Research centre
for toxic compounds
in the environment

Ecotoxicology
Part 1 - Introduction

Ludek Blaha + ecotox colleagues

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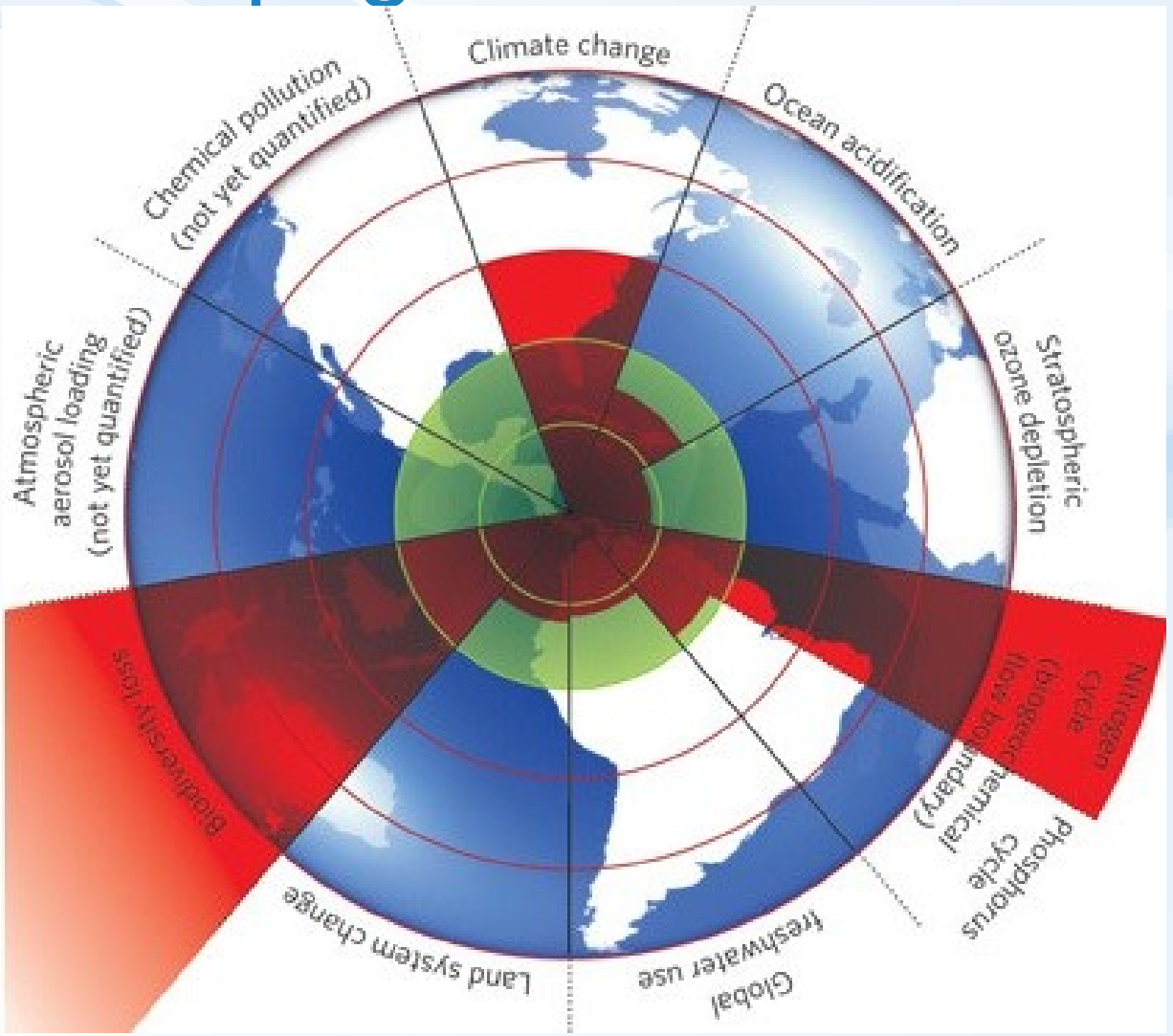
Global anthropogenic threats ?

A safe operating space for humanity & the nine planetary boundaries

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



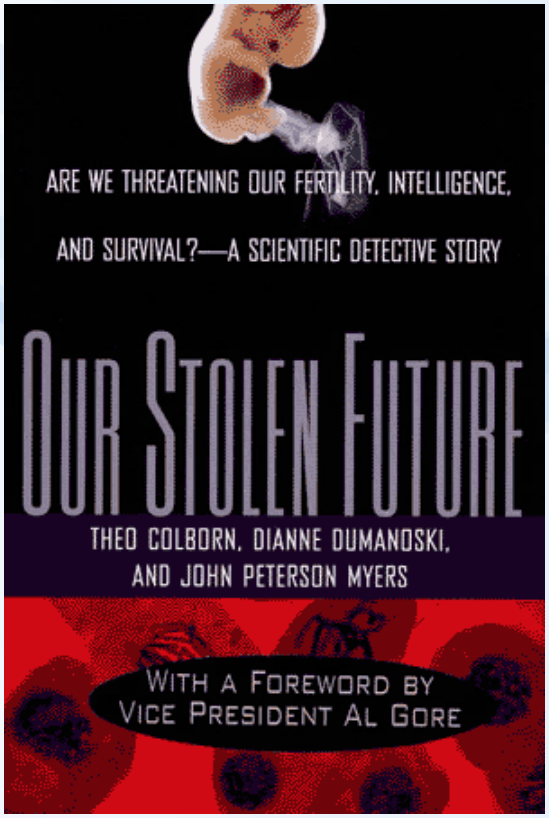
1996 - Chemicals in the environment

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

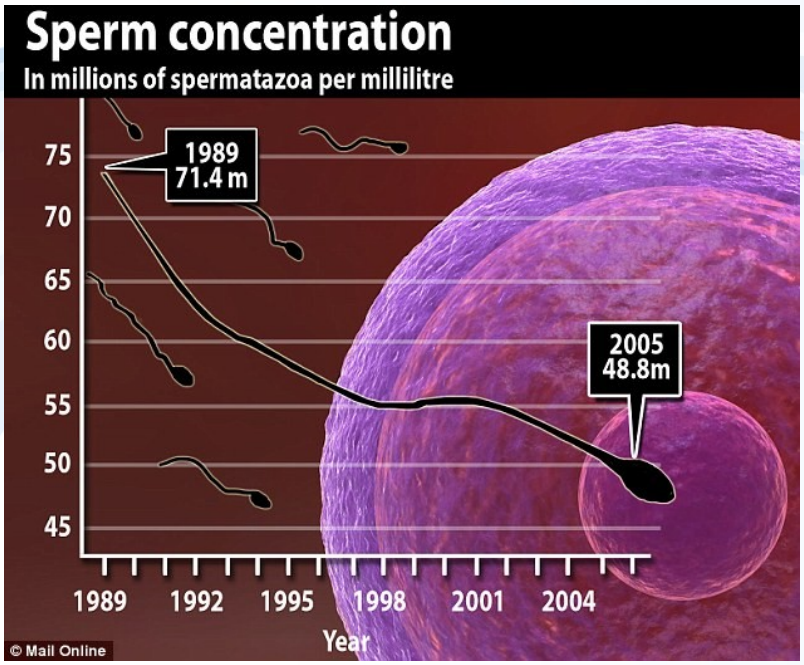
Man-made chemicals blamed as many more girls than boys are born in Arctic

