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# Ecotoxicology Part 1 - Introduction

Ludek Blaha + ecotox colleagues

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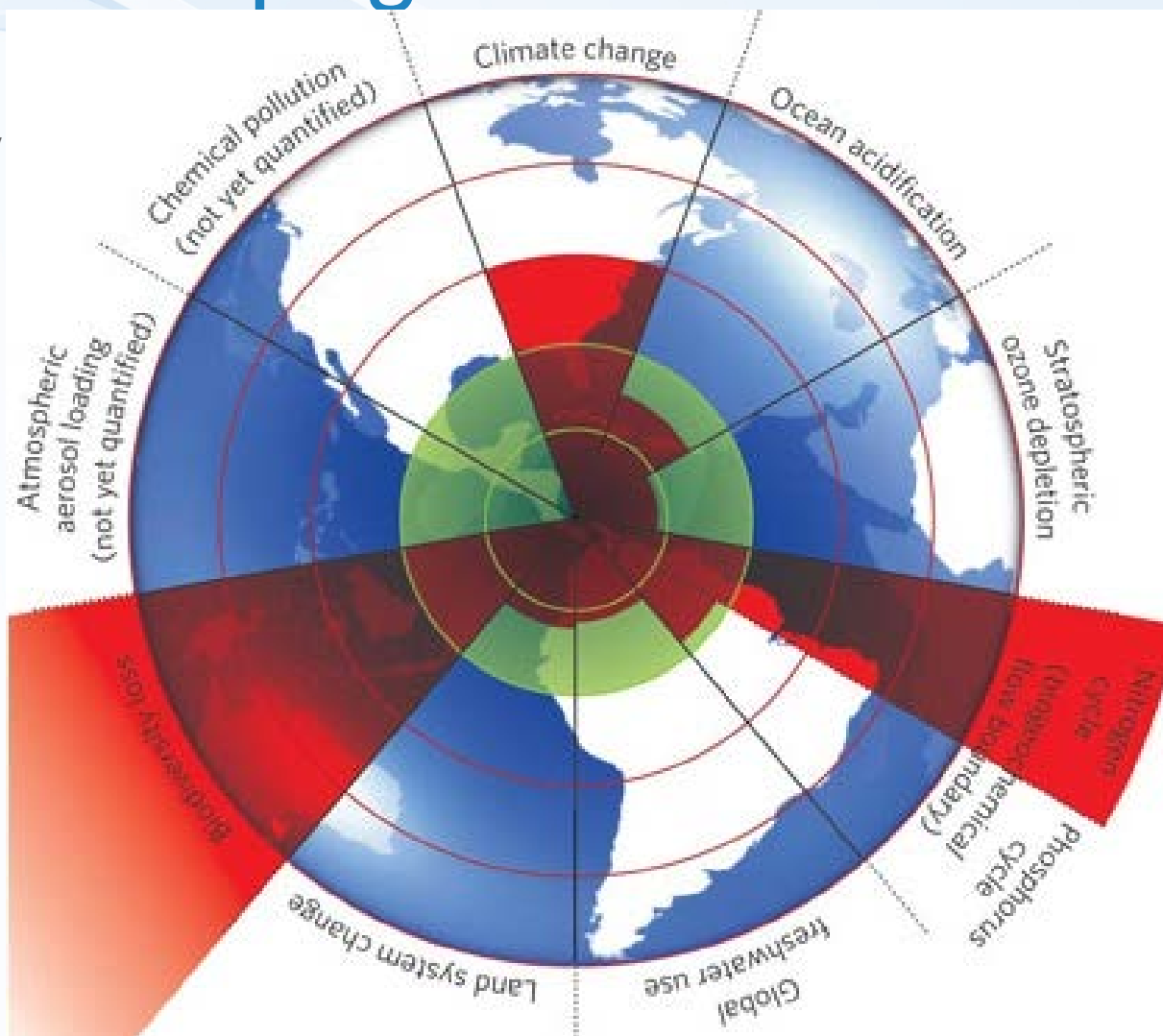
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# Global anthropogenic threats ?

## A safe operating space for humanity & the nine planetary boundaries

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



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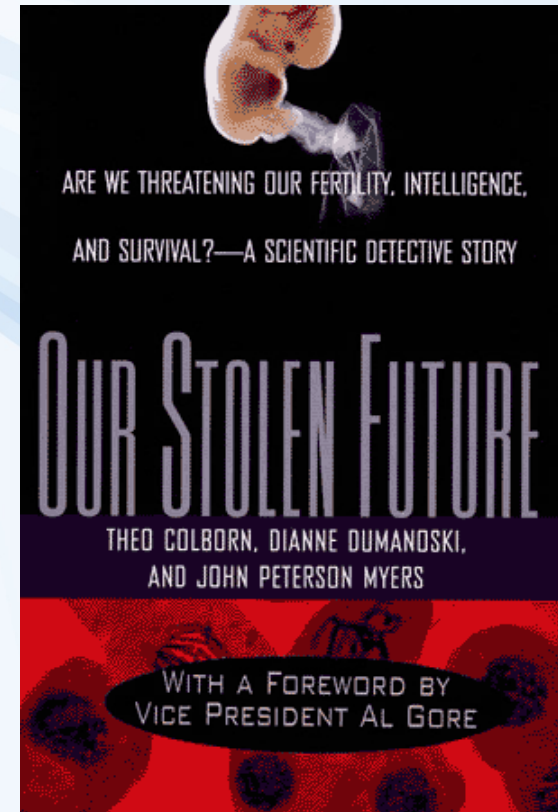
# 1996 - Chemicals in the environment

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 ?



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## How we stand 20 years later?

