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Health Physics and the Linear No-Threshold Model

Understanding Radiation and Its Effects

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Outline

- What is health physics?
 - What organizational bodies govern health physics?
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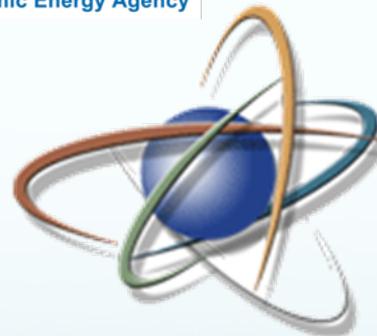
- How does radiation affect the human body?
 - What units do we use to describe radiation's effect?
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- What is the Linear No-Threshold model?
- How trustworthy is it? Are there other models?

What is Health Physics?

- Health physics = The Physics of Radiation Protection
- The protection of human beings and the environment from the harmful effects of ionizing radiation, while permitting its beneficial applications
 - First HP task – shielding for Fermi's CP-1 (1942)
- “A marriage... of physics and biology”

Organizations





Nuclear Regulatory Commission

- Established 1975 post-AEC
- Oversees nuclear energy, nuclear medicine, and more
 - ❖ **10 CFR 20** – Standards for Protection Against Radiation
 - ❖ **10 CFR 50** – Domestic Licensing of Production and Utilization Facilities
 - ❖ **10 CFR 71** – Packaging and Transportation of Special Nuclear Material



- Independent advisory bodies, **not** governmental
- Issue similar reports, but are not legally binding

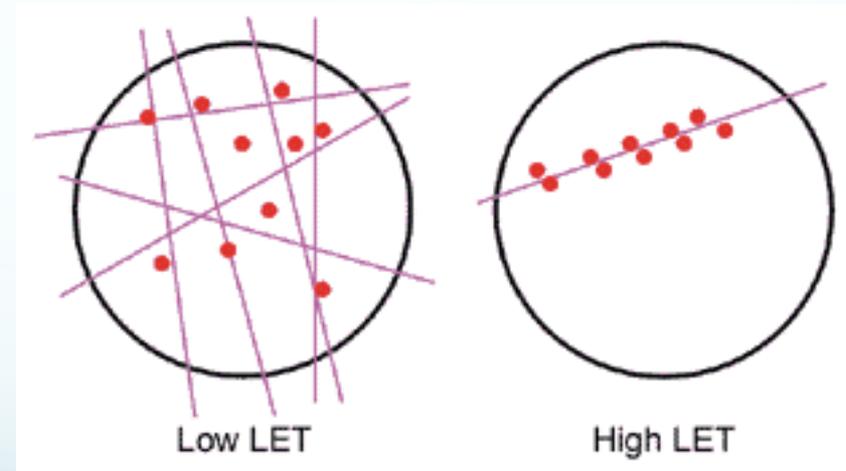
Radiation Biology Basics

Common Particles Encountered

- Alpha particles (${}^4\text{He}^{++}$)
- Beta particles (e^- OR e^+)
- Gamma rays (γ)
- X-rays & UV rays
- Neutrons
- Protons
- “Heavy ions” ($Z>2$) & fission fragments