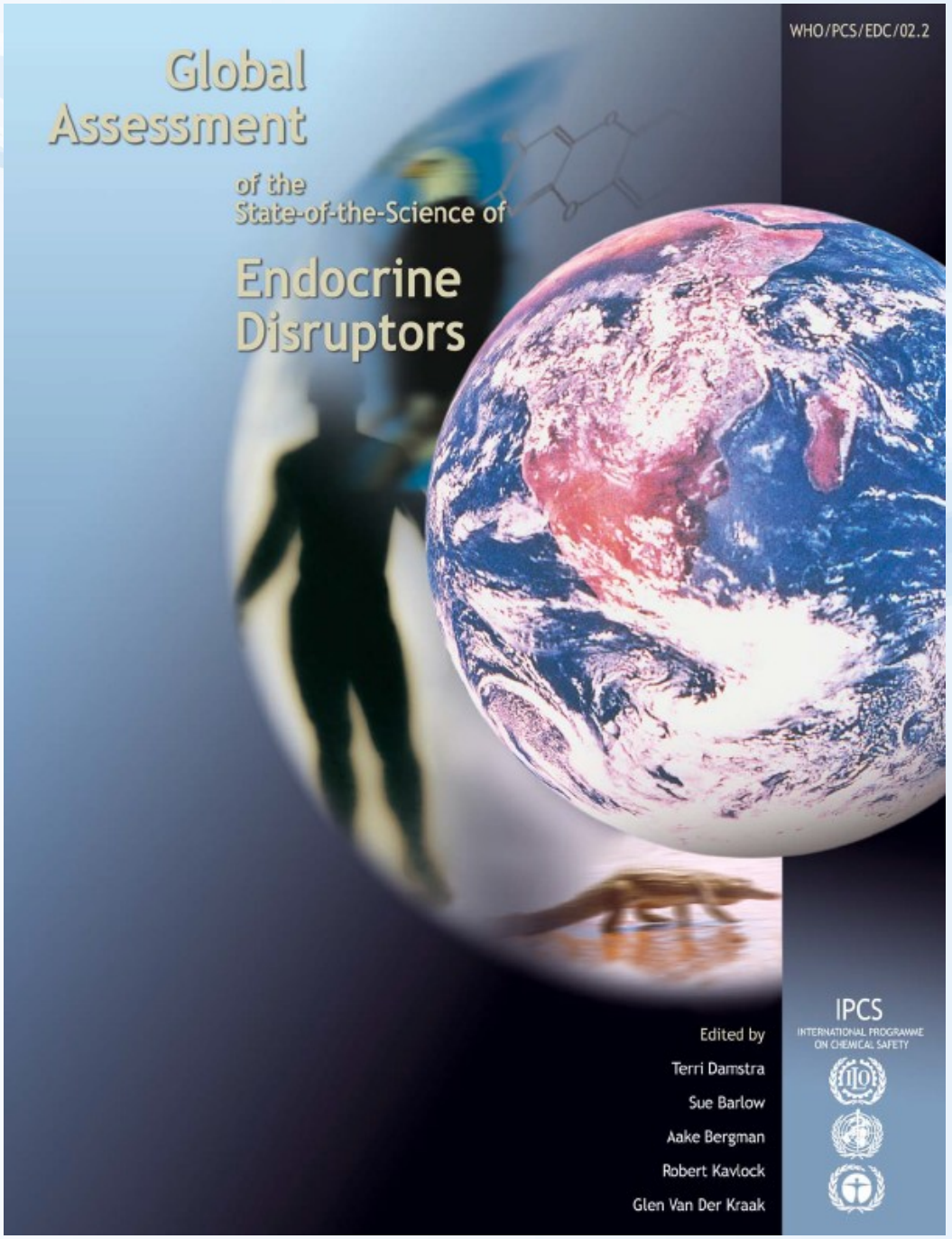
- High levels can change sex of child during pregnancy
- Survey of Greenland and east Russia puts ratio at 2:1

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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Changes in biodiversity

NATURE (2012) 482: 20

ATTACK OF THE BLOBS

Blooms of giant Nomura's jellyfish (*Nemopilema nomurai*) have troubled Japanese fishing crews.

KODOMO NEWSCOM

increase in the global population of jellyfish — a catch-all term that covers some 2,000 species of true cnidarian jellyfish, ctenophores (or comb jellies) and other floating creatures called tunicates. But many marine biologists are now questioning the idea that jellyfish have started to overrun the oceans.

This week, a group of researchers published preliminary results from what will be the most comprehensive review of jellyfish population data[1]. They say that there is not yet enough evi-

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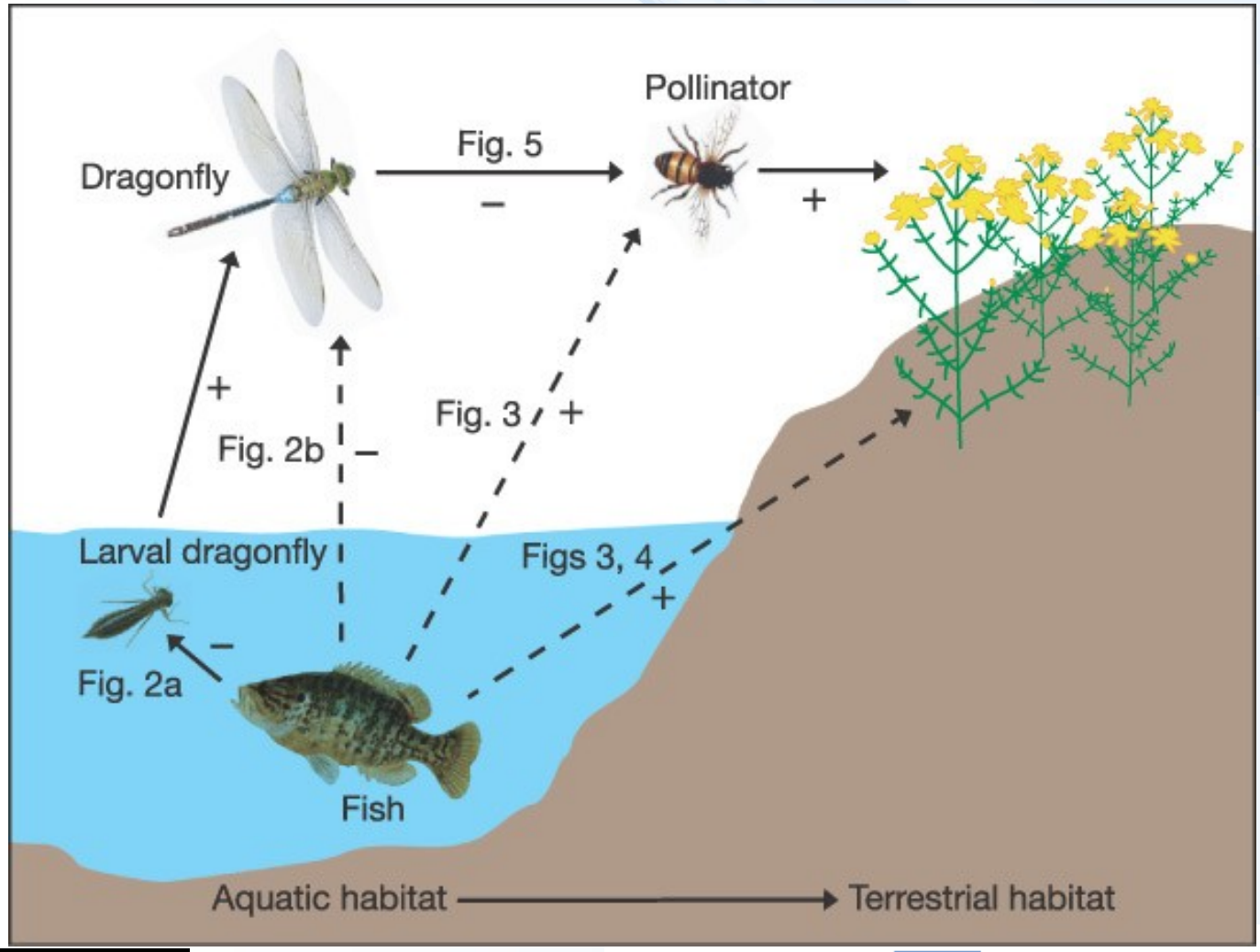
Major impacts

