Research centre
for toxic compounds
in the environment

Ecotoxicology
Part 1 - Introduction

Ludek Blaha + ecotox colleagues

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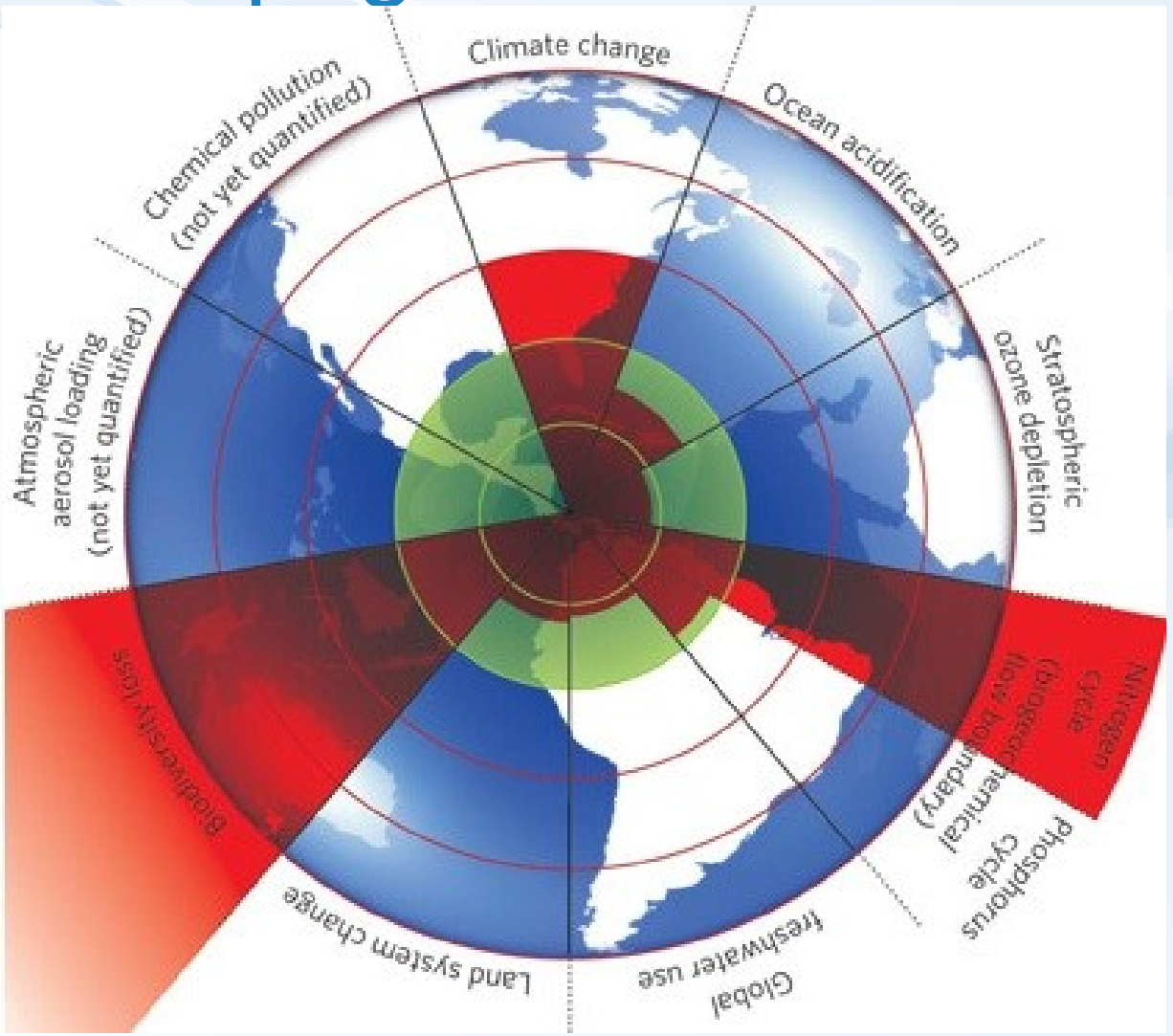
Global anthropogenic threats ?

A safe operating space for humanity & the nine planetary boundaries

Rockstrom et al. 2009
(*Ecology and Society* **14**(2): 32; Nature **461**, 472-475)



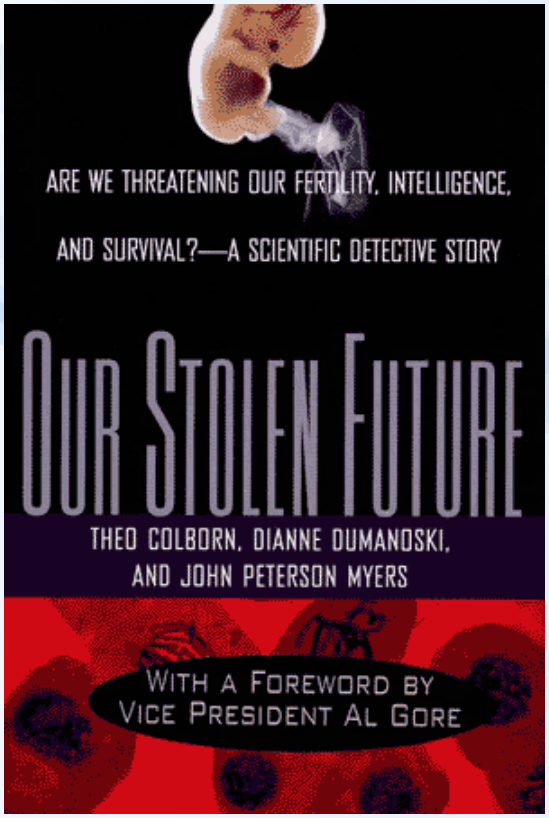
1996 - Chemicals in the environment

Do you believe that chemicals in products sold to consumers have been proven safe?

Think again

most chemicals in modern use have simply not been tested for their impacts on
human, even very basic effects.

… what about the effects in nature, then ?



How we stand 20 years later?

news@nature.com
The best in science journalism

Published online: 21 October 2005; | doi:10.1038/news051017-16

Pollution makes for more girls

The stress of dirty air skews sex ratios in Sao Paulo.

Erika Check

Toxic fumes favour the fairer sex, a group of researchers in Brazil has found.

