Doses from tritium

EU Seminar, November 2007

Doses from tritium

Effective dose

Dose coefficients for HTO and OBT

RBE, DDREF and w_R

OBT in Cardiff Bay fish

Use of effective dose

Health Protection Agency

A protection device

Allows summation of doses from different radionuclides and external dose

Use for regulatory purposes for comparison with dose limits / constraints

Relates to stochastic effects only

→ total detriment of 7% Sv^{-1} (6% in new recommendations)

Use of effective dose

Not individual specific

- → reference biokinetic and dosimetric models, and defined w_R and w_T values, are used to calculate reference dose coefficients for protection purposes

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Use of individual monitoring data

- better assessment of intake / exposure for the calculation of effective dose to a reference person

Calculation of equivalent and effective dose

1. Absorbed dose in tissues / organs, Gy

2. Equivalent dose in tissues / organs, Sv

   - Gy x w_R $\quad$ $H_T = \sum_R w_R D_{T,R}$

3. Effective dose, Sv

   - equivalent dose x w_T $\quad$ $E = \sum_T w_T H_T$

Weighting factors

Equivalent dose in tissues / organs, Sv

w_R	1	for low LET radiations
	20	for α particles

Effective dose, Sv

w_T	0.01	bone surface, skin
	0.05	bladder, breast, liver, oesophagus, thyroid remainder
	0.12	bone marrow, colon, lung, stomach
	0.2	gonads

Tissue weighting factors

Current	0.01	bone surface, skin
	0.05	bladder, breast, liver, oesophagus, thyroid, remainder
	0.12	bone marrow, colon, lung, stomach
	0.2	gonads
New	0.01	bone surface, skin, brain, salivary glands
	0.04	bladder, liver, oesophagus, thyroid
	0.08	gonads
	0.12	bone marrow, colon, lung, stomach, breast, remainder

Sex-specific detriment

Applying to ages from 0 - 85 at exposure

Overall detriment is about 40% greater in females than males

Differences include:

Colon	x 0.4 in females cf. males
Liver	x 0.5
Lung	x 2.0
Thyroid	x 4.3
Breast	one-quarter of total detriment in females

Age-specific cancer risks
- life-time attributable risk

Cases per 10^6 exposed to a single dose of 10 mGy (BEIR VII)

Cancer site	Age at exposure, years					
	Males			Females		
	0	20	60	0	20	60
Breast	-	-	-	1171	429	31
Colon	336	173	94	220	114	62
Liver	61	30	14	28	14	7
Lung	314	149	89	733	346	201
Thyroid	115	21	0.3	634	113	1
Leukaemia	237	96	82	185	71	57
All cancers	2563	977	489	4777	1646	586

