A Tiered Approach for the Use of Non-Testing Methods in the Regulatory Assessment of Chemicals

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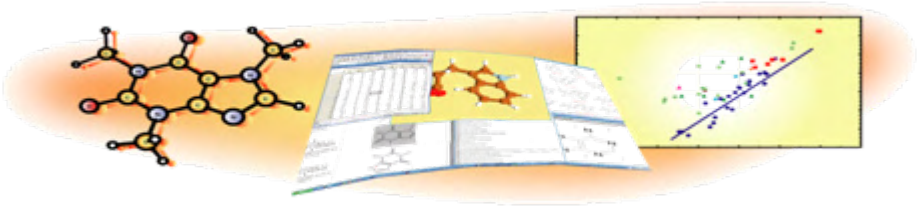
US EPA Chemical Prioritisation meeting; 25 June 2009

http://ecb.jrc.ec.europa.eu/qsar/



Overview

1. Computational toxicology at the JRC
2. Role of non-testing methods in hazard and risk assessment
3. Assessing and documenting the adequacy of predictive methods
4. Non-testing strategy – a stepwise approach
5. Conclusions

The European Commission's Joint Research Centre

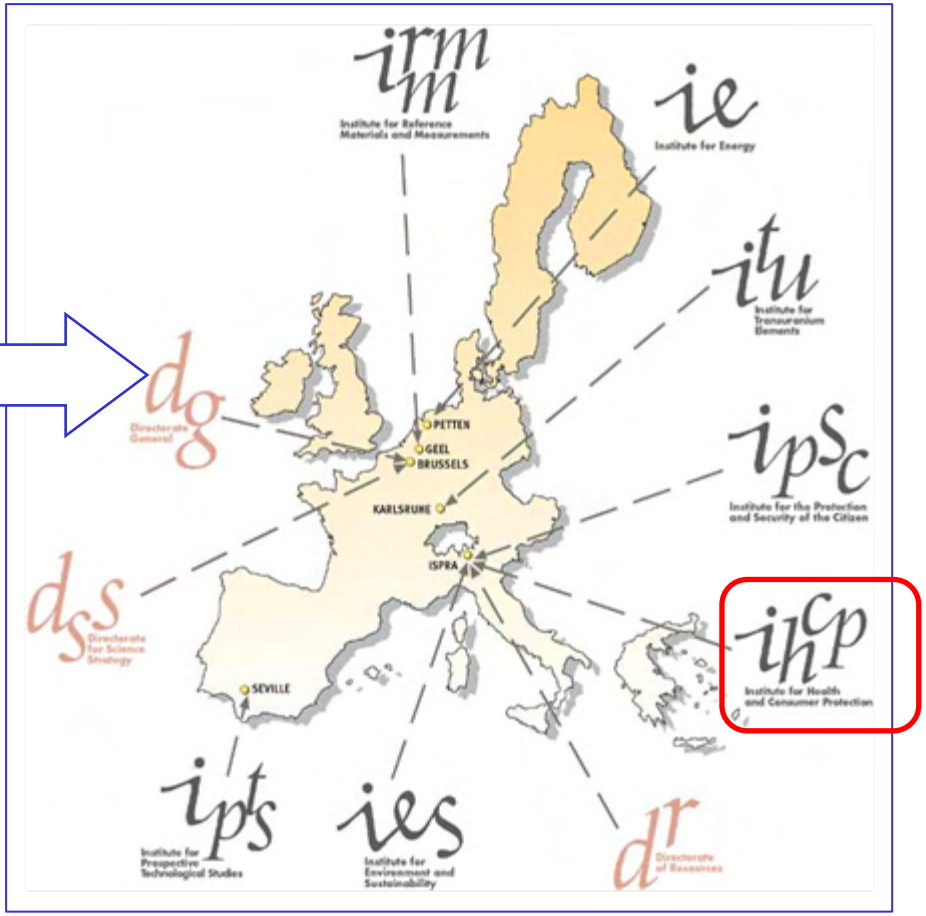
European Commission

Directorates-General

Directorates or Institutes

Units

JRC



Molecular Biology
In Vitro Methods
Nanobiosciences
Chemical Assessment & Testing
Systems Toxicology

Genetically Modified Organisms
Alternative Methods & ECVAM
Nanotechnology
Health and Environment
Consumer Products & Nutrition

Policy Areas

Systems Toxicology at the JRC

Computational Toxicology: development, assessment and application of computer-based assessment methods (e.g. QSARs and biophysical models) for chemicals

High-throughput screening: automation of robust and informative cell-based and biochemical assays, to generate high quality *in vitro* data for the targeted assessment of chemicals

Metabolomics: use of metabolomics and metabonomics to describe the metabolic status and biochemical events associated with a cellular or biological system, both in its steady-state and in its dynamic responses to environmental stressors such as chemicals

Chemometrics and Biostatistics: application of statistical approaches to support IHCP projects, e.g. experimental design and analysis of validation studies

Information requirements under REACH

Information on chemical properties, fate and (eco)toxicological effects is used for various regulatory purposes: classification & labelling, risk assessment, PBT and vPvB assessment

Information requirements are largely tonnage dependent, however …

… (animal) testing can be reduced or avoided by "replacing traditional test data with predictions or equivalent data"

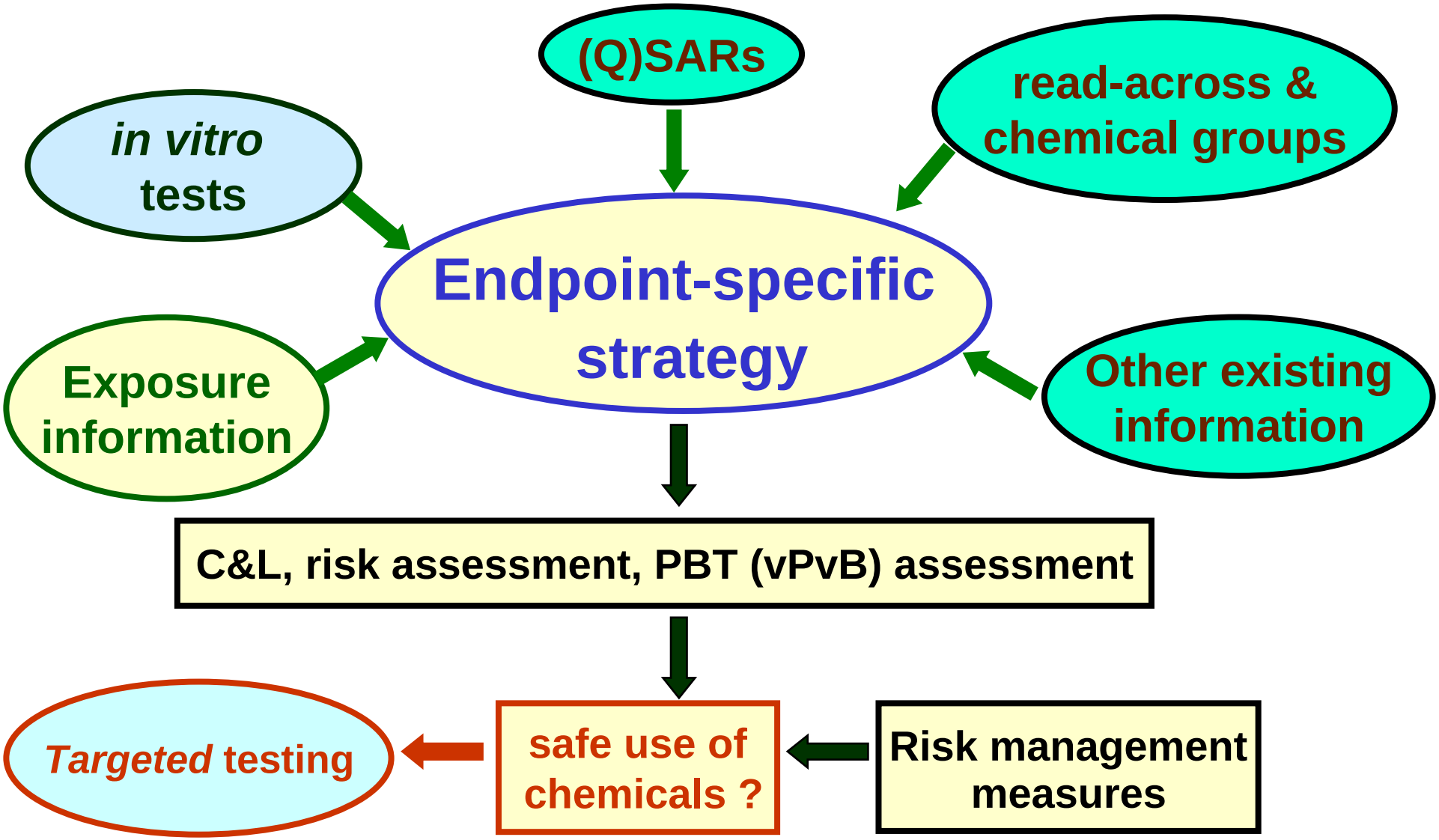
→ *in silico* predictions (SARs, QSARs, expert systems, read-across)

→ *in vitro* data

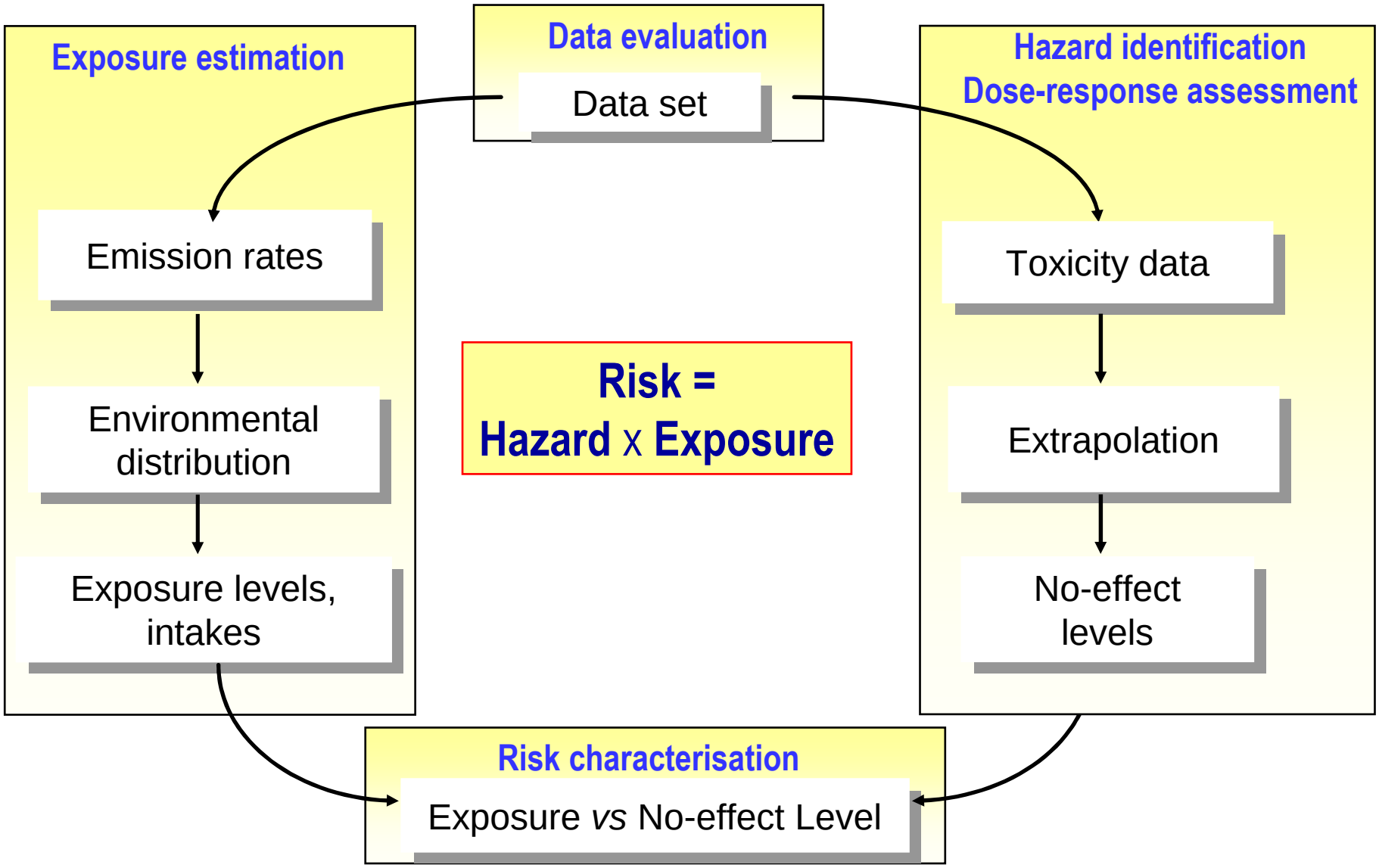
→ Integrated Testing Strategies

"Information on intrinsic properties of substances may be generated by means other than tests, provided that the conditions set out in Annex XI are met" (Article 13, REACH)

