision problems, and mental disorders are the most common causes of disability.
9. Almost 10% of adults worldwide suffer from diabetes.
10. About 75% of the new infectious diseases affecting humans over the past 10 years were caused by bacteria, viruses, and other pathogens that originated in animals or animal products.

Source: World Health Organization, Global Burden of Disease Study (December 2013).

Emerging and Reemerging Diseases

- New diseases are always developing
- Emerging Disease - not previously observed in humans
  - Usually jumps from animal host
  - Ex: AIDS, lime disease, West Nile Virus
- Reemerging Disease existed in the past and are recently increasing in incidence
  - Ex: tuberculosis, yellow fever, malaria

Reasons for Emergence/Reemergence

- Evolution of disease so it transitions to human host
- Evolution of antibiotic resistance in disease
- Urbanization and overcrowding
- Increased pop. of elderly - susceptible to disease
- Pollution and environmental degradation
- Growth in international travel and commerce
- Poverty and social inequality

Lynn Johnson/National GeographicCreative

Global Polio Eradication

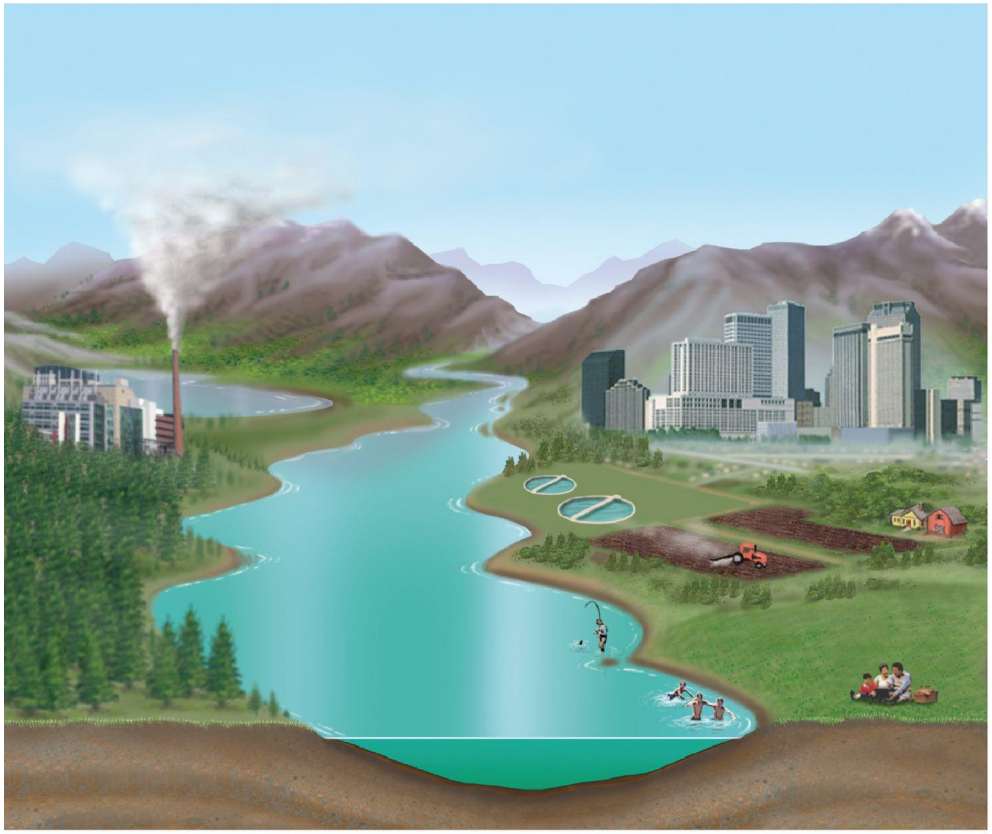
- Incidence of many diseases greatly decreased with vaccinations
  - Smallpox, measles, polio
- Polio spread by drinking water contaminated by poliovirus, attacks CNS
- WHO global vaccination project 1988
  - Reduced incidence
- Nigerian state halted vaccines, questioned safety, polio increased
- Anti-vaccines movement in the U.S.?

