Protection of the environment

Why and how ?

Protection of the environment

Why ?

Relevant background issues

- A global appreciation of the limits of, and the damage to, natural resources
- Concern loss of species and natural habitats

- Increase in international and regional wildlife and ecosystem protection legislation (EC Directives)

Environmental 'regulatory' issues at international level

- Need to comply with national or regional 'environmental' and 'wildlife' protection legislation – species and habitats, surface waters, marine environment
- Differences in such legislation within and amongst geographic areas – ethical and moral issues for international companies

- Integrated approaches to pollution control
- Advances in non-radioactive chemical emission's control

Marine Strategy Framework Directive

objectives … protection and preservation of the marine environment

- the achievement of the Convention on Biological Diversity …
- marine and coastal biodiversity ….. halting the loss of biological diversity nationally …
- marine ecosystems to support the provision of goods and services
- ecologically representative systems of marine protected areas by 2012
- designate Natura 2000 sites under the Birds Directive and Habitats Directives

Marine Strategy Framework Directive

- prevent and reduce inputs into the marine environment, with a view to phasing out pollution …
- … as to ensure that there are no significant impacts on, or risks to, marine biodiversity, marine ecosystems, human health or legitimate uses of the sea ….
- Pressures and impacts
  - contamination by hazardous substances
  - introduction of radionuclides.

Implications specifically within Europe ….

- Changes in ‘conservation status’ of areas around existing nuclear sites
- Environmental Impact Assessments etc needed for new or proposed future sites
- Need for consistency in regulatory approaches amongst all large industries

A global dialogue

- 1996 Stockholm Conf.
- 1999 IAEA Consultation Report & Ottawa Conf.
- 2001 Oslo IUR Consensus Conf.
- 2002 NEA Seminar, Taormina
- 2002 IAEA Report
- 2002 IAEA Darwin Conf.
- 2002 CEC Meeting, Luxembourg
- 2003 IAEA Stockholm Conf.
- 2000 FASSET Prog.
- 2004 ERICA Prog.

ICRP

- 2000 TG (to MC) established
- 2003 ICRP *91*
- 2005 Cttee 5 established
- 2007 ICRP *103*
- 2008 ICRP *108*
- 2009 ICRP *114*
- 2012/13

  TG 82/C5 rpt, public consultation

  RBE,

  improved terrestrial dosimetry

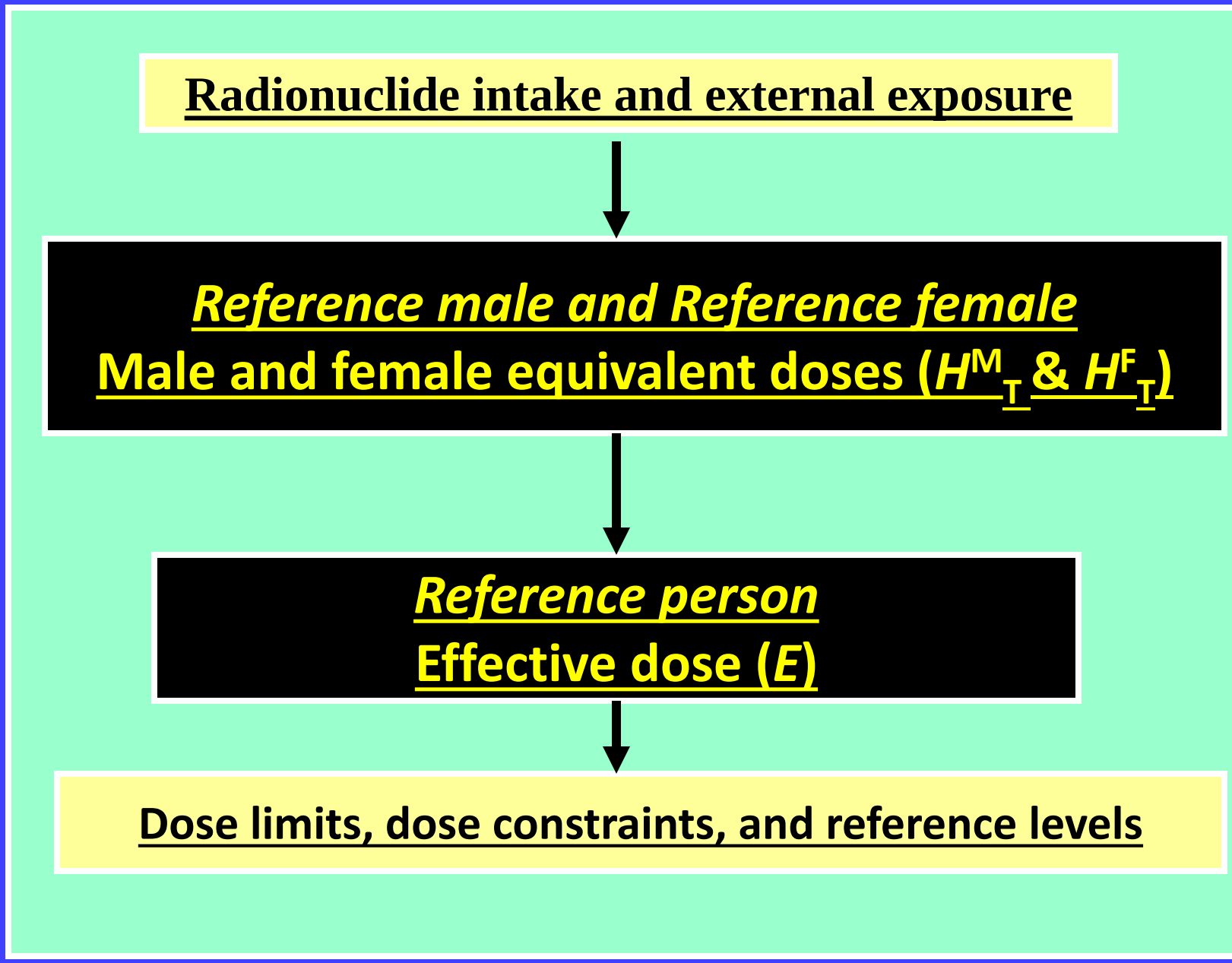
Protection of the environment

How ?

Human health

ICRP aims to protect individuals by:

- Preventing deterministic effects (seen in individuals, and for which there is a threshold for the effect) and
- Reducing the risks of stochastic effects to the extent reasonably achievable (LNT model)
- Based on a knowledge of relationships between exposure, dose, and effect or (by studies on populations) risk of effect


Radionuclide intake and external exposure
Reference male and Reference female
Male and female equivalent doses (H^{M}_{T} & H^{F}_{T})
Reference person
Effective dose (E)
Dose limits, dose constraints, and reference levels

Environmental protection

- ICRP 91 (2003) - discussed the problem, ethics, scope etc, and ways of approaching the subject

- ICRP 103 (2007) - general statements and commitment to RAP approach

Environmental protection

- ICRP 91 (2003) - discussed the problem, ethics, scope etc, and ways of approaching the subject
- ICRP 103 (2007) - general statements and commitment to RAP approach
- ICRP 108 (2008) - introduced RAPs, very basic dose models, dose effects, DCFs, and DCRLs as a starting point

ICRP 103 (2007)
Environmental protection objectives

To prevent or reduce the frequency of deleterious radiation effects to a level where they would have a negligible impact on:

- the maintenance of biological diversity,
- the conservation of species, or
- the health and status of natural habitats, communities, and ecosystems.

So, needed to examine the science base with regard to the relationships between……

- …….exposures and dose,
- …….doses and effects, and
- …….effects and consequences

  for different types of animals and plants that are typical of the major environments.
- Decided it was necessary to establish some ‘points of reference’ ……

- TO PRODUCE A SCIENTIFICALLY AUDITABLE TRAIL
- TO BE ‘COMPATIBLE’ WITH (OR AT LEAST RECOGNISABLE IN RELATION TO!) THE SYSTEM FOR THE PROTECTION OF THE HUMAN ANIMAL

Reference Animals and Plants (ICRP 108) 2008

- Points of reference
- To provide conceptual and numerical 'models'
- To examine aspects of dosimetry at different stages in the life cycle of different types of biota
- To relate dosimetry to radiation effects, risks, and consequences for different types of biota during their life cycles

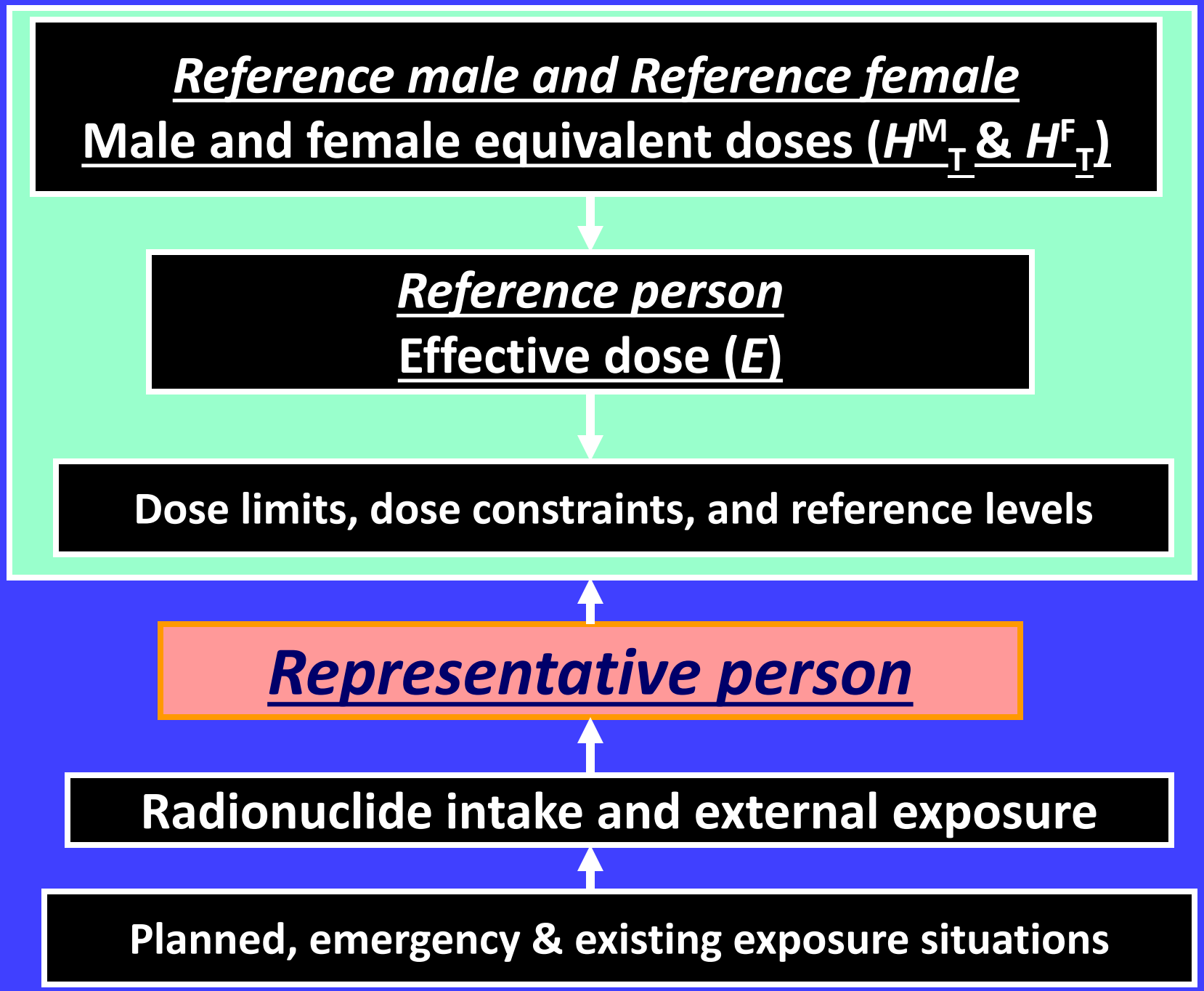
- Some data sets already available
- Be amenable to further controlled experimentation to bridge the inevitable data gaps
- But they are not, necessarily, the objects of protection