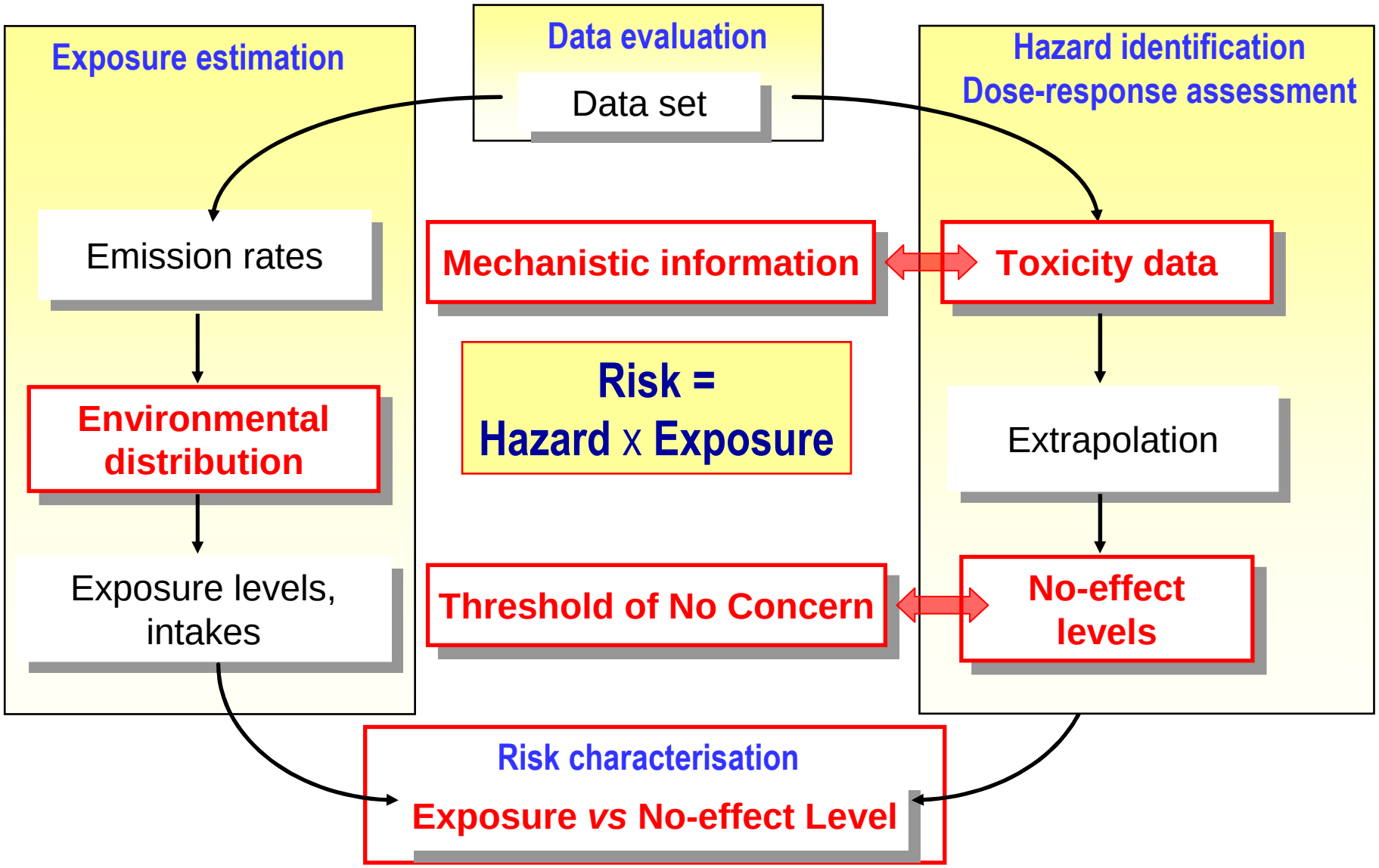
Integrated Testing Strategies (ITS)



Risk assessment process

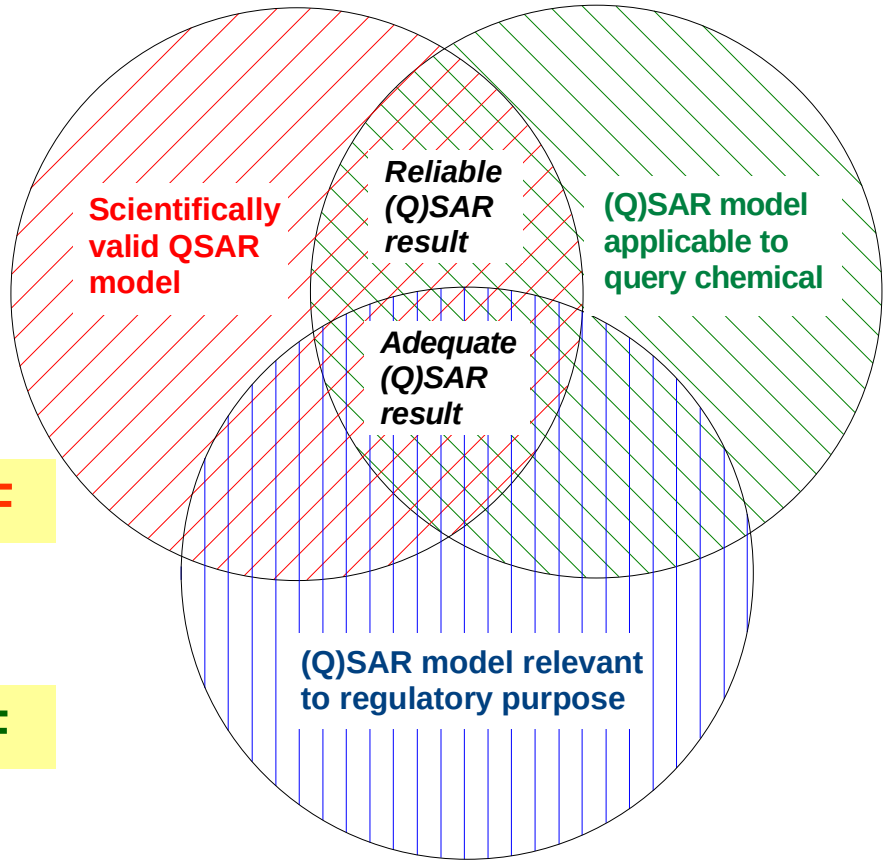


Role of computational methods



Adequacy of (Q)SAR prediction

In order for a (Q)SAR result to be adequate for a given regulatory purpose, the following conditions must be fulfilled:



- the estimate should be generated by a valid (reliable) model → **QMRF**
- the model should be applicable to the chemical of interest with the necessary level of reliability → **QPRF**
- the model endpoint should be relevant for the regulatory purpose → **QPRF**

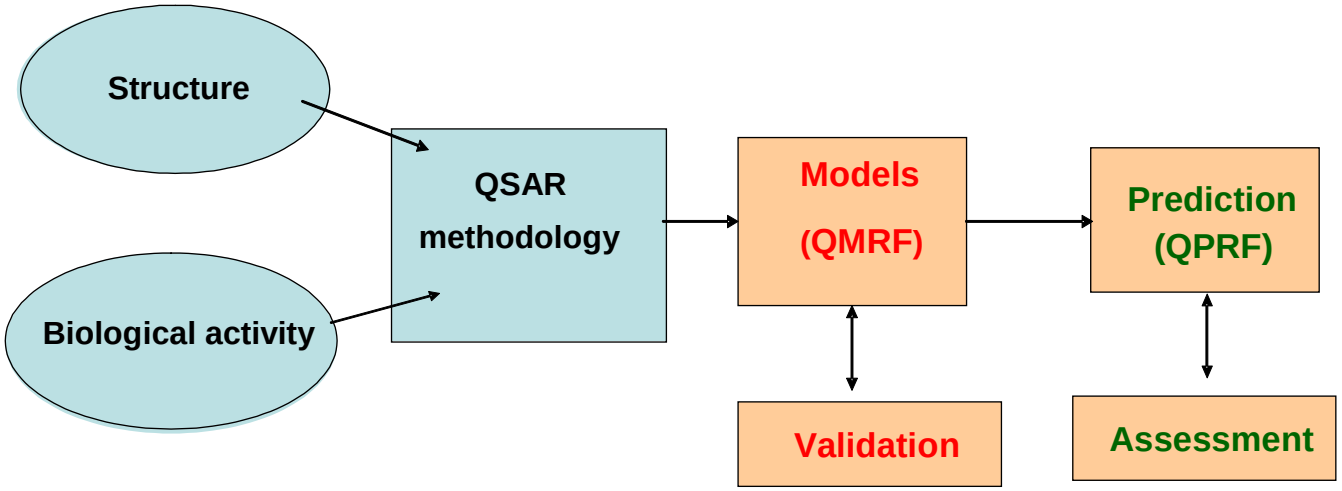
http://ecb.jrc.ec.europa.eu/qsar/qsar-tools/

Standardised (Q)SAR Reporting Formats

The need for "adequate and reliable" documentation is met by using standardised reporting formats:

A (Q)SAR Model Reporting Format (QMRF) is a robust summary of a (Q)SAR model, which reports key information on the model according to the OECD validation principles

A (Q)SAR Prediction Reporting Format (QPRF) is a description and assessment of the prediction made by given model for a given chemical



(Q)SAR Reporting Formats: QMRF

QMRF captures information on fulfilment of OECD validation principles, but no judgement or "validity statement" is included

A (Q)SAR should be associated with the following information:

1. a defined endpoint
2. an unambiguous algorithm
3. a defined applicability domain
4. appropriate measures of goodness-of-fit, robustness and predictivity
5. a mechanistic interpretation, if possible

- **Principles adopted by 37th Joint Meeting of Chemicals Committee and Working Party on Chemicals, Pesticides & Biotechnology; 17-19 Nov 2004**
- **ECB preliminary Guidance Document published in Nov 2005**
- **OECD Guidance Document published in Feb 2007**
- **OECD Guidance summarised in REACH guidance (IR and CSA)**

(Q)SAR Reporting Formats: QPRF

QPRF captures information on the substance and its prediction, and is intended to facilitate considerations of the adequacy of a prediction

