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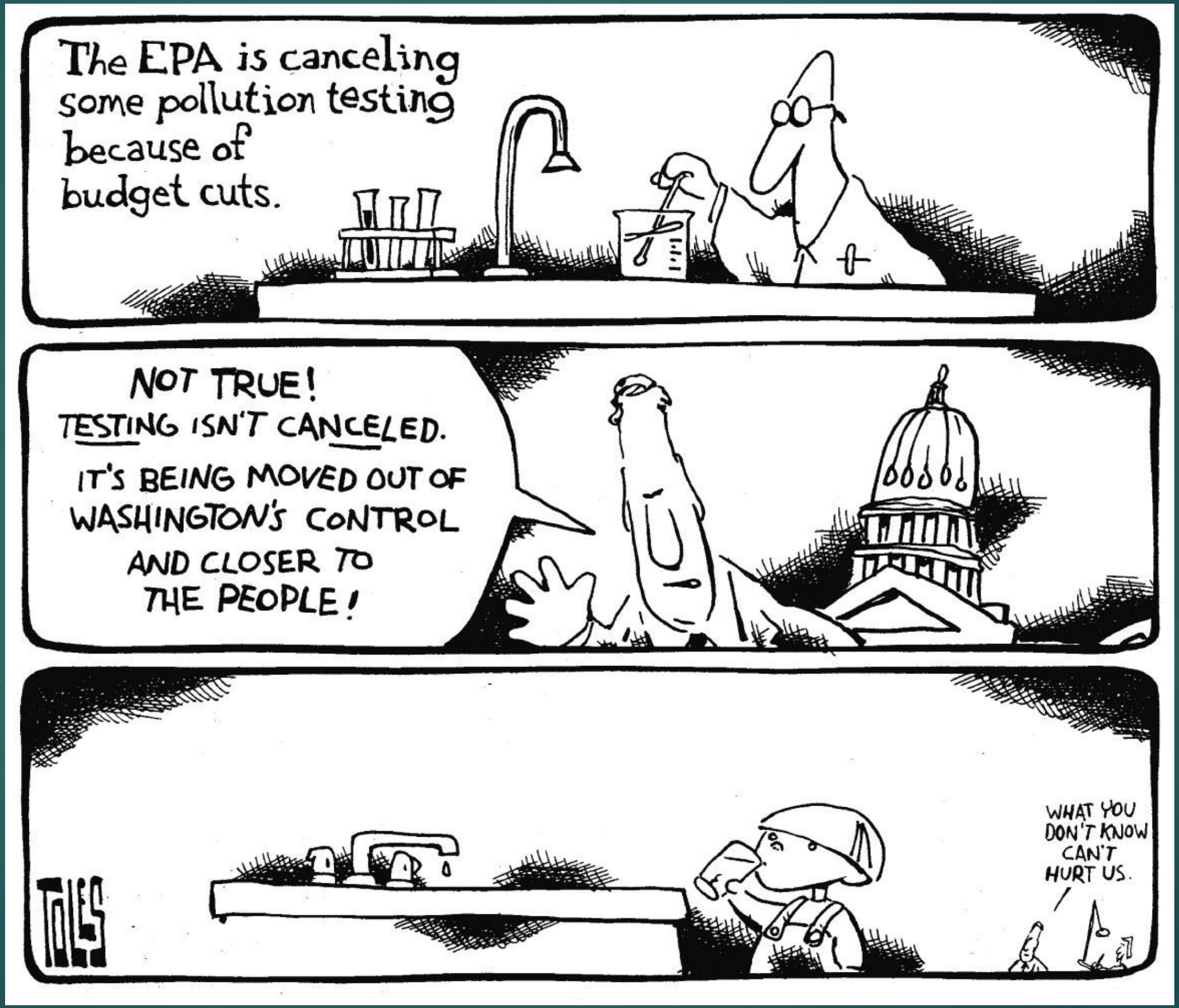
Introduction to Pollution & Ecotoxicology



Introduction to Pollution & Ecotoxicology

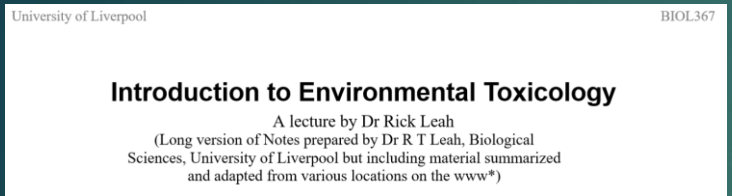
Introduction to Pollution & Ecotoxicology

THE TOXICOLOGY FOR ECOSYSTEMS

Skills you gain:
1- Understand the main concepts of pollution science & ecotoxicology
2- Get familiar with the assumptions when assessing potential environmental toxicity
3- Learn about the terminology used
4- Critically evaluate the current environmental limits for pollution

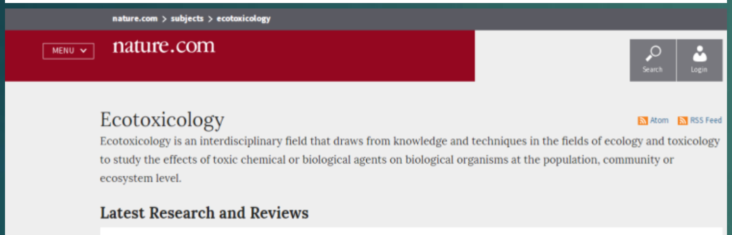
Lecturer: Abel Machado

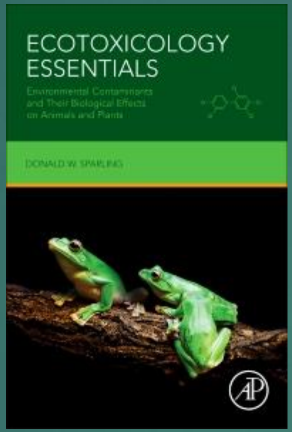
References:

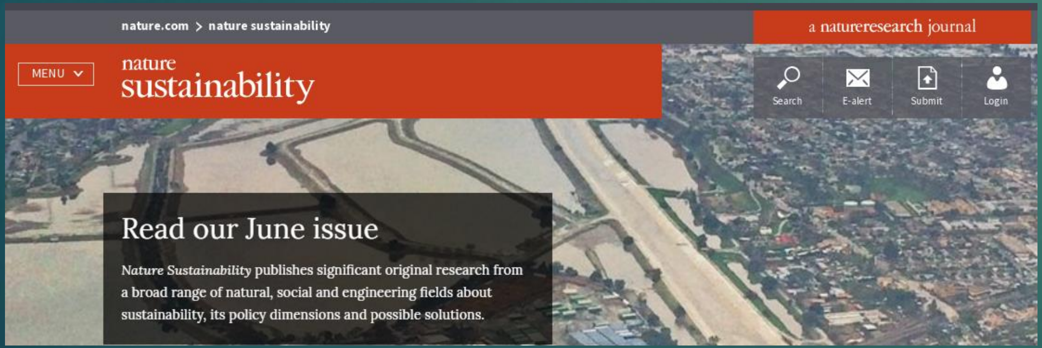

University of Liverpool BIOL367

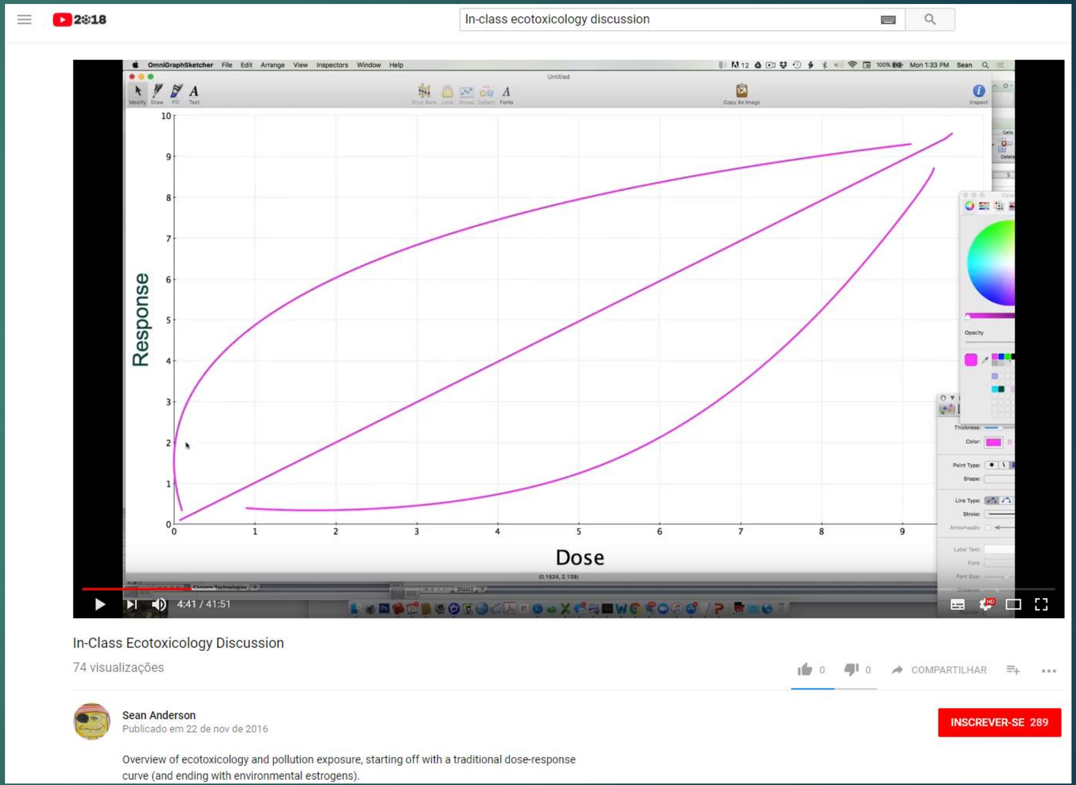
Introduction to Environmental Toxicology

A lecture by Dr Rick Leah
(Long version of Notes prepared by Dr R T Leah, Biological Sciences, University of Liverpool but including material summarized and adapted from various locations on the www*)









https://www.youtube.com/watch?v=3-WzVJNqEuw&t=280s

Introduction to Pollution Science

STUDENT ACTIVITY: A-B DIALOGUE

Lecturer: Abel Machado

Pollution & Sustainability Science

A pragmatic science bridging between environmental stewardship and human (economic) development

Biology

Mathematics

Chem

Wider view of the environmental consequences we pay as a price for a modern economy

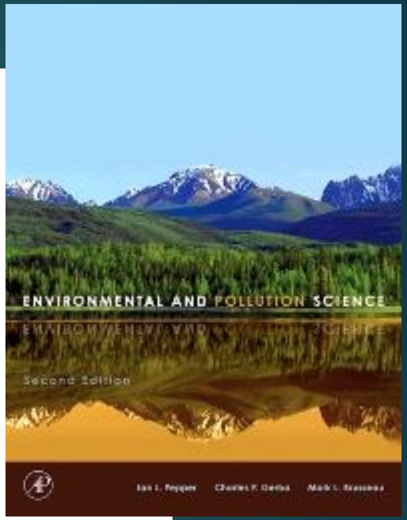
The main topics in pollution science

Sustainable economic and environmental development, with particular focus on ecosystems and society

- Aquatic Toxicology, Ecology and Stress Response
- Terrestrial Toxicology, Ecology and Stress Response
- Predictive and Statistical toxicology
- Fate & Effects of Contaminants
- Environmental Risk Assessment
- Chemistry and Exposure Assessment
- Policy, Management and Communication
- Engineering, Remediation and Restoration
- System Approaches

SETAC®

Society of Environmental Toxicology and Analytical Chemistry



How could we assess whether a novel entity is potentially harmful to ecosystems?

What are the contaminant's physical, chemical and biological structure and properties?

Where is it produced, used, transported to or disposed?

Is it degraded? How? What are the physical, chemical, and biological properties of daughter compounds?

Which physical, chemical, and biological properties of living systems could it interact with?

To which organisms and ecosystems could occur non-intended impacts?

What environmental or biological processes might emerge?