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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



This article is 8 years old

Shares

79



Save for later

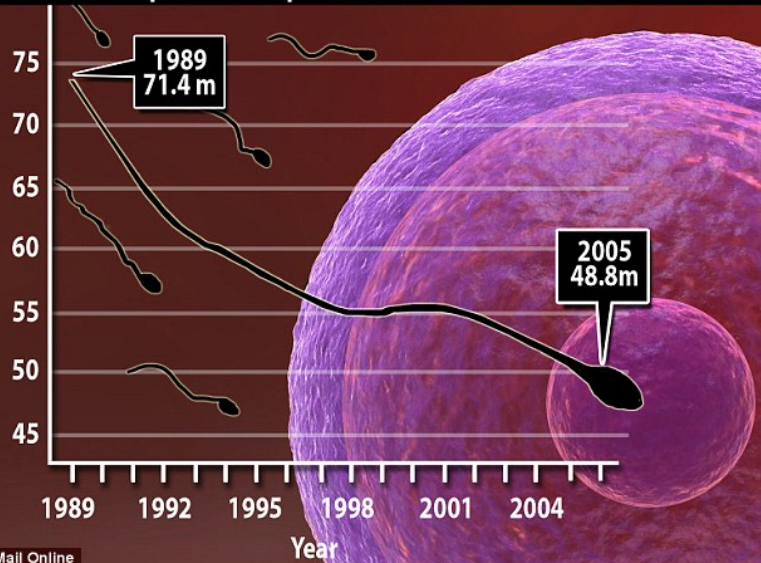


An Inuit child in a traditional parka. Photograph: Joel Sartore/Getty/National Geographic



# Sperm concentration

In millions of spermatazoa per millilitre



© Mail Online

# Global Assessment

of the  
State-of-the-Science of

# Endocrine Disruptors

WHO/PCS/EDC/02.2



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Edited by

Terri Damstra

Sue Barlow

Aake Bergman

Robert Kavlock

Glen Van Der Kraak

IPCS

INTERNATIONAL PROGRAMME  
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# Environmental pollution

## Examples and ecological cosequences



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# Major anthropogenic threats – example: waters

Direct



Indirect



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# Major impacts

- **Loss of 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.

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<sup>1</sup>. They say that there is not yet enough evi-

PHOTO: NEWSCOM



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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

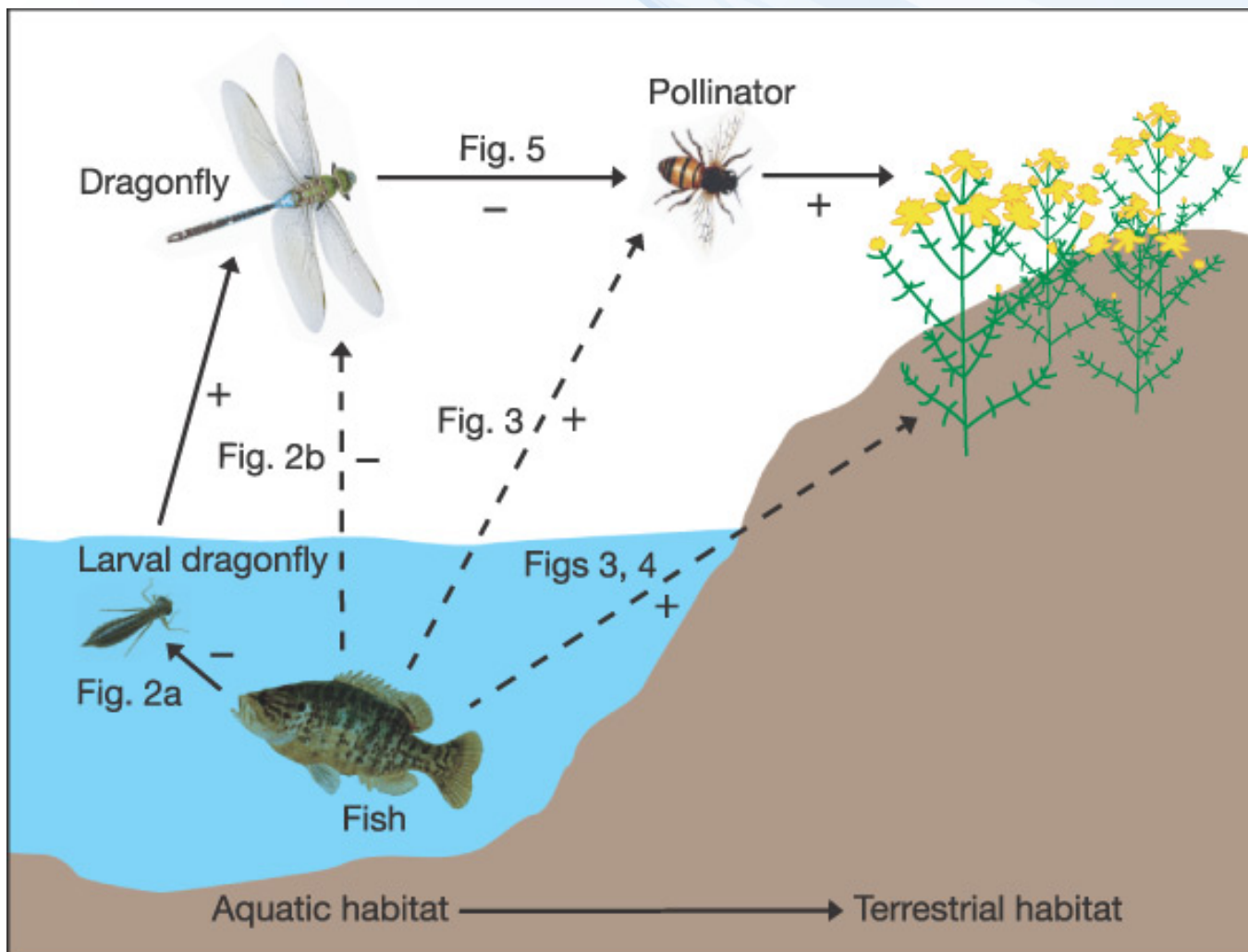
### – Shrinking of food supplies

- Direct → lowering fish amounts
- Indirect → crop yield



# Impacts on fish → decreased crop yields

NATURE (2005) 437: 880



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# 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)]



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# Ecotoxicology

assessment of hazards  
and risks of chemicals in  
ecosystems



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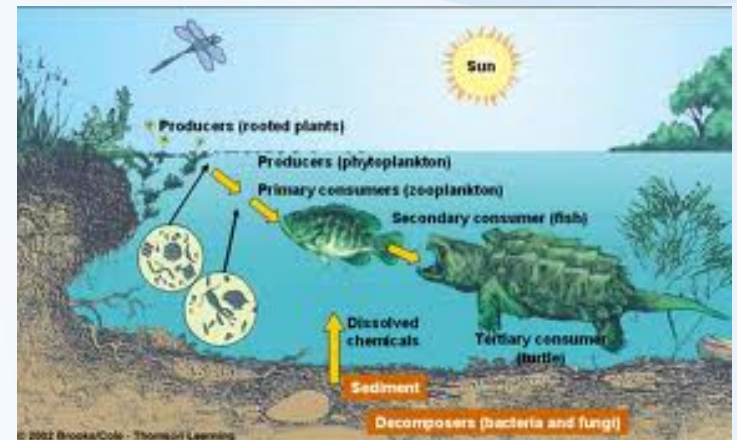
# Assessment of chemical hazards

