Ultra-low radioactivity, a new frontier for biology ?

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Credit: M. Belli, D. Biron, N. Lampe, P. Morziano, G. Warot

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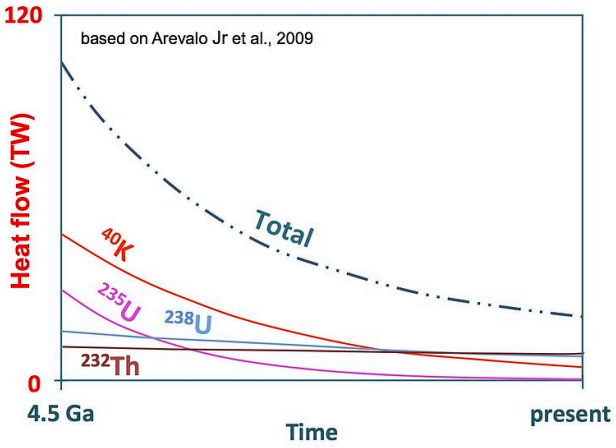
Everywhere there is life, there is radioactivity

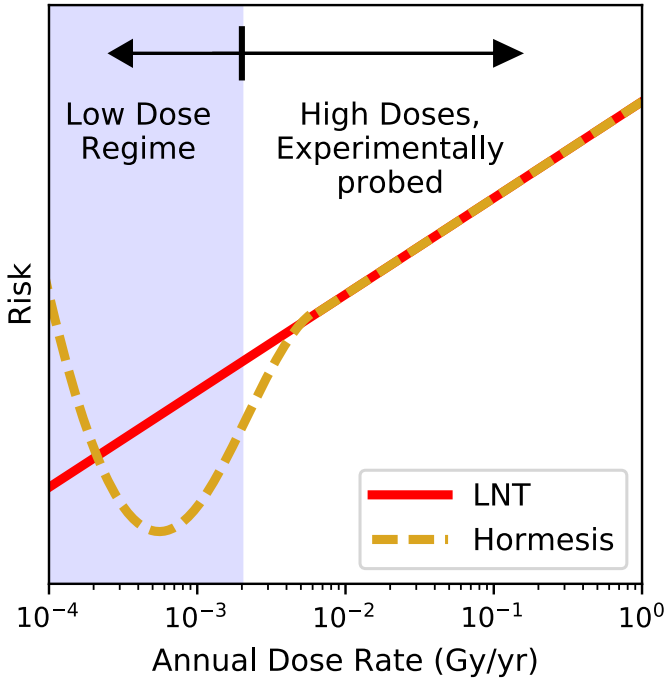


El Albani et al, nature 2010

- Radioactivity is at the heart of every living organism
  - ^{40}K: isotopic fraction = 0,1167 % , half life = 1,248 Billion years
- How long ago did the first multicellular organisms appear: 600 millions or 2,1 Billion years?
  - Fossils discovered 30 km away from natural nuclear reactors (Oklo, Gabon)

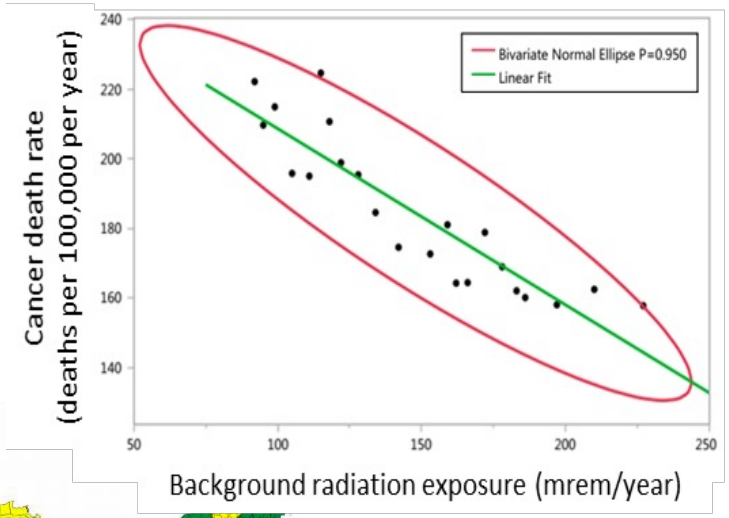
Radiation risk in humans

- Models for radiation risk in humans have existed for decades
  - Origin: Nuclear disasters, high radiation exposure (UNSCEAR, 2008)
- However there is still debate about what happens at low dosages.
- At very low (approaching natural) dosages, there is debate about whether these models:
  - remain linear,
  - or even display hormesis



