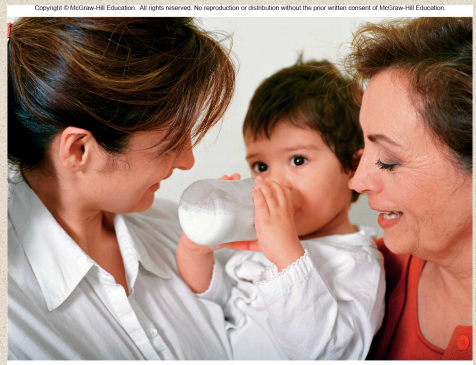
Environmental Health and Toxicology



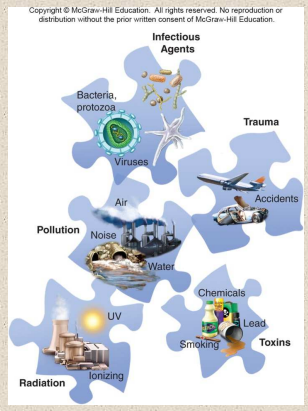
Outline

- Environmental Health
  - Infectious and Emergent Diseases
  - Antibiotics and Pesticide Resistance
- Toxicology
- Movement, Distribution, and Fate of Toxins
- Toxicity and Risk Assessment
- Establishing Health Policy

Environmental Health

- Health - a state of complete physical, mental, and social well-being
- Disease - an abnormal change in the body's condition that impairs physical or psychological function
- Diet and nutrition, infectious agents, toxic chemicals, genetics, trauma and psychological stress all play roles in morbidity (illness) and mortality (death).

Environmental Health Risks



What are Risks?

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

Global Disease Burden

- **Life expectancy increasing as infant mortality decreases.**
- **Disability-adjusted life years (DALYs) - combine premature deaths and loss of healthy life resulting from illness or disability**
- **Chronic conditions account for premature death and disease in both developed and developing countries today.**
  - **By 2020, heart disease may become the leading source of disability and disease worldwide. Global cancer rates will increase by 50%.**

Global Disease Burden

- Diabetes is on the increase. One-third of children born in North America today will develop diabetes in their lifetime due to poor diet and little exercise.
- WHO projects that psychological conditions could increase their share of the global disease burden from 10% currently to 15%.
  - Depression will be the second largest cause of all years lived with disability.
- Tobacco related lung diseases are increasing. Biggest single cause of death worldwide.

Infectious Diseases

- Communicable diseases are still responsible for about 1/3 of all disease-related deaths.
  - Majority in countries with poor nutrition, sanitation, and vaccination
- New diseases test our defenses in developed countries.
- Better nutrition, clean water, improved sanitation and inoculation of children could eliminate most of the deaths.

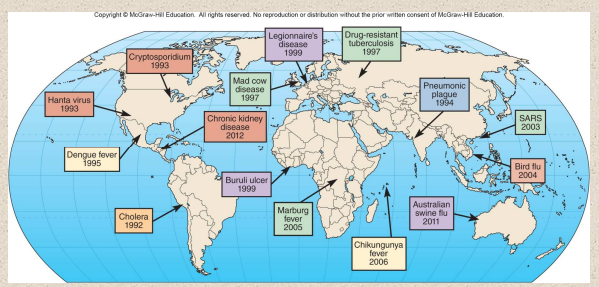
Pathogens

- Pathogens are disease-causing organisms. They include:
  - Viruses
  - Bacteria
  - Protozoans
  - Parasitic worms including flukes
- Greatest loss of life in a single year from a pathogen was in 1918 when the flu epidemic killed 50 to 100 million people worldwide.
- Malaria is a major disease in tropical areas. About 600,000 people die each year.

