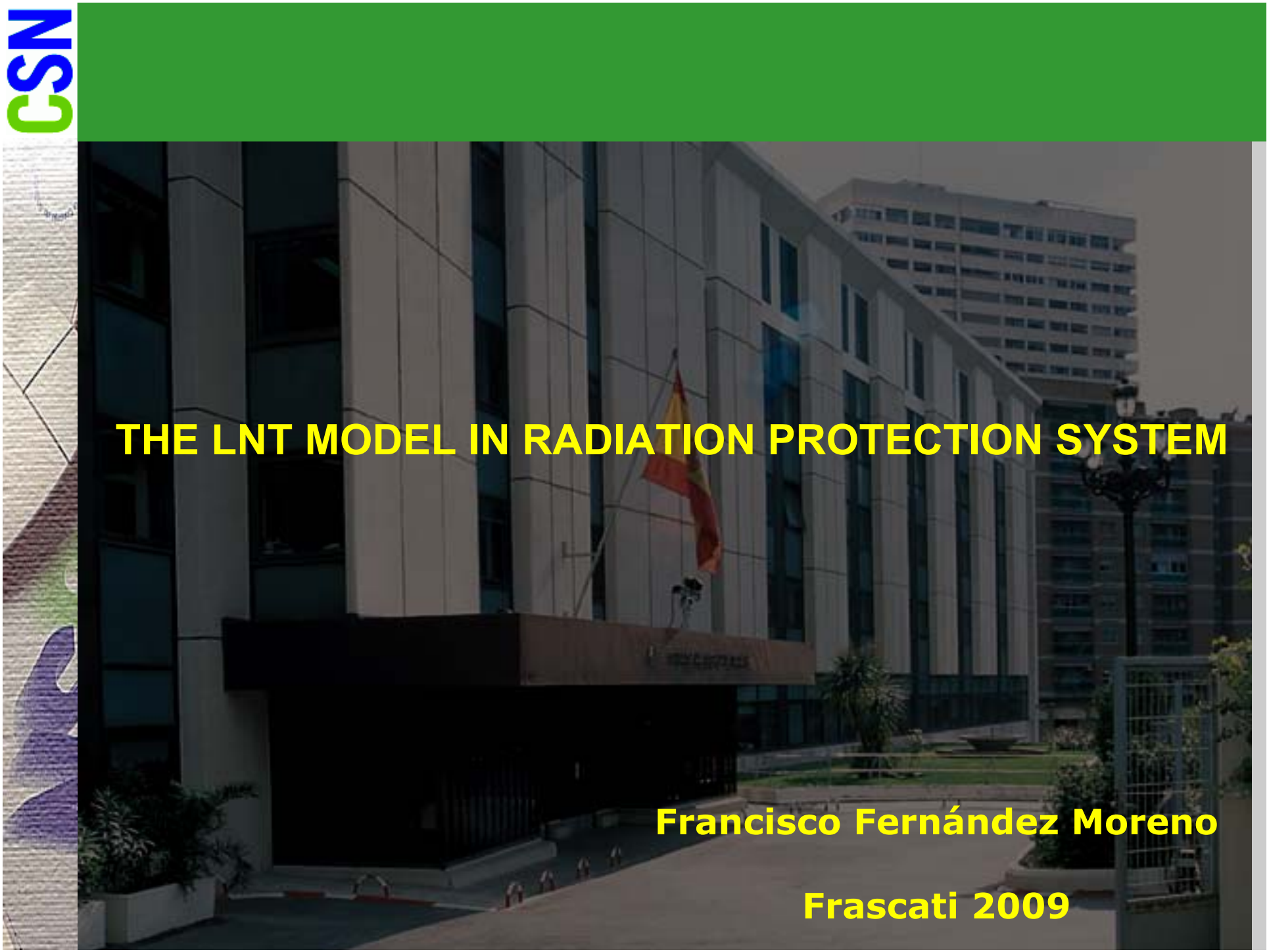
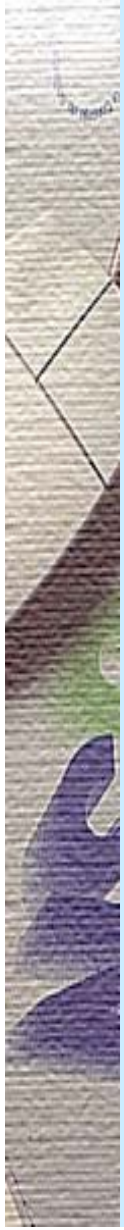


THE LNT MODEL IN RADIATION PROTECTION SYSTEM

Francisco Fernández Moreno

Frascati 2009



- Introduction
- Biological Effects and Repair Processes
- The scientific bases of radioprotection
- The linear-non threshold hypothesis
- Conclusions

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RADIATION PROTECTION

DEFINITION

Radiation protection is a technical and scientific discipline aimed at protecting humans and the environment against the harmful effects of ionizing radiation, without necessarily limiting the beneficial practices giving rise to radiation exposure.

Diapositiva 3

f1 ffmr; 19/05/2009

BIOLOGICAL EFFECTS OF IONIZING RADIATION

Shortly after the discovery of X-rays (1895), it became apparent that some injuries (cataracts, skin burns) observed by researchers and physicians could be attributed to exposure to ionizing radiation

DETERMINISTIC EFFECTS

BIOLOGICAL EFFECTS OF IONIZING RADIATION

DETERMINISTIC EFFECTS

- Their severity increases with the dose.
- The protection against deterministic effects are quite simple:
- They are characterized by a threshold dose, below which the deterministic effect does not occur.
  - To establish dose limits well below the threshold doses for the occurrence of deterministic effects.
  - To establish the necessary procedures (design and operation) to ensure that such limits are met.

Only in the case of an accident it should be possible

BIOLOGICAL EFFECTS OF IONIZING RADIATION

The epidemiological survey of atomic bomb survivors (Hiroshima and Nagasaki) revealed (at dose levels below the threshold doses) the incidence of cancer was higher than of the general population.

The problem is not easy: Others biological effects

Cellular survival
Chromosome aberrations
Cellular transformations
Mutations

STOCHASTIC EFFECTS

BIOLOGICAL EFFECTS OF IONIZING RADIATION

STOCHASTIC EFFECTS

- The excess of cancer incidences among the survivors of atomic bombs starts being evident at doses above 100 mSv.
- No excess of cancer incidences are found at the low dose levels below: **(1 mSv/year)**

Dose (mSv)	Subjects	Cases	Excess	%	
< 5	38.507	4.270	2	0	NO EXCESS
5 – 100	29.860	3.387	44	1	
100 – 200	5.949	732	41	6	EXCESS
200 – 500	6.380	815	99	12	
500 -1000	3.426	483	116	24	
1000 – 2000	1.764	326	113	35	
> 2000	625	114	64	564	

D.L. Preston. Radiation health risks at low doses among atomic bomb survivors. Data for solid cancers. 2004

BIOLOGICAL EFFECTS OF IONIZING RADIATION

What is low dose and "low dose rate"?

