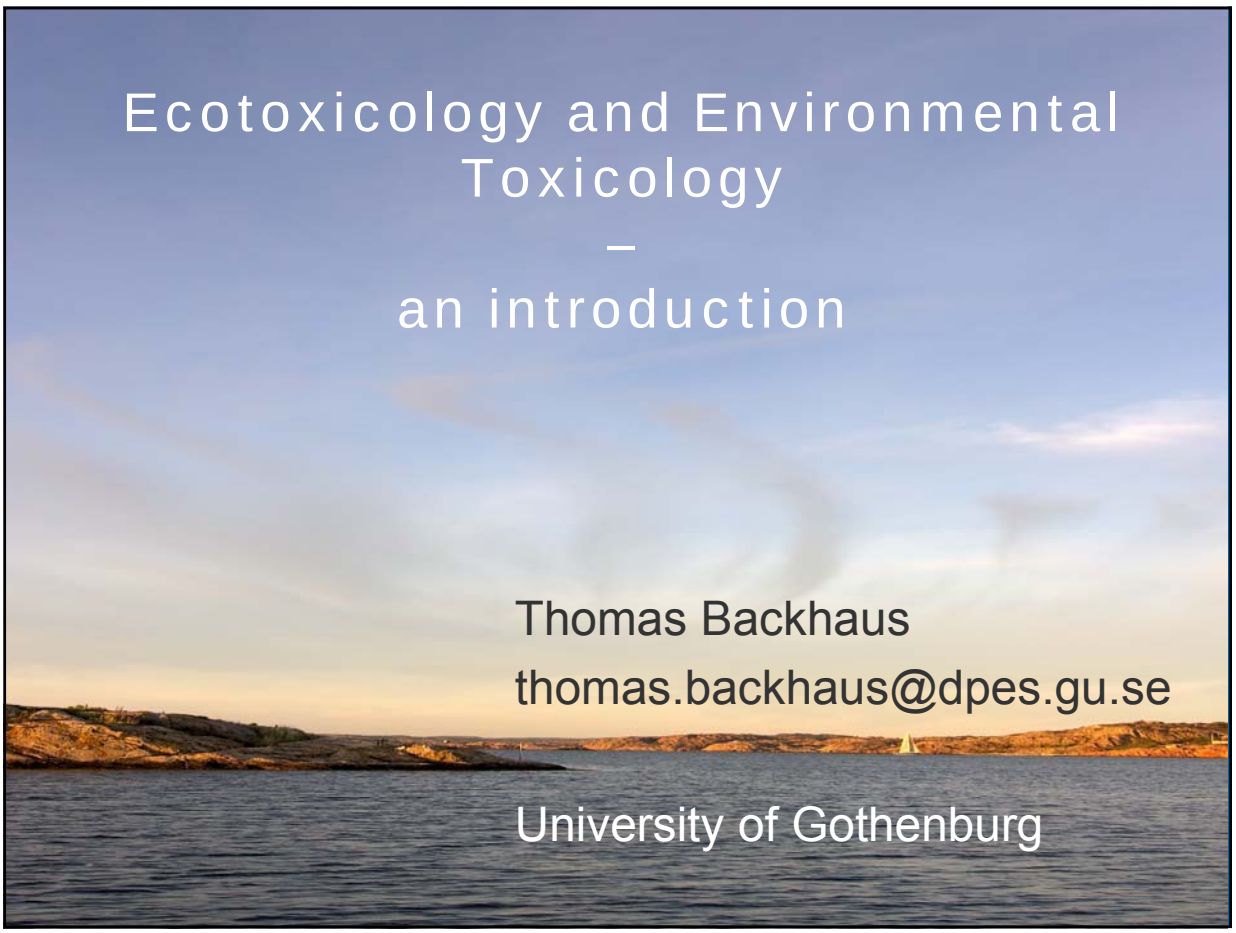
Ecotoxicology and Environmental Toxicology
–
an introduction
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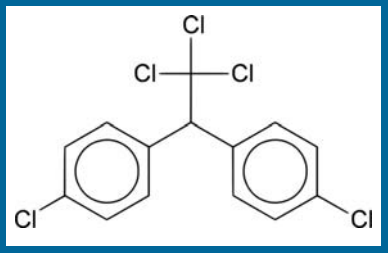
"Silent spring" by Rachel Carson

- Book published in 1962
- DDT: organochlorine insecticide
- Nobel prize 1948 in "physiology or chemistry" for the discovery of its insecticidal properties
- DDT biomagnification in birds of prey lead to egg-shell thinning and hence drastically reduced hatching success
- Banned in several countries from the early 70's onward
- Global ban after the Stockholm convention 2001
- Exception: vector control (i.e. for fighting malaria)
- Ongoing debate.



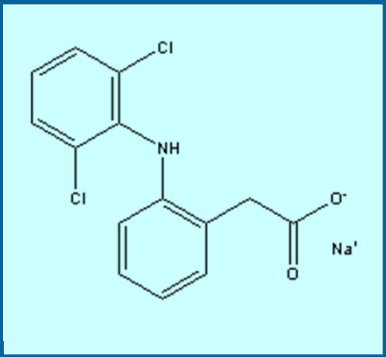
Lesson learned?

- DDT and other organochlorine pesticides
- Agricultural pesticides…
- Tributyltin…
- Endocrine disrupters…
- CFCs and the ozone layer…
- Climate change…

- New and emerging issues
  - pharmaceuticals in the environment
  - nanomaterials in the environment

Pharmaceuticals in the environment

Diclofenac



- Arthrotec, Voltaren
- Nonsteroidal Antiinflammatory Agent for the treatment of arthritis, rheuma (Painkiller)
- In Europe / US: exclusively in human medicine
- In Asia, India: also used in veterinary medicine

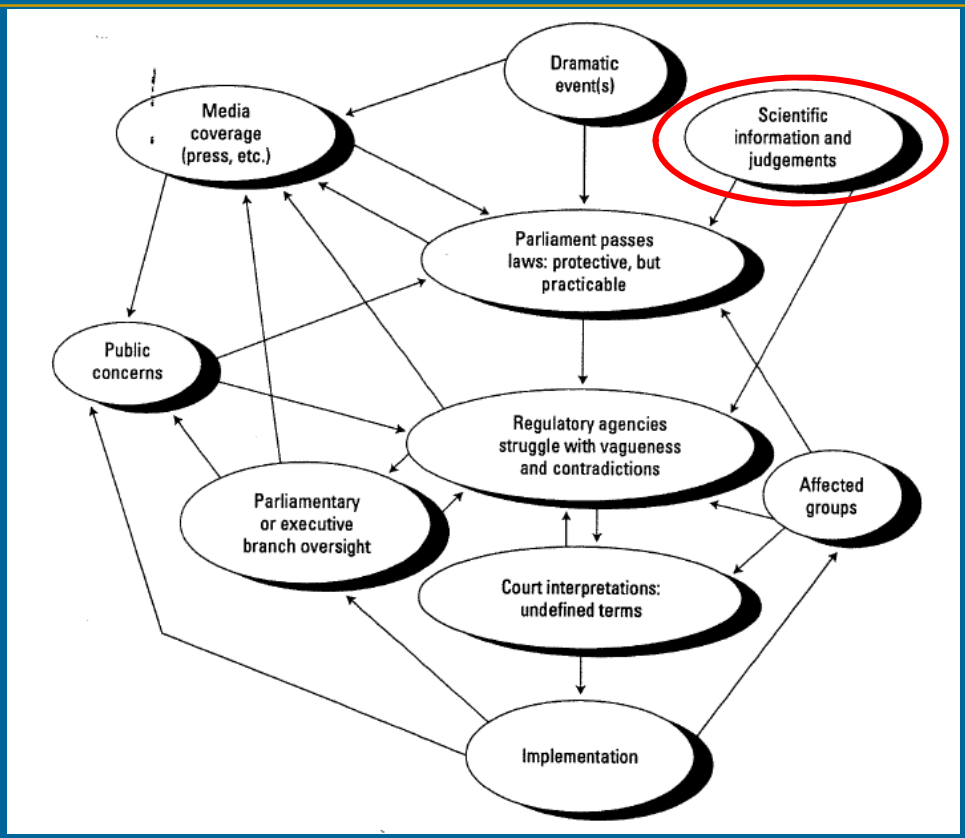
Ecological Impact of Diclofenac Use

- Vultures feeding on Diclofenac-treated animals die of kidney failure [1]
- Drastic population decline (>95%) on the Indian subcontinent
- Vultures are now on the brink of extinction