...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**



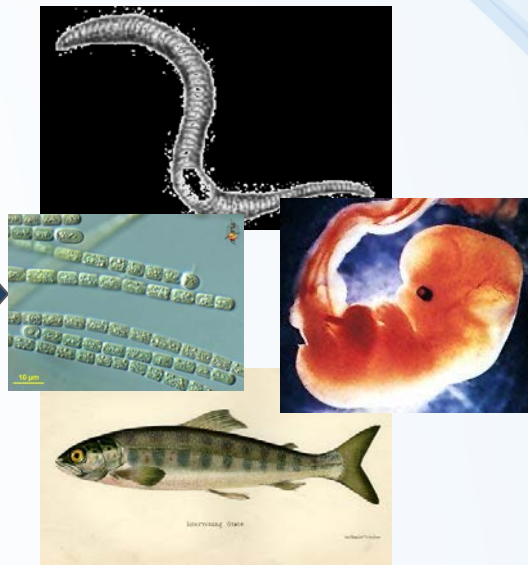
**Bioavailable  
fraction**



**"EXPOSURE"**

acute

chronic



**CHEMICAL  
ENTERS THE  
ORGANISM**

*biomonitoring*



**Toxicokinetics**

*biotransformation  
bioactivation  
excretion / sequestration*

**Target site**

**"EFFECT"**



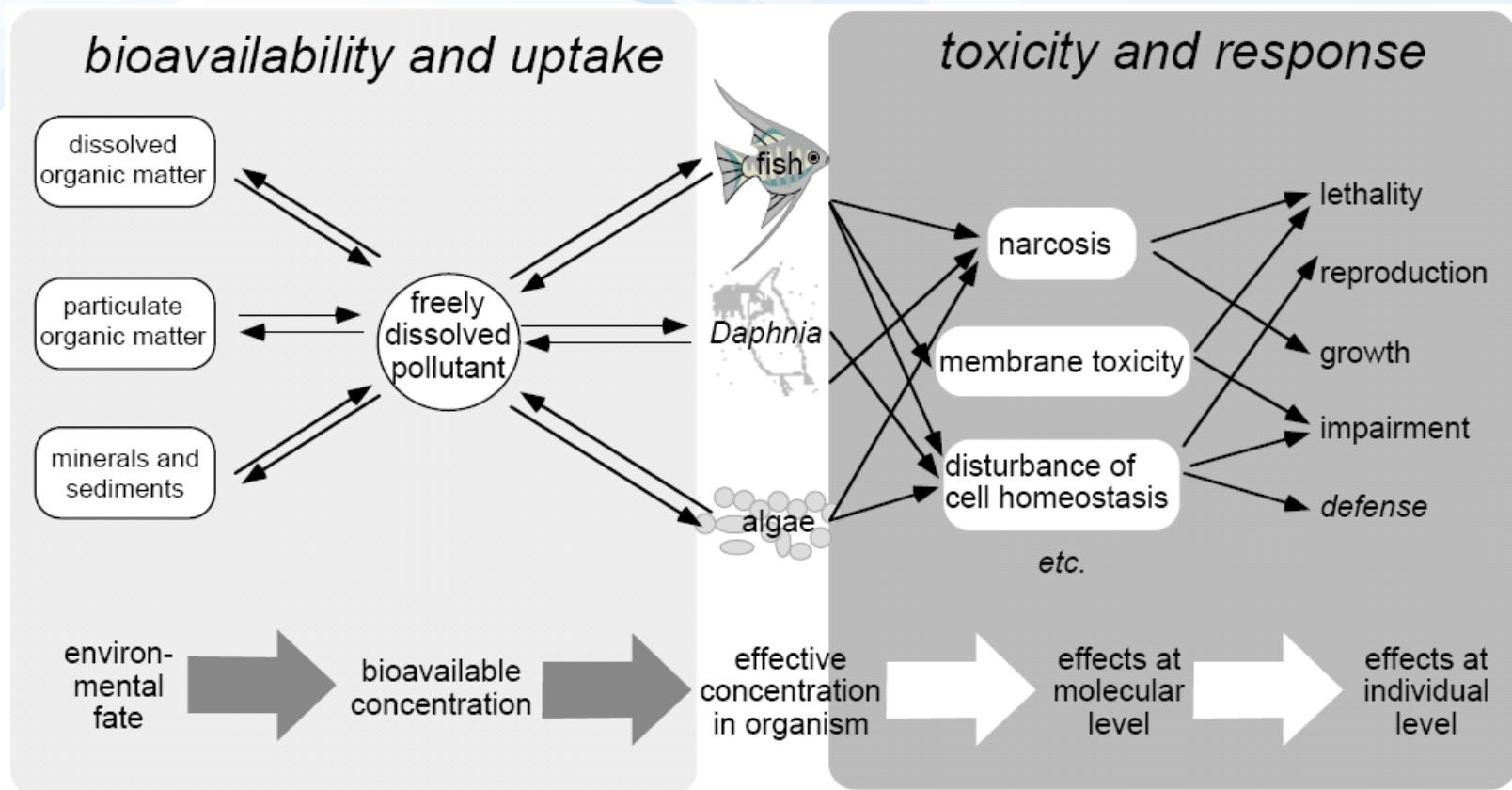
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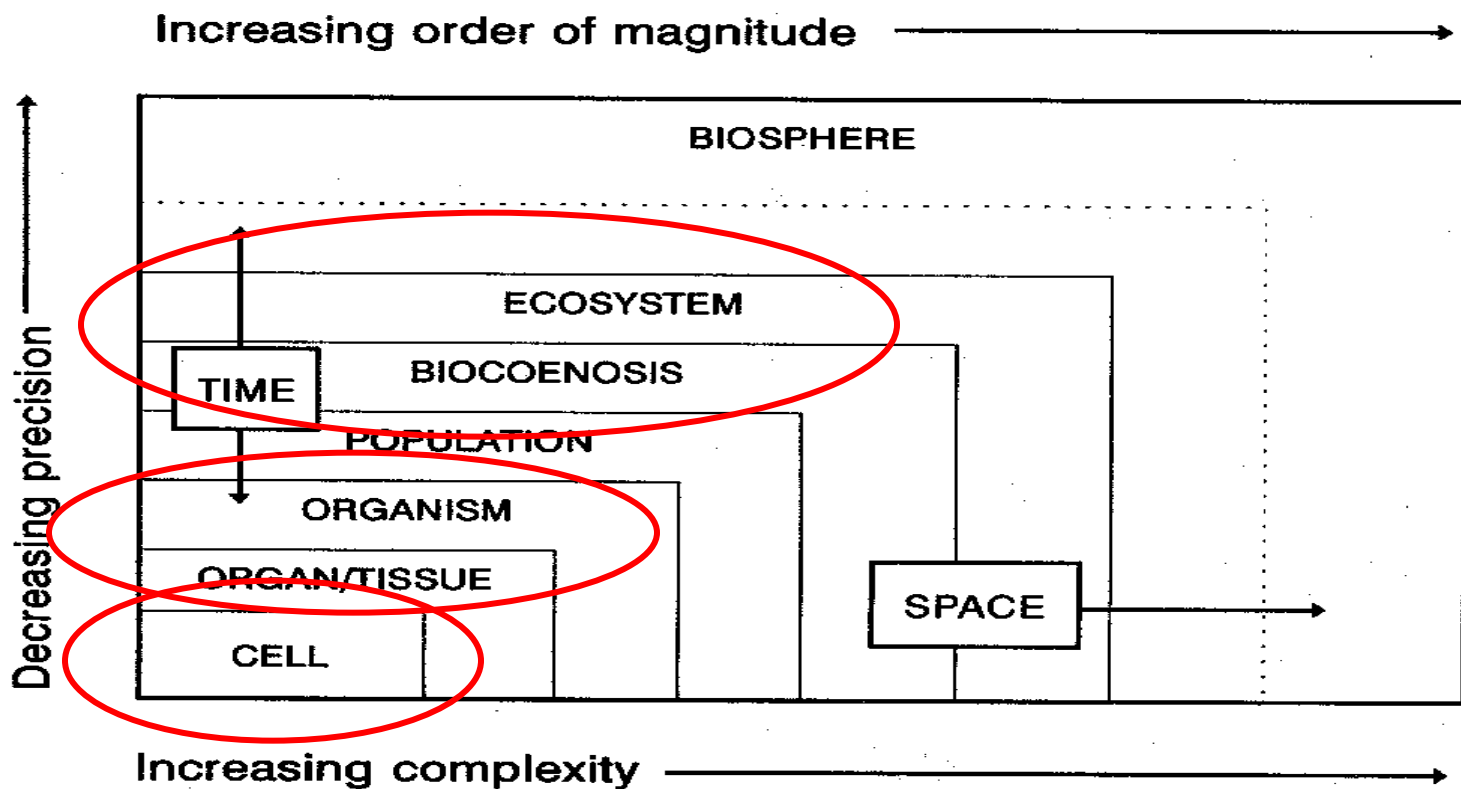
# Ecotoxic effects