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)]

Ecotoxicology

assessment o hazards and risks of chemicals in ecosystems

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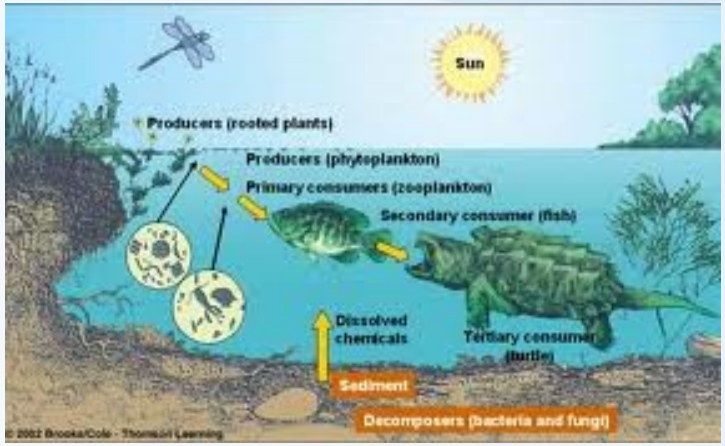
Assessment of chemical hazards

…to…

Humans (**TOXICOLOGY**)

Other organisms (**ECO**toxicology)



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ECOTOXICOLOGY by definition

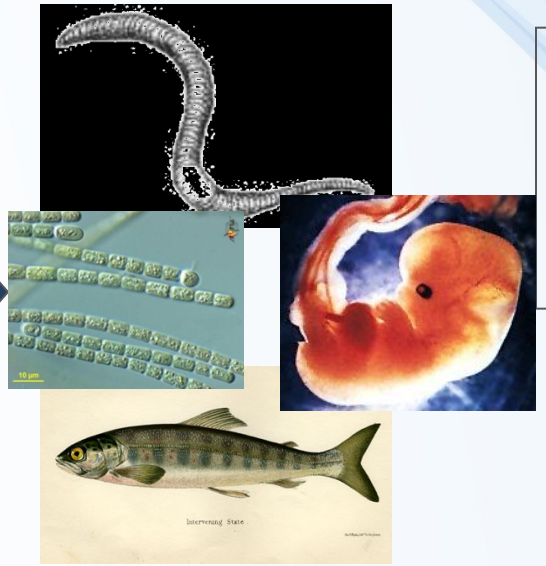
- **Aim:** to maintain the natural structure and function of ecosystems

- **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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Ecotoxic effects

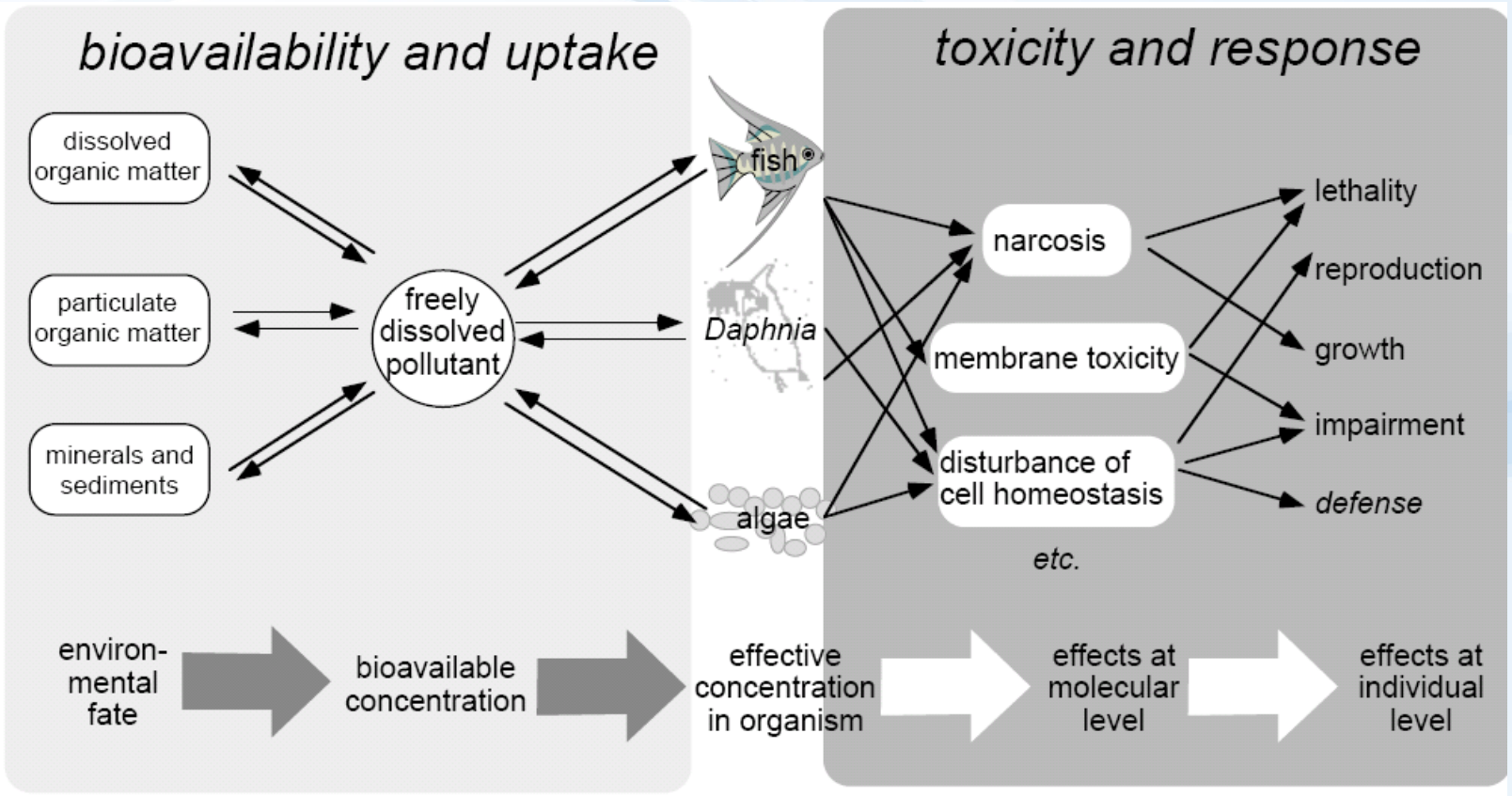


Figure 1 *The effective concentration of a pollutant in an organism (e.g. fish, daphnia, algae) or at the target site inside the organism is the link between the environmental fate of a pollutant and its toxic effect.*

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.

