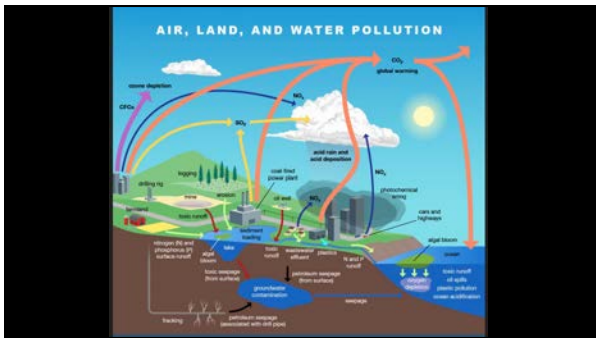
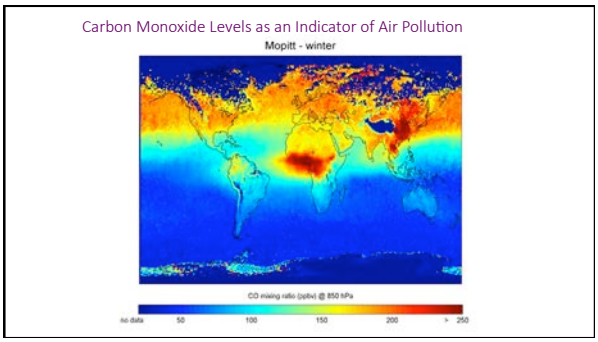
Pollution

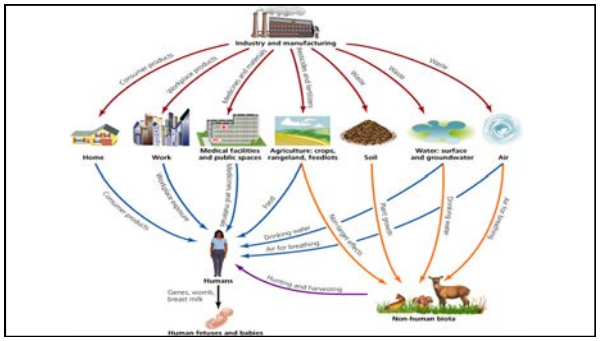
Pollution

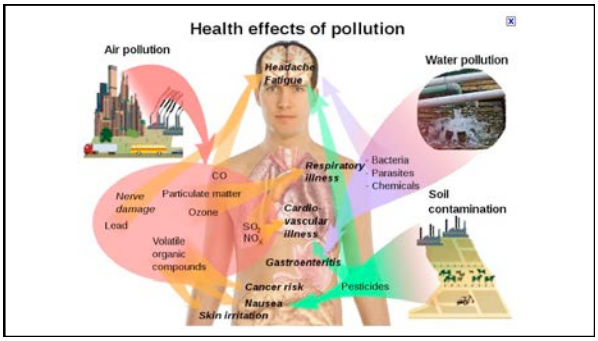
- Contamination of the
  - **Air**
  - **Water**
  - **Soil**
- Contamination by
  - **Toxic chemicals**
  - **Infectious agents**
  - **Excessive eutrophication**
  - **Physical factors**
    - **Thermal**
    - **Light**
    - **Radioactive**
    - **Fouling / clogging / burying**
    - **pH**
    - **Acoustic**



Carbon Monoxide Levels as an Indicator of Air Pollution







Pollution

- Contamination by
  - **Redistribution/concentration of natural compounds**
  - **Synthetic (xenobiotic) compounds**

Redistribution/concentration of natural compounds

Eutrophication

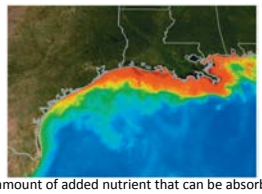


Figure 56.24
A phytoplankton bloom arising from nitrogen pollution in the Mississippi basin that leads to a dead zone

Critical load is the amount of added nutrient that can be absorbed by plants without damaging ecosystem integrity

Nutrients that exceed the critical load leach into groundwater or run off into aquatic ecosystems

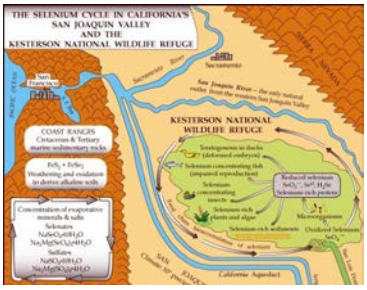
Agricultural runoff and sewage lead to phytoplankton blooms