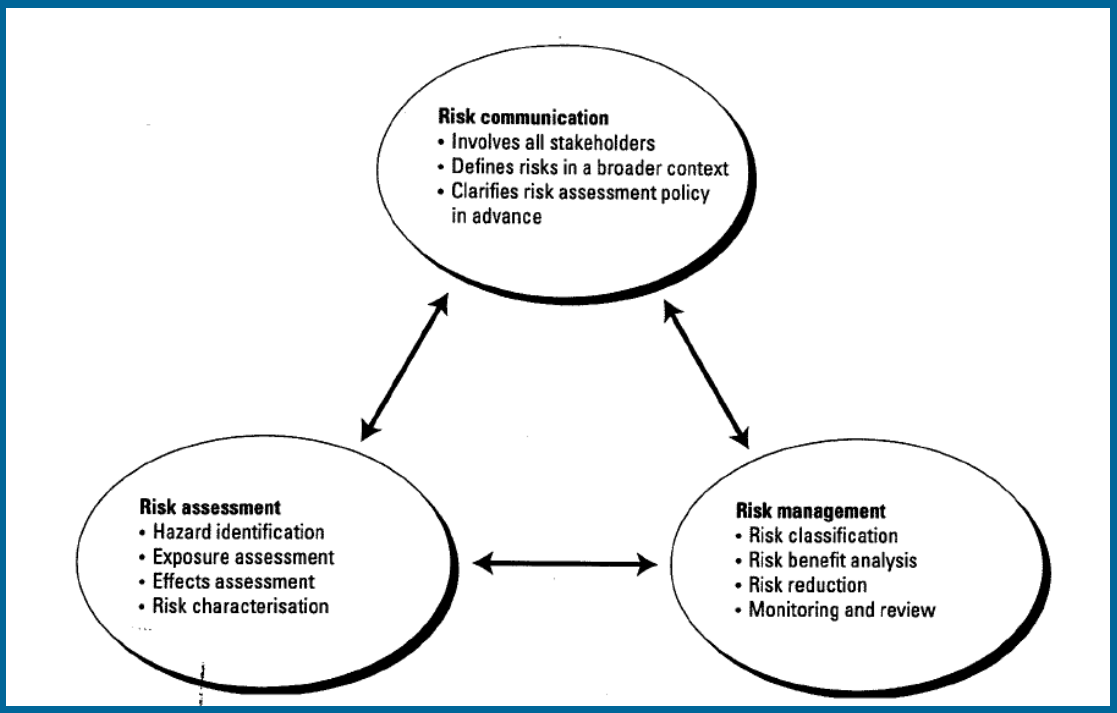
[1] Oaks, et al., Nature (427), 2004

Human Health and Social Consequences

- Vultures play an especially important role in India
- Role of scavenger taken over by feral dogs and rats
- Increased rate of rabies
- “sky burials“ of Parsi not longer possible



Leuwen, Introduction to Chemical Risk Assessment, 2007



Leuwen, Introduction to Chemical Risk Assessment, 2007

Toxicology

The study of the adverse effects of chemicals on living organisms

- **Humans**
- **Non-human organisms**

(Klaasen und Eaton, 1991)

Ecotoxicology

...the branch of toxicology, concerned with the study of toxic effects, caused by natural or synthetic pollutants, to the constituents of ecosystems, animals (including human), vegetable and microbial in an integral context

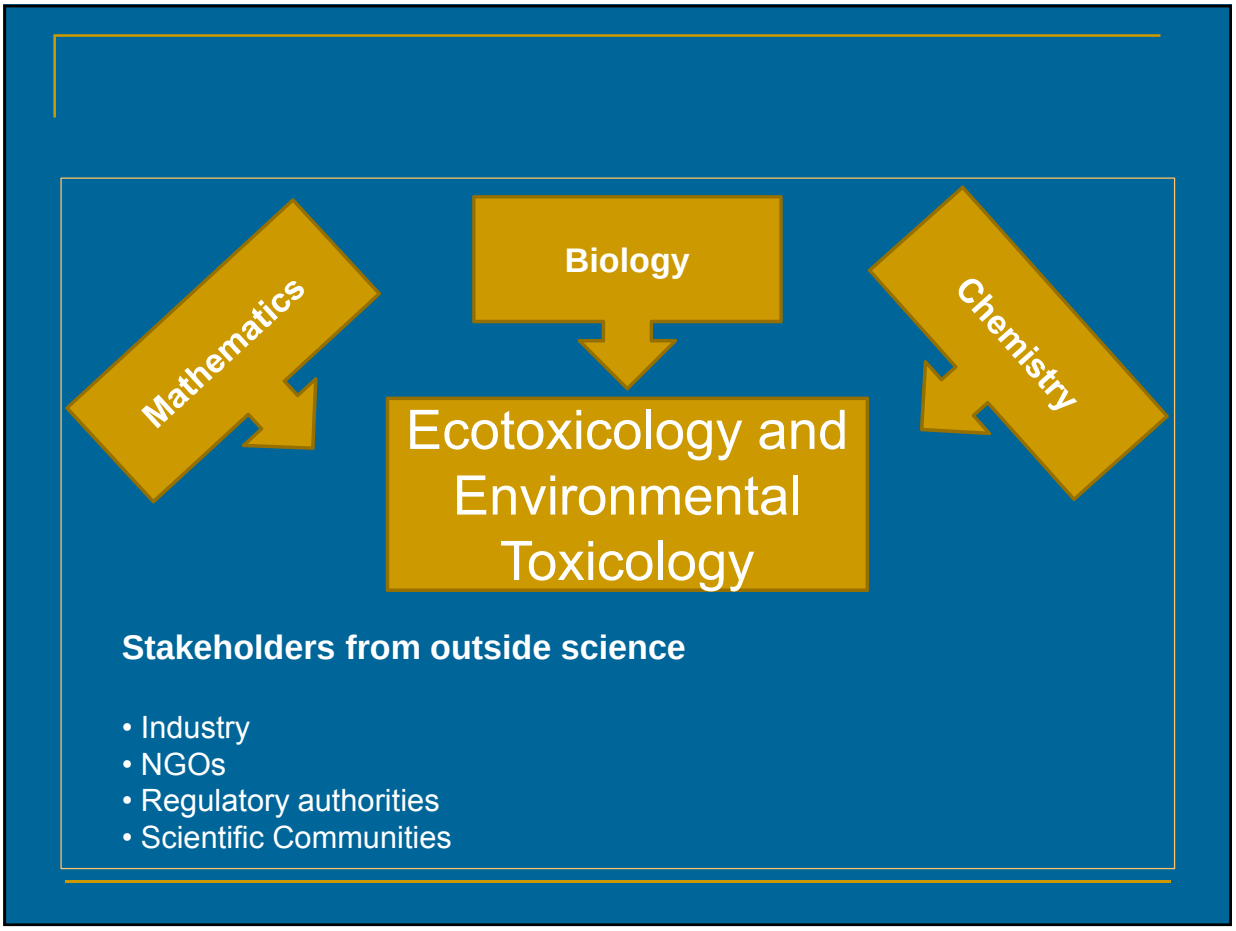
(Truhaut, 1977)

The science, which seeks to predict the impacts of chemicals on ecosystems

(Levin 1989)