Babies born in highly polluted areas are more likely to be girls.

theguardian

World news

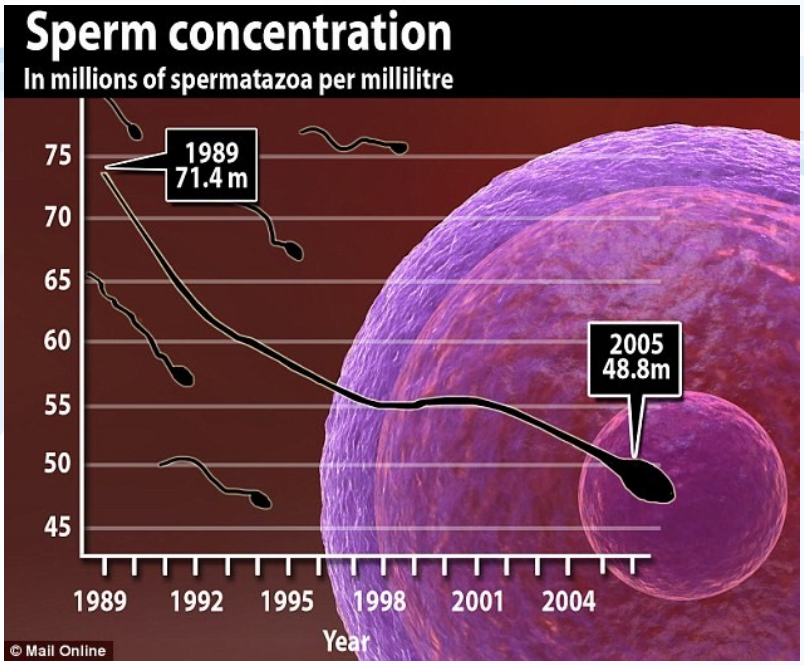
Man-made chemicals blamed as many more girls than boys are born in Arctic

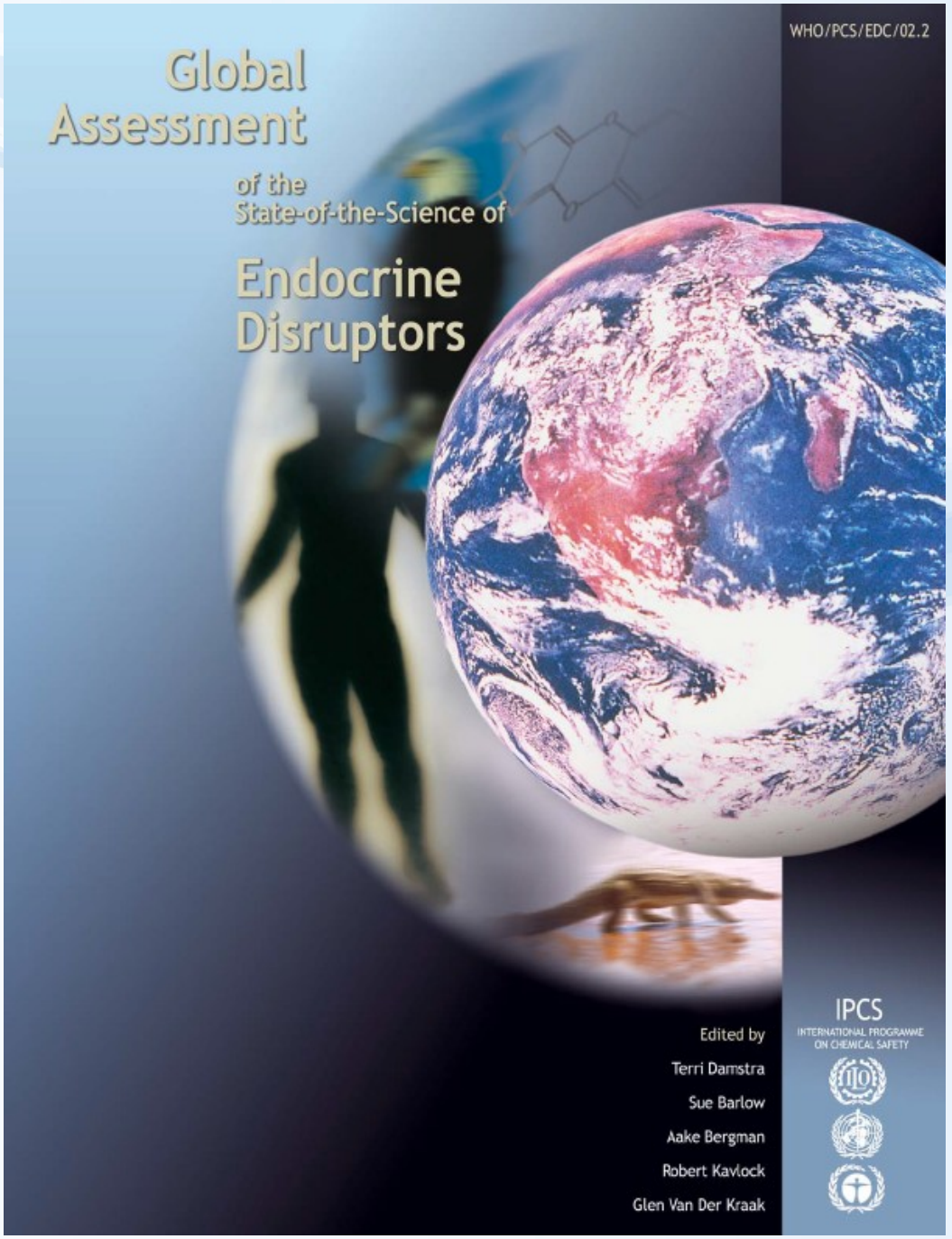
- High levels can change sex of child during pregnancy
- Survey of Greenland and east Russia puts ratio at 2:1

Paul Brown in Nuuk, Greenland

Wednesday 12 September 2007
03.00 BST

An Inuit child in a traditional parka. Photograph: Joel Sartore/Getty/National Geographic





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Environmental pollution

Examples and ecological cosequences

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Major anthropogenic threats – example: waters

