Human Health, Pollution and Toxicology

Diseases

- Disease is often due to an imbalance between individuals and their environment.
  - Continuum from state of health to disease
  - Gray in-between zone between health and disease
  - As a result of exposure to chemicals in the environment we may be in the midst of an epidemic of chronic disease.

Diseases

- Seldom have a one-cause- one-effect relationship w/ the environment
- Depends on several factors
  - Physical environment
  - Biological environment
  - Lifestyle

Diseases

- Chances of experiencing serious environmental health problems and disease depends on
  - The water we drink
  - The air we breathe
  - The soil we grow crops in
  - The rocks we build our homes on

Diseases

- Natural processes can release harmful materials into the soil, water or air.
- Lake Nyos in Cameroon, Africa
  - Experienced sudden release of carbon dioxide
  - Killed 1,800 people in near by town.

Terminology

- Pollution refers to the occurrence of unwanted change in the environment
  - introduction of harmful or toxic materials into the surroundings
- Contamination
  - similar to that of pollution
  - implies making something unfit for a particular use through the introduction of toxic materials

Terminology

- Toxic refers to materials (pollutants) that are poisonous to people and other living things.
  - Toxicology is the science that studies chemicals that are known to be or may be toxic based upon animal studies.
- Carcinogen - a kind of toxin that increases the risk of cancer.
  - Most feared and regulated toxins in our society.

Infectious Agents

- Infectious disease
  - Spread by interactions between individuals and through food, water, air or soil.
  - Can travel globally via airplanes
  - New diseases emerging and previous ones reemerging
  - Some infectious diseases can be controlled by manipulating the environment

Environmentally Transmitted Infectious Diseases

- Legionellosis
  - Occurs where air-conditioning systems have been contaminated by disease-causing organisms.
- Giardiasis
  - a protozoan infection of the small intestine spread via food, water, or person-to-person contact. Spread by fecal material
- Salmonella
  - a food-poisoning bacterial infection spread via water or food. Also found in enteric (intestinal) systems

Environmentally Transmitted Infectious Diseases

- Malaria
  - a protozoan infection transmitted by mosquitoes. (Usually tropical areas)
- Lyme disease
  - Transmitted by ticks.
- Cryptosporidosis
  - a protozoan infection transmitted via water or person-to-person contact.
- Anthrax
  - Bacterial infection spread by terrorist activity, though it is naturally occurring in agricultural areas where it is generally non-pathogenic

Toxic Heavy Metals

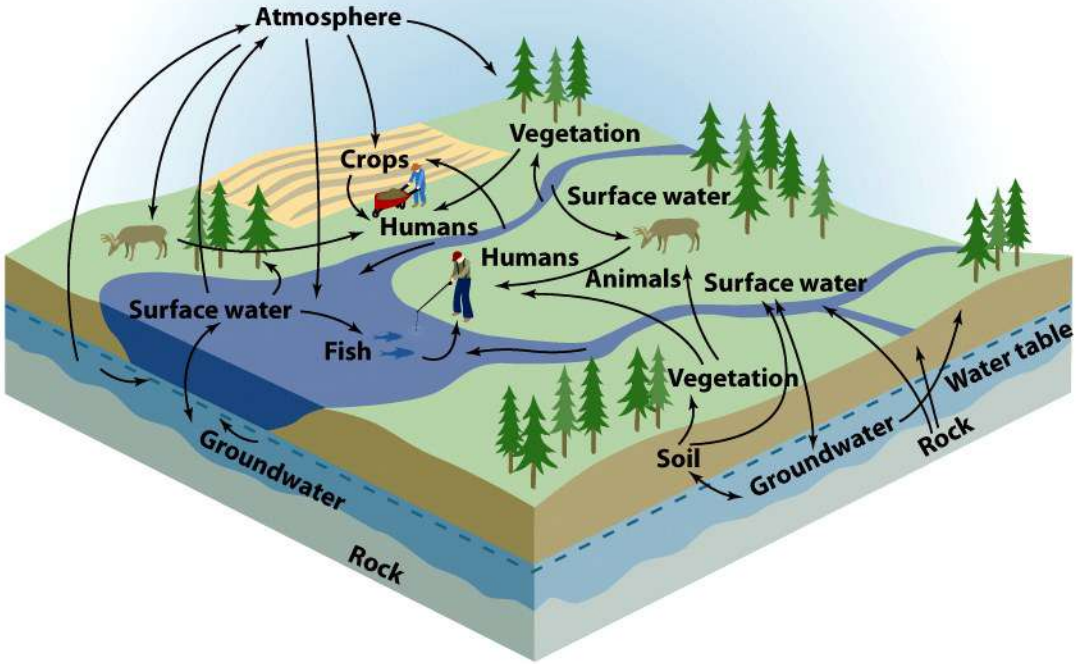
- The major heavy metals that pose health hazards to people and ecosystems include:
  - mercury, lead, cadmium, nickel, gold, platinum, silver, bismuth, arsenic, selenium, vanadium, chromium, and thallium.
- Each may be found in soil and water not contaminated by humans, though they are also found in extreme environments such as deep sea vents and hot springs

