



Research centre
for toxic compounds
in the environment

Ecotoxicology Part 1 - Introduction

Ludek Blaha + ecotox colleagues

cecoen



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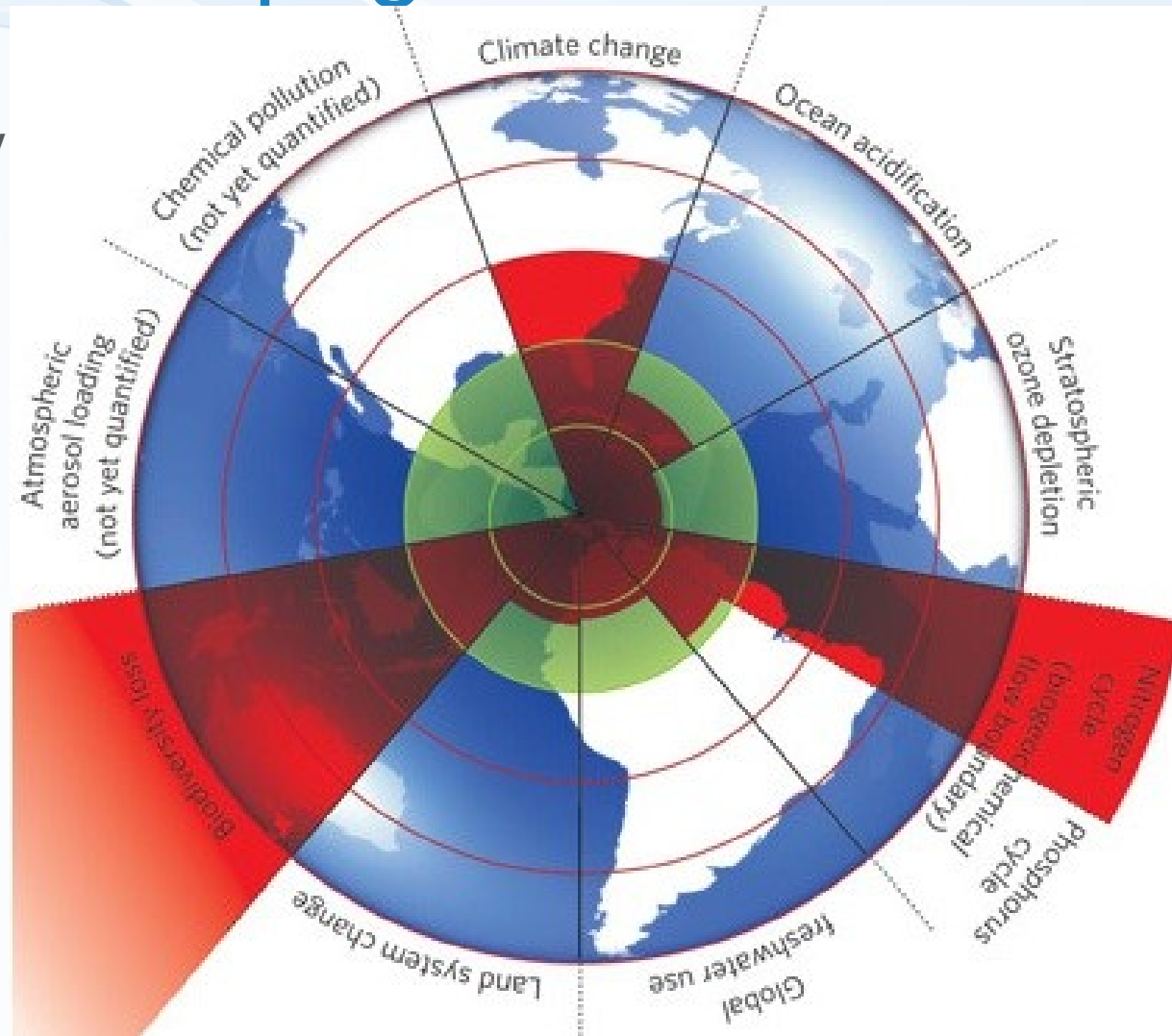
OP Research and
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Global anthropogenic threats ?

A safe operating space for humanity & the nine planetary boundaries

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



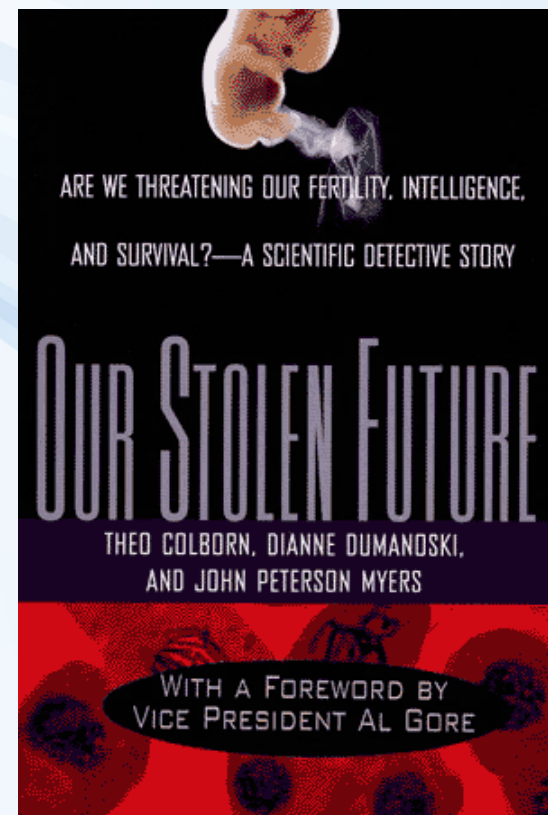
1996 - Chemicals in the environment

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?