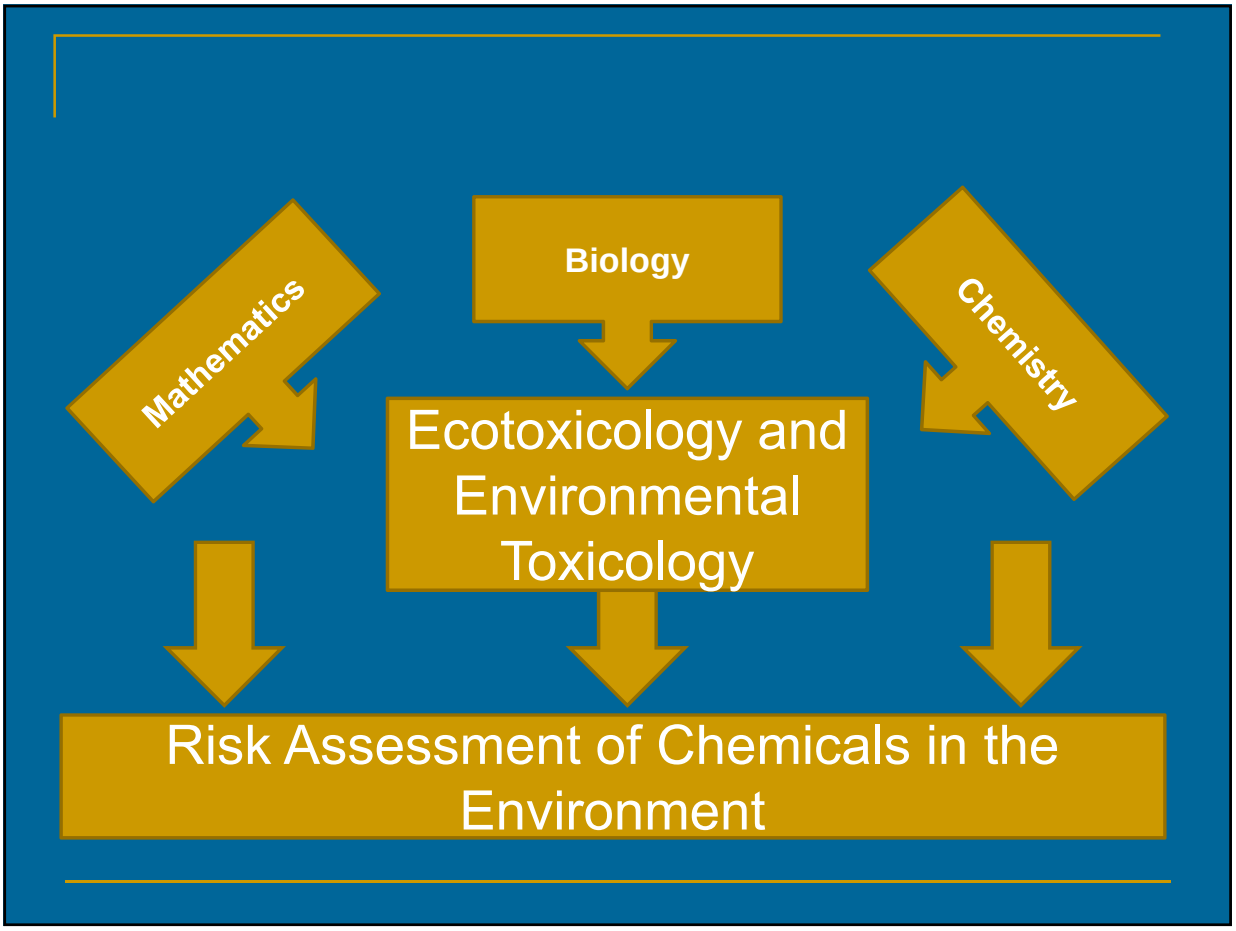
The task of ecotoxicology is to assess, monitor and predict the fate and effects of foreign substances in the environment

(Moriarty, 1988)



Stakeholders from outside science

- Industry
- NGOs
- Regulatory authorities
- Scientific Communities

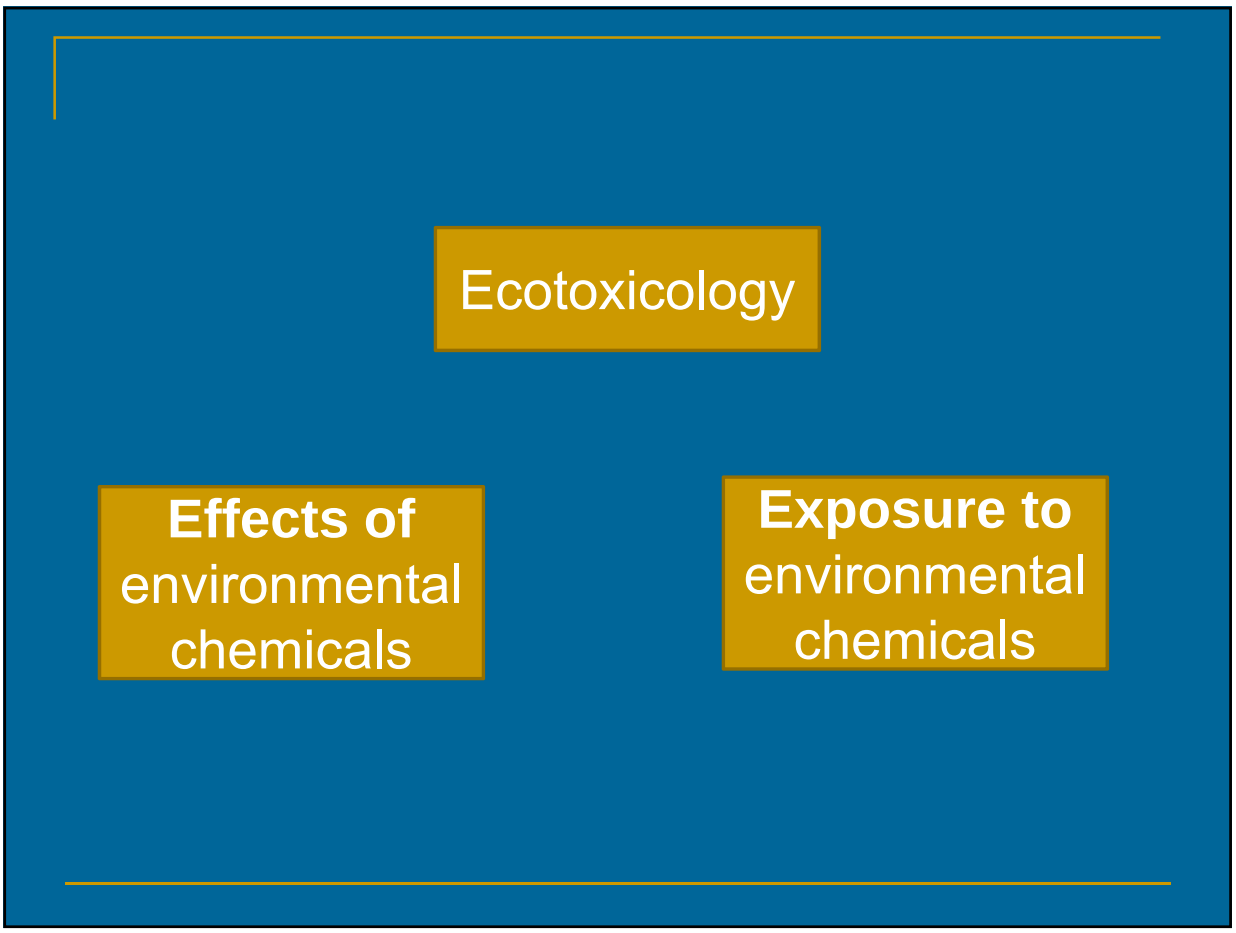

Mathematics
Biology
Chemistry
Ecotoxicology and Environmental Toxicology
Risk Assessment of Chemicals in the Environment