1. Substance information
2. General (administrative) information on QPRF
3. Information on prediction (endpoint, algorithm, applicability domain, uncertainty, mechanism)
4. Adequacy (optional, legislation-specific, and includes judgement and indicates whether additional information is needed for WoE assessment)

- Assessment of adequacy depends on reliability and relevance of prediction, but also on the availability of other information, and the consequence of being wrong
- Not just a scientific consideration, but also a policy decision

Outline of a non-testing strategy

1. Existing information
2. Preliminary assessment of reactivity & fate
3. Classification schemes & structural alerts
4. Preliminary assessment of reactivity, fate & toxicity
5. Chemical grouping & read-across
6. QSARs

Working Matrix

	A	B	C
Chemical			
Metabolite 1			
Metabolite 2			

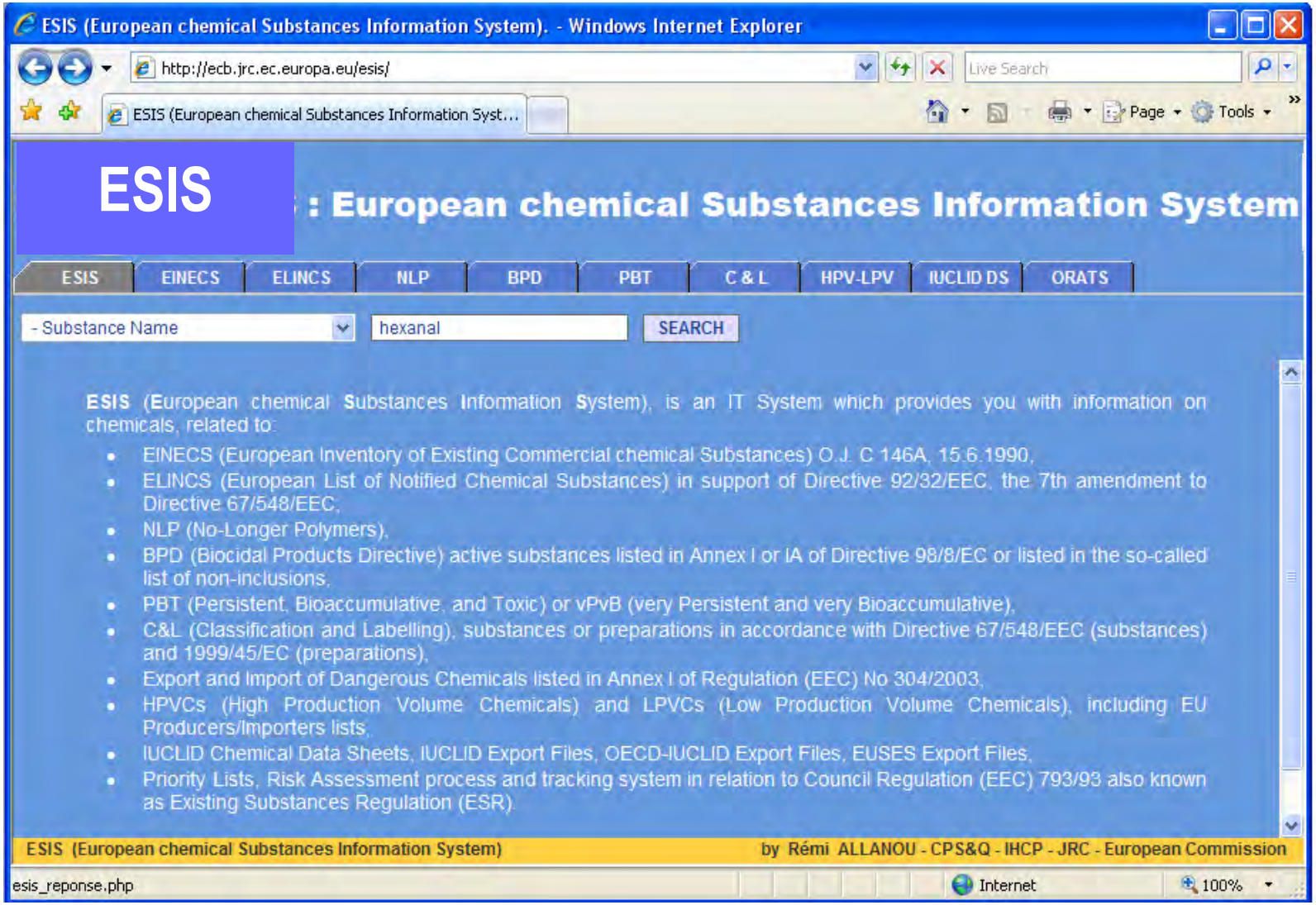
Assess adequacy

Conclusion or targeted testing

Step 1: Information collection

- Chemical composition (components, purity/impurity profile)
- Structure generation and verification
- Key chemical features (functional groups, protonation states, isomers)
- Experimental data: physicochemical properties, (eco)toxicity, fate
  - Freely-accessible web resources (ESIS, ChemSpider, PubChem, AMBIT2)
  - Databases in freely-available software tools (OECD Toolbox)
  - Commercial databases (Vitic, …)
- Estimated data: pre-generated QSAR or read-across estimates
  - Freely-accessible web resources (ChemSpider, Danish QSAR database)
  - Chemical category databases (OECD Toolbox)

European chemical Substances Information System



http://ecb.jrc.ec.europa.eu/esis/

ENDDA – Endocrine Active Chemicals Database

European Commission
Joint Research Centre
Institute for Health and Consumer Protection
European Commission JRC IHCP CPSQ ENDDA New Search

Home Search External Resources Qsar Models

Search

name:
cas:
smiles:

Search by Structure

File Edit View Insert Tools Help
H C N O F React Select Erase Paste Undo Redo Zoom
- + P S Cl More Br I

Type of Search: Substructure

Chemical Group
-all-
(organo) metals
Alkylbenzenes and styrenes
Alkylphenols and derivatives
Benzamidazoles
Biphenyls
Bisphenols
Carbamates
Chlorinated cyclodienes and camphenes
Chlorinated paraffins (CPs)
Chlorophenols and benzenes
Chlorophenoxy compounds
DDT, derivatives and metabolites
Dicarboximides
Diesel exhaust particle (DEP)
Dioxins
Furans
Musk Fragre

Moa
-all-
(+)e
(+)th
+e
+pi

mol. w. between
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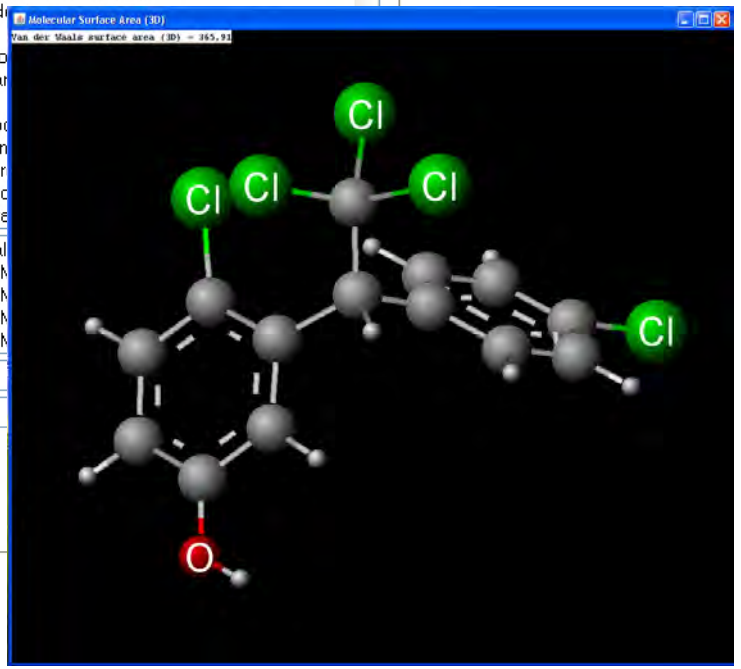
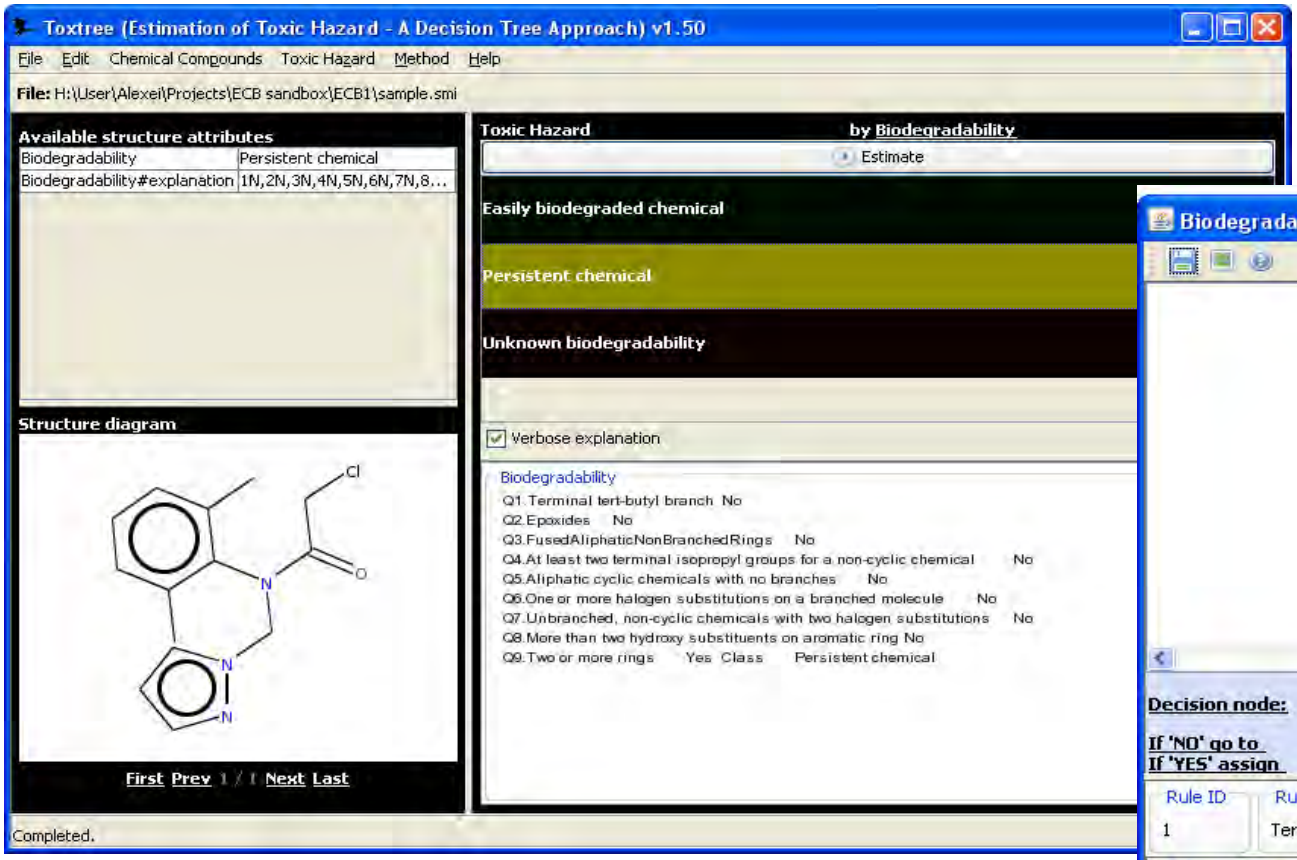