Ecotoxicology - from molecules to ecosystems … and backwards

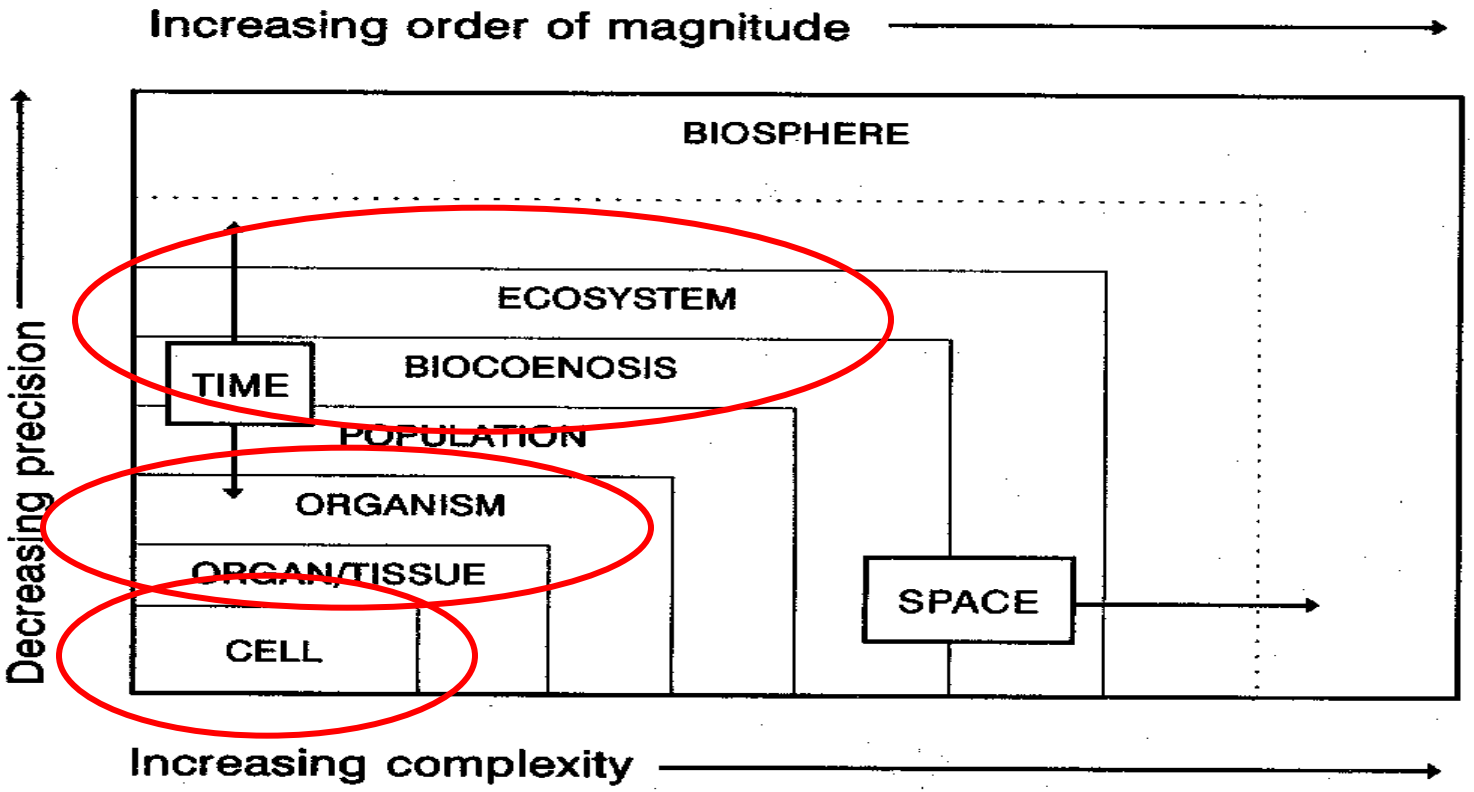


Figure 3.1 **Biological levels of organization. The dimensions of time and space are less important for the investigation up to the levels of populations and biocoenoses.**

From ecosystems

→

down the mechanisms

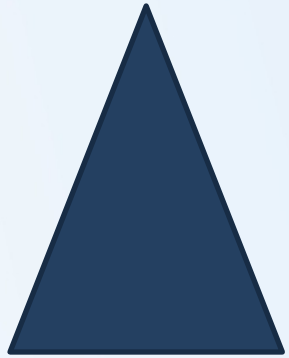
OR

?

From mechanisms (molecules)

→

up to effects and ecosystems



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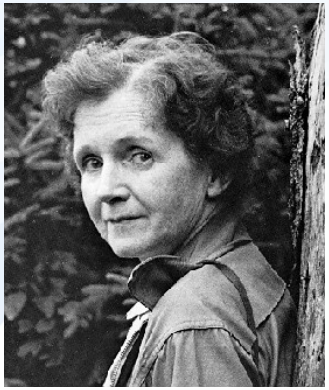
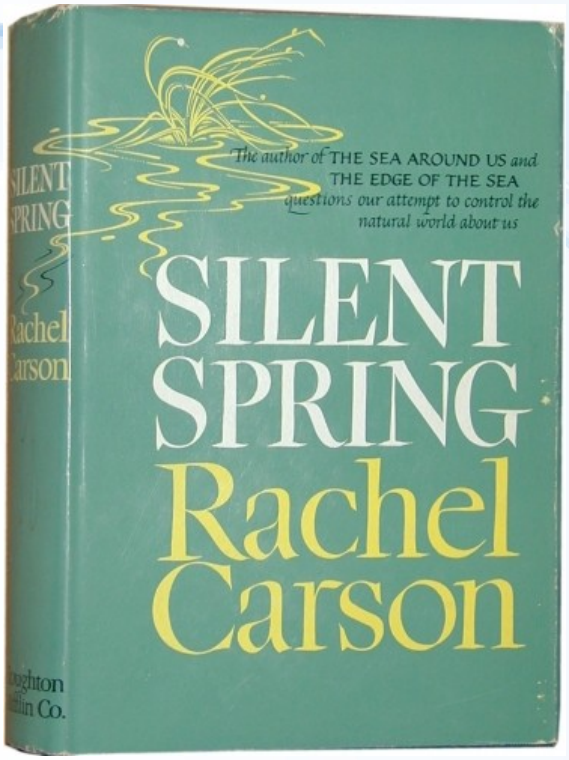
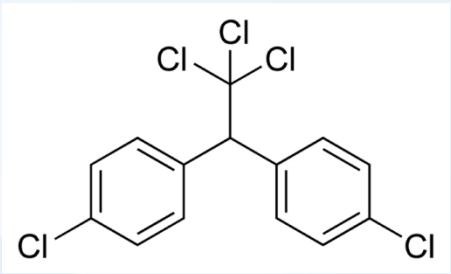
1962