Direct





Indirect

Impacts

Major impacts

- **Loss of biodiversity**

Changes in biodiversity

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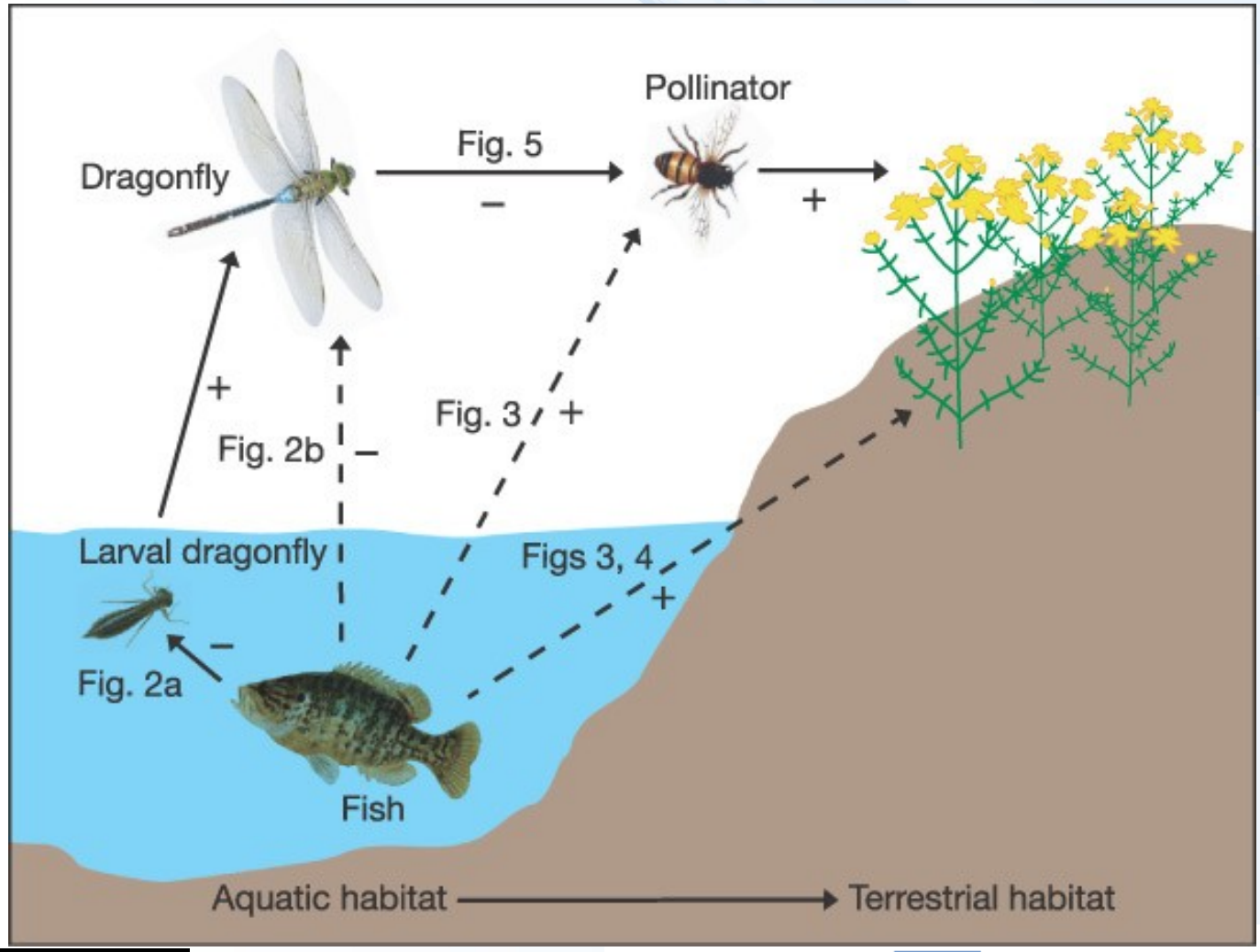
Major impacts

Loss of biodiversity

- **Impairment of ecosystem services**
  - **Unbalanced water cycles**
    - Water scarcity
    - Draughts/floods
  - **Impaired water quality**
    - Drinking waters
    - Bathing waters
    - Toxicants in food chain
  - **Shrinking of food supplies**
    - Direct → lowering fish amounts
    - Indirect → crop yield

Impacts on fish → decreased crop yields

NATURE (2005) 437: 880



Impacts on biota → global effects

Mixing oceans

→ cooling the atmosphere

[Nature 447, p.522, May 31, 2007]

Marine life supplies up to 50% of the mechanical energy required worldwide to mix waters from the surface to deeper cool layers

[Dewar, Marine Res 64:541 (2006)]

[Katija a Dabiri, Nature 460:624 (2009)]

POLICYFORUM

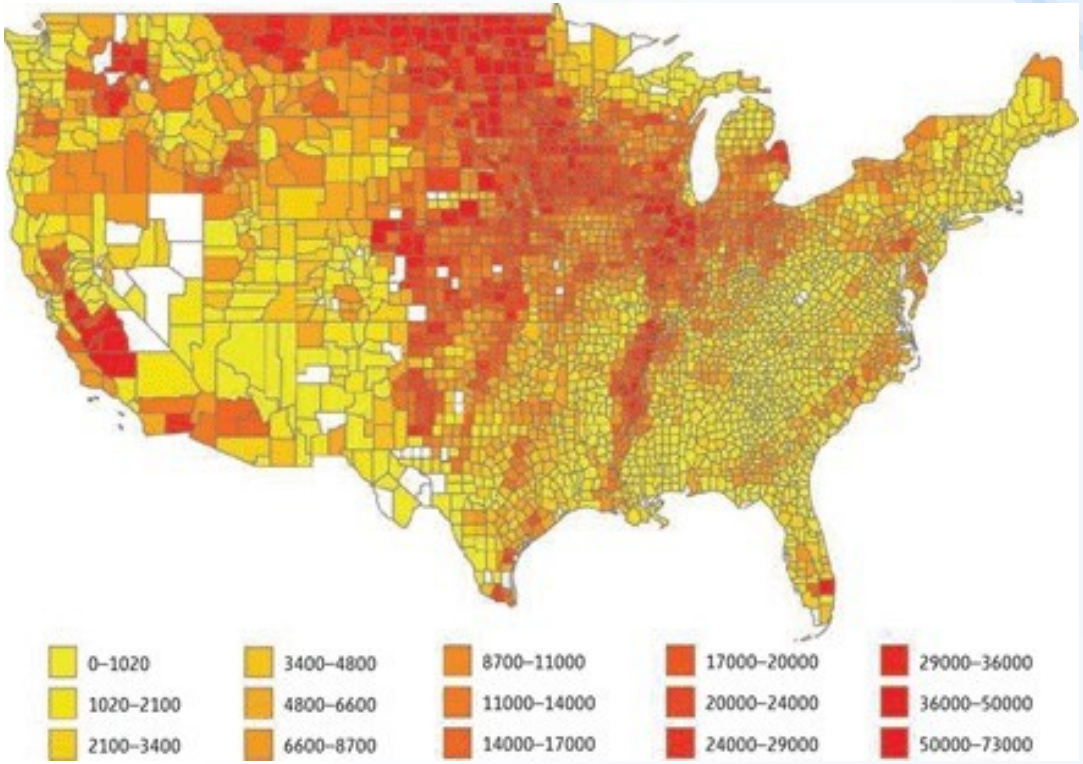
Science
AAAS

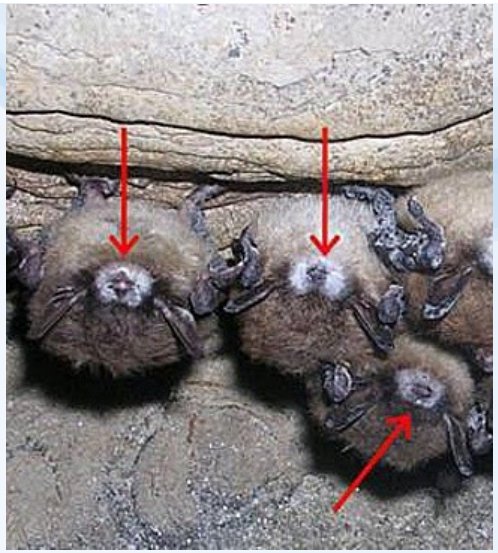
CONSERVATION

Economic Importance of Bats in Agriculture

Insectivorous bat populations, adversely impacted by white-nose syndrome and wind turbines, may be worth billions of dollars to North American agriculture.