Reference Animals and Plants (RAPs)

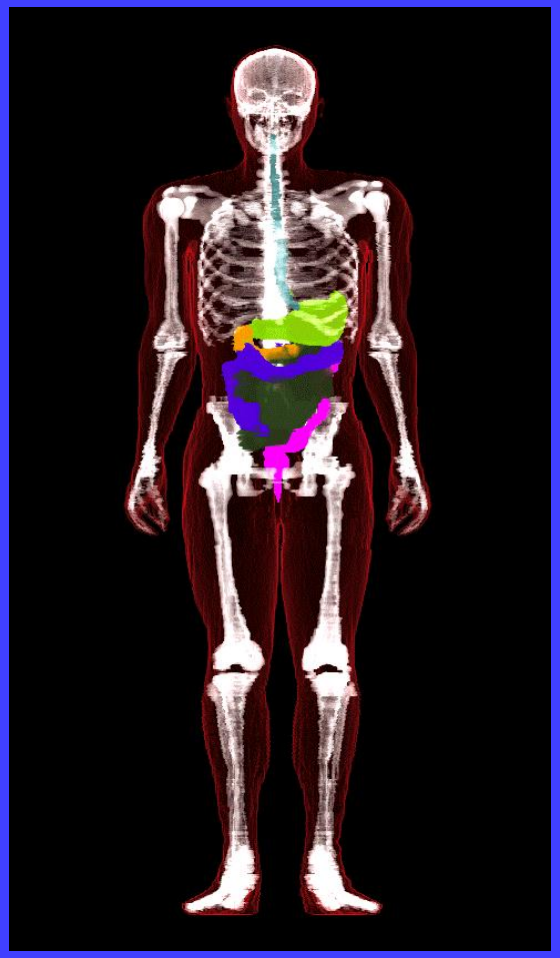
- Deer
- Rat
- Bee
- Worm (and egg)
- Pine tree
- Grass

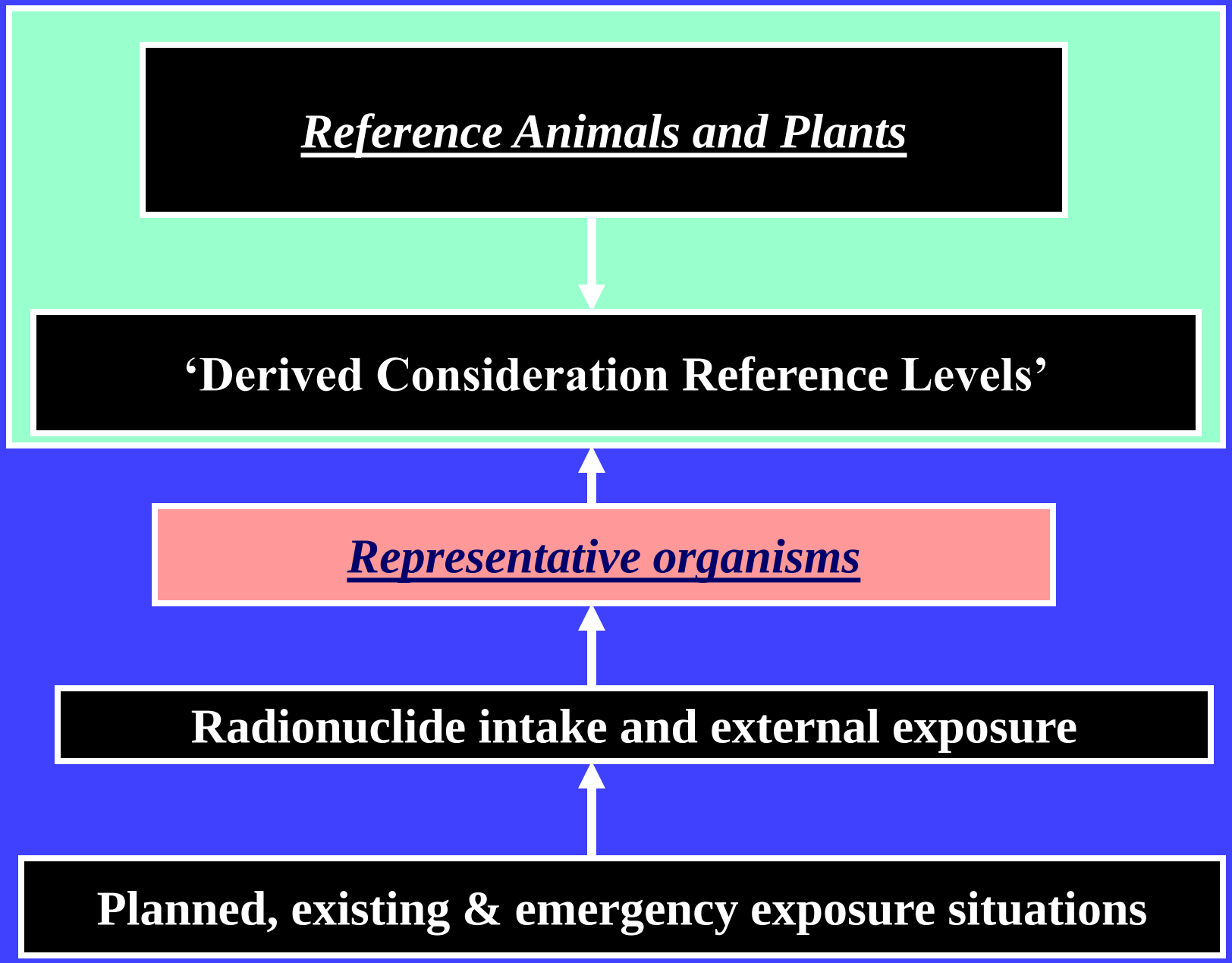
- Duck (and egg)
- Frog (egg, tadpole, adult)
- Trout (and egg)

- Flat fish (and egg)
- Crab (and egg and larvae)
- Brown seaweed


Reference male and Reference female
Male and female equivalent doses (H^{M}_{T} & H^{F}_{T})
Reference person
Effective dose (*E*)
Dose limits, dose constraints, and reference levels
Representative person
Radionuclide intake and external exposure
Planned, emergency & existing exposure situations

Voxel (hermaphrodite) phantoms
(based on medical tomographic images)




Reference Animals and Plants
'Derived Consideration Reference Levels'
Representative organisms
Radionuclide intake and external exposure
Planned, existing & emergency exposure situations

What are we actually trying to protect; and hence what 'representative organisms' are relevant –

under different situations of exposure ?

Actual object(s) of protection could be:

- **Environment in general**
- **Specific habitats (eg fresh water, estuary, wetland)**
- **Specific types of biota**
- **Specific species**

Environmental protection: science base

- Effects data – almost all at high dose rates
- Principal effects are mortality, morbidity, reduced reproductive success (fertility or fecundity), chromosomal damage, observed in individuals
- No LNT models, or DDRFs
- In fact, no underlying theories or models of radiation effects on biota in general - so difficult to extrapolate or interpolate amongst different types of organisms

Dose –effect data

Dose rate (mGy d^{-1})	Reference Deer	Reference Flatfish
100 - 1000	Reduction in lifespan due to various causes.	Some mortality expected in larvae and hatchlings
10 - 100	Increased morbidity. Possible reduced lifespan. Reduced reproductive success.	Reduced reproductive success
1 - 10	Potential for reduced reproductive success	Possible reduced reproductive success due to reduced fertility
0.1 - 1	Very low probability of various effects	No information
0.01 – 0.1	No observed effects.	No information
< 0.01	Natural background	Natural background

Planned exposures

Dose rate (mGy d^{-1})	Reference Deer	Reference Flatfish
100 - 1000	Reduction in lifespan due to various causes.	Some mortality expected in larvae and hatchlings
10 - 100	Increased morbidity. Possible reduced lifespan. Reduced reproductive success.	Reduced reproductive success
1 - 10	Potential for reduced reproductive success	Possible reduced reproductive success due to reduced fertility
0.1 - 1	Very low probability of various effects	No information
0.01 – 0.1	No observed effects.	No information
< 0.01	Natural background	Natural background

Existing exposures

Dose rate (mGy d^{-1})	Reference Deer	Reference Flatfish
100 - 1000	Reduction in lifespan due to various causes.	Some mortality expected in larvae and hatchlings
10 - 100	Increased morbidity. Possible reduced lifespan. Reduced reproductive success.	Reduced reproductive success
1 - 10	Potential for reduced reproductive success	Possible reduced reproductive success due to reduced fertility
0.1 - 1	Very low probability of various effects	No information
0.01 – 0.1	No observed effects.	No information
< 0.01	Natural background	Natural background

Accidents and emergencies

Dose rate (mGy d^{-1})	Reference Deer	Reference Flatfish
100 - 1000	Reduction in lifespan due to various causes.	Some mortality expected in larvae and hatchlings
10 - 100	Increased morbidity. Possible reduced lifespan. Reduced reproductive success.	Reduced reproductive success
1 - 10	Potential for reduced reproductive success	Possible reduced reproductive success due to reduced fertility
0.1 - 1	Very low probability of various effects	No information
0.01 – 0.1	No observed effects.	No information
< 0.01	Natural background	Natural background

Differences between RAPs and ROs (ICRP 108)

- Biology
- Exposure pathway
- *Dosimetry (quantifiable)*
- *Effects (likely to be similar)*
- Consequences

Additional material necessary to apply RAPs and DCRLs to exposure situations

- ICRP 114 (2011) Set of CRs for all 12 RAPs
- Application to different exposure situations (TG 82) – and how does all this fit into the ICRP 'system'?

