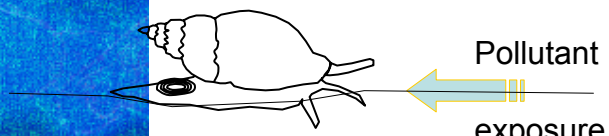
Concept of biomarkers

RF-Akvamiljø
Mekjarvik 12
4070 Randaberg
http://www.rf.no

Contact person:
Dr. Odd Ketil Andersen
Head of Research
Tel.: +47 51 87 50 50
E-mail: oka@rf.no

The biomarker concept



Pollutant

exposure

Animal density
Biodiversity
Indicator species

Ecosystem change

Fitness;
- survival
- reproduction

Community

Chemical anal.
Biomarkers
Bio-assays

Population

Later-effects

Individual

Chain of events…

Cells

Molecules

At different levels of biological organisation

Early-effects

Chemical exposure

Biochemical responses

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Biomarker definition

- Biomarkers
  - Refers to any biological response in a living organism that results from the exposure to a pollutant chemical (or chemicals)
    - Sometimes confused with Biomarkers as a term used for organic chemical markers (e.g. persistent components in oil, such as pristane, phytane, hopane etc.)

Biomarker definition

Biochemical, cellular, physiological or behavioral variations

that can be measured in tissue
or body fluid samples
or at the level of whole organisms

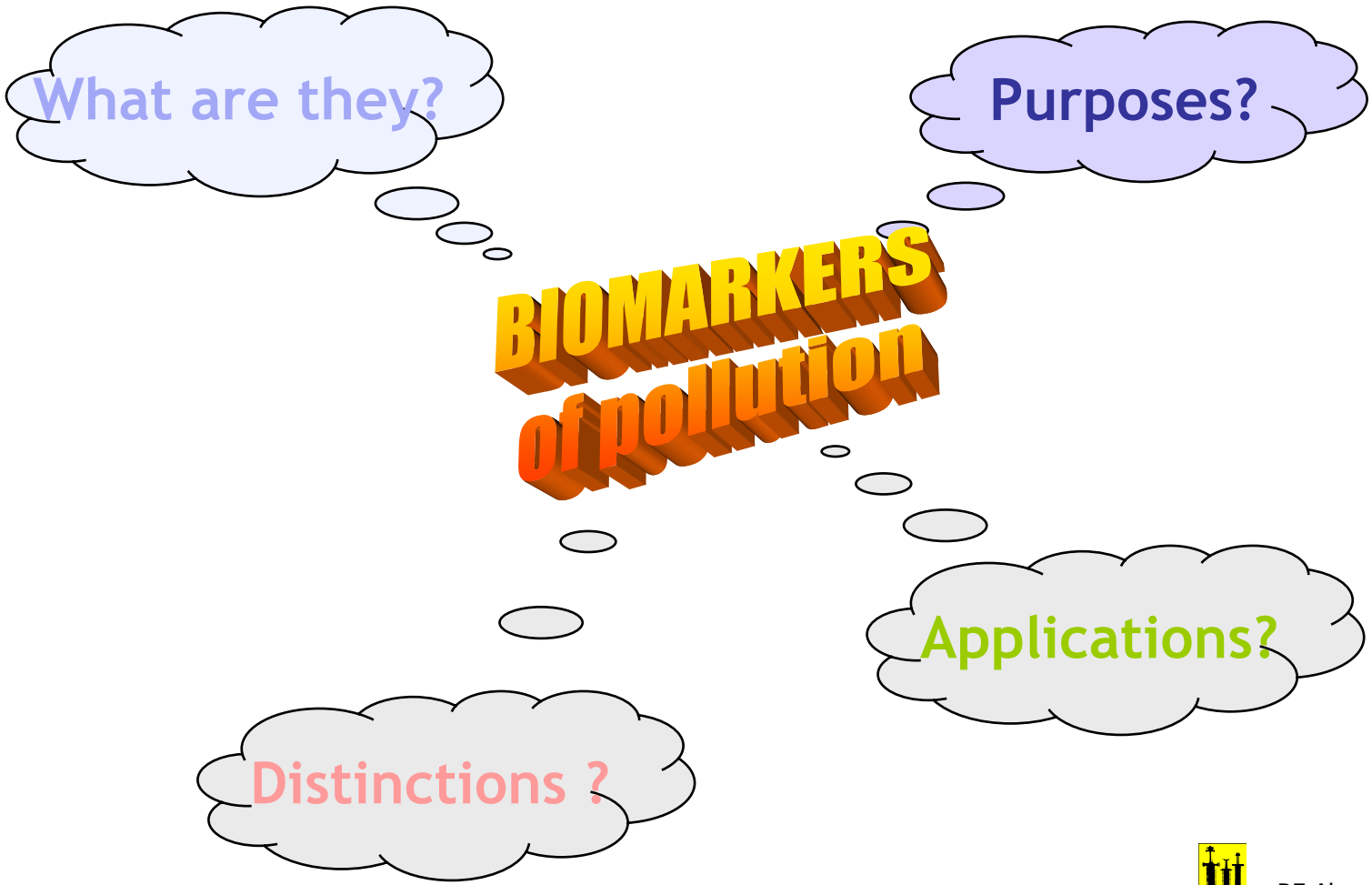
that provide evidence of exposure to
and/or effects of one or more chemical pollutants