Justin G. Boyles,[1]* Paul M. Cryan,[2] Gary F. McCracken,[3] Thomas H. Kunz[4]





Boyles et al. (2011) Science 332 (60251) 41-42

Ecotoxicology

assessment o hazards and risks of chemicals in ecosystems

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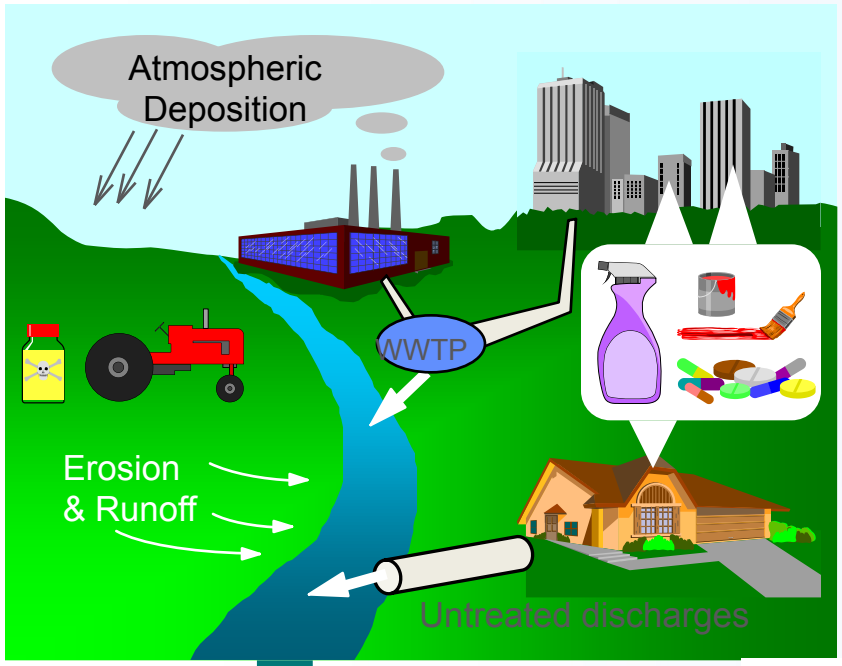
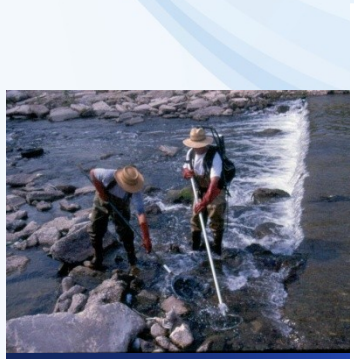
Cause → Effect (Causality)
Dose → Response
Risk assessment

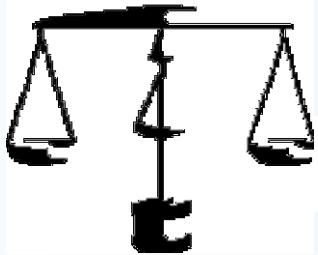
Exposure
(concentration >> dose)



Effect
(What exposure causes effects?)



Ecotoxicologica bioassays, field studies, biomonitoring…



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What is hazardous? What is toxic? How to define toxicity?

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Paracelsus (1493 - 1541)

'What is there which is not a poison?

- *All things are poison and nothing without poison.*
- *Solely the dose determines that a thing is not a poison.*

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(Eco)toxicology – ultimate goal ?

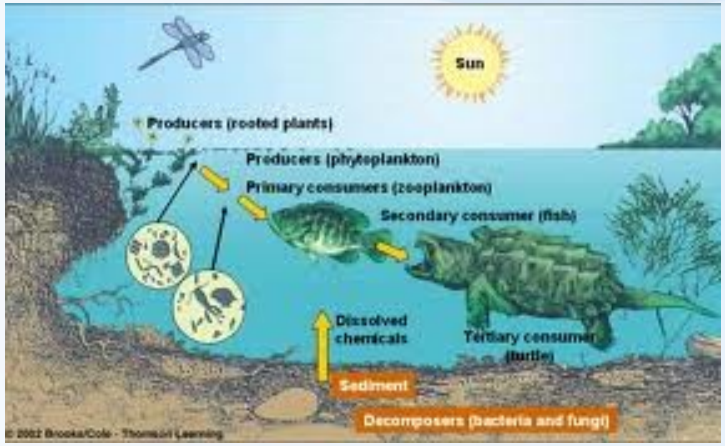
To identify (or predict)
safe *vs* hazardous levels

Assessment of one of the hazards (i.e. toxicity) to different targets

…to…

Humans (**TOXICOLOGY**)

Other organisms (**ECO**toxicology)



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ECOTOXICOLOGY by definition

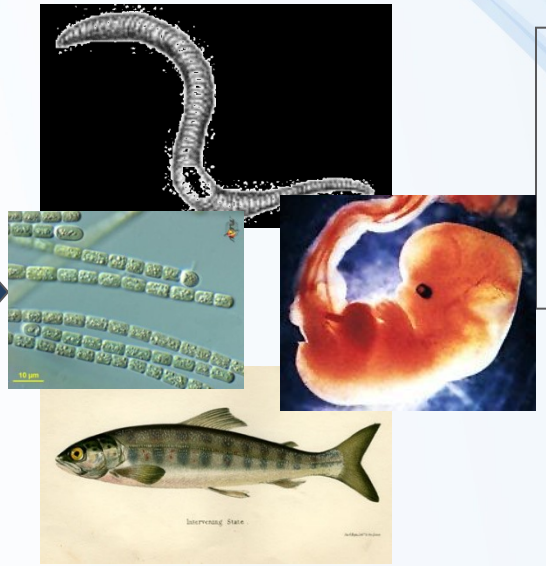
- **Aim:** to maintain the natural structure and function of ecosystems

- **Definitions:**
  - ecotoxicology is concerned with the **toxic effects** of chemical and physical agents on living organisms, especially on populations and communities within defined ecosystems; **it includes the transfer pathways** and their interactions with the environment
  - science of contaminants in the biosphere and their effect on constituents of the biosphere, including humans' (Newman & Unger, 2002)
  - science that provides critical information on effects of toxic compounds on living organisms which **SERVE various practical** aims (environmental protection)

CHEMICAL ENTERS THE ENVIRONMENT

LEVELS, FATE, PROCESSES

Bioavailable fraction



CHEMICAL ENTERS THE ORGANISM

biomonitoring

Toxicokinetics

biotransformation
bioactivation
excretion / sequestration

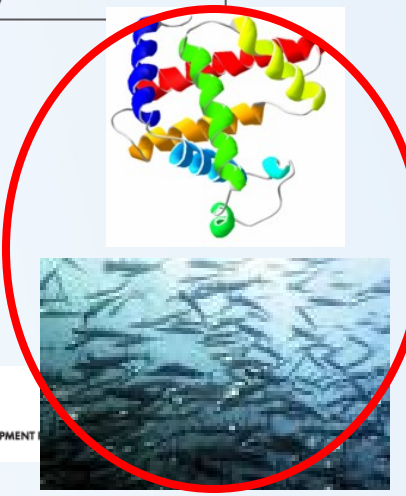
Target site

"EFFECT" toxicodynamics

"EXPOSURE"

acute

chronic



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Ecotoxicology - from molecules to ecosystems … and backwards