Emergent Diseases

- An emergent disease is one not previously known, or one which has been absent for at least 20 years.
  - Bird flu
  - Ebola fever
  - HIV

Recent Human Disease Outbreaks



Conservation Medicine Combines Ecology and Health Care

- Ecological diseases - animal epidemics
  - White nose syndrome in bats is due to a fungus recently introduced into the eastern US
  - California sea lions have herpes 1 virus spread to them from human sewage.
  - An imported fungus is killing oak, redwoods, and Douglas fir trees in California.
  - Dermo, a parasite of oysters, is spreading rapidly along the east coast due to climate warming.
- Conservation medicine – examines

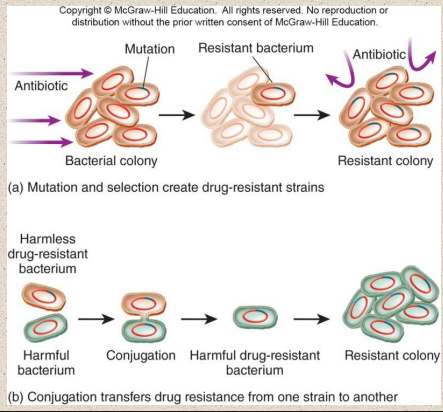
Pesticide Resistance

- **The protozoan parasite that causes malaria is now resistant to most antimalaria drugs, while the mosquitoes that transmit the protozoan have developed resistance to many insecticides.**
  - **Natural selection and the ability of organisms to evolve rapidly**
  - **Human tendencies to overuse pesticides speeds up this process.**

Antibiotic Resistance

- **Antibiotics are chemicals that kill or inhibit the growth of bacteria**
- **Many people do not finish the full-course, creating resistant strains of bacteria.**
  - ❖ Antibiotic resistant strains of MRSA are spreading through hospitals in the US and China resulting in thousands of deaths. In the US over 19,000 deaths are estimated to have occurred from over 100,000 MRSA infections.
- **At least half of the 100 million antibiotic doses prescribed in the U.S. every year are unnecessary or are the wrong drug.**
- ❖ **Antibiotics are routinely fed to U.S. farm animals to stimulate weight gain. These are excreted in urine and feces, and find their way into surface waters where they create more antibiotic resistance.**

Antibiotic Resistance



Toxicology

- Toxicology is the study of poisons and their effects on living systems.
- Dangerous chemicals are divided into two broad categories:
  - Toxic – known poisons that damage or kill cells/tissues
    - Can be general or very specific. Often harmful even in dilute concentrations.
  - Other Hazards - dangerous but not toxic
    - Flammable, explosive, irritant, acid, caustic
- Ecotoxicology deals with the interactions, transformation, fate, and effects of natural and synthetic chemicals in the biosphere.

Toxins

- Allergens - substances that activate the immune system
  - Antigens - substances that are recognized as foreign by white blood cells and stimulate the production of specific antibodies
    - Other allergens act indirectly by binding to other materials so they become antigenic.
    - For example, formaldehyde and carbon monoxide that cause Sick Building Syndrome

Toxins

- Immune System Depressants - pollutants that depress the immune system
- Endocrine Disrupters - disrupt normal hormone functions
  - Environmental estrogens - environmental contaminants (e.g., BPA, dioxins) which cause reproductive problems in animals even at very low doses

Toxins

- Neurotoxins - metabolic poisons that specifically attack nerve cells; most are extremely toxic and fast acting.
  - Different types act in different ways.
    - Heavy Metals kill nerve cells.
    - Anesthetics and Chlorinated Hydrocarbons disrupt nerve cell membranes.
    - Organophosphates and Carbamates inhibit signal transmission between nerve cells.

Toxins

- Mutagens - Agents that damage or alter genetic material. Can lead to birth defects or tumors.
- Teratogens - specifically cause abnormalities during embryonic growth and development
  - Alcohol - Fetal Alcohol Syndrome
- Carcinogens - substances that cause cancer
  - Cancer is the 2nd leading cause of death.
  - 1 in 2 males and 1 in 3 females in the U.S. will have cancer in their lifetime.

Diet

- Correlation between a high fat/high salt diet and cardiovascular disease
- Fruits, vegetables, whole grains, complex carbohydrates, and fiber are beneficial.
- Sixty percent of all U.S. adults are now considered overweight.
- U.S. Centers for Disease Control warn one in three U.S. children are at risk of becoming diabetic.