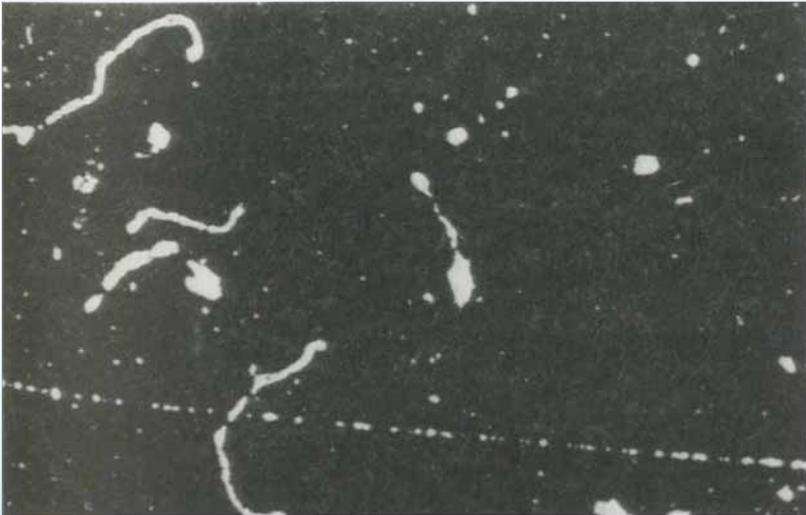
All Particles Are Not Created Equal

- **Linear Energy Transfer (LET)**



How Radiation Causes Biological Damage

Linear Energy Transfer



SSBs & DSBs



Damage: 30% Direct, 70% Indirect

Units of Radiation

Absorbed Dose (D)

- Energy Absorbed per Mass
1 **gray (Gy)** = 1 Joule/kilo
(100 rad = 1 **Gy**)

Effective Dose (E)

- When radiation is applied non-uniformly, organ sensitivity matters!

$$E = \sum H \times W_T$$

[Sv]

Equivalent Dose (H)