FOR STOCHASTIC EFFECTS		DOSE	DOSE RATE
NCRP 1980		200 mSv	50 mGy/year
ICRP 1990		200 mSv	0,1 Gy/hour
UNSCEAR 1993	X, γ-radiation	200 mSv	0,05 mGy/min
	neutrons	50 mSv	
FOR CELL BIOLOGICALEFFECTS		1 -100 mSv	
IN MICRODOSIMETRICAL TERM		When 20% of target gets hits	
Natural background		50 – 200 mSv	1 – 3 mSv/year
"Insignificant individual dose"		0,01 mSv	

BIOLOGICAL EFFECTS OF IONIZING RADIATION

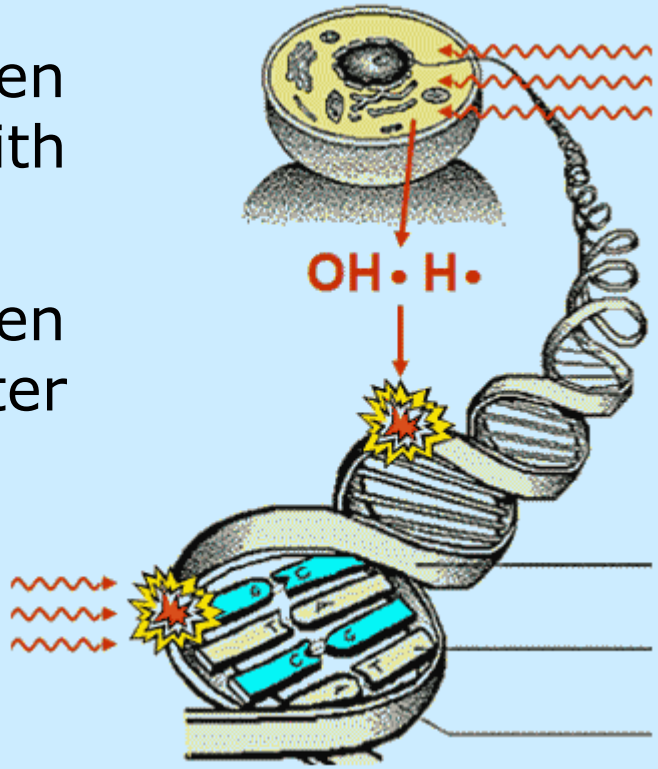
Average worldwide exposure to natural radiation

Source	Annual effective dose (mSv) Average	Typical range
Cosmic rays	0,39	0,3 – 1,0
External terrestrial	0,48	0,3 – 0,6
Inhalation (mainly radon)	1,15	0,2 – 10
Ingestion	0,29	0,2 – 0,8
Total	2,4	1 – 10

MECHANISMS OF BIOLOGICAL EFFECTS

- There is considerable evidence suggesting that DNA is the critical target for the manifestation of biological effects induced by radiation.
- When ionizing radiation interacts with DNA several lesions can occur in the form of base damage or strand breaks as a result of:
  - The ionization caused when radiation interacts directly with the DNA molecule.
  - The free radicals produced when radiation interacts with water molecules.