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



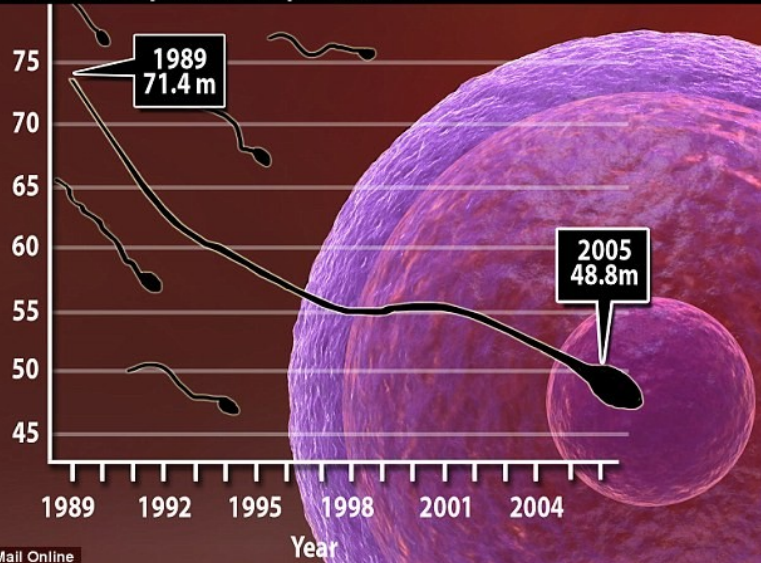
Save for later



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

Sperm concentration

In millions of spermatazoa per millilitre



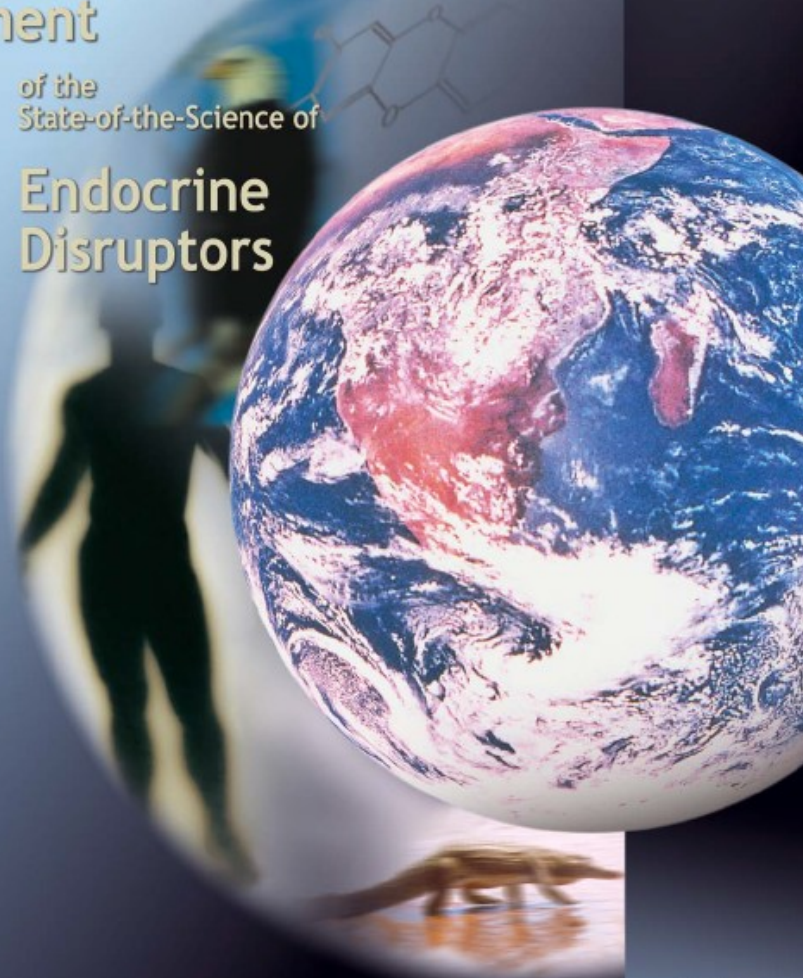
© Mail Online

Global Assessment

of the State-of-the-Science of

Endocrine Disruptors

WHO/PCS/EDC/02.2



IPCS
INTERNATIONAL PROGRAMME
ON CHEMICAL SAFETY

Edited by

Terri Damstra

Sue Barlow

Aake Bergman

Robert Kavlock

Glen Van Der Kraak



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Environmental pollution

Examples and ecological consequences

Major anthropogenic threats – example: waters

Direct



Indirect



Major impacts

- **Loss of biodiversity**



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 data¹. They say that there is not yet enough evi-