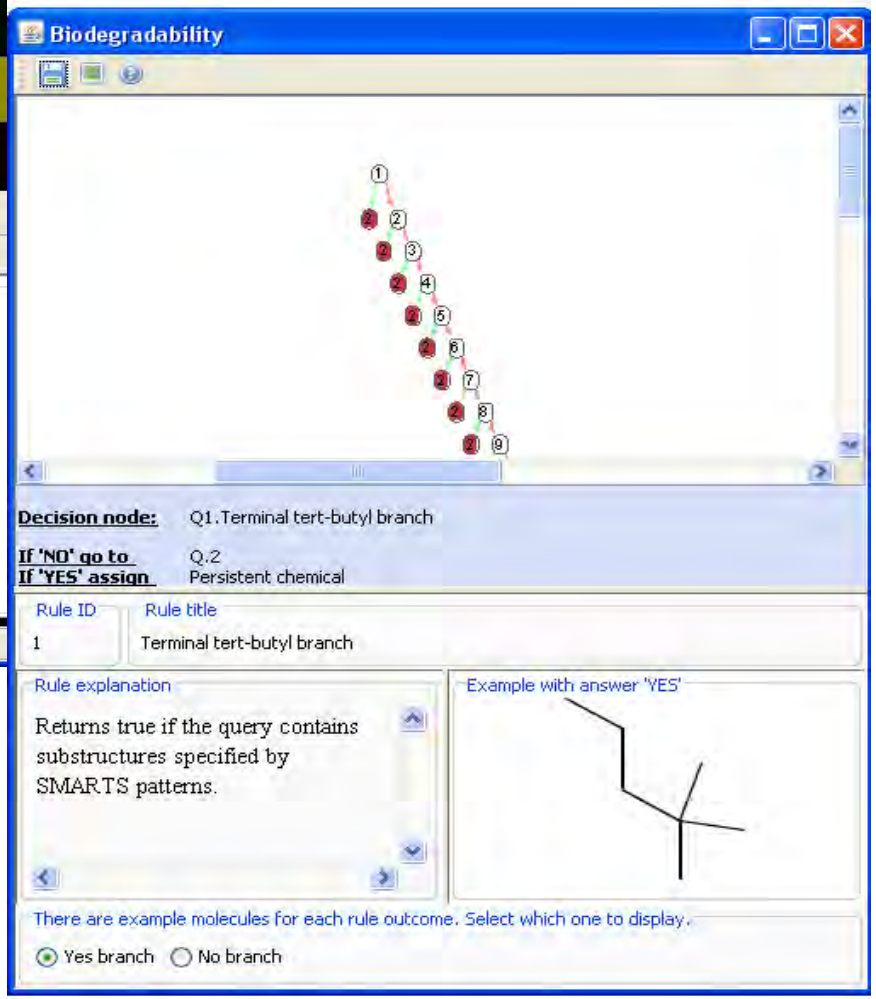
web-accessible database under development

Step 2: Preliminary assessment of reactivity & fate

- Prediction of abiotic / biotic reactivity to identify reactive potential and possible transformation products / metabolites
- Freely-available software
  - CRAFT (Chemical Reactivity & Fate Tool)
  - START (Structural Alerts in Toxtree)
  - OECD Toolbox
- Commercial software and databases
  - CATABOL, TIMES, Meteor, Mexalert, MetabolExpert …
  - MetaPath, SciFinder, MDL Reaction Database …
  - *InSilico*First (MetaboGen and CRAFT)

START - STructural Alerts for Reactivity in Toxtree

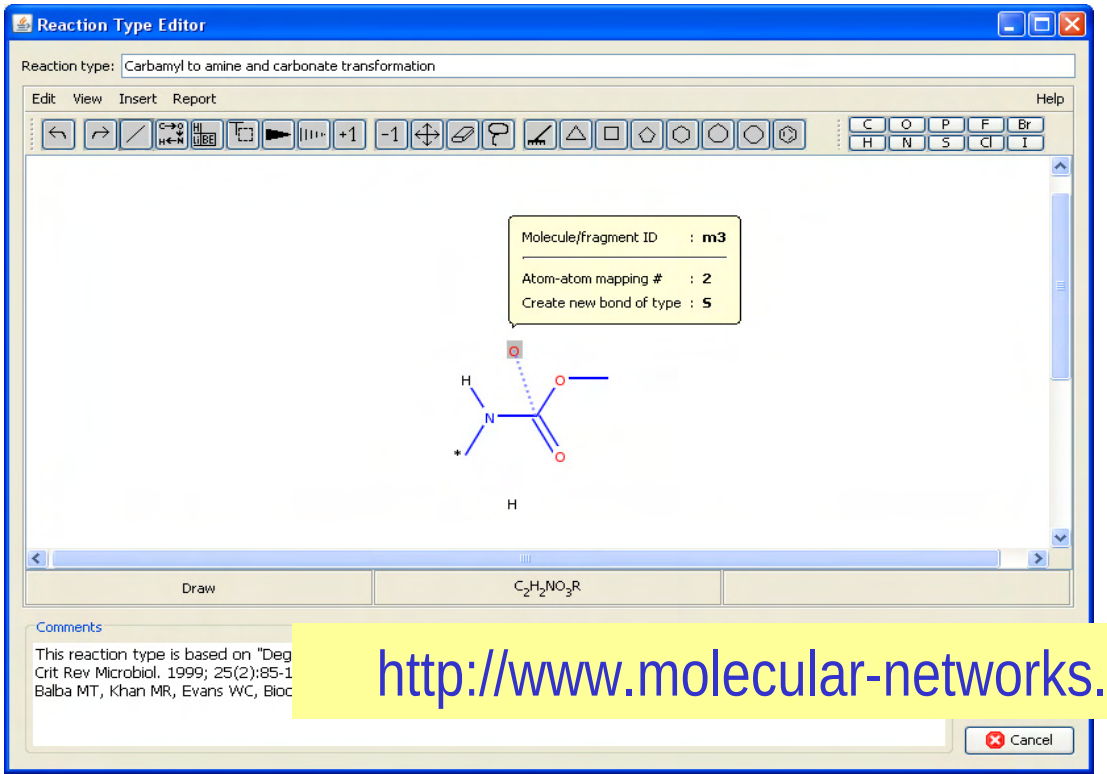


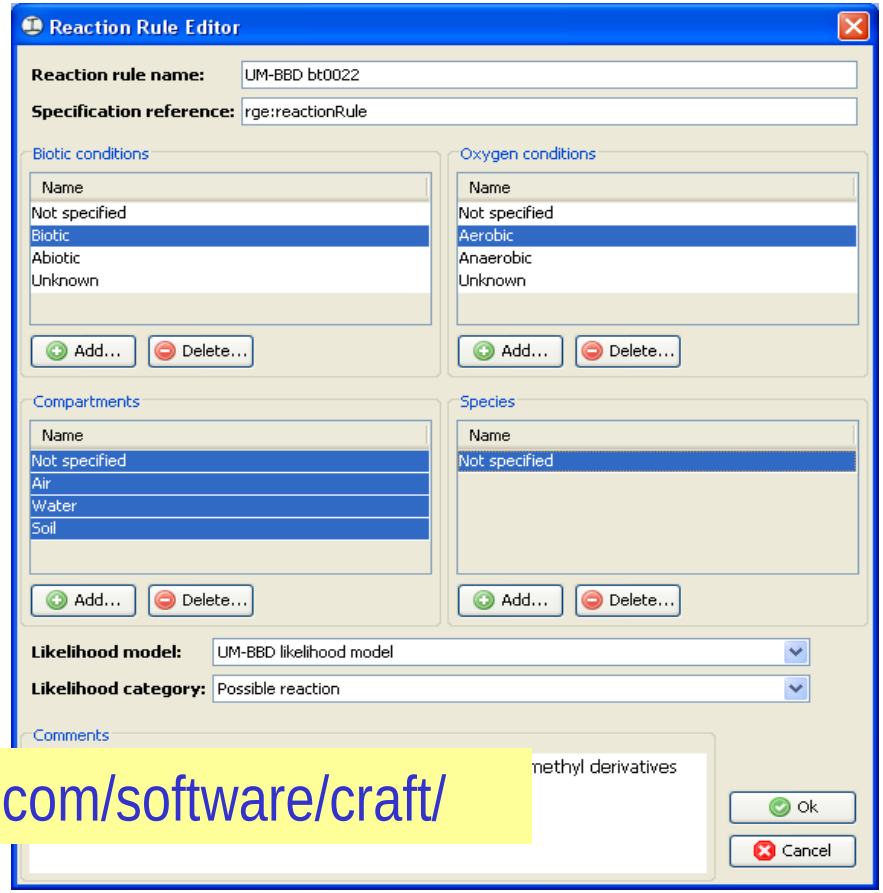


- Collaboration with Molecular Networks (Germany)
- Toxtree plug-in
- Estimates biodegradation potential

CRAFT - Chemical Reactivity And Fate Tool

- Collaboration with Molecular Networks (Germany)
- Generates & visualises reactions, ranks transformation products
- Initial emphasis on abiotic processes & microbial biodegradation
- Data model based on AMBIT technology
- User can modify knowledge base and rulebase





http://www.molecular-networks.com/software/craft/

Steps 3 & 6: SARs, QSARs and expert systems

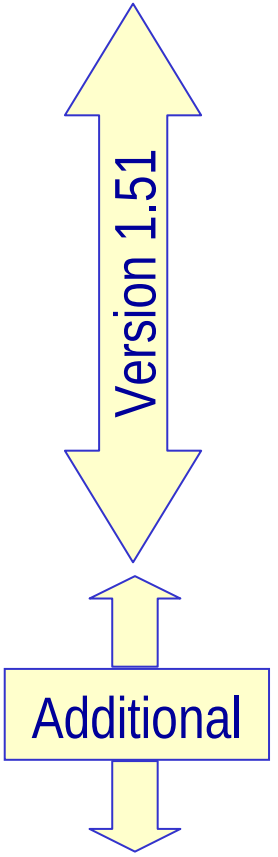
- Models and rulebases for mode-of-action classification, hazard identification, hazard classification and potency prediction
- Freely-available software
  - Episuite, Toxtree, AMBIT2, OECD Toolbox …
  - OpenTox framework (http://www.opentox.org)
- Commercial software
  - DEREK, MultiCASE, HazardExpert, ToxAlert, ToxBoxes …
  - *Insilico*first consortium (Multicase Inc, Lhasa Ltd, Molecular Networks GmbH, Leadscope Inc)
- QSAR Model Databases (QMDBs)
  - JRC QSAR Model Database
  - OECD Toolbox

Toxicity Estimation Tool: Toxtree

Toxtree is a flexible, user-friendly, open source application, which is able to estimate toxic hazard by applying decision tree approaches

