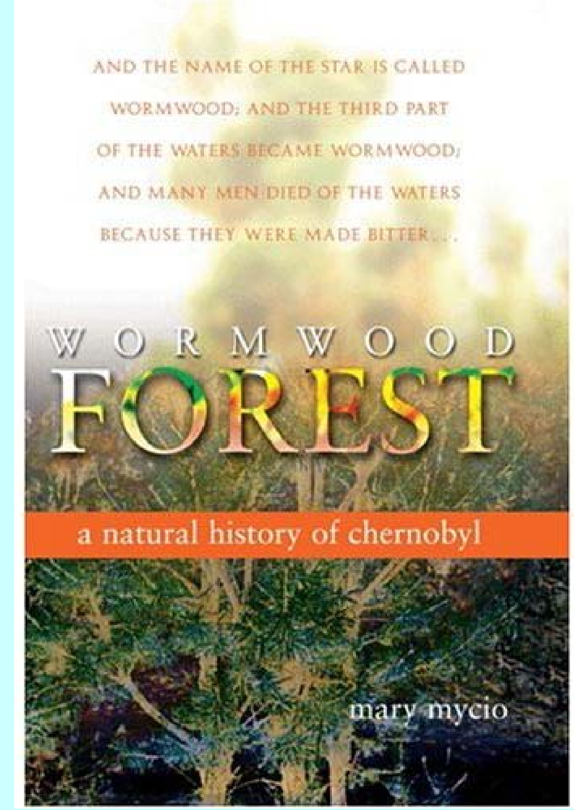
Understanding how civil nuclear technology is the safe green solution

Wade Allison, Oxford Physics

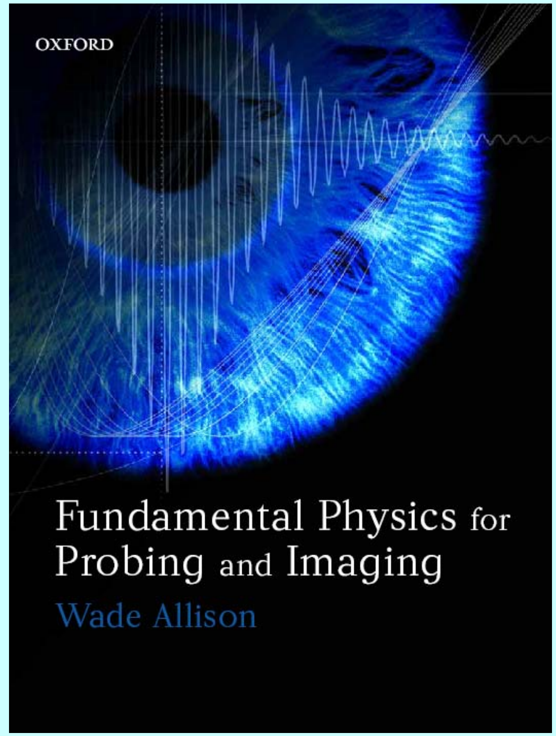
"It ain't what you don't know that counts. It's what you know that ain't so." - Will Rogers (with thanks to Jonathan Jones)

A thought-provoking popular book on Chernobyl today “Wormwood Forest” by Mary Mycio

http://www.chernobyl.in.ua/



“Fundamental Physics for Probing and Imaging” Wade Allison, OUP (2006)

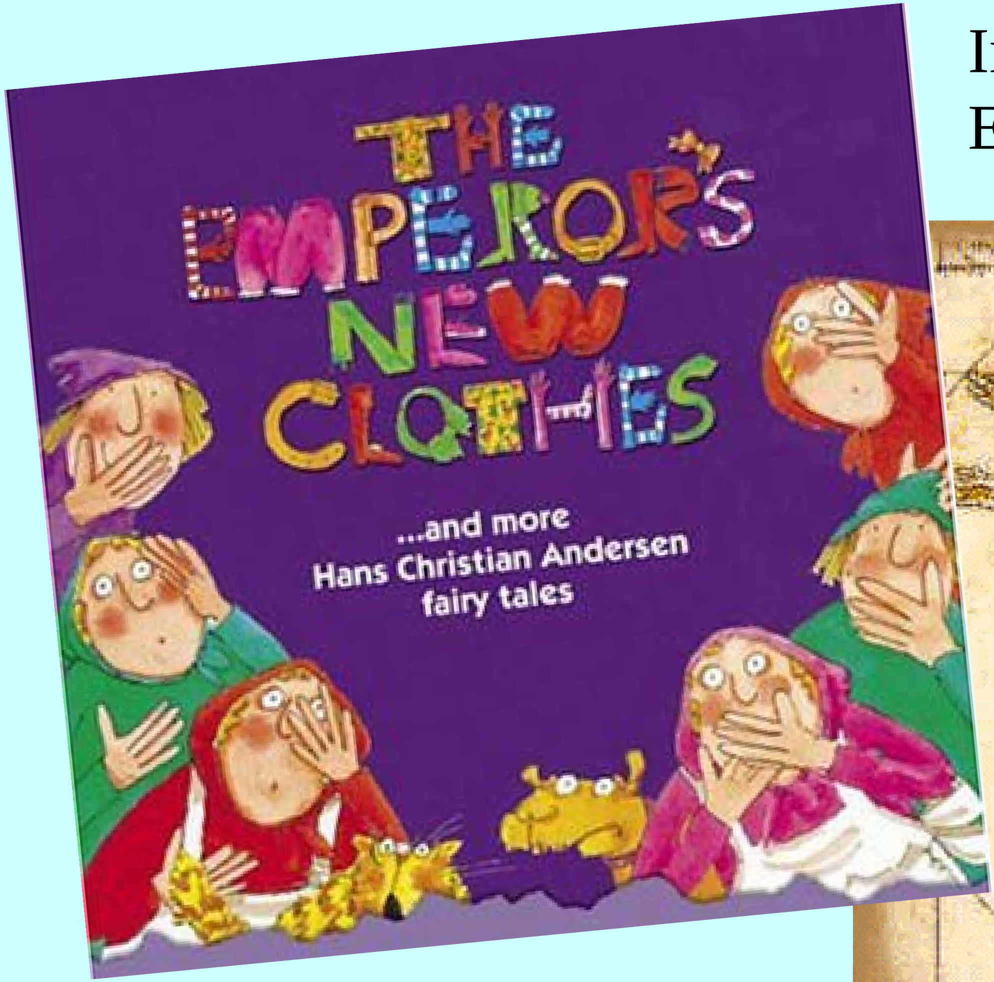


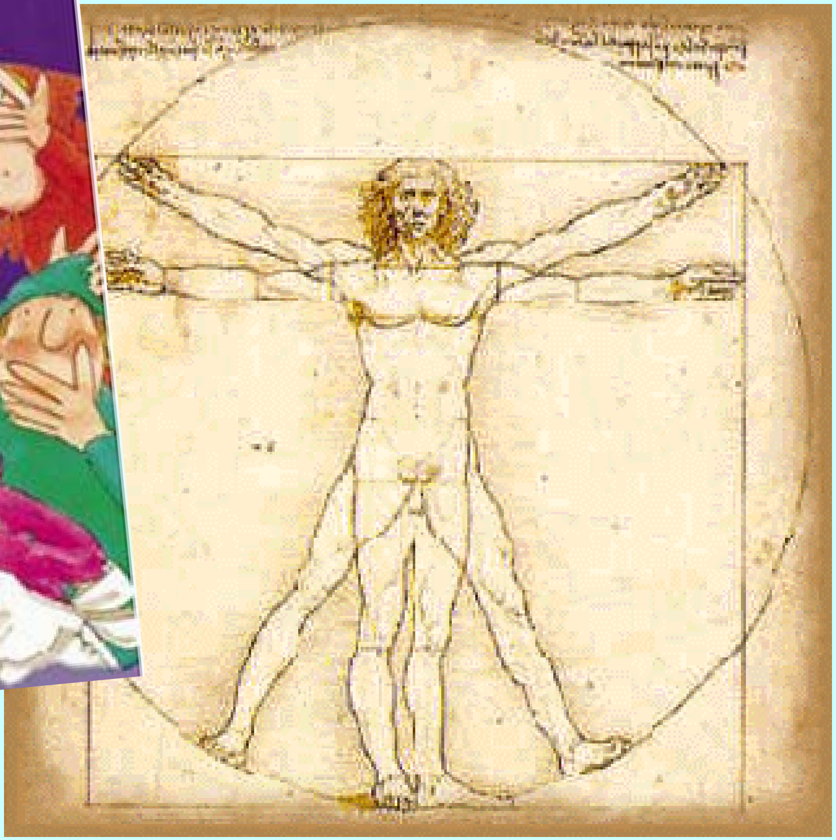
“Radiation Protection Dosimetry: a Radical Reappraisal” Jack Simmons & David Watt, Med Phys Publ (1999)

Work in progress, but for more details, slides, references, links, popular accounts, etc. see (to be updated)

http://www.physics.ac.uk/nuclearsafety

The nuclear regulatory industry
and Greenpeace have lost the plot.
In an era of climate change this Emperor has no clothes!