Negative correlation between cancer risk and background radiation in the United States (2021)

A



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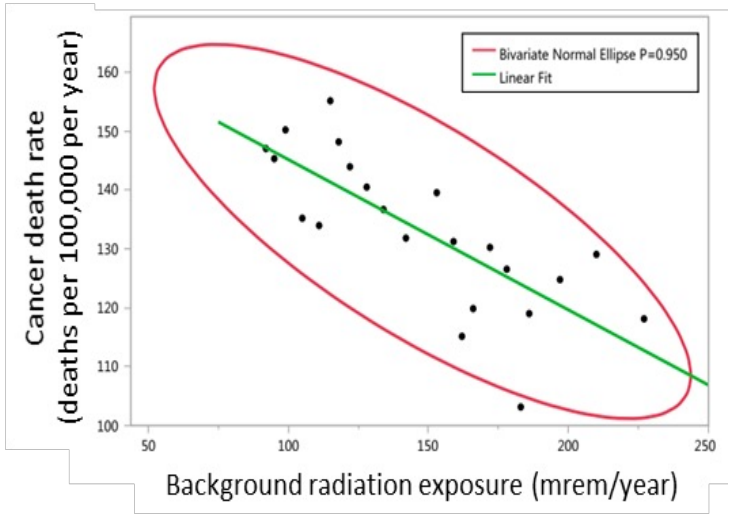
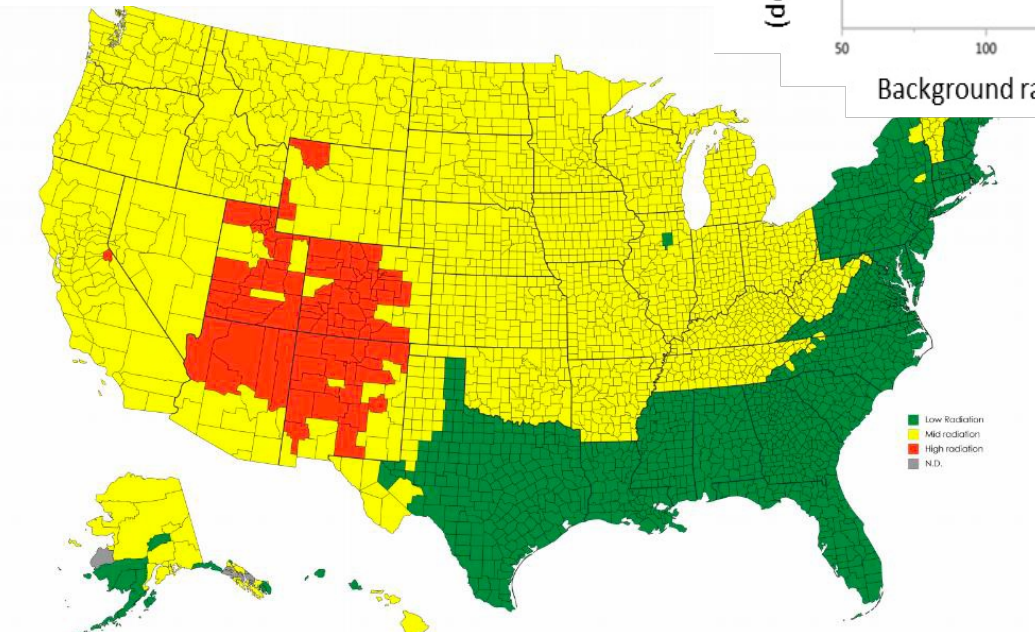