Dose x Radiation Weighting Factor

$$H = D \times W_R$$

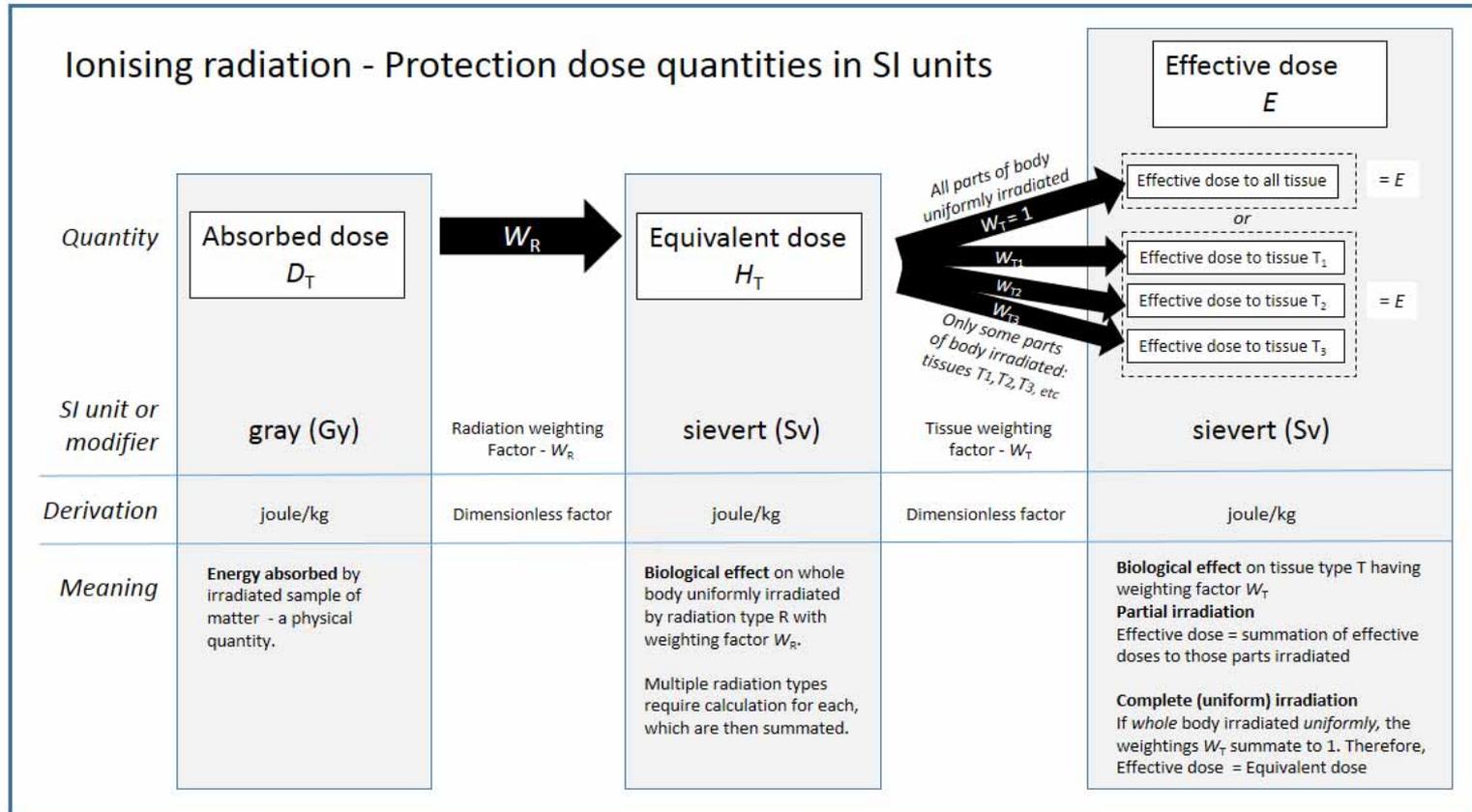
W_R depends on radiation type

$$1 \text{ sievert (Sv)} = 1 \text{ Gy} \times W_R$$

[J/kg]

[Sv]

Three Types of Dose



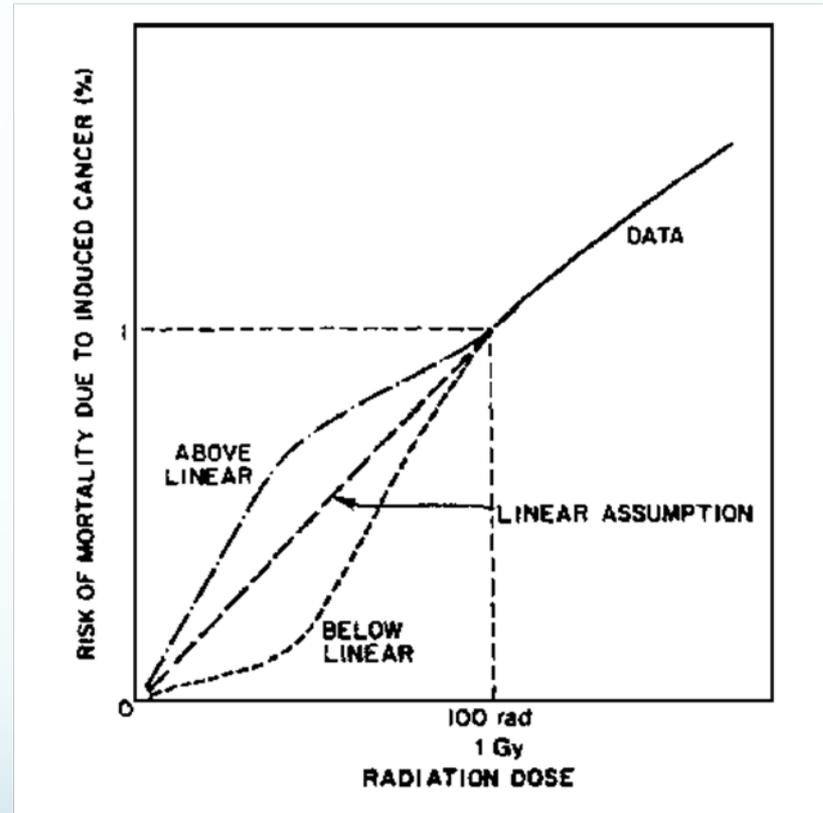
Linear No-Threshold

(How Little is Too Little?)

What is LNT?