The Flu (Influenza)

- Flu season late fall – early winter
  - 5-20% of U.S. contracts flu
  - ~36,000/year die
- Always evolving and can strains can be worse
  - 1918 850,000 died, 1% of the population at time
- Researchers need to predict which strain for the vaccine
- Threat of a flu pandemic – disease that reaches nearly every part of world, infect every person
  - Avian flu, swine flu (2009) – mix of human, bird, swine flu genetic material

Environmental Pollution and Disease

- Pathways of Pollution
- Often difficult to link pollutants to their effects on people
  - Persistence
  - Bioaccumulation & magnification



Persistence

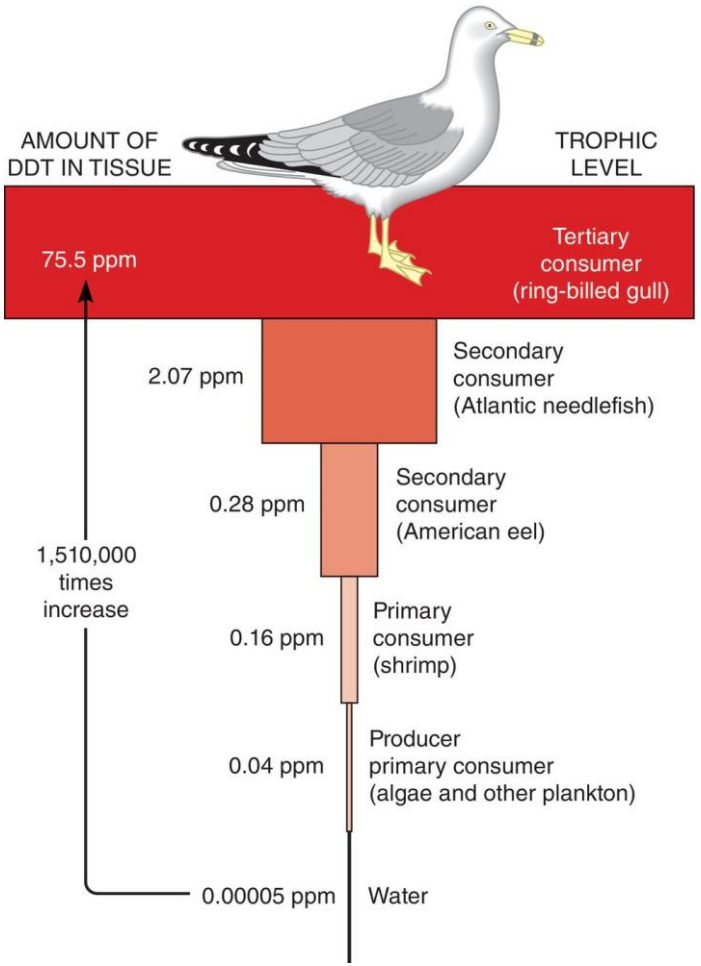
- A characteristic of certain chemicals that are extremely stable and may take many years to be broken down into simpler forms by natural processes
  - Synthetic chemicals (those not found in nature)
  - Ex: DDT
- Natural decomposers (bacteria) have not evolved a way to break it down