NYOUDU/NEWS.COM

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

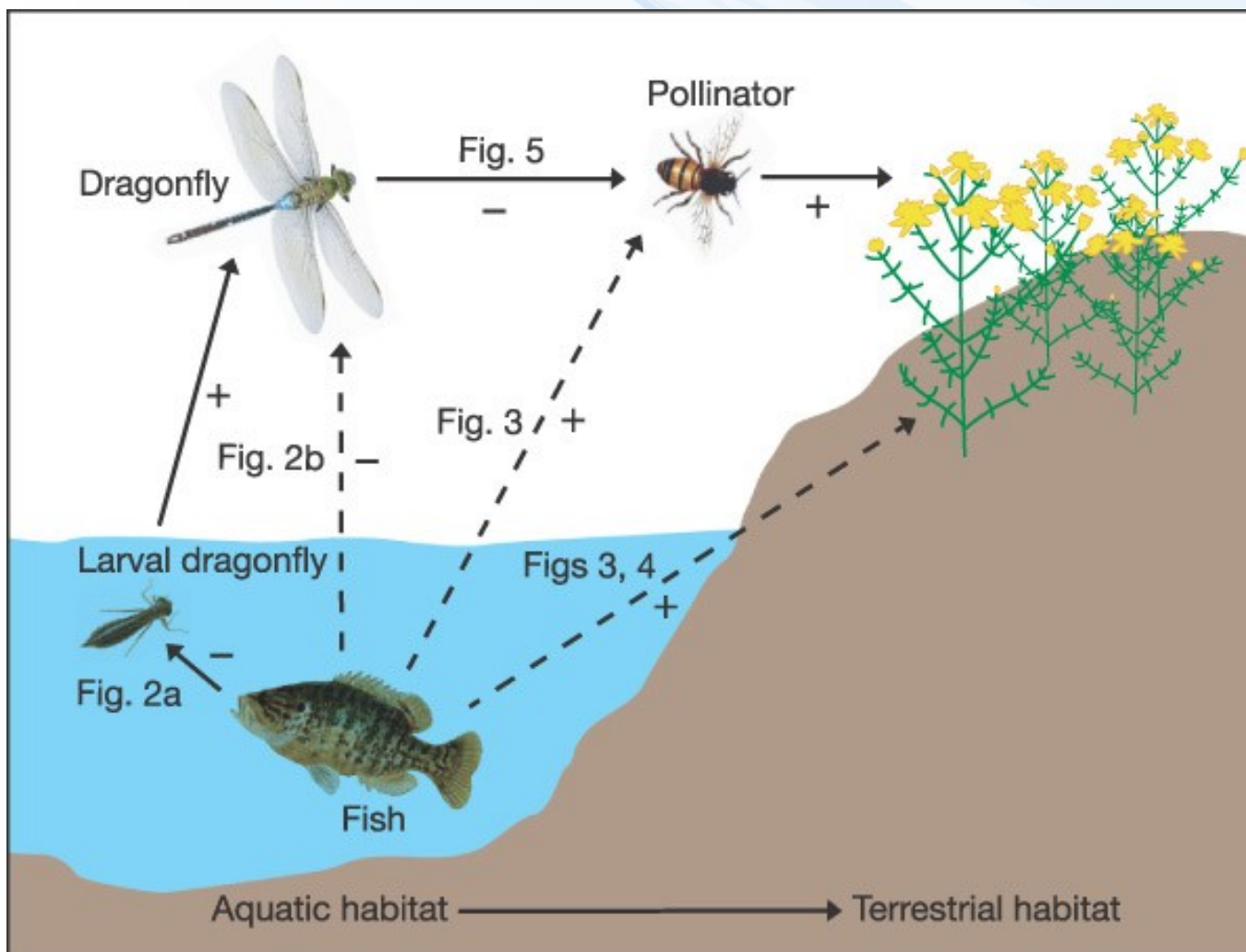
– Shrinking of food supplies

- 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

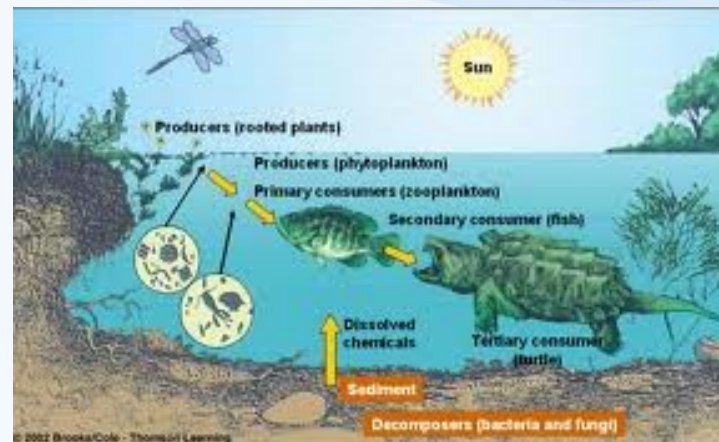
Assessment of chemical hazards

...to...

Humans
(TOXICOLOGY)



Other organisms
(ECOTOXICOLOGY)



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)

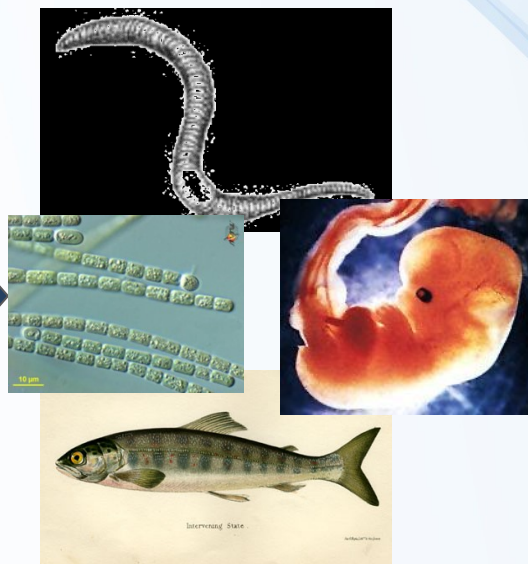
**CHEMICAL
ENTERS THE
ENVIRONMENT**



**LEVELS, FATE,
PROCESSES**



**Bioavailable
fraction**



**CHEMICAL
ENTERS THE
ORGANISM**

biomonitoring



Toxicokinetics

*biotransformation
bioactivation
excretion / sequestration*

Target site

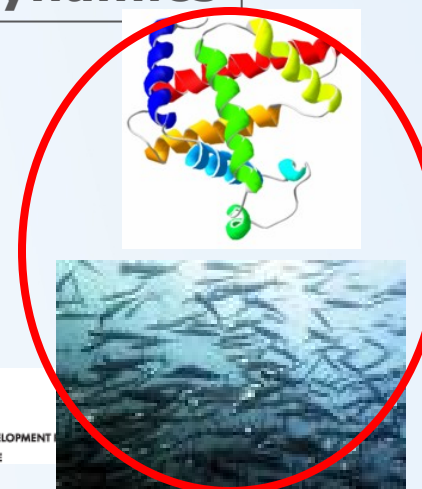
**"EFFECT"
toxicodynamics**

"EXPOSURE"