Plan

1. **Safety and linearity**
2. **Ionising radiation, is it different?**
3. **Case histories**
4. **How did we get here and what next?**

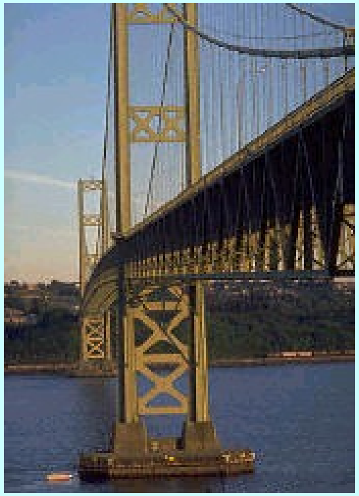
1. Safety and linearity

Thinking about safety:

- ✗ Insurance – no protection at all
- ✗ Reliance on experts – does not reassure
- ✗ Legislation – usually comes too late when problem is understood and under control
- ✗ *As low as reasonably achievable* (ALARA). *Precautionary Principle* – run away from the problem.
  Principles applied at the expense of incurring something worse! They lack balance.
- ✓ The latest threat may be the largest. Get educated, understand the balance of risks, communicate, take decisions – and survive with luck. Physicists should give leadership

Approaches to safety

- ✓ <u>Both</u> actual safety and apparent safety needed. Not to be confused. First addressed by science, second by education
- ✓ Actual safety described by a stress-damage curve
- ✓ eg a bridge.
  If well designed, small stresses give no damage at all.
  Only for stresses beyond elastic limit is there damage.

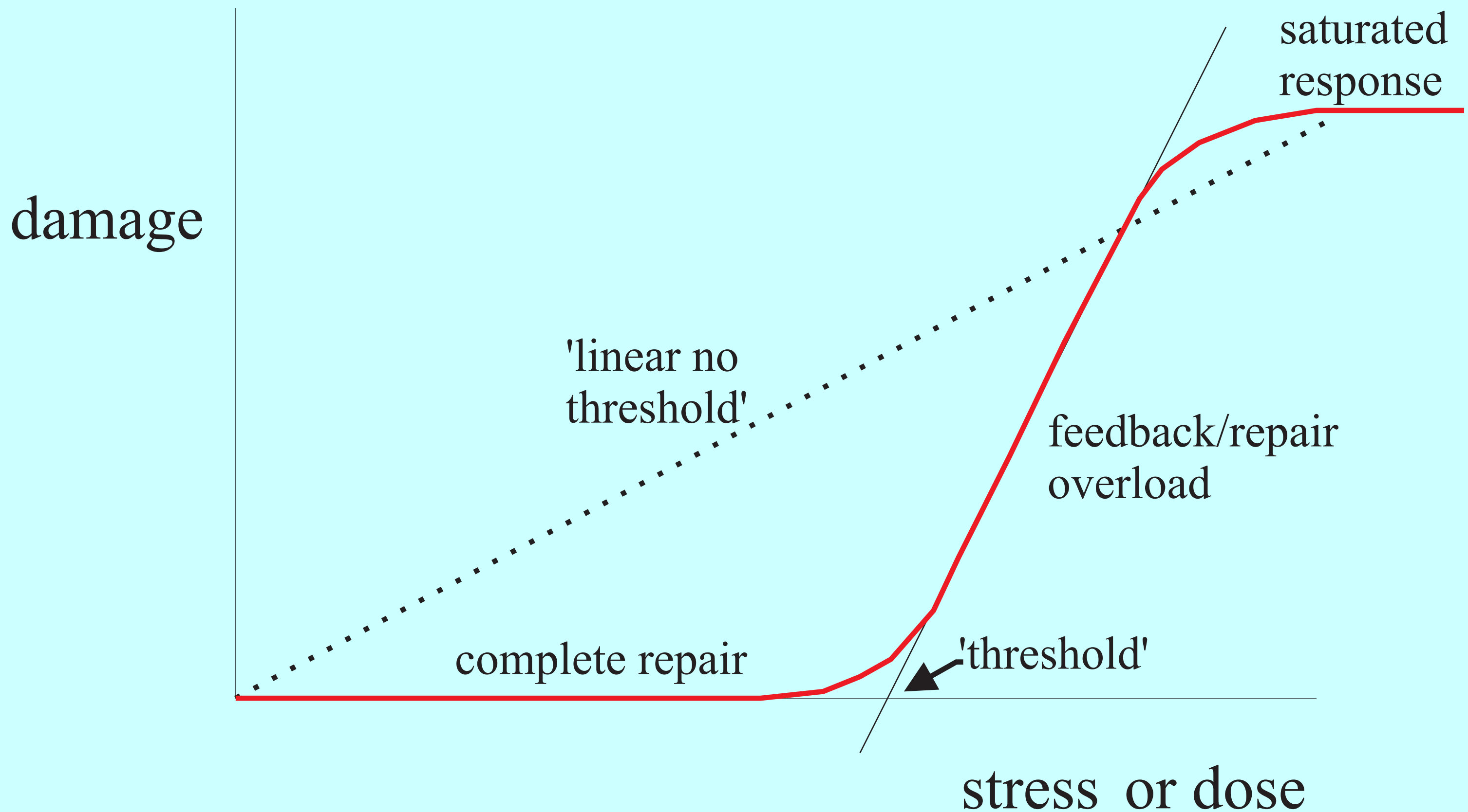


Tacoma narrows 1940

simple thoughts about stress-damage

- reversible changes – linear
  reversible strain vs. stress. No damage
- irreversible changes – non-linear
  damage vs. stress, hysteresis for example
- at low stress, response is stabilised,
  eg by repair or feedback
- at high stress, there is sharply rising failure, then saturation with total failure
- S-shaped response, eg of a well designed bridge, stabilised electronic amplifier, or a biological system

Alternatively, a naive mathematically simple linear model (LNT = linear no threshold).
But does ANY system behave like this, mechanical, electronic or biological? [Actually, no. But we need to test it for sure]



tests of linearity

- plot of damage damage against stress should be **straight** and pass through origin
- **superposition principle**: two stresses A and B separated in **time** should produce the same total damage as the stress A+B at the same time
- two stresses A and B separated in **location** should produce the same total damage as the stress A+B at the same location
- the **slope** of the damage/stress plot due to A should be independent of whether stress B is present or not, and vice versa

correction and feedback

- natural simplicity ≠ mathematical simplicity
- biological protection against regular hazards has evolved using feedback and repair
- such feedback takes time, so does repair
- over shorter times the dose integrates.
  If this exceeds a threshold, damage ensues
- need to know a) threshold,
  b) repair time,
  c) confirm with data in the real world,
  d) check that there is a repair mechanism, at least in outline

a simple example – blood loss

Capacity of human body about 5 litres.

Threshold? >½ litre.

Repair time? < 56 days for complete recovery.

Loss of 5 litres for 1 person = death

Loss of 5 litres between 10 people = blood donation

Loss of 5 litres for 1 person over 18 months = blood donation

If blood were not replaced (like gold), every 5 litres = 1 death. But blood is replaced, so such calculations fail.