- The **linear no-threshold model (LNT)** is a model that assumes the *long-term biological damage caused by ionizing radiation** is directly (**linearly**) proportional to the received dose. There is **no threshold** below which this relationship does not apply.

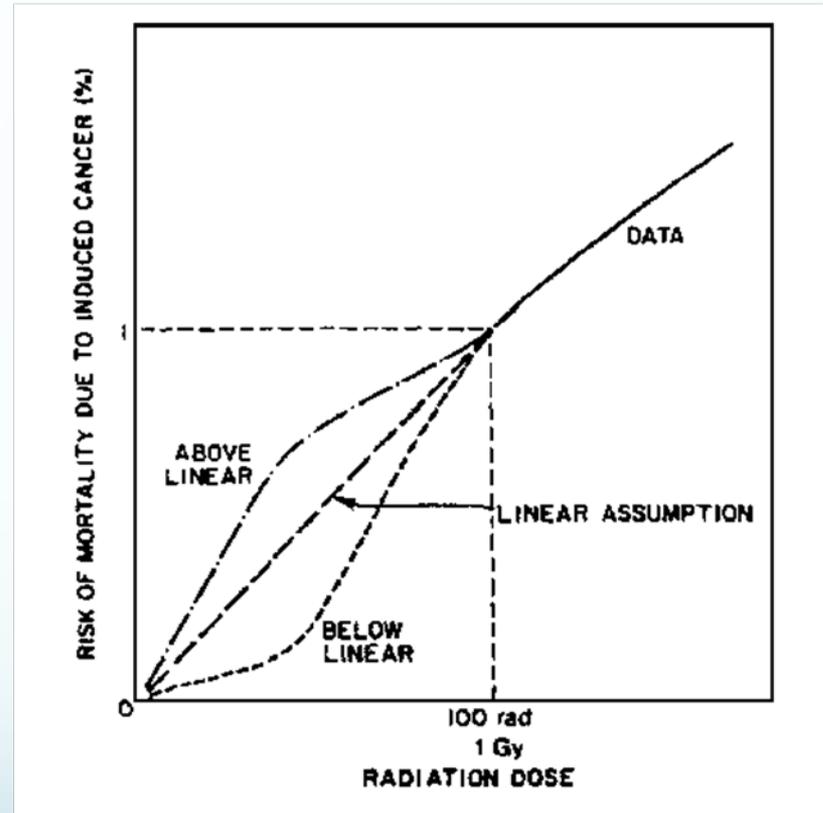
*Essentially, cancer risk



Linear No-Threshold

“The relationship between dose and DNA damage in vivo seems linear from 1 mGy to 100 Gy with use of H2AX foci as a marker for DNA double-strand breaks (DSBs)” – 2009 Tubiana et. al.

- Data at moderate to high dose levels comes from Hiroshima, Nagasaki, Chernobyl, Fukushima Daiichi, etc.



Linear No-Threshold

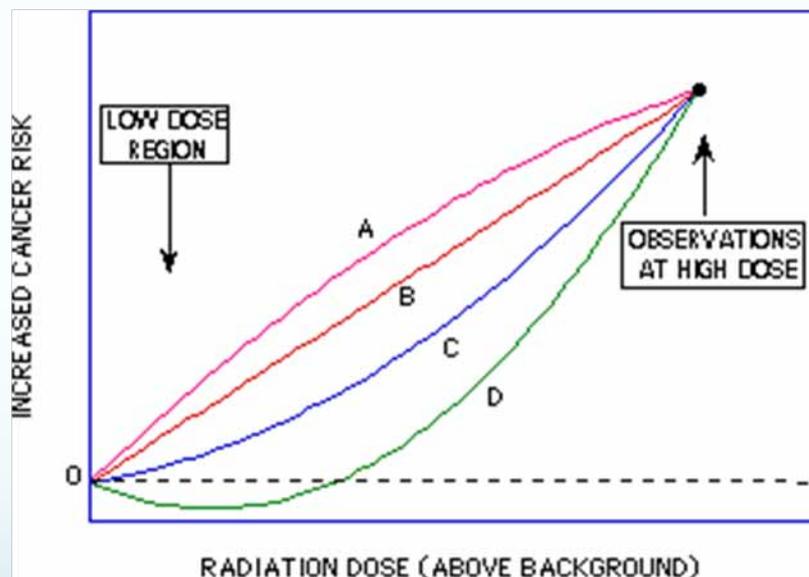
Tubiana cont.