Toxic Chemicals

- Fatal to over 50% of test subjects at given concentrations.
  - Ex: Dioxin, mercury cyanide, benzene chloroform
  - Kill cell or impair their function

Hazardous Chemicals

- Flammable, explosive, corrosive

Mutagens

- Chemicals or radiation that cause mutations

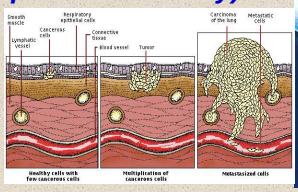
Table II. Partial list of chemicals evaluated with Mutatox and Ames Test for genotoxicity.

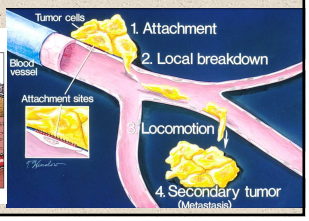
Compound	Mutatox	Ames
Aflatoxin B1	Positive	Positive
2-Aminoanthracene	Positive	Positive
2-Aminoflurorene	Positive	Positive
9-Aminoacridine	Positive	Positive
Benzene*	Positive	Negative
Benzidine	Positive	Positive
Benzoin*	Negative	Negative
Benzo(a)pyrene	Positive	Positive
Captan	Positive	Positive
2-Chloroethanol*	Positive	Positive
Cyclophosphamide	Positive	Positive
1,2-Dichloropropane	Positive	Positive
1,3-Dichloropropene	Negative	Positive
Dioxane	Negative	Negative
Ethylene glycol	Negative	Negative
8-Hydroxyquinoline*	Positive	Positive
Lindane	Negative	Negative
Monuron*	Postive	Negative
3-methylcholanthrene	Postive	Positive
Nalidixic acid	Positive	Negative
Pyrene	Postive	Negative

* Designated National Toxicology Program Chemical

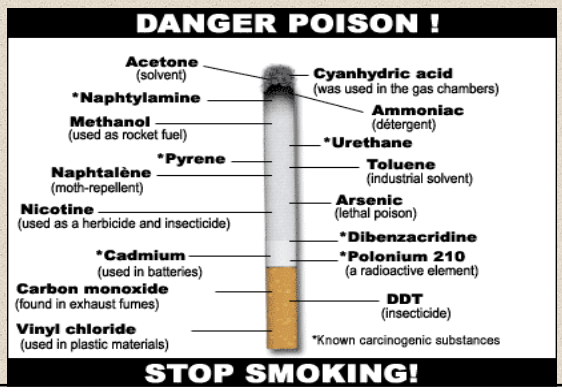
Carcinogens

- Chemicals, radiation or viruses that cause malignant (cancerous) tumors.
- Cancer: Cells cannot regulate their growth, divide uncontrollably, and ***metastasize (break off from tumors and travel to other parts of the body).***





*Carcinogens in Cigarette



Carcinogens

- 2nd highest cause of death in the U.S.
- Rates of cancer survival are increasing

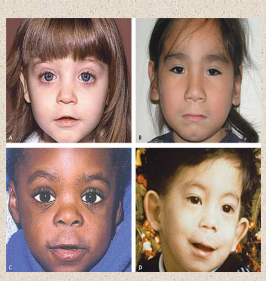
Centers for Disease Control and Prevention

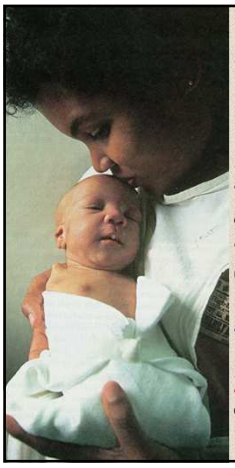
Number of deaths for leading causes of death

- Heart disease: 596,577
- Cancer: 576,691
- Chronic lower respiratory diseases: 142,943
- Stroke (cerebrovascular diseases): 128,932
- Accidents (unintentional injuries): 126,438
- Alzheimer's disease: 84,974
- Diabetes: 73,831
- Influenza and Pneumonia: 53,826
- Nephritis, nephrotic syndrome, and nephrosis: 45,591
- Intentional self-harm (suicide): 39,518