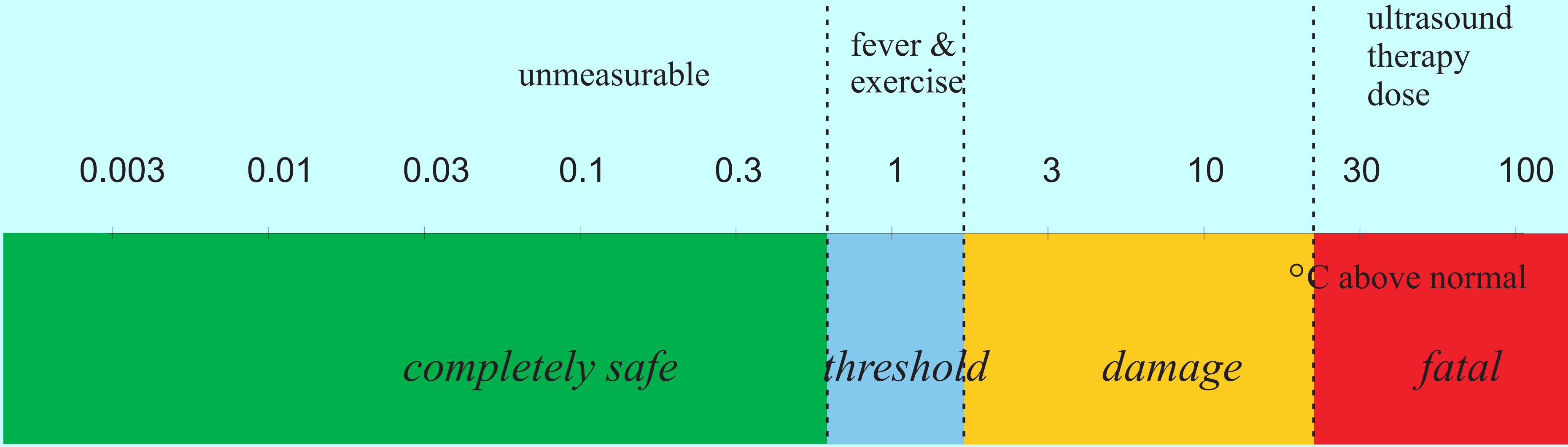
More simple examples

laceration.

- modest laceration, 10 days and then complete recovery
- intermediate laceration, leaves scar tissue but full function
- severe laceration, permanent loss of function – incapacity – even death

tissue overheating...

a) tissue heated above normal temperature (35°C)

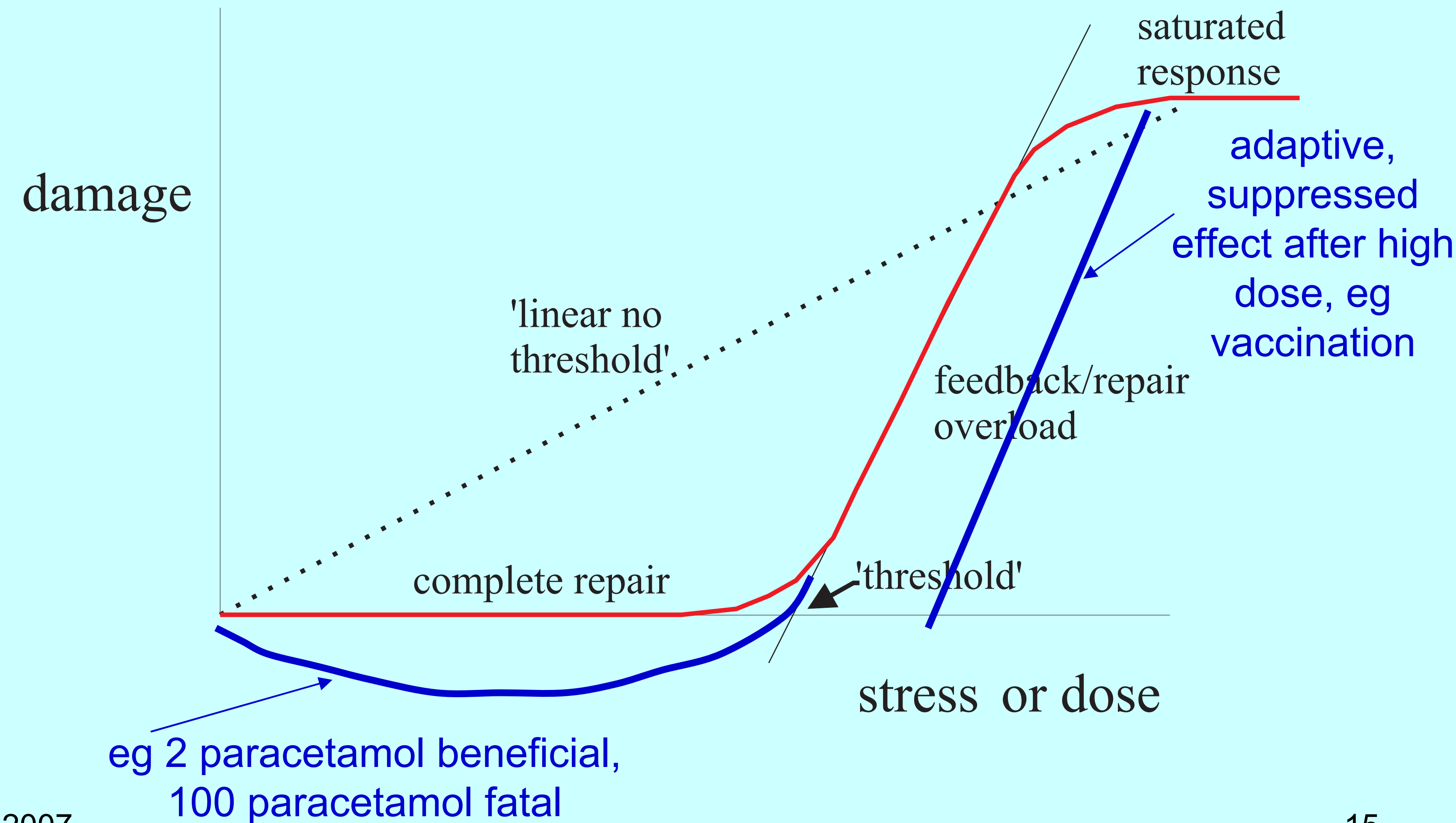


- body has an efficient cooling mechanism with large dynamic range – by blood flow and evaporation
- body temp changes of 1-2 degs C?
  Just mild fever or exercise and no lasting damage
- higher temp? damage.
- At +20C (55/56C) living tissue melts, cooks, dies.
- as with blood supply, nature seems to have evolved about a factor ten between damage threshold and fatal damage

adaptive/beneficial response?

- Some biological systems are even cleverer. They adjust the stress-response as a result of experience
- eg Jenner and vaccination. Low level stimulation generates improved immunity to later larger stresses
- illustrative example: success of plastic surgery and burns in Northern Ireland in the 1970/80s. The hospitals developed the skills – the best place to go!
- additionally, drugs often follow a response with positive response at low levels and toxic effects at high dose – example paracetamol

examples of adaptive/beneficial effects of low level doses



2. Ionising radiation, is it different?

- A question for experimental data, not dogma
- Does radiation damage pass the linearity tests?
- Has evolution given correction/feedback mechanisms that protect life?
- If so, what are the threshold(s), timescale(s) and mechanism(s) that characterise this response?
- Are there adaptive or beneficial effects?

This question is important because

- we need the massive zero-carbon contribution of civil nuclear power (to add to renewables)
- the “professional bodies” are committed to LNT, seemingly irrevocably. The anti-s are entrenched. Result: punitively low safety levels
- the “nuclear waste problem” and costs ride on these unrealistic safety levels (factor ~500 and more)
- the population and media (and many scientists and doctors) are ill-informed or intimidated

Traditional approach based on linear model (LNT)

“Whether there is a threshold dose below which no effect is produced is still open to doubt, but on present knowledge it seems unlikely that any such threshold exists. It must, therefore, be assumed that even very small doses produce some small risk of cancer and, if the individual is not beyond reproductive age, some risk of causing subsequent offspring to have a genetic defect.”

From ‘**Epidemiological evidence of effects of small doses of ionising radiation with a note on the causation of clusters of childhood leukaemia’** R Doll 1993 *J. Radiol. Prot.* **13** 233-241

This is not logical. Resolution should be determined by data not by preconceptions!

NB Even the Int Comm for Radiological Prot has now reduced the risk estimate for inheritable effects by a factor 8 (2007)

Aside: units

- gray (Gy) = radiation energy absorbed in joules per kg
- sievert (Sv) = radiation dose with equivalent damage to 1Gy of X-ray or electrons
- relative biological equivalence RBE = *w*, damage (Sv) = *w* * absorbed energy (Gy). Note: slow, highly charged particles each deposit more energy (LET) compared with an electron *AND* have a large *w*
- natural average background rate in UK: 2.7mSv per year (7.5 in Cornwall)
- Single doses:
  CTscan ~5mSv, fatal dose ~5500mSv

Dangerously mistaken safety ideas – Collective Dose

http://www-pub.iaea.org/MTCD/publications/PDF/SS-115-Web/Pub996_web-1a.pdf *preamble p. 6*

IAEA Safety Standards 115

"Basic Principles

The total impact of the radiation exposure due to a given practice or source depends on the number of individuals exposed and on the doses they receive. The collective dose, defined as the summation of the products of the mean dose in the various groups of exposed people and the number of individuals in each group, may therefore be used to characterize the radiation impact of a practice or source. The unit of collective dose is the man-sievert (man-Sv)."