Issues:
RELATING EXPOSURE TO DOSE

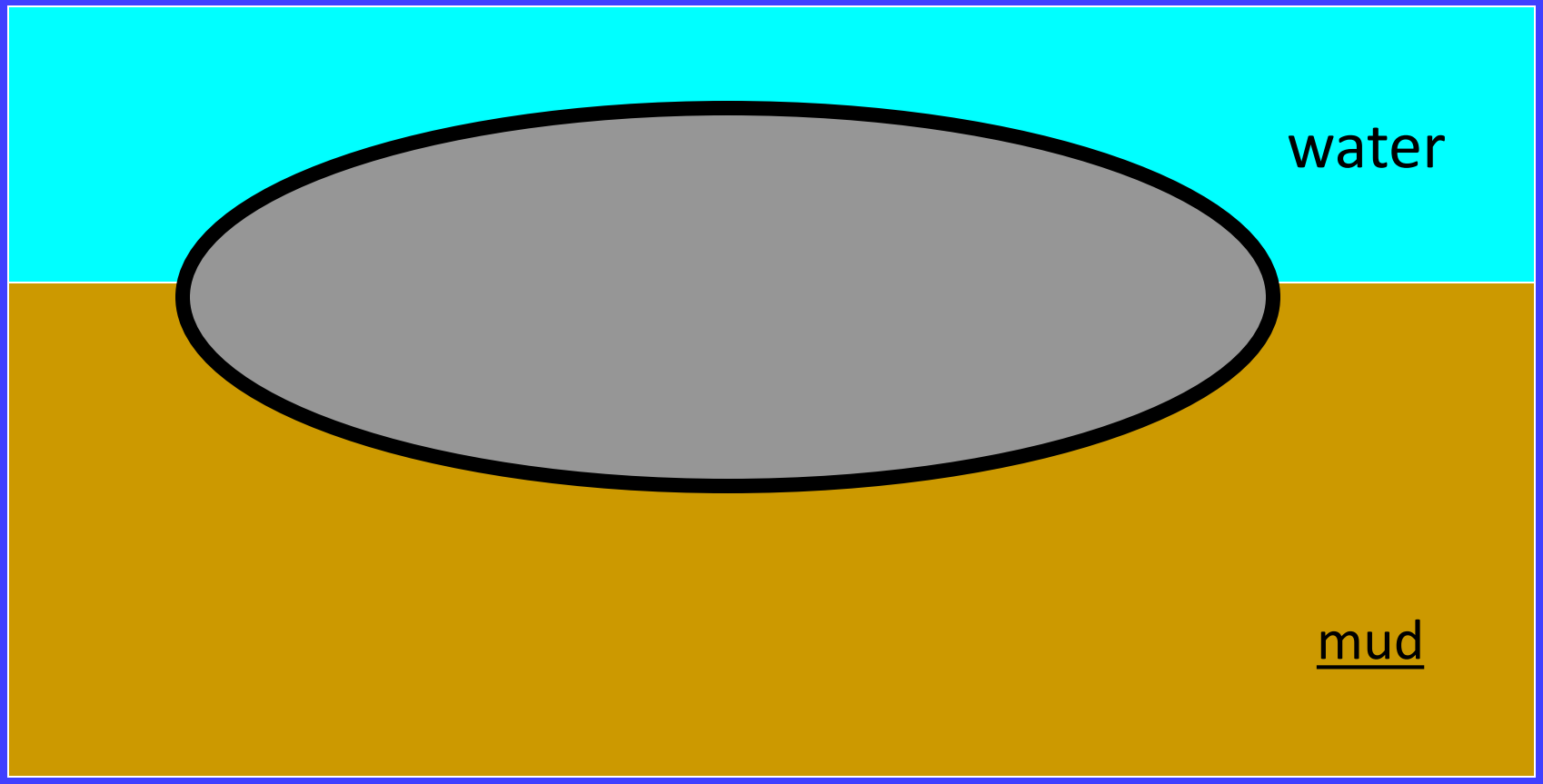
Many data sets exist.
However there are a limited few that can effectively serve as true "reference" data sets because:

- are not specific to RAPs;
- they do not cover all organs of interest;
- they do not cover all relevant life cycle stages;
- they were obtained where the environmental concentrations were variable;
- relate to quasi-steady state conditions;
- do not usually allow for chemical speciation.

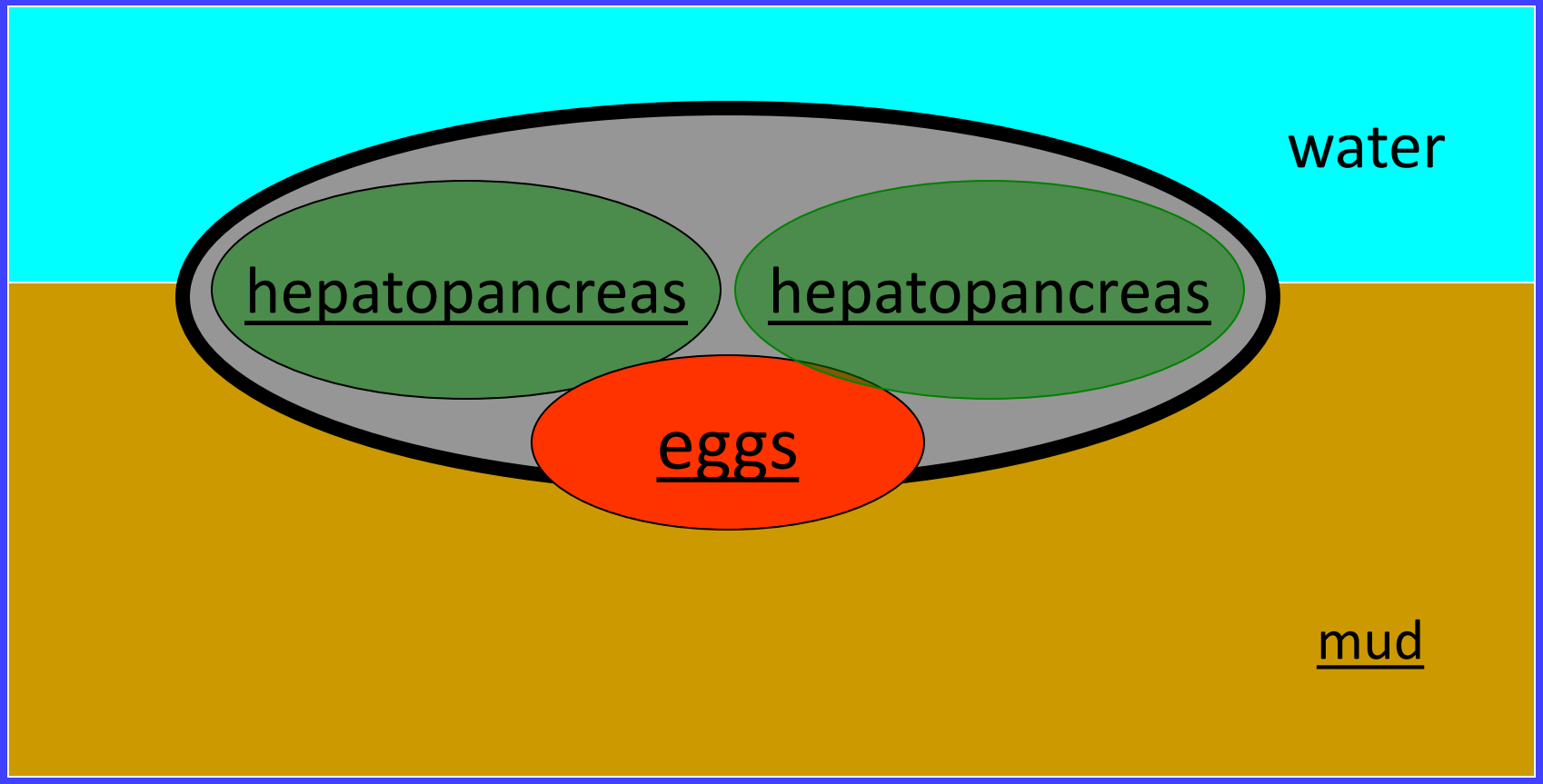
Other missing bits

- Current gaps in dosimetry (TG 74) - terrestrial exposures in more detail
- What about more realistic dosimetry of trees, and for animals > 1kg
- What about RBE and radiation weighting factors? (TG 72)