**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.**



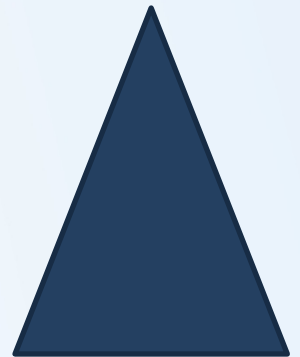
**From ecosystems  
→  
down the mechanisms**



**OR**

**?**

**From mechanisms (molecules)  
→  
up to effects and ecosystems**



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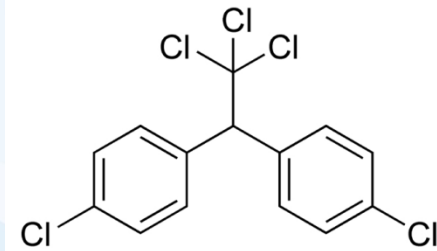
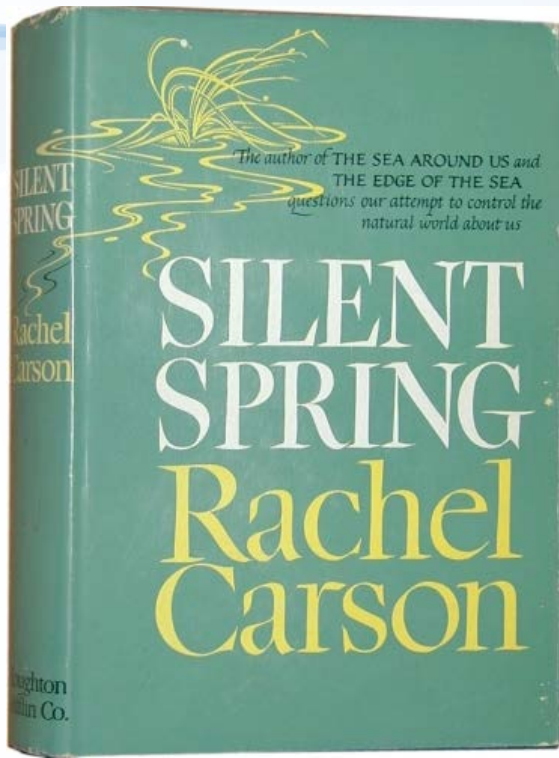
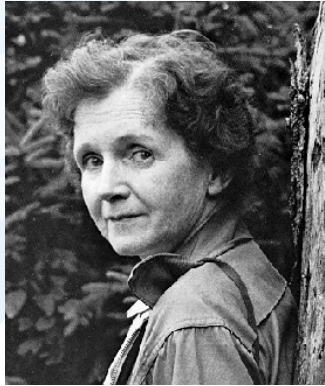


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1962



© Patuxent Wildlife Refuge, MA, USA

**"DDT is good for me-e-e!"**

The great expectations held for DDT have been realized. During 1946, exhaustive scientific tests have shown that, when properly used, DDT kills a host of destructive insect pests, and is a benefactor of all humanity.

Pennsalt produces DDT and its products in all standard forms and is now one of the country's largest producers of this amazing insecticide. Today, everyone can enjoy added comfort, health and safety through the insect-killing powers of Pennsalt DDT products . . . and DDT is only one of Pennsalt's many chemical products which benefit industry, farm and home.