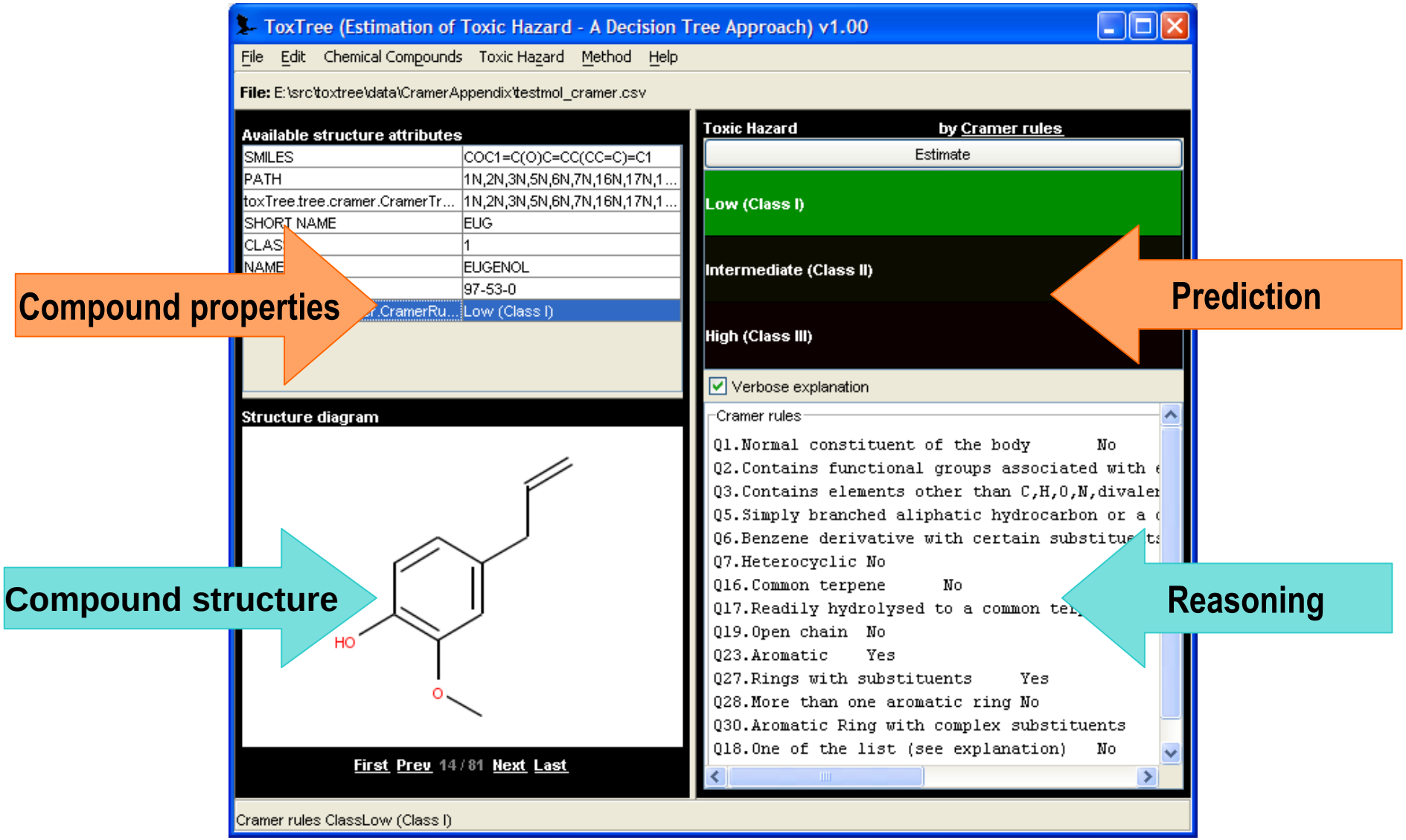
Rulebases available:

- Oral systemic toxicity (Cramer scheme)
- Acute Fish Toxicity (Verhaar scheme)
- Skin irritation & corrosion potential (BfR rulebase)
- Eye irritation & corrosion potential (BfR rulebase)
- Mutagenicity & carcinogenicity (Benigni-Bossa rulebase)
- Mutagenicity & carcinogenicity (*In Vivo* Micronucleus rulebase)
- Biodegradation potential (START rulebase)



http://ecb.jrc.ec.europa.eu/qsar/qsar-tools/

Main screen in Toxtree



Cramer rules in Toxtree

The Cramer classification scheme is probably the best known approach for structuring chemicals in order to estimate a Threshold of Toxicological Concern.

Chemicals are divided into three structural classes based on a decision tree. This comprises 33 structural rules and places evaluated compounds into one of three classes:

Class I substances are simple chemical structures with efficient modes of metabolism suggesting a low order of oral toxicity

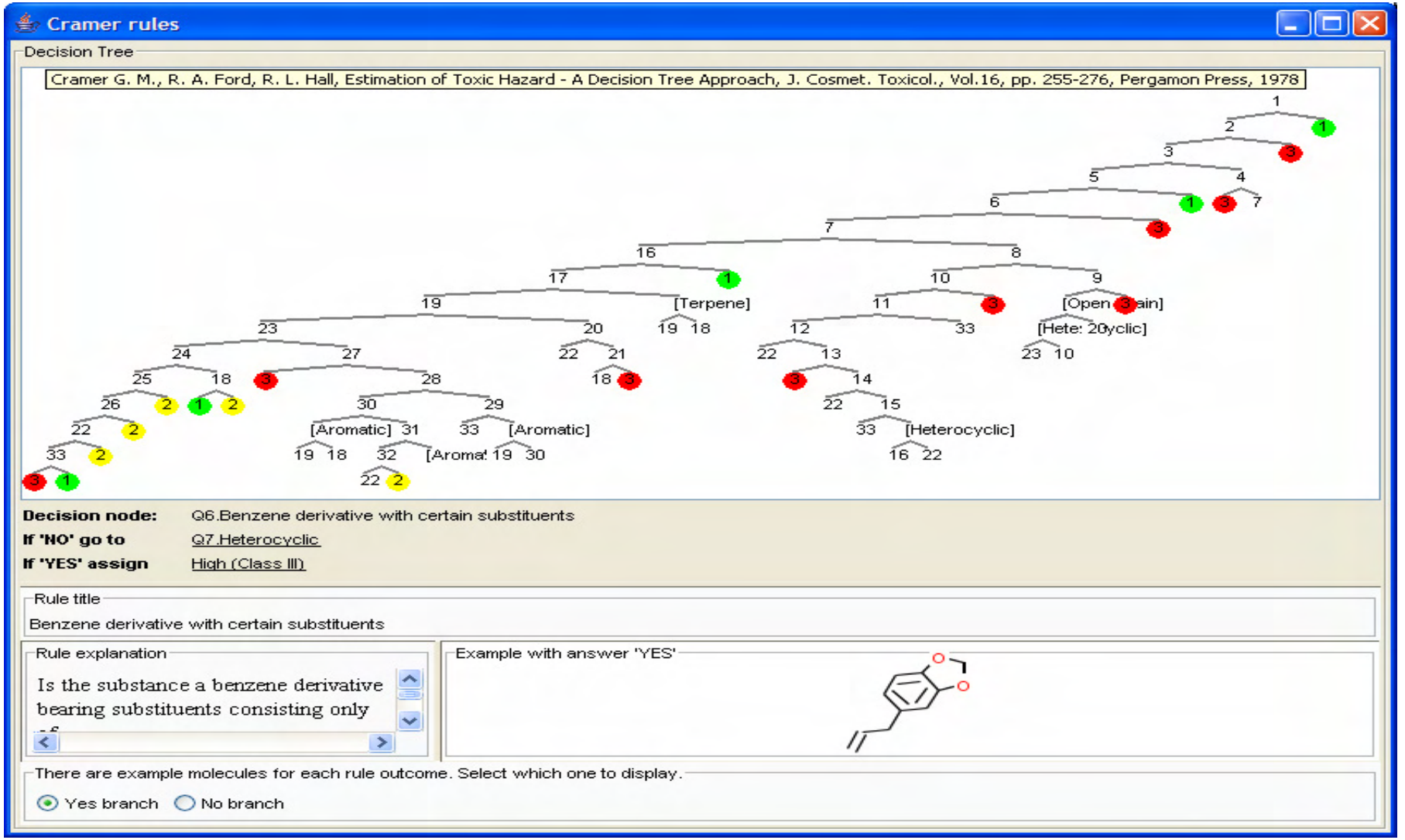
Class II are of intermediate toxicity

Class III substances are those that permit no strong initial presumption of safety, or may even suggest significant toxicity or have reactive functional groups

Cramer GM, Ford RA & Hall RL (1978). Estimation of Toxic Hazard - A Decision Tree Approach. *J. Cosmet. Toxicol.*, Vol.16, pp. 255-276, Pergamon Press.

Patlewicz G, Jeliazkova N, Safford RJ, Worth AP & Aleksiev B (2008). An evaluation of the implementation of the Cramer classification scheme in the Toxtree software. *SAR and QSAR in Environmental Research* 19, 495-524.

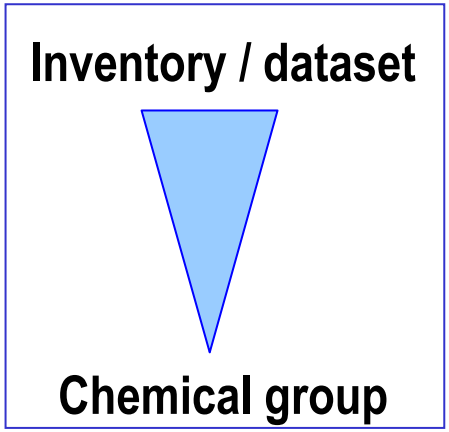
Cramer rules in Toxtree



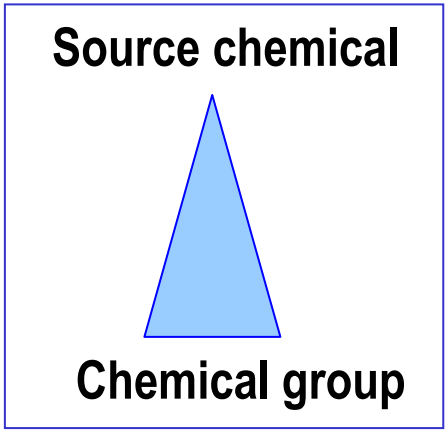
Chemical grouping and read-across

Chemical read-across within analogue and category approaches

- Chemical grouping by a top-down approach
  - Supervised and unsupervised statistical methods
  - Ranking methods (DART)