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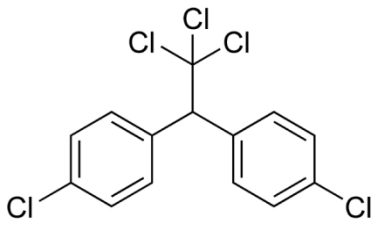
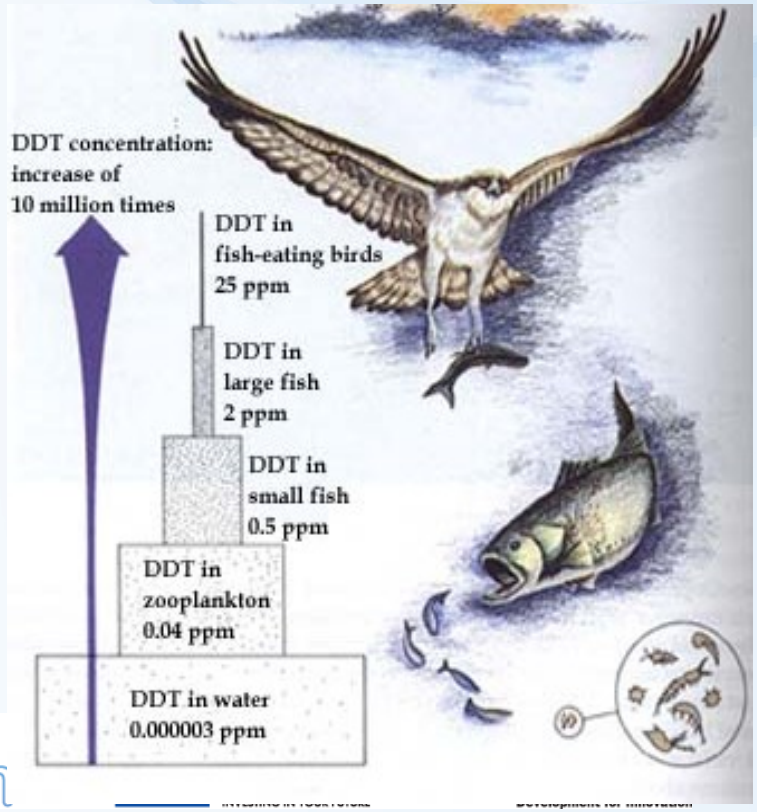
http://www2.ucsc.edu/scpbrg/

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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in the environment

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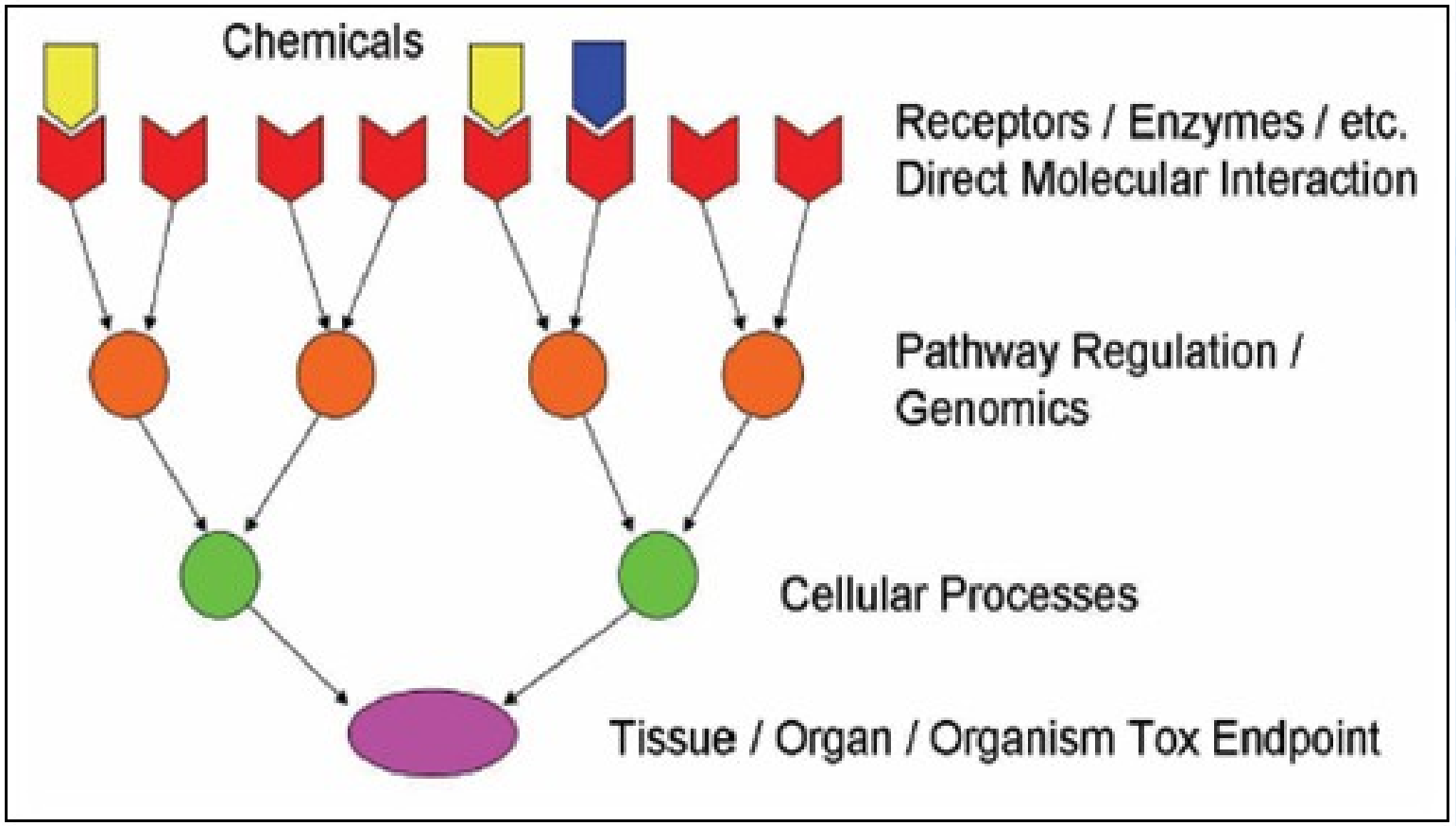
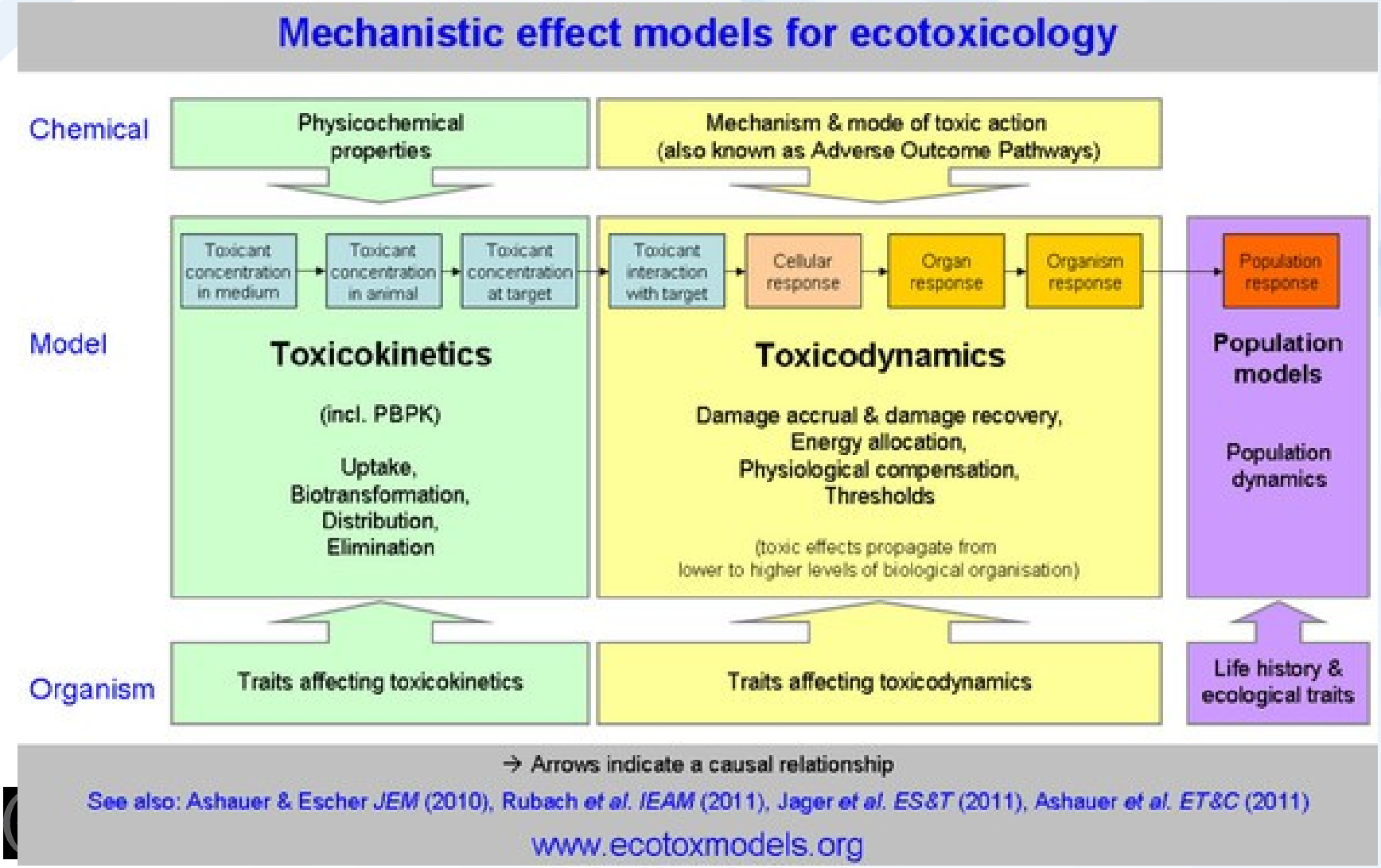
1) From molecules to individuals