Beware the collective dose!

If such a quantity is defined, people start to use it

- although nothing depends on it.

Blood loss? Collective dose? eg 5 man-litres?

- to 1 man, a fatality
- to 10 men, just 10 regular blood donations.

or paracetamol tablets: 80 in 1 man = death, in 40 men = relief

non-linearity of dose-response curve

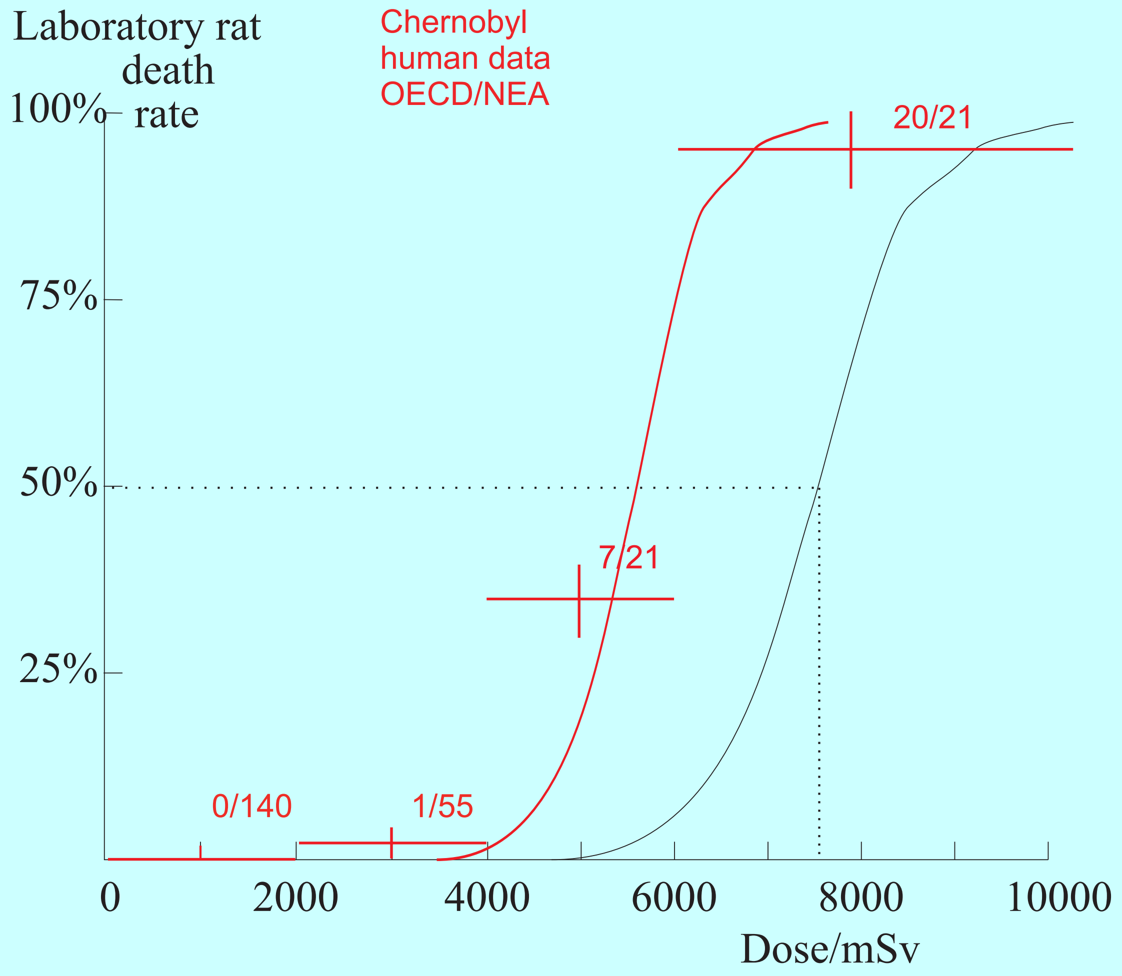
S-shaped curve at high dose

Chernobyl data

238 acute cases with 28 early deaths

By 1998 a further 11 had died of a variety of causes

Source OECD/NEA report 2003 (web)



Dispersion in time – test of superposition principle

Effectiveness of radiotherapy depends on being administered in 20/30 'fractions', a sequence of doses each separated by 24hr recovery periods.

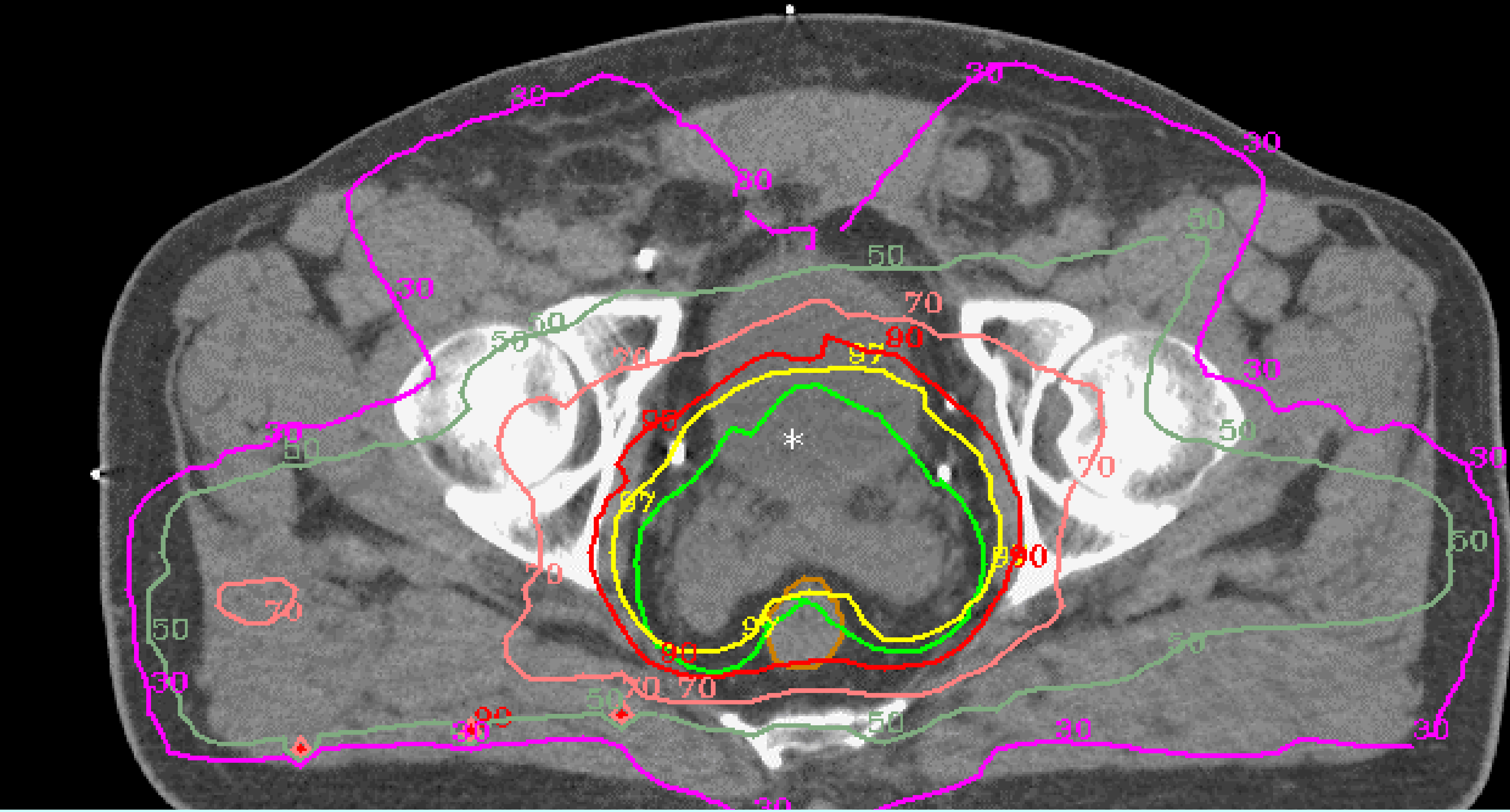
Works by the iterative application of non-linear response curve – involves ~20th power of S-curve.