LN(?)T

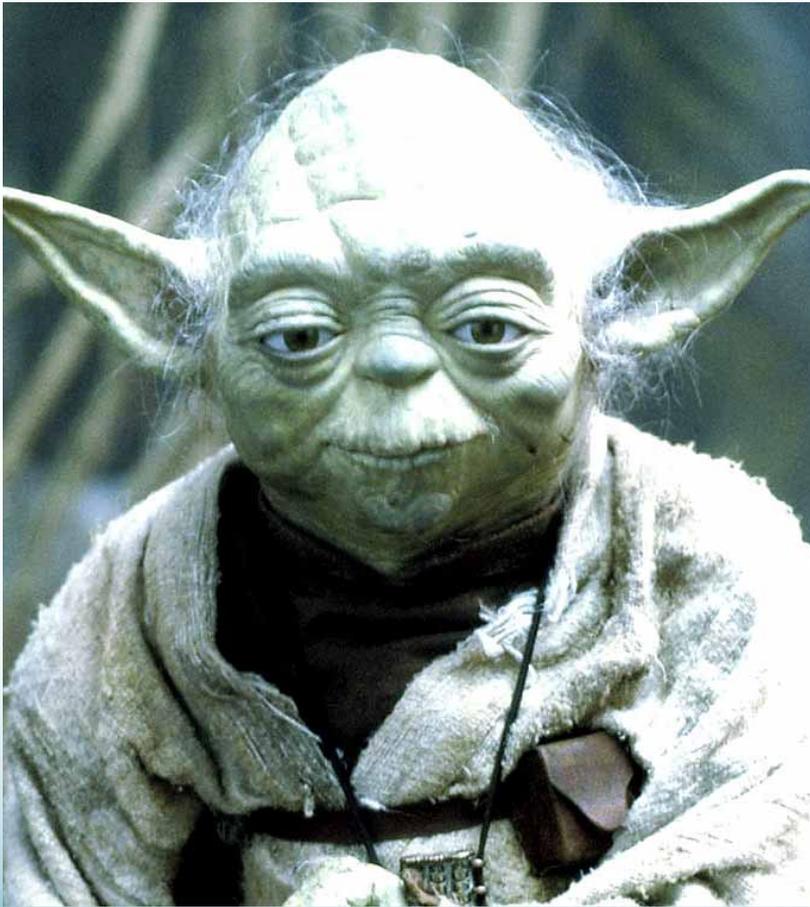
Life developed in a bath of ionizing radiation and solar ultraviolet radiation and created aerobic organisms requiring (a) defenses against the metabolically induced reactive oxygen species, (b) DNA repair, and (c) elimination of damaged cells. **Several sets of data show the efficacy of these defenses to be much higher at low than at high doses and for fractionated or protracted irradiation than for acute irradiation.**

The LNT model was introduced as a concept to facilitate radiation protection. But the use of this model led to the claim that even the smallest dose (one electron traversing a cell) may initiate carcinogenesis—for instance, from diagnostic x-ray sources.

This claim is highly hypothetical and has resulted in medical, economic, and other societal harm.