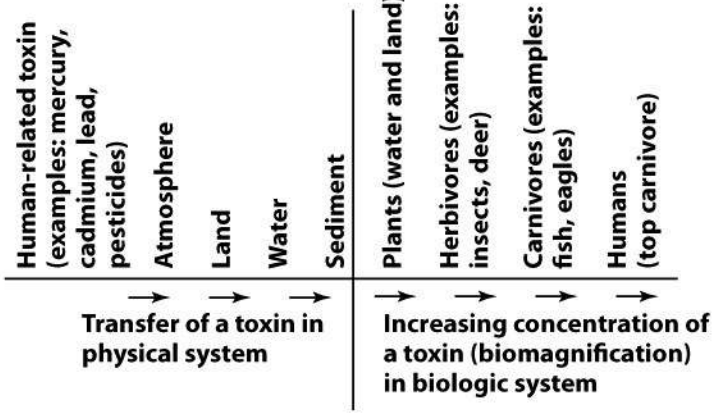
Toxic Heavy Metals

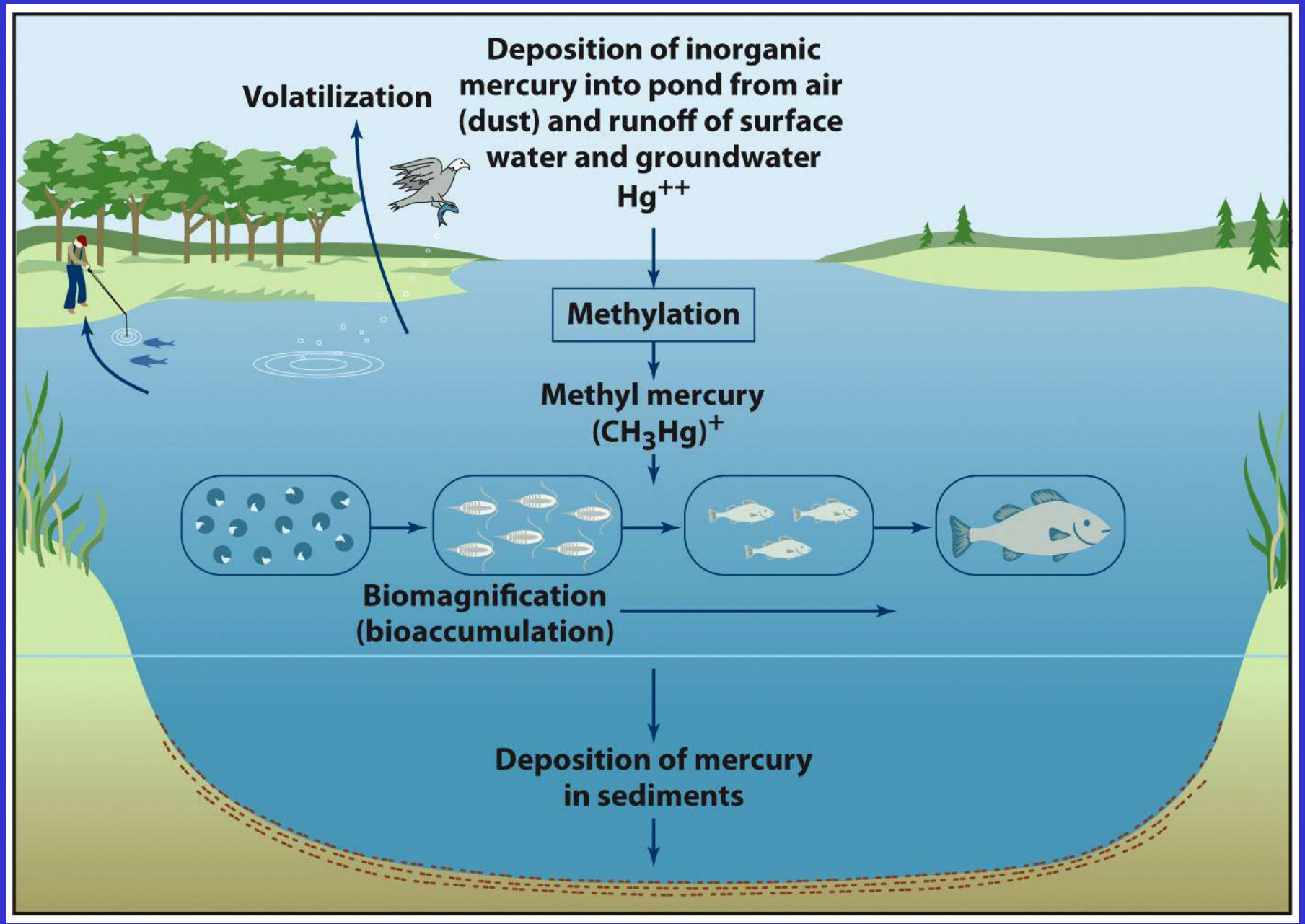
- Often have direct physiological effects.
  - Stored and incorporated in living tissue
    - Fatty body tissue
  - Content in our bodies referred to as body burden.
  - Central nervous system is often affected (Mercury and Lead))
  - Associated with birth defects as well