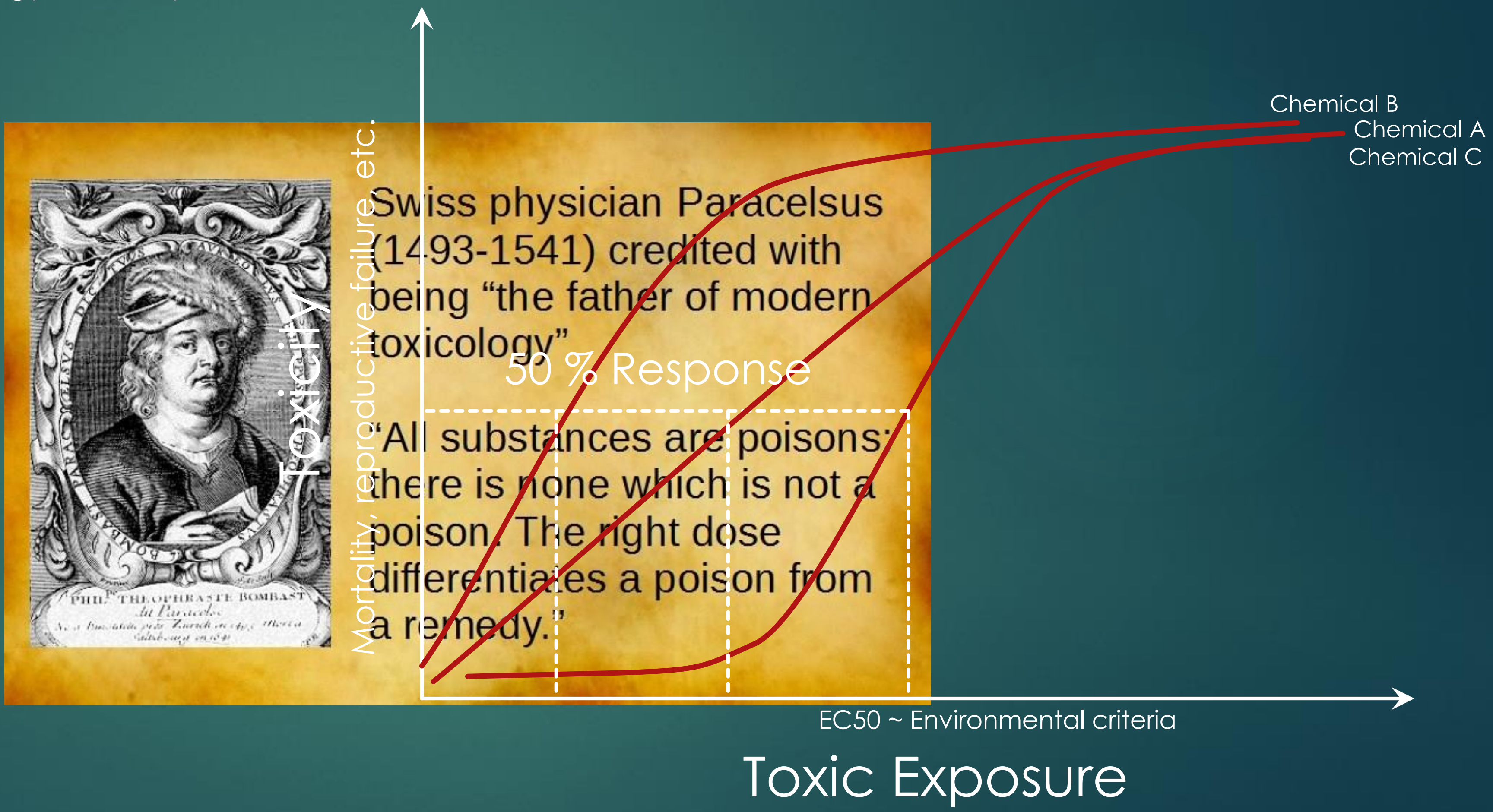
Ecotoxicological approach!

Introduction to Ecotoxicology

STUDENT ACTIVITY: A-B DIALOGUE

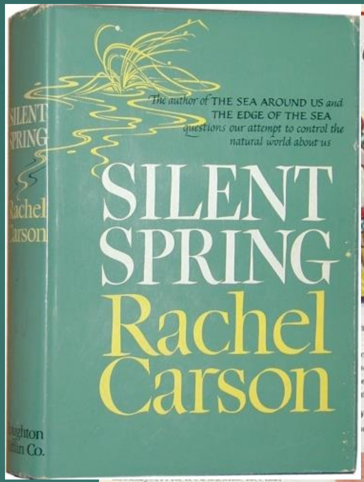
Ecotoxicology

The recent science of the toxicology of ecosystems



Toxicology evolved as the science of human (chemical) poisoning

Non-target toxicity:
What have we learned?



Endocrine disruption &
Reproductory failure of seagulls

Bird carbonate dehydratase

Time-dependence on the rat development

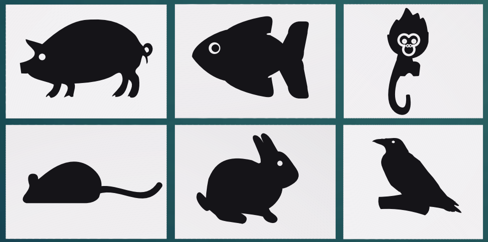
The Swiss chemist Paul Müller was awarded the Nobel Prize in Physiology & Medicine (1948) for discovering Dichlorodiphenyltrichloroethane.