Factor ~2 between the dose to tumour and healthy tissue.

Healthy tissue just recovers (many times).

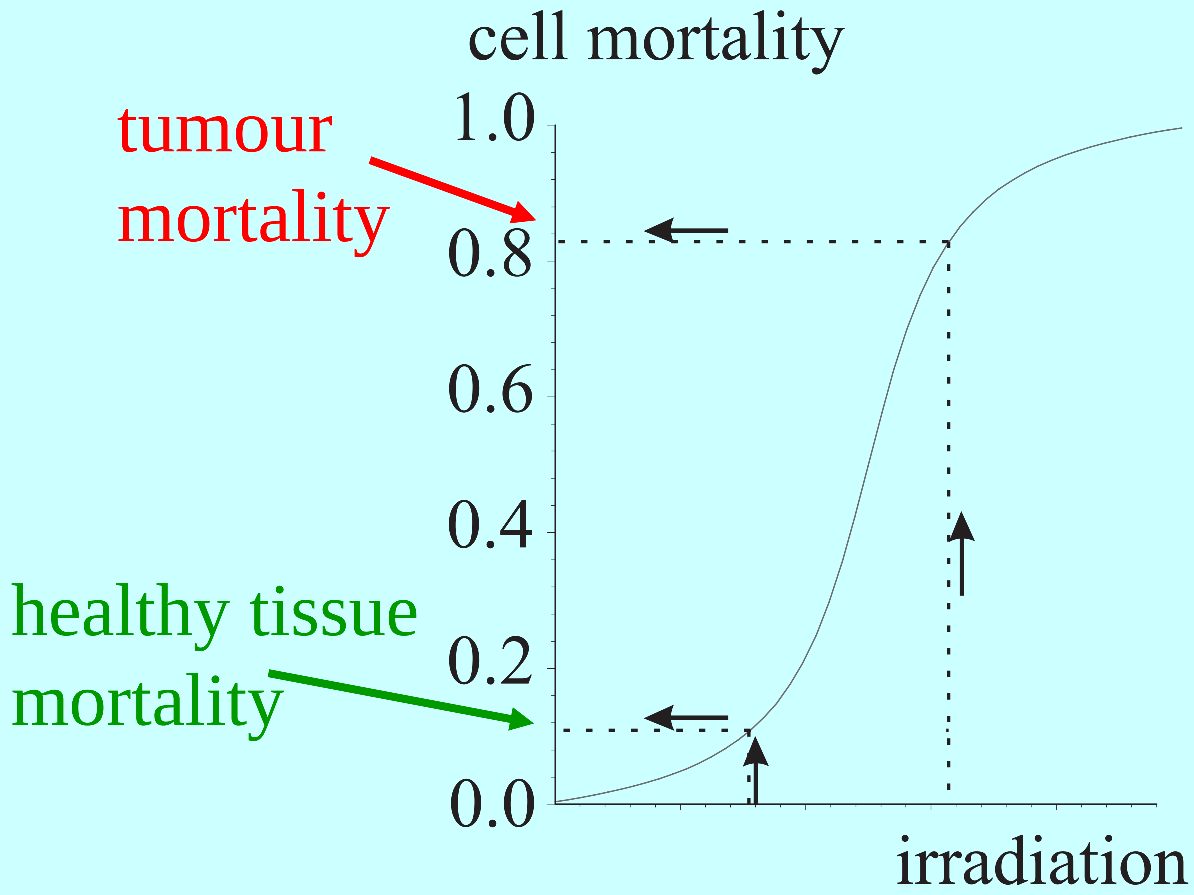
Tumour tissue does not recover, hopefully.

Public accepts intense radiation in radiotherapy. Its success requires this non-linearity



Example: Percentage contours of maximum dose to treatment of prostate(*)
100% = 3000 mSv per fraction, repeated about 20/30 times daily (example only)
so healthy tissue suffers perhaps 1500 mSv or more, also repeated 20/30 times.
Result: frequent success but much scar tissue and poor protracted patient experience

Qualitative illustration. For a factor 2 in dose, we can get a factor 8 in survival - because of S-shaped curve



Summary:
Current radiotherapy only works at all <u>because of</u> the non-linearity

Dispersion in location – test of superposition principle

Compare damage due to same energy deposited by
a) many lightly ionising with
b) few heavily ionising tracks.

a) Delocalised irradiation (e, mip,γ) single DNA hits, → optimised repair, less damage

b) Localised irradiation (non rel. protons, fission fragments, low energy n) multiple DNA hits, → poor repair, more damage.

Factor up to 20

Table 6.4 Some values of the radiation weighting factor w_R for different kinds of radiation.

Radiation	Energy	w_R
X-rays and γ-rays	any	1
Electrons	any	1
Muons and muons	any	1
Protons	>2MeV	5
Alpha/light ions	any	20
Fission fragments	any	20
Neutrons	<10 keV	5
Neutrons	10–100 keV	10
Neutrons	0.2–2 MeV	20
Neutrons	2–20 MeV	10
Neutrons	>20 MeV	5

$$Sv = w_R \, Gy$$

Test of linearity: slope of dose-damage

- Radon data, including effect of smoking
- Radon, radioactive noble gas inhaled and absorbed in lung, alpha-decays with high *w*,
- radon in homes eg Cornwall.. and other such places (Czechoslovakia, Massif Central, China, India,..) ~3-5 times natural radiation levels, 7.5mSv per year
- Do people in Cornwall and such places have an extra risk of lung cancer?
- No! Consider study of data from all such places in Europe combined

Percentage of homes with Radon above the “action level” 200 Bq m^{-3}

Darkest areas > 30%

From HPA website

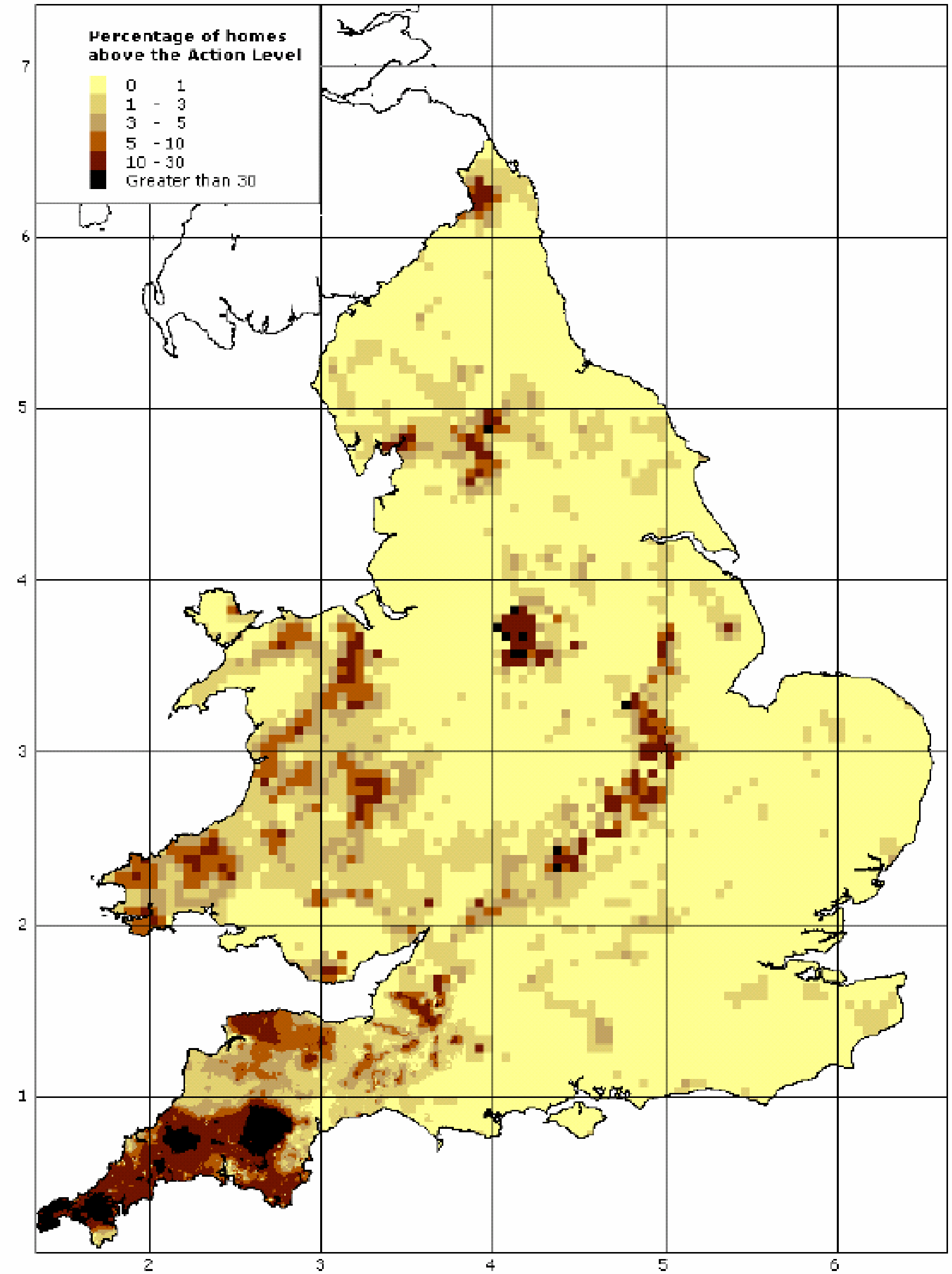


Figure 5 Overall map of radon Affected Area in England and Wales (axis numbers are the 100 km co-ordinates of the Ordnance Survey National Grid)