Dosimetric **phantoms**
- MIRD and Voxel

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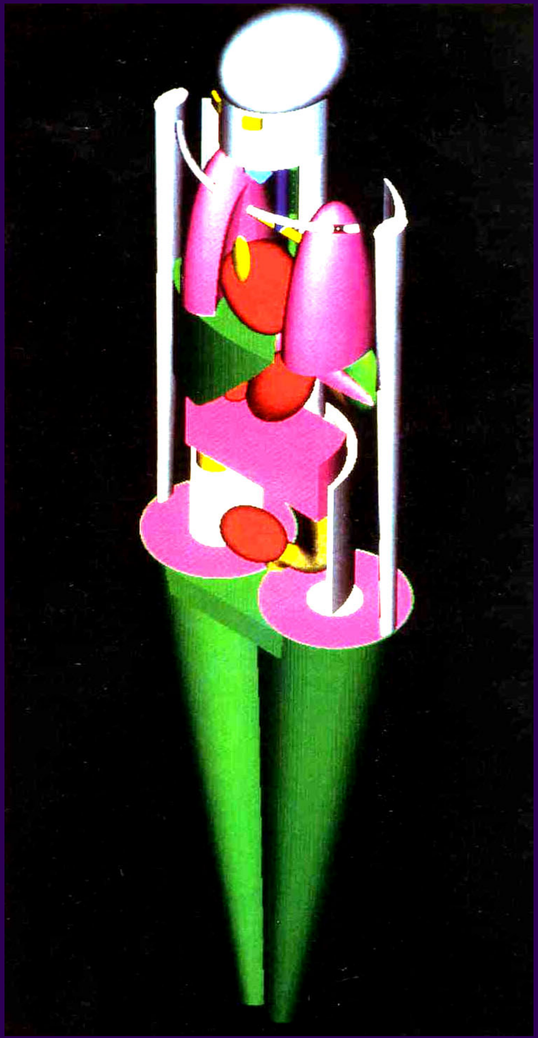
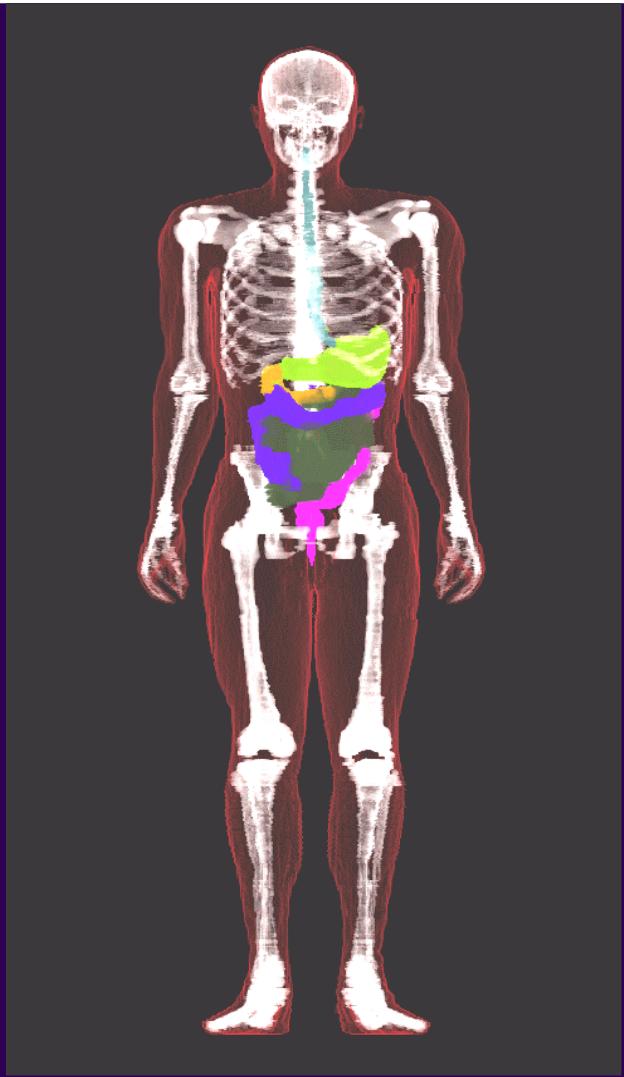
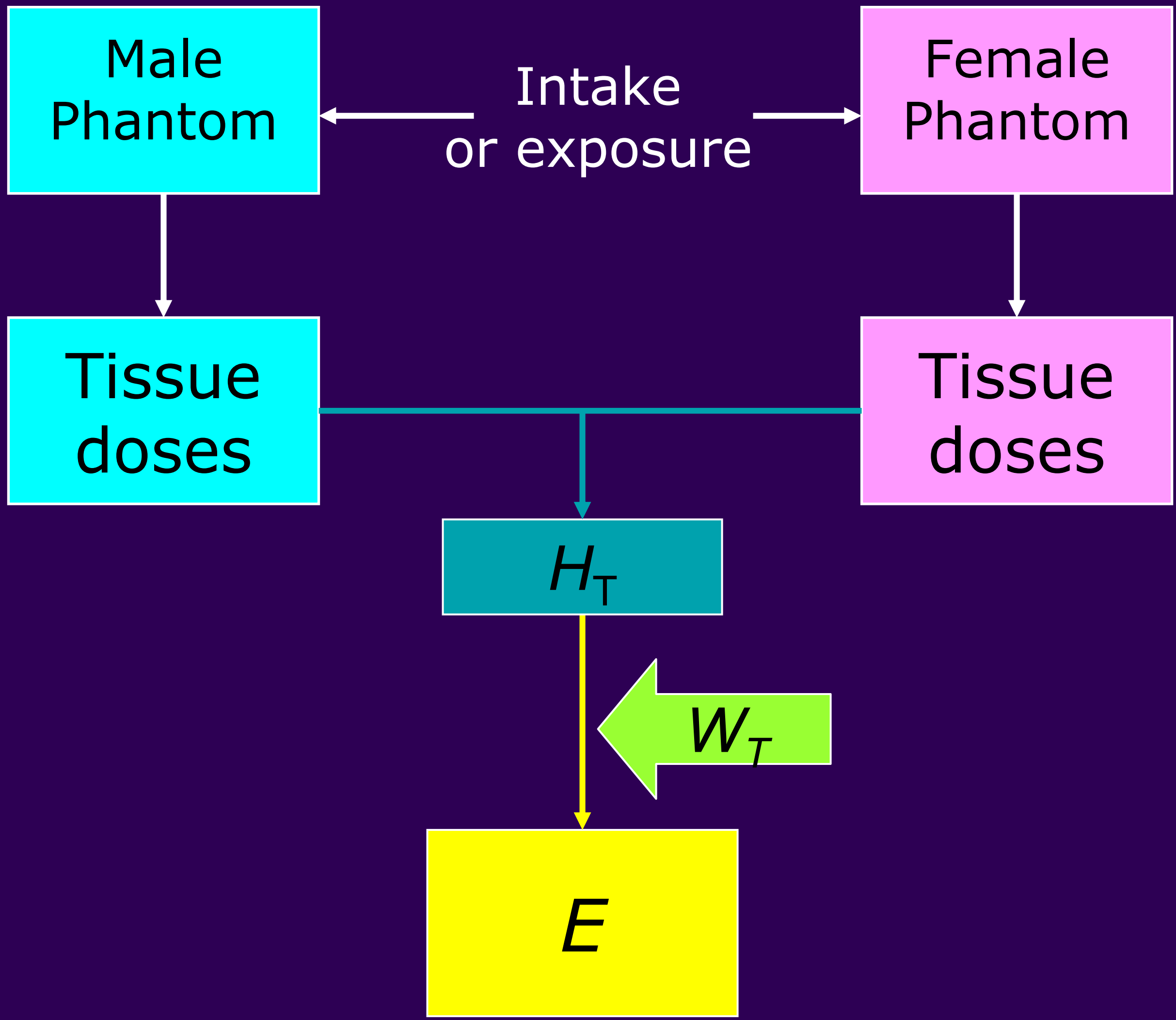