Ecotoxicology

What protects human health not always protects the environment

Toxicology

Human health

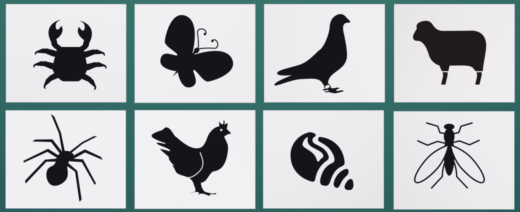


Multiple species models for one species

Environmental Toxicology

Any organism's health

Acute & Chronic



Multiple species models for several species

Ecotoxicology

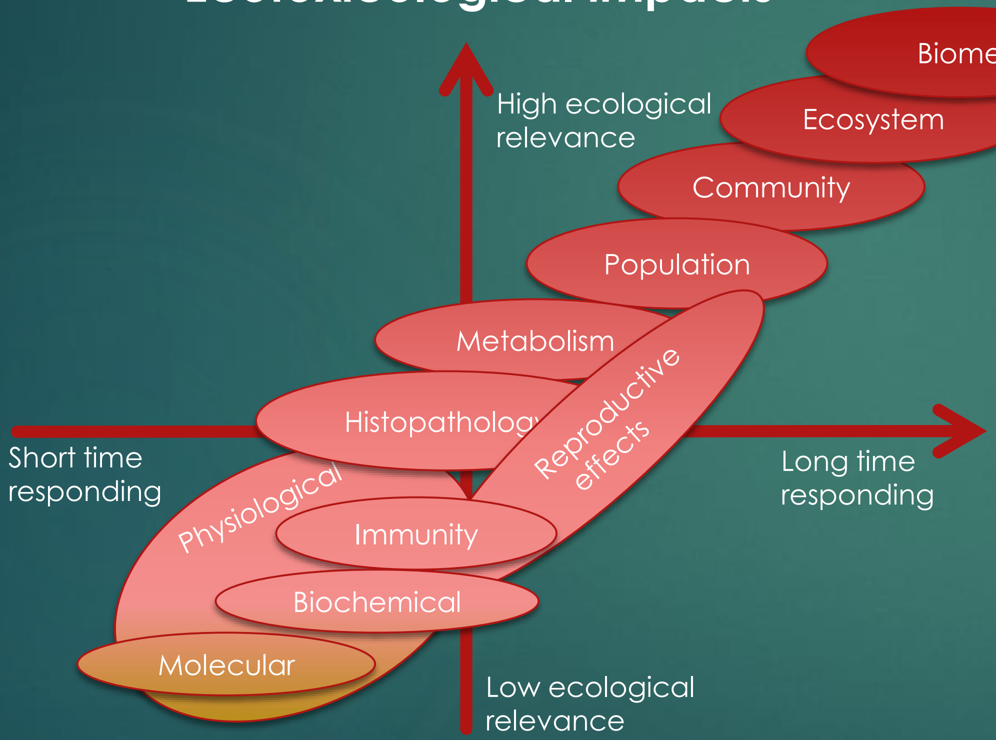
Ecosystem health

Multiple species models for biosphere

Ecotoxicology & Biological Hierarchy

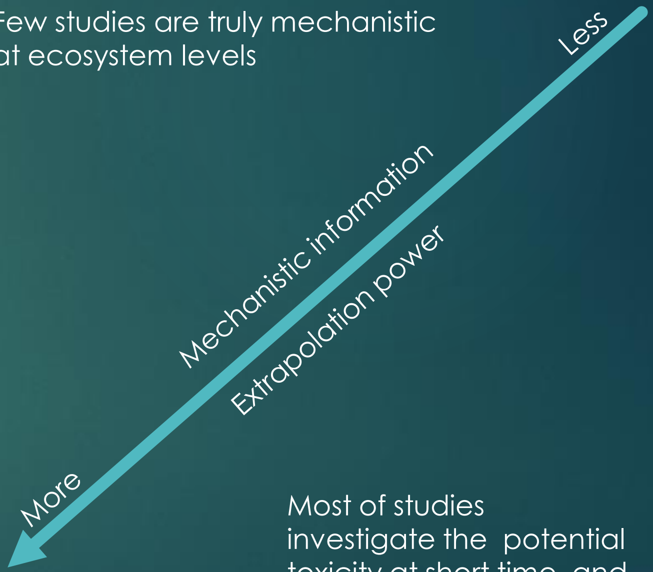
Assumption: toxicity starts at biochemical/biomolecular level and propagates to upper levels of biological hierarchy

Ecotoxicological impacts



Practical consequence

Few studies are truly mechanistic at ecosystem levels



Most of studies investigate the potential toxicity at short time and in vitro scales

Ecotoxicology is the field of study which integrates the ecological and toxicological effects of pollutants on populations, communities and ecosystems with the fate (transport, transformation and breakdown) of such pollutants in the environment.

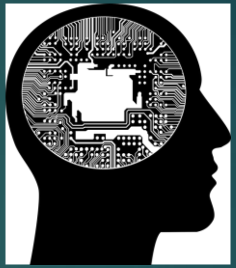
Ecotoxicology: goals & main concepts

Let's make sure we are talking about the same things

Risk assessment

Legal requirements

Principles & theories



- **Pollutants in the environment**
- **Fate & Effects of Contaminants**
- **Biomarkers of Exposure & effect**
- **Responses at supra-organismal level**
- **In vitro, In vivo, Mesocosms & Field trials**

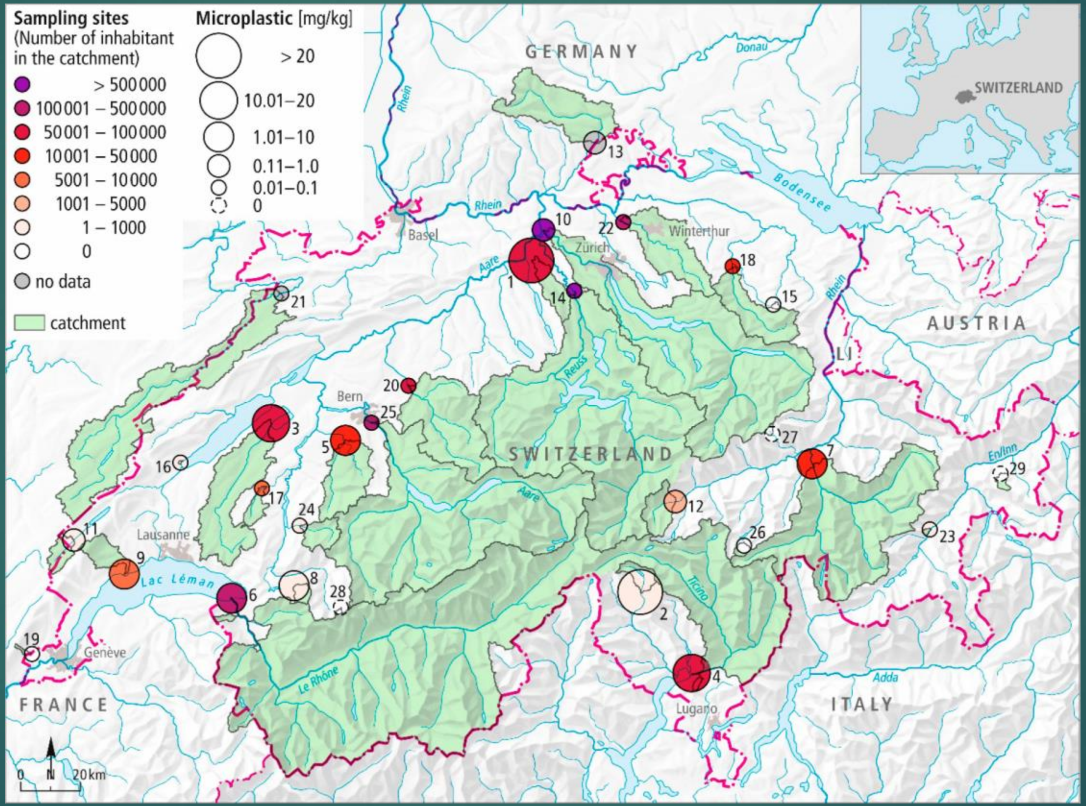
- **Hazard & Risk**
- **Toxicity testing of potential contaminants: Standard or Specific**
- **Bioindicators & Biomonitor species**
- **Exposure, Dose, Mode of Action, Mechanism, Target**

Pollution vs Contamination

Microplastic fibers were found at various concentrations in soils of Swiss natural reserves. There is no report of effects.

Student activity (A-B dialogue): Are microplastics a contaminant or a pollutant? Does it matter? Examples?

Pollution comes from latin "Polluere", i.e. defile.
It implies anthropogenic deviation of a "clean state" that was lost.
Used in management context as loss of (biological or ecological) function.