Toxic Pathways

- Chemical elements can become concentrated
- Biomagnification-
  - the accumulation or increase in concentration of a substance in living tissue as it moves through the food chain.
  - E.g. Cadmium, mercury are biomagnified


Atmosphere
Vegetation
Crops
Surface water
Humans
Humans
Animals
Surface water
Surface water
Fish
Vegetation
Water table
Groundwater
Soil
Groundwater
Rock
Rock


Human-related toxin (examples: mercury, cadmium, lead, pesticides)
Atmosphere
Land
Water
Sediment
Plants (water and land)
Herbivores (examples: insects, deer)
Carnivores (examples: fish, eagles)
Humans (top carnivore)
Transfer of a toxin in physical system
Increasing concentration of a toxin (biomagnification) in biologic system


Volatilization
Deposition of inorganic mercury into pond from air (dust) and runoff of surface water and groundwater
Hg^{++}
Methylation
Methyl mercury
$(CH_3Hg)^+$
Biomagnification (bioaccumulation)
Deposition of mercury in sediments

Organic Compounds

- Organic compounds
  - compounds of carbon produced naturally by living organisms or synthetically by human industrial practices.
- Synthetic organic compounds
  - Used in industrial processes, pest control, pharmaceuticals, and food additives.
  - Over 20 million known compound though most are poorly characterized for their pathogenicity

Persistent Organic Pollutants

- POPs may produce a hazard for decades or hundreds of years.
  - First produced when their harm was not known
  - Now banned or restricted
  - Commonly composed of plastics that are partially decomposed

Table 15.1 Selected Common Persistent Organic Pollutants (POPs)

Chemical	*Example of Use*
Aldrin[a]	Insecticide
Atrazine[b]	Herbicide
DDT[a]	Insecticide
Dieldrin[a]	Insecticide
Endrin[c]	Insecticide
PCBs[a]	Liquid insulators in electric transformers
Dioxins	By-product of herbicide production

Source: Data in part from Anne Platt McGinn, "Phasing Out Persistent Organic Pollutants," in Lester R. Brown et al., *State of the World 2000* (New York: Norton, 2000).

[a] Banned in the United States and many other countries.

[b] Degrades in the environment. It is persistent when reapplied often.

[c] Restricted or banned in many countries.

Persistent Organic Pollutants

- POPs have several properties that define them:
  - They have a carbon-based molecular structure, often containing highly reactive chlorine.
  - Most are synthetic chemicals.
  - They do not easily break down in the environment.

Hormonally Active Agents (HAA's)

- HAA are also POPs.
- Have potential to cause developmental and reproductive abnormalities in animals, including humans.
  - Include a wide variety of chemicals, herbicides, pesticides, phthalates, and PCBs

Hormonally Active Agents

- Evidence in support of hypothesis
  - Alligator populations in Florida exposed to DDT have genital abnormalities & low egg production.
  - Major disorders studied in wildlife have centered on abnormalities including
    - thinning of eggshells of birds (DDT effect), decline in populations of various animals and birds, reduced viability of offspring, and changes in sexual behavior.