Teratogens

- **Chemicals, radiation, viruses that cause birth defects during pregnancy**
  - **ex. Alcohol**
- **Fetal Alcohol Syndrome mental defects, developmental delays, behavioral problems**



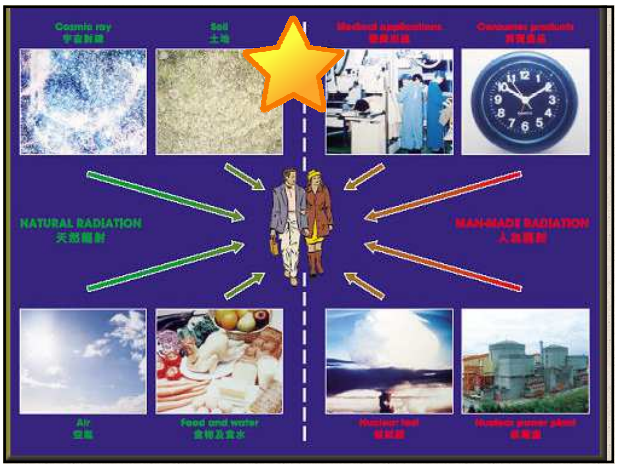


Teratogen - Thalidomide

- **1960's: thalidomide prescribed as a sleeping pill in Europe.**
- **Caused abnormal fetal development resulting in incomplete limb development**
- ***12,000* thalidomide babies were born**
- **US Food and Drug Assoc. had safety concerns so didn't approve it in the USA**

Ionizing Radiation

- Radiation causes atoms to become ionized.
- Health Effects:
  - impair the functioning of tissues and/or organs
  - can produce acute effects such as skin redness, hair loss, radiation burns.



Neurotoxins

- Attack the Nervous System
- Chlorinated hydrocarbons (DDT)
- Heavy metals (Lead, Mercury)
- Organophosphates (Malathion)

Long Beach Island, NY, July, 8, 1945

Bioaccumulation and Biomagnificatio

(within individual) (moving up food chain)

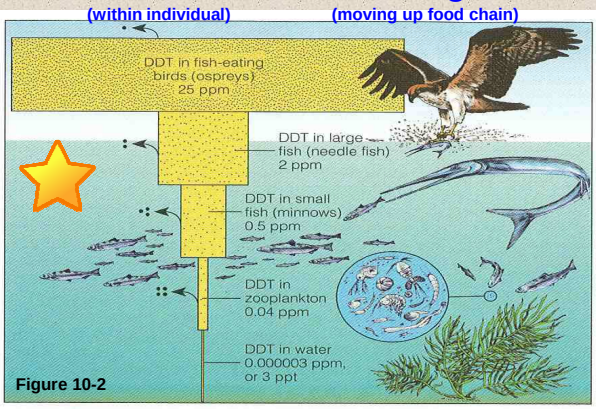
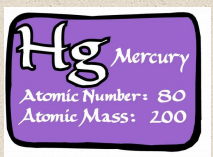


Figure 10-2

•Heavy-Metal Poisoning

"Minimata Disease" or "Mad as a Hatter"