Bioaccumulation

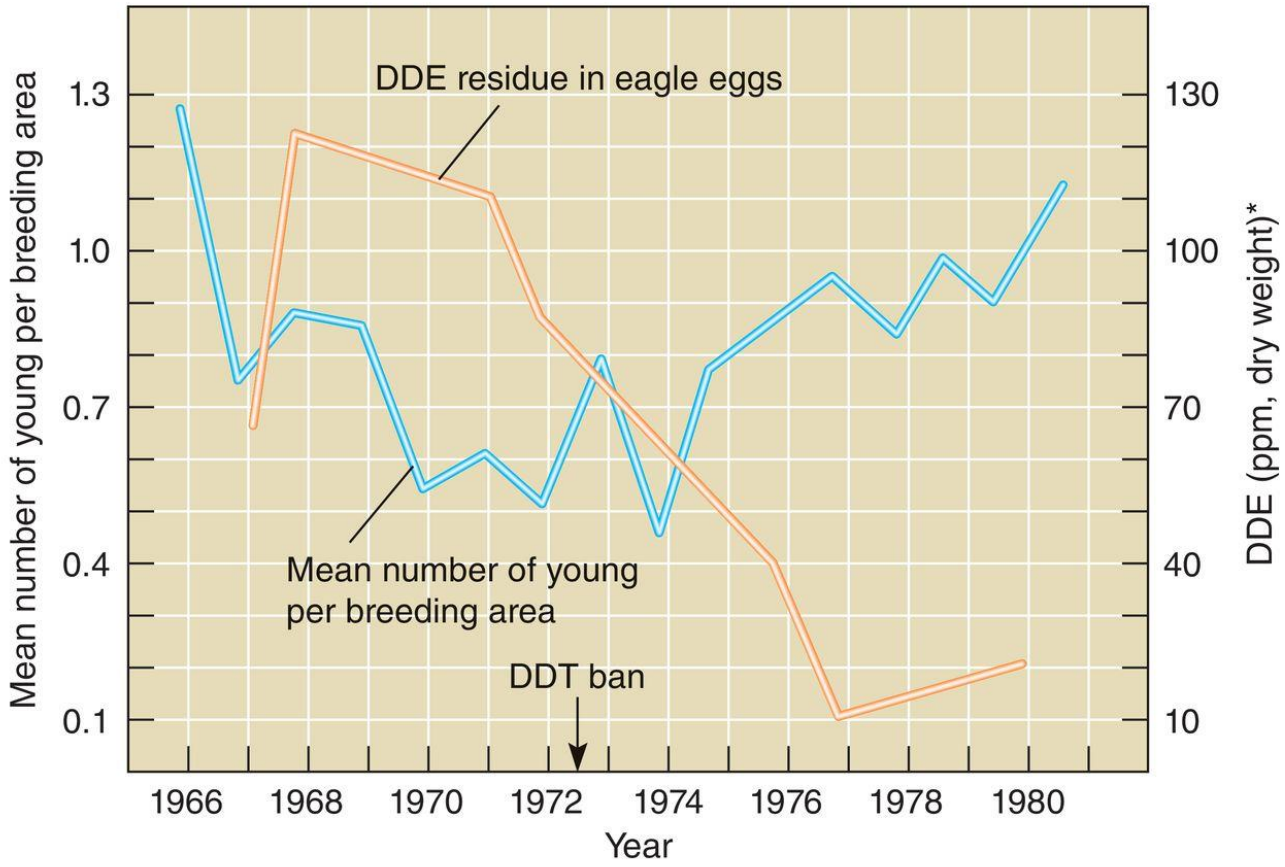
- Or bioconcentrate
- The buildup of a persistent toxic substance in an organism's body, often in fatty tissues
  - Synthetic chemicals do not metabolize well
  - They remain in the body for extended periods of time

Biomagnification

- The increased concentration of toxic chemicals in the tissues of organisms that are at higher levels in food webs
- Diagram (right) is example of biomagnification of DDT
- Nearly killed off bald eagle



Effect of DDT on Bald Eagles



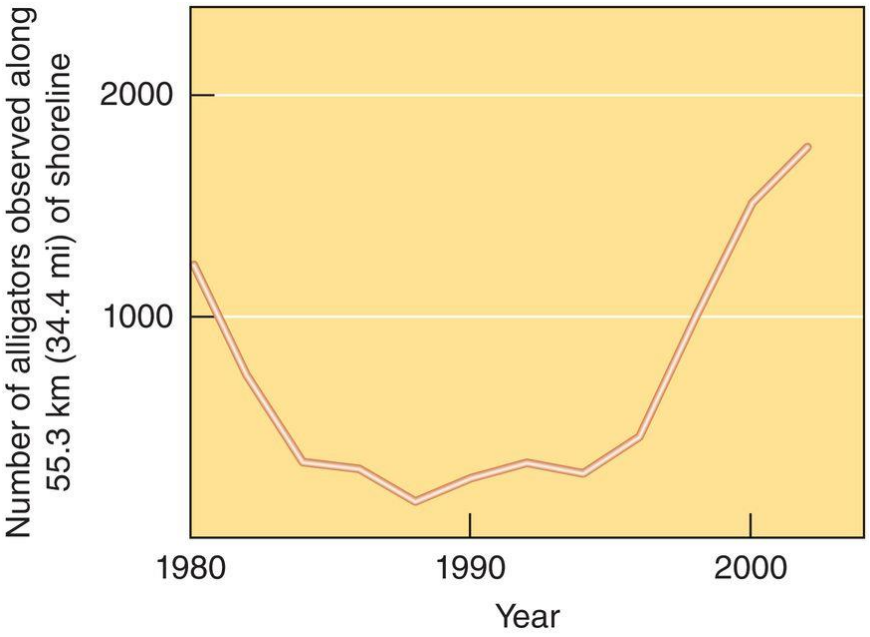
*DDT is converted to DDE in the birds' bodies

Endocrine Disrupters

- A chemical that mimics or interferes with the actions of the endocrine system in humans and wildlife
- Examples include:
  - PCBs, Dioxins
  - Heavy metals – lead and mercury
  - DDT
- Animals exposed to these chemicals have altered reproductive development and are often sterile

Endocrine Disrupters

- Case Study: 1980 chemical spill into Lake Apopka, FL
  - Male alligators began to exhibit low testosterone levels and high estrogen levels



Endocrine Disrupters and Humans

- Infertility and hormonally related cancers are increasing
  - Breast cancer and testicular cancer
- Phthalates have been implicated as potential endocrine disrupters
  - Common ingredient in: cosmetics, fragrances, nail polish, medication, toys, food packaging

Endocrine Disrupters and Humans

- Bisphenol A (BPA) – chemical in hard plastics, such as baby and drink bottles
  - Contested whether BPA is a problem
  - Banned in many countries and CA, not in U.S. and Australia
- Science is uncertain
  - Acute versus chronic use
  - Scientific studies have difficultly with chronic, multiple types of exposures
    - Limited by funding and testing
- Thoughts on regulations?