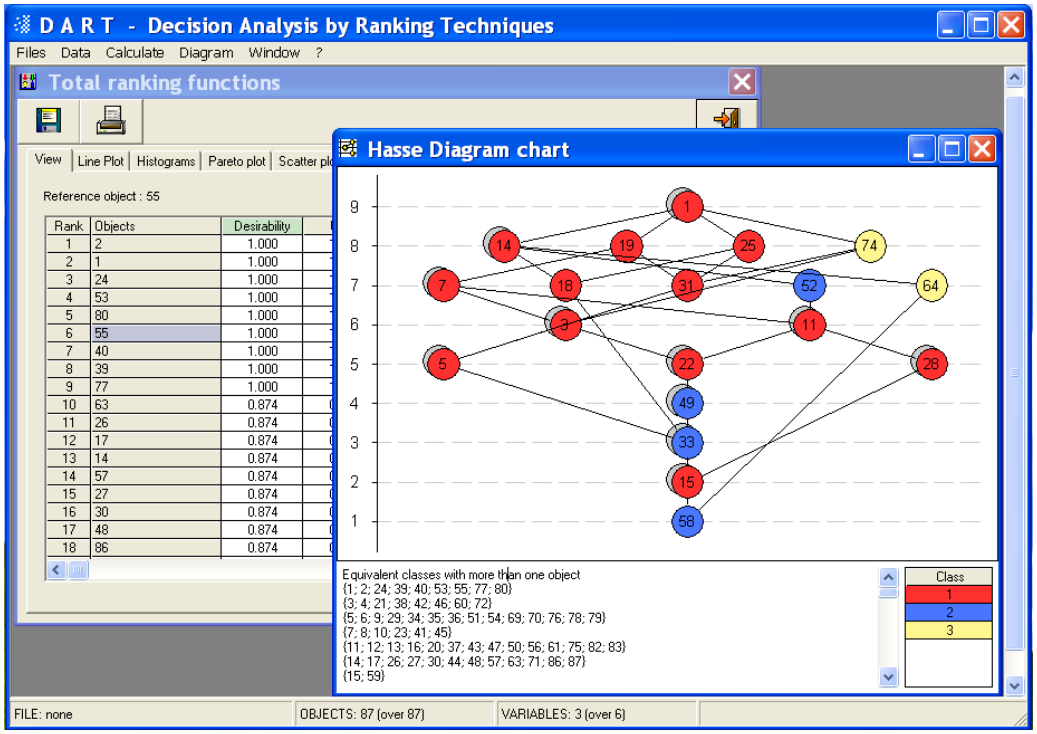


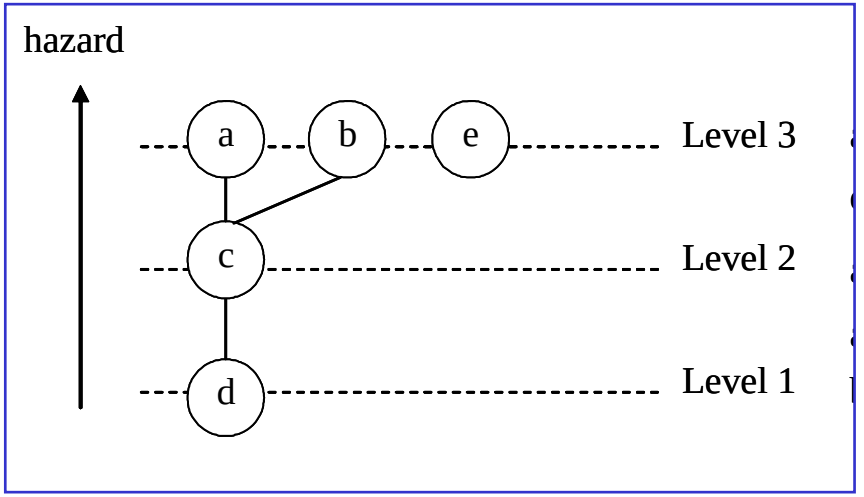
- Chemical grouping by a bottom-up approach
  - Freely available tools with analogue-searching capability (Toxmatch, AMBIT2, AIM, PubChem, OECD Toolbox)



Worth A et al (2007). The Use of Computational Methods in the Grouping and Assessment of Chemicals - Preliminary Investigations. EUR 22941 EN

DART (Decision Analysis by Ranking Techniques) is a flexible, user-friendly, open source application, which is able to rank and group chemicals according to properties of concern





- collaboration with Talete srl (Italy)
- supports priority setting of chemicals

Pavan M & Worth AP (2008). A set of case studies to illustrate the applicability of DART (Decision Analysis by Ranking Techniques) in the ranking of chemicals. EUR 23481 EN.

Ranking methods in DART

- desirability functions
- utility functions
- dominance functions
- concordance functions
- Pareto plots

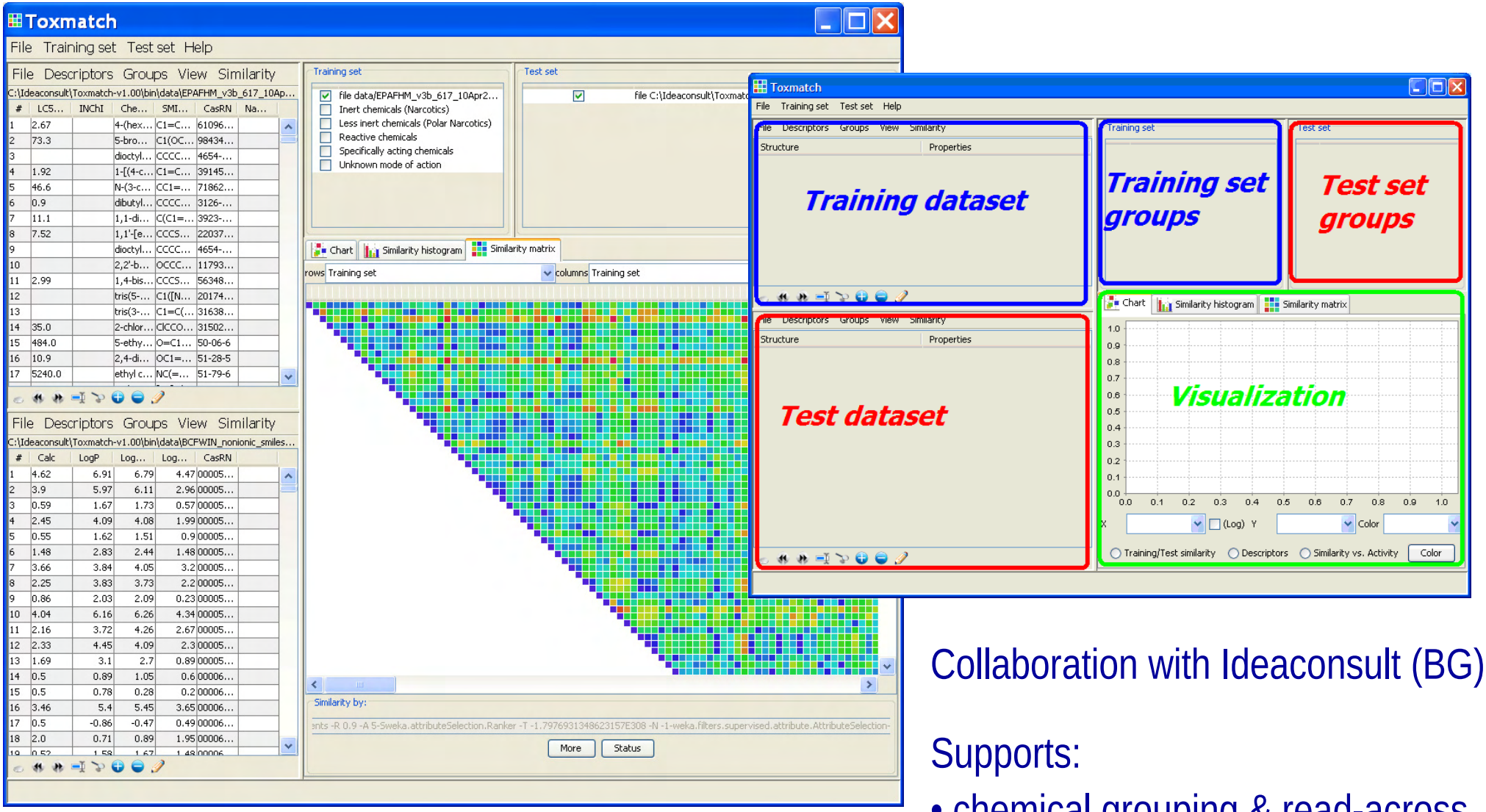
→ total ranking

- Hasse diagrams → partial ranking

Pavan M & Todeschini R (2008). Optimization: Multi-criteria Decision Making methods, in *Comprehensive Chemometrics*. B Walczak, RT Ferré & S Brown (Eds), in press. Elsevier.

Pavan M & Todeschini R, Eds (2008). Scientific Data Ranking Methods: Theory and Applications. 1st Edition. Elsevier, pp. 51-72.

Toxmatch: chemical similarity tool



Collaboration with Ideaconsult (BG)

Supports:

- chemical grouping & read-across
- comparison of training & test sets

http://ecb.jrc.ec.europa.eu/qsar/qsar-tools/

Similarity indices in Toxmatch

Toxmatch includes descriptor-based (distance-like) and fragment-based (correlation-like) similarity indices

- Euclidean distance
- Cosine similarity
- Hodgkin-Richards index
- Tanimoto distance on descriptors
- Tanimoto distance on fingerprints
- Hellinger distance on atom environments
- Maximum Common Structure similarity

$$D_{AB}(k,x) = [Z_{AA} + Z_{BB} - 2Z_{AB}]^{1/2}$$

$$C_{AB} = Z_{AB}[Z_{AA}Z_{BB}]^{-1/2}$$

$$H_{AB} = 2Z_{AB}[Z_{AA} + Z_{BB}]^{-1}$$

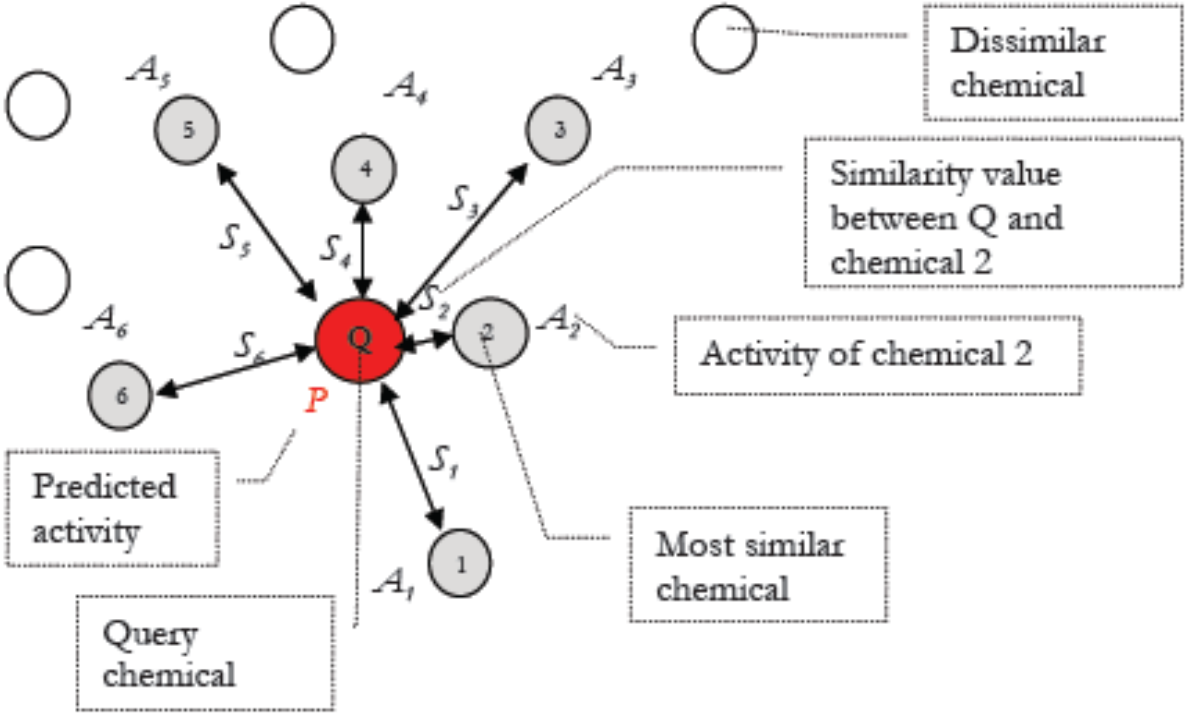
$$T_{AB} = 2Z_{AB}[Z_{AA} + Z_{BB} - Z_{AB}]^{-1}$$

$$T_{AB} = \frac{N_{AB}}{N_A + N_B - N_{AB}}$$

Gallegos Saliner A & Worth AP (2007). Development and Beta Testing of the Toxmatch Similarity Tool. JRC report EUR 22854 EN.

Read-across in Toxmatch

Many-to-one read-across of a quantitative property (*k* Nearest Neighbours)

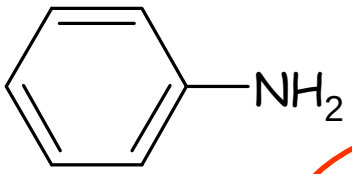


Patlewicz G, Jeliazkova N, Gallegos Saliner A & Worth AP (2008). Toxmatch – A new software tool to aid in the development and evaluation of chemically similar groups. *SAR and QSAR in Environmental Research* 19, 397-412.