Depledge, M., *The rationale basis for the use of biomarkers as ecotoxicological tools*, in *Nondestructive Biomarkers in vertebrates*, M.C. Fossi and C. Leonzio, Editors. 1994, CRC Press: Boca Raton, Florida, USA. p. 271-295.

Background for biomarker approach

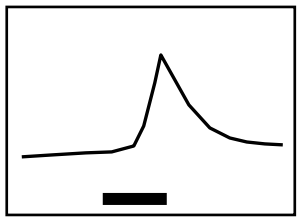
- Derived from human health diagnostics
  - a need for measurement techniques that gives an early warning signal of disease or declining health status
- Growing environmental concern
  - techniques with similar properties are needed to warn about biological effects of pollution

Biomarkers of pollution –
a tool to monitor biological impact



What are BIOMARKERS of pollution?

Responses at individual level

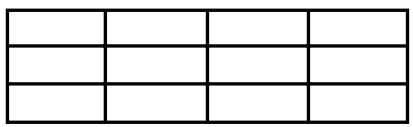


Contaminant responses

BIOMARKERS of pollution

Biochemical, cellular, physiological, behavioral parameters

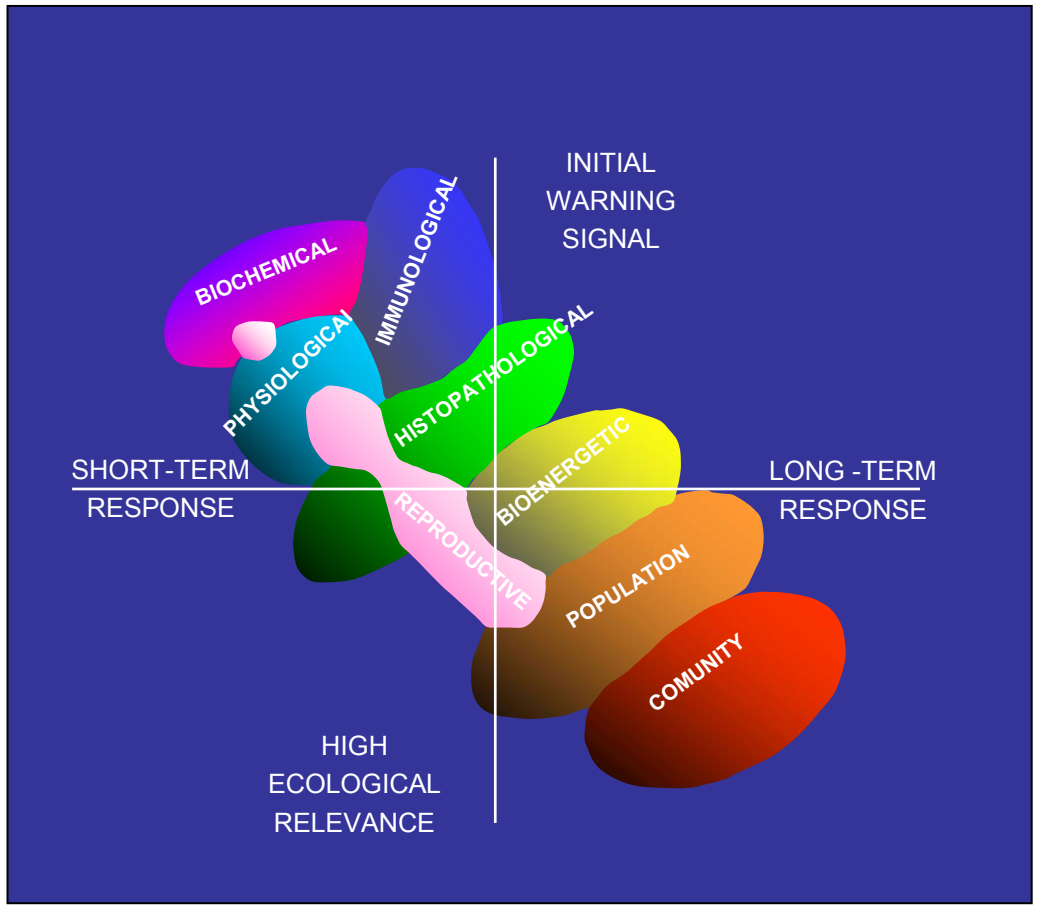
A suite of parameters



Suite of biomarkers

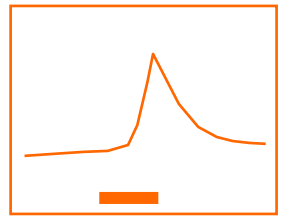
… a selection of techniques
analogues to human health diagnostic methods
to serve as tools for pollution diagnostics