Sex averaging in calculation of Effective Dose



Forms of tritium

Tritiated Water (HTO)

Organically-bound Tritium (OBT)

- Non-exchangeable binding of ^{3}H to C atoms in organic molecules

  Includes ^{3}H in carbohydrates
  lipids
  proteins
  nucleic acids

ICRP biokinetic assumptions

HTO, OBT ingestion, inhalation as vapour

Absorption to blood = 100%

Uniform distribution in all body tissues

Two components of retention, corresponding to HTO (A) and OBT (B) in body tissues

		A,%	B,%
Intakes as	HTO	97	3
	OBT	50	50

ICRP biokinetic assumptions - retention half-times

Age	Half-time, d	
	A	B
3 months	3.0	8
1 year	3.5	15
5 years	4.6	19
10 years	5.7	26
15 years	7.9	32
Adult	10.0	40

ICRP tritium ingestion dose coefficients

Age	Committed effective dose $Sv\ Bq^{-1} \times 10^{11}$	
	HTO	OBT
3 months	6.3	12
1 year	4.8	12
5 years	3.0	7.3
10 years	2.3	5.7
15 years	1.8	4.2
Adult	1.8	4.2

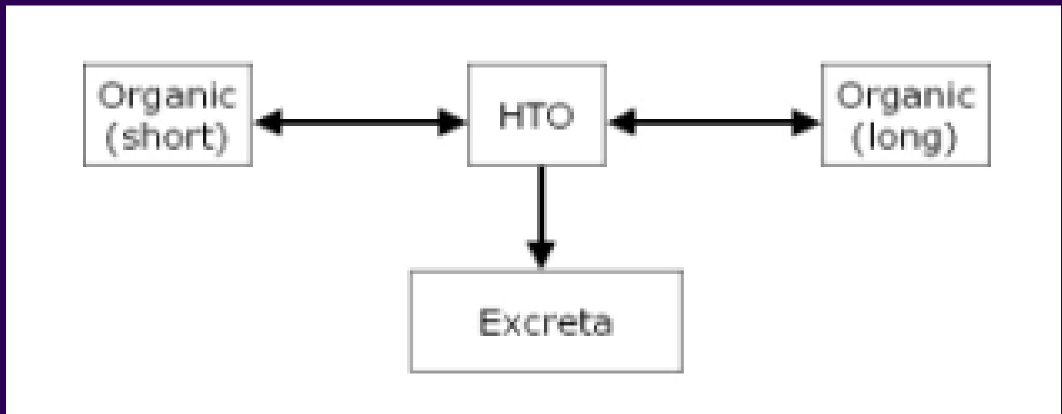
Proposed ICRP assumptions - occupational intakes

Dose coefficients and interpretation of bioassay

Taylor ; Rad. Prot. Dosim. ***105****, 225 ; 2003*

Intakes of HTO: 99% 10d, 0.98% 40d, 0.02% 350d

Dose coefficient: 1.7 x 10^{-11} Sv Bq^{-1}



Comparative doses to adult members of the public

Radionuclide	Comparative doses	
	Ingestion	Inhalation
Tritium (HTO)	1	1
Carbon-14	30	30
Strontium-90	1,600	1,300
Iodine-131	1,200	400
Caesium-137	720	260
Plutonium-239	14,000	2,800,000

ICRP dose coefficients
- fetus / infant

Ingestion during pregnancy and lactation

Radionuclide	Ratio of offspring : adult dose	
	Pregnancy	Lactation
Tritium (HTO)	1.7	1.2
Phosphorus-32	10	0.7
Calcium-45	11	2.7
Strontium-90	1.5	0.6
Iodine-131	1.1	2.4
Caesium-137	0.4	0.3
Polonium-210	0.1	0.4
Plutonium-239	0.04	0.0004

Uncertainties in data used in tritium dose coefficients

Harrison, Khursheed, Lambert; Rad. Prot. Dosim. ***98****, 299; 2002*.

5 - 95% range for uncertainty on central values for population groups

Absorption to blood

Incorporation into OBT in body tissues

Retention half-times

Relative biological effectiveness (RBE)