Decomposition of phytoplankton blooms causes "dead zones" due to low oxygen levels

Redistribution/concentration of natural compounds

Toxic concentration of natural elements via over-irrigation

1. Irrigation water percolates through soil — dissolves trace amounts of selenium
2. Drains into ponds in Kesterson Refuge.
3. Evaporation of ponds concentrates selenium to toxic levels.
4. Lethal and teratogenic impacts on fish and migratory birds



Redistribution/concentration of natural compounds

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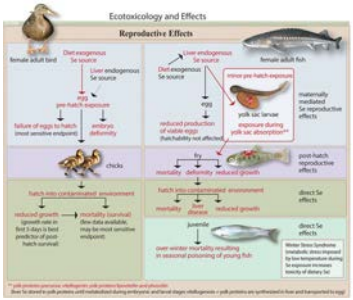
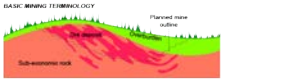
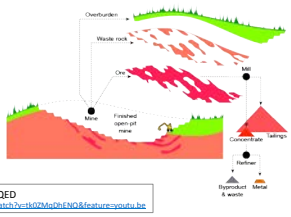


Redistribution/concentration of natural compounds

Toxic concentration of natural elements via mine tailings

1. Tons of ore are ground and slurried with **mercury** or **cyanide** to extract a few ounces of metal.
2. Mud-like "tailings" with concentrated non-target metals dumped in ponds.
3. Contaminated byproduct also dumped.



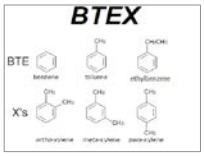


Mercury in the Bay - KQED
https://www.youtube.com/watch?v=tk0ZMqDhENQ&feature=youtu.be

Synthetic Chemicals

People are largely unaware of the health risks of many toxicants.

- Definition : **XENOBIOTIC**
  - a chemical that is foreign to the biosphere i.e. is not produced by a natural biological or abiotic source
  - Also called anthropogenic, man-made, synthetic, pollutant, recalcitrant, persistent, and toxicant
  - Distinguishes between quantity and scale – Gordon Gribble e.g. studied the natural occurrence of organohallogens (chlorbenzoates in fungi) – this is different from large scale chemical processes for the production of PCBs



  - **BTEX** is an acronym for the volatile organic compounds (VOCs): **b**enzene, **t**oluene, **e**thylbenzene, and **x**ylene.
  - BTEX compounds are among the most abundantly produced chemicals in the world, created and used during the processing of petroleum products and during the production of consumer goods such as paints and lacquers, thinners, rubber products, adhesives, inks, cosmetics and pharmaceutical products.
  - The primary man-made releases of BTEX compounds are through emissions from motor vehicles and aircrafts, and cigarette smoke. Benzene is a known carcinogen; all contribute to photochemical smog and respiratory disease.
  - Natural sources of BTEX compounds include gas emissions from volcanoes and forest fires.

Environmental Toxicology

- Studies toxicants that come from or are discharged into the environment, and:
  - ***Health effects on humans***
  - ***Effects on animals***
  - ***Effects on ecosystems***
- Animals are studied:
  - ***For their own welfare***
  - ***To warn of possible effects on humans***

Environmental Toxicology

- Persistent toxins
  - Fat soluble or skeletal
  - Bioaccumulate in individuals
  - Biomagnify in food chains
- Neurotoxins
  - Disrupt neural function
  - Alter behaviors
- Endocrine disruptors
  - Interfere or imitate hormone action
  - Perturb reproduction and/or development
- Mutagens
  - Damage DNA
  - Carcinogenic
- Teratogenic
  - Developmental disorders & birth defects

Persistent Environmental Toxins

Toxin	Sources / comments	Risks
PCBs (polychlorinated biphenyls)	Banned industrial chemical, still persists after decades.	Cancer, impaired fetal brain development
Pesticides	60% of herbicides, 90% of fungicides, 30% of insecticides known to be carcinogenic	Cancer, Parkinson's disease, miscarriage, nerve damage, birth defects, blocking nutrient absorption
Phthalates	Leach from soft plastic food storage containers, etc. Used to stabilize artificial fragrances.	Endocrine disrupter
VOCs (Volatile Organic Compounds)	Decompose to form ozone	Cancer, eye and respiratory tract irritation, headaches, dizziness, visual disorders, and memory impairment
Dioxins	Form during combustion of organic wastes and fuels	Endocrine disrupter; carcinogenic, contact irritant; liver damage
Heavy Metals esp. mercury, lead, arsenic, cadmium, aluminum	Industrial sources; mining; concentrated by over-irrigation practices	Cancer, developmental & neurological disorders; cardiovascular damage; impair blood cell production; block enzyme activity
Chlorine & Chloroform	Industrial processing. Leach from synthetic materials.	Cancer, reproductive damage & birth defects, neurological disorders, liver and kidney damage.