- Criteria
  - Different properties
  - Hierarchy of effects
  - Improve biological interpretation



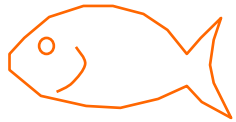
Criteria of candidate biomarkers of pollution

Contaminant responses



- Response relevant indicator of biological effect
- High sensitivity
- Well-defined dose-response relationship
- Consistency of response
- Non-responsive to natural fluctuations (ideally)

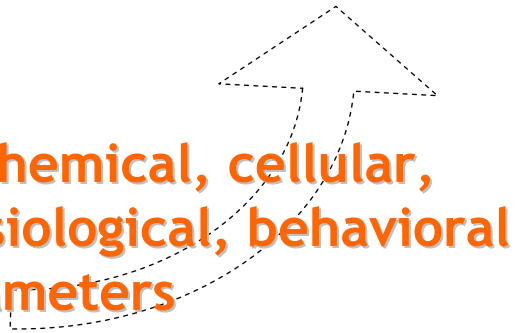
Criteria of candidate biomarkers of pollution



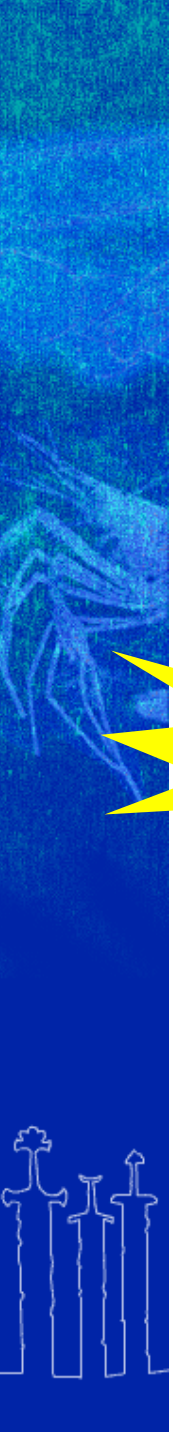
- Responses at individual level
  - Applicable in a broad range of organisms
  - Non-destructive sampling (ideally)
  - Easy, rapid and cost-effective

Hierarchy of biomarkers

- Biochemical
  - proteins/enzymes, metabolites
    - vitellogenin,
    - biliary PAH metabolites
- Subcellular
  - lysosomal membrane stability
- Cellular
  - Immunological responses
- Physiological
  - grazing rate / scope for growth
- Histological
  - cancerous tumors,
- Behavioral
  - animal interactions, signal substance reactions
    - prey search,
    - spawning control