MECHANISMS OF TOXICITY



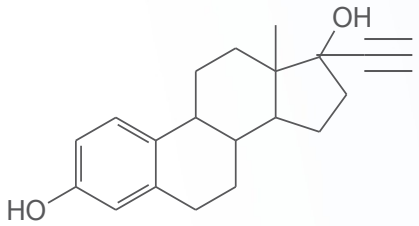
2) From molecules to individuals - AOPs

ADVERSE OUTCOME PATHWAYS

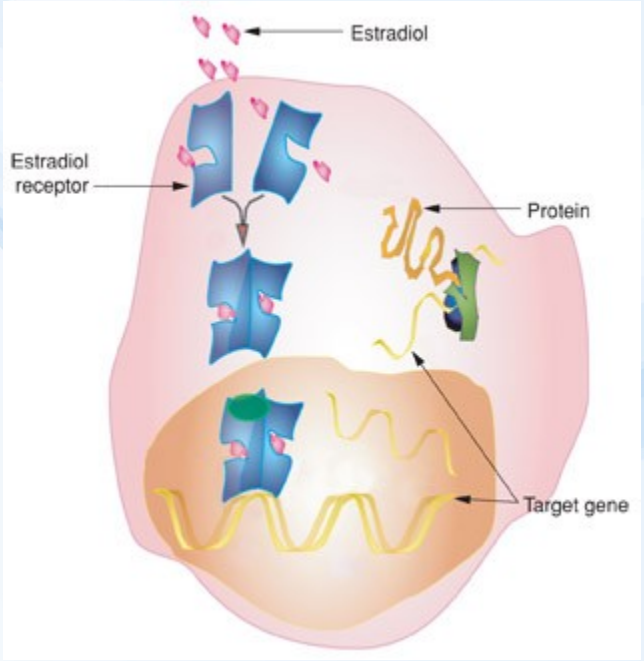


AOP Example: ethinylestradiol

Ethinylestradiol



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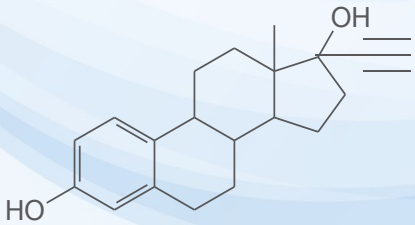
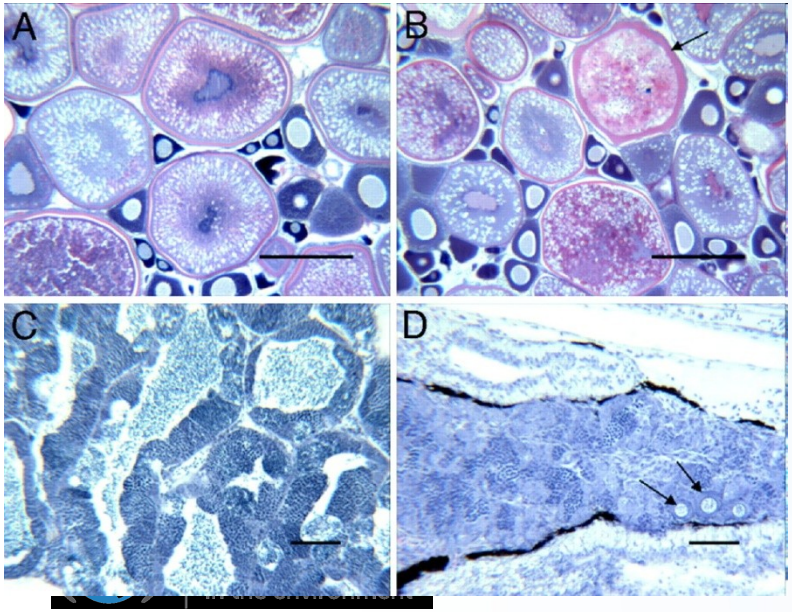
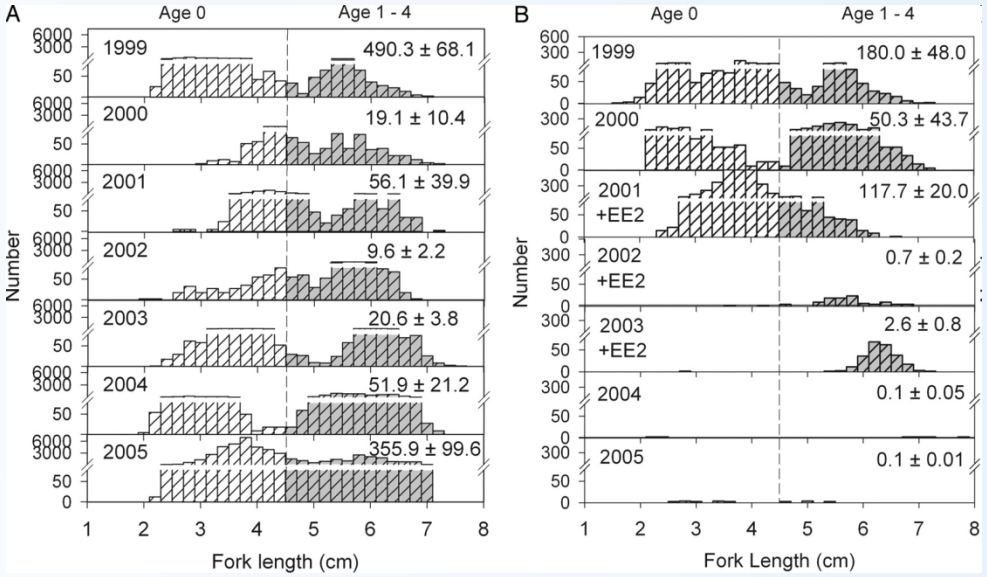
Kidd, K.A. et al. 2007. **Collapse of a fish population** following exposure to **a synthetic estrogen**. *Proceedings of the National Academy of Sciences* 104(21):8897-8901