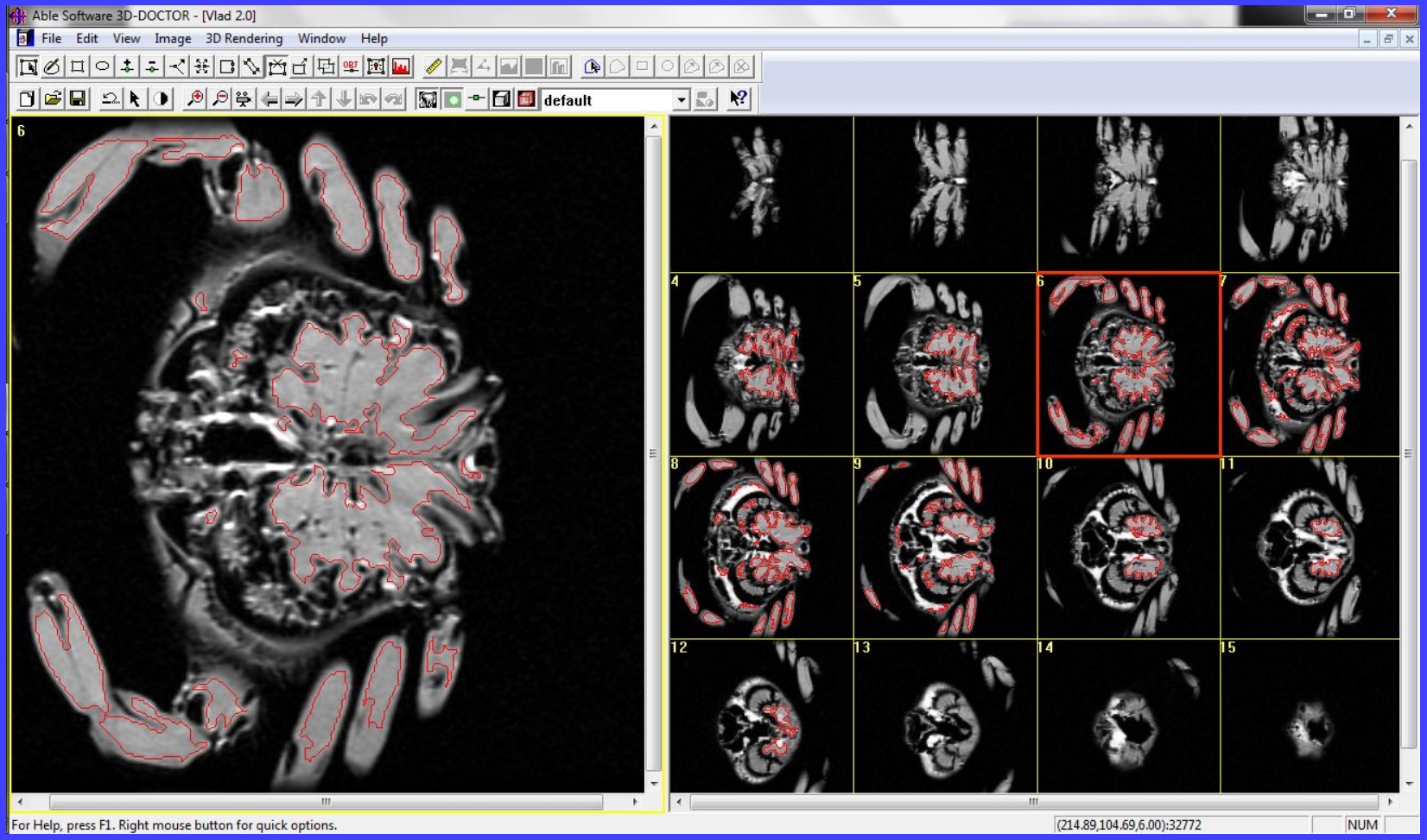
More realistic dosimetric models for >1kg (eg adult crab)



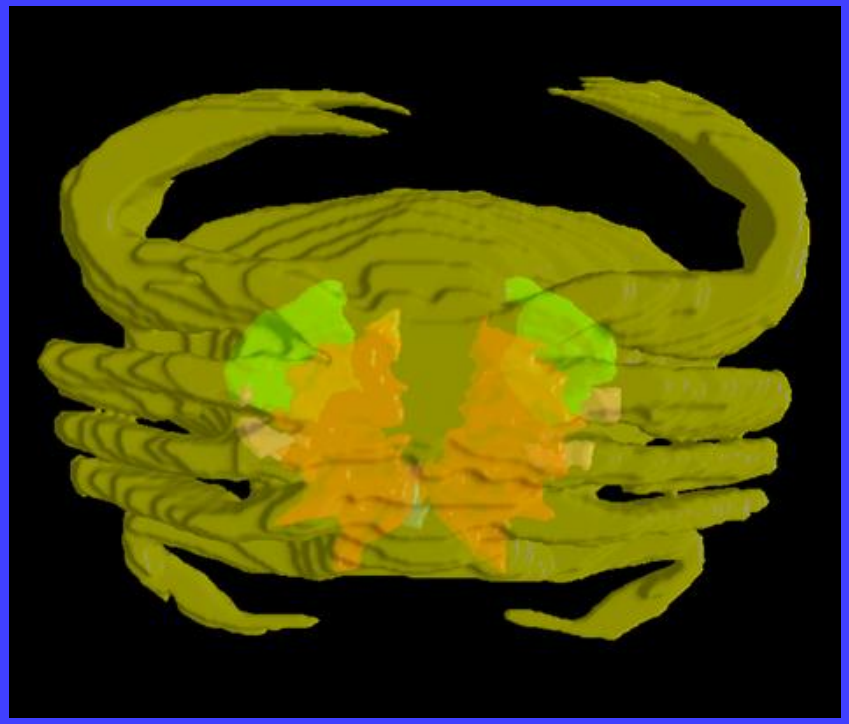
More realistic dosimetric models for >1kg (eg adult crab)

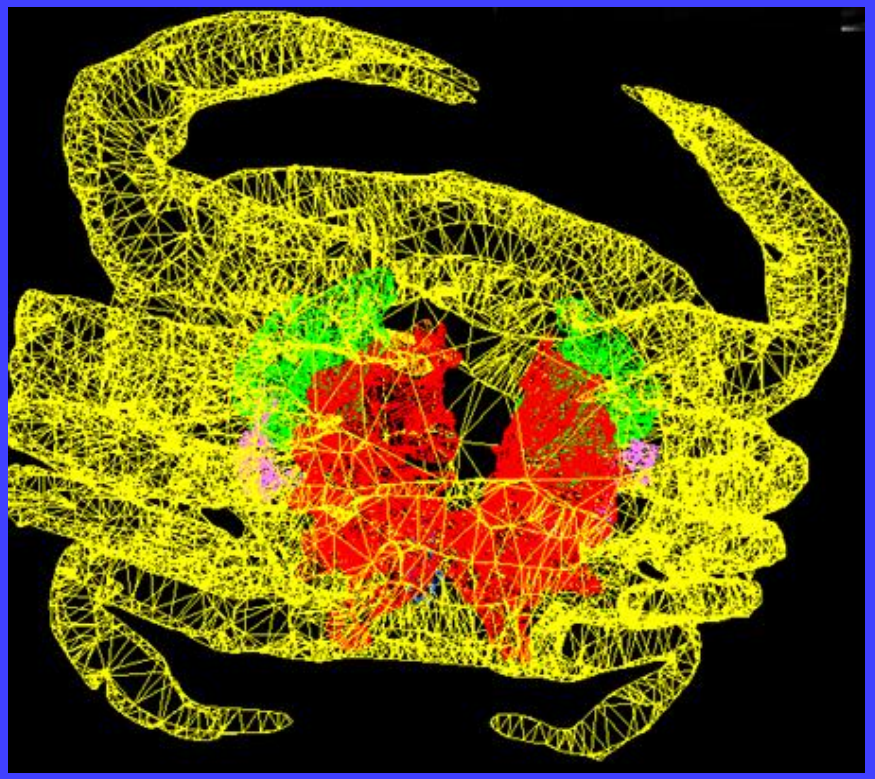


Editing the auto-segment boundaries: gills



3D Doctor: Surface rendering





RBE and radiation weighting factors

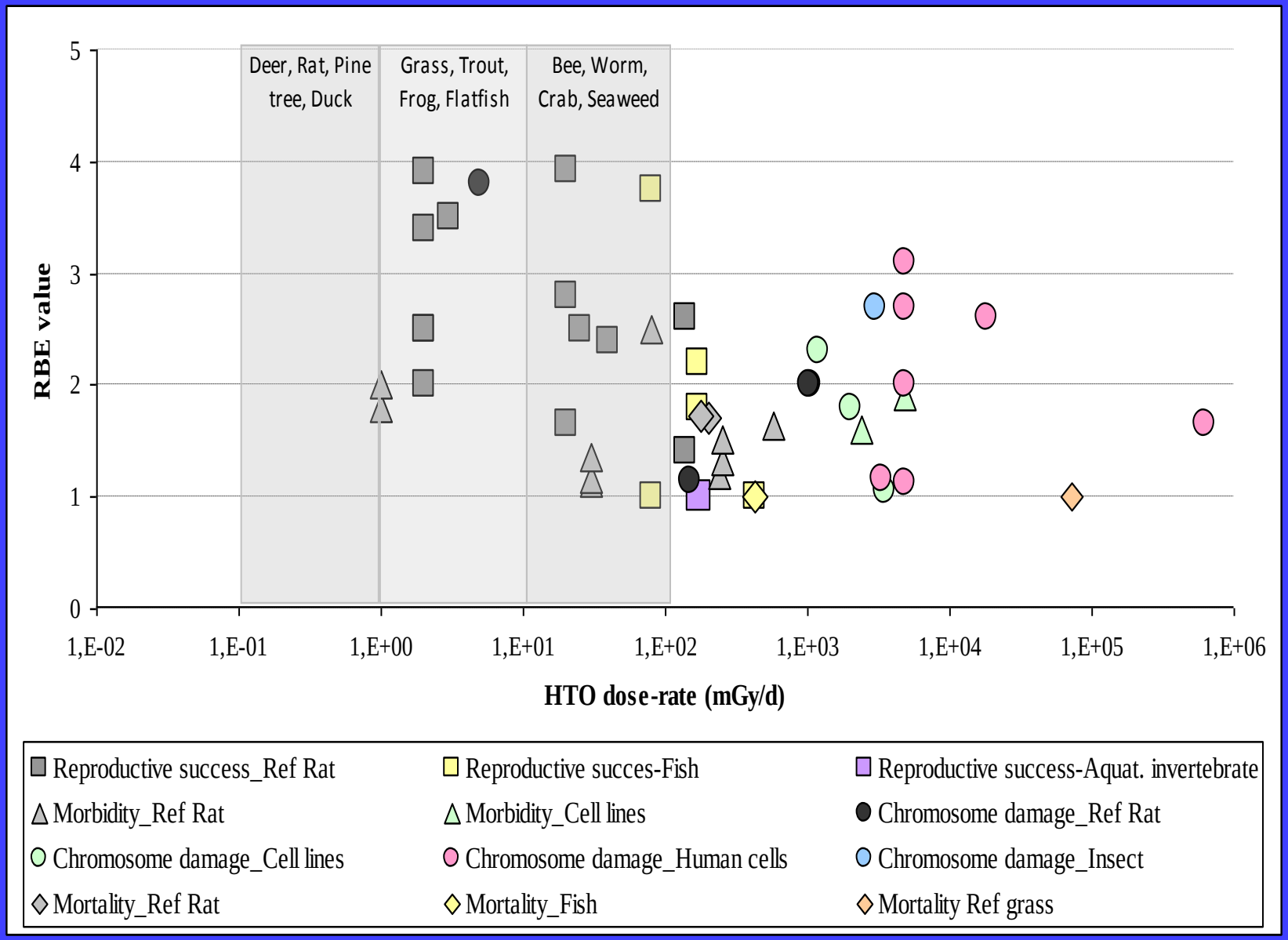
In considering the data base in relation to observations on RBE in biota