Mercury is Fat Soluble



Bioaccumulation and Biomagnificatio

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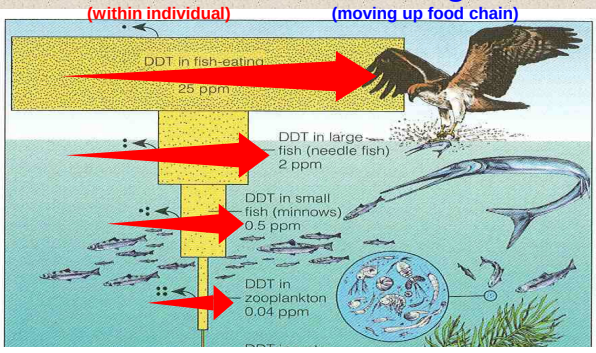
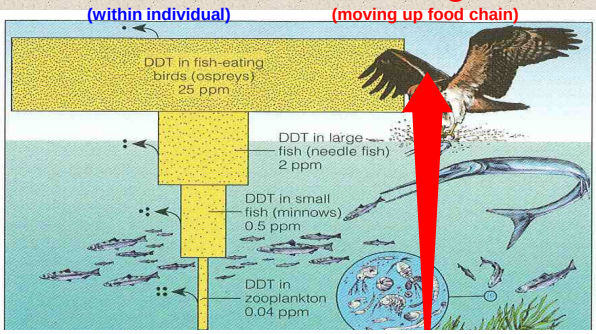


Bioaccumulation: Fat Soluble toxins increase in an individual organisms as more toxin is ingested

Bioaccumulation and Biomagnificatio

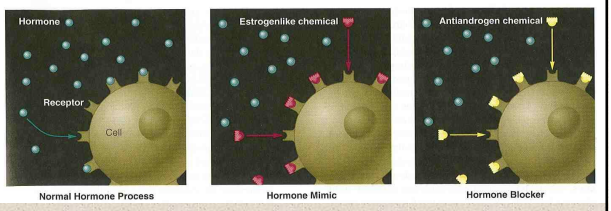
(within individual) (moving up food chain)



Bioaccumulation: Animals higher up on the food chain have higher levls of toxins because they are longer lived and have consumed more prey containing small amounts.

Hormone Mimics and Disrupters

Figure 10-4



These chemicals prevent natural hormones from attaching to their receptors. (dioxins, PCB's, plastics, pesticides, lead, mercury, BPA)

click here

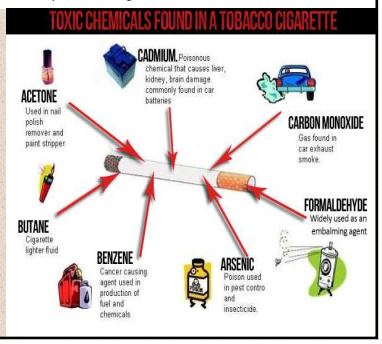
Respiratory Fibrotic Agents

- **Irritants that damage/scar lung tissue ex. Coal dust causing black lung (coal) asbestosis, brown lung (cotton)**

Cigarette smoking causes about one of every five deaths in the United States each year.[1,6] Cigarette smoking is estimated to cause the following:[1]

- More than 480,000 deaths annually (including deaths from secondhand smoke)

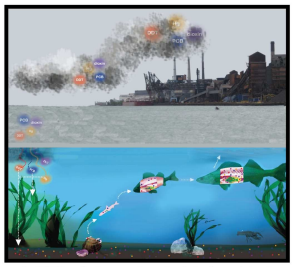
- **Nation's leading cause of preventable death**
- **30% of cancers caused by smoking.**
- **1,300 deaths per day.**



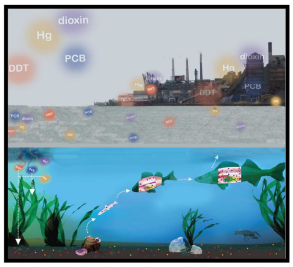
Persistence and Chemical Interactions

- ***Persistent Chemicals – Last a very long time in the environment. DDT, Hg, Dioxin, PCB's.***

Persistent Chemicals in Action



In 1970, a factory puts out a lot of persistent chemicals through its smoke stacks.



In 2011, the factory has pollution control devices on its smoke stacks, but the chemicals put out in past years still remain behind.