The different aims of ecotoxicological research

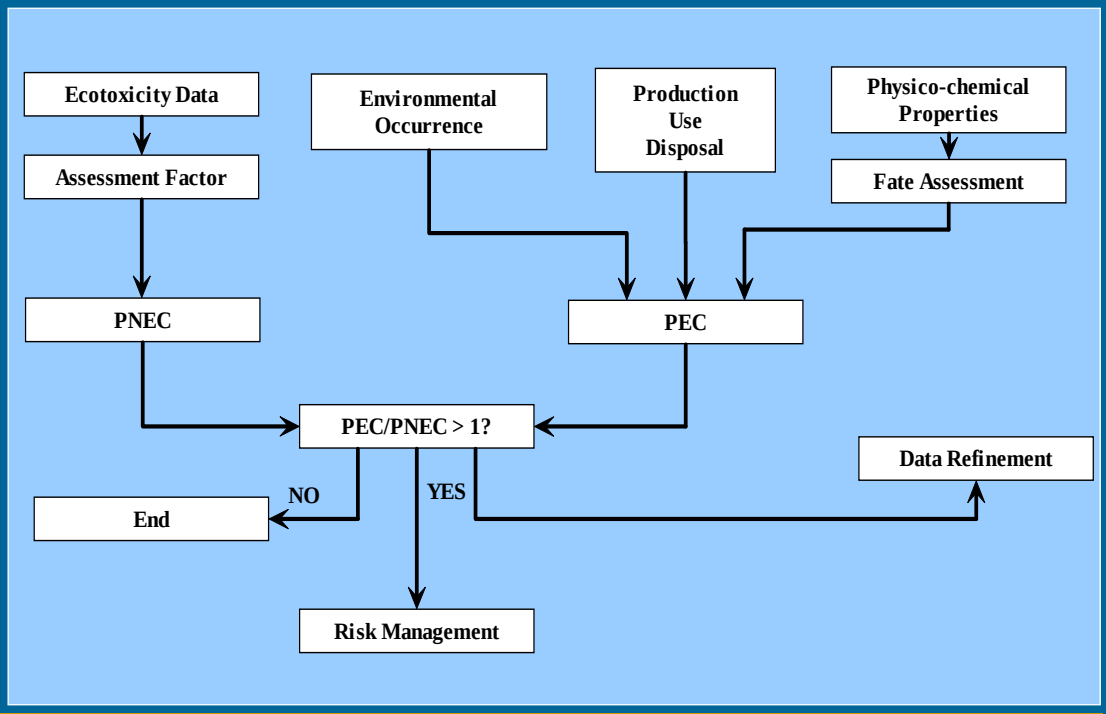
- as a scientific discipline
  - understand the fundamentals of the interactions between chemicals and biological systems on different levels of complexity
  - curiosity driven
- as a technological field
  - development of bioassays on various levels of complexity, for different compounds and different environmental compartments
  - development of models of distribution, fate and effects of chemicals in the biosphere
  - (chemical analytical techniques)

The different aims of ecotoxicological research

- as an input provider for environmental regulation
  - provide the scientific basis for environmental quality standards that ensure ecosystem services, sustainable development and ecosystem health
  - provide clean-up goals and strategies
  - provide options


Ecotoxicology
Effects of environmental chemicals
Exposure to environmental chemicals

Env. Risk Assessment of Chemicals



Exposure assessment

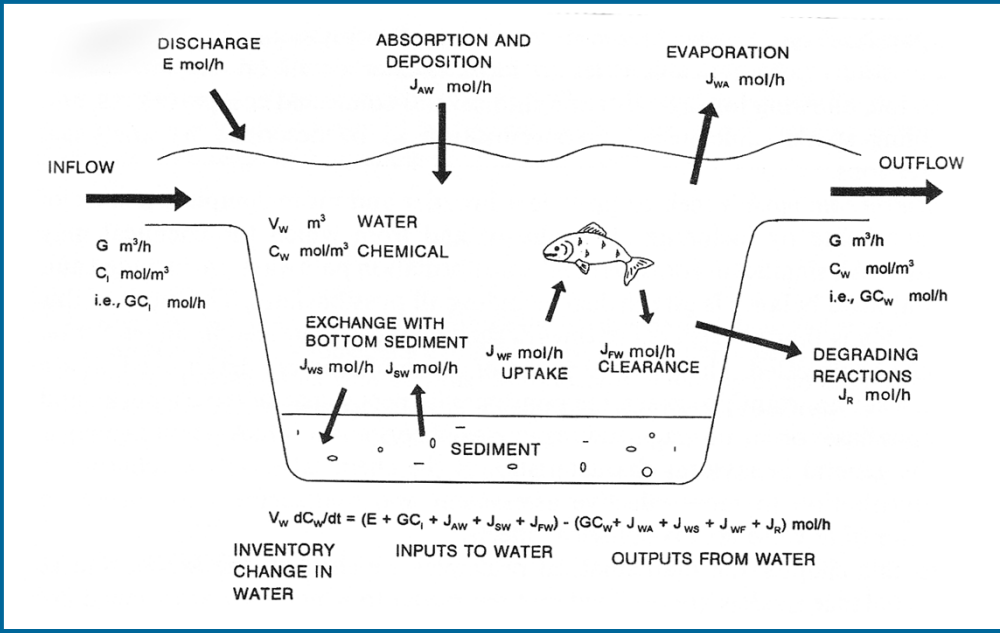
- Tier 1
  - Basic physico-chemcial data (e.g. lipophilicity, pK_A)
  - Equilibrium partitioning between environmental compartments
  - Steady state model predictions
- Tier 2
  - Non-steady state modeling
  - Biological measurements (biosensors, biomonitoring)
  - Chemical measurements (analytical chemistry)

Multimedia mass balance models

Primary media	Secondary media
Air	Aerosols, rain, snow
Water	Suspended solids, biota (e.g. fish)
Soils	Mineral matter, organic matter, pore water, air, biota
Sediments	Solids, porewater, biota
Others	Groundwater

from: D. Mackay: "Multimedia mass balance models of chemical distribution and fate"
G. Schüürmann (Ed.): Ecotoxicology, Wiley, 1998

Multimedia mass balance models



from: D. Mackay: "Multimedia mass balance models of chemical distribution and fate"
G. Schüürmann (Ed.): Ecotoxicology, Wiley, 1998

Exposure assessment

- Measurements
  - **Pros:** exact measurement, no modeling error
  - **Limitations:** restricted to a pre-defined (group of) chemicals; only a snapshot of pollution, resource-intense (time, money), only retrospective analysis
- Modeling
  - **Pros:** prospective (if-then) analysis possible, not as resource demanding as chemical analysis
  - **Limitations:** only applicable to certain groups of chemicals, models need to be validated, model specification needed

Sidestep...