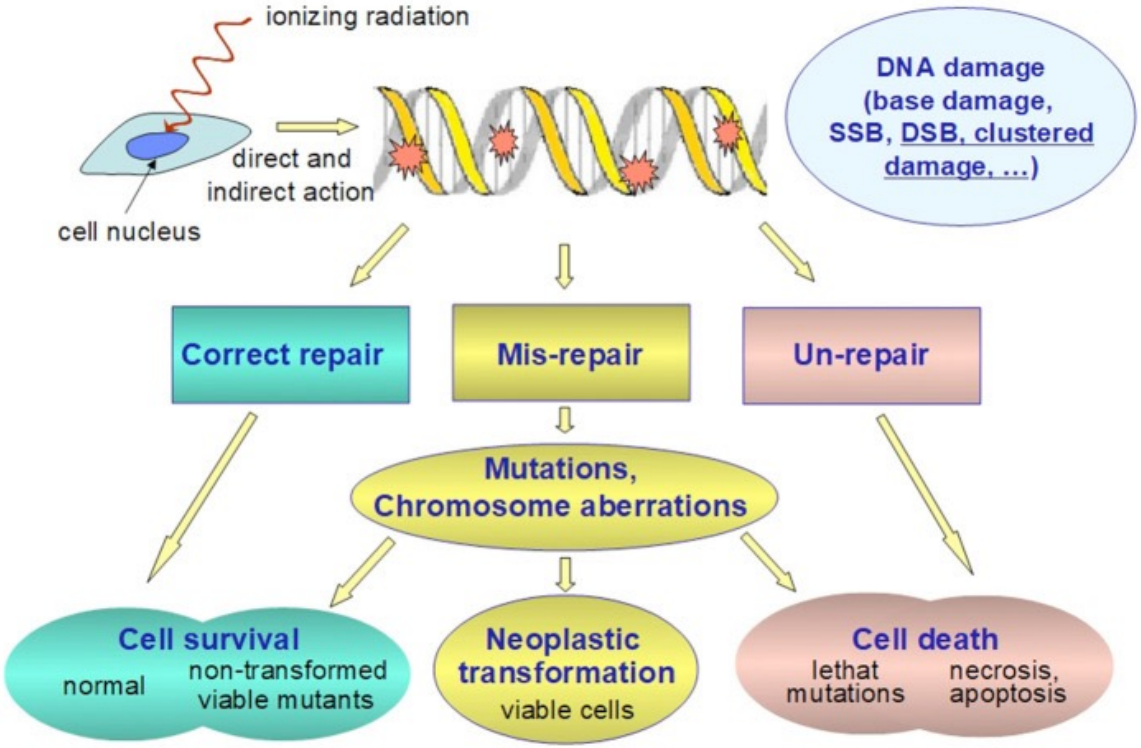


1 mrem = 0,01 mSievert

David, E., Wolfson, M. & Fraifeld, V.E. Background radiation impacts human longevity and cancer mortality: reconsidering the linear no-threshold paradigm. *Biogerontology* **22,** 189–195 (2021). https://doi.org/10.1007/s10522-020-09909-4

Conventional paradigm of radiobiology

- The DNA damage in directly exposed cells is the main event for biological effects
- DNA damage occurs during or very shortly after irradiation of the nuclei in targeted cells
- The potential for biological consequences can be expressed within one or two cell generations
- At low doses the biological effect is in direct proportion to the energy deposited in nuclear DNA (this is the rational basis for assuming a Linear No-Threshold (LNT) relationship between risk and dose)

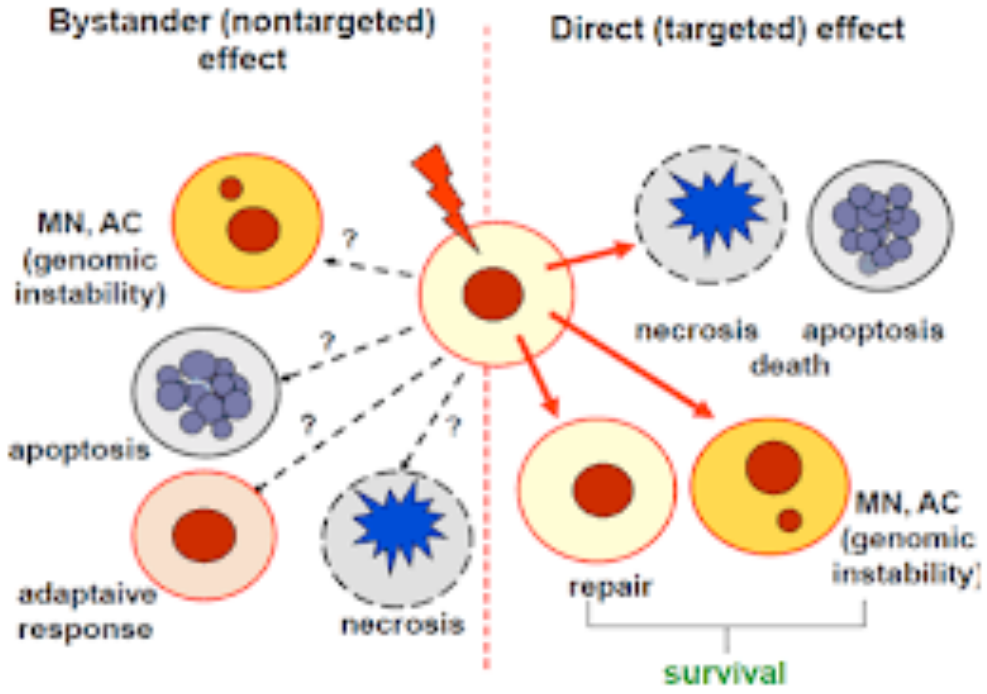


Goodhead D. New radiobiological, radiation risk and radiation protection paradigms. Mutat Res. (2010) 687:13–16. 10.1016/j.mrfmmm.2010.01.006