Determining Health Effects of Pollutants

- Toxicology is the study of the effect of toxicants on the human body
  - Toxicant - chemical with adverse human health effects
- Toxicity measured by dose and response
  - Dose: amount that enters that body of an exposed organism
  - Response: the amount of damage caused by a specific dose

Toxicology

- Acute toxicity
  - Adverse effects occur within a short period after exposure to toxin
- Chronic toxicity
  - Adverse effects occur some time after exposure, or after prolonged exposure to toxin
- Epidemiology
  - Study of the effects of toxic chemicals and diseases on human populations

Toxicology and Epidemiology

- Toxicologist
  - Dose rats with varying levels of chemicals to see if they develop cancer
  - Difficult to extrapolate results to humans
- Epidemiologists
  - Look at historical exposure of groups of humans
  - See if exposed group have increased cancer rate
    - Centers for Disease Control (CDC in U.S.)
    - World Health Organization (WHO)

Toxicity

- LD_{50}
  - Lethal dose to 50% of the test organisms
  - Smaller the LD_{50}, the more lethal the chemical
  - Determined for all new synthetic chemicals

Table 7.2 LD_{50} Values for Selected Chemicals

Chemical	*LD_{50} (mg/kg)**
Aspirin	1750
Ethanol	1000
Morphine	500
Caffeine	200
Heroin	150
Lead	20
Cocaine	17.5
Sodium cyanide	10.0
Nicotine	2.0
Strychnine	0.8

*Administered orally to rats.

Toxicity

- ED_{50}
  - Effective dose to 50% of the test organisms
  - ED_{50} causes 50% of the population to exhibit whatever effect is under study
- Dose-Response Curve
  - Illustrates the effect of different doses on a population
  - Threshold Level
    - Maximum dose with no measurable effects

Toxicity

Table 7.3 Hypothetical Data Set for Animals Exposed to a Chemical

Number of Animals in Test	*Number of Animals with Cancer*	*Dose (mg/kg/day)*	*Probability of Cancer**
50	0	0.0	0
50	2	5.0	0.04
50	6	10.0	0.12
50	22	20.0	0.44

*The probability of getting cancer at a given dose is the number of animals with cancer at that dose level divided by the total number exposed at that dose level.