Description of paraquat from www.paraquat.com

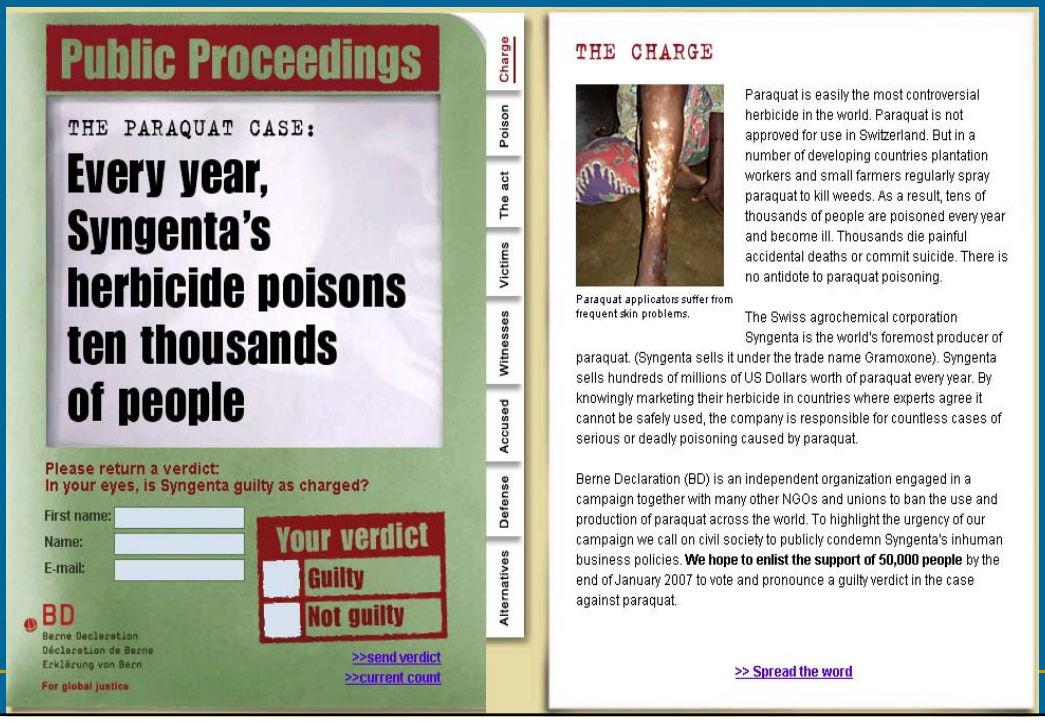
Structural formula	Paraquat is a strong cation and stays where applied	
Description	White crystalline solid	like sucrose
Solubility	Very soluble in water. Not soluble in fat	like sodium chloride
Vapor pressure	Negligible, below 1 x 10-9 mm Hg Inhalation not possible	like copper coins
Toxicity (45.6% technical)	Oral LD_{50} (technical material in the rat) = 283mg/kg	like gasoline

Molecular Structure

Paraquat (1,1'-dimethyl-4,4'-bipyridylium) dichloride

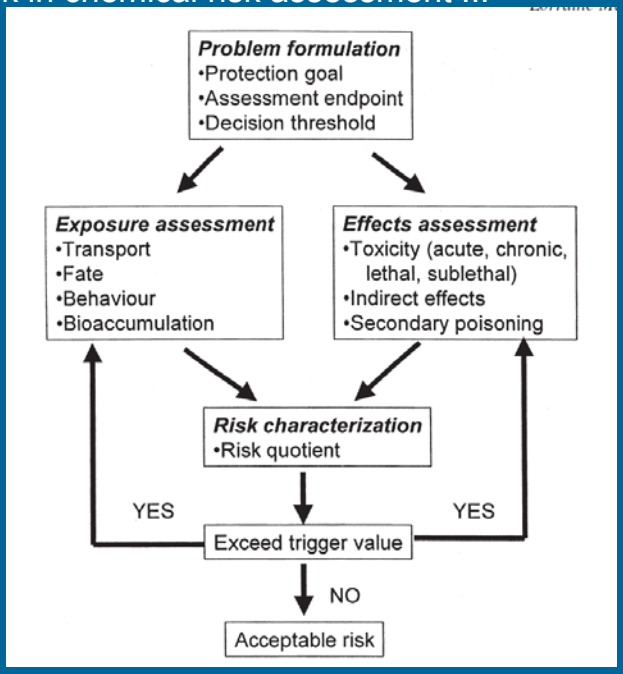
Sidestep continued

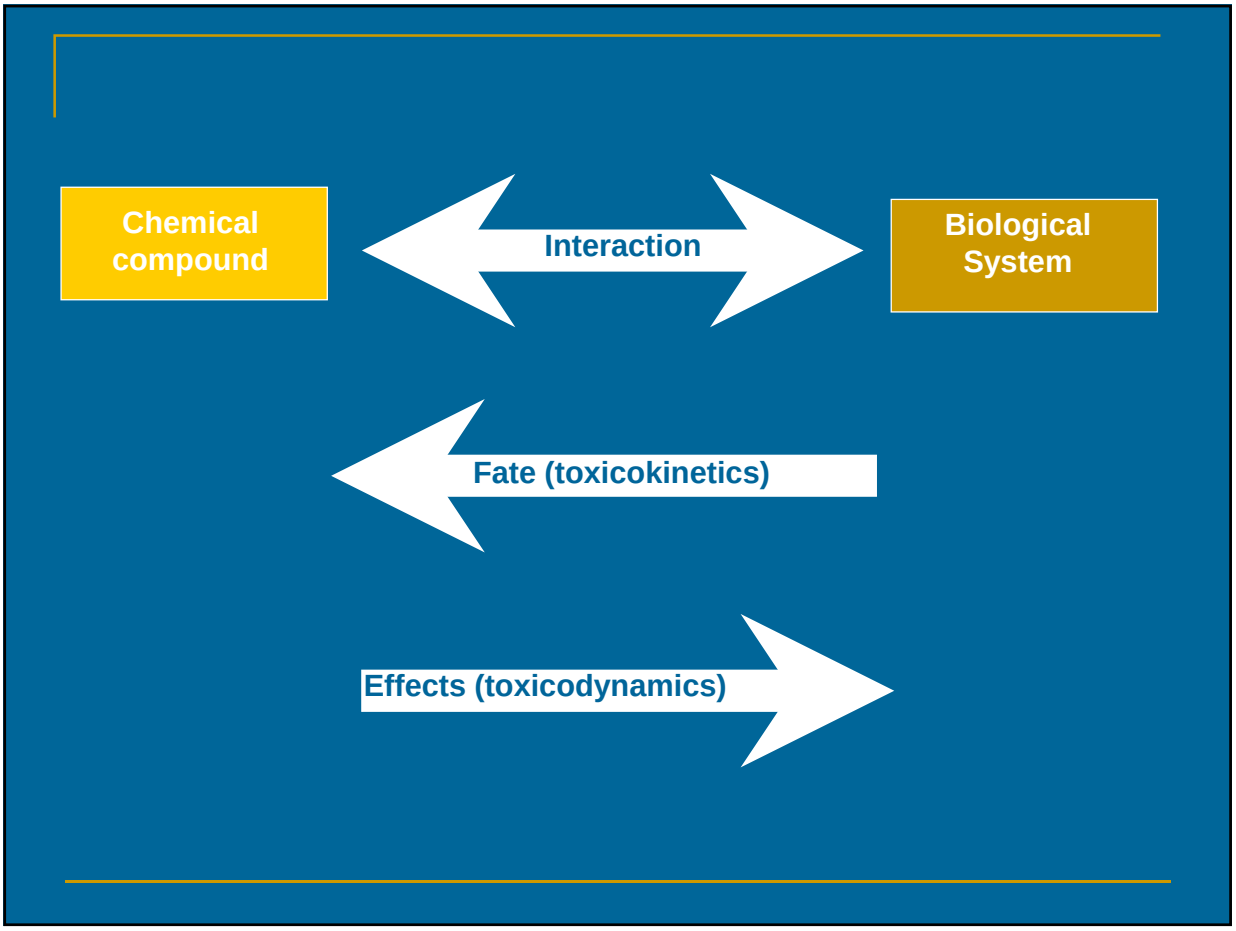
Description of paraquat from www.paraquat.ch