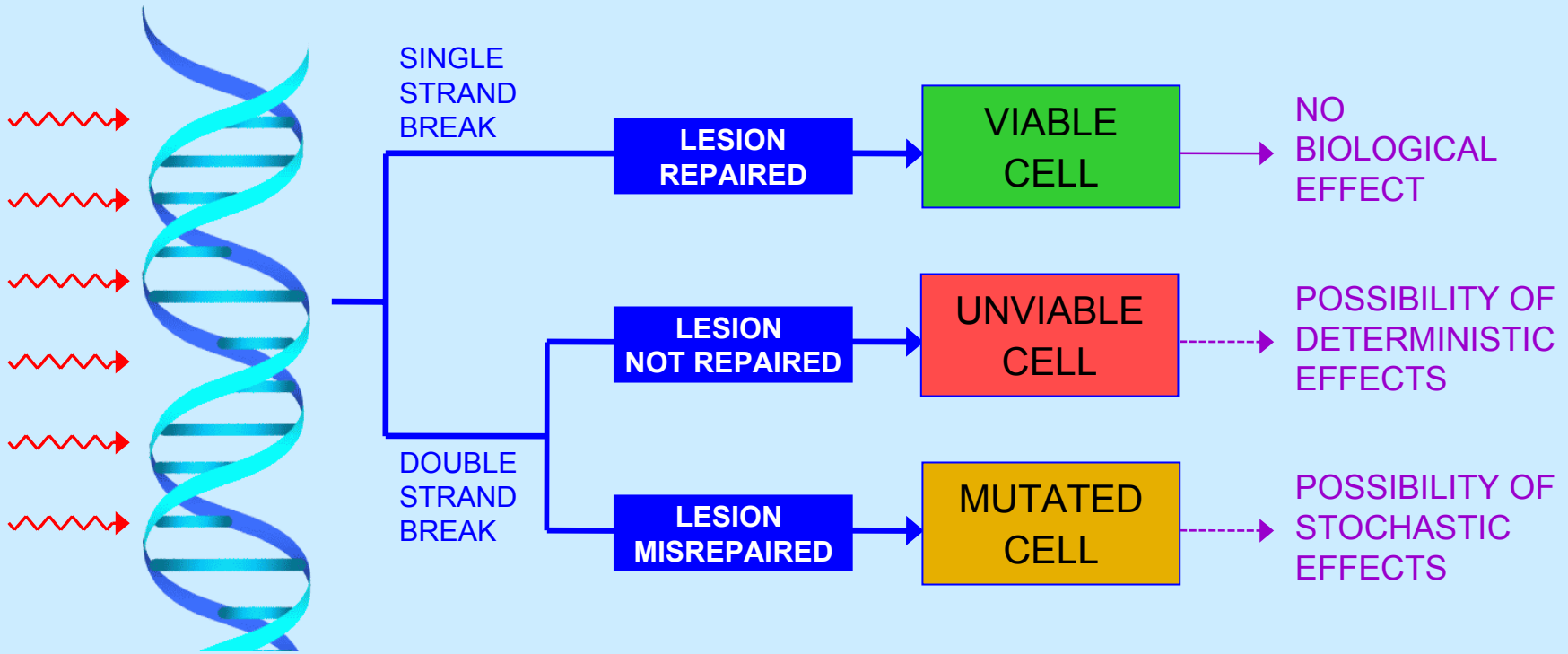
$$H_2O \rightarrow OH^- + H^+$$



MECHANISMS OF BIOLOGICAL EFFECTS

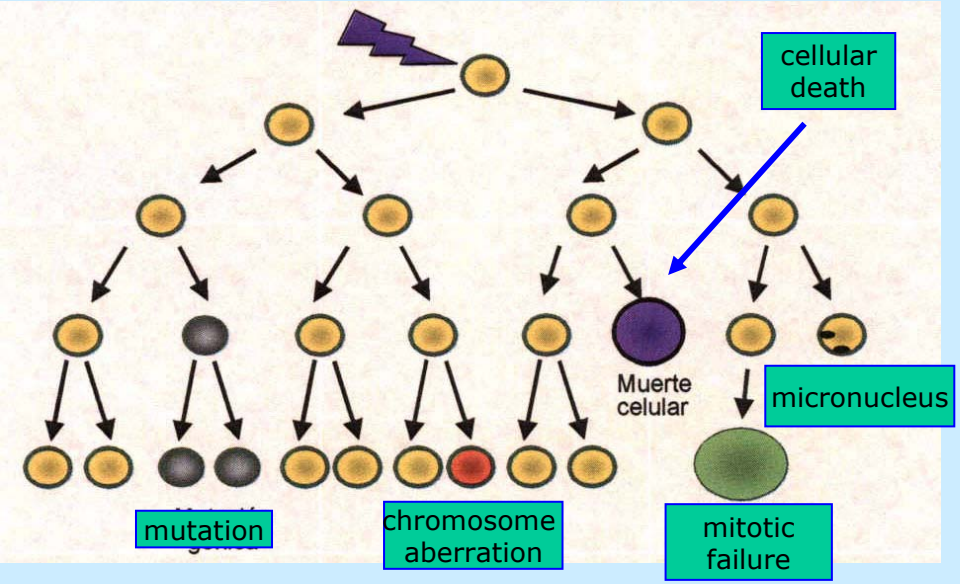
There are active enzymatic repair processes capable of repairing the lesions produced by radiation in DNA.

The effectiveness of these processes in repairing the DNA damage depends on the magnitude of the lesions:

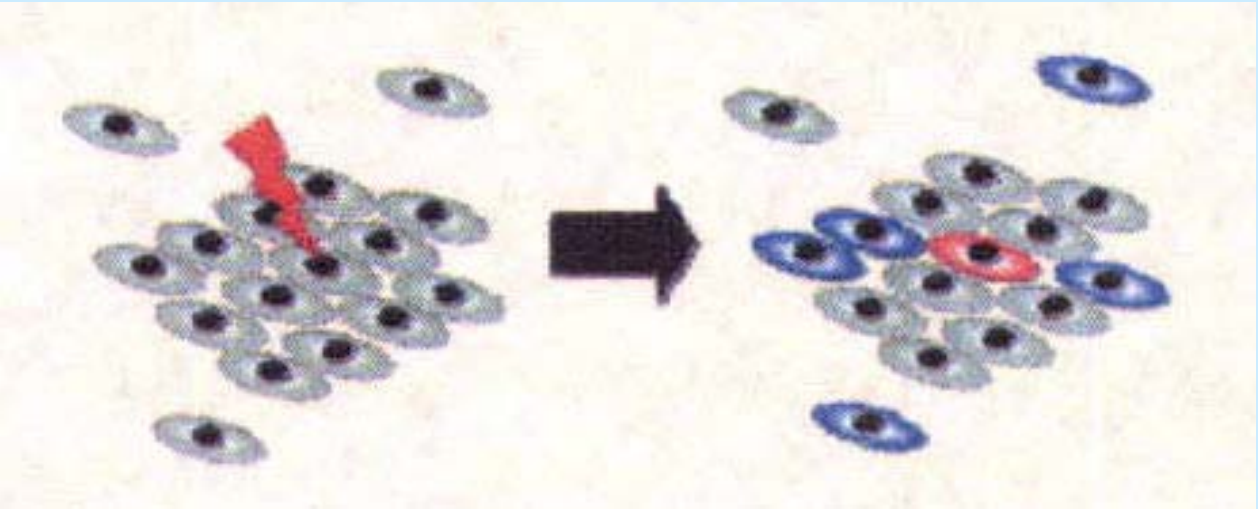


THE SCIENTIFIC BASES OF RADIOPROTECTION

Genomic instability



Bystander effect



MECHANISMS OF BIOLOGICAL EFFECTS

RELEVANT ASPECTS

- At the dose levels of: (1mSv/year) the frequency of interaction is extremely low:

  1mSv/year $\rightarrow$ 1 interaction / year/ cell

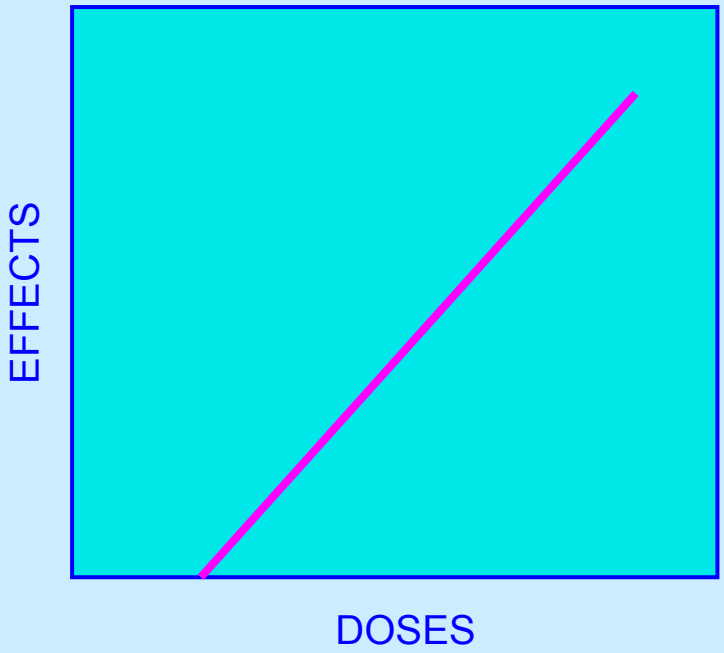
- The occurrence of double strand breaks in DNA has a low probability in comparison with other less severe (and repairable) lesions:

DNA DAMAGE PRODUCED IN ONE CELL BY 1GY X-RAYS	
DAMAGE	NUMBER PER CELL
base damage	1000 - 2000
crosslink	200 - 400
single-strand breaks	~1000
double-strand breaks	~40