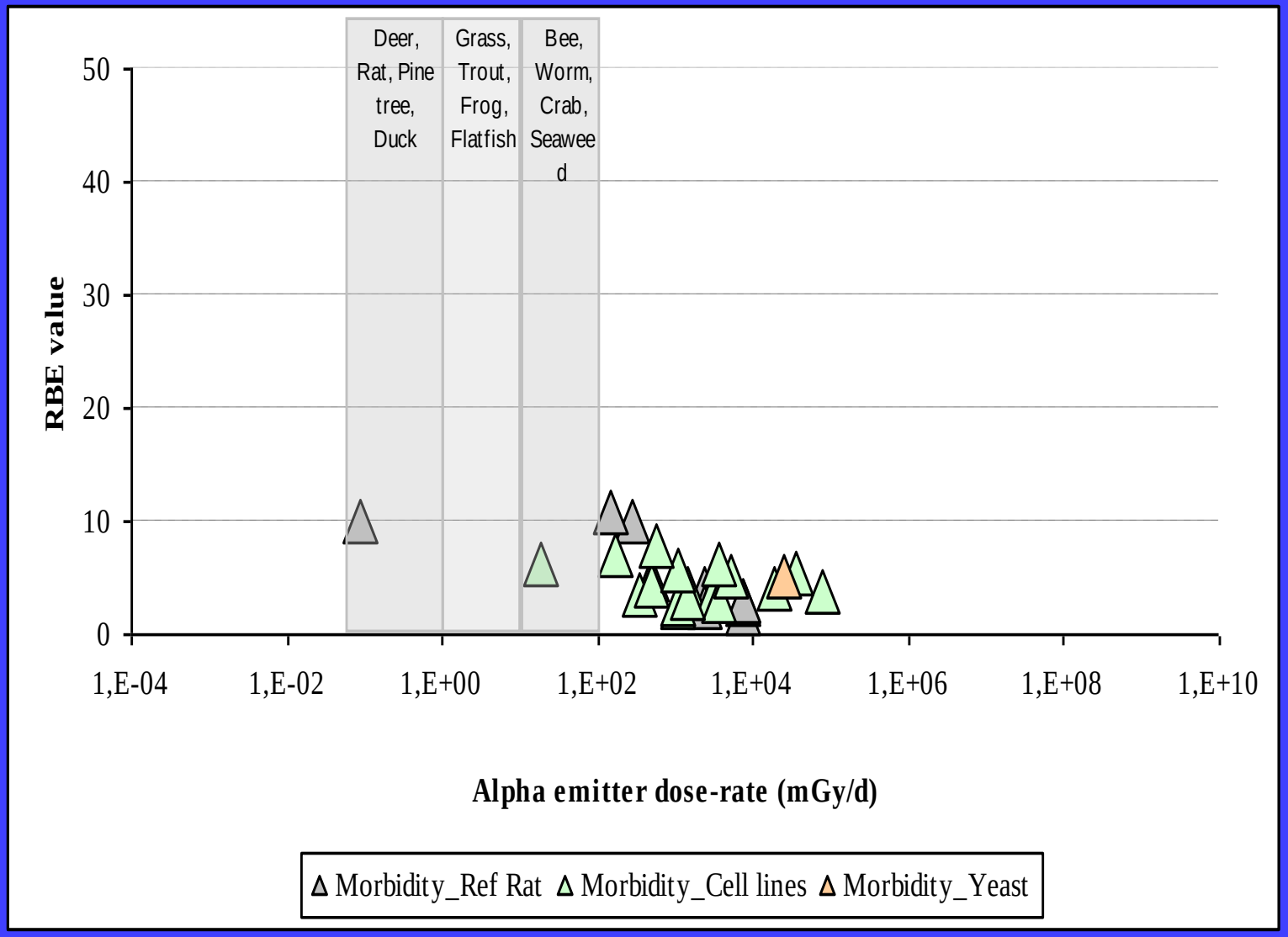
If the effect has a known dose threshold:

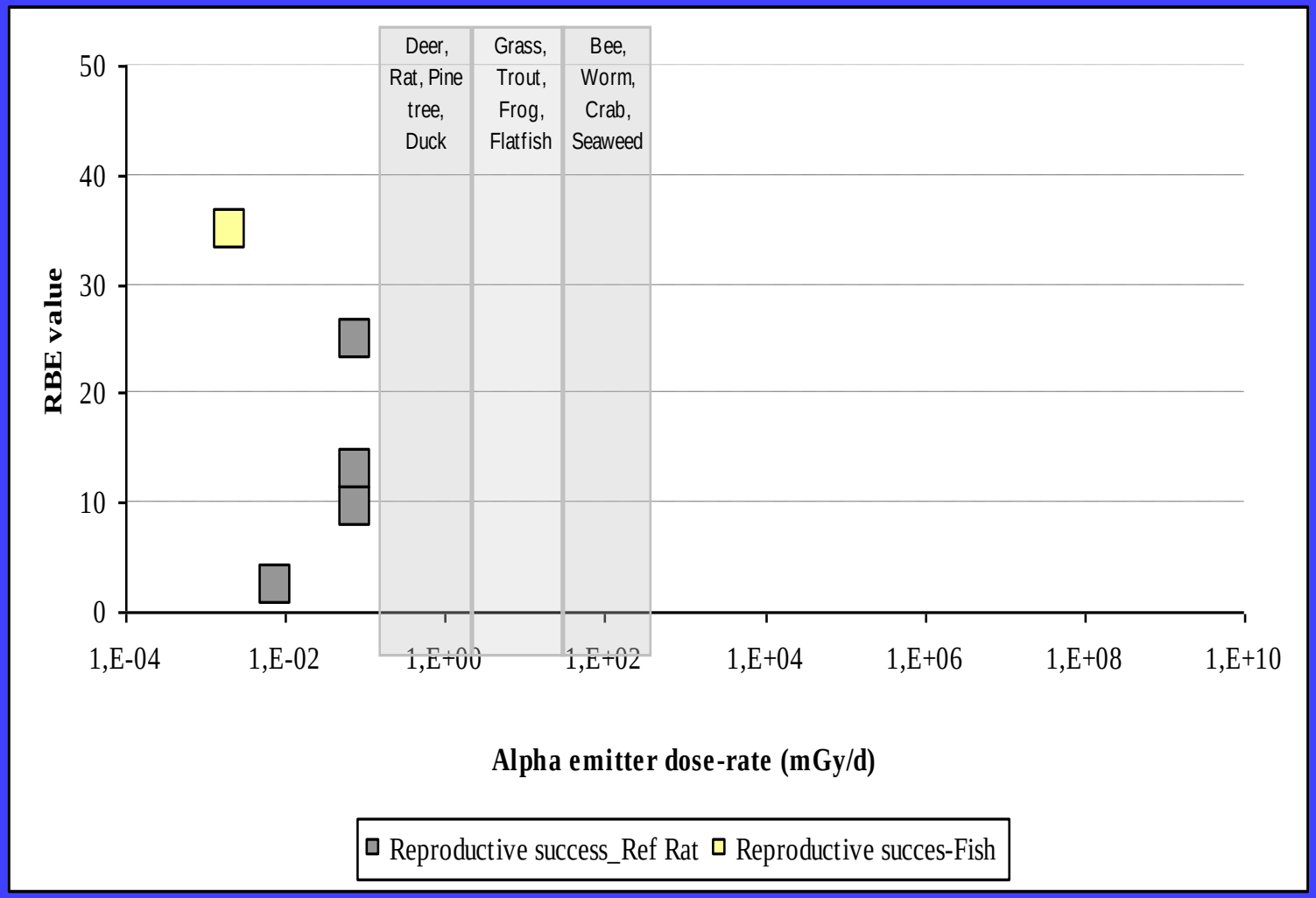
- **what is that dose (rate) threshold relative to the relevant RAP DCRL?**

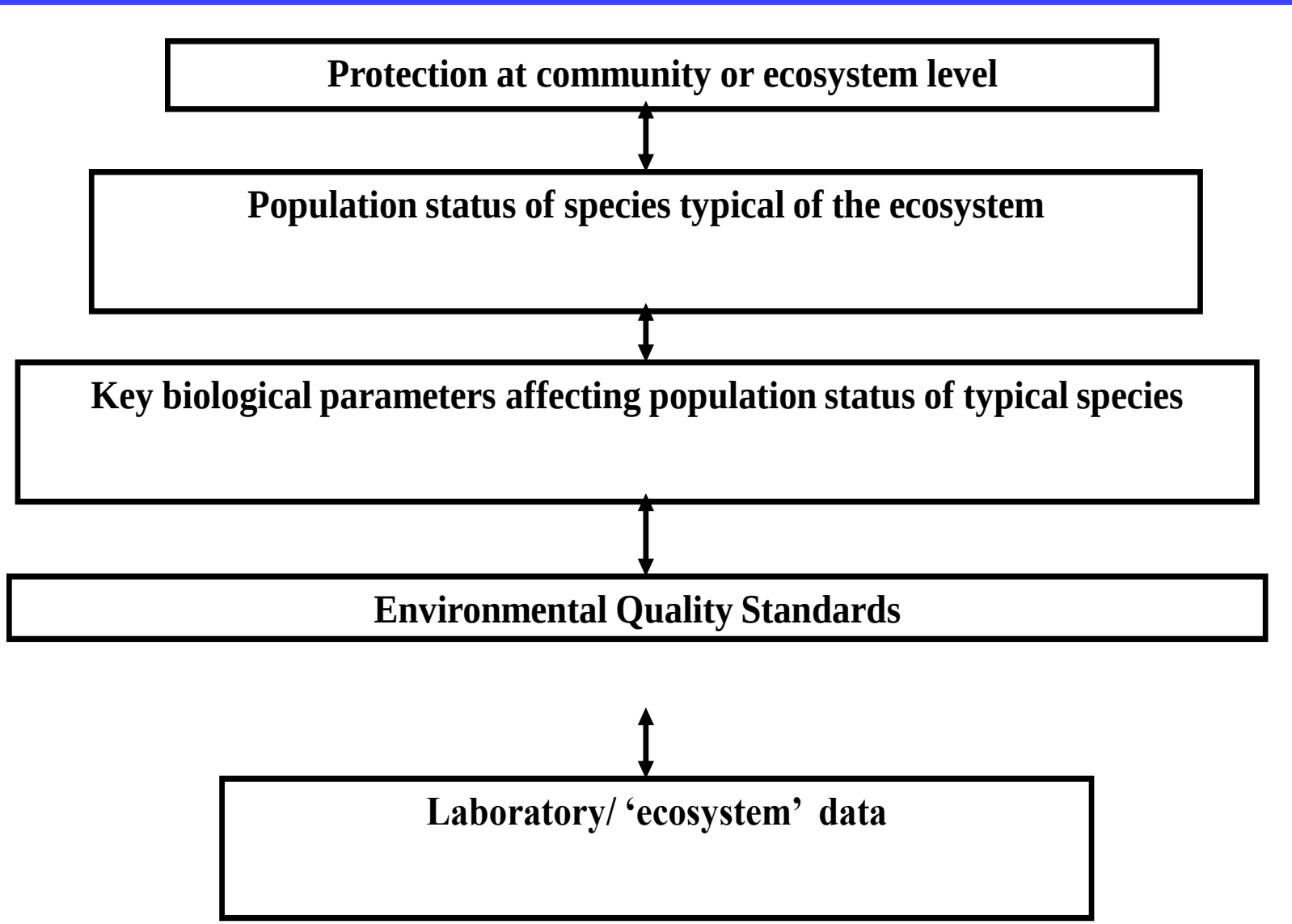
If the effect has no threshold:

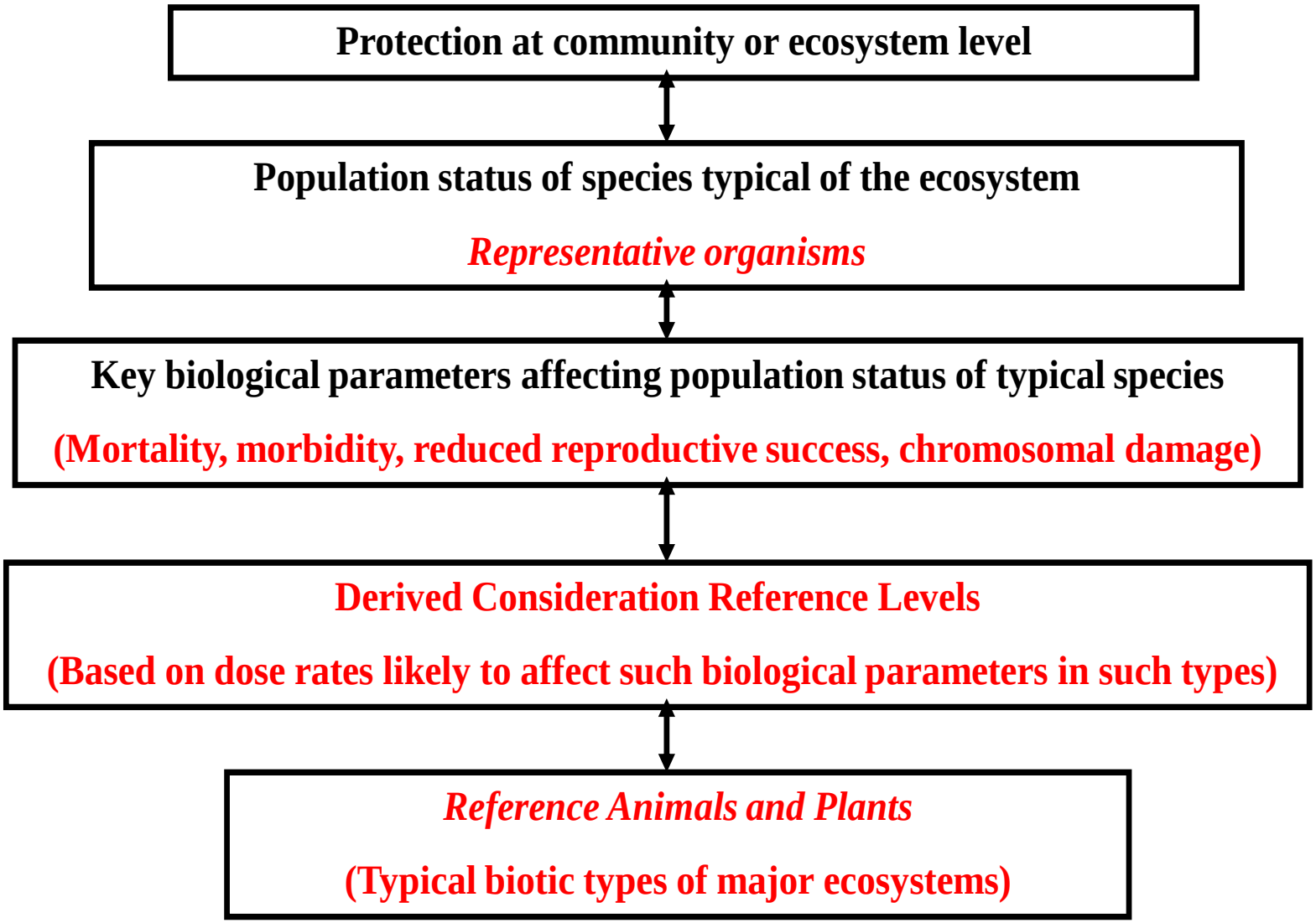
- **what are the risks (%) if the data are extrapolated to the DCRLs?**
- **what are the actual biological effects, and what is their potential relevance?**

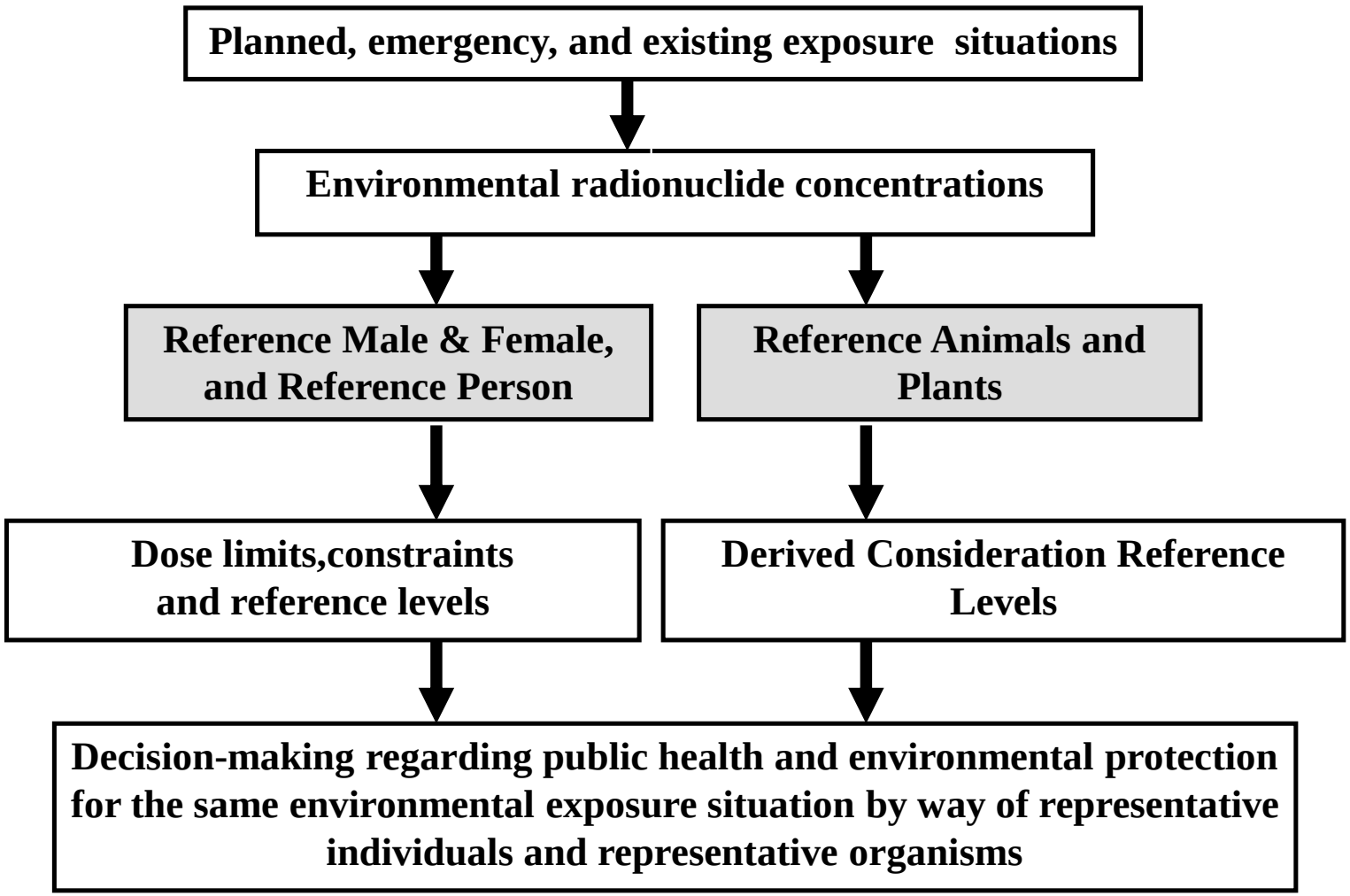

Deer, Rat, Pine tree, Duck
Grass, Trout, Frog, Flatfish
Bee, Worm, Crab, Seaweed
RBE value
0
1
2
3
4
5
1,E-02
1,E-01
1,E+00
1,E+01
1,E+02
1,E+03
1,E+04
1,E+05
1,E+06
HTO dose-rate (mGy/d)
Reproductive success_Ref Rat
Reproductive succes-Fish
Reproductive success-Aquat. invertebrate
Morbidity_Ref Rat
Morbidity_Cell lines
Chromosome damage_Ref Rat
Chromosome damage_Cell lines
Chromosome damage_Human cells
Chromosome damage_Insect
Mortality_Ref Rat
Mortality_Fish
Mortality Ref grass


Deer, Rat, Pine tree, Duck
Grass, Trout, Frog, Flatfish
Bee, Worm, Crab, Seaweed
RBE value
50
40
30
20
10
0
1,E-04
1,E-02
1,E+00
1,E+02
1,E+04
1,E+06
1,E+08
1,E+10
Alpha emitter dose-rate (mGy/d)
Morbidity_Ref Rat
Morbidity_Cell lines
Morbidity_Yeast


Deer, Rat, Pine tree, Duck
Grass, Trout, Frog, Flatfish
Bee, Worm, Crab, Seaweed
50
40
30
20
10
0
RBE value
1,E-04
1,E-02
1,E+00
1,E+02
1,E+04
1,E+06
1,E+08
1,E+10
Alpha emitter dose-rate (mGy/d)
Reproductive success_Ref Rat
Reproductive succes-Fish