Uncertainties in tritium dose coefficients

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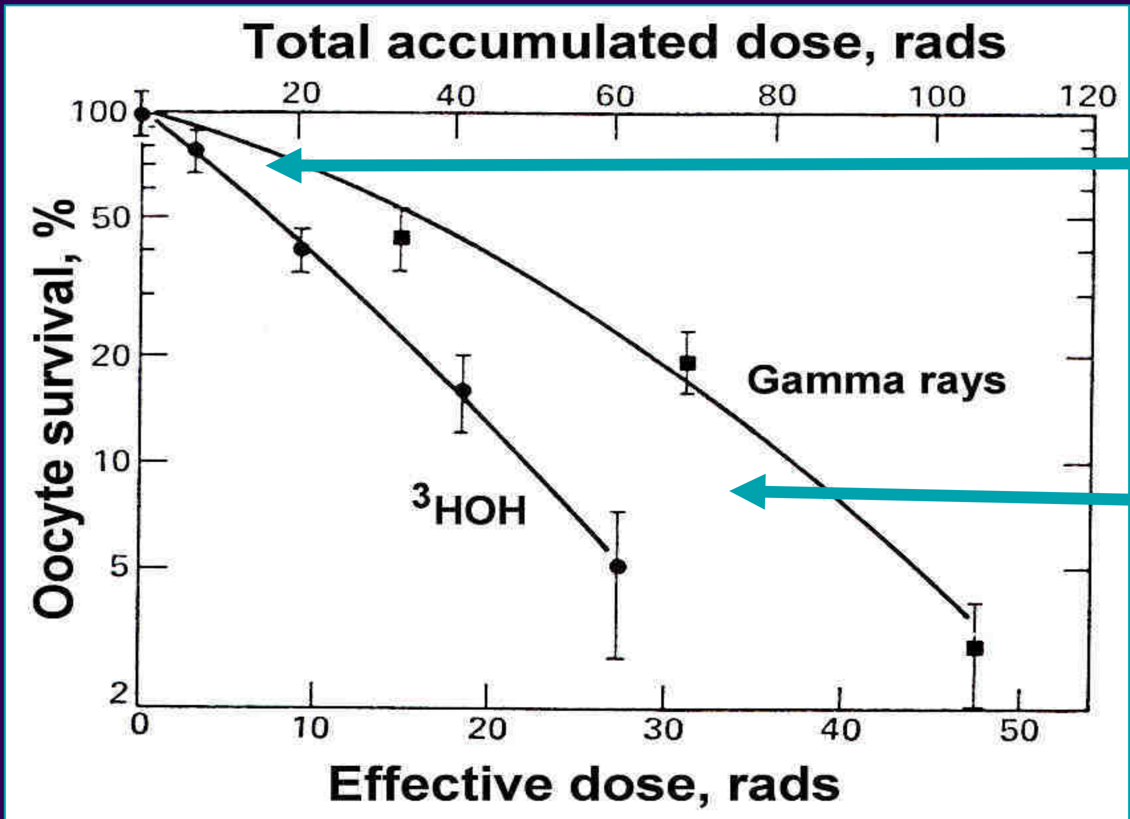
Probability Distributions on Ingestion Dose Coefficients for Adults, Sv Bq^{-1} x 10^{11}

Form	Range, %			ICRP
	5	50	95	
HTO	2.1	3.9	6.6	1.8
OBT	3.9	8.7	20.0	4.2

Strictly, Gy Bq^{-1} x RBE

In utero / germ cell sensitivity

HTO ingestion / ^{60}Co gamma ray exposure of mice throughout pregnancy and 14d lactation - oocyte survival in offspring