acute



chronic



Ecotoxic effects

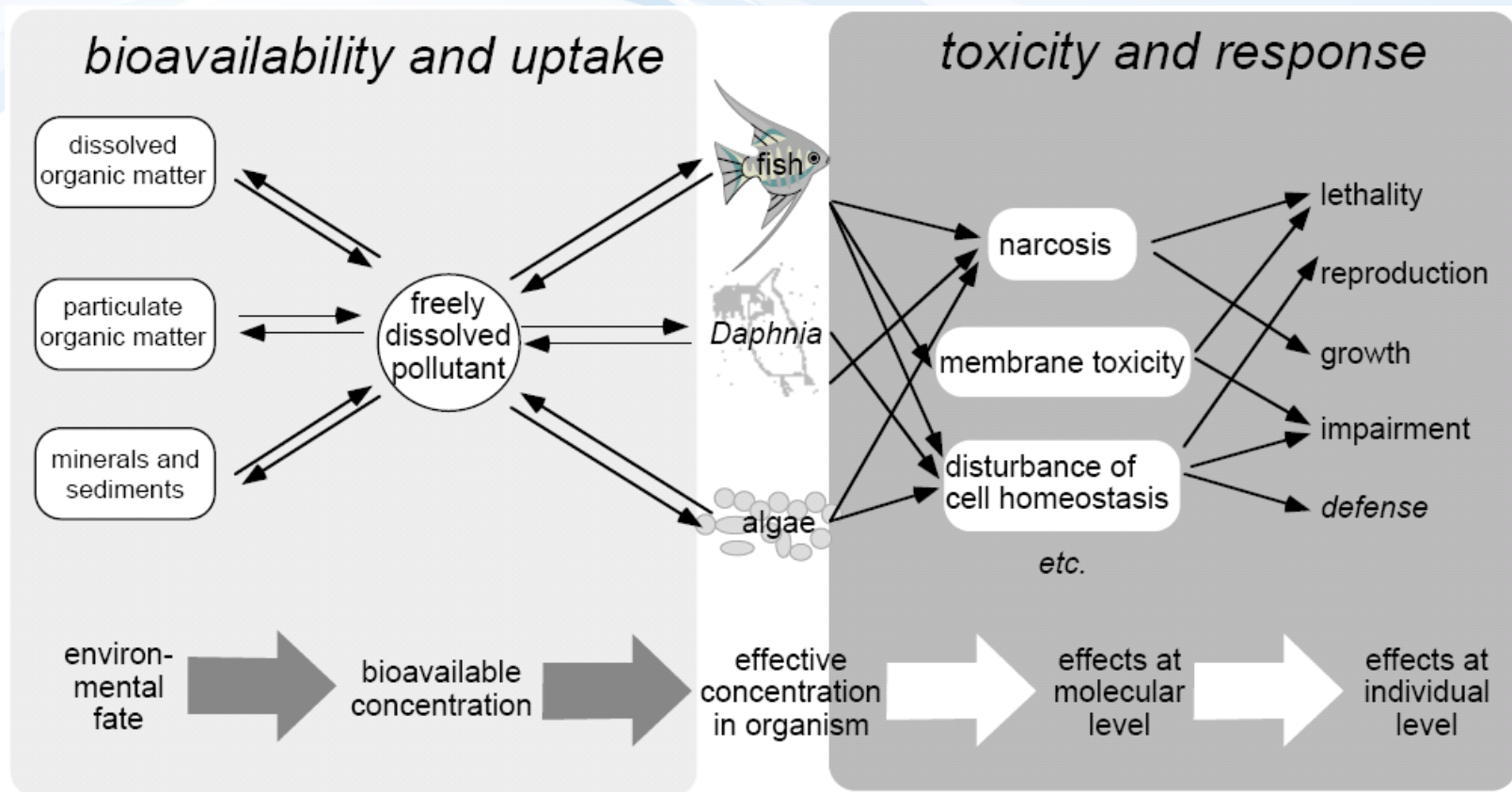


Figure 1 The effective concentration of a pollutant in an organism (e.g. fish, daphnia, algae) or at the target site inside the organism is the link between the environmental fate of a pollutant and its toxic effect.

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

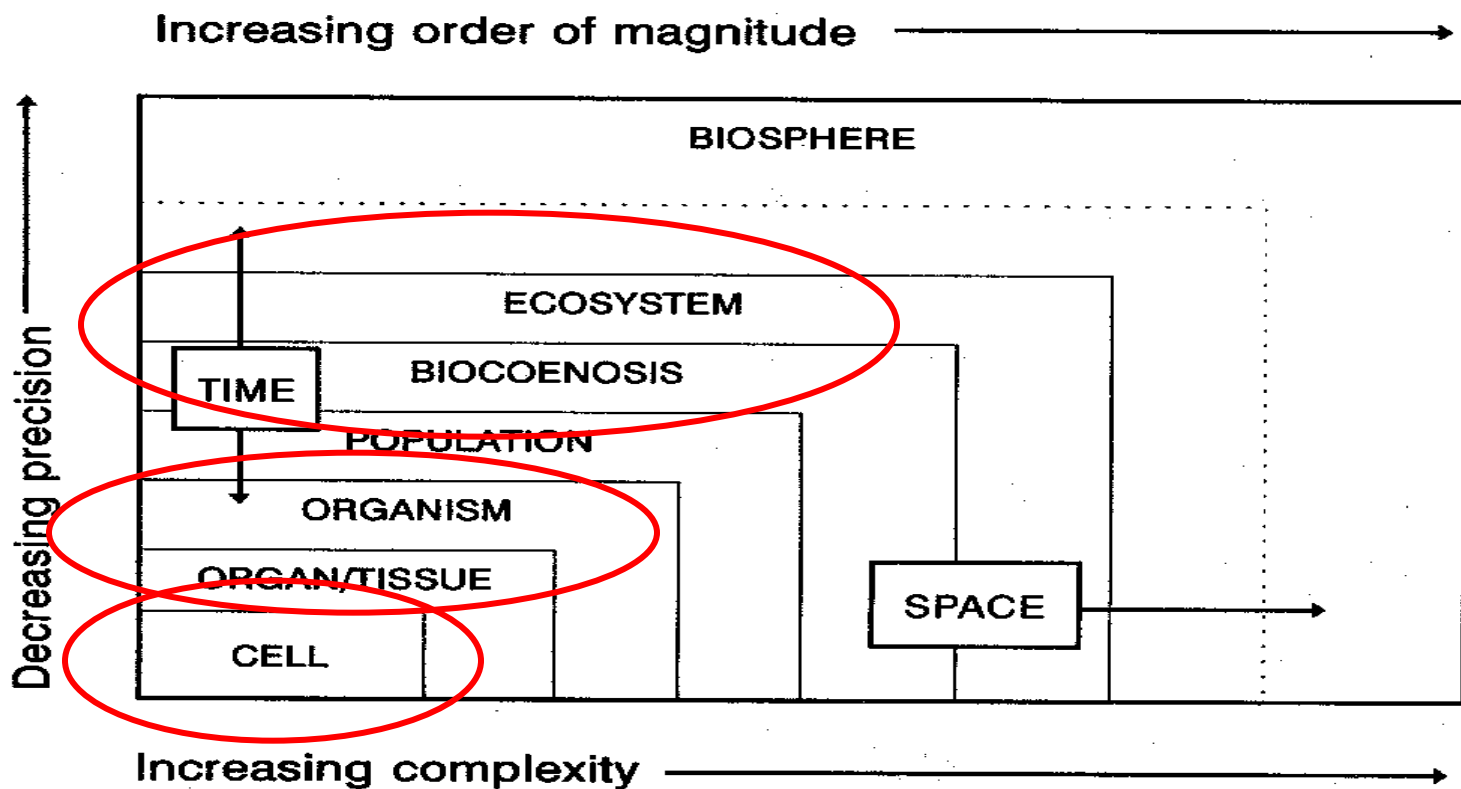


Figure 3.1 Biological levels of organization. The dimensions of time and space are less important for the investigation up to the levels of populations and biocoenoses.