Biological Hazards

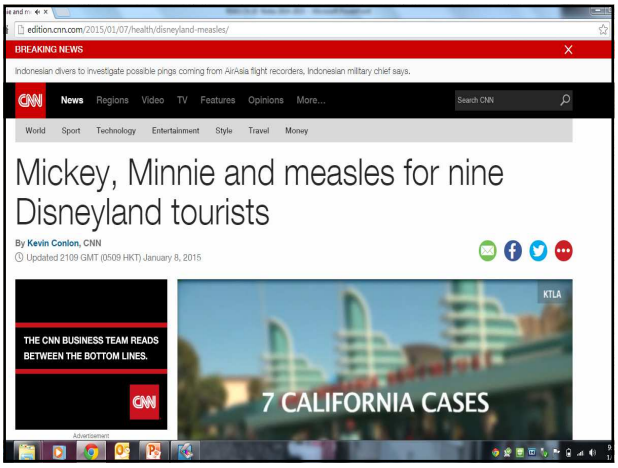
- **Living Pathogens**
  - **spread by air, water, food, body fluids**
  - **Ex: bacteria, virus, protozoa.**

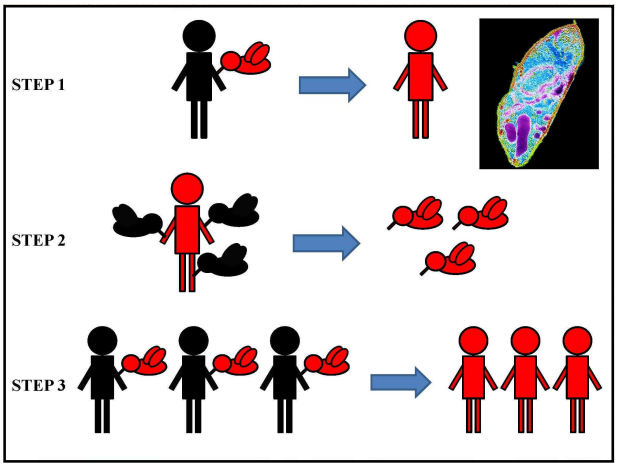
Amoebic dysentery

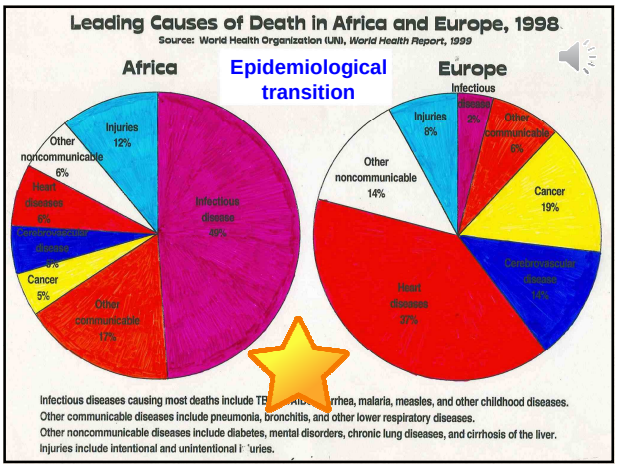
Seven Most Deadly Infectious Diseases

Disease (type of agent)	Deaths per year
Pneumonia and flu (bacteria and viruses)	3.2 million
HIV/AIDS (virus)	3.0 million
Diarrheal diseases (bacteria and viruses)	1.9 million
Tuberculosis (bacteria)	1.7 million
Malaria (protozoa)	1 million
Hepatitis B (virus)	1 million
Measles (virus)	800,000

Table 10-2







Movement, Distribution, and Fate of Toxins

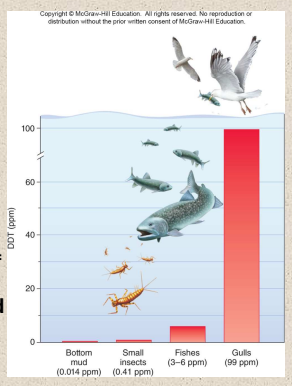
- Solubility - one of most important characteristics in determining the movement of a toxin
- Chemicals are divided into two major groups:
  - Those that dissolve more readily in water
  - Those that dissolve more readily in oil
  - Water soluble compounds move rapidly through the environment and have ready access to cells via tissue fluid.
  - Fat soluble compounds need a carrier to move through the environment, but once inside the body they penetrate tissues easily and cross cell membranes. They are stored in body fat and persist for many years.