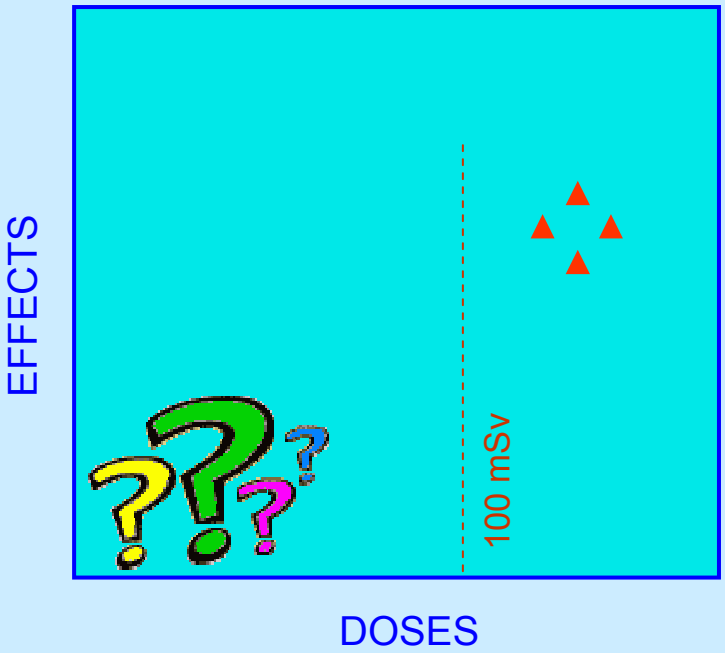
THE SCIENTIFIC BASES OF RADIOPROTECTION

The establishment of a radioprotection system needs to know (in a quantitative manner) the relation between dose and effects.