Environ. Sci. Technol. 52, 3591-3598. DOI: 10.1021/acs.est.7b06003

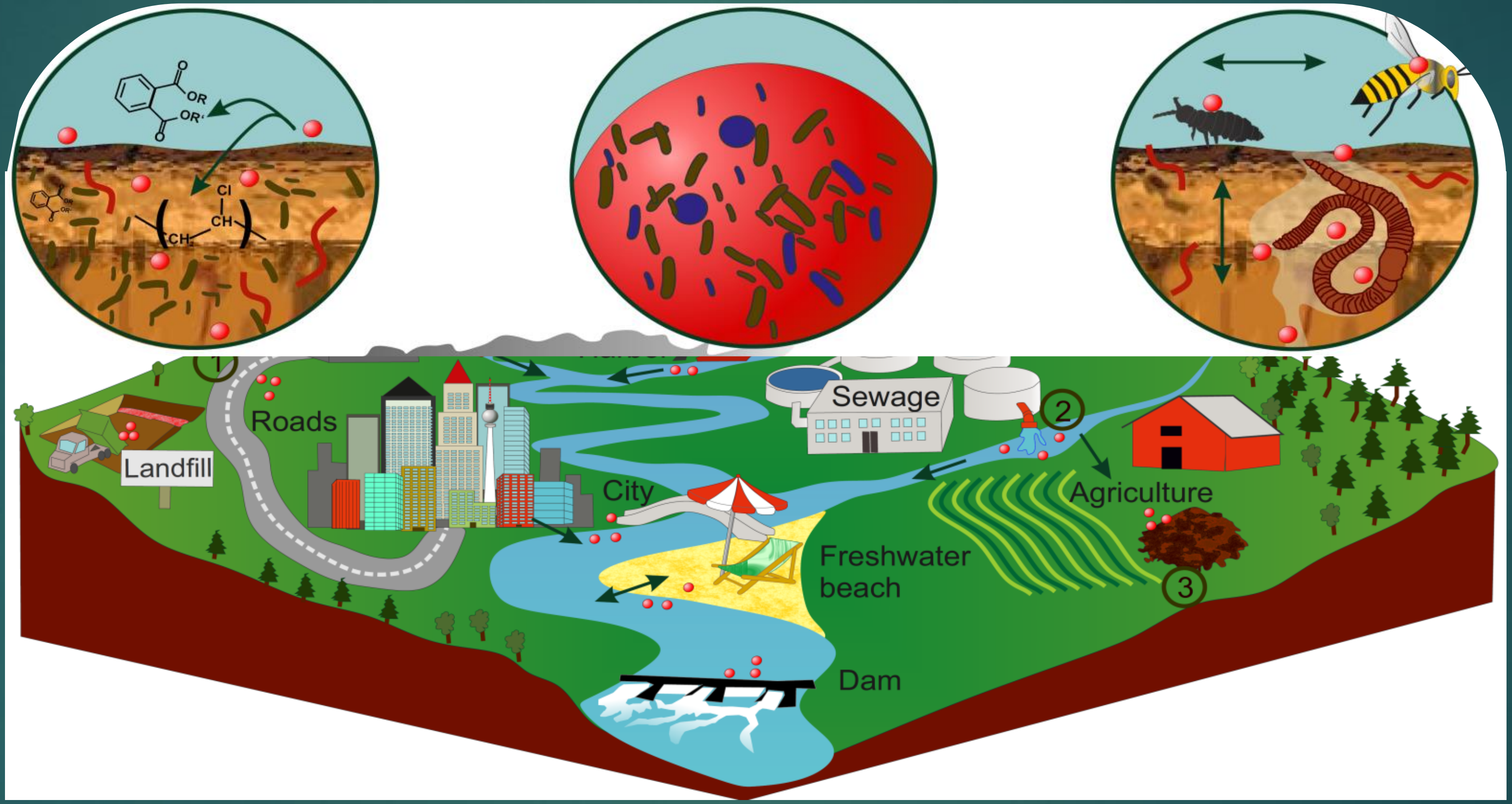
Contamination comes from latin "Contamen", i.e. To put into contact.
It implies anthropogenic increased natural levels.
Used in management context as exposure potential.

Xenobiotic is used to describe compounds that are "foreign" to a particular organism.

Pollutants and **Contaminants** are anthropogenic (with exceptions) substance, matter, or energy.

Fate and Effects

The environmental behaviour and its deleterious impacts



Fate is the movement and fate of toxic chemicals at both the organism level and that of the whole ecosystem

Effects imply deleterious impacts.

DOI: 10.1111/gcb.14020

Hazard vs Risk

A matter of potential and probabilities

Hazard is the potential to cause harm

daily.jstor.org

Risk is the probability that harm will be caused.

In vitro, In vivo, Mesocosms & Field trials

A matter of space, time, and control

In vitro

Sub-organismal exposure

Carrot roots in culture

In vivo

Organismal exposure

Lettuce in hydroponic culture

Mesocosms

Multiple organisms & species

Soil and rhizosphere microbiomes

Field trials

Exposure under realistic variability

Field work with multiple stressors planned

Control: More ← → Less

Mechanistic information: More ← → Less

Ecological relevance: Less → More

FUB Plant Ecology lab investigates the effects of microplastics at multiple spatial, temporal, and mechanistic scales

Toxicity testing: Standard vs Specific

A matter of purpose for the regulatory or research audience

Managers

How much can we use without causing substantial harm?

OECD Common standard tests
Bacterial toxicity tests
Algal Growth tests with a variety of species
Acute and Reproduction tests in *Daphnia magna*
Acute toxicity tests with the marine copepod *Acartia tonsa*
Acute toxicity test with the marine invertebrate *Mysidopsis bahia*
Earthworm toxicity tests
Toxicity Tests with sediment dwelling organisms such as *Chironomus* or *Lumbriculus*
Acute toxicity tests with freshwater and marine fish
Early Life Cycle tests with fish

Scientists

What if?

Any specific test possible

Toxicity testing: Important metrics

Either standard or specific toxicity test must control important parameters

Bugs bunny & Ether intoxication

Toxicant: Ether
Amount: 1 bottle
Environment: Lab
Bunny weight: ~ 2 Kg
Ventilation rate: 60 breath/ min
Tidal volume: 20 mL of air

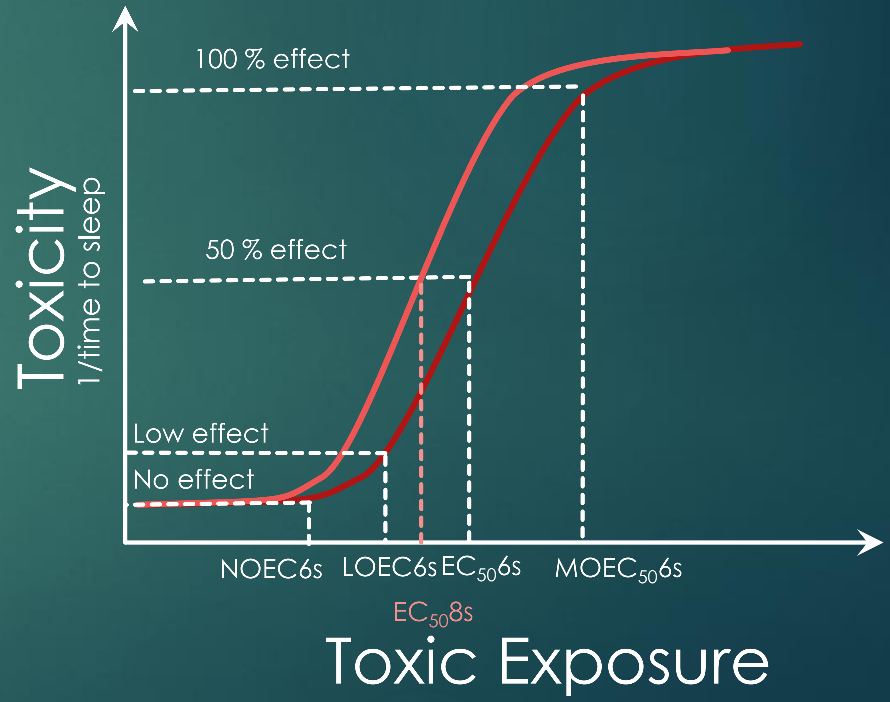
Endpoint: A particular quantitative outcome of toxic exposure — E.g. time to sleep