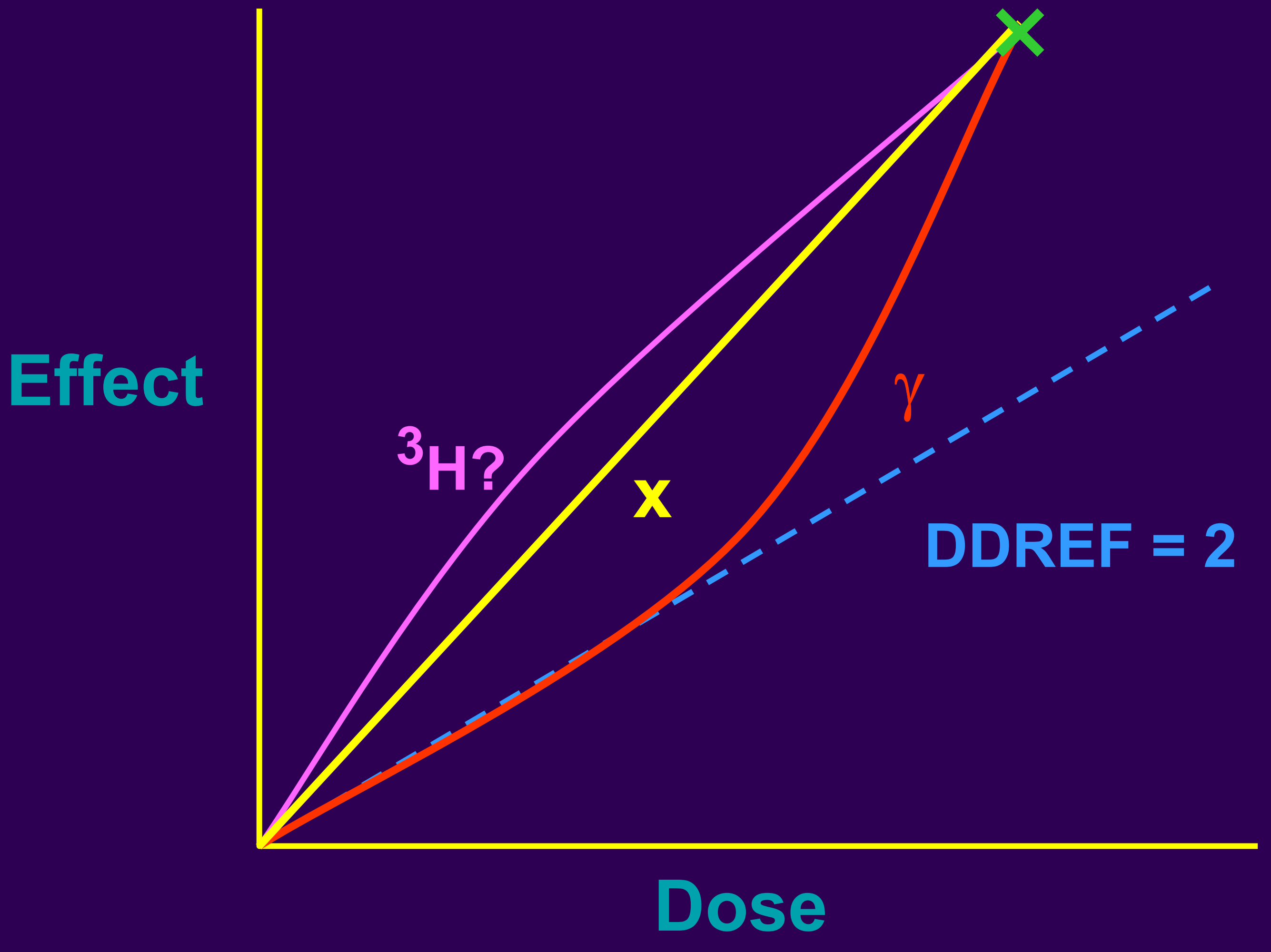
$RBE_M = 3$

$RBE = 1.6$

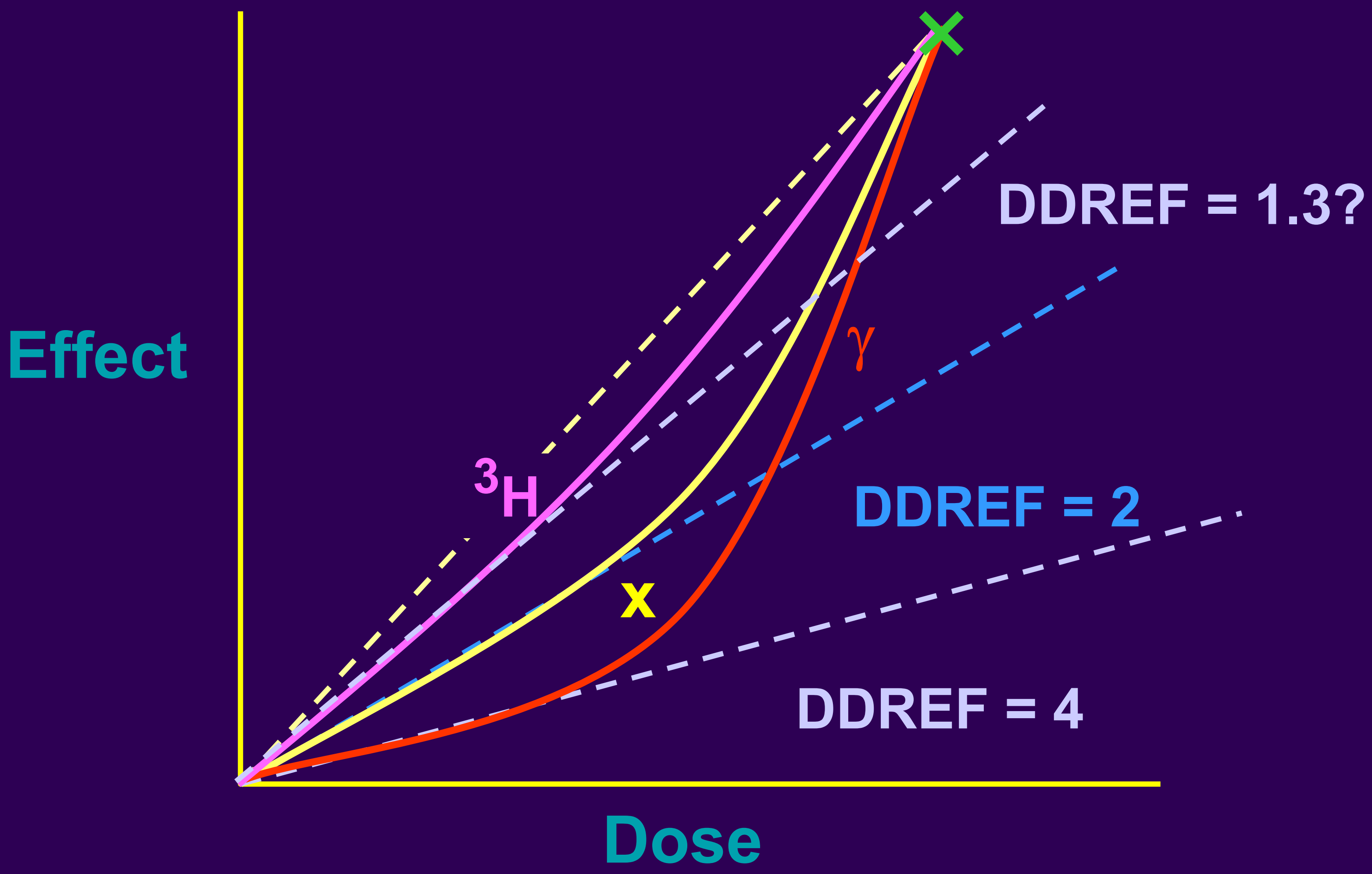
Dobson and Kwan

Rad. Res. 66:615; 1976

DDREF and RBE



DDREF and RBE



DDREF, RBE and w_R

High tritium RBEs in systems with high DDREF

DDREF of 2 for cancer in humans implies RBE of ≤ 2

More complex treatment of w_R for low LET radiations ?

- inconsistent with intended use of effective dose
- implies greater knowledge of risk at low doses than is justified?

OBT in Cardiff Bay fish

Whole body retention of tritium in rats after ingestion of freeze-dried flounder or HTO

Rat data

HTO	0.97	3d	0.03	10d
Fish OBT	0.7	3d	0.3	25d

Human					$Sv\ Bq^{-1} \times 10^{11}$
HTO	0.97	10d	0.03	40d	1.8
OBT	0.5	10d	0.5	40d	4.2
Fish OBT	0.7	10d	0.3	100d	6.1

Hodgson et al. J. Radiol. Prot. 25, 149; 2005

Conclusions

- Effective dose is a protection tool
- Metabolism of HTO understood
  OBT treated generically
- Uncertainties relatively small
- RBE ≤ DDREF ?
- Specific OBT may differ from ICRP