Synthetic Chemicals

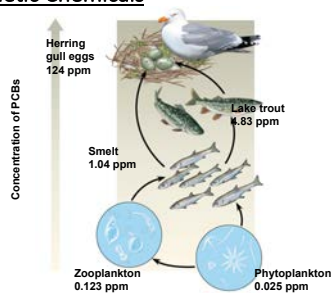
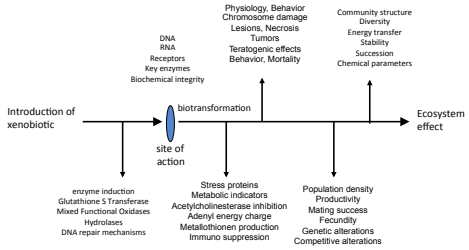
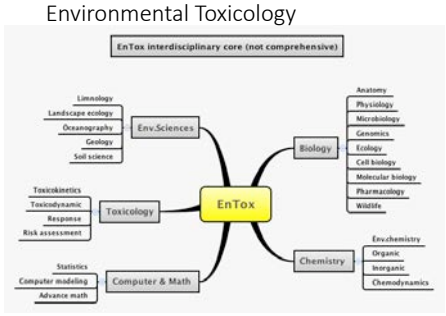


Figure 56.25 Biological magnification of PCBs in a Great Lakes food web

Environmental Toxicology

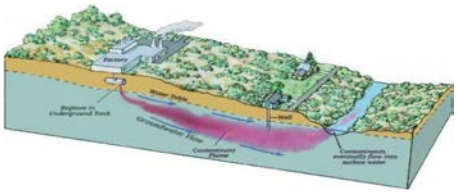


Environmental Toxicology



- Environmental toxicology depends on
  - Lab work
    - Effects of toxicants on biochemistry and physiology
  - Field work
    - Field observations of reproduction and survival in polluted vs. non-polluted sites
  - Modeling of fate and transport of toxicants in the environment i.e. exposure and risk assessment
    - Static models : short term modeling of ecosystems
    - Strategic models : model of a specific aspect of a system
    - Testable models : model makes predictions that can be tested in the field or laboratory

- **Abiotic environmental fate**
  - Partitioning
  - Adsorption
  - Transport/advection

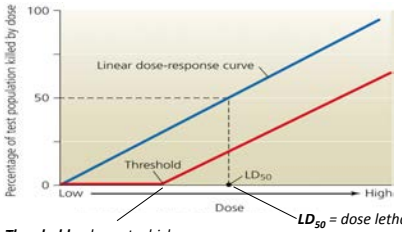


- **Biotic environmental fate**
  - The interaction of a xenobiotic at the site of action in an organism is often 'molecular happenstance' i.e. xenobiotic mimic compounds which are naturally found in species that they affect – hormone mimics
  - **Bioaccumulation**
    - The storage of a compound in fatty tissue of an animal
    - Result of food chain / trophic levels
  - **Biotransformation**
    - Metabolic processes, mainly by environmental bacteria, that alter the structure and toxicity of a compound
  - **Biodegradation**
    - Breakdown of a xenobiotic to CO_2 and water

- **Biotic mode of action (Receptors)**
  - **Chemicals that interfere with biochemical receptor sites**
    - Signaling
    - proteins in membranes
    - Replication
    - Protein synthesis
  - **Chemicals that damage biochemical or molecular targets**
    - DNA damage
    - Strange breakage
    - Chromosome abnormalities
    - Cancer
    - Non-genotoxic effects such as immunosuppression

Measuring Ecotoxicity

Dose-response curve



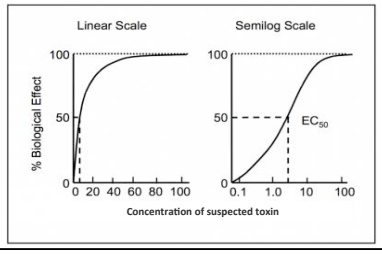
Threshold *= dose at which response begins*