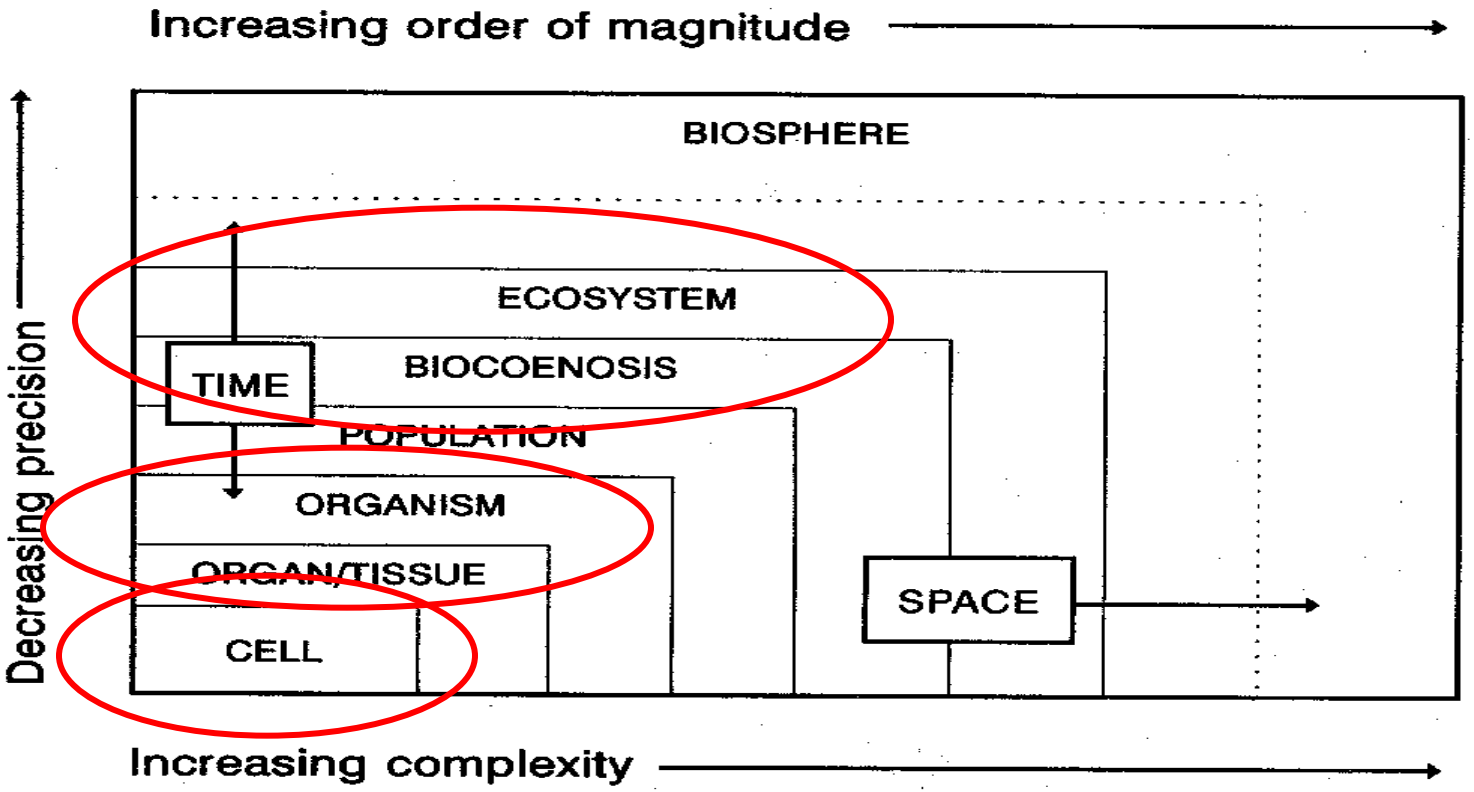
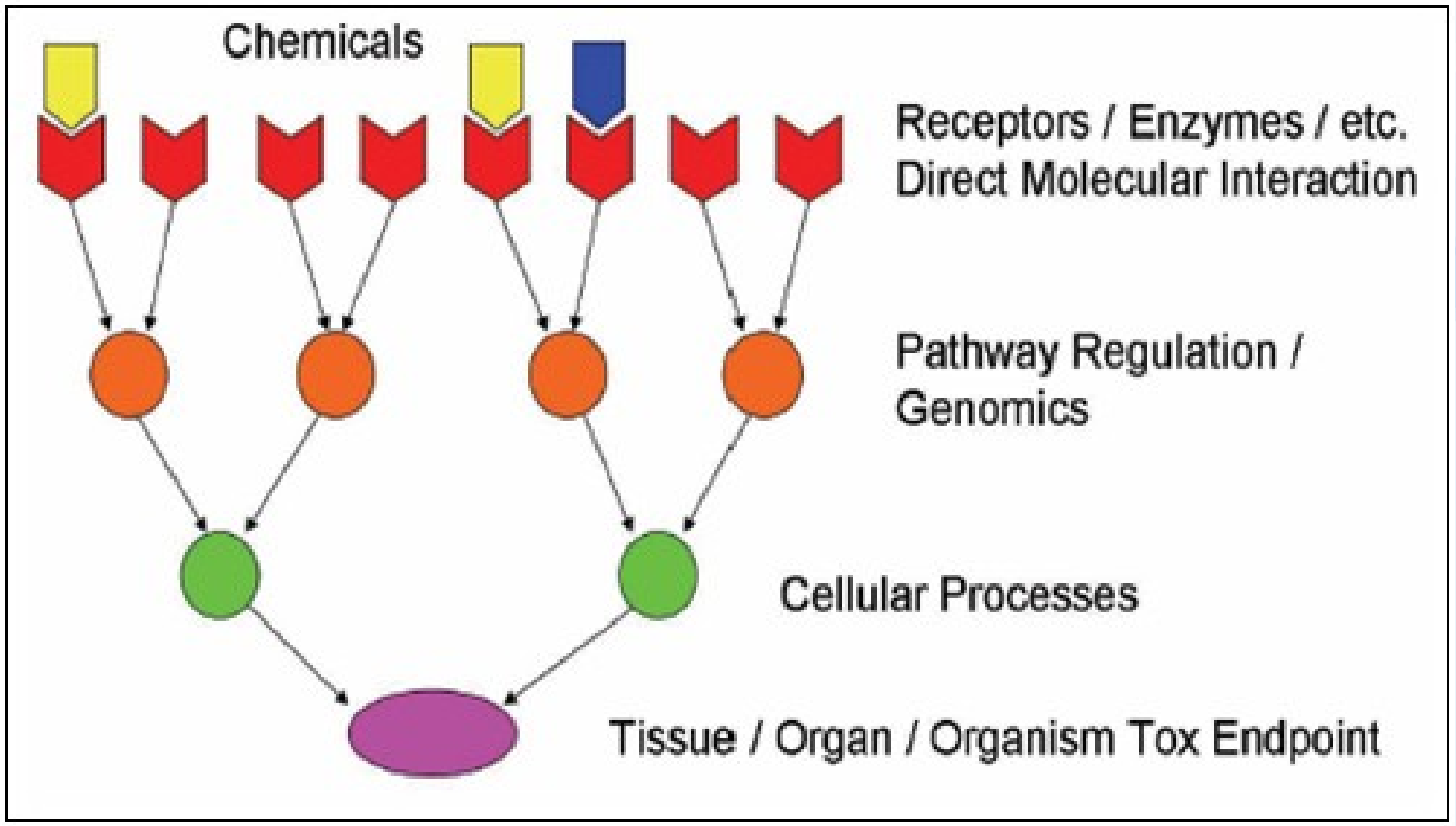