Exposure and Susceptibility

- Airborne toxins generally cause more ill health than any other exposure.
  - Lining of lungs easily absorbs toxins.
- Food, water and skin contact are other ways to be exposed to toxins.
- Largest toxin exposure reported in industrial settings
- Condition of organism and timing of exposure also have strong influences on toxicity. Children more vulnerable than adults.

lation and Biomagnifi cation

- Bioaccumulation - selective absorption and storage of toxins
  - Dilute toxins in the environment can build to dangerous levels inside tissues.
- Biomagnification - Toxic burden of a large number of organisms at a lower trophic level is accumulated and concentrated by a predator at a higher trophic level. Example: DDT



Persistence

- Some chemical compounds are very unstable and degrade rapidly under most conditions, thus their concentrations decline quickly after release. For example, most modern pesticides.
- Others are more persistent. The stability of these substances such as metals and BPA can cause problems as these toxins may be stored for a long period of time and spread to unintended victims.

Some Examples of Persistent Organic Pollutants

- Flame retardants (PBDE) are now found in humans and other species everywhere in the world. Harm children's reproductive and nervous systems.
- Chemicals used in non-stick plastic coatings (PFOS and PFOA) are infinitely persistent in the environment and found in your blood. Cause liver damage and cancer.
- Phthalates found in plastics mimic estrogen and are linked to reproductive abnormalities and reduced fertility.

Chemical Interactions

- Antagonistic Reaction - one material interferes with the effects, or stimulates the breakdown, of other chemicals
- Additive Reaction - effects of two chemical occurring together are added to one another
- Synergistic Reaction - one substance exacerbates the effect of the other
  - For example: Asbestos exposure increases risk of lung cancer 20X; smoking has same risk. But together, they increase risk 400X.

Mechanisms for Minimizing Toxic Effects

- Every material can be poisonous under certain conditions.
  - Most chemicals have a safe threshold under which their effects are insignificant.
- Metabolic Degradation
  - In mammals, the liver is the primary site of detoxification of both natural and introduced poisons.
    - Sometimes compounds that are harmless can be broken down into products that are harmful.

Excretion and Repair

- Effects of waste products and environmental toxins reduced by eliminating via excretion.
  - Breathing
  - Urine
- Tissues and organs often have mechanisms for damage repair by cellular reproduction.
  - Any irritating agent can be potentially carcinogenic because the more times that cells divide, the greater the chance that they will have a mistake (mutation) while copying their DNA. This can lead to cancer.

Measuring Toxicity

- Animal Testing
  - Most commonly used and widely accepted toxicity test is to expose a population of laboratory animals to measured doses of specific toxins.
- Humanitarian concerns in using animals
- Different individuals have different sensitivities to the same toxin. Should we aim to protect the average person or the most sensitive?

Complications in Measuring Toxicity

- **Dose Response Curves not symmetrical**
  - **LD50 - dose at which 50% of the animal test population dies**
- **Unrelated species can react quite differently to the same toxin due to differences in physiology and metabolism.**
- **These variations make it difficult to estimate the risk to humans.**

Toxicity Ratings

- **Moderate toxin takes about (1) g/kg of body weight to produce a lethal dose.**
  - **Very toxic materials require about 10% of that amount.**
    - **Extremely toxic materials require 1% of that amount.**
      - Supertoxic chemicals can be lethal in a dose of a few micrograms (an amount invisible to the naked eye).

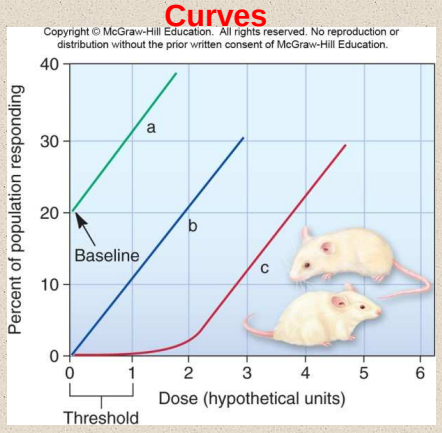
Toxicity Ratings

- **Many carcinogens, mutagens, and teratogens are dangerous at levels far below their direct toxic effect because abnormal cell growth exerts a form of biological amplification. One cell mutated by a toxin can form a tumor that kills the individual.**