LD$_{50}$ *= dose lethal to 50% of test animals*

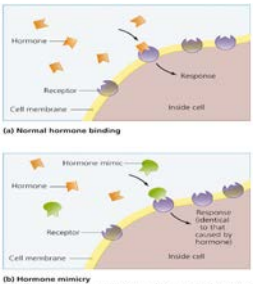
- Physiological and behavioral effects
  - Standard tool for assessing toxicological effects on populations
  - Tissue lesions
  - Tumors
  - Reproductive success

Measuring Ecotoxicity

- **LC_{50}: Lethal Concentration**: exposure causing mortality in 50% of the population
- **EC_{50}: Effective Concentration**: exposure producing a significant effect in 50% of the population

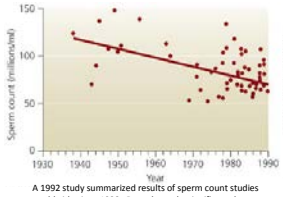


Endocrine Disruption



- Some chemicals, once inside the bloodstream, can "mimic" hormones.
- If molecules of the chemical bind to the sites intended for hormone binding, they cause an inappropriate response.
- Thus these chemicals disrupt the *endocrine* system.

- The hormone system is geared to working with tiny concentrations of hormones, so it can respond to tiny concentrations of environmental contaminants.



A 1992 study summarized results of sperm count studies worldwide since 1938. Data showed a significant decrease in men's sperm counts over 50 years.

Others hypothesize that endocrine disruptors are behind the rise in testicular cancer in many nations.

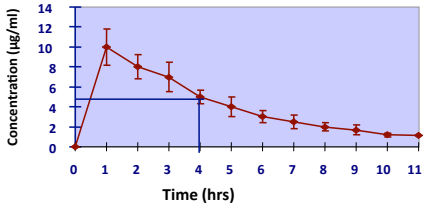
Toxicology

Exposure & Absorption

- Route of exposure
  - Skin (dermal)
  - Lung (inhalation)
  - Oral (gut)
- Timing
  - In utero
  - Infant
  - Pregnancy
  - Elderly
- Frequency Of Exposure
  - Number of Times
  - Intervals
- Duration Of Exposure
  - Acute Exposure
  - Sub-chronic Exposure
  - Chronic Exposure
- Distribution
  - Where It Goes (body water, fat, bone)
  - Where It Accumulates
- Metabolism
  - How The Body Breaks It Down
  - What It Turns Into
  - How Fast It Does It

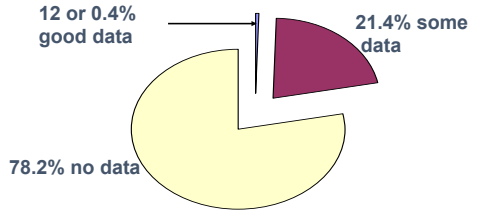
Half-life

How Long It Takes To Go



So Many Chemicals so Little Data

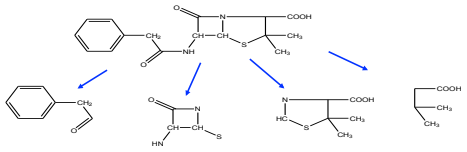
2863 above 1 Million pounds



www.preventingharm.org

How do we measure these effect ?

- Physio-chemical characteristics:
  - QSAR (quantitative structure activity relationship)



– Estimate the contribution of portions of the molecule to physio-chemical characteristics
  - Ionic interactions
  - Hydrophobic interactions
  - Van der Vaals forces
  - Hydrogen bonding

Mixtures of Toxicants

- Substances may interact when combined together.
- Mixes of toxicants may cause effects greater than the sum of their individual effects.

  These are called **synergistic** effects.
- *A challenging problem for toxicology:*
  There is no way to test all possible combinations!

  (And the environment contains complex mixtures of many toxicants.)

- Population effects
  - Population age structure – xenobiotics often exert a stronger effect on juveniles => a shift in age structure might indicate that a population is not doing well, because it is affected by a xenobiotic
  - Shift in bacterial communities – contamination reduces bacterial diversity; bacterial numbers often increase because the contaminant is food for some while it is toxic for others
- Community effects
  - Species diversity
  - Abundance
  - Distribution
- Ecosystem effects
  - Productivity
  - Trophic level structure
  - Stability