5 ng/L (!)
7 years



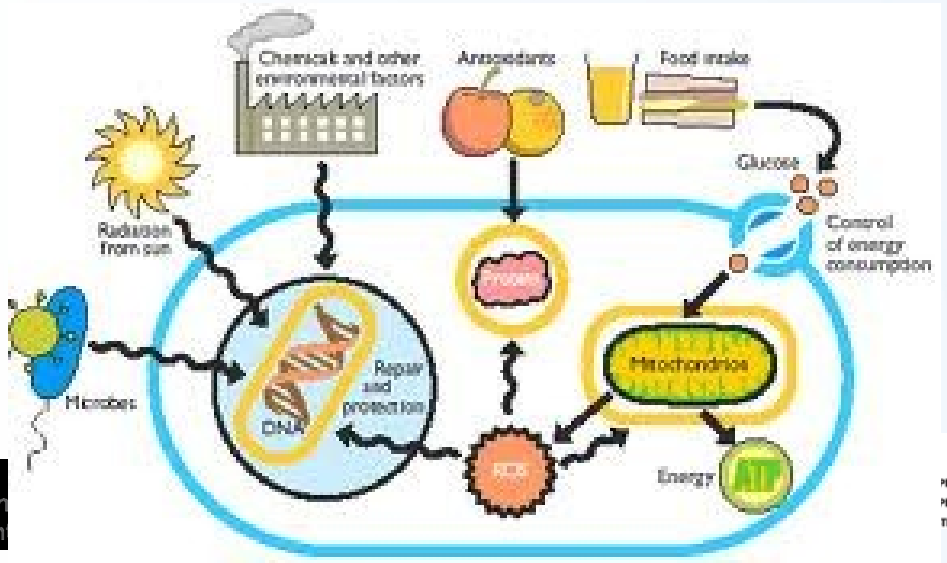


Controls **+Ethinylestradiol**



Effects at different levels - molecular

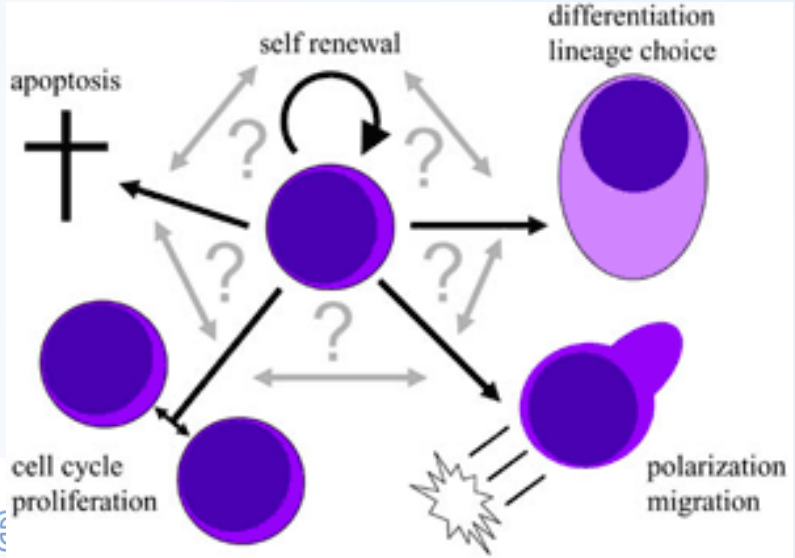
- **Molecular**
  - Nonspecific effects
    - Hydrophobic interactions with phospholipid membranes (baseline = narcotic toxicity)
    - Direct reactivity: electrophilic compounds → nucleophilic organism (e.g. oxidation of PROTEINS, lipids (membranes), DNA …)
  - Specific effects
    - Activation of ER, AR and other „nuclear receptors“
    - Inhibition of enzymes (e.g. CN- inhibits hemes in mitochondria/hemoglobin, insecticides …)



Effects at different levels - cellular

- **Cellular**
  - Effects on structure
  - Effects on metabolism (maintenance)
  - Effects on regulation

→Changes in functions (e.g. Ethinylestradiol)
→Repair, survival, growth
→Death (apoptosis or necrosis)
→Proliferation
→Differentiation



Effects at different levels - ORGANISM

- **Organism level –** important in ecotoxicology (see Bioassays)
  - Effects on structure
  - Effects on metabolism (maintenance)
  - Effects on regulation

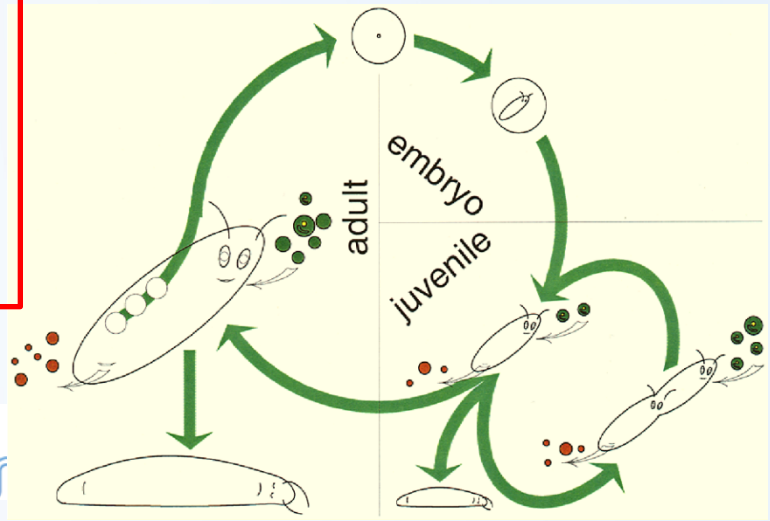
→Changes in functions (e.g. Ethinylestradiol)