Purposes



Inform about type of contaminant

Show actual impact

Make a diagnosis

Provide early-warning

BIOMARKERS of pollution

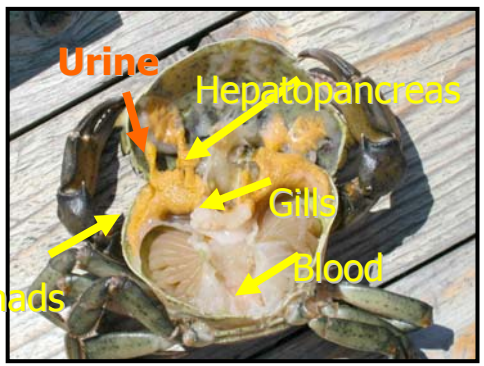
Monitor recovery

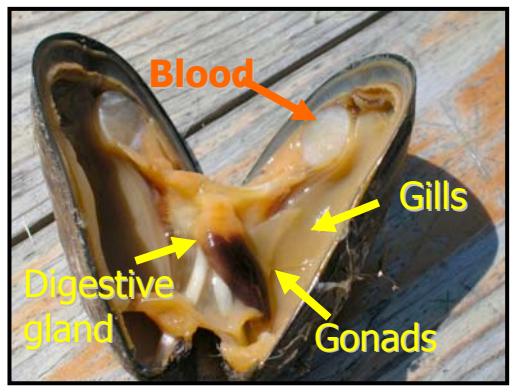
Validate models

Prognosis

Different kind of organisms - Biomarkers in invertebrates

- Analogues to human health diagnostics
- Blood- and urine samples

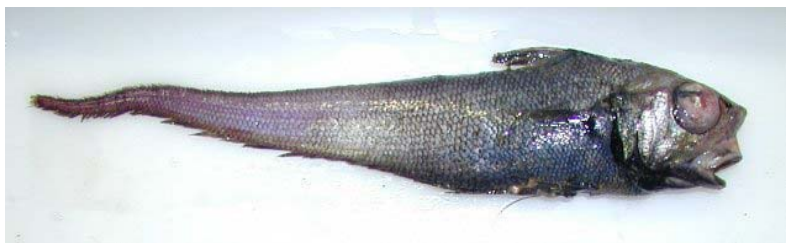




Different kind of organisms - Different ecosystems

- Biomarkers in Fish
- In Deep-sea

Macrouridae sp. (1500m depth)



MUSCLE
AChE
PACs & OCs

GILLS
Histopathology

BILE
Fluorescent aromatic metabolites

LIVER
TOSC assay
Catalase
DNA adducts
EROD / CYP1A / GST
Metals

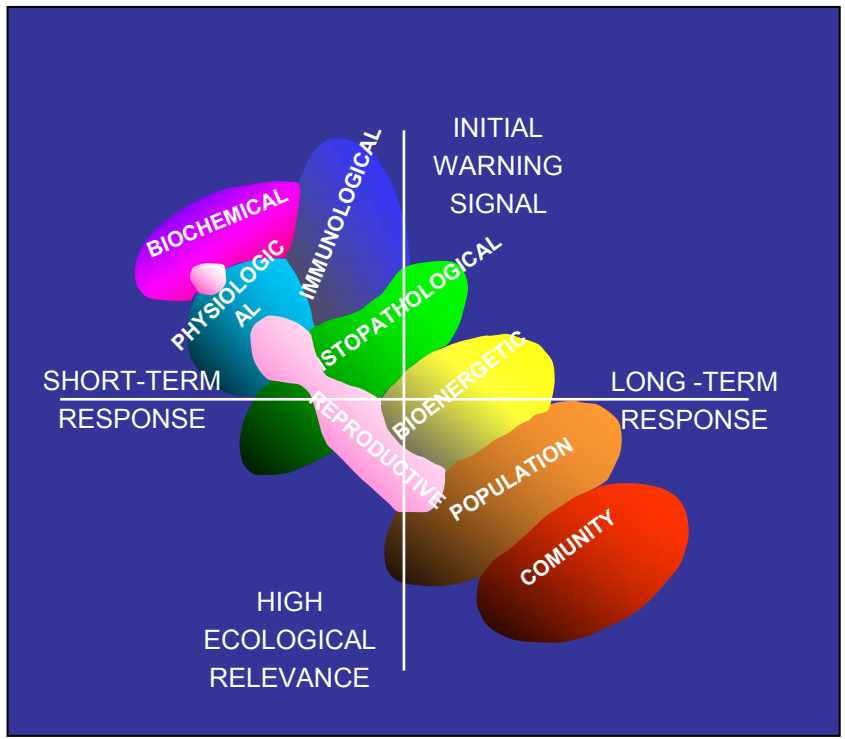
BLOOD
NRRT / CMS
Vitellogenin

- Global approach
  - Validation required for background levels, seasonality variations etc.