Belli M, Indovina L. The Response of Living Organisms to Low Radiation Environment and Its Implications in Radiation Protection. *Front Public Health*. 2020;8:601711. Published 2020 Dec 15. doi:10.3389/fpubh.2020.601711

Observation of radiobiological effects that do not follow the conventional paradigm

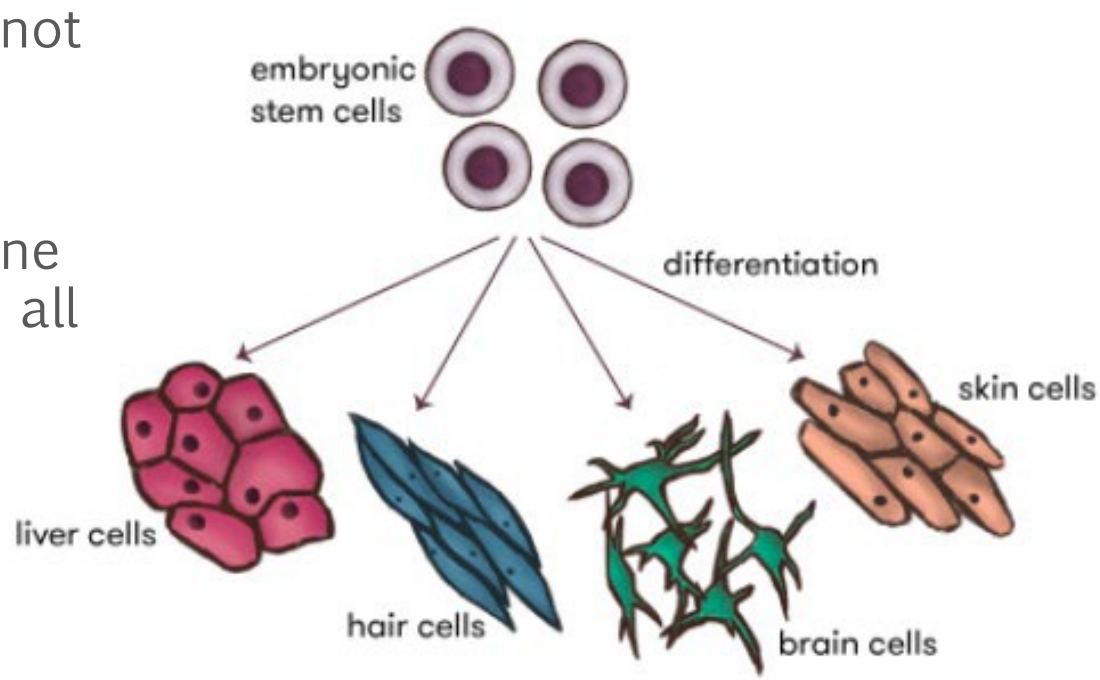
- Bystander effects: effects from hit cells to unhit ones -> Inter-signalling in cells
- Adaptative response: induction, in cells pre-exposed to a low « priming » dose, of cellular radioresistance to subsequent larger doses -> epigenetic effects