**GOOD FOR STEERS**—Beef grows healthier nowadays . . . for it's a scientific fact that—compared to untreated cattle—beef steers gain up to 50 pounds extra when protected from horn flies and many other pests with DDT insecticides.

**KEEP FOR THE HOME**—helps you to make healthier, more comfortable homes . . . protects your family from dangerous insect pests. Use Knox-Out DDT Powders and Sprays as directed . . . then watch the bugs "bite the dust"!

**GOOD FOR DAIRIES**—Up to 20% more milk . . . more butter . . . more cheese . . . tests prove greater milk production when dairy cows are protected from the annoyance of many insects with DDT insecticides like Knox-Out Stock and Barn Spray.

**GOOD FOR FRUITS**—Bigger apples, juicier fruits that are free from smugly worms . . . all benefits resulting from DDT dusts and sprays.

**GOOD FOR ROW CROPS**—25 more barrels of potatoes per acre . . . actual DDT tests have shown crop increases like that! DDT dusts and sprays help truck farmers pass these gains along to you.

**KEEP FOR INDUSTRY**—Food processing plants, laundries, dry cleaning plants, hotels . . . dozens of industries gain effective bug control, more pleasant work conditions with Pennsalt DDT products.

**PENN SALT**  
CHEMICALS  
87 Years' Service to Industry • Farm • Home  
PENNSYLVANIA SALT MANUFACTURING COMPANY  
WIDENER BUILDING, PHILADELPHIA 7, PA.

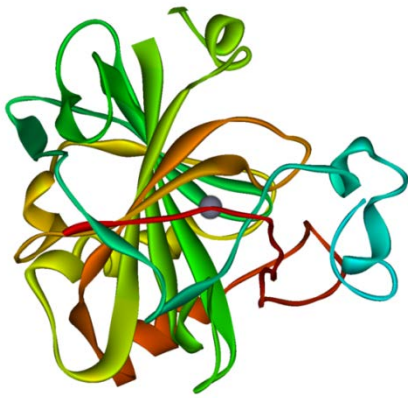


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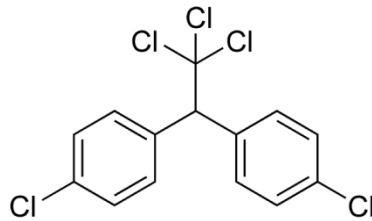
<http://www2.ucsc.edu/scpbrg/>

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



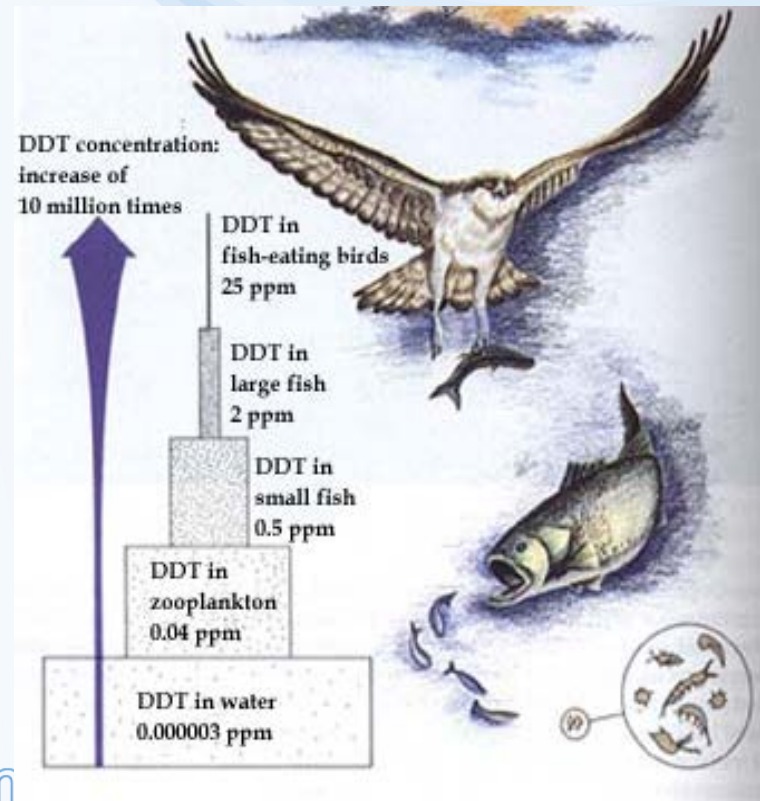
## Biochemistry

bird carbonate dehydratase



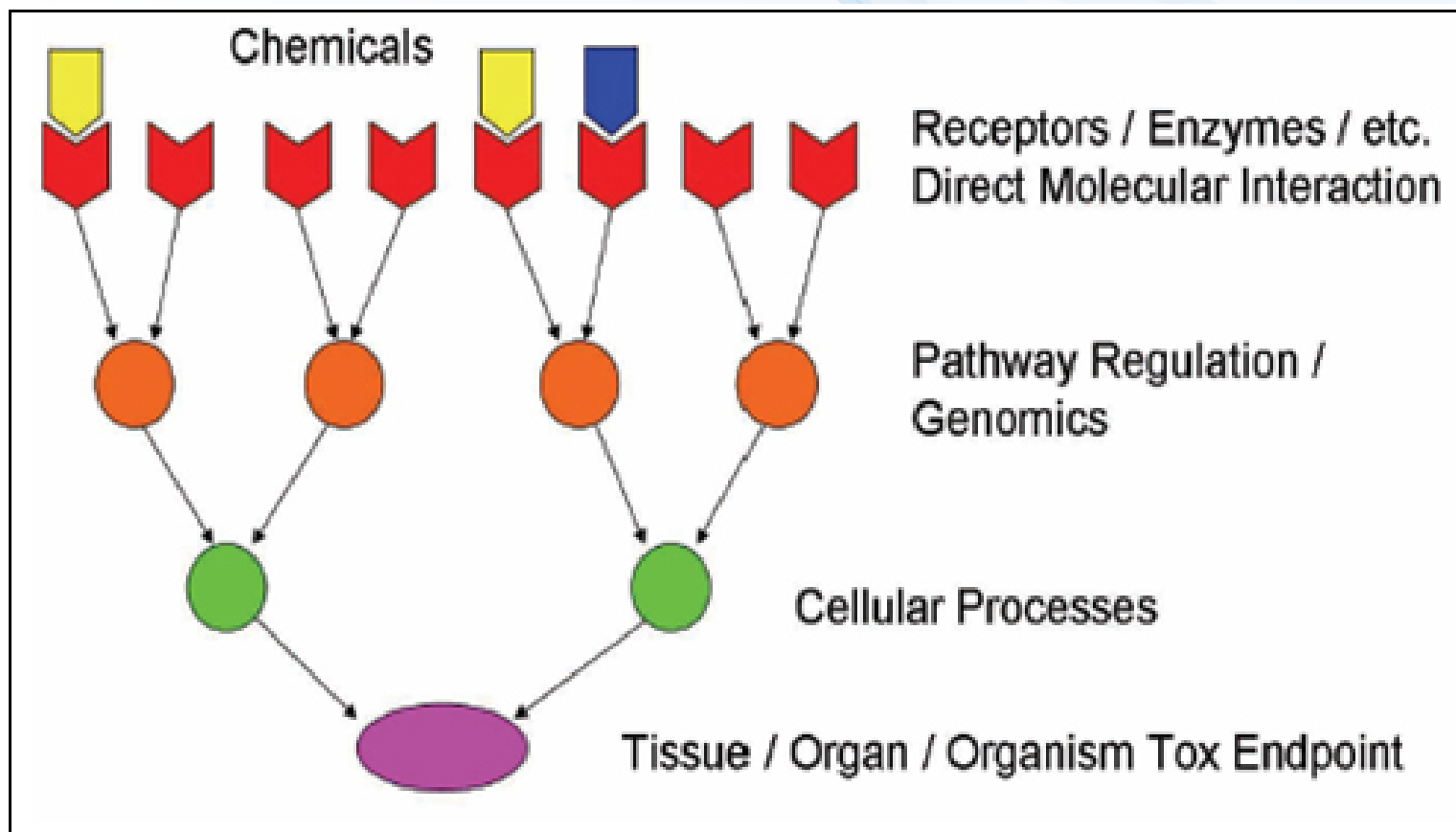
In situ: bioaccumulation  
-> **bird population decline**