Cite this article as: BMJ, doi:10.1136/bmj.38308.477650.63 (published 21 December 2004)

Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies

S Darby, D Hill, A Auvinen, J M Barros-Dios, H Baysson, F Bochicchio, H Deo, R Falk, F Forastiere, M Hakama, I Heid, L Kreienbrock, M Kreuzer, F Lagarde, I Mäkeläinen, C Muirhead, W Oberaigner, G Pershagen, A Ruano-Ravina, E Ruosteenoja, A Schaffrath Rosario, M Tirmarche, L Tomášek, E Whitley, H E Wichmann, R Doll

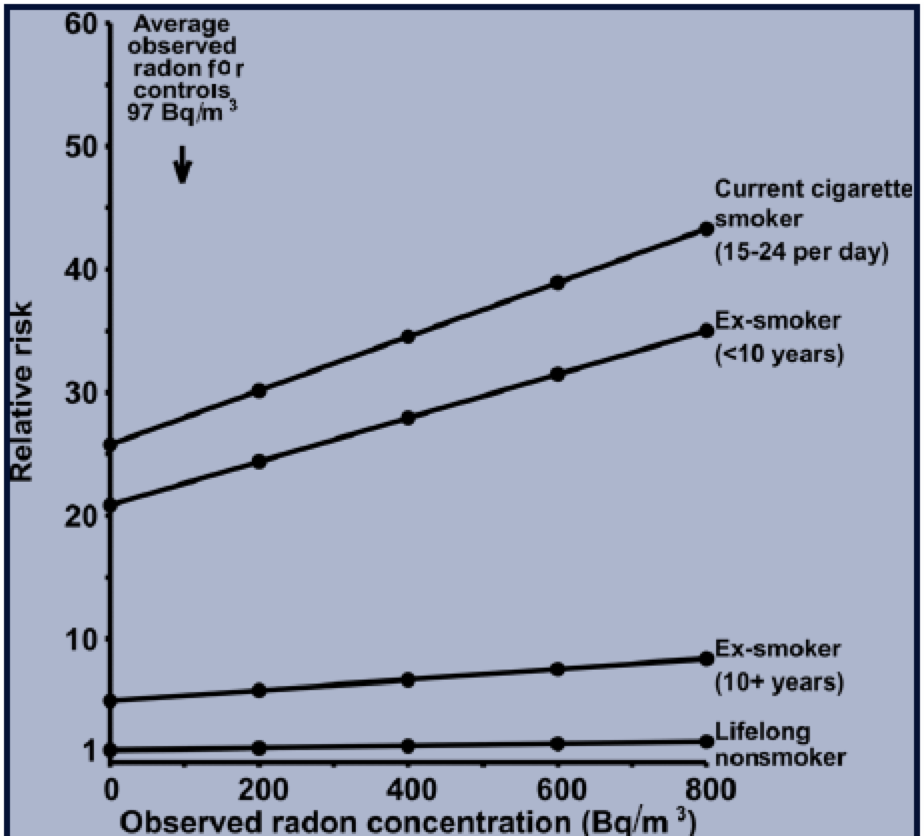


Figure 5. Risk of lung cancer relative to that of lifelong nonsmokers with no radon exposure by the observed radon concentration. See table 28 for the methodological details.

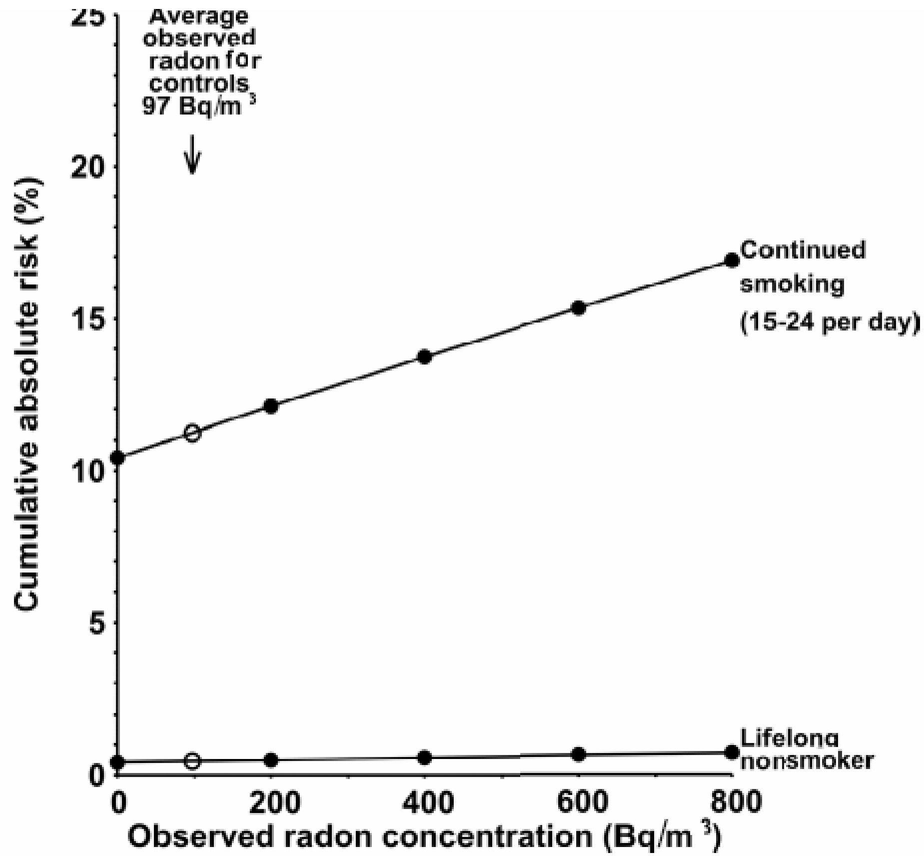


Figure 6. Cumulative risk of death from lung cancer by 75 years of age for various smoking histories by the observed radon concentration. (see table 29 for the methodological details.)

some simple remarks

- statistics were 7148 cases of lung cancer and 14208 controls, so statistical errors not much smaller than 1%
- with two causes the most general linear relationship
  prob. of cancer by 75 = A + B×radon + C×smoking
  with *smoking* = 1 for smokers (15-24 per day)
  and 0 for non-smokers
- *A* = 0.4% chance of lung cancer, without radon or smoking
- chance of cancer due to smoking (no radon) is
  C = 10% (15-24 per day)
- in any linear model all lines plotted against radon (*B*) must have the same slope
- This is not true

Observed radon concentration [a]	Relative risk [b]	95% CI
Current cigarette smokers (15–24 per day)		
0 Bq/m³	25.8	–
100 Bq/m³	27.9	26.5–29.8
200 Bq/m³	30.1	27.3–33.9
400 Bq/m³	34.4	28.9–42.1
800 Bq/m³	43.1	32.0–58.3
Ex-smokers (<10 years)		
0 Bq/m³	20.8	–
100 Bq/m³	22.6	21.5–24.1
200 Bq/m³	24.3	22.1–27.4
400 Bq/m³	27.8	23.3–34.0
800 Bq/m³	34.8	25.8–47.2
Ex-smokers (≥10 years)		
0 Bq/m³	5.0	–
100 Bq/m³	5.4	5.1–5.8
200 Bq/m³	5.8	5.3–6.6
400 Bq/m³	6.7	5.6–8.1
800 Bq/m³	8.3	6.2–11.3
Lifelong nonsmokers		
0 Bq/m³	1.0	–
100 Bq/m³	1.1	1.0–1.2
200 Bq/m³	1.2	1.1–1.3
400 Bq/m³	1.3	1.1–1.6
800 Bq/m³	1.7	1.2–2.3