DETERMINISTIC

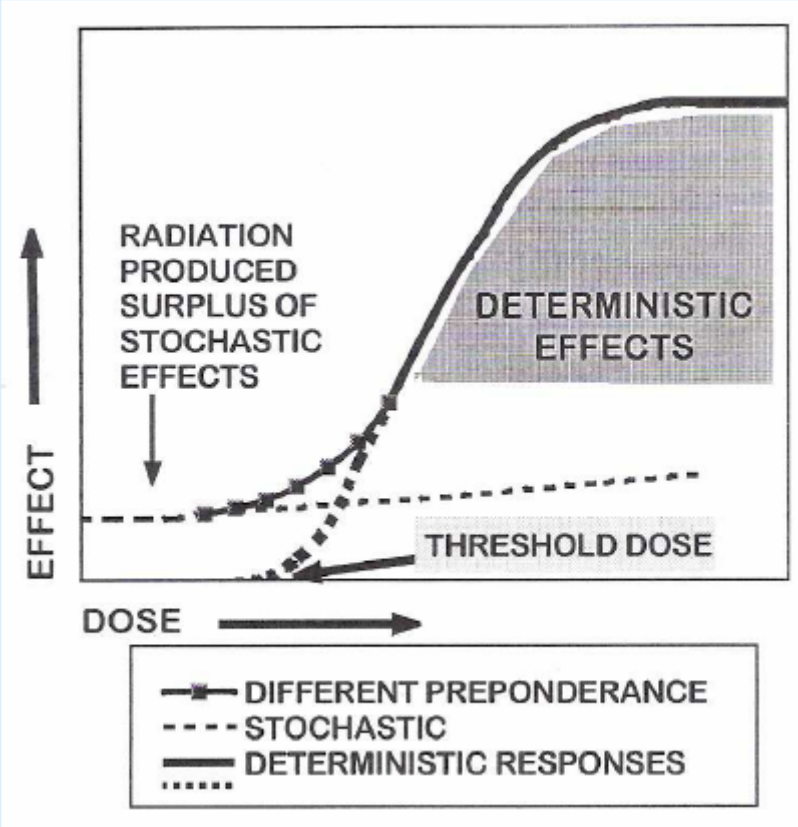


STOCHASTIC

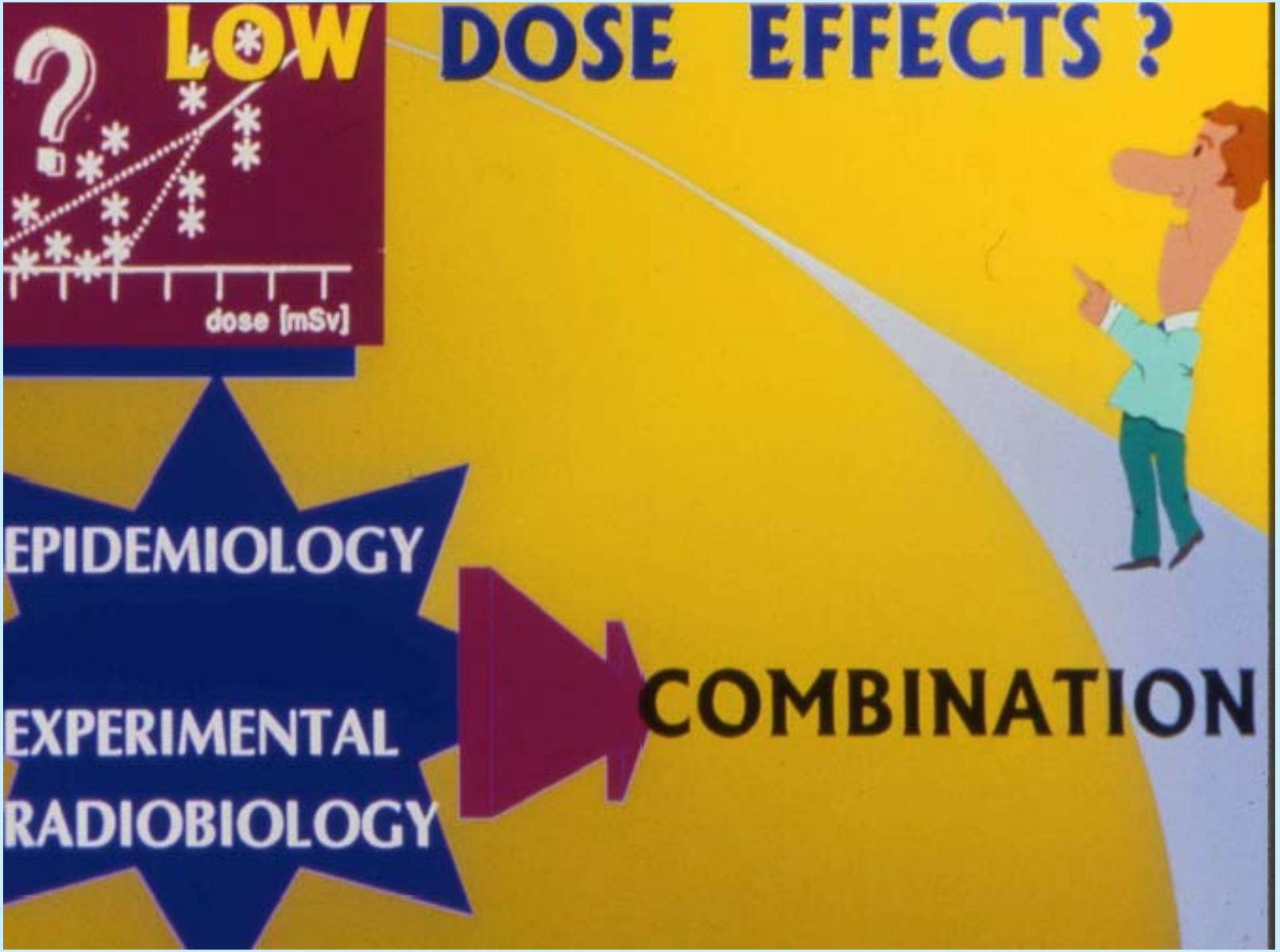


THE SCIENTIFIC BASES OF RADIOPROTECTION

Schematic dose-response curves for the stochastic and deterministic effects of ionizing radiation

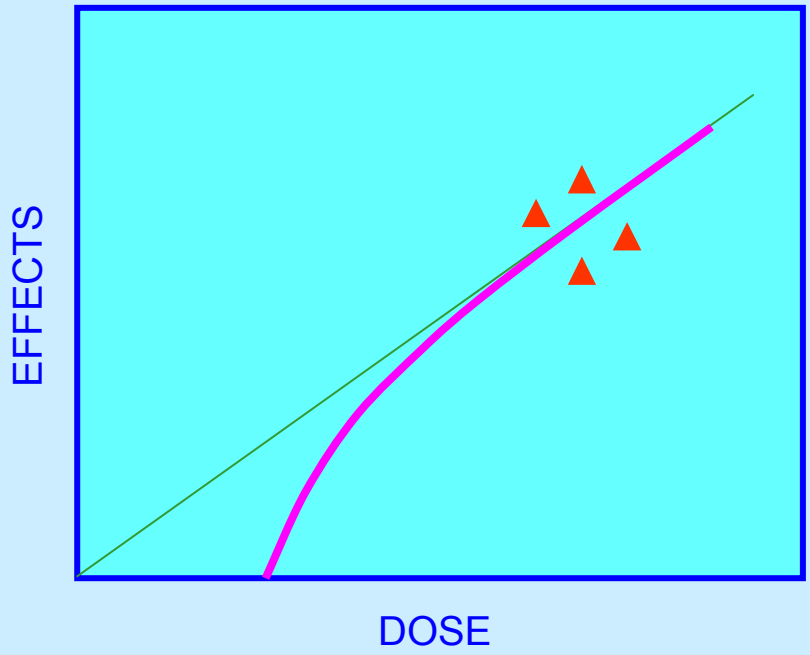


THE SCIENTIFIC BASES OF RADIOPROTECTION



THE SCIENTIFIC BASES OF RADIOPROTECTION

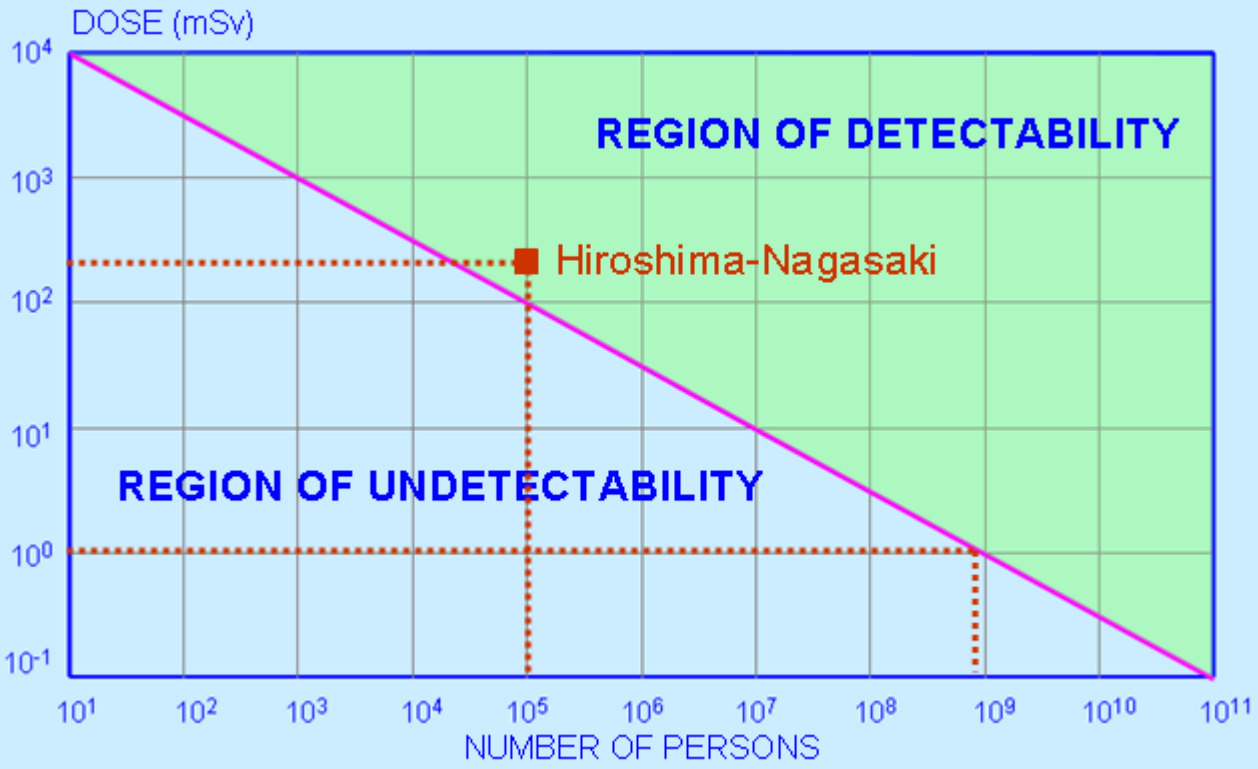
Given that epidemiological studies have been unable to detect an increase of cancer incidence at dose levels below 100 mSv, some scientific organizations suggest the existence of a threshold dose for stochastic effects