**From ecosystems
→
down the mechanisms**



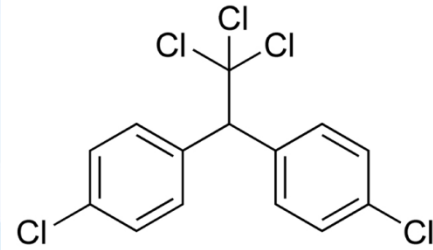
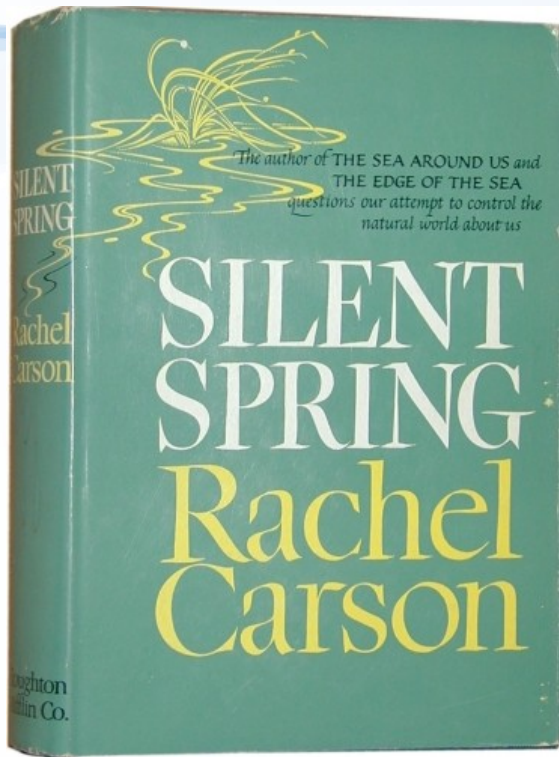
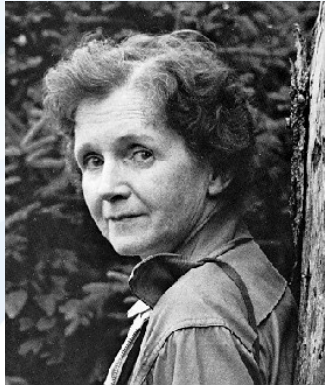
OR

?

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



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 meatier 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.

GOOD FOR THE HOME—helps 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 unsightly 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.

KNOX 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.

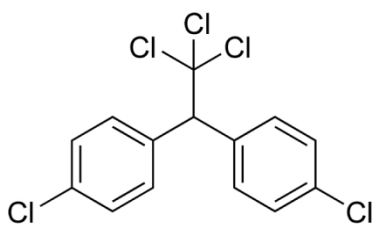
PENN SALT
CHEMICALS
87 Years' Service to Industry • Farm • Home
PENNSYLVANIA SALT MANUFACTURING COMPANY
WIDENER BUILDING, PHILADELPHIA 7, PA.