Credit: M. Widel

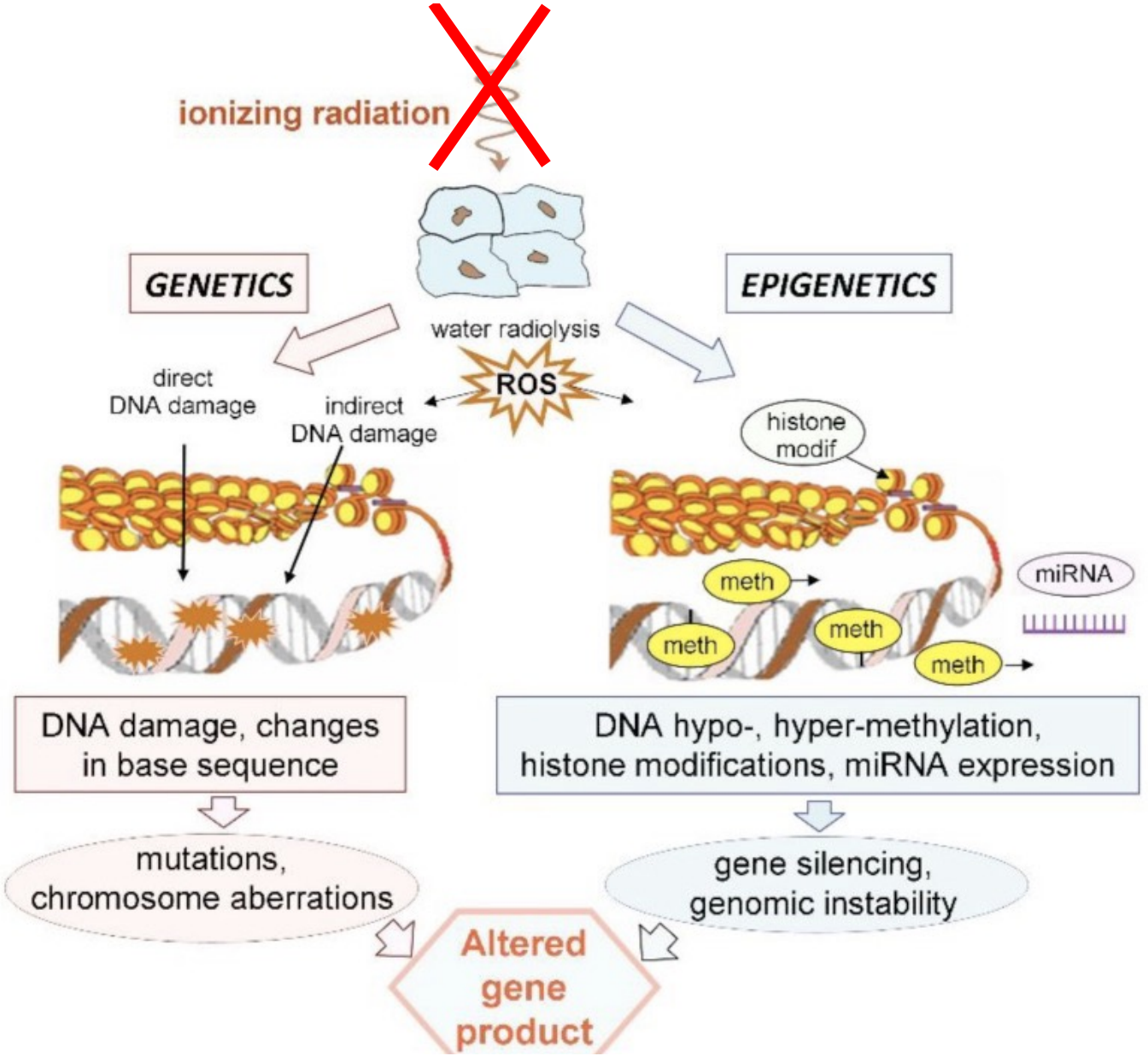
The role of epigenetics

- Heritable changes in genes expression not related to changes in DNA sequence
- Epigenetic mechanisms regulate the gene expression in our body's cells to create all the different cell types of our body although they have the same genome.



How is epigenetics involved in radiation-induced effects? ?

- Epigenetic mechanisms are involved in adapting the gene expression programme of the cell to the stress situation, often when they are transient.



What happens to living organisms when natural background radiation is reduced ?

- Are organisms capable of sensing below-background levels of radiation?
  - At the surface, the chance per day that a single bacteria (e-coli) is touched is 6.0×10^{-5}
  - Underground, this drops to 8.2×10^{-6}

- If they are, what are their response and sensing mechanisms ?

- Is this response different among prokaryotes/eukaryotes, unicellular/multicellular organisms?

Deep Underground Laboratories (DULs)
are unique places where it is possible to investigate
the effects of reduced natural background radiation

Experimental method

- Set up parallel experiments under different radiation environments

Underground laboratory:
- Cosmic rays (charged) << 1nGy/hr^{-1}
- Cosmic rays (neutrons) << 1nGy/hr^{-1}
- Gamma background : 10 -100 nGy/ hr^{-1}
- Radon: 10-70 Bq/m^3

Reference laboratory (above ground):
- Cosmic rays (charged): tens of nGy/hr^{-1}
- Cosmic rays (neutrons): A few nGy/hr^{-1}
- Gamma background : tens - hundreds nSv/h
- Radon: 10-70 Bq/m^3

Same temperature
Same humidity
Same atmospheric pressure
Same culture medium

Radiation sources by environment