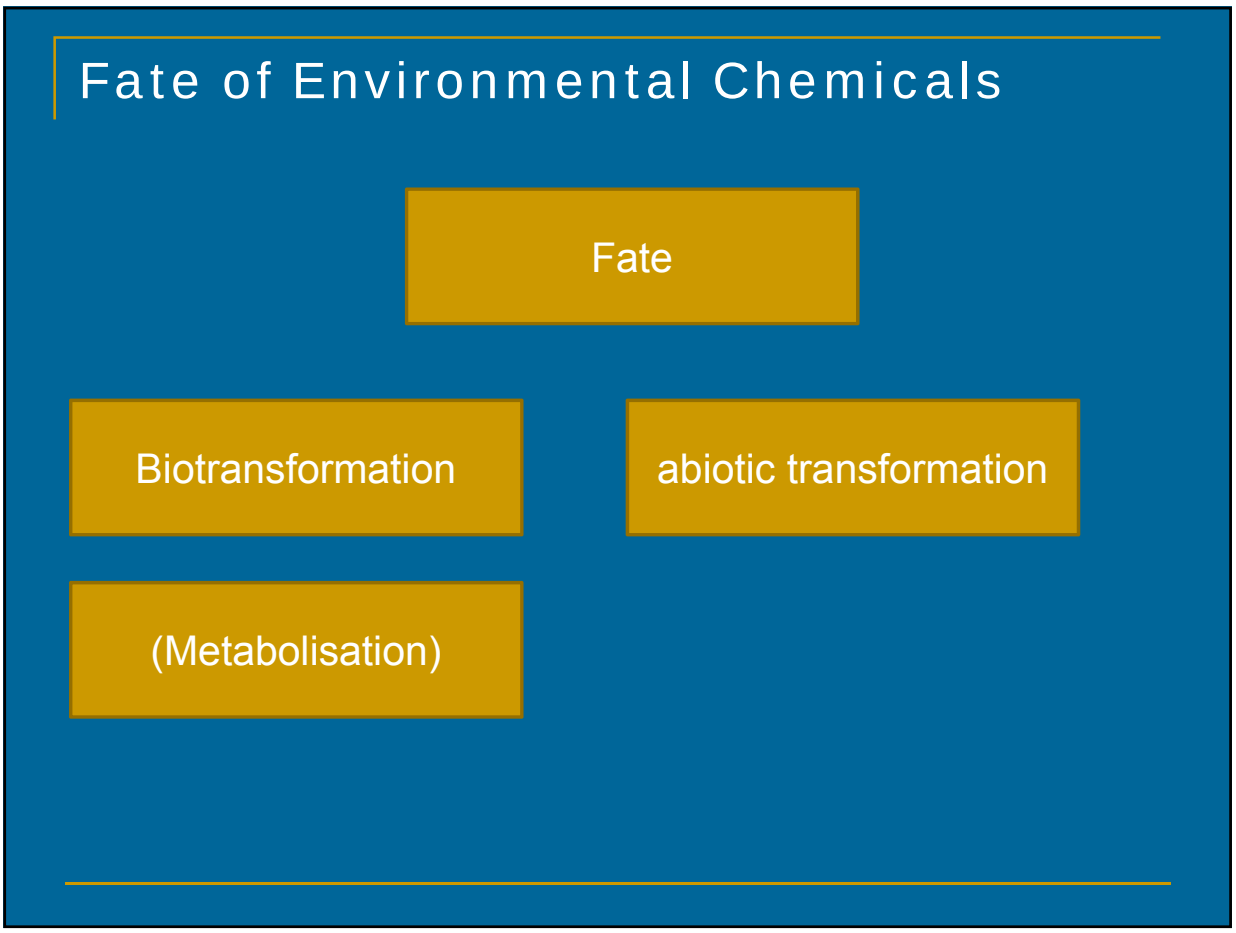
Sidestep continued

From a textbook in chemical risk assessment ...




Chemical compound
Interaction
Biological System
Fate (toxicokinetics)
Effects (toxicodynamics)

Fate of Environmental Chemicals



Fate of Environmental Chemicals

Fate

Detoxification

Toxification

Fate of Environmental Chemicals

Chemical Substance

Phase I

- Oxidation
- Reduction
- Hydrolysis

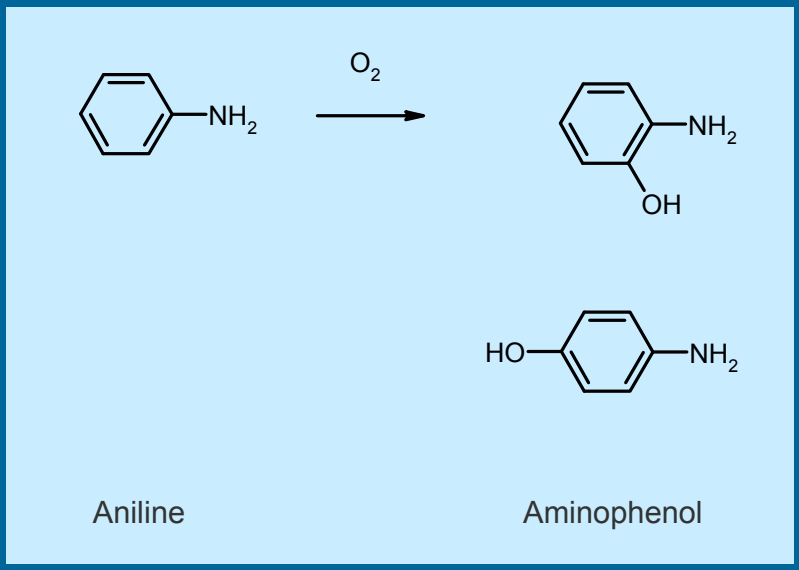
Phase II

- Conjugation to
  - Glutathione
  - Glycine
  - Glucuronate

Phase III

- Excretion
- "Storage"

Example for an oxidative biotransformation



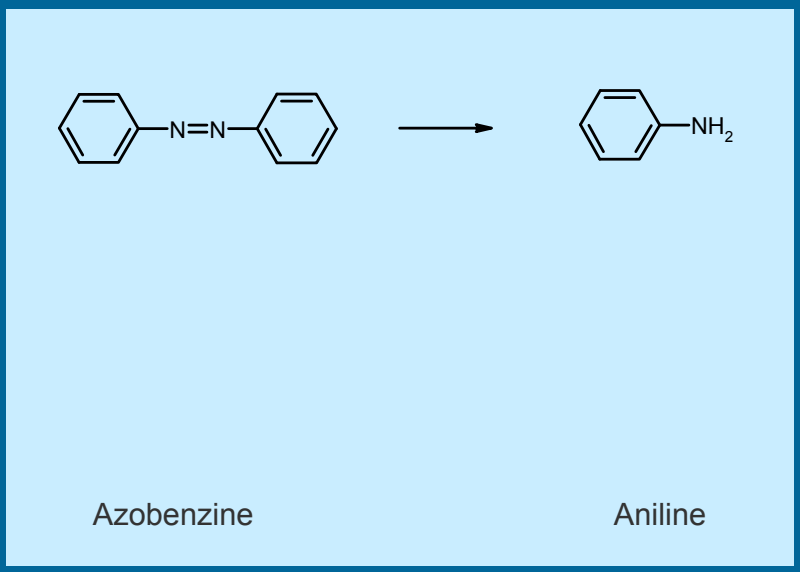
Cytochrome P450

- An extremly large and complex superfamily of oxidases that in general catalyse the following reaction:

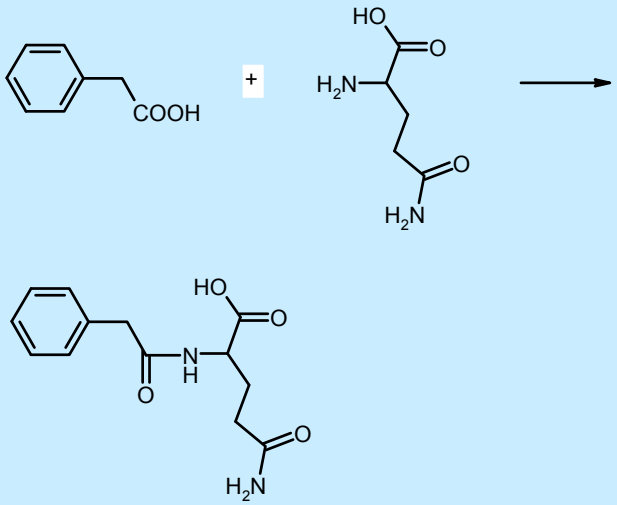
$$RH+O_2+2H^++2e^- \rightarrow R\text{-}OH+2H_2O$$