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



Biochemistry

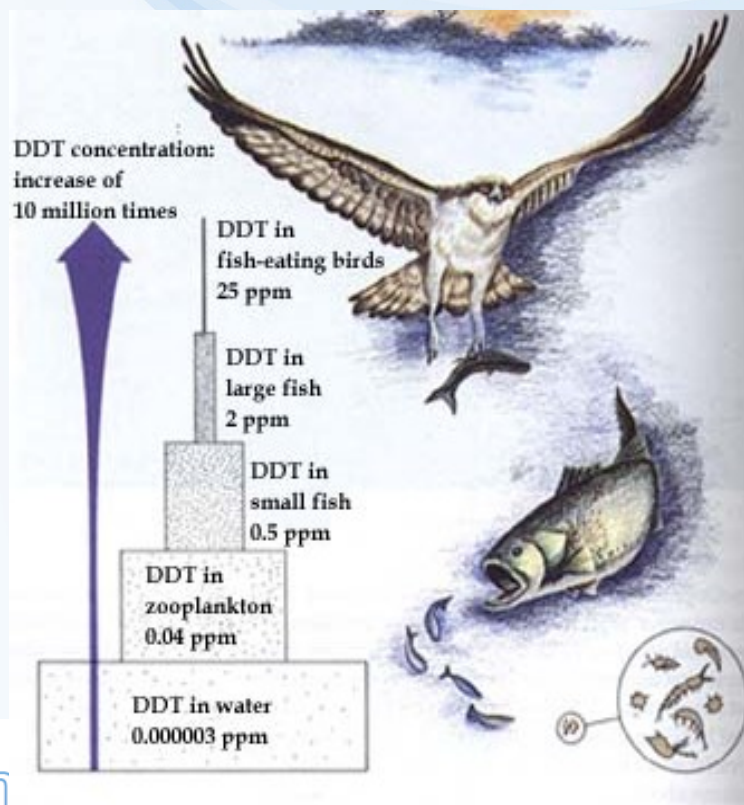
bird carbonate dehydratase



In vivo: shell thinning

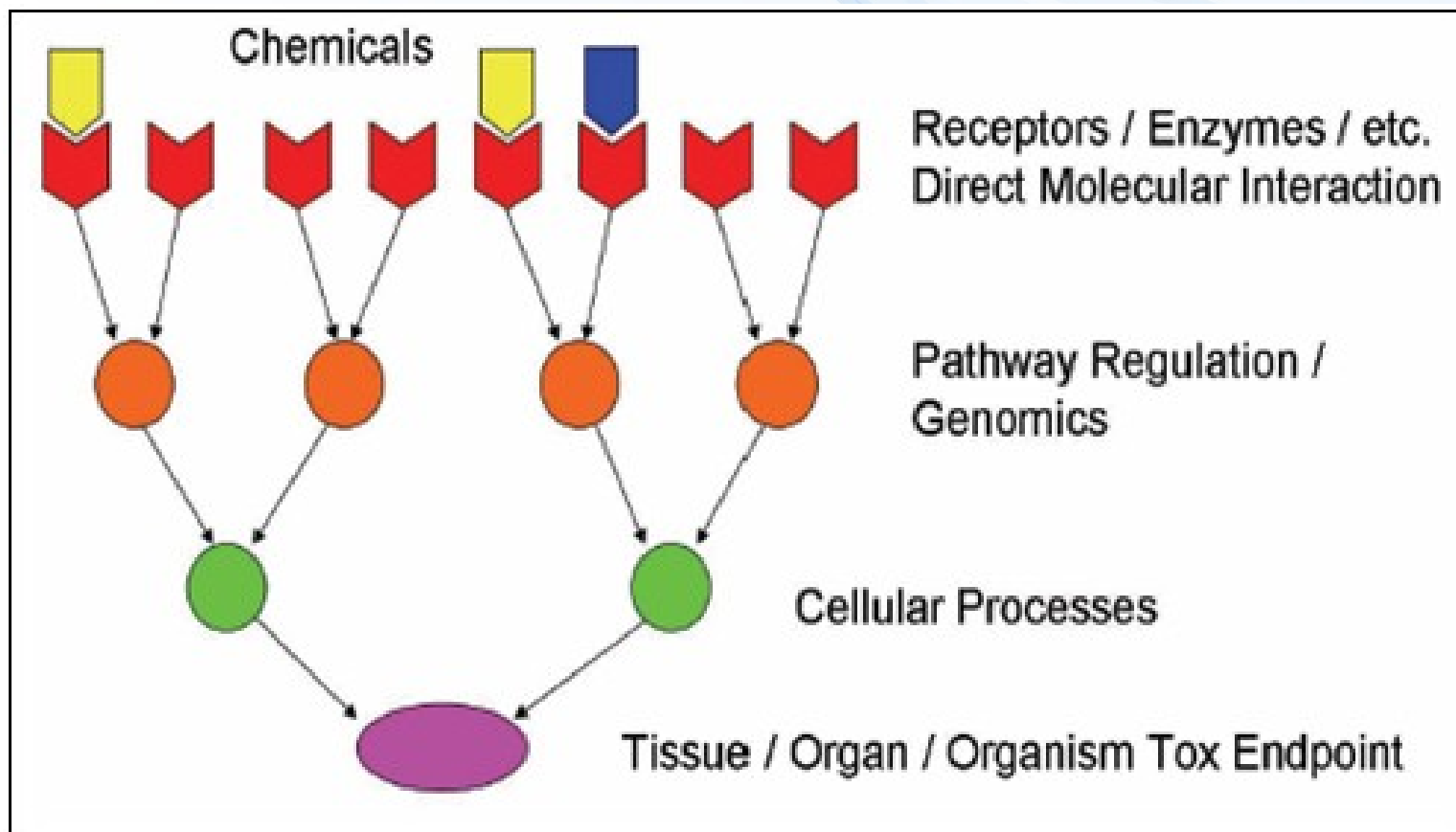


In situ: bioaccumulation
-> bird population decline



1) From molecules to individuals

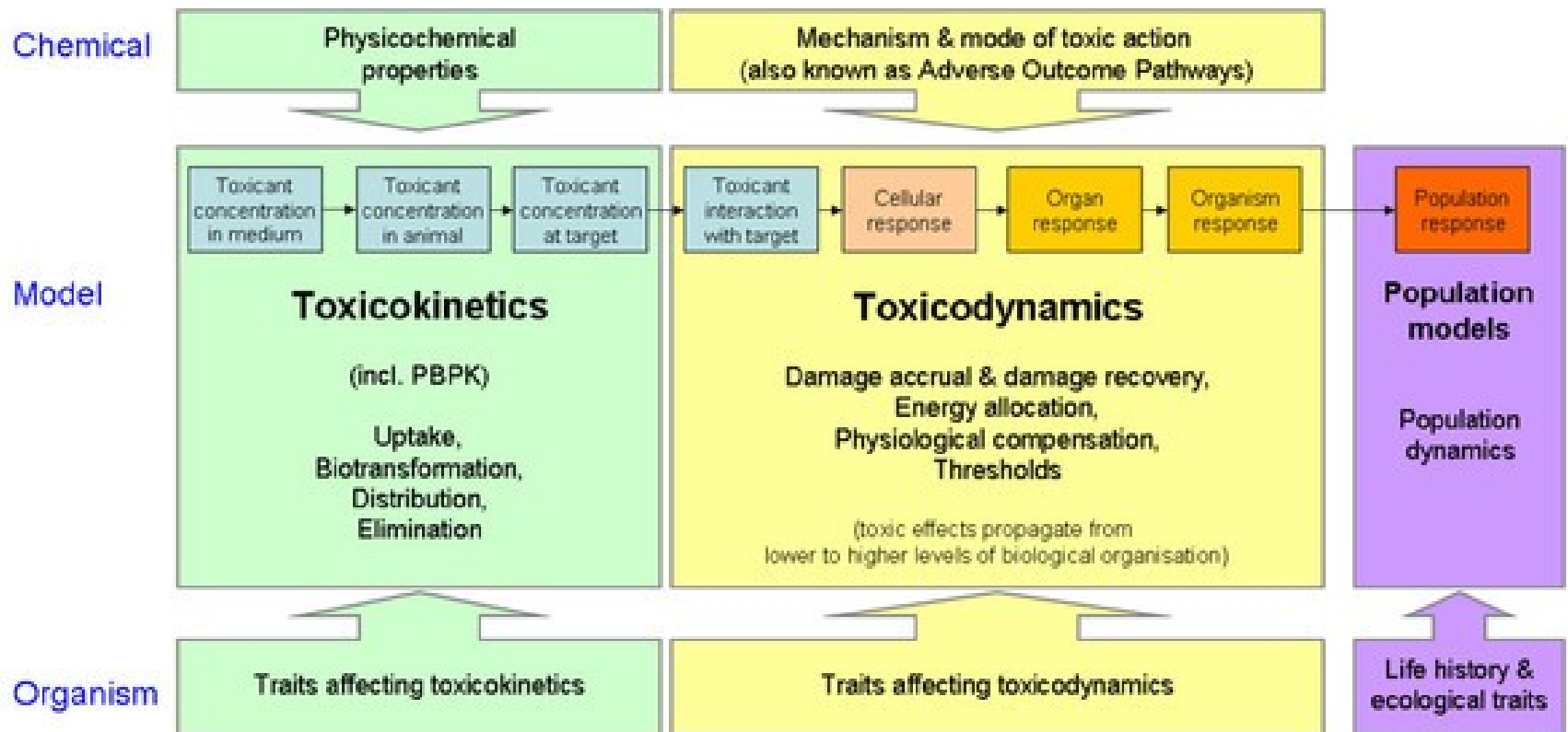
MECHANISMS OF TOXICITY



2) From molecules to individuals - AOPs

ADVERSE OUTCOME PATHWAYS

Mechanistic effect models for ecotoxicology



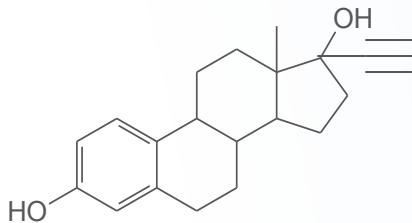