Concentration: The level of (environmental) exposure to a toxic (**measured** & **nominal**) — E.g. 1 bottle of ether/ lab room

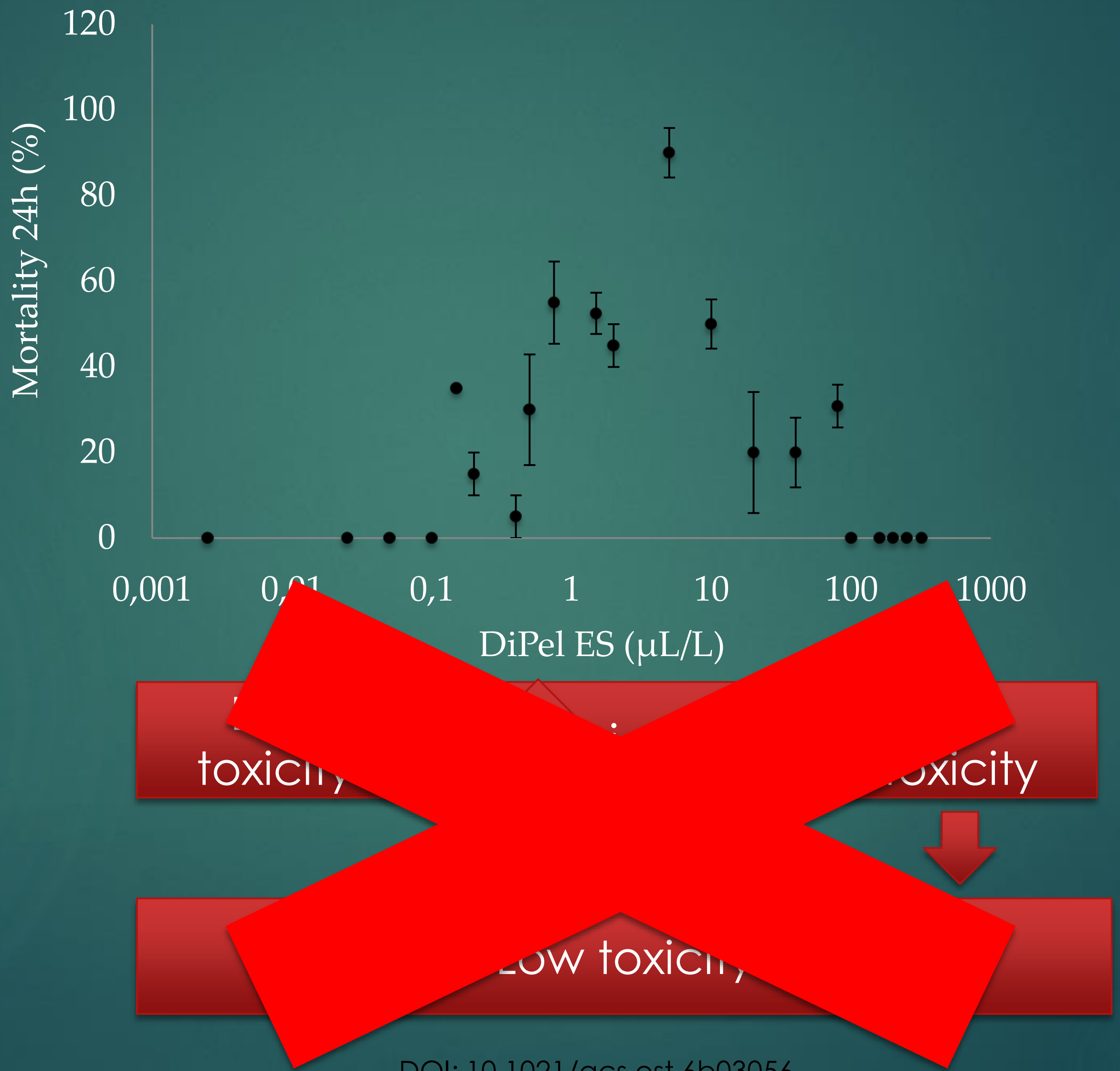
Exposure: The interaction between concentration, time, and other important variables affecting bioavailability — E.g. 1 bottle of ether/ lab room during 4 s (bunny), 6 s(scientist)

Dose: The effective exposure, often per mass of metabolic active tissue. 20mL air/ beath, 30-60 breath/ min, 2kg — 60 mL ether air/ kg (bunny) (what about the scientist?)

Next step: a dose response curve



Ecotoxicologial implications of monotonicity assumptions



The official instruction is: “there is no official instruction”.

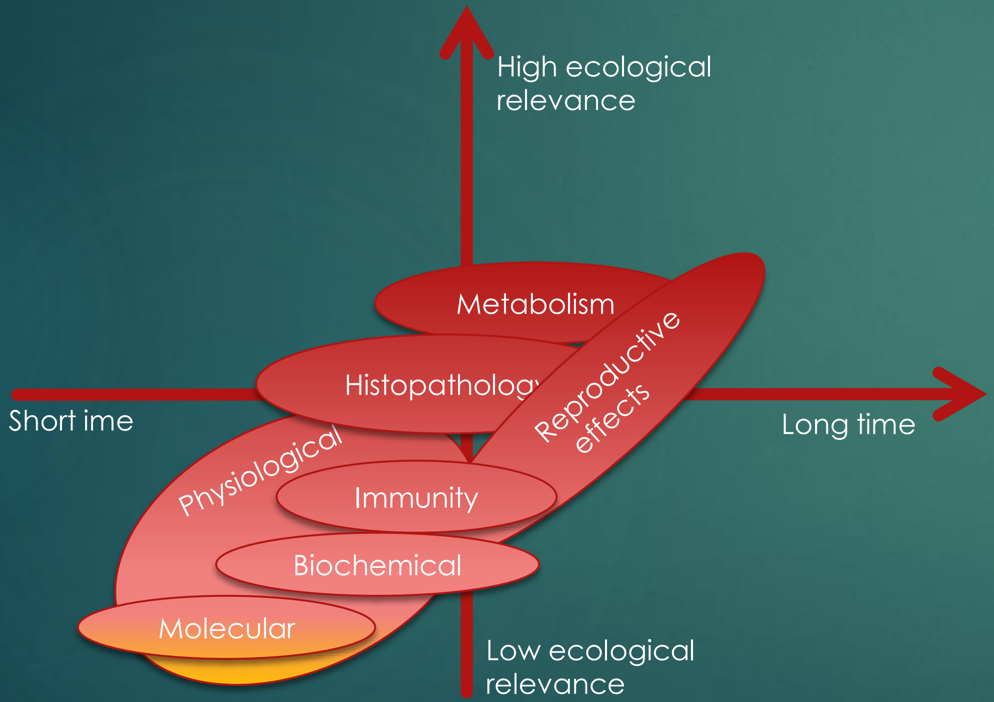
There is no environmental limit for this pesticide