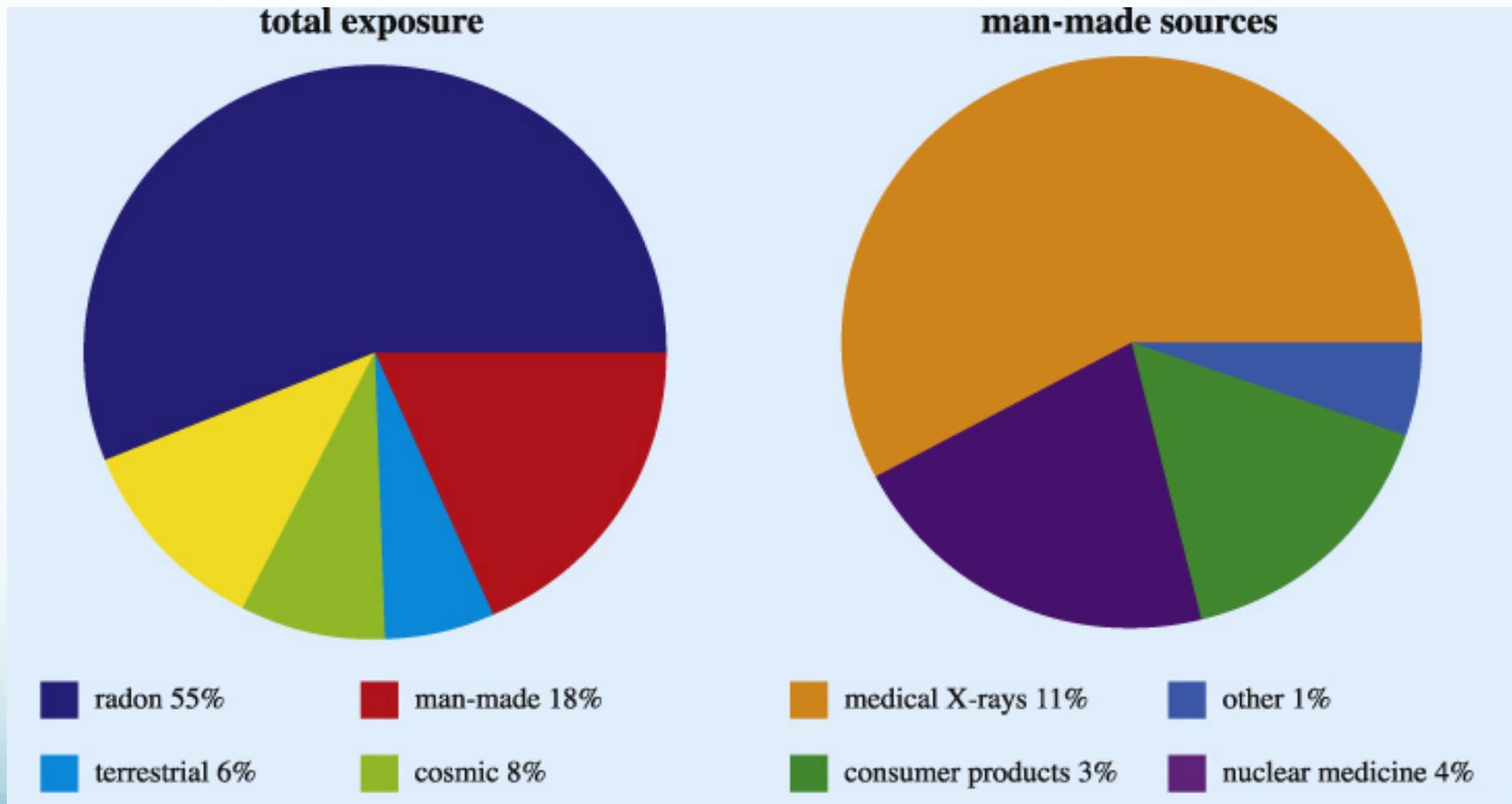
Background Radiation



“Its energy surrounds us and binds us. Luminous beings are we, not this crude matter. You must feel the [radiation] around you; here, between you, me, the tree, the rock, everywhere, yes!”