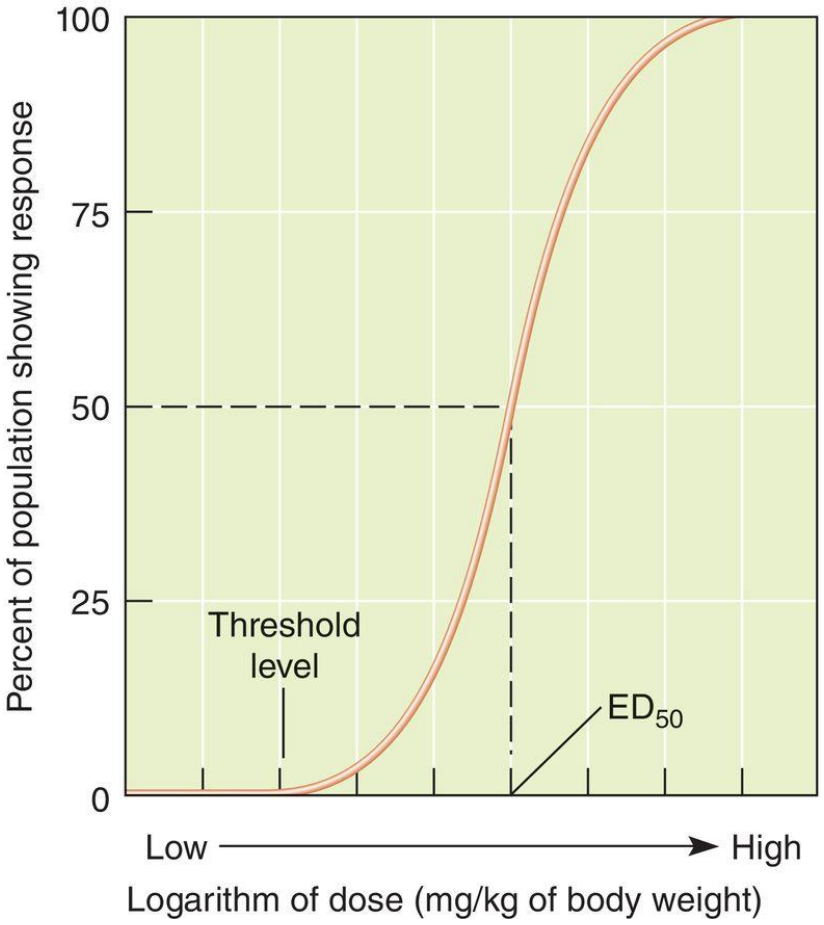
Toxicity

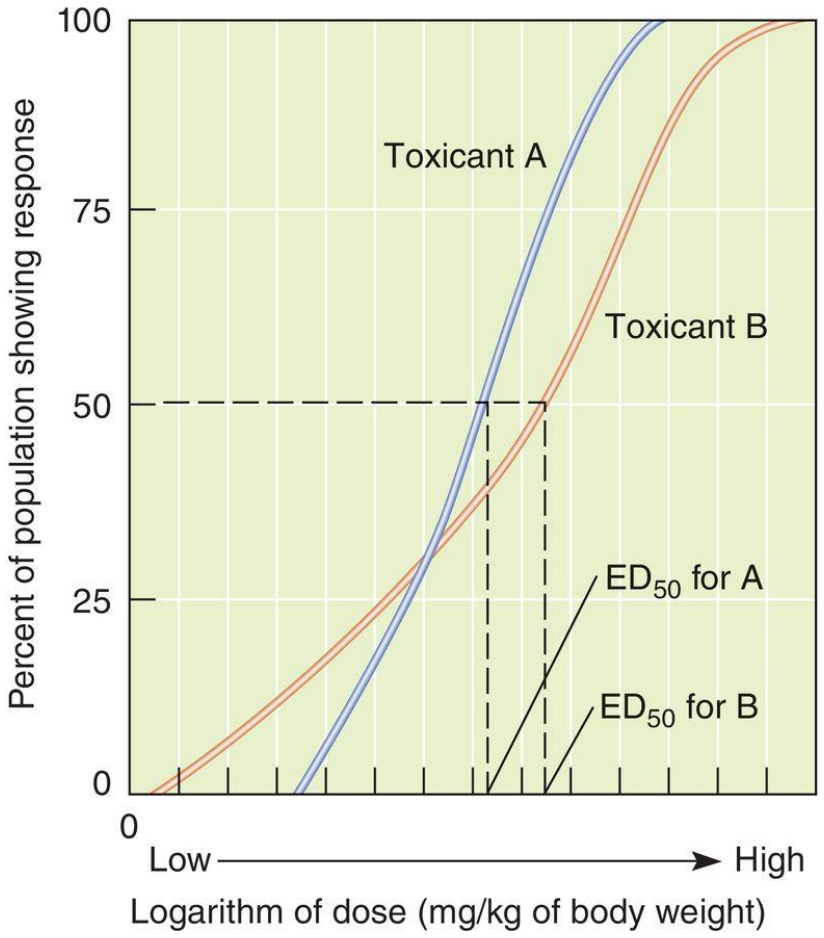
Table 7.4 Comparison of Advantages and Disadvantages of Toxicological and Epidemiological Studies

Epidemiology	*Toxicology*	*Advantage*
Human subjects	Typically animal subjects	Epidemiology
Exposure to multiple chemicals	Exposure to a single chemical	Toxicology
Retrospective (backward-looking)	Prospective (forward-looking)	Toxicology
Arbitrary dose ranges	Specified dose ranges	Toxicology
Estimated doses	Administered doses	Epidemiology
Exposed group genetically diverse	Exposed group genetically homogeneous	
Sample size of 100 to 10,000	Sample size of 10 to 100	Epidemiology
Risk to exposed group near or slightly above background rate	Risk to exposed group substantially above background rate	Toxicology

Source: D. M. Hassenzahl and A. Finkel (2008) "Risk Assessment for Environmental and Occupational Health." In Heggenhougen and Quah, *International Encyclopedia of Public Health*.