DOI: 10.1021/acs.est.6b03056

Biomarkers vs Biological Responses

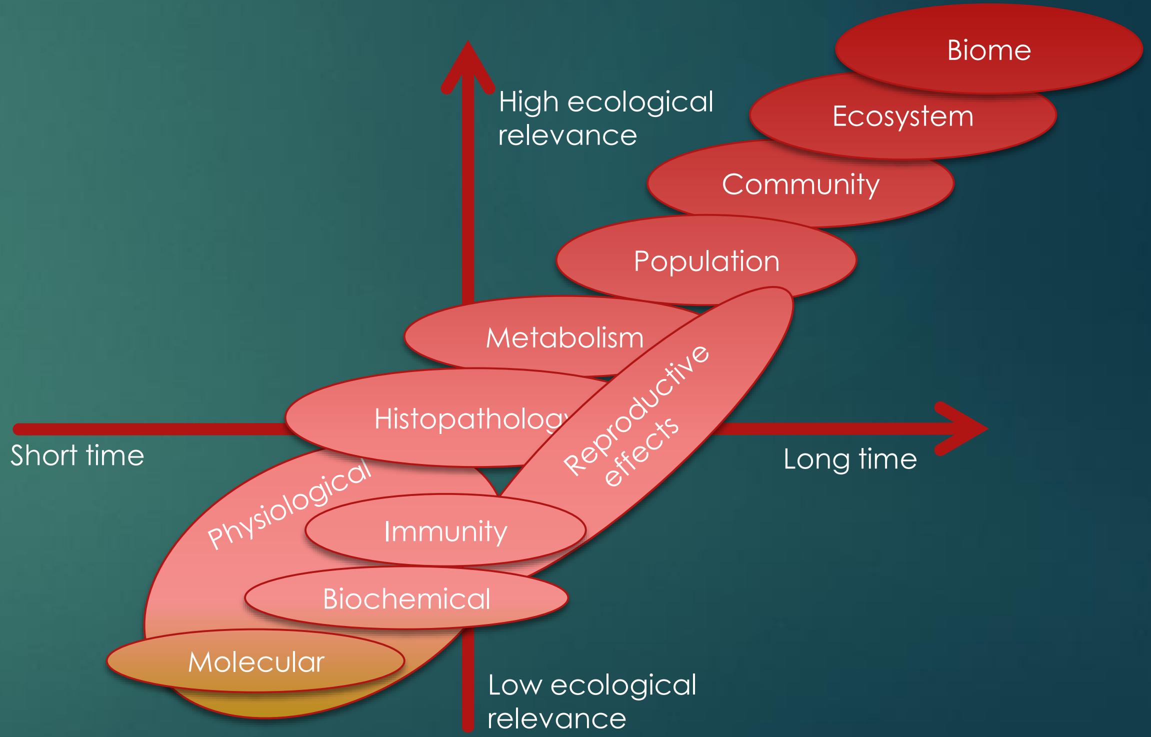
Biomarkers

Early quantitative sub-organismal responses to exposure or effect associated to a particular stressor



Biological responses

Biological responses to exposure or effect associated to pollution

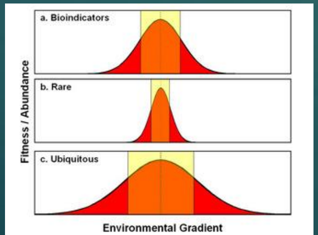


Bioindicator vs Biomonitor

Bioindicator

Organism whose presence or absence informs about the quality of the ecosystem

www.epa.gov

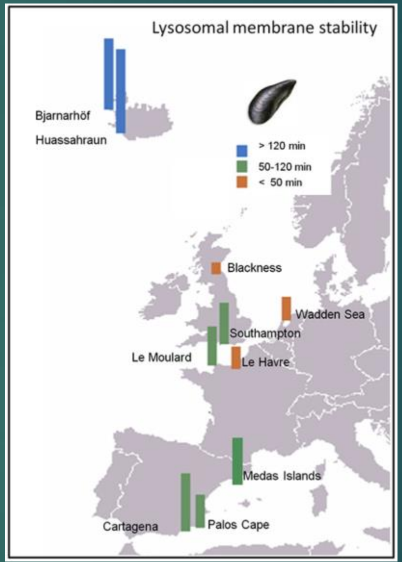


Nature Education Knowledge 3(10):8

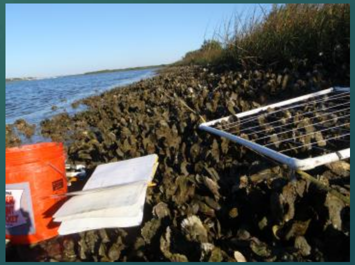
Ideal bioindicator species should be relatively sensitive to stressors and associated with ecosystem function

Biomonitor

Organism that display quantitative responses to pollution



doi.org/10.1016/j.marenvres2015.10.012



Ideal biomonitor species do not change habitats, present some tolerance, **bioaccumulate, bioconcentrate, and biomagnify** pollution