[a] Observed radon concentration for each address in the 30-year period ending 5 years prior to the index date weighted according to the length of time that the person lived there.
[b] Risk of lung cancer relative to lifelong nonsmokers with 0 Bq/m³ radon concentration. Risks for smokers of 15–24 cigarettes per day, ex-smok-

All consistent with 1.2 and no radon effect at 95% CL

(95% CI = 95% confindence interval)

Age	Lifelong nonsmokers		Continuing smokers of 15–24 cigarettes per day	
	Cumulative risk (%)	95% CI	Cumulative risk (%)	95% CI
Observed radon concentration of 0 Bq/m³				
75 years	0.42	–	10.43	–
80 years	0.59	–	14.26	–
85 years	0.81	–	19.06	–
Observed radon concentration of 100 Bq/m³				
75 years	0.46	0.42–0.49	11.25	10.45–11.97
80 years	0.64	0.59–0.68	15.36	14.30–16.32
85 years	0.88	0.81–0.94	20.48	19.11–21.72
Observed radon concentration of 200 Bq/m³				
	0.49	0.43–0.56	12.07	10.48–13.49
	0.69	0.59–0.78	16.45	14.34–18.33
	0.95	0.81–1.06	21.88	19.16–24.29
oncentration of 400 Bq/m³				
	0.56	0.43–0.69	13.68	10.54–16.45
	0.79	0.60–0.96	18.58	14.42–22.21
	1.08	0.82–1.32	24.61	19.26–29.18
Observed radon concentration of 800 Bq/m³				
75 years	0.71	0.43–0.95	16.81	10.66–22.06
80 years	0.98	0.60–1.33	22.69	14.58–29.42
85 years	1.35	0.83–1.82	29.78	19.47–38.04

[a] Absolute risk of lung cancer for the lifelong nonsmokers taken from a prospective study of the American Cancer Society. The relative risk of lung cancer for continuing smokers of 15–24 cigarettes per day was assumed to be equal to the overall estimates in the present study (see table 3). The

Data show

1. Superposition Principle violated and linearity fails
2. For non-smokers there is no increased incidence of lung cancer at all
3. At this level radon is not a hazard. Money spent on regulating radon in homes would be better spent persuading people not to smoke.

The conclusions of Darby et al:

1. "The dose-response relation seemed to be linear, with no evidence of a threshold dose."

   UNTRUE

2. **"Absolute hazard of radon for smokers and non-smokers.**
   If the proportionate increases in risk per unit exposure are approximately independent of smoking history then, as lung cancer is much commoner in cigarette smokers than in lifelong non-smokers, radon poses a much greater absolute hazard to cigarette smokers, and to recent ex-smokers, than to lifelong non-smokers."

   CONFUSED DENIAL OF LINEARITY

We may conclude that the data have failed every linearity test we have applied.

ICRP respond (the Chairman to me, 27/4/07)

- the LNT Model is only a model – “it does not describe mechanisms”
  Sure to make inconsistencies (my comment)
- ICRP cannot see how to work with anything more complicated.
  A case of weak maths! (my comment)
- the LNT Model should not be abused.
  By encouraging the use of Collective Dose? Because it fails? (my queries)

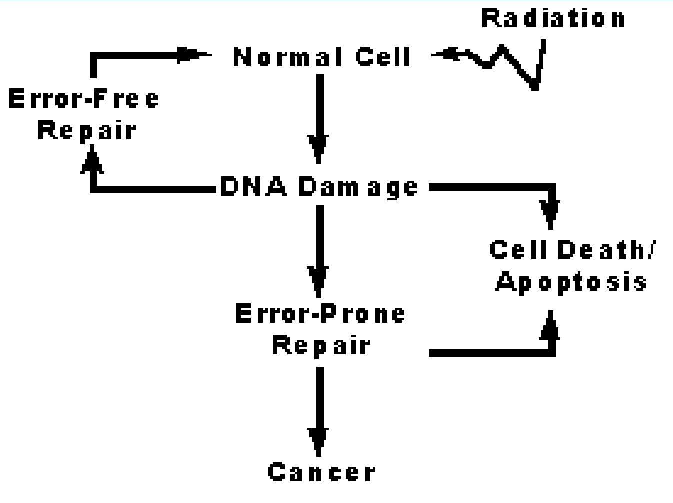
3. Case histories, the data

- Knowledge from test tube and animal experiments
- Hiroshima and Nagasaki
- Chernobyl
- Evidence for adaptive or beneficial effects

Knowledge from test tube and animal experiments

- Radiation generates broadband chemical and biological disruption.
- Stimulated by the radiation environment, cell biology has evolved effective defences:

  a) Back up: redundancy by multiple DNA copies, depends on phase of cell cycle, as expected
  b) Repair: DNA single strand breaks repaired by enzymes (hours)
  c) Programmed cell replacement (days/wks) removes most DNA multiple strand breaks by removing dysfunctional cells (apoptosis).
- Initial damage depends on oxygen, water (~×2)



The effect of these repair mechanisms is non-linear in principle. *n* breaks ~ *n*th power dependence.

Failed repair of multiple breaks leaves “scar tissue” [eg damaged chromosomes].

These record long-term radiation dose (with non-linear calibration as expected).

Hiroshima and Nagasaki survivors

- largest experiment,
- longest experiment, data for 60 years
- 429,000 population, >103,000 died in 4 months
- since 1950 health records of 283,000 followed
- dose for 86,611 modelled (mean 160mSv), checked with ESR & chromosome counts
- control sample of 25,580 outside city
- leukaemia and solid cancers recorded, (data on pregnancies, etc also)

Table 6.7 An analysis of leukaemia and solid cancer deaths amongst the survivors of Hiroshima and Nagasaki between 1950 and 1990. The figures in brackets give the number predicted from the control sample. The excess gives the extra risk due to the radiation. This is shown per 10,000 people with estimated statistical errors. [Data from www.eh.doe.gov/radiation/workshop2005/presentations/neta.ppt]

Dose range (mSv)	Number	Leukaemia deaths	Extra risk per 10^4	Number	Cancer deaths	Extra risk per 10^4
0–5	35458	73(64)	3 ± 3	38507	4270(4268)	0 ± 20
5–100	32915	59(62)	-1 ± 3	29960	3387(3343)	15 ± 20
100–200	5613	11(11)	0 ± 10	5949	732(691)	70 ± 45
200–500	6342	27(12)	24 ± 10	6380	815(716)	155 ± 45
500–1000	3425	23(7)	46 ± 16	3426	378(262)	340 ± 60
1000–2000	1914	26(4)	120 ± 30	1764	326(213)	640 ± 100
>2000	905	30(2)	310 ± 60	625	114(58)	900 ± 170

Green box: Radiation dose less than 100mSv gives no increased risk of cancer death over 40 years at level of 1 in 1000 -- that is a change in average life expectancy of less than 2 weeks.
Dashed box: For leukaemia the acceptable dose is 200mSv.

Hiroshima and Nagasaki conclusions

If a over 40 years of less than 1 or 2 in 1000 is tolerable (2-4 weeks average life expectancy, a hundred times smaller than that due to smoking), then

- in the case of leukaemia a radiation dose of 200 mSv is harmless
- in the case of solid cancers a dose of 100 mSv is harmless
- studies of other abnormalities show no significant effects at these low doses (not discussed here).

Chernobyl – causes & local victims

- cause 1: poor reactor design and management – much better now
- cause 2: effects of ionising radiation
- cause 3: failure of communication, health provision and social structure. Socioeconomic collapse and panic. End of USSR

- acute victims 28 deaths
- thyroid cancer from ^{131}I (8 day), especially in children. 3 deaths but many non-fatal cases of cancer (1036). Avoidable, iodine tablets should have been provided
- Cancer/leukaemia in population & recovery operation workers (less than 150 in 40 years, next slide)
- Inheritable effects? None confirmed.