In vivo: shell thinning



# 1) From molecules to individuals

## MECHANISMS OF TOXICITY

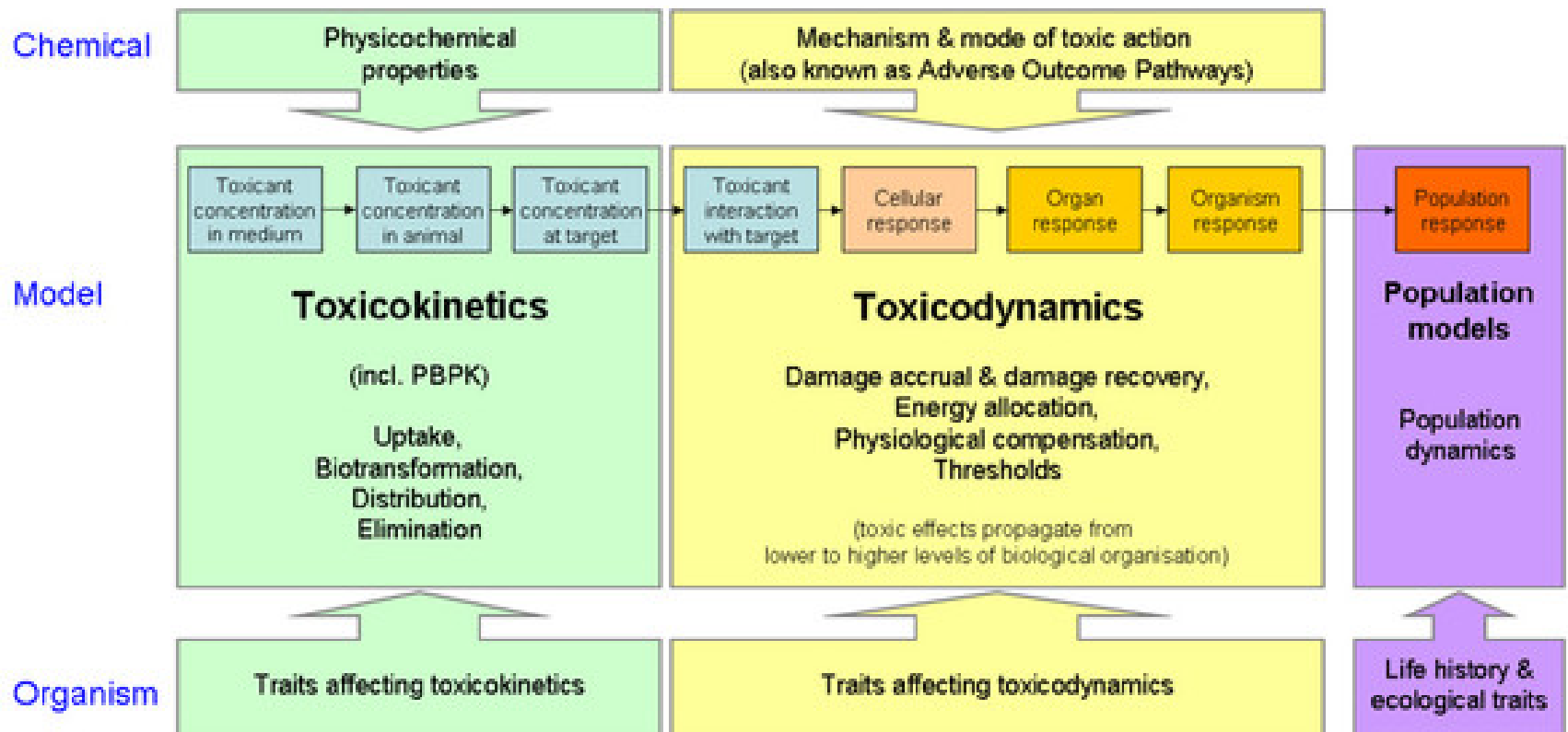




# 2) From molecules to individuals - AOPs

## ADVERSE OUTCOME PATHWAYS

### Mechanistic effect models for ecotoxicology



→ Arrows indicate a causal relationship

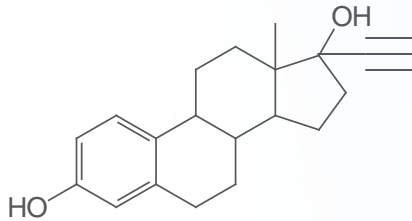
See also: Ashauer & Escher *JEM* (2010), Rubach *et al. IEAM* (2011), Jager *et al. ES&T* (2011), Ashauer *et al. ET&C* (2011)