– Master Yoda, CHP

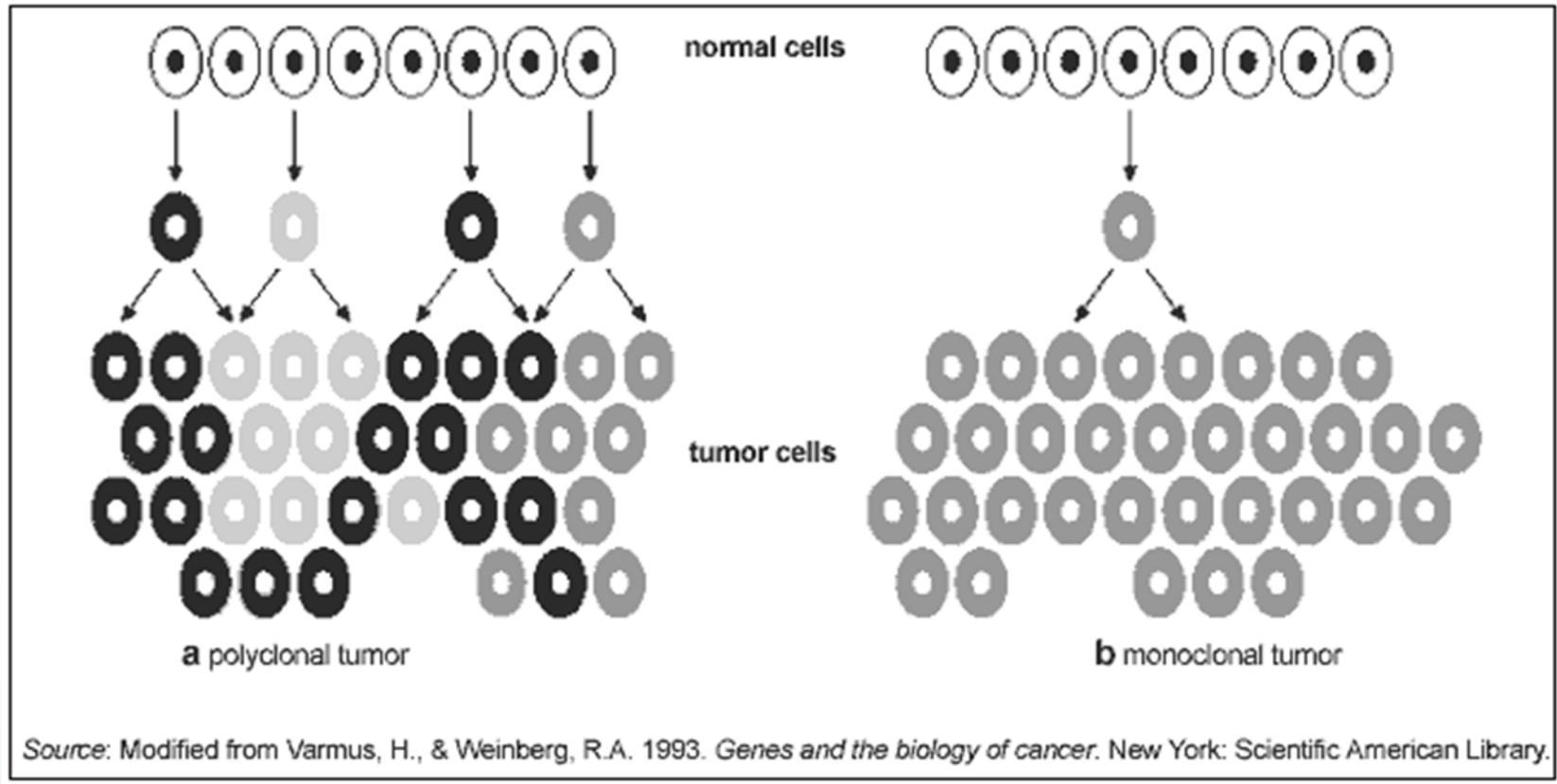
Background Radiation