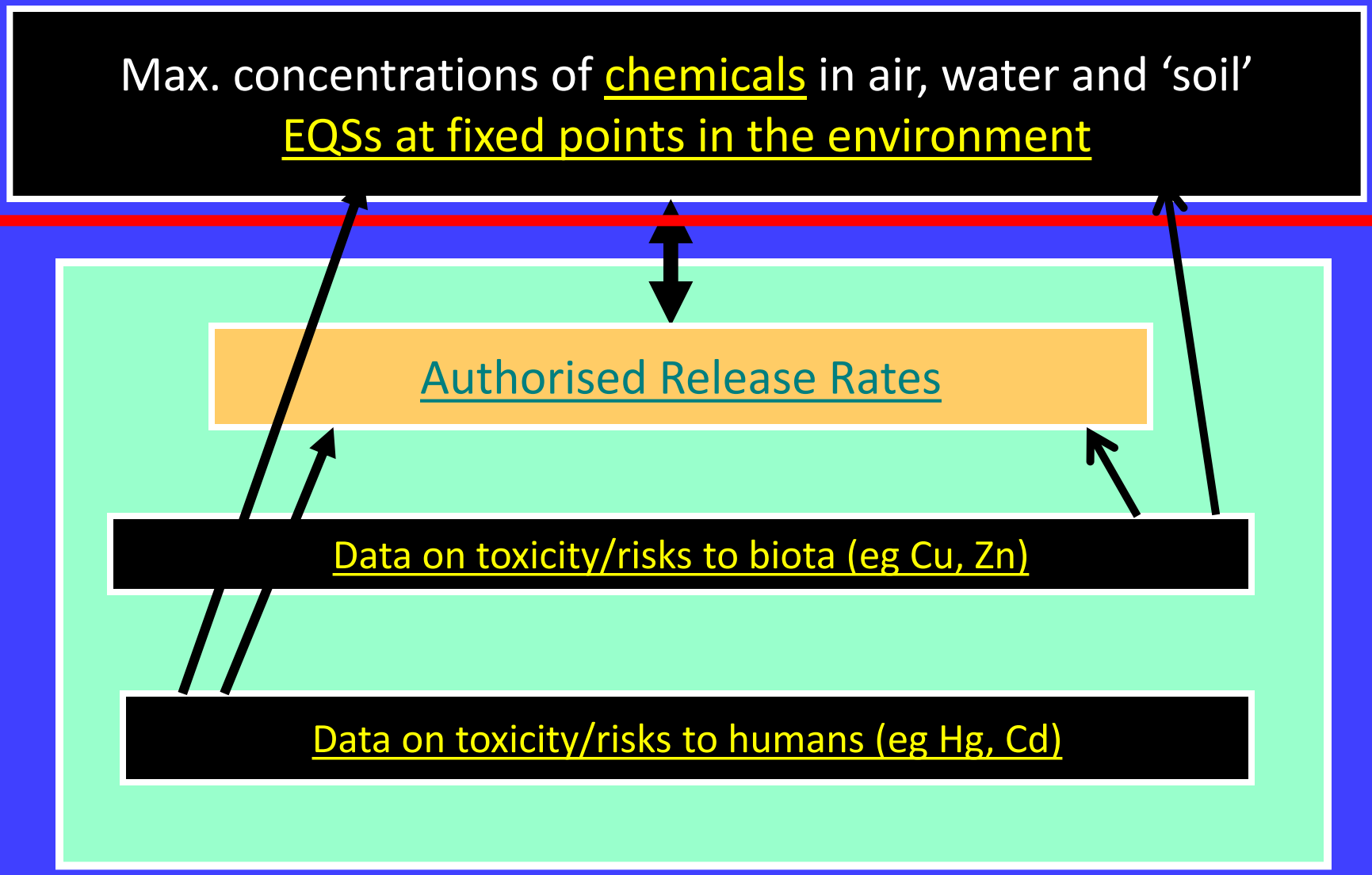

Protection at community or ecosystem level
Population status of species typical of the ecosystem
Key biological parameters affecting population status of typical species
Environmental Quality Standards
Laboratory/ 'ecosystem' data

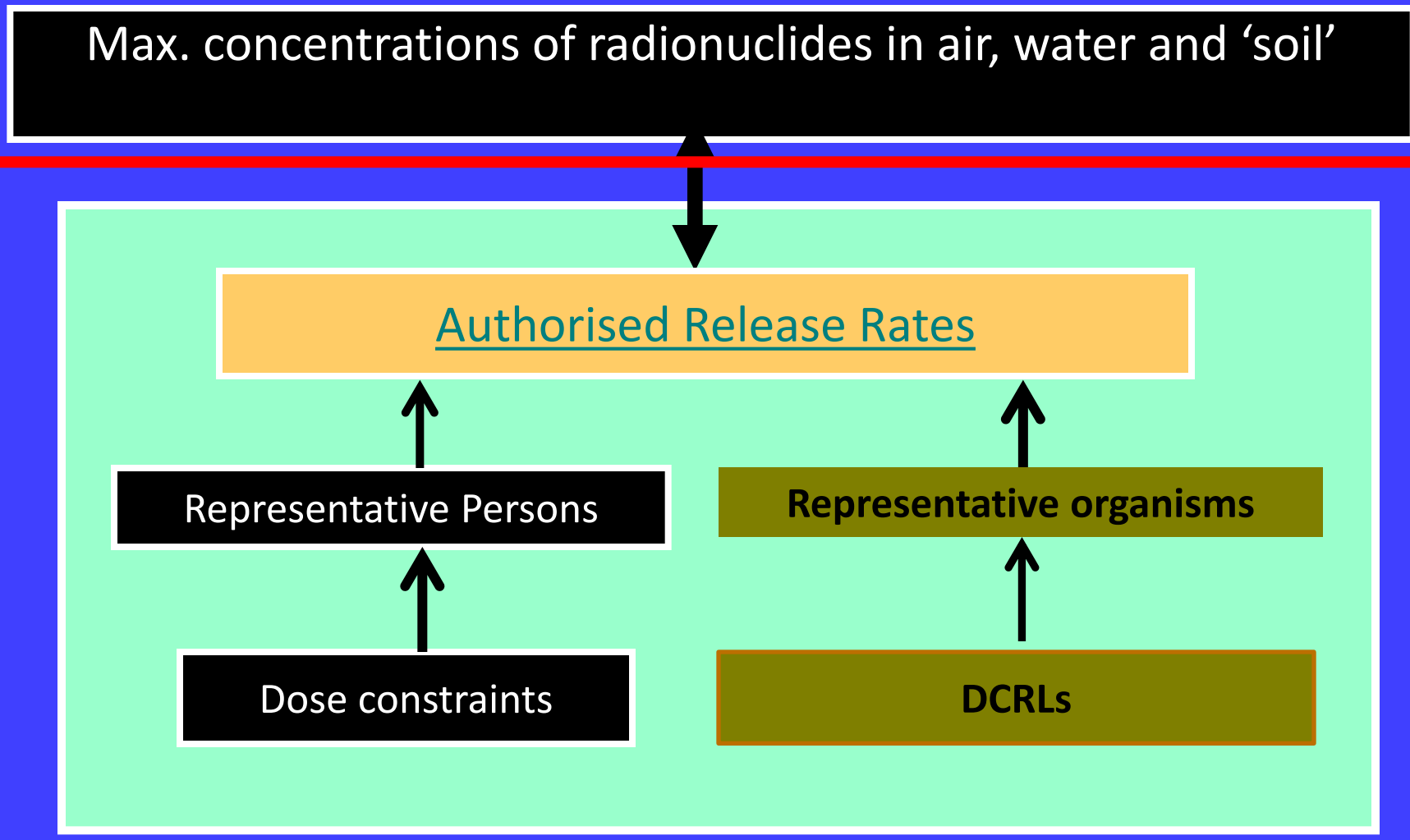

Protection at community or ecosystem level
Population status of species typical of the ecosystem
Representative organisms
Key biological parameters affecting population status of typical species
(Mortality, morbidity, reduced reproductive success, chromosomal damage)
Derived Consideration Reference Levels
(Based on dose rates likely to affect such biological parameters in such types)
Reference Animals and Plants
(Typical biotic types of major ecosystems)


Planned, emergency, and existing exposure situations
Environmental radionuclide concentrations
Reference Male & Female, and Reference Person
Reference Animals and Plants
Dose limits,constraints and reference levels
Derived Consideration Reference Levels
Decision-making regarding public health and environmental protection for the same environmental exposure situation by way of representative individuals and representative organisms

Protection of the environment

The future ?


Max. concentrations of chemicals in air, water and 'soil'
EQSs at fixed points in the environment
Authorised Release Rates
Data on toxicity/risks to biota (eg Cu, Zn)
Data on toxicity/risks to humans (eg Hg, Cd)


Max. concentrations of radionuclides in air, water and ‘soil’
Authorised Release Rates
Representative Persons
Representative organisms
Dose constraints
DCRLs

Environmental Compliance Index

If:

(a) ∑ radionuclides not greater than x

&

(b) no individual radionuclide greater than y

then both humans and biota (independently) protected

Max. concentrations of radionuclides in air, water and 'soil' at specific locations around a site (REQSs)

Authorised Release Rates

Research priorities : filling RAP data gaps

- RAP approach leaves plenty of scope for:
- - better dosimetric models
- - better information on chemical composition and radionuclide kinetics in different types of biota
- - radiation effects (even simple experimental data are lacking)