Hormonally Active Agents

- In humans
  - HAAs may be linked to breast cancer
  - PCBs and neurological behavior
  - Phthalates and endocrine and hormone disruption
    - Endocrine system helps regulate growth & development

Radiation

- Nuclear radiation is linked to serious health problems
  - Including cancer, as well as acute radiation poisoning. Exposure may be “chronic” as exposure over long periods of time, or “acute” as shorter/lethal exposure

Thermal Pollution

- Heating river water changes natural conditions and disturbs the ecosystem
  - Fish spawning cycles may be disrupted
  - Fish may have heightened susceptibility to disease.
  - Physical stress on fish
  - Easier prey
  - Change in type and availability of food

Particulates

- Small particles of dust released into the atmosphere by many natural processes and human activities.
  - Modern farming
  - Burning oil and coal
  - Dust storms
  - Volcanic eruptions
  - Graineries

Noise Pollution

- Unwanted sound
- Sound is a form of energy that travels as waves

Table 15.2 Examples of Sound Levels

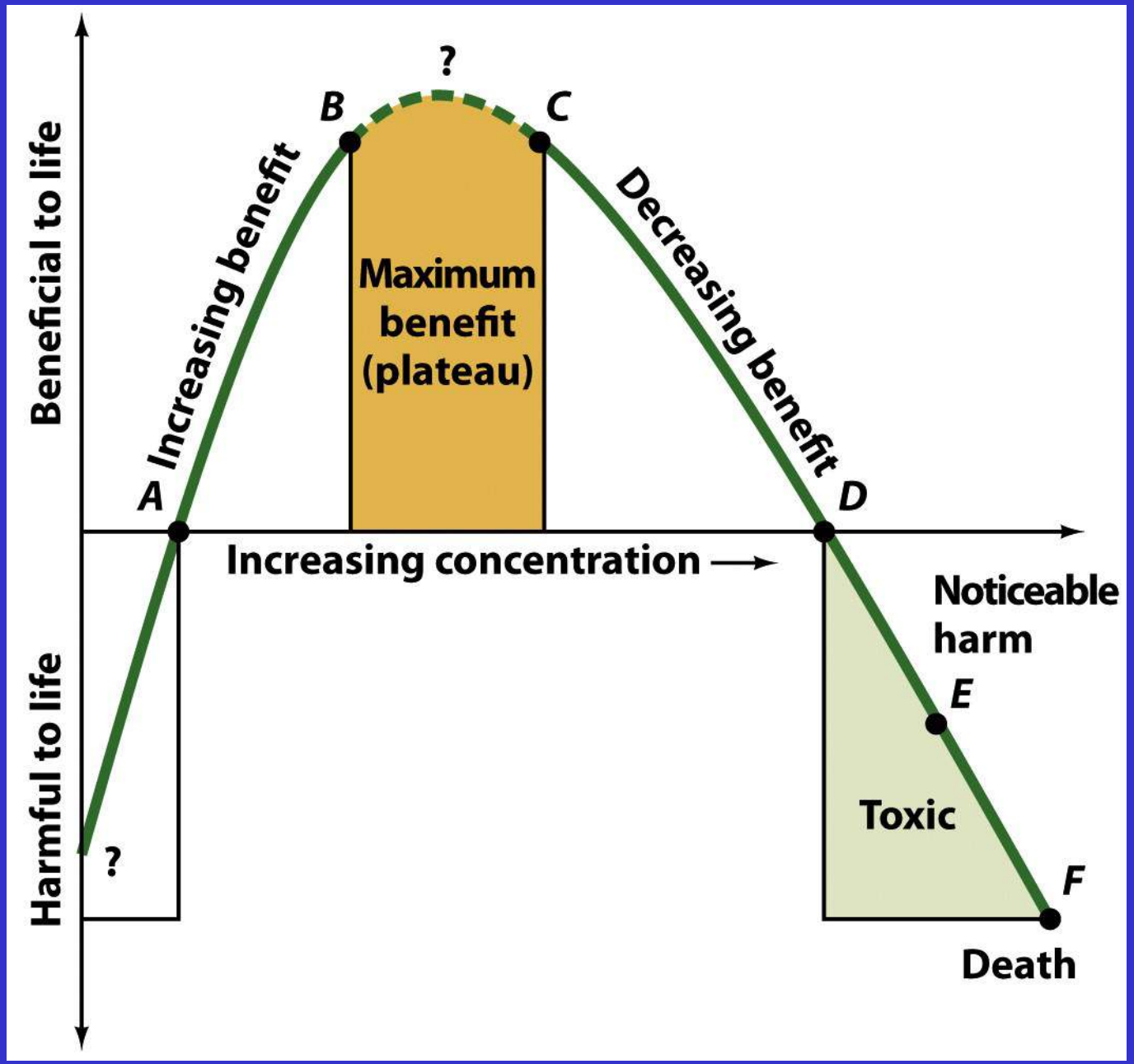
Sound Source	*Intensity of Sound (dB)*	*Human Perception*
Threshold of hearing	0	
Rustling of leaf	10	Very quiet
Faint whisper	20	Very quiet
Average home	45	Quiet
Light traffic (30 m away)	55	Quiet
Normal conversation	65	Quiet
Chain saw (15 m away)	80	Moderately loud
Jet aircraft flyover at 300 m	100	Very loud
Rock music concert	110	Very loud
Thunderclap (close)	120	Uncomfortably loud
Jet aircraft takeoff at 100 m	125	Uncomfortably loud
	140	Threshold of pain
Rocket engine (close)	180	Traumatic injury