→Repair, survival, **growth**

→**Death**

→Proliferation = **Reproduction**

3 key apical endpoints
(reflected e.g. in regulations)



Energy
hv
food

Losses
heat
faeces

Life
(*maintenance*)

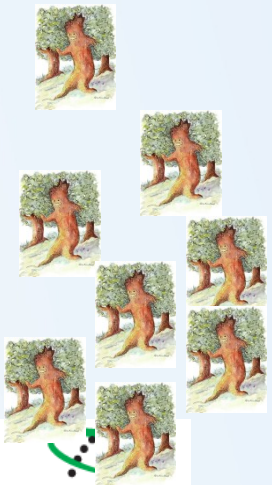
Metabolism

Control,
Interactions
with environment

Defence
against pathogens
predators …

Growth
to sexual
maturity

Reproduction



Defence against
toxicants

Chemical
stress

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Chemical stress
→ energy re-allocation
→ „insufficient“ resourses elsewhere

Energy
hv
food

Losses
heat
faeces

Life
(*maintenance*)

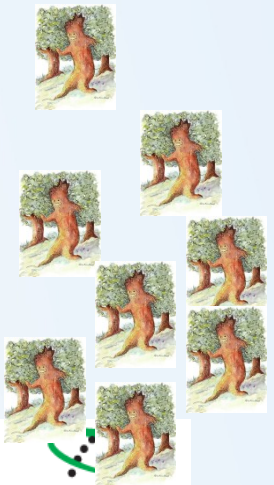
Metabolism

Control,
Interactions
with environment

Defence
against pathogens
predators …

Growth
to sexual
maturity

Reproduction



Defence against
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Chemical
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Chemical stress

+ ... another stress
(food scarcity)

Energy
hv
food

Losses
heat
faeces

Life
(*maintenance*)

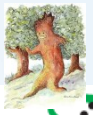
Metabolism

Control,
Interactions
with environment

Defence
against pathogens
predators …

Growth
to sexual
maturity

Reproduction



Defence against
toxicants

Chemical
stress

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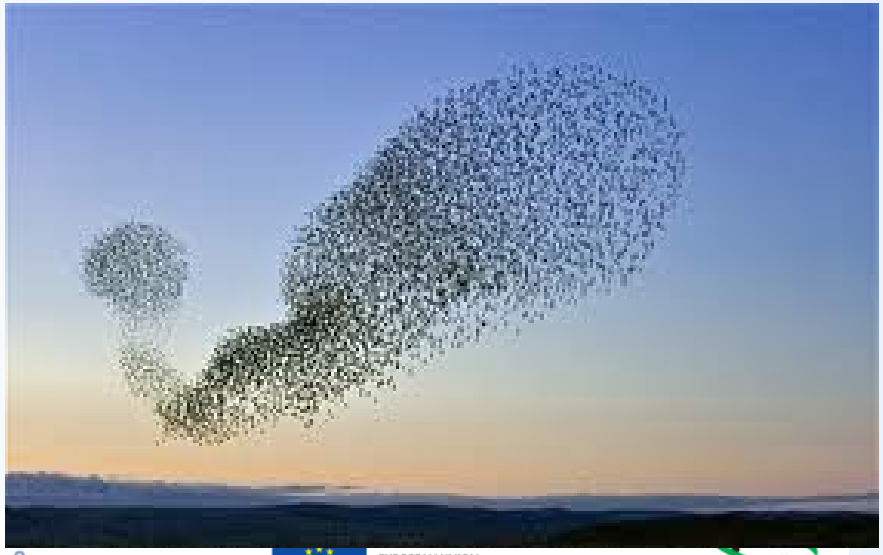
Effects at different levels

- **Population**

  (… all the organisms that both belong to the same group or species (i.e. can sexually reproduce) and live in the same time within the same geographical area)

  - Effects on structure
    - elderly vs. young, males vs. females
  - Effects on maintenance & growth
    - Natality, mortality, reproduction fitness



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Effects at different levels

- **Community & Ecosystem**

  (… a group of interacting living organisms sharing a populated environment)

  - Effects on structure
    - Loss of species, loss of biodiversity
  - Effects on functioning
    - (including „ecosystem functions“)

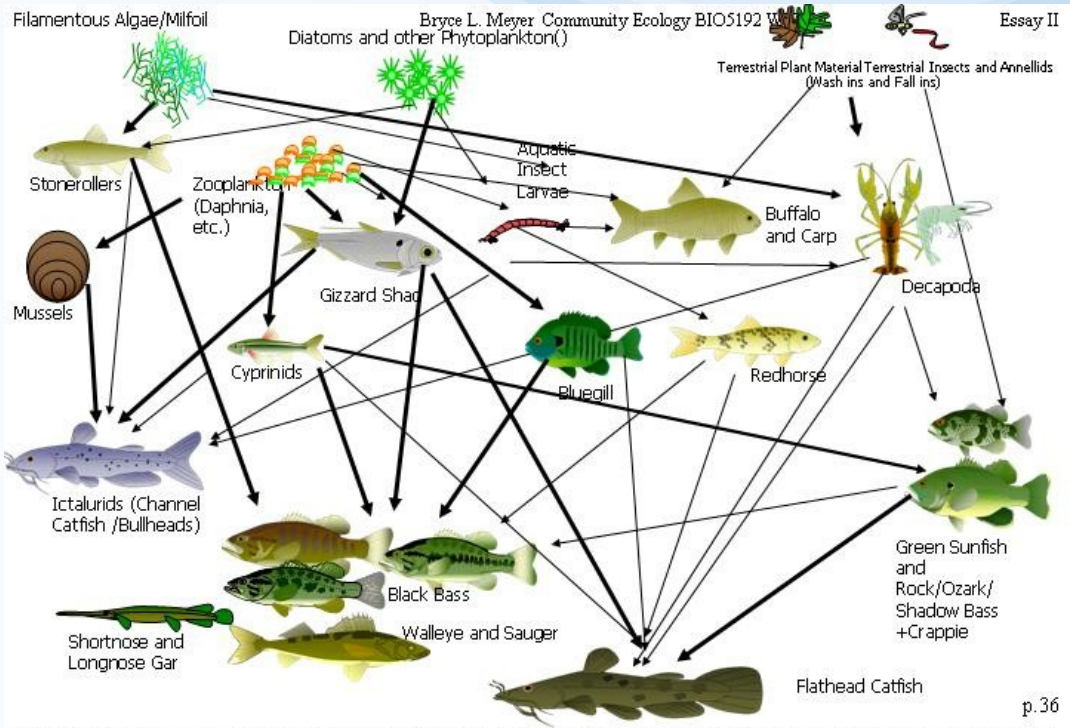

Figure #31: Simplified Food Web (Source Down) similar to warm water lower end of river before entry into Mississippi River System or impoundment. The Flathead acts as a super predator when present as large specimens, and many predators such as walleyes and Gars compete for minnows and shad. Channel Catfish also appear and prey upon mussels and other invertebrates.

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 examples of effects at these different levels
  - Know example(s) of „Adverse Outcome Pathway(s)“
- Understand keywords such as
  - Exposure - Bioavailability
  - Toxicokinetics – Toxicodynamics
  - Apical endpoints in ecotoxicology … and interaction among them