→ Arrows indicate a causal relationship

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

AOP Example: ethinylestradiol

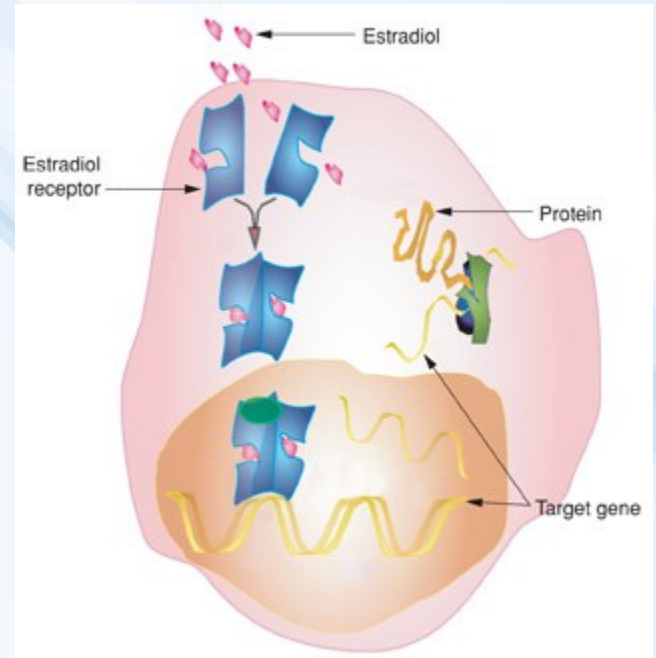
Ethinylestradiol



**Binds to
ESTROGEN
RECEPTOR**

Target genes

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



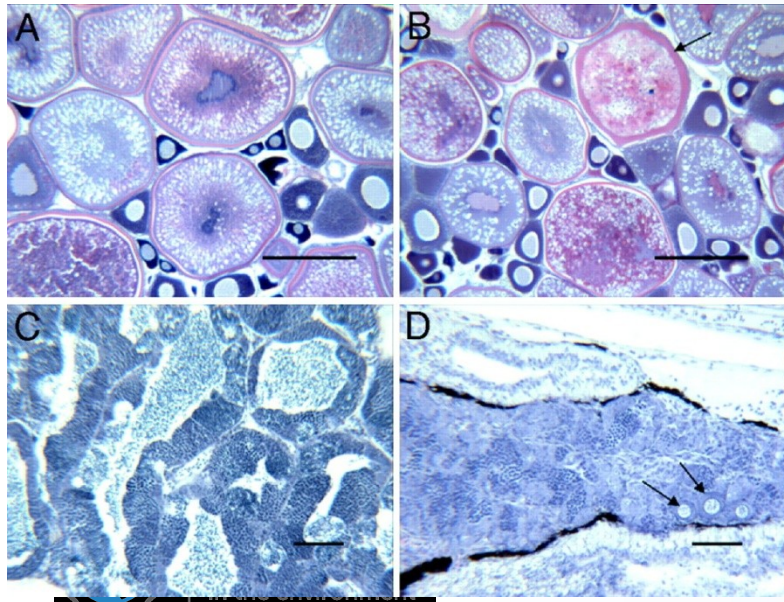
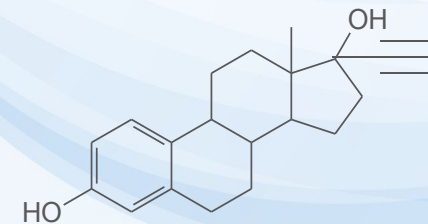
Effects

- Females: reproduction regulation
- Males: feminization
(+ e.g. cancer promotion, development, immunomodulation)