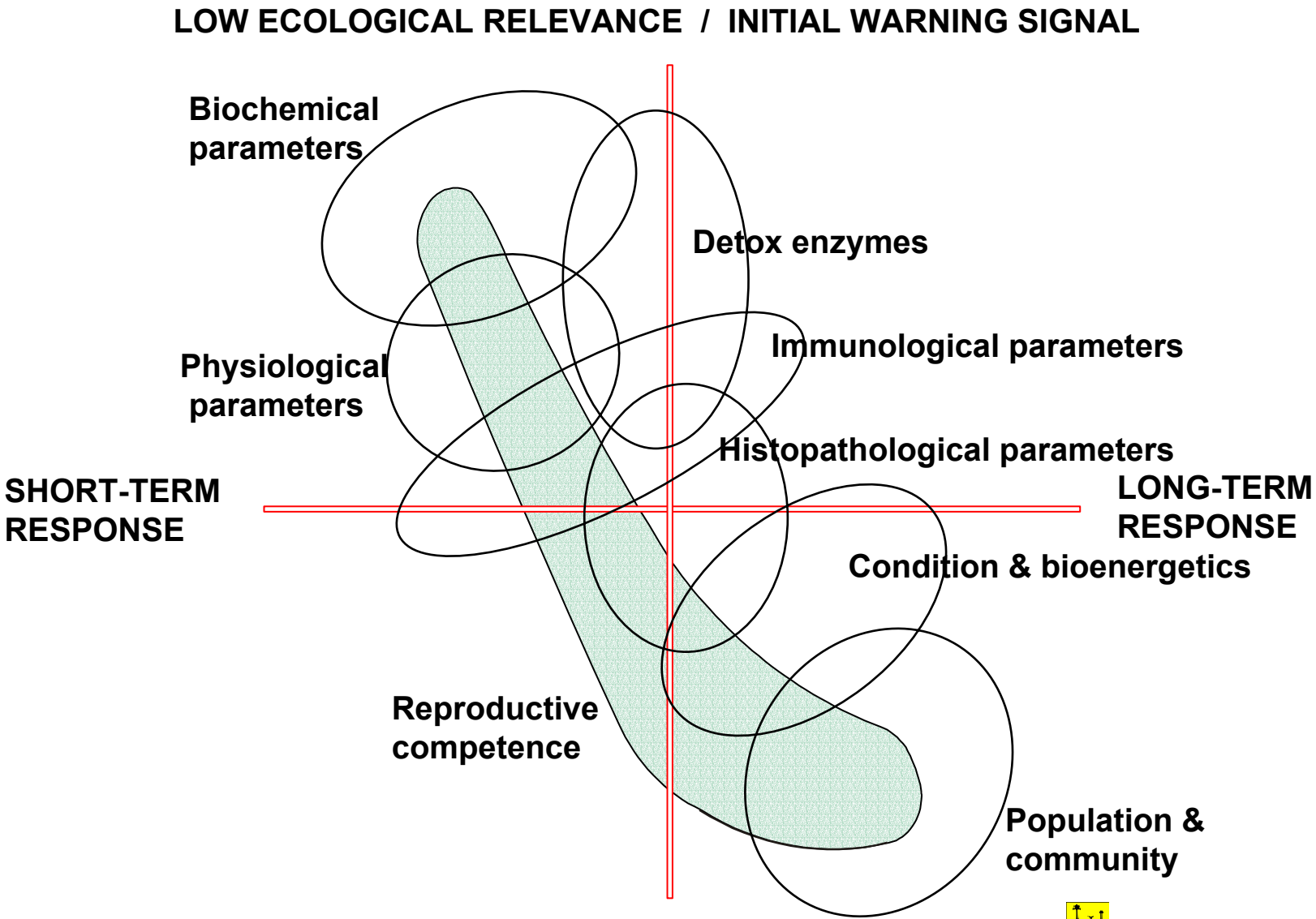
Biomarkers – applicability

in the 'Long term : chronic exposure'