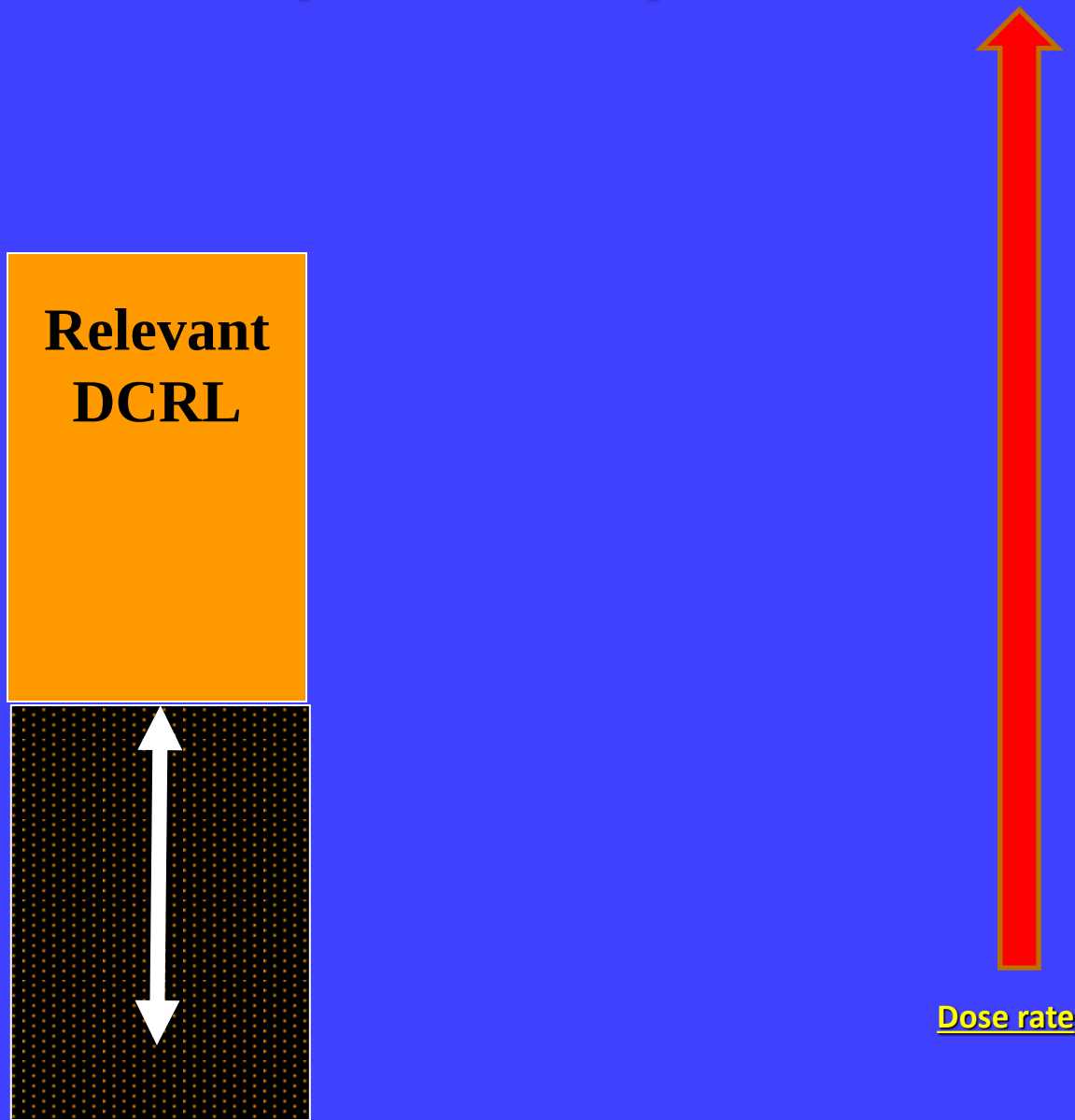
Research needs in PhD-size bites

ICRP web site

Issues

- ‘Optimisation’ below the bands of DCRLs
- Questioning need for an ‘ERL’ in planned (normal) exposure situations for individual sources
- Protection of individuals or populations

Planned (normal)



ICRP 103 (217)

The optimisation of protection is a forward-looking iterative process aimed at preventing or reducing future exposures. It takes into account both technical and socio-economic developments and requires both qualitative and quantitative judgements. The process should be systematic and carefully structured to ensure that all relevant aspects are taken into account Optimisation is a frame of mind, always questioning whether the best has been done in the prevailing circumstances, and whether all that is reasonable has been done to reduce doses. It also requires commitment at all levels in all concerned organisations as well as adequate procedures and resources.

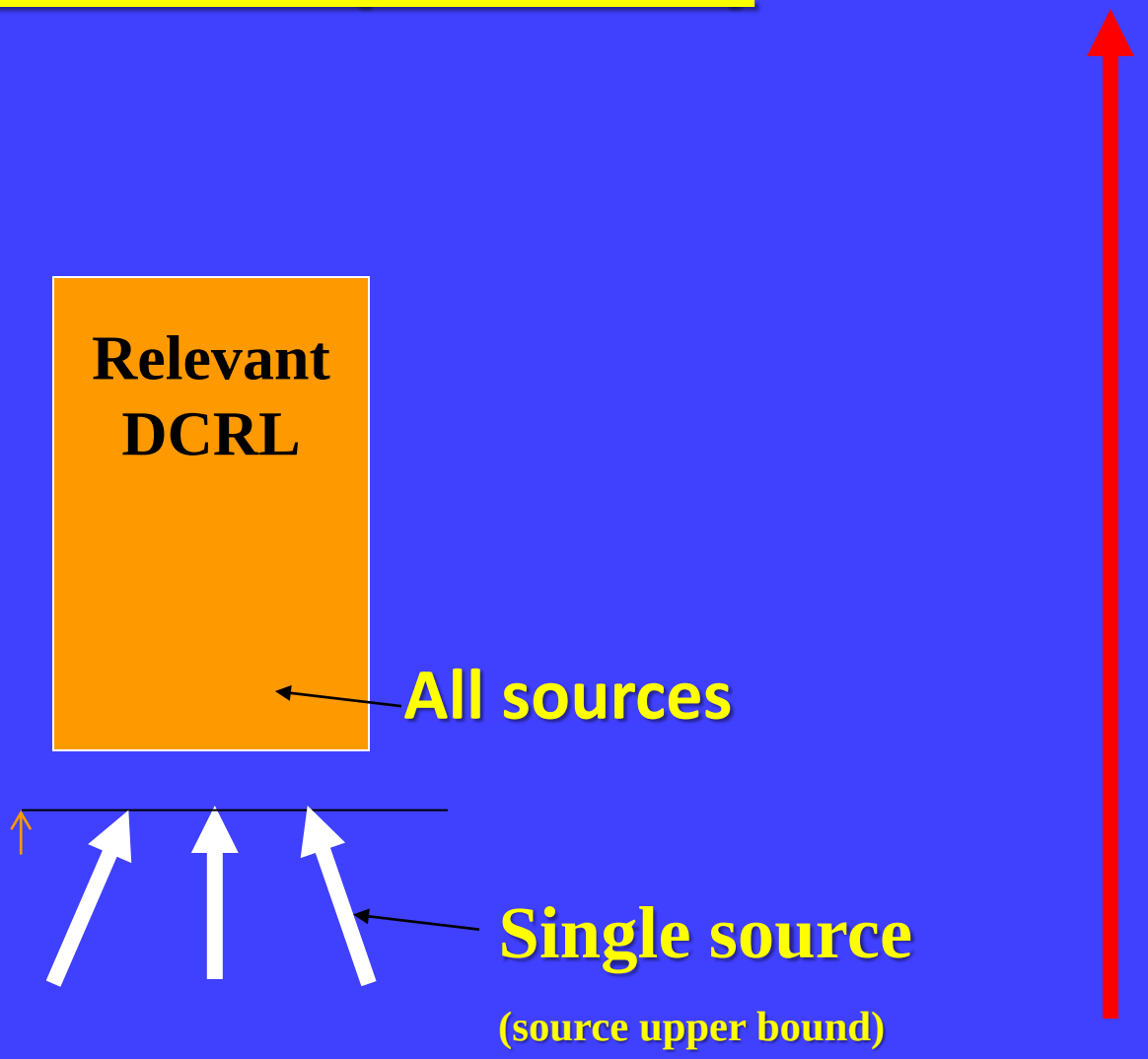
Issues

- **'Optimisation' below the bands of DCRLs**

- **Questioning need for an 'ERL' in planned (normal) exposure situations for individual sources**

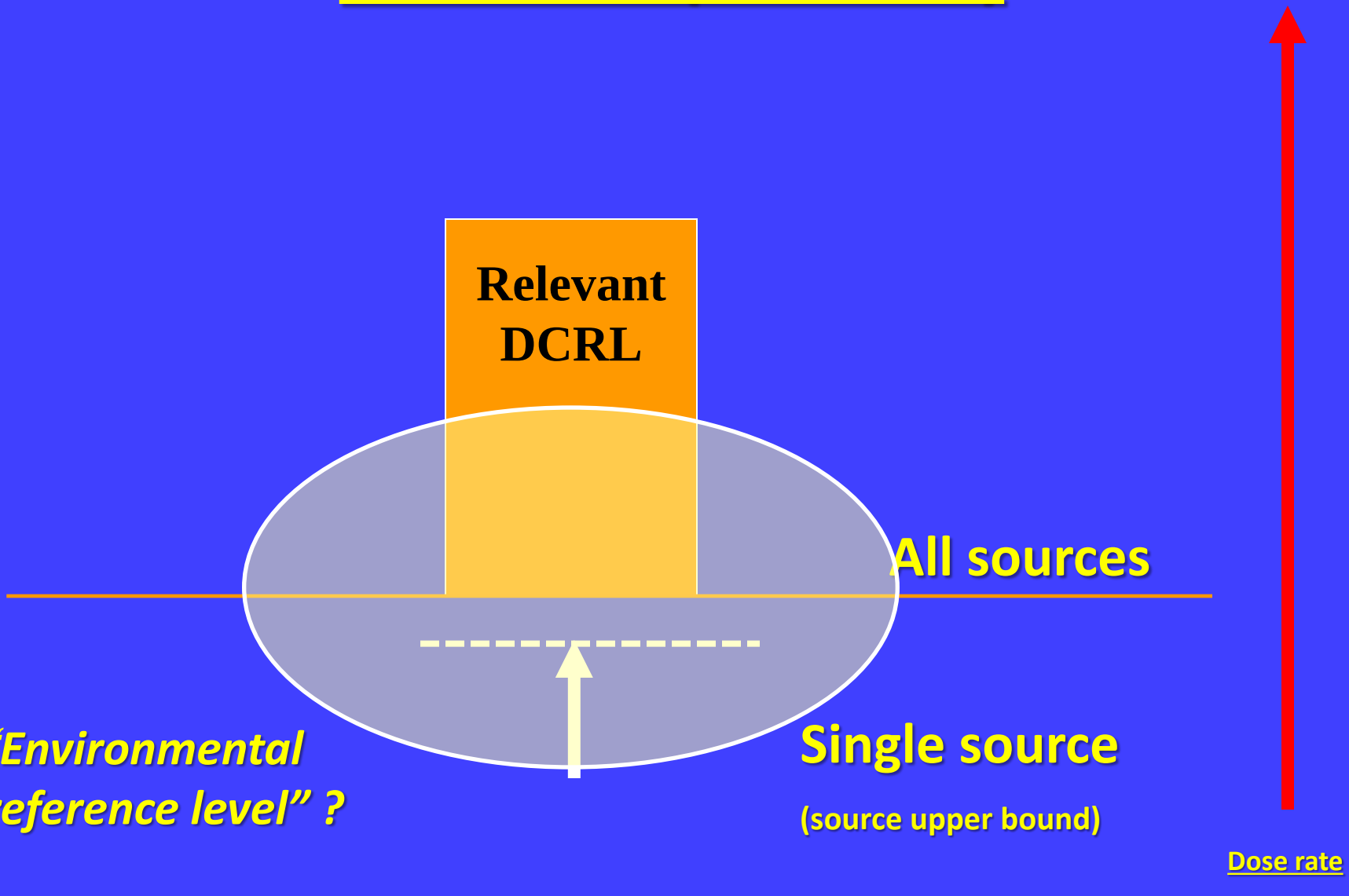
- **Protection of individuals or populations**

Planned (normal)



"Environmental reference level" ?

Planned (normal)



Issues

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- Protection of individuals or populations