Figure 3.1 **Biological levels of organization. The dimensions of time and space are less important for the investigation up to the levels of populations and biocoenoses.**

From molecules to individuals → to populations

MECHANISMS OF TOXICITY



Ecotoxic effects

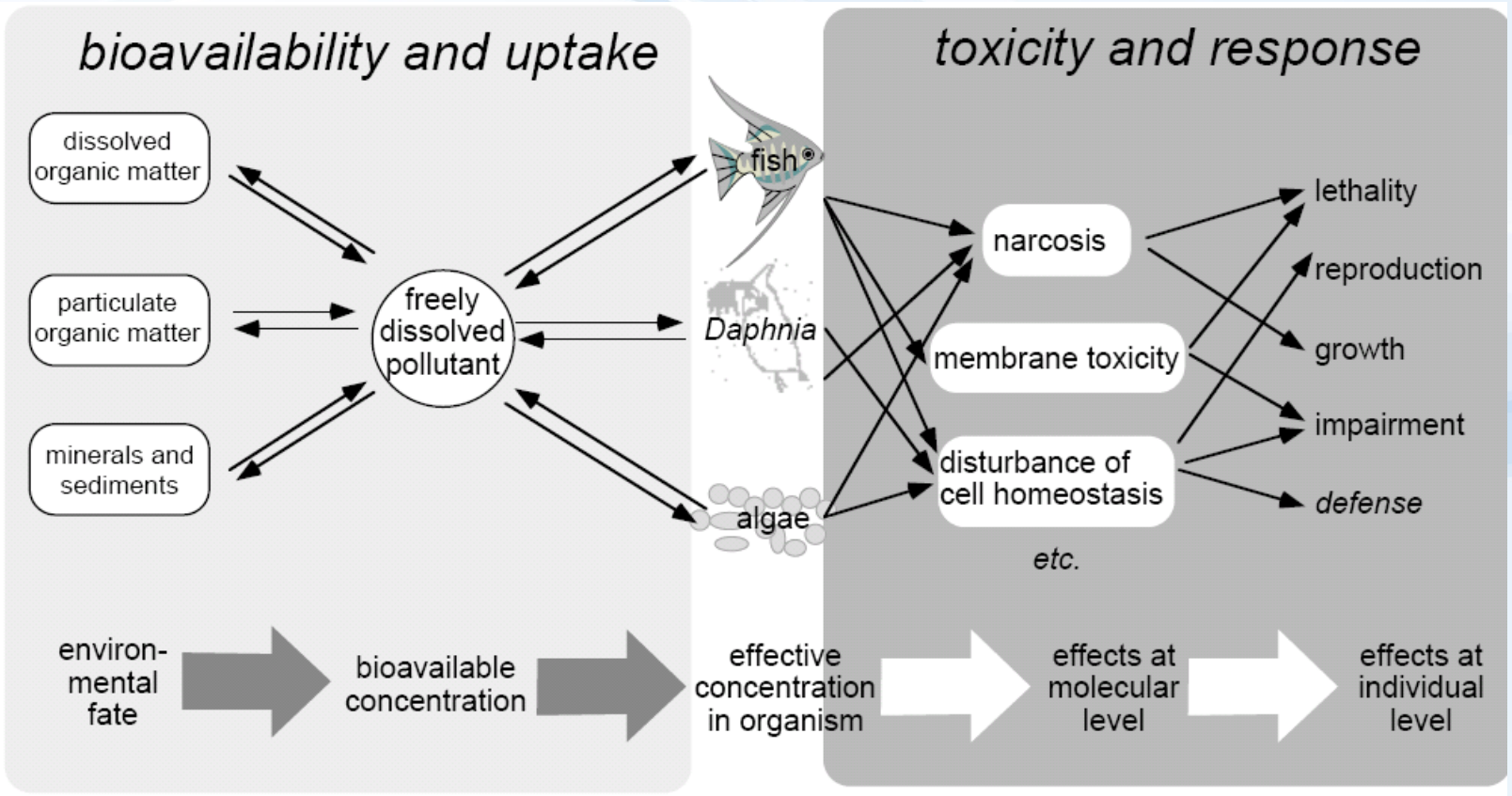
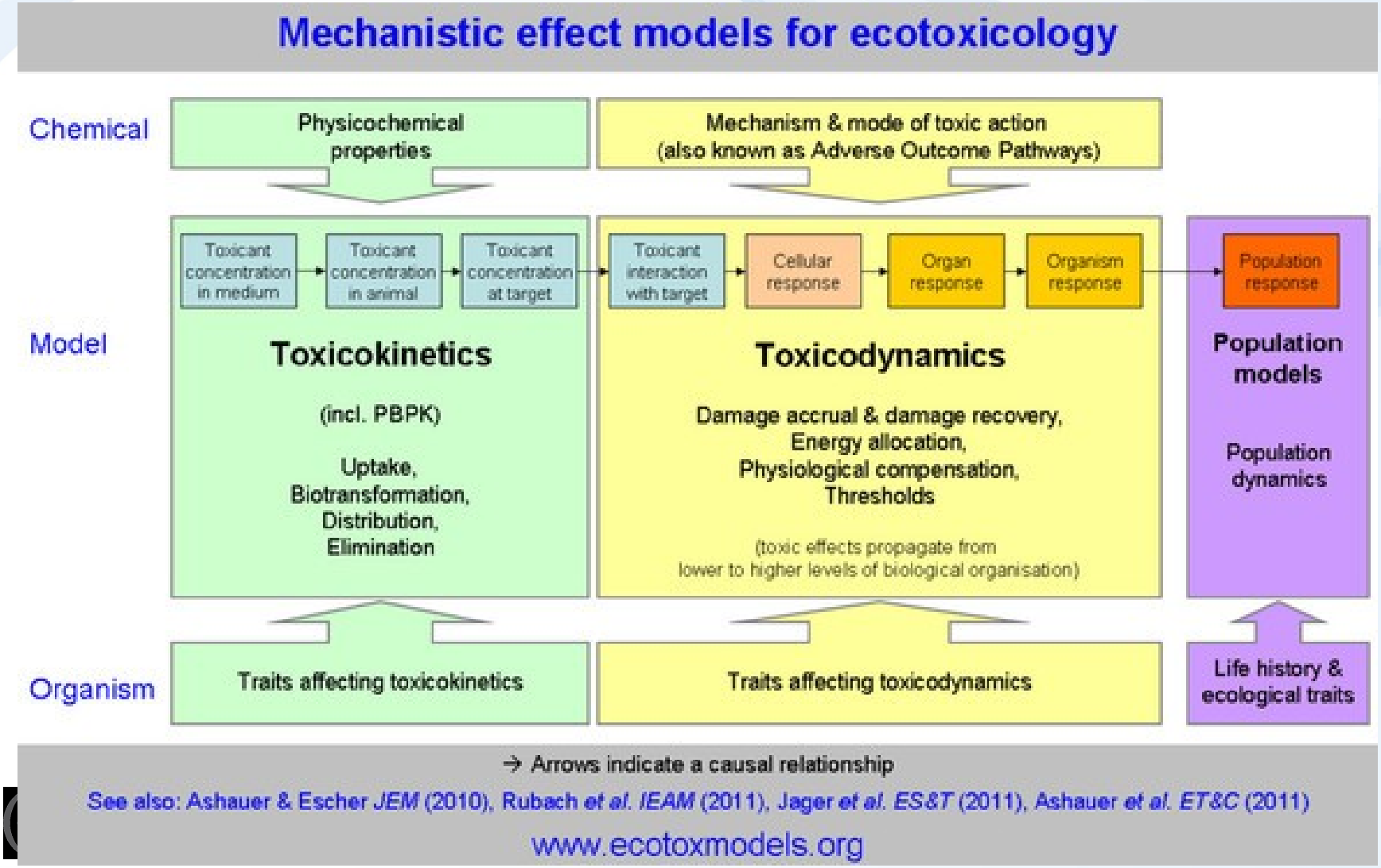