Concept of Dose and Response

- Five centuries ago, the physician and alchemist Paracelsus wrote that “everything is poisonous, yet nothing is poisonous.”
- For Example
  - Selenium required in small amounts by living things
  - May be toxic in high concentrations

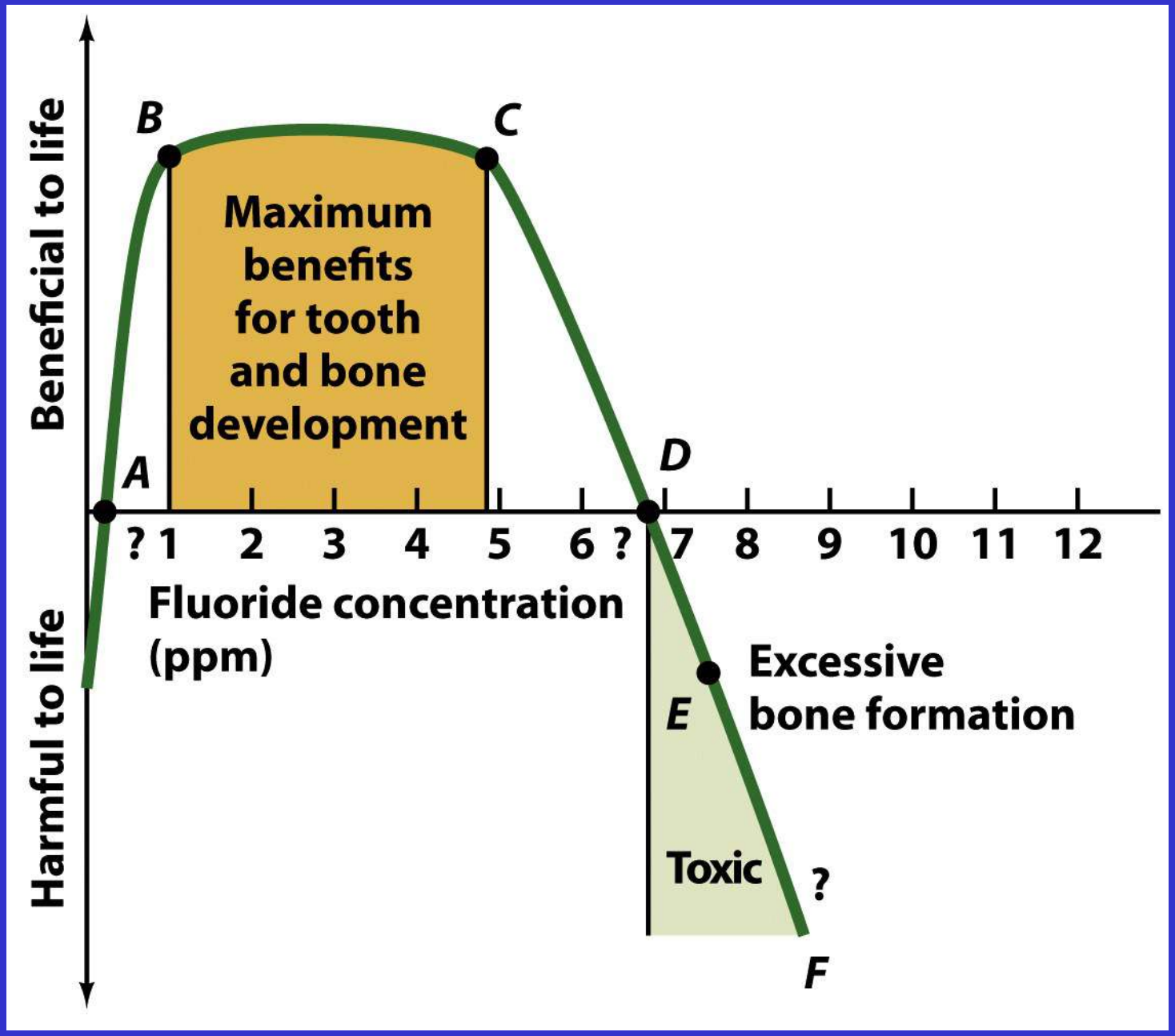
Concept of Dose and Response

- The effect of a chemical on an individual depends on the dose.
  - Dose response
  - Dose dependency can be represented by a generalized dose response curve.


Beneficial to life
Harmful to life
Increasing benefit
Maximum benefit (plateau)
Decreasing benefit
?
B
C
A
D
Increasing concentration
Noticeable harm
E
Toxic
F
Death
?

Concept of Dose and Response

- Doses that are beneficial, harmful, or lethal may differ widely for different organisms and are difficult to characterize.
- E.g. fluoride and dental health
  - Fluorine forms fluoride compounds that prevent tooth decay and promote healthy bone structure.
  - Toxic effects are noticed at concentrations of 6-7 ppm


Beneficial to life
Harmful to life
B
C
Maximum benefits for tooth and bone development
A
D
? 1 2 3 4 5 6 ? 7 8 9 10 11 12
Fluoride concentration (ppm)
Excessive bone formation
E
Toxic
?
F

Dose-Response Curve

- How individuals will respond to a chemical is not known. Therefore…..
- Instead predictions are made about how a percentage of the population will respond to a specific dose.
- Dose at which 50% of the population dies
  - Lethal dose 50, LD-50 is used as a generalized zone where we expect to see toxicity among a population

Table 15.4 Approximate LD–50 Values (for Rodents) for Selected Agents

Agent	*LD-50(mg/kg)*[a]
Sodium chloride (table salt)	4,000
Ferrous sulfate (to treat anemia)	1,520
2,4-D (a weed killer)	368
DDT (an insecticide)	135
Caffeine (in coffee)	127
Nicotine (in tobacco)	24
Strychnine sulfate (used to kill certain pests)	3
Botulinum toxin (in spoiled food)	0.00001