- The environmental focus shifted from acute toxicity…
  - to Long term : chronic exposures
    - chronic exposure – produced water
    - regionally elevated levels of contaminants
  - Sub lethal effects
    - effects on reproduction
- Biomarkers - applicability
  - early warning signals
  - with relevance to potential ecological effects



Significance of biomarkers



Adams et al., 1989

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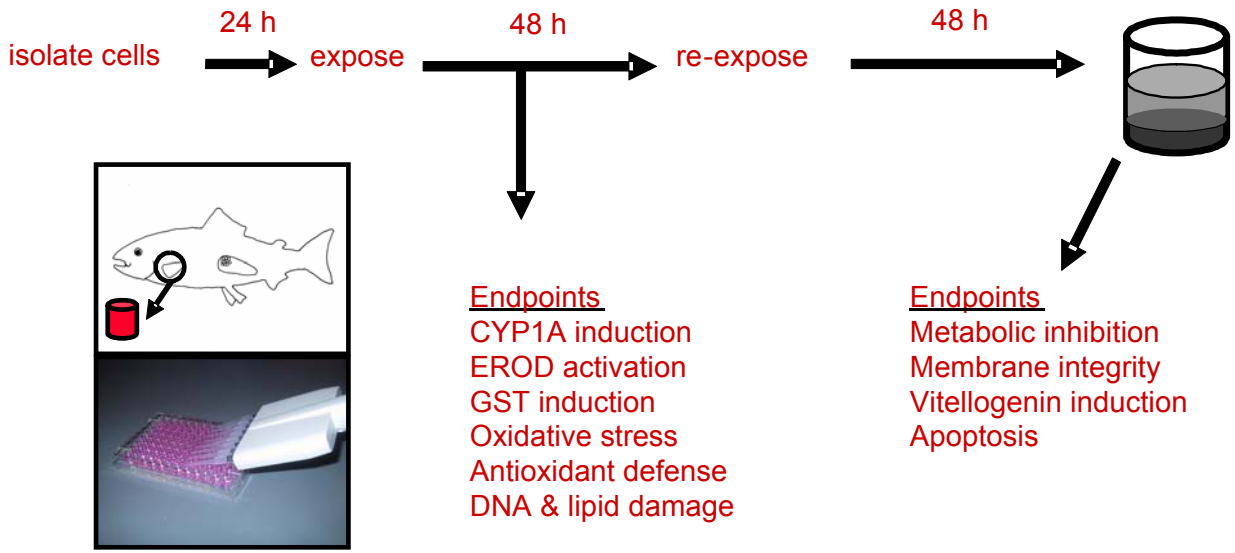
Distinction of biomarkers from bio-assays and bio-indicators

- **Bio-assays**
  - Definition
    Appraisal of the biological activity of a substance by testing its effect on an organism and comparing the result with some agreed standard
    - in-vitro; e.g. cell cultures (sub-individual level - screening)
    - in-vivo; e.g. ecotox tests (individual level – fitness)
  - TIE approach
    - Toxicity Identification and Evaluation
      - bioassays combined with chemical fractionation and analysis to identify chemicals that are responsible for different biological effects.

Bioassays used in TIE approach



- **Schematic drawing of fish in vitro bioassay**
  - **small scale testing system for various toxic endpoints related to:**
    - **arylhydrocarbon receptor activation**
    - **phase II biotransformation**
    - **free radical formation**
    - **enzymatic antioxidant defense**
    - **damage to double and single stranded DNA**
    - **peroxidative damage to lipid membranes**
    - **acute toxicity**
    - **estrogenicity**
    - **programmed cell death**

Knut-Erik Tollefsen, NIVA

Distinction of biomarkers from bio-assays and bio-indicators

- Bio-indicators (term with ambiguous meaning ?)
  - Species whose absence at a site is indicative a change in environmental conditions
  - Species used in bio-assays (tests)
    - biomarkers can be measured in bio-indicator species !
  - also used for:
  - Parameters indicating environmental pollution
    - will then include Biomarkers

Summary

- This was a brief introduction to biomarkers
  - In the following we will present in more detail
    - what the different drivers behind the biomarker approach,
    - which biomarkers are used in the oil and gas industry,
    - how biomarkers are used and perform in different studies,
    - what the interests are in developing the biomarker concept further,
    - and what are the challenges and further goals