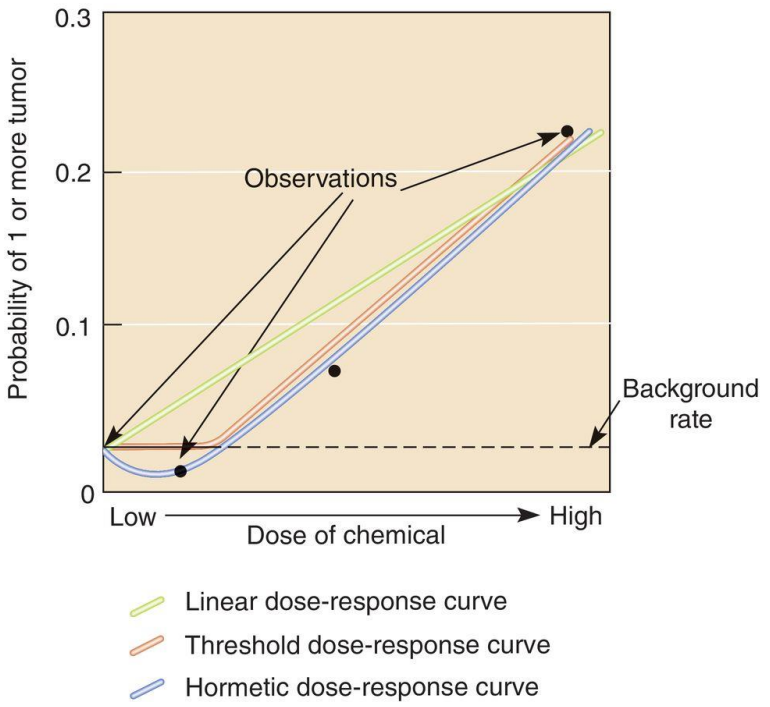
Toxicity: ED_{50}





Contrasting Dose-Responses

- Hormesis- small exposure improves health, larger causes illness
- Additive mixtures- effect of each adds to produce response



Effect of Chemical Mixtures

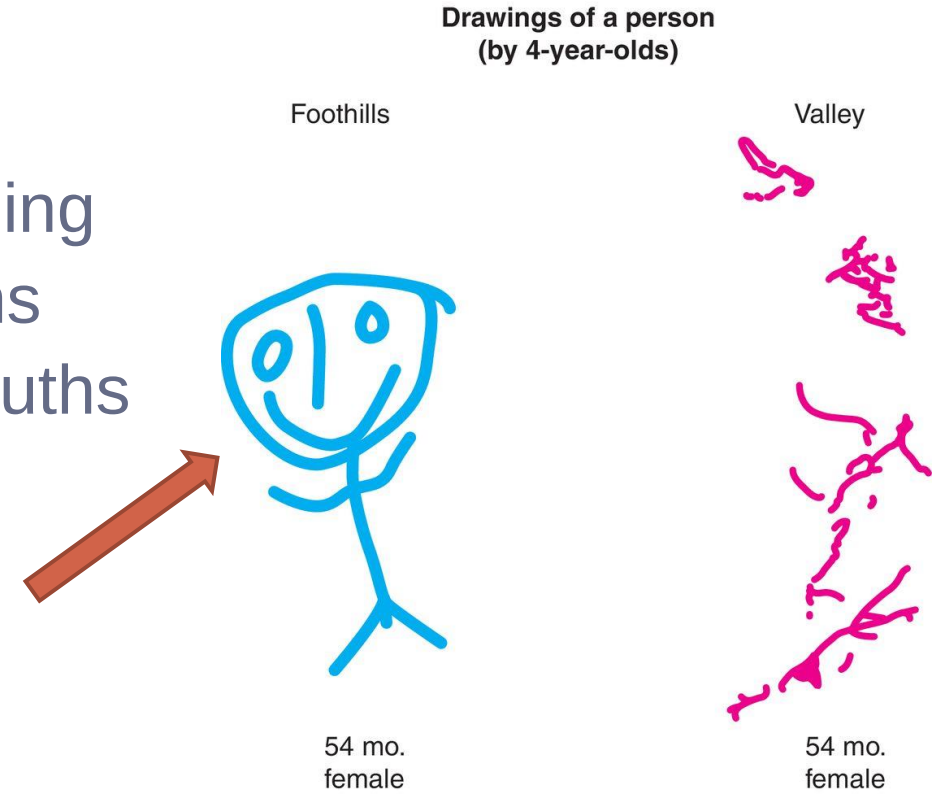
- Many chemicals in environment and home
  - How does each effect us individually and when mixed?
- Additive mixtures- effect of each adds to produce response
- Synergistic-mixture results in greater response than predicted by individual effects
- Antagonistic-mixture results in smaller response than predicted
- Difficult, if not impossible, to test all combinations

Toxicology Without Animals?