Solid cancers and leukaemia and Chernobyl

Table 6.12 Distribution of estimated total effective doses received by the populations of contaminated areas (1986–1995) excluding dose to thyroid [Source: table 10 *www.nea.fr/html/rp/reports/2003/nea3508-chernobyl.pdf.*]

Dose mGy	Belarus	Number Russia	Ukraine
<1	133053	155301	
<5	1163490	1253130	330900
<20	439620	474176	807900
<50	113789	82876	148700
<100	25065	14580	7700
<200	5105	2979	400
>200	790	333	

Calculated from Hiroshima and Nagasaki survivor data

Using extra risk of death in 40 years using data per 10^4 from H & N survivors

Number of extra deaths in contaminated areas:

cancers		leukaemia	
-	0	-	0
-	0	-	0
-	0	-	0
-	0	-	0
-	0	-	0
→ $*70*10^{-4}$	= 60	-	0
→ $*155*10^{-4}$	= 18	$*24*10^{-4}$	= 3

approx calculated total deaths 78 3

Chernobyl conclusions

- 28(acute)+3(thyroid)+c.78(solid cancers)+c.3(leukaemia). Crude but unbiassed estimate. Anway less than 200 deaths
- collapse of society and then USSR
- flora and fauna are living better
with no humans and with radioactivity than
with humans and no radioactivity (Mary Mycio)
- Surprisingly, not a very serious accident!
(see next slide)

Some chemical, radiation and other disasters

Date	Agent	Occasion	Deaths, lower bound
Dec 2004	Natural	Tsunami	230,000 +
Aug 1945	Nuclear	Hiroshima & Nagasaki	100,000 +
Feb 1945	Chemical	Bombing Dresden	35,000 +
Dec 1984	Chemical	Bhopal	3,800 +
Sept 2001	Terrorism	World Trade Center	2,996
Aug 2005	Natural	Katrina	900 +
April 1986	Nuclear	Chernobyl	112 +
July 1976	Chemical	Seveso	0 +
March 1979	Nuclear	Three Mile Island	0

Evidence for adaptive effects?

DNA repair mechanism exercised by exposure to low dose rates?
If then exposed to medium doses cells/organisms/tissue sustain less than normal damage?
Like a vaccination?

There is much lab data to support this, eg http://www.radscihealth.org/rsh/ see paper by **R. E. J. Mitchel and D. R Boreham (2000)** .

Is there any high statistics human data?

Look at this…

Journal of American Physicians and Surgeons Volume 9 Number 1 Spring 2004

Is Chronic Radiation an Effective Prophylaxis Against Cancer?

W.L. Chen, Y.C. Luan, M.C. Shieh, S.T. Chen, H.T. Kung, K.L. Soong, Y.C. Yeh, T.S. Chou, S.H. Mong, J.T. Wu, C.P. Sun,W.P. Deng,M.F.Wu, M.L. Shen

Summary An extraordinary incident occurred 20 years ago in Taiwan. Recycled steel, accidentally contaminated with cobalt-60 (half-life: 5.3 y), was formed into construction steel for more than 180 buildings, which 10,000 persons occupied for 9 to 20 years. They unknowingly received radiation doses that averaged 0.4 Sv, a ‘collective dose’ of 4,000 person-Sv.

Table 2. Natural, Predicted, and Observed 20-Year Results

Natural (expected) cancer deaths	Natural (expected) congenital malformations	ICRP model predicted cancer deaths	ICRP model predicted congenital malformations	Observed cancer deaths	Observed congenital malformations
232	46	302	67	7	3
Includes 4-5 leukemia deaths	All congenital diseases	232 natural plus 70 caused by radiation	46 natural plus 21 caused by radiation	3% of the general public cancer death rate	6.5% of the general public congenital disease rate

W L Chen is Director, Department of Medical Radiation Technology, National Yang-Ming University; Head, Radiation Protection Department of AEC; and former Head, Health Physics Division of INER.

Y C Luan is Senior Scientist and Manager of Radiation Protection, NUSTA; consultant to NBC Society; former Manager, Radioactive Waste Management Plant; etc etc

see http://www.jpands.org/vol9no1/chen.pdf

4. How did we get here and what next?

Attitude of extreme caution accepted after 1945 during the Cold War because:

- politically expedient that the public was frightened – encouraging fear of nuclear radiation and nuclear weapons. (forbears of "WMD", "45 minutes")
- there were no good long-term data on health effects
- cell biology was less well understood
- there was less urgency to press the question, climate change was not on the agenda, carbon-based energy seemed a reasonable choice
- public is easily intimidated by the invisible if not reassured

General conclusions (within factors of 2)

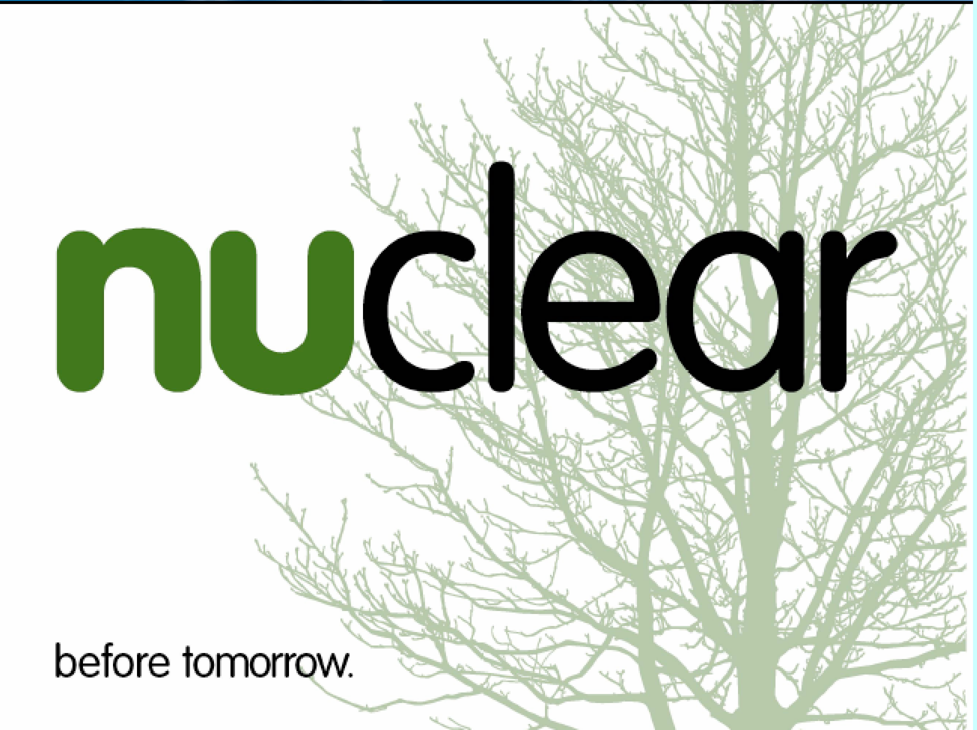
- Radiation is like other hazards – life has defences
- Low-dose repair time is on the scale of a day or so
- Doses below threshold (100mSv) cause no damage.
- Above threshold, permanent damage (scar tissue) results. Such scar tissue may remain benign, or later become malignant, like other scars
- A single dose of 100mSv or a dose rate of 100mSv in any week should be allowed (5000mSv/yr).
  Current legal limits: Public: 1 mSv/year;
  employees working with ionising radiation: 20 mSv/yr.
  Note: in radiotherapy healthy tissue receives up to 1500mSv/day repeatedly, with generation of scar tissue.
- **This is 500,000Xcurrent legal limit & 100Xsuggested limit**

Message for public understanding...

- Climate change is a big threat.
  Prepare to take risks for the health of the planet,
  as in radiotherapy you do for personal health.
- Dangers from nuclear radiation are moderate and manageable.
- If safety regulations were sensible, nuclear costs would be far far lower.
- Civil nuclear power - and zero-carbon renewables - should all be adopted.
- Society should be educated, co-ordinated and informed - ready to minimise any accident like Chernobyl. Not a big deal

And

- Free solid-state radiation meters for school children. Let them learn to ‘see’ radiation, but without dramatic JAWS-like clicking!
- Free iodine tablets ready in every home
- As unreasoned fear recedes
  - Terrorists? De-value the fear of a dirty bomb, the currency of their threats
  - Nuclear weapons? Still a problem, like biological weapons
  - Waste? Not a problem. Manage, store, bury



Campaign: "NUCLEAR before tomorrow"

1. to reassure the public of nuclear acceptability, in general as in medicine
2. to encourage civil nuclear power for zero-carbon electricity, de-salination and hydrogen production
3. to encourage irradiation of food to reduce food wastage and refrigeration energy
4. to end blackmail by the nuclear waste "problem", by military fear of irradiation, by Trident, etc
5. to accept continued surveillance for weapons-grade enrichment plant