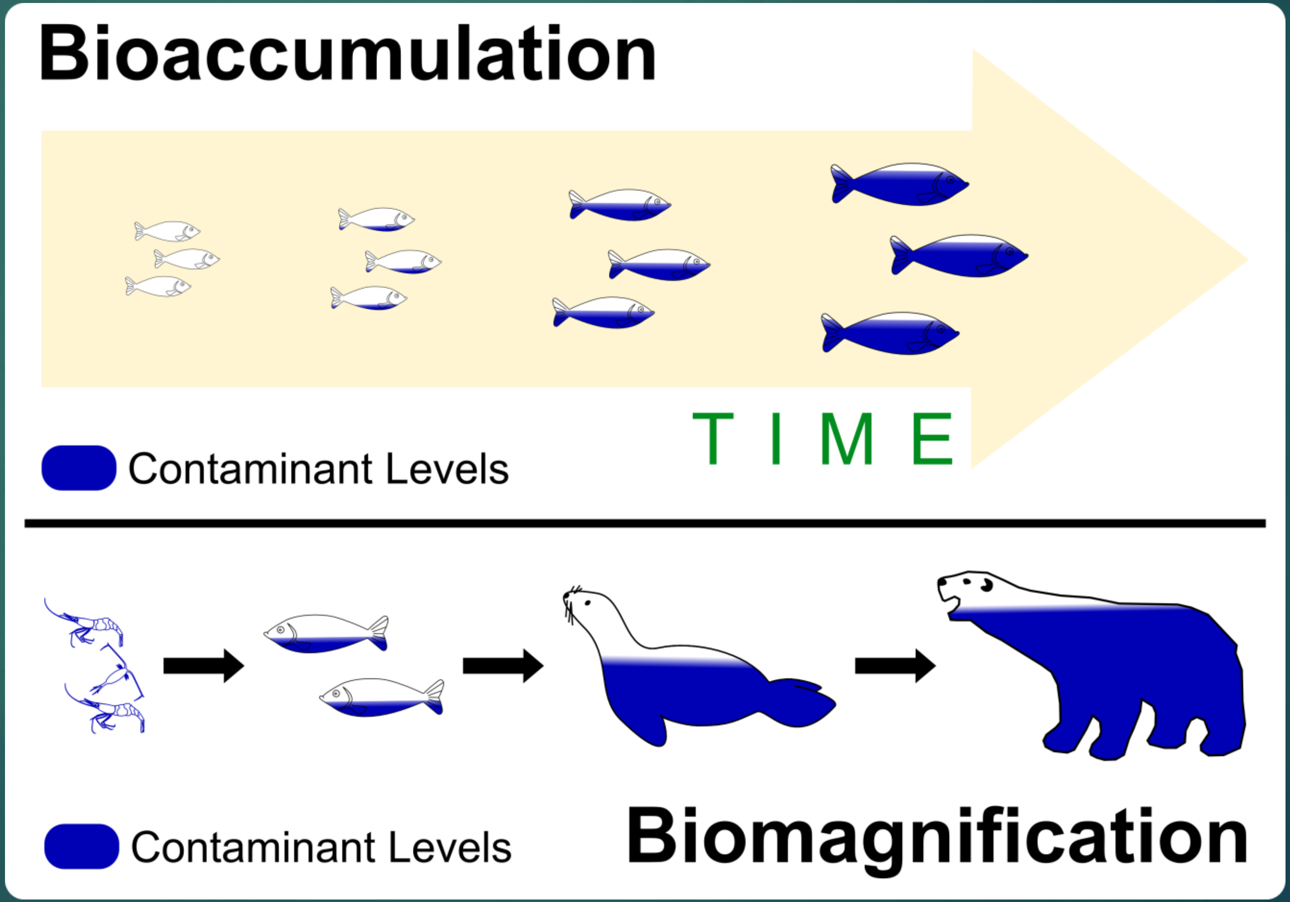
www.gtmnerr.org

Contaminants & Biomonitors

Biokinetic concepts: Bioconcentration, bioaccumulation, and Biomagnification

Bioconcentration

Microalgae cells can concentrate ~120-fold waterborne zinc after 48h



https://hemtecks.wordpress.com

Student activity (A-B dialogue): Why could it be important to classify contaminants according to their biokinetics?

STUDENT ACTIVITY: A-B MONOLOGUE

Main ecotoxicological topics:

- Pollutants in the environment
- Fate & Effects of Contaminants
- Biomarkers of Exposure & effect
- Responses at supra-organismal level
- Exposure, Dose, Mode of Action, Mechanism, Target
- Hazard & Risk
- Toxicity of potential contaminants: Standard or Specific
- Bioindicators & Biomonitor species
- In vitro, In vivo, Mesocosms & Field trials

USING THE CONCEPTS WE LEARNED TODAY, EXPLAIN TO YOUR COLLEAGUES WHETHER NANOPLASTIC IS A CONTAMINANT OR A POLLUTANT.

CAN WE ASSESS POLLUTION EFFECTS OF NANOPLASTICS IN THE ENVIRONMENT?

WHAT ABOUT HAZARD AND RISK?

HOW WOULD YOU DESIGN AN EXPERIMENT TO ANSWER THESE QUESTIONS?

Summary: Pollution & Ecotoxicology

- Pollutants in the environment
- Aquatic Toxicology, Ecology and Stress Response
- Fate & Effects of Contaminants
- Terrestrial Toxicology, Ecology and Stress Response
- Biomarkers of Exposure & effect
- Predictive and Statistical toxicology
- Responses at supra-organismal level
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- Environmental Risk Assessment
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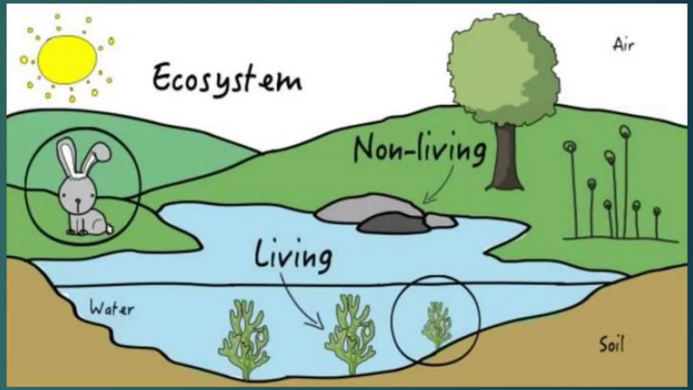
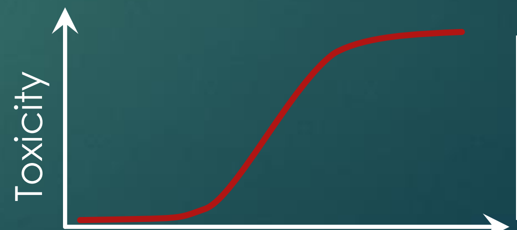
- Chemistry and Exposure Assessment
- Toxicity testing of potential contaminants: Standard or Specific
- Policy, Management and Communication
- Engineering, Remediation and Restoration
- Bioindicators & Biomonitor species
- System Approaches
- Exposure, Dose, Mode of Action, Mechanism, Target

Pollution & Ecotoxicology

Ecosystem health





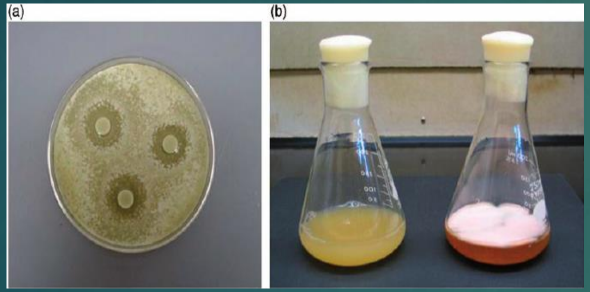
Thanks

HOW COULD WE OBTAIN RELEVANT ECOTOXICOLOGICAL INFORMATION FROM OUR TOXICITY TESTS?

MAKE A QUICK RECALL AT HOME OF THE CONCEPTS WE LEARNED TODAY TO SHARE NEW INSIGTHS WITH US TOMORROW

Terrestrial model

Filamentous fungi



Animal model

Zooplankton community

Primary Producer model

Microalgae

Primary Producer model

Terrestrial plant

LET'S DIVIDE THE GROUPS TO WORK IN THE NEXT PRACTICAL ECOTOXICOLOGICAL ACTIVITIES