- Pros – test on animals of some kind before humans
- Cons- cost, relevance to humans, animal cruelty
- Using human cells in test tubes rather than animals?
  - Relevance, cost, humane treatment?

Children and Chemical Exposure

- Children more susceptible to chemicals
  - Weigh less than adults
  - Bodies are still developing
  - Play on floors and lawns
  - Put things into their mouths
- Developmental effects
  - Children in foothills not exposed to pesticides
  - Children in valley were exposed



Children and Chemical Exposure

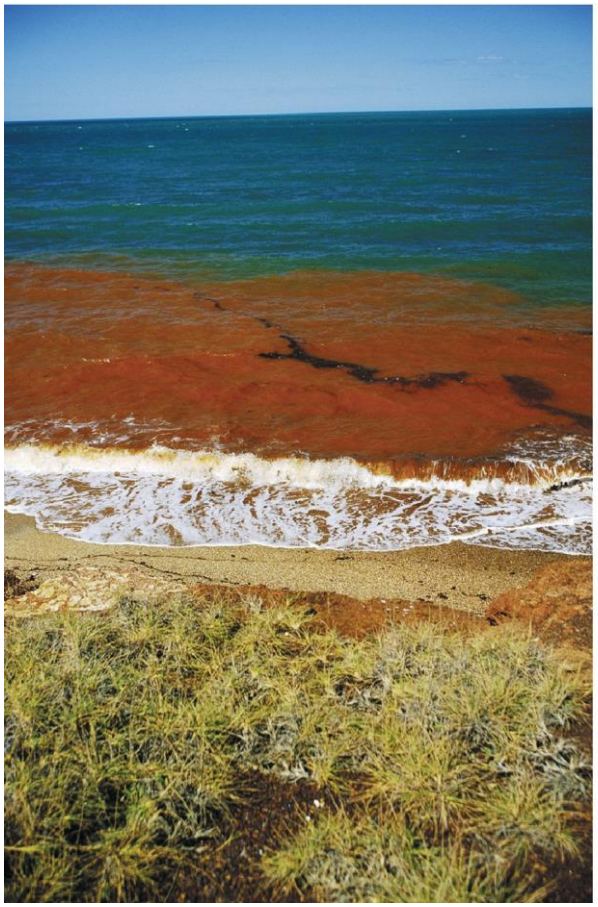
- Chronic *in utero* exposure or short term exposure during specific time *in utero* can cause lifelong effects
  - Brain development, central nervous system, everything
- California study – pregnant women and pesticide exposure (2003)
  - Delayed mental and general development
- Current problem includes lead in city soils

Ecotoxicology

- Dilution Paradigm is *not* valid
  - "Dilution is the solution to pollution"
- Boomerang Paradigm is accepted
  - "What you throw away can come back and hurt you"
- Ecotoxicology
  - The study of contaminants in the biosphere and their harmful effects on ecosystems
  - Helps policy makers determine costs and benefits of industrial and technological "advances"

Case Study: The Ocean

- Land based nutrient and pollution runoff into ocean is affecting microorganisms
- Ex: Red Tide
  - Red pigmented poisonous algal blooms
  - Toxins kill off fish and make humans sick



Bill Bachman/Science Source

Risk Assessment

- Risk- probability that a particular adverse effect will result from some exposure or condition
- We assess risk daily with four steps
  1. Hazard identification
  2. Dose response assessment
  3. Exposure assessment
  4. Risk characterization
- Precautionary Principle
  - No action should be taken when science is inconclusive but risks are unknown
    - Not allowed into products, etc.

Risk Assessment

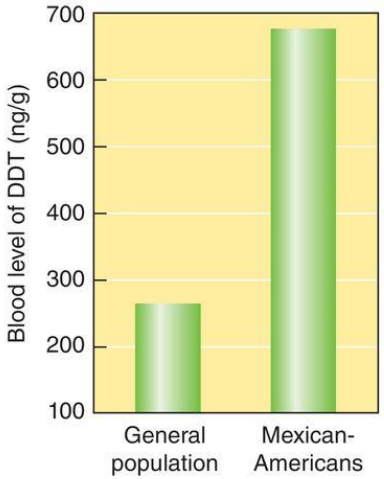
1 Hazard identification
Does exposure to substance cause increased likelihood of adverse health effect such as cancer or birth defects?

2 Dose-response assessment
What is the relationship between amount of exposure (dose) and seriousness of adverse health effect? A person exposed to a low dose may have no symptoms, whereas exposure to a high dose may result in illness.