- Found in all major organism groups (mammals, plants, bacteria, fungi)
- Major role in biotransformation of environmental chemicals, but also in endogenous metabolic processes, such as the biosynthesis of steroid hormones

Example for a reductive biotransformation



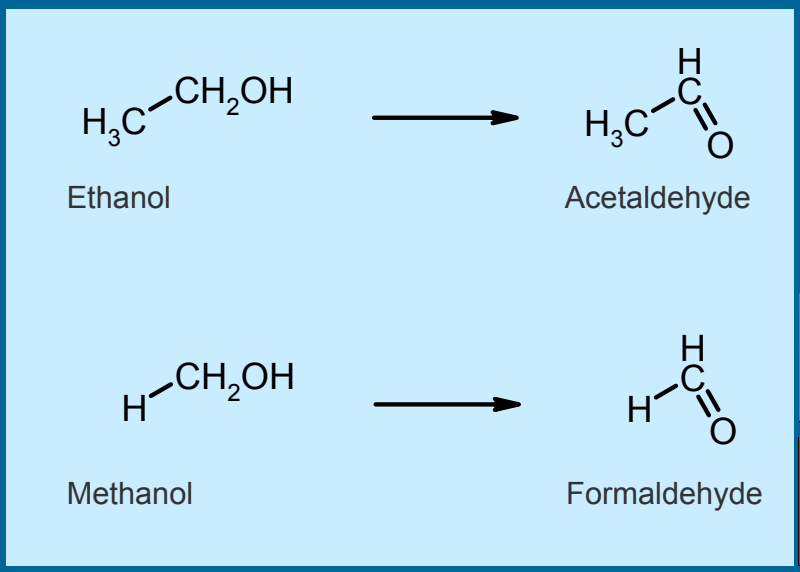
Conjugation



Phenylacetic acid + Glutamine ->

Phenylacetylglutamine

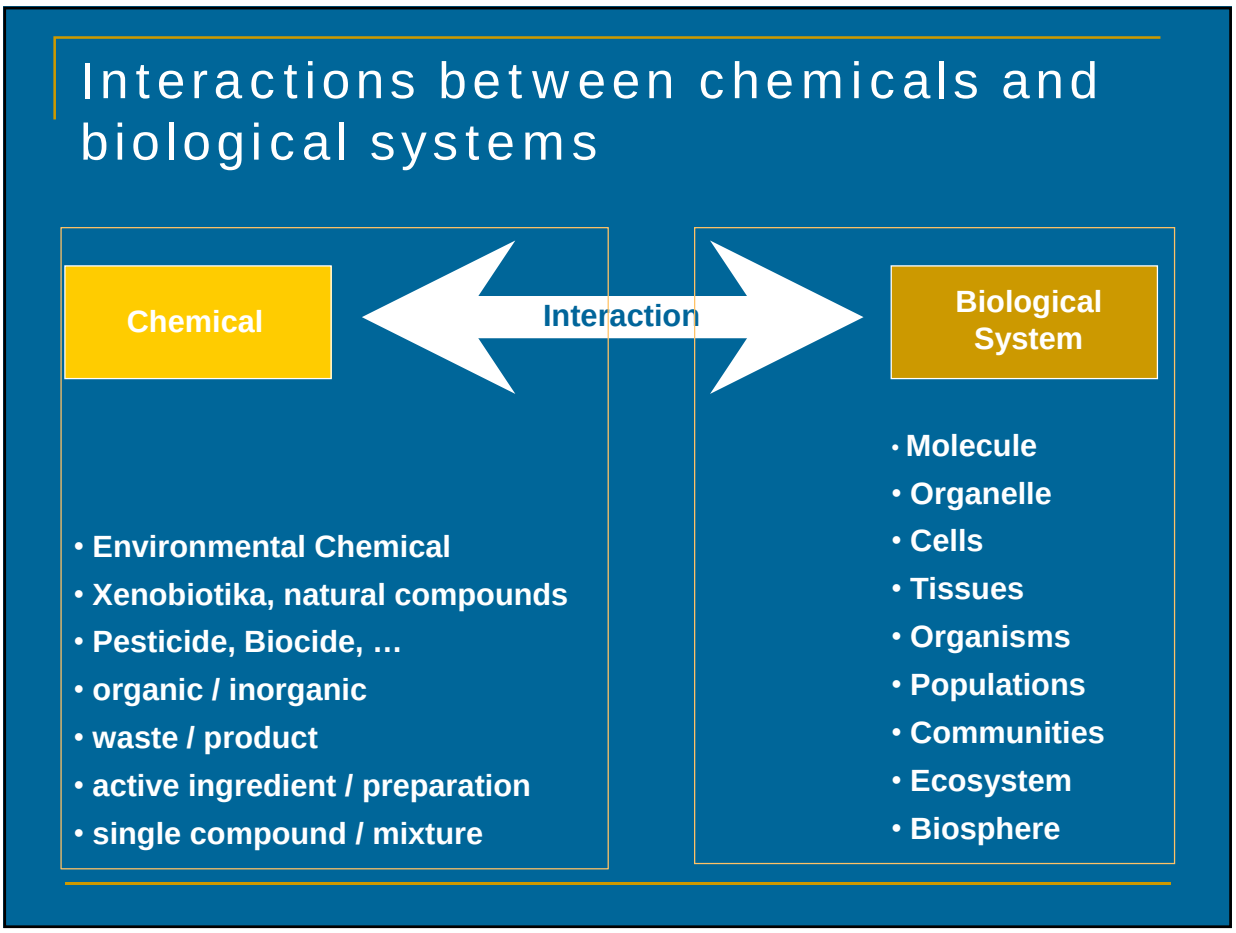
Alcohol biotransformation



Consequences of biotransformations

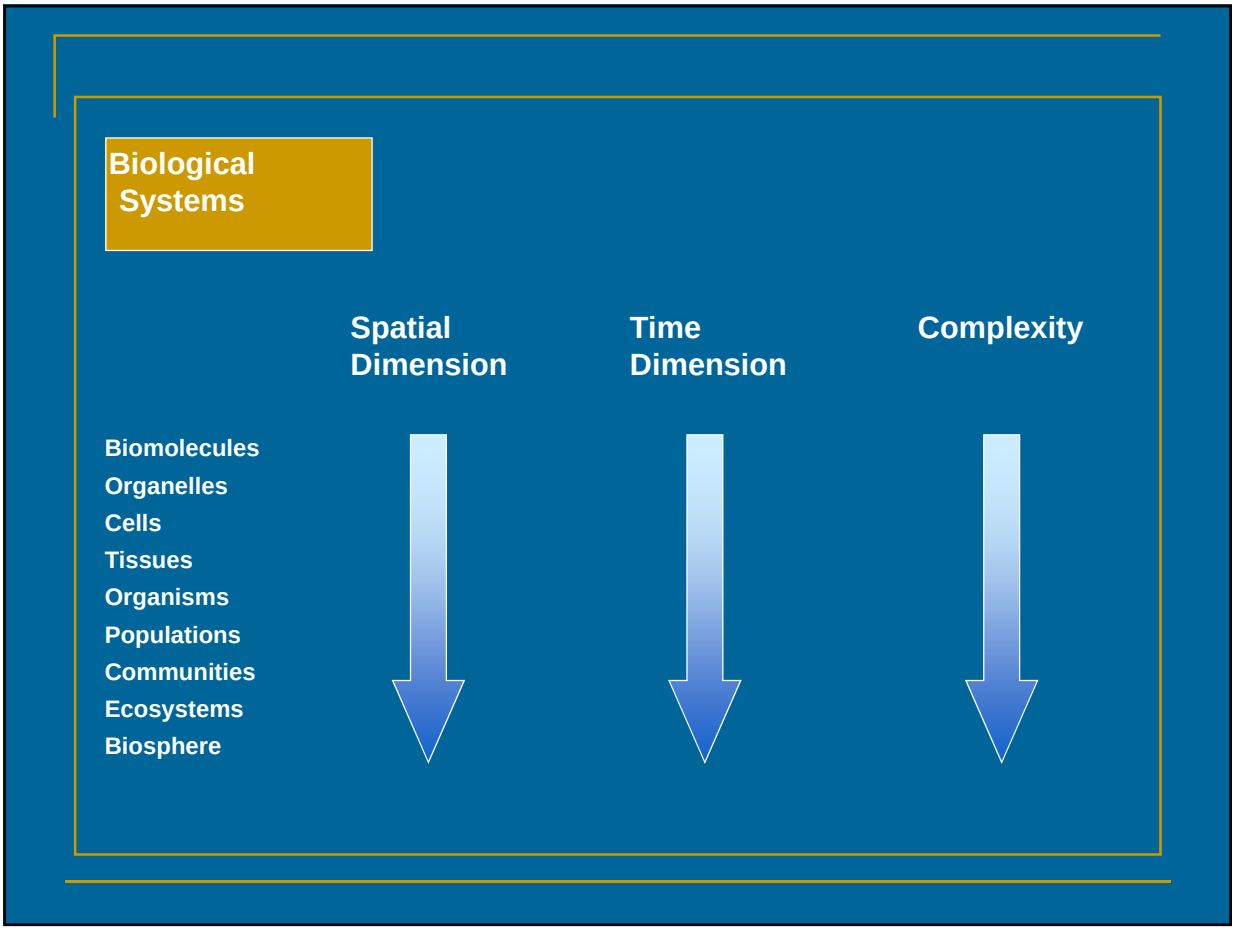
- Production of a stable, water soluble compound that can be excreted or safely stored (cell wall, vacuole)
- Investment of physiological energy
- Sometimes toxicification instead of de-toxification