Figure 1 *The effective concentration of a pollutant in an organism (e.g. fish, daphnia, algae) or at the target site inside the organism is the link between the environmental fate of a pollutant and its toxic effect.*

Escher, B. I., Behra, R., Eggen, R. I. L., Fent, K. (1997), "Molecular mechanisms in ecotoxicology: an interplay between environmental chemistry and biology", *Chimia,* **51**, 915-921.

From molecules to individuals → to populations

ADVERSE OUTCOME PATHWAYS



From ecosystems

→

down the mechanisms

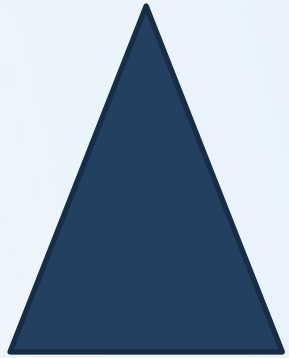
OR

?

From mechanisms (molecules)

→

up to effects and ecosystems



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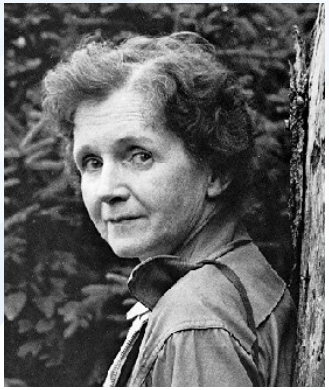
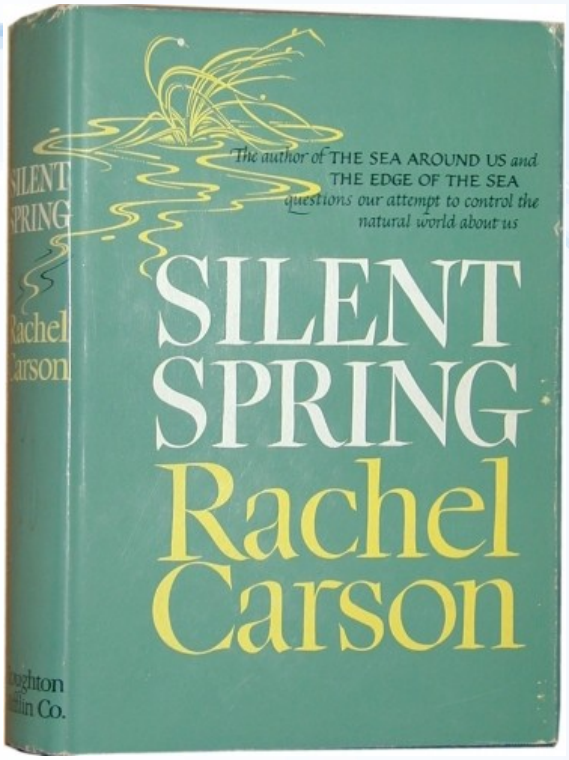
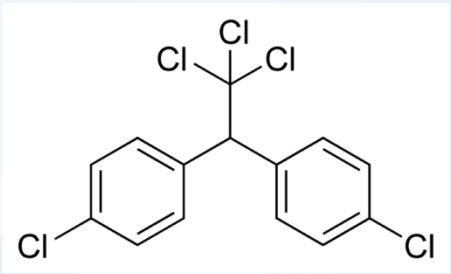
1962







© Patuxent Wildlife Refuge, MA, USA

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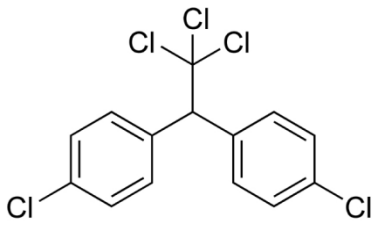
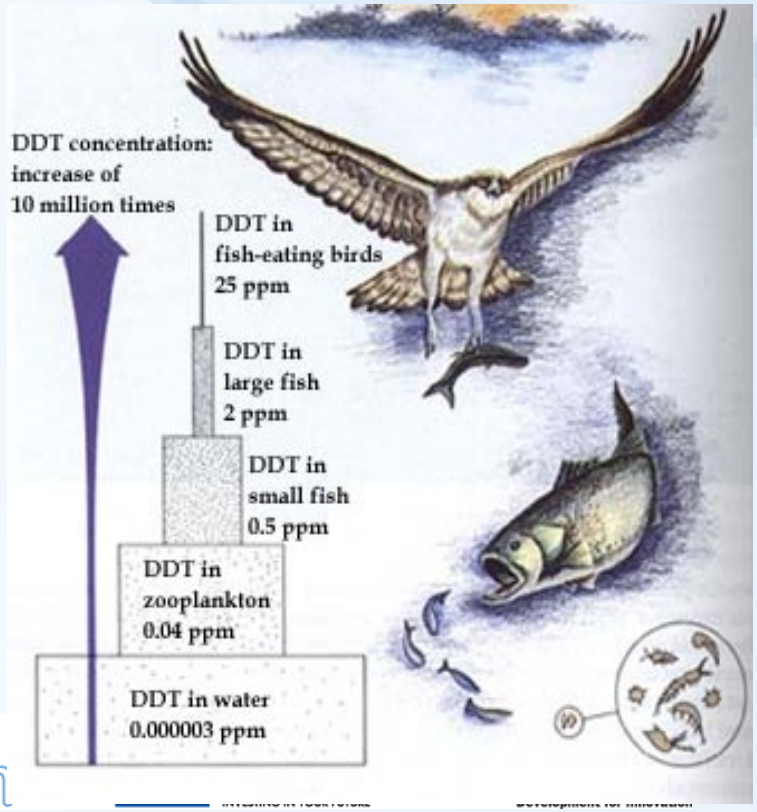
http://www2.ucsc.edu/scpbrg/