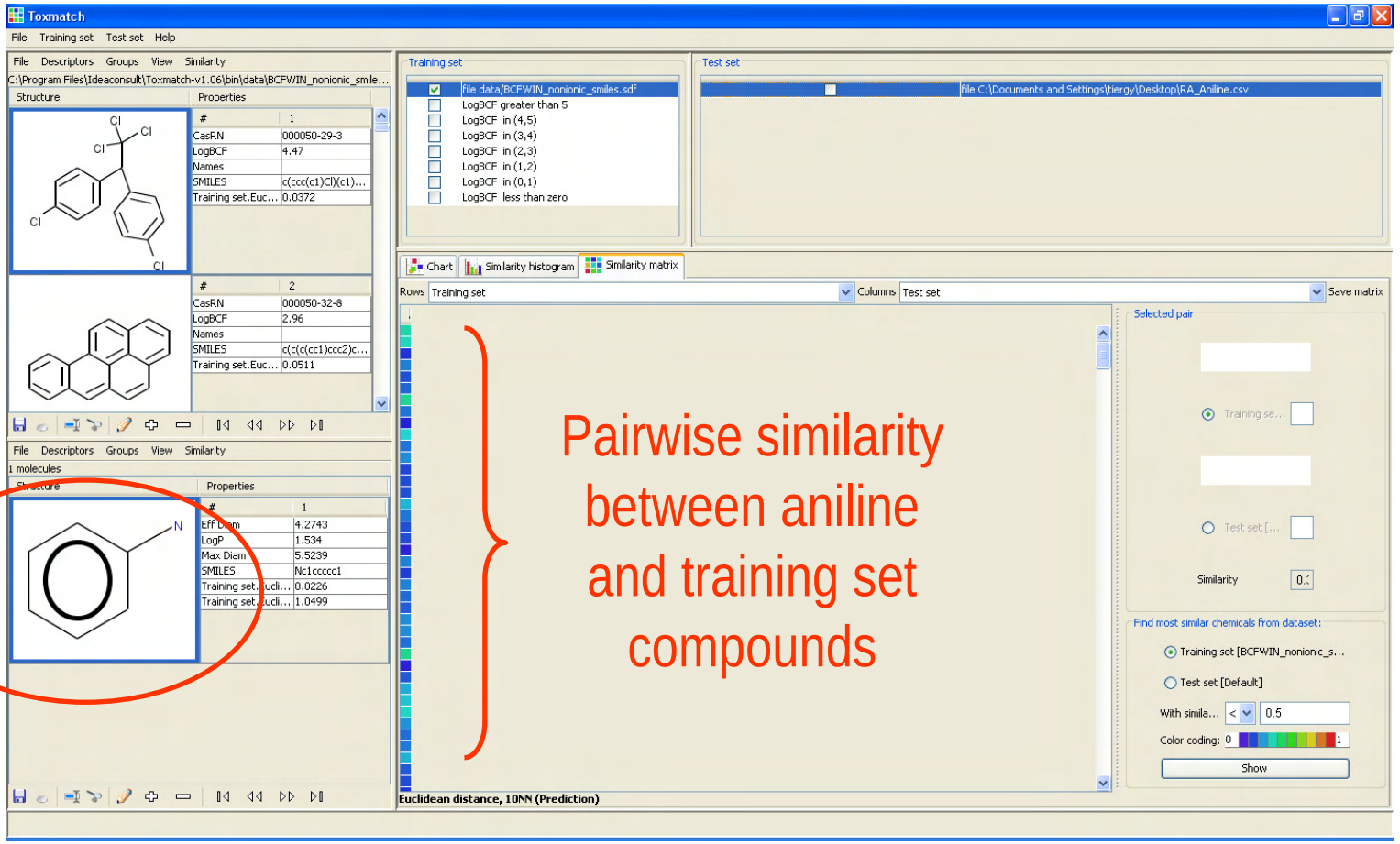
Example of read-across in Toxmatch

- BCF of aniline predicted on basis of effective diameter, maximum diameter and LogP
- Predicted LogBCF = 1.05
- Experimental LogBCF = 0.78 (Hazardous Substances Databank)

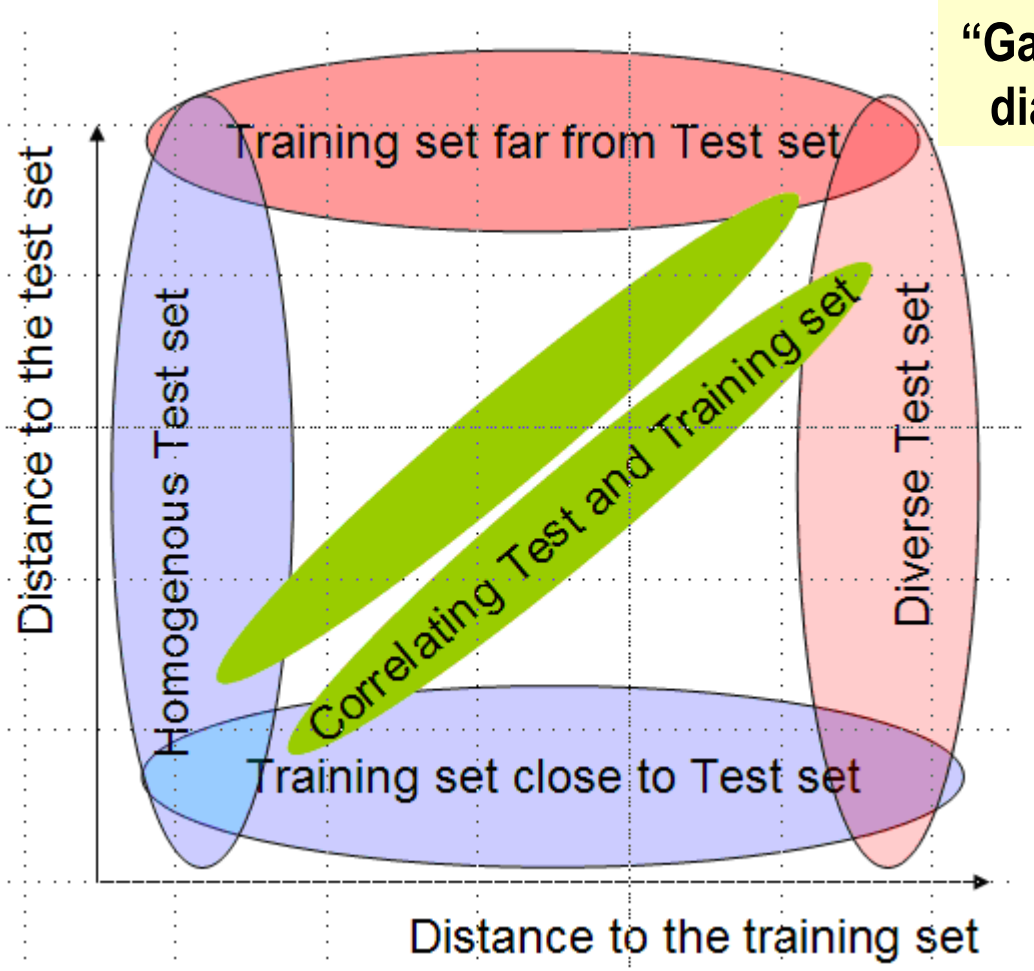
Training set of 610 chemicals



Aniline - test chemical

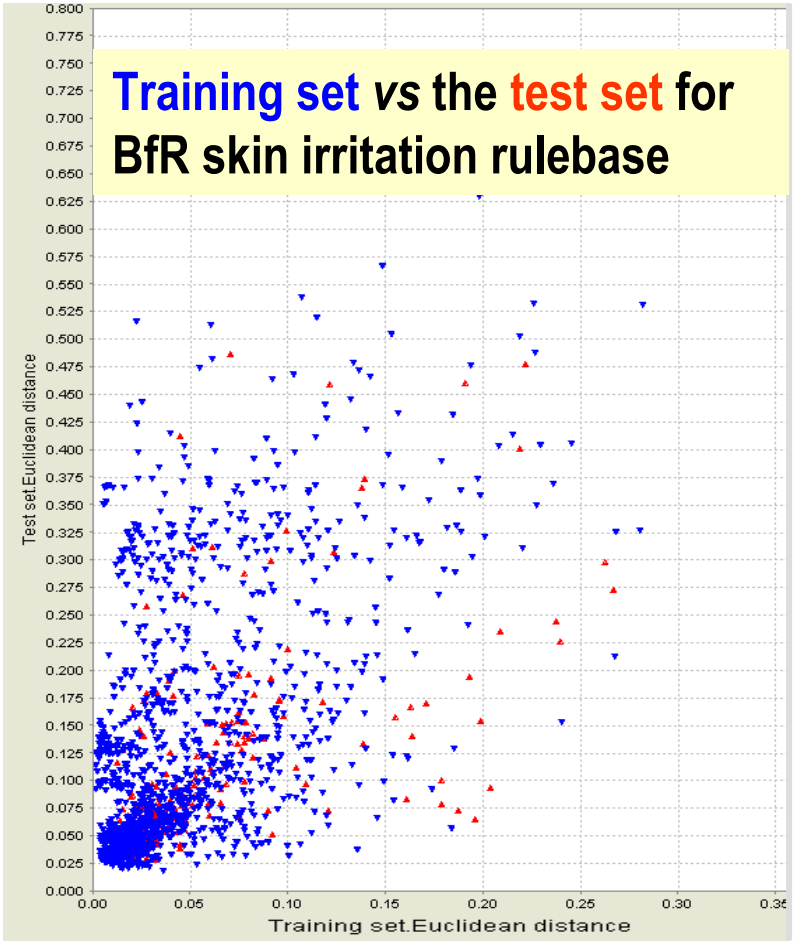


Comparison of datasets in Toxmatch



"Gallegos" diagram

Training set *vs* the test set for BfR skin irritation rulebase



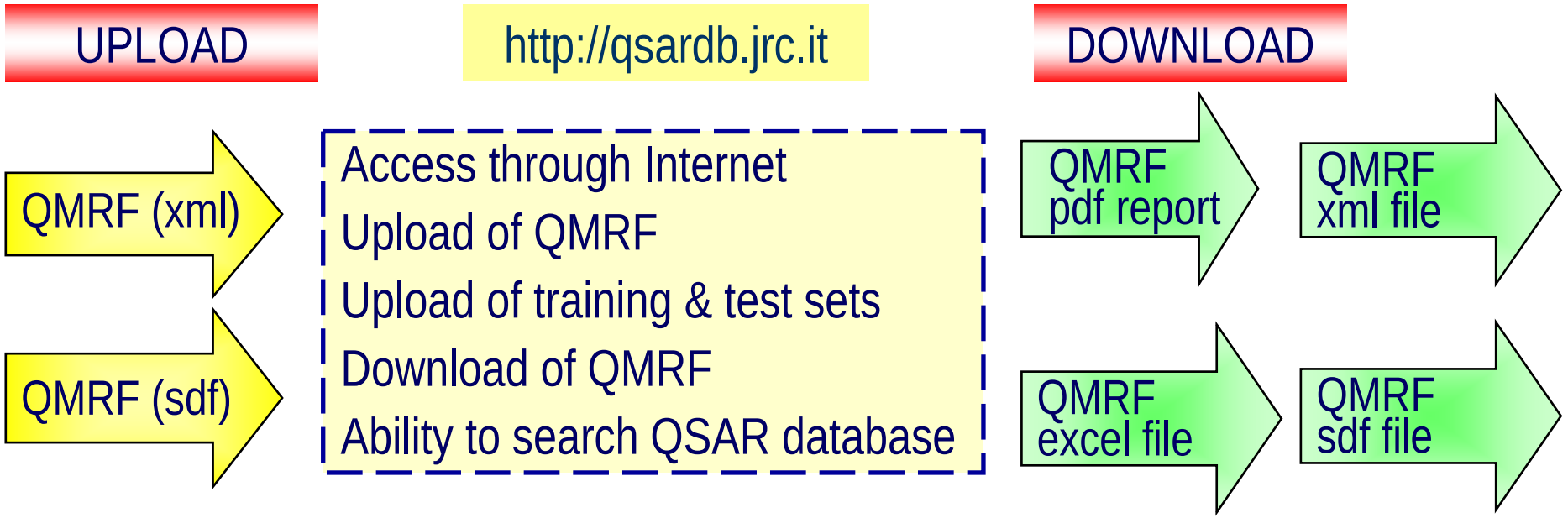
Gallegos Saliner A, Poater A, Jeliazkova N, Patlewicz G & Worth AP (2008). Toxmatch - A Chemical Classification and Activity Prediction Tool based on Similarity Measures. Regulatory Toxicology and Pharmacology 52, 77-84.