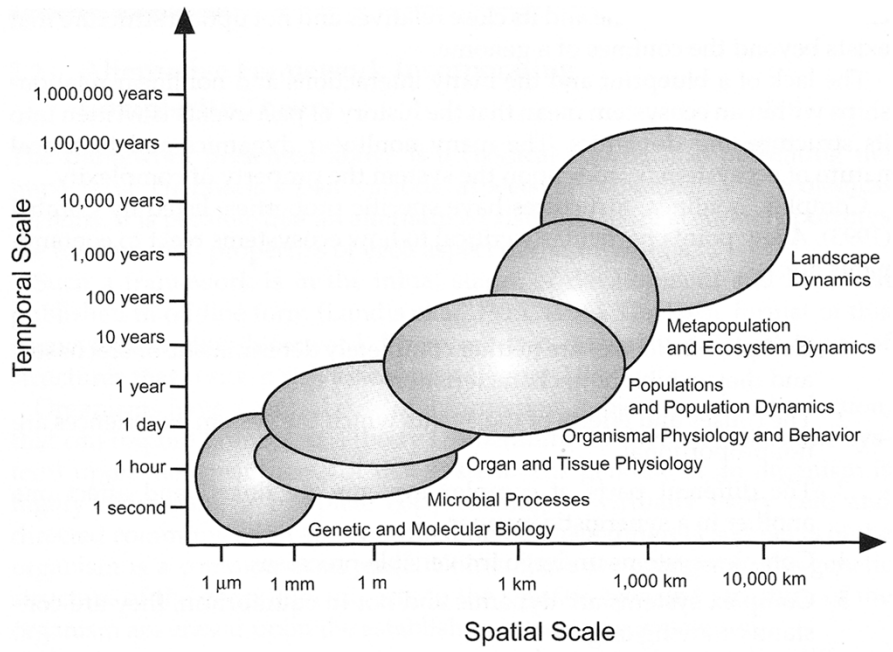
Interactions between chemicals and biological systems



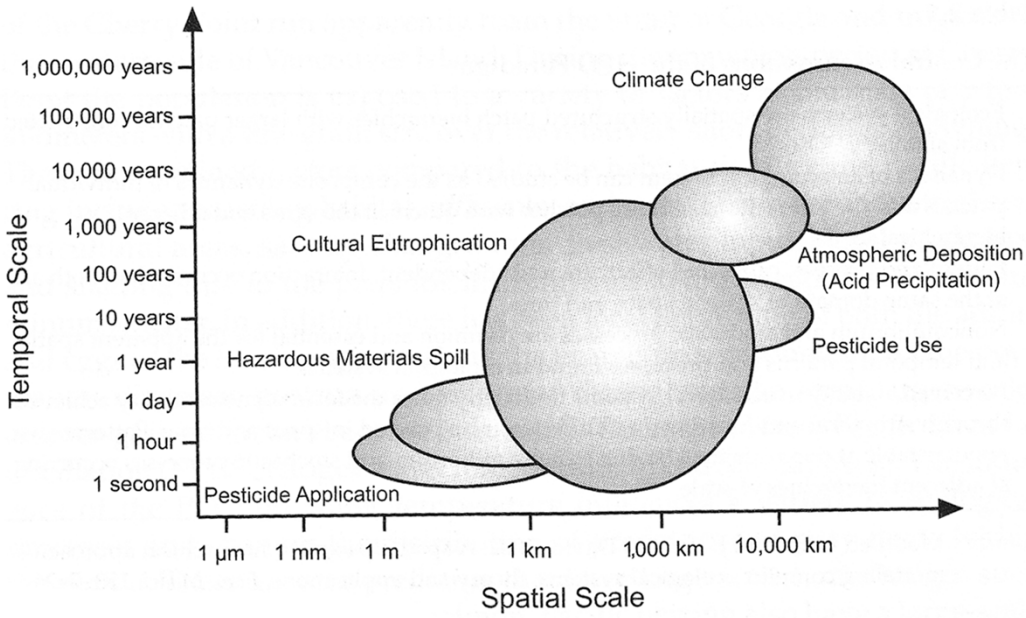
Biological System

	Structures	Functions / Characteristics
Biomolecules	Proteins, nucleic acids, Lipids, carbohydrates	Catalysis, Storage of informations Compartimentalisation, Structure
Organelles	Mitochondria, Nucleus, Ribo-somes, Chloroplast, Membranes, etc.	Energy conversion, Transcription, Translation, Biosynthesis, Compartimentalisation, Biotransformation
Cells	Stomata, Erythrocytes, Bacteria	Growth, Reproduction
Tissues	Phloem, Muscles, etc.	Differentiation
Organisms	Individuals	Birth, Ageing, Death, Gender
Populations	Age distribution, Spatial distribution, Population-density, Genpool	Evolution, Production, Consumption, Extinction, Competition
Communities	Biodiversity	Prey, Preditor, Competition, Trophic level
Ecosystems	Geography, Hydrology Climate	Sucession, energy flow, material flow
Biosphere	Climate	Totality of all biological entities


Biological Systems
Spatial Dimension
Time Dimension
Complexity
Biomolecules
Organelles
Cells
Tissues
Organisms
Populations
Communities
Ecosystems
Biosphere



W.G. Landis, M.H. Yu: Introduction to Environmental Toxicology, 2003



W.G. Landis, M.H. Yu: Introduction to Environmental Toxicology, 2003

Summary

- Ecotoxicology is the science that analyses the interactions between environmental chemicals and non-human biological systems
- Complementary to environmental toxicology
- 3 roles:
  - scientific discipline
  - technology development
  - environmental regulation
- Chemicals act on different levels of complexity
  - spatial scale
  - temporal scale
- Interactions on a lower level might lead to consequences on higher levels

Summary

- Toxikokinetics: what does the biology to a chemical? (Fate)
  - 3 phases of biotransformation
- Abiotic transformations (not covered in the lecture)
- Toxikodynamics: what does the chemical to a biological system? (next lecture)