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

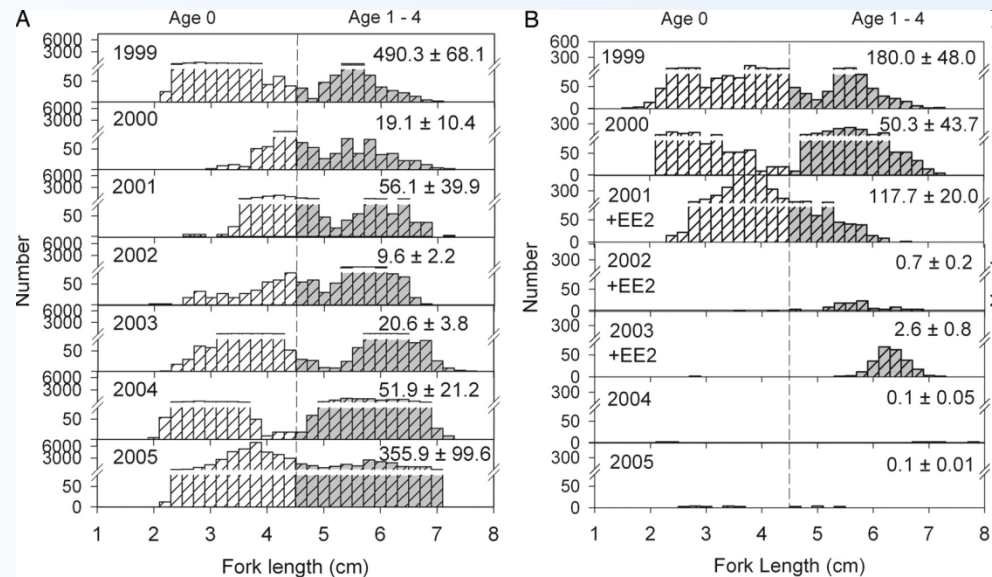


5 ng/L (!)
7 years



Controls

+ Ethinylestradiol



Effects at different levels - molecular

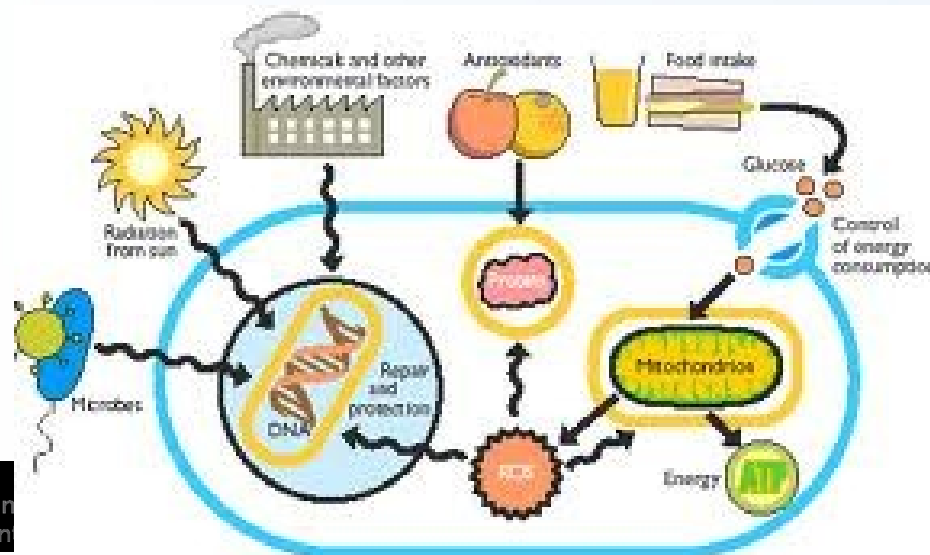
- **Molecular**

- **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

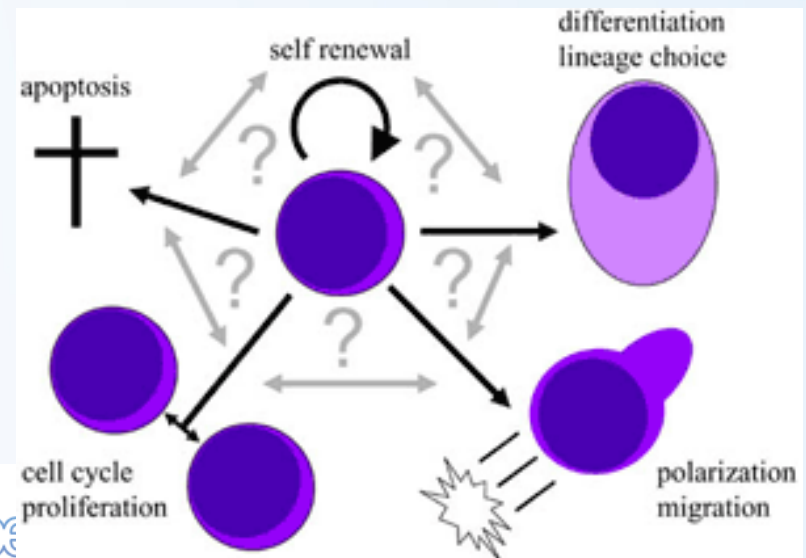
→ Changes in functions (e.g. Ethinylestradiol)

→ 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

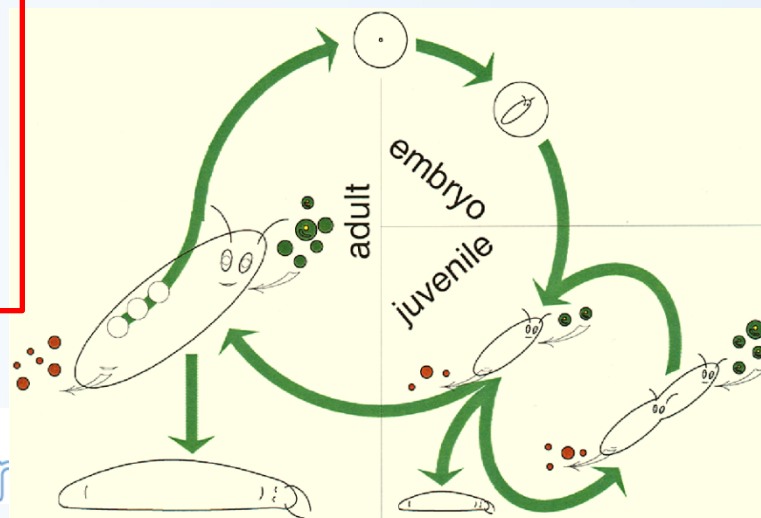
→ Changes in functions (e.g. Ethinylestradiol)

→ 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

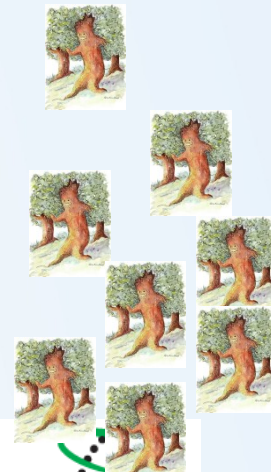


Chemical
stress

Growth
to sexual
maturity



Reproduction



Chemical stress

+ ... another stress
(food scarcity)

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



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“)

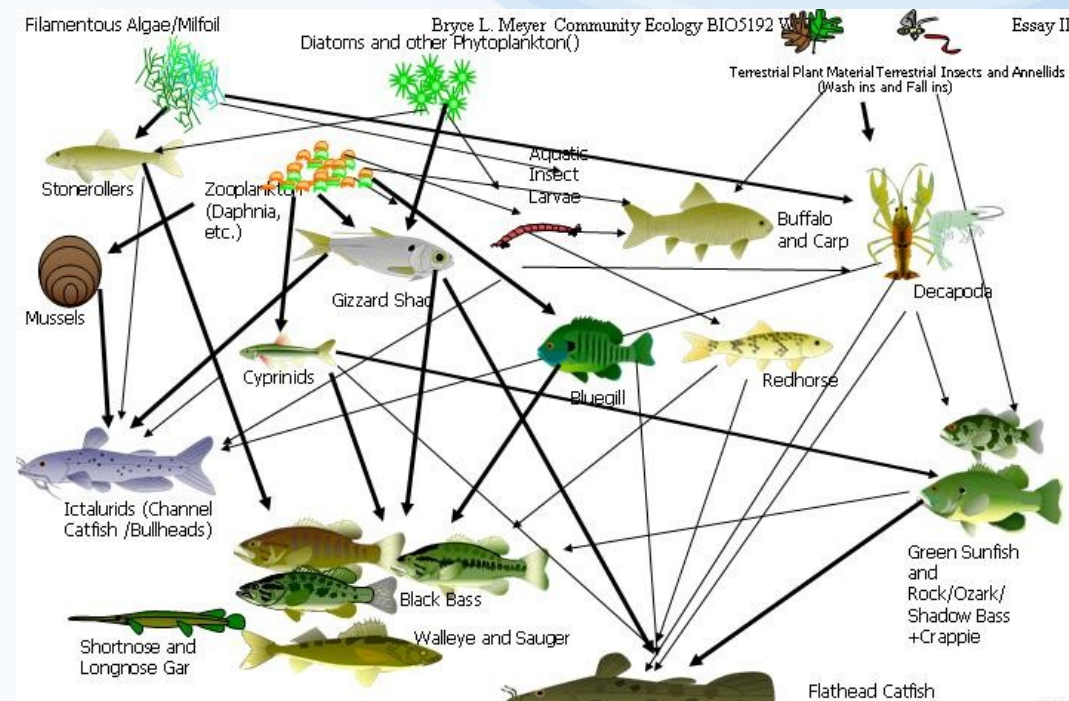


Figure #31: Simplified Food Web (Source Down) similar to warm water lower end of river before entry into Mississippi River System or impoundment. The Flathead acts as a super predator when present as large specimens, and many predators such as walleyes and Gars compete for minnows and shad. Channel Catfish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