THE SCIENTIFIC BASES OF RADIOPROTECTION

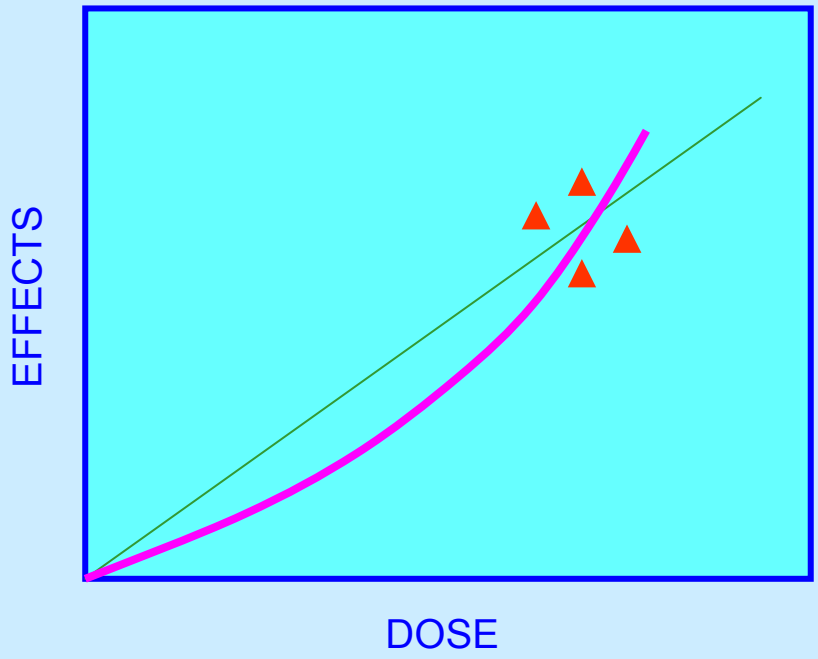
The validity of this approach is questionable. It does not take into account the statistical limitations inherent to epidemiological studies in cancer risk estimates.

CANCER MORTALITY IN EUROPEAN COUNTRIES: 25/100
RISK OF FATAL CANCER AT A DOSE OF ABOUT 1 mSv ~ 5/100.000



THE SCIENTIFIC BASES OF RADIOPROTECTION

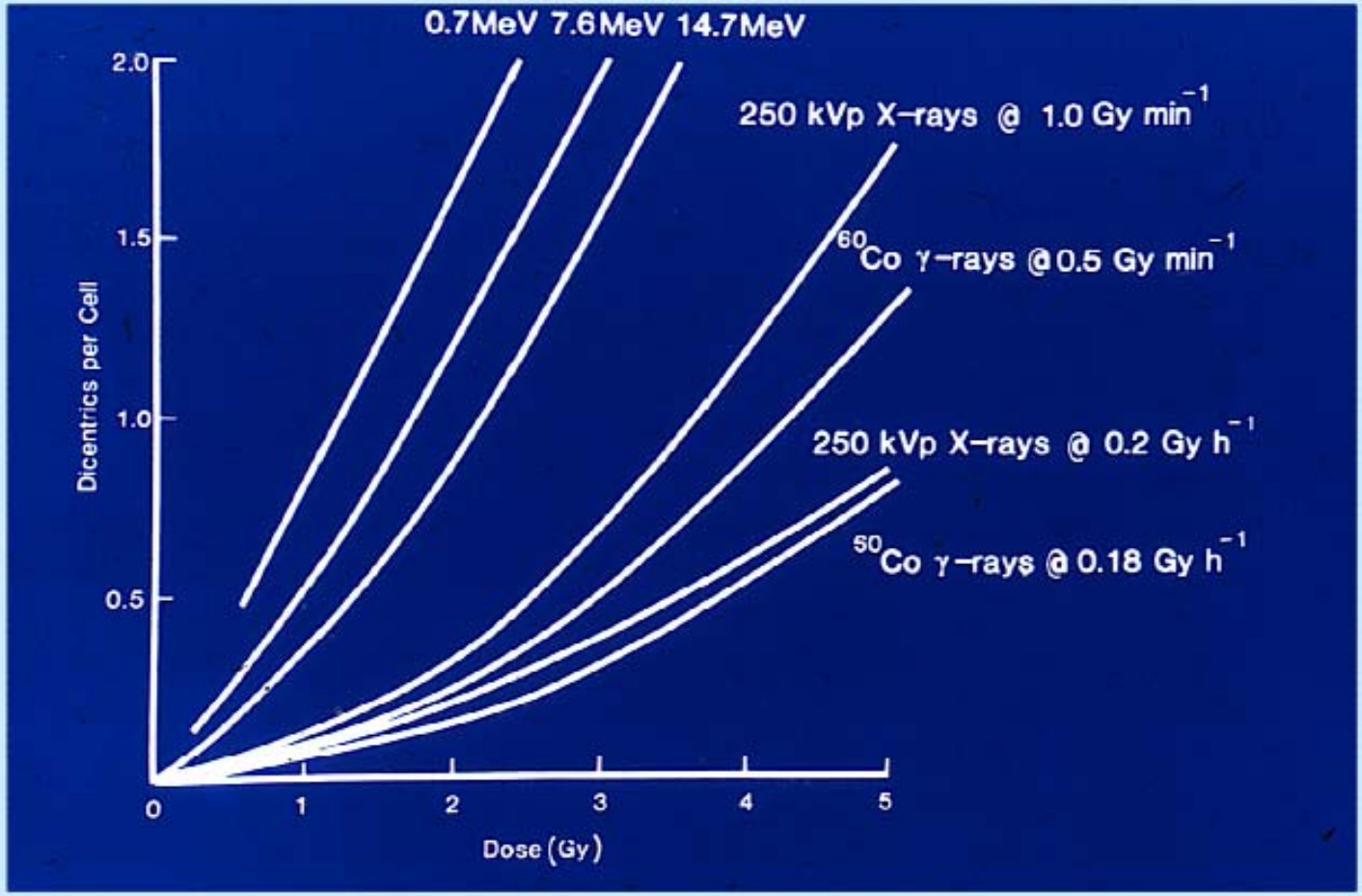
There are radiobiological evidences suggesting that double strand breaks in DNA can be induced by very low doses of radiation.



Well-known Institutions (French Academy of Sciences) state that there is not a threshold for the occurrence of stochastic effects.

THE SCIENTIFIC BASES OF RADIOPROTECTION

Dose-response relationships of dicentric aberrations for several qualities of radiation

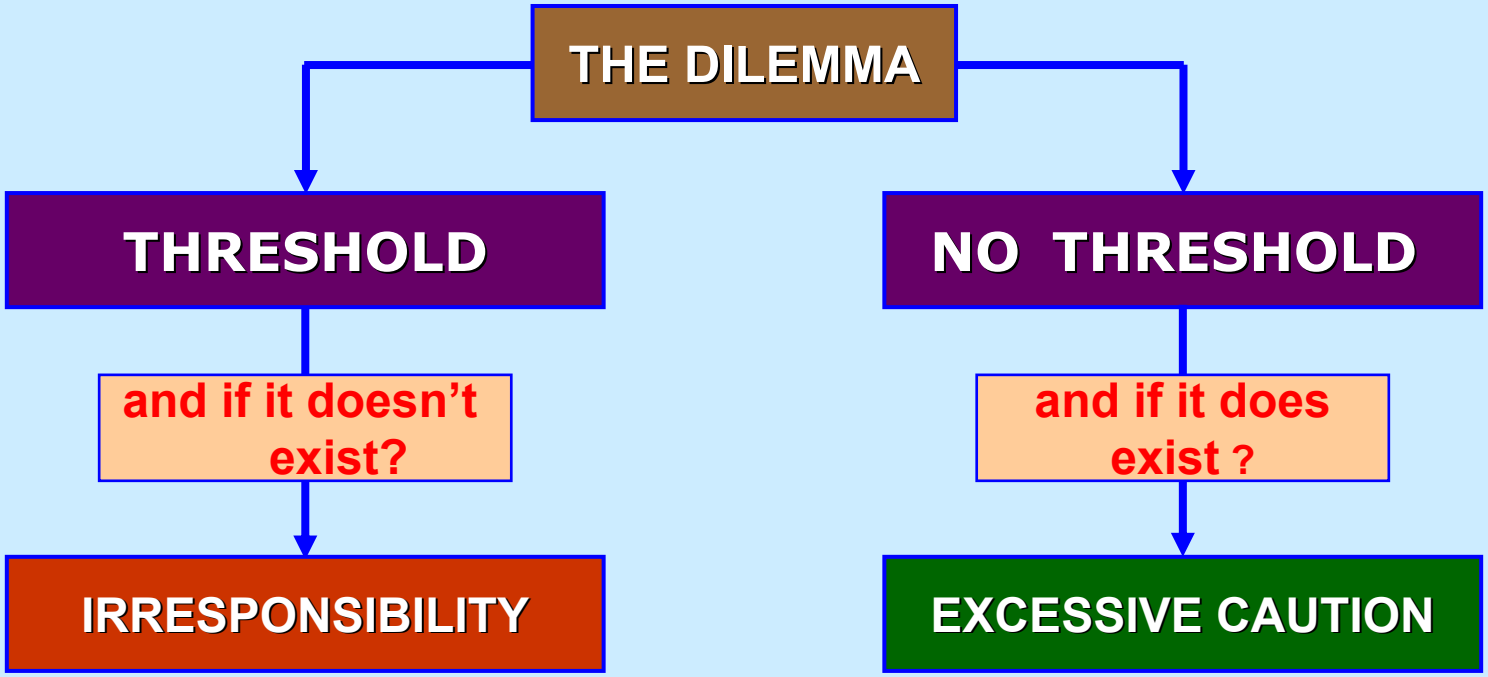


THE SCIENTIFIC BASES OF RADIOPROTECTION

CURRENT SITUATION

In spite of the number of studies made, there is no scientific evidence to conclude if a dose threshold exist or not for: **STOCHASTIC EFFECTS**

THE SCIENTIFIC BASES OF RADIOPROTECTION



THE SCIENTIFIC BASES OF RADIOPROTECTION

ICRP POSITION

Before the lack of conclusive scientific evidence, ICRP, in a prudent and preservative attitude has assumed following hypothesis:

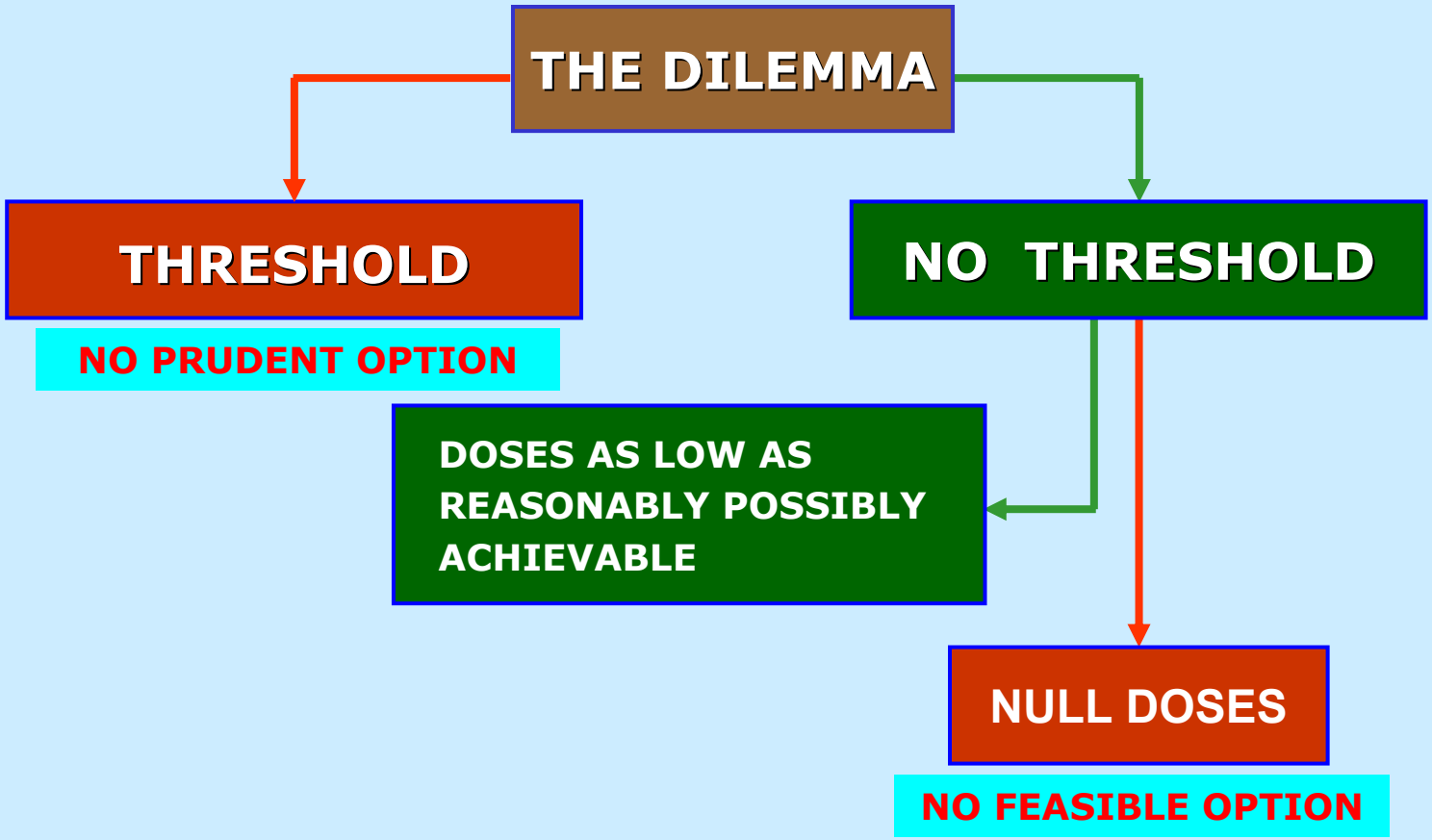
- A threshold dose for stochastic effects is non-existent
- The existent of a linear relation between dose and effect.

(the relation D-E at low doses is obtained by extrapolation of the data D-E observed at high doses).

LINEAR NON-THRESOLD HYPOTHESIS (LNT)

THE SCIENTIFIC BASES OF RADIOPROTECTION

As a logical consequence of LNT hypothesis model, the optimization principle arises, which supports our present radioprotection system



RADIATIONPROTECTION OBJECTIVES

DETERMINISTIC EFFECTS

THRESHOLD DOSE

THERE IS A DOSE LEVEL BELOW WHICH NO BIOLOGICAL EFFECT IS PRODUCED

TO PREVENT THE OCCURRENCE OF DETERMINISTIC EFFECTS BY KEEPING THE EXPOSURES BELOW THE RELEVANT THRESHOLD DOSE

RADIATIONPROTECTION OBJECTIVES

STOCHASTIC EFFECTS

LNT HYPOTHESIS

EVEN VERY LOW DOSES OF RADIATION ARE SUSCEPTIBLE TO INDUCE STOCHASTIC EFFECTS

TO REDUCE THE INDUCTION OF STOCHASTIC EFFECTS BY KEEPING DOSES AT LEVELS AS LOW AS REASONABLY ACHIEVABLE, SOCIETAL AND ECONOMIC FACTORS BEING TAKEN INTO ACCOUNT.

THE LINEAR-NON THRESHOLD HYPOTHESIS

ARGUMENT IN FAVOUR OF LNT

The probability of mutation (p_D) at a dose level D is:

$$p_D = (a\,D + b\,D^2).\ e^{-cD}$$

The frequency of interaction (at low doses) is very low:

$$p_D = (a\,D + b\,D^2).\ e^{-cD}$$

$$\mathbf{p_D = a\,D}$$

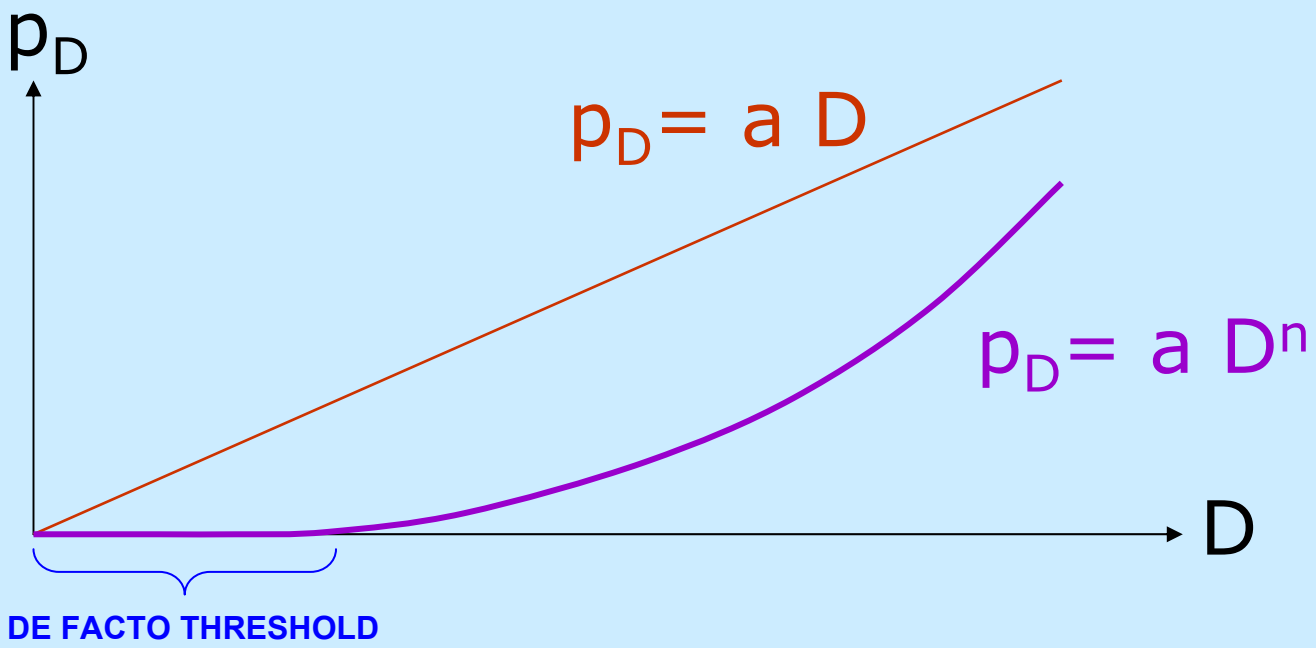
THE LINEAR-NON THRESHOLD HYPOTHESIS

ARGUMENT AGAINST LNT

One single mutated cell can not initiate a malignant tumor

Several mutations (n) are required

$$p_D = a\,D \rightarrow p_D = a\,D^n$$



THE LINEAR-NON THRESHOLD HYPOTHESIS

MAIN CRITICISMS

- The scientific and biological basis for establishing the LNT hypothesis are quite questionable.
- The LNT approach is too conservative, it leads to magnifying the health risks from exposure to low levels of ionizing radiation.
- The LNT hypothesis has given rise to an inadequate public perception of the carcinogenic power of ionizing radiation (radiophobia).

THE LINEAR-NON THRESHOLD HYPOTHESIS

IN SPITE OF THOSE CRITICISMS

IT IS A USEFUL TOOL TO FACILITATE RADIATION PROTECTION

- It makes possible to consider each source and exposure separately because the probability of harm per unit dose will always be the same.
- It allows dose within an organ or tissue to be averaged over that organ or tissue.
- It allows doses received at different times to be added.
- It allows doses received from one source to be considered independently of the doses received from other sources.

THE LAST NEWS

The RISC-RAD project

Radiosensitivity of Individuals and Susceptibility to Cancer Induced by Ionizing Radiation

It is a research project in the field of cellular and molecular biology

Period: 2004- 2008 (EURATOM 6th Program)

Budget: 30 million €

Laboratories: 36 (11 countries)

Research persons: 28 post-doc and 53 PHD

Articles: 163

CONCLUSIONS

- The results did not question the use of LNT model for estimating the radiological risk.
- Different dose/effect relationships according to observed mechanisms
- Importance of genetic predisposition in the individual sensitivity to low doses
- The use of effective dose as protection/limiting quantity implies to accept the LNT model


CSN
Thank you very much
for
your attention