Bitman et al. *Science* 1970, 168(3931): 594

Biochemistry
bird carbonate dehydratase



In situ: bioaccumulation
-> bird population decline



In vivo: shell thinning

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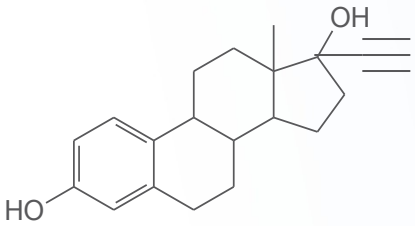
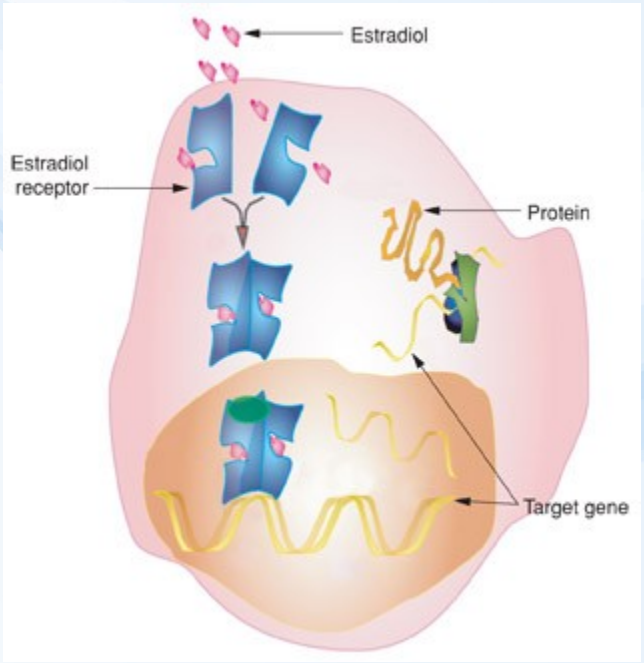
AOP Example: Activation of ER - estrogen receptor (e.g. by EE2) leads to reproductive disorders and population decline in fish

Ethinylestradiol (EE2)



Binds to ESTROGEN RECEPTOR



Target genes
- Proliferation/Apoptosis (sexual organs)
- Synthesis of egg yolk (fish, amphibia)

Effects
- Females: reproduction regulation
- Males: feminization

(+ *e.g. cancer promotion, development, immunomodulation)*

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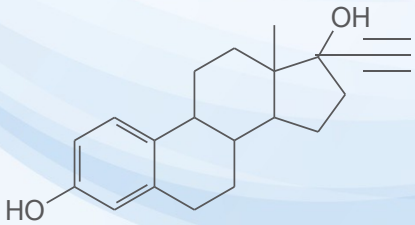
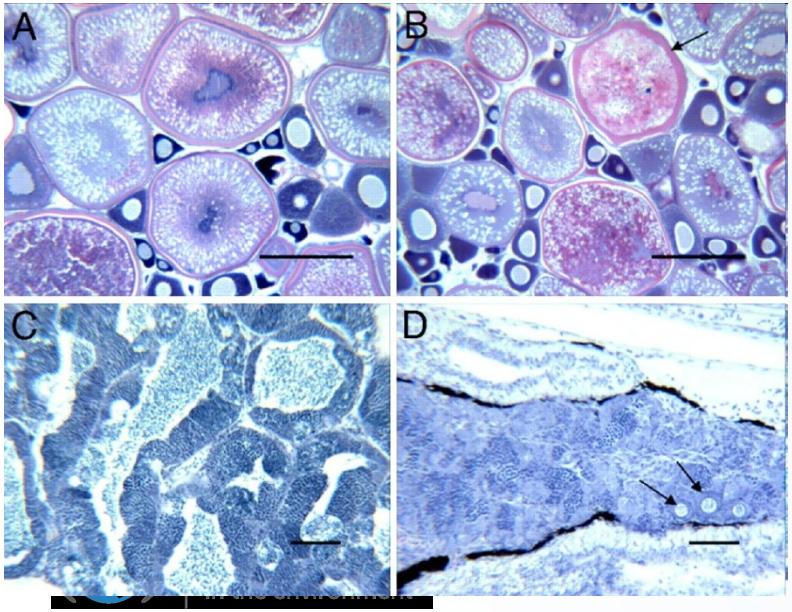
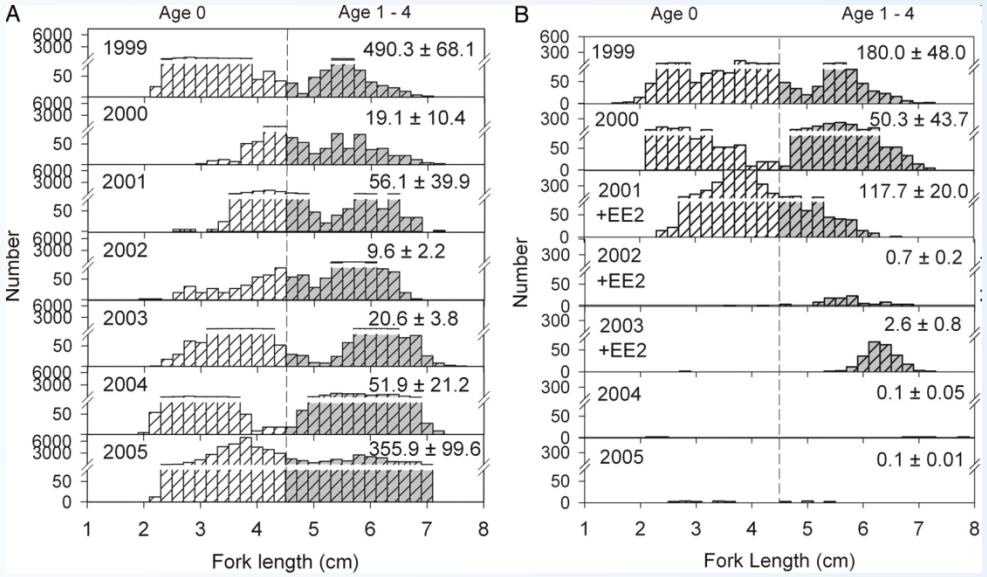
Kidd, K.A. et al. 2007. **Collapse of a fish population** following exposure to **a synthetic estrogen**. *Proceedings of the National Academy of Sciences* 104(21):8897-8901

5 ng/L (!)
7 years





Controls **+Ethinylestradiol**



WRAP UP … take home message

- Ecotoxicology as a science with close links to practical environmental protection
  - Understand the importance and links between ECOTOXICITY --- BIODIVERSITY --- ECOSYSTEM SERVICES

- From molecular events to higher levels
  - Be aware of different biological levels - from molecules to communities
  - Know example(s) of „Adverse Outcome Pathway(s)“