[a] Milligrams per kilogram of body mass (termed mass weight, although it really isn't a weight) administered by mouth to rodents. Rodents are commonly used in such evaluations, in part because they are mammals (as we are), are small, have a short life expectancy, and their biology is well known.

Source: H. B. Schiefer, D. C. Irvine, and S. C. Buzik, *Understanding Toxicology* (New York: CRC Press, 1997).

Dose-Response Curve

- The ED-50 (effective dose 50%) is the dose that causes an effect in 50% of the population of observed subjects.
  - E.g. ED-50 of aspirin would be the dose that relieves headaches in 50% of the people.

Dose-Response Curve

- The TD-50 (toxic dose 50%) is defined as the dose that is toxic to 50% of the population.
  - Often used to indicate responses such as reduced enzyme activity, decreased reproductive success, or onset of specific symptoms.

Tolerance

- The ability to resist or withstand stress resulting from exposure to a pollutant or harmful condition.
  - Result from behavioral, physiological, or genetic adaptation.

Tolerance

- Physiological tolerance- the body of an individual adjusts to tolerate a higher level of pollutant.
  - Many mechanisms including detoxification
    - the toxic chemical is converted to a nontoxic form (Ethanol consumption among humans)
  - Internal transport of the toxin to a part of the body where it is not harmful, such as fat cells.

Tolerance

- Genetic tolerance- (adaptation) when some individuals in a population are naturally more resistant to a toxin than others.
  - Strains of mosquitoes resistance to DDT
  - Antibiotic resistance

Acute and Chronic Effects

- Acute effects – occur soon after exposure.
  - Usually to large amounts of a pollutant or pathogen
- Chronic effects takes place over a long period
  - Often as a result of exposure to low levels of pollutant (asbestos, smoking, coal mining)