3 Exposure assessment
How much, how often, and how long are humans exposed to a substance in question? Where humans live relative to emissions is also considered.

4 Risk characterization
What is probability of individual or population having adverse health effect? Risk characterization evaluates data from dose-reponse assessment and exposure assessment. Risk characterization indicates that Mexican-Americans, many of whom are agricultural workers, are more vulnerable to pesticide exposure than other groups (see photo and graph).

Agricultural workers have a greater than average exposure to chemicals such as pesticides. (Sisse Brimberg/National Geographic Image Collection)



Risk Assessment

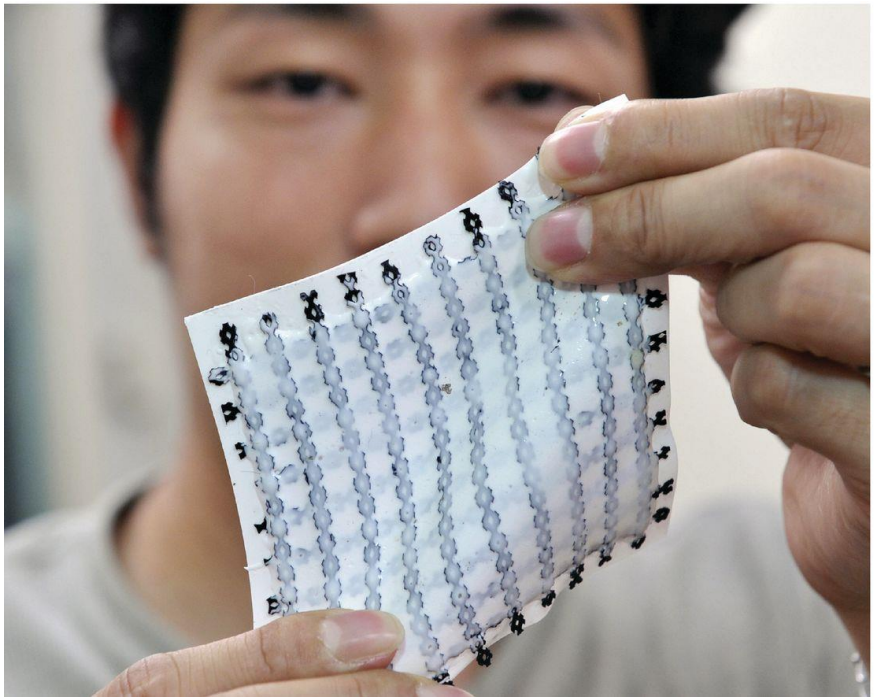
Table 7.5 Probability of Death by Selected Causes for a U.S. Citizen

Cause of Death	*One-Year Odds**	*Lifetime Odds**
Cardiovascular disease	1 in 300 (3.3×10^{-3})	1 in 4 (2.5×10^{-1})
Cancer, all types	1 in 510 (2.0×10^{-3})	1 in 7 (1.4×10^{-1})
Motor vehicle accidents	1 in 6700 (1.5×10^{-4})	1 in 88 (1.1×10^{-2})
Suicide	1 in 9200 (1.1×10^{-4})	1 in 120 (8.3×10^{-3})
Homicide	1 in 18,000 (5.6×10^{-5})	1 in 240 (4.2×10^{-3})
Killed on the job	1 in 48,000 (2.1×10^{-5})	1 in 620 (1.6×10^{-3})
Drowning in bathtub	1 in 840,000 (1.1×10^{-6})	1 in 11,000 (9.1×10^{-5})
Tornado	1 in 3,000,000 (3.3×10^{-7})	1 in 39,000 (2.6×10^{-5})
Commercial aircraft	1 in 3,100,000 (3.2×10^{-7})	1 in 40,000 (2.5×10^{-5})
Hornet, wasp, or bee sting	1 in 6,100,000 (1.6×10^{-7})	1 in 80,000 (1.3×10^{-5})

*Probability of risk is in parentheses.
Probabilities calculated by L. Berg from multiple sources.

Ecological Risk Assessment

- Speed of new technologies, chemicals
  - How may these affect us?
  - Nanotechnology and nanomaterials
- Fractional risk attribution



YOSHIKAZU TSUNO /AFP/ GettyImages Inc

Ecological Risk Assessment

- Difficult to assess because effect occur at wide range of scales
  - Individual plants and animals
  - Ecological communities over wide regions
- Human-induced environmental stressors also range greatly
- There is a need to quantify risks to the environment