Step 6: JRC QSAR Model Database

Need to identify and use relevant, reliable and well documented (Q)SARs

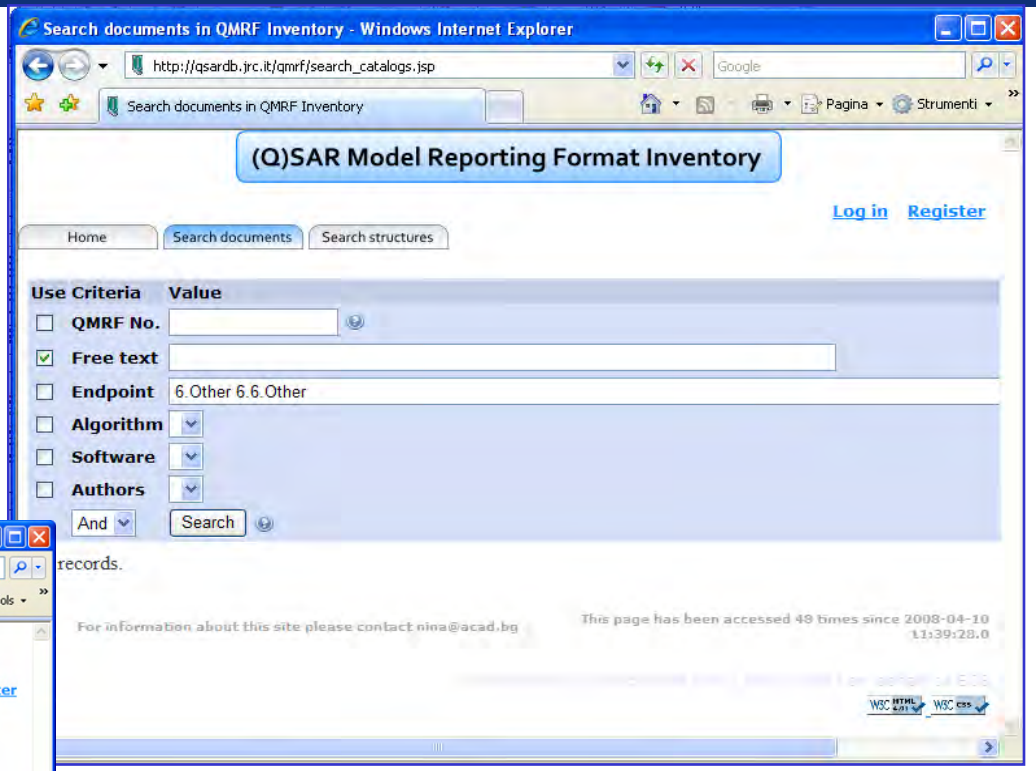
The JRC QSAR Model Database is a searchable inventory of peer-reviewed information on (Q)SAR models

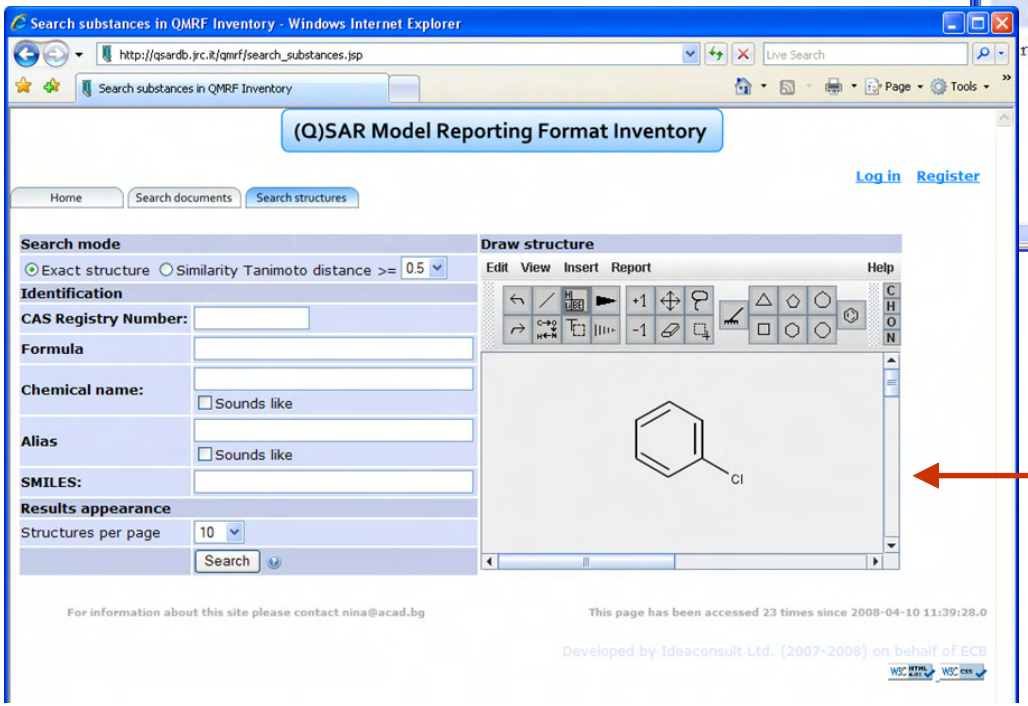
Developers and users of (Q)SAR models can submit information on (Q)SARs by using the (Q)SAR Model Reporting Format (QMRF)



Searching the QSAR database

- QMRF No.
- Free text
- Endpoint
- Algorithm
- Software
- Authors





- CAS No.
- Formula
- Chemical name
- Alias
- SMILES

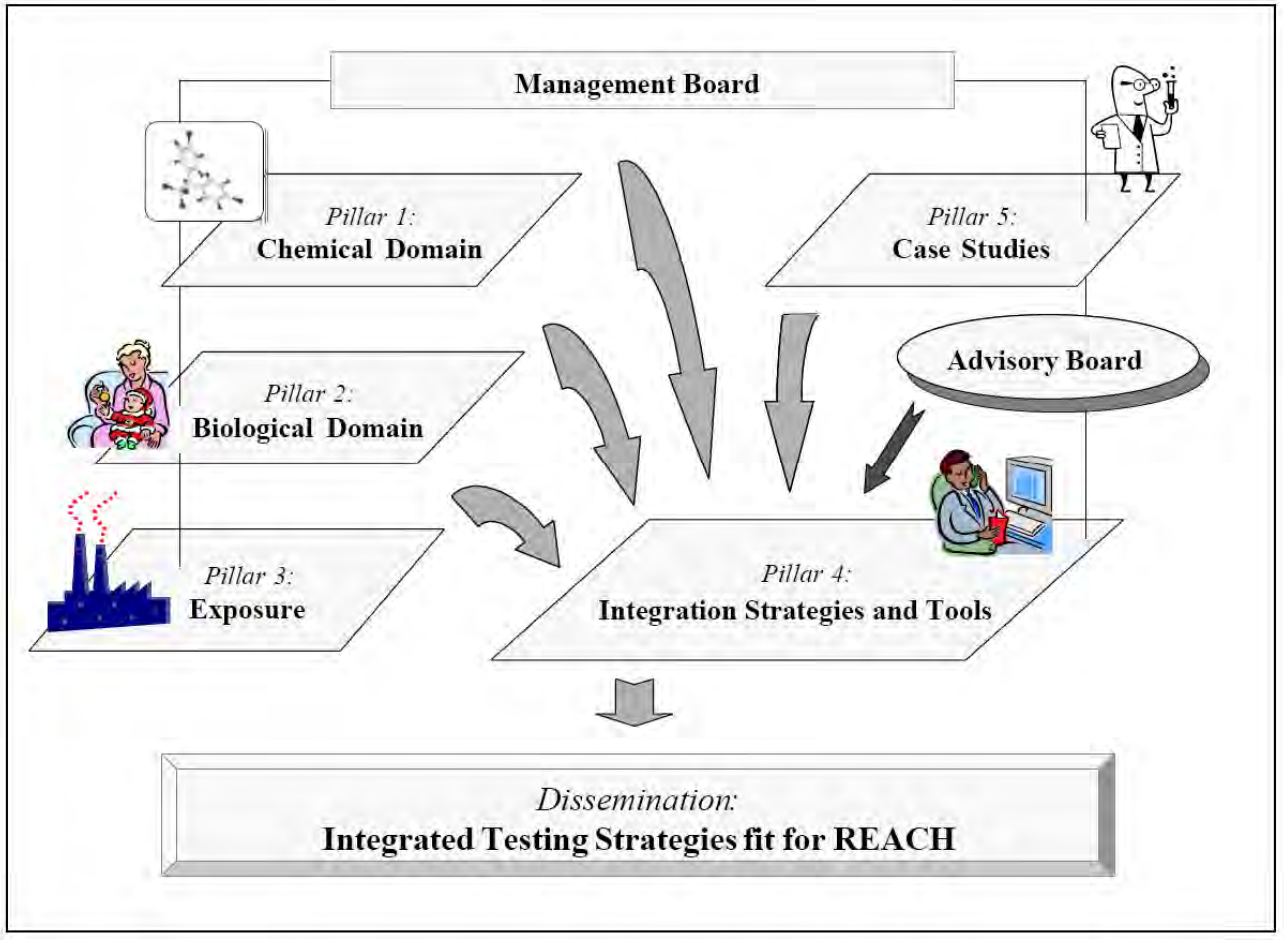
http://qsardb.jrc.it

JRC-EFSA project on pesticide modelling

- Need to assess the toxicological significance of pesticide active metabolites and degradation products (not tested under *Directive 91/414/EEC*)
- Three projects funded by EFSA (2009-2010)
  - Applicability of QSAR analysis in assessing metabolite toxicity
  - Applicability of the TTC concept in assessing metabolite toxicity
  - Impact of metabolism on toxicological properties
- Next steps by EFSA
  - Opinion of the PPR panel (2010-2011)
  - Guidance document on pesticide residue definition for dietary risk assessment (2011-2012)

OSIRIS – an EU Project on Integrated Testing

Optimized Strategies for Risk Assessment of Industrial Chemicals through Integration of Non-Test and Test Information (OSIRIS)



http://www.osiris-reach.eu/

Concluding remarks

- To optimise the use of non-testing data, a conceptual framework is provided in the REACH guidance documentation
- An increasing number of models are being implemented in a range of software tools
- There is a need to incorporate mechanistic knowledge in the models (e.g. based on chemical reactivity and “omic” data)
- There is a need to facilitate the use of multiple tools by developing automated workflows
- Further guidance is needed on how to assess the adequacy of non-testing and alternative test data by weight-of-evidence approaches