[www.ecotoxmodels.org](http://www.ecotoxmodels.org)



# AOP Example: ethinylestradiol

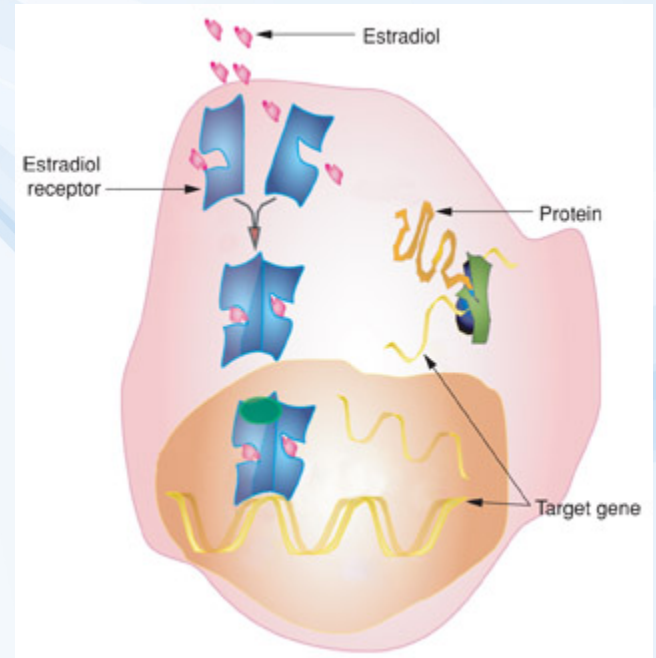
## Ethinylestradiol



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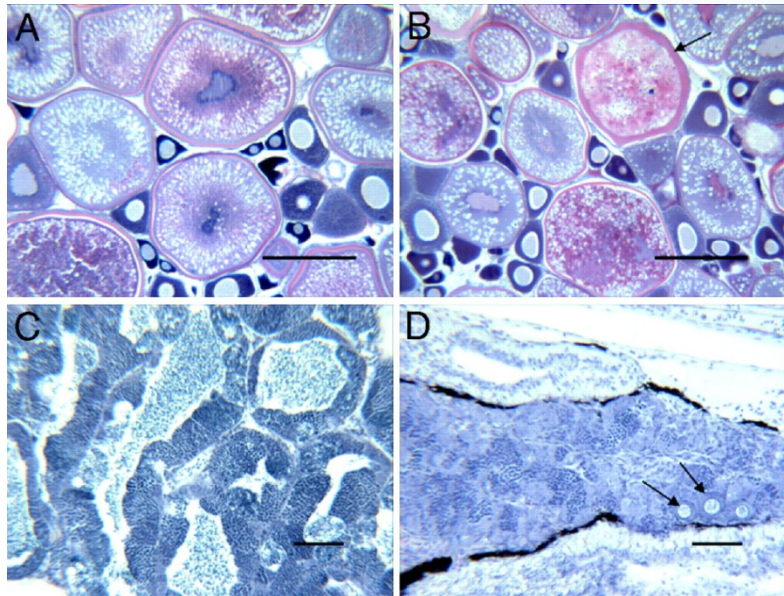
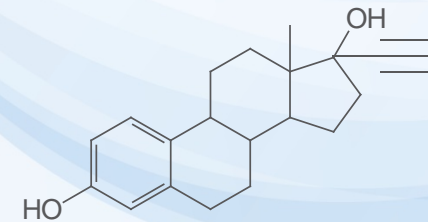
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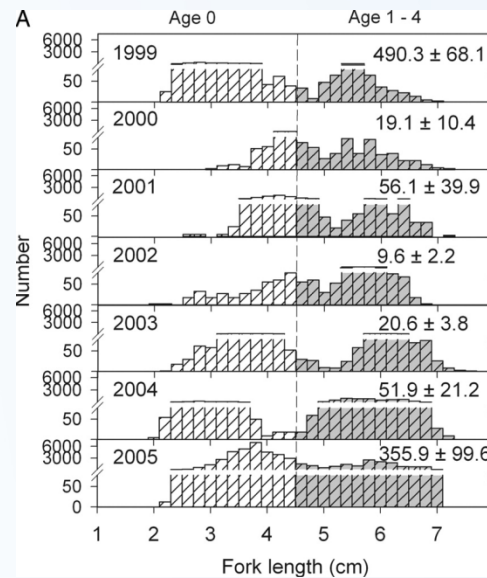
Kidd, K.A. et al. 2007. **Collapse of a fish population** following exposure to **a synthetic estrogen**. *Proceedings of the National Academy of Sciences* 104(21):8897-8901