Acute versus Chronic Doses and Effects

- Acute Effects - caused by a single exposure and results in an immediate health problem
- Chronic Effects - Long-lasting, perhaps permanent. Can be result of single large dose or repeated smaller doses.
  - Also refer to long-lasting exposures as chronic
  - Difficult to study the effects of chronic exposure since aging or other diseases may be acting as well.

Three Possible Dose-Response Curves



Thresholds

- The Delaney Clause of the U.S. Food and Drug Act forbids the addition of any amount of known carcinogens to food and drugs.
- This standard was impossible to meet and was replaced in 1996 by a “no reasonable harm” requirement defined as less than one cancer for every million people exposed over a lifetime.

Risk Assessment and Acceptance

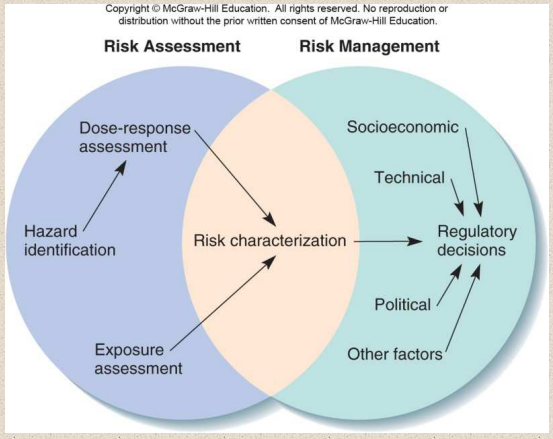
- Risk - possibility of suffering harm or loss
- Risk Assessment - scientific process of estimating the threat that particular hazards pose to human health
  - Risk Identification
  - Dose Response Assessment
  - Exposure Appraisal
  - Risk Characterization

Risk Assessment is not Rational

- Interested parties tend to downplay or emphasize risks to suit their agenda.
- We tend to tolerate risks we choose, while objecting to risks that we cannot control.
- Most people do not understand probability.
- Personal experience can be misleading.
- We have an exaggerated view of our own abilities. Most people consider themselves above average drivers.
- News media over-report sensational events and under-report mundane events, skewing our perception of their frequency.
- Irrational fears can lead to overestimation of danger

Risk Acceptance

- People will tolerate a high probability of an occurrence if the harm caused is low.
- Great harm is acceptable only at very low levels of frequency.
- For most people, a 1 in 100,000 chance of dying is a threshold for changing behavior.
- Environmental Protection Agency assumes that a risk of 1 in 1 million is acceptable for environmental hazards.
  - Risk of dying of lung cancer if you smoke is 1 in 4, while risk of drinking water contaminated with the limit of trichloroethylene is 1 in 10 million. Yet many people are focused on the latter



Lifetime Chance of Dying in the U.S.

Table 8.3 Lifetime Chances of Dying in the United States

Source	Odds (1 in x)
Heart disease	6
Cancer	7
Stroke	29
Motor vehicle accident	98
Intentional self-harm	109
Unintentional poisoning	126
Falls	163
Firearm assault	321
Pedestrian accidents	701
Motorcycle accident	761
Drowning	1,103
Fires	1,344
Bicycle accidents	4,381
Firearm accidental discharge	6,609
Storms	29,196
Bee, wasp, or hornet stings	79,842
Lightning strikes	134,906
Dog bites	144,899
Floods	589,896

Establishing Health Policy

- It is difficult to separate the effects of multiple hazards and evaluate their risks accurately, especially when exposures are near the threshold of measurement and response.
- In setting standards, we should consider:
  - combined effects of exposure
  - different sensitivities
  - effects of chronic as well as acute exposure
- Not reasonable to be protected from every contaminant no matter how small the risk
- We must consider the effects on other organisms that define and maintain our environment.

The End