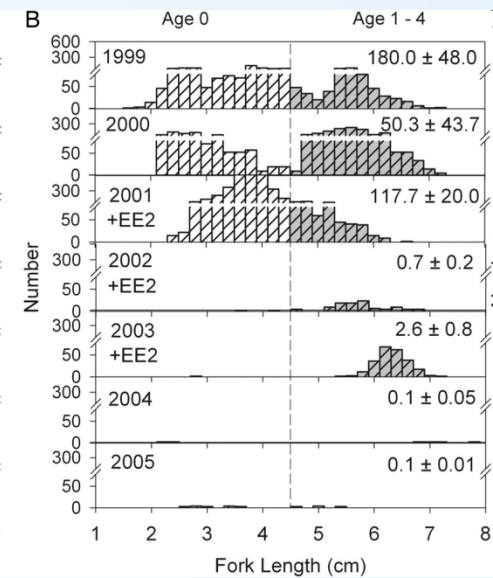
5 ng/L (!)  
7 years



### Controls



### + Ethinylestradiol



# Effects at different levels - molecular

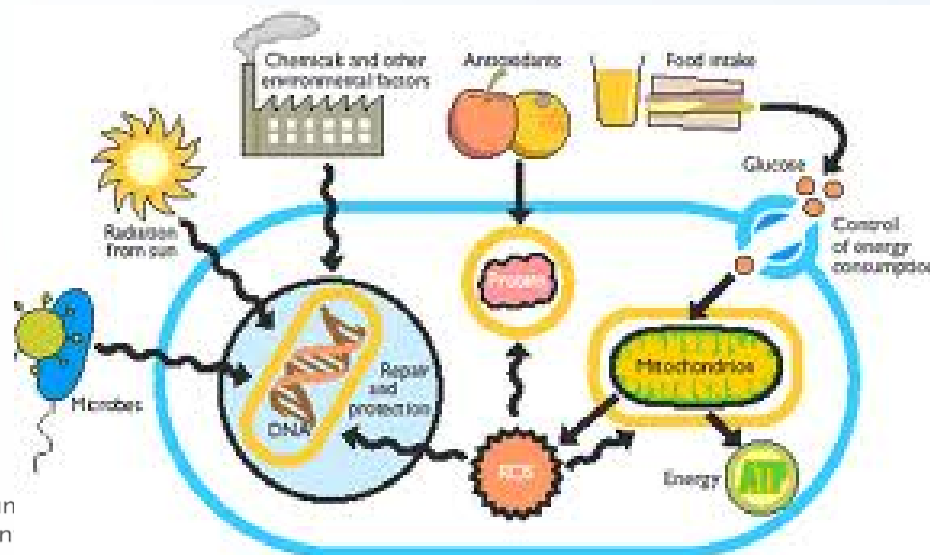
- **Molecular**

- **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

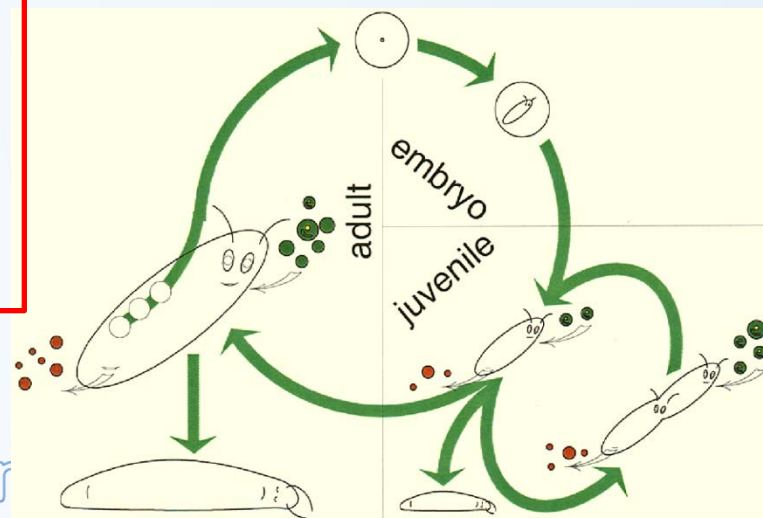
→ Changes in functions (e.g. Ethinylestradiol)

→ 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 ...



Defence against  
toxicants



**Chemical  
stress**

**Growth  
to sexual  
maturity**



**Reproduction**



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# Chemical stress

→ energy re-allocation  
→ „insufficient“ resources elsewhere

Energy  
*hv*  
food



Losses  
*heat*  
*faeces*



Life  
*(maintenance)*



Metabolism



Control,  
Interactions  
with environment



Defence  
against pathogens  
predators ...



Defence against  
toxicants



Chemical  
stress

Growth  
to sexual  
maturity



Reproduction



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# Chemical stress

+ ... another stress  
(food scarcity)

Energy  
*hν*  
food



Losses  
*heat*  
*faeces*



Life  
(maintenance)



Metabolism



Control,  
Interactions  
with environment



Defence  
against pathogens  
predators ...



Defence against  
toxicants



Growth  
to sexual  
maturity



Reproduction



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



# 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“)

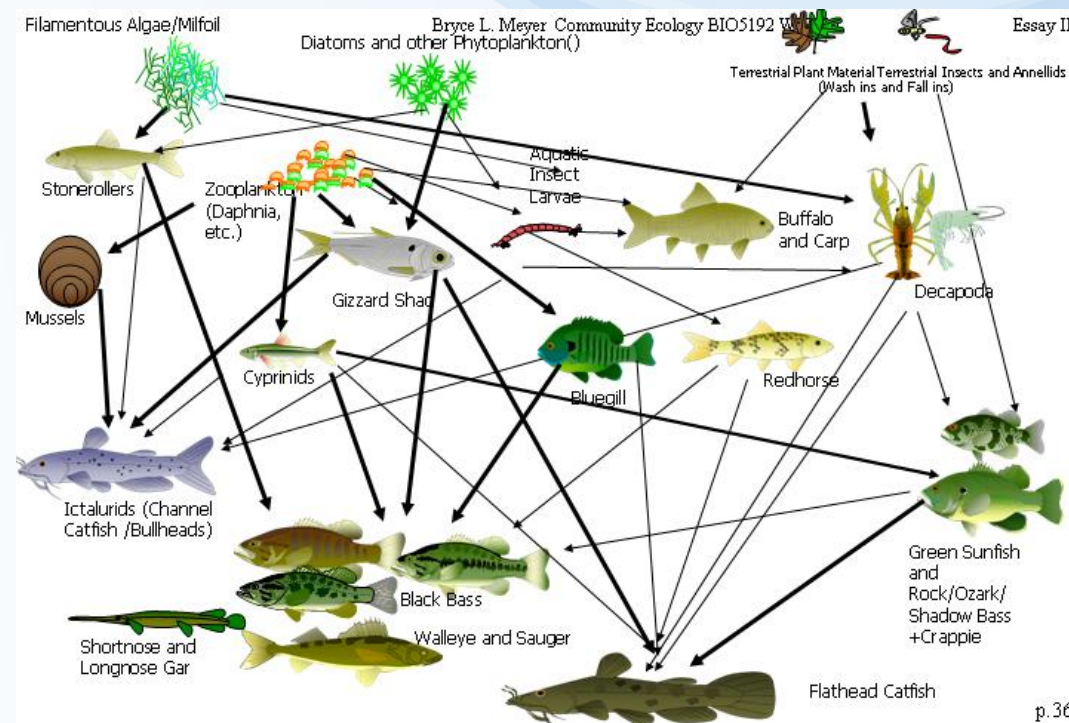


Figure #31: Simplified Food Web (Source Down) similar to warm water lower end of river before entry into Mississippi River System or impoundment. The Flathead acts as a super predator when present as large specimens, and many predators such as walleyes and Gars compete for minnows and shad. Channel Catfish 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 BIODIVERSITY and ECOSYSTEM SERVICES
- Understand keywords such as
  - Exposure
  - Bioavailability
  - Toxicokinetics
  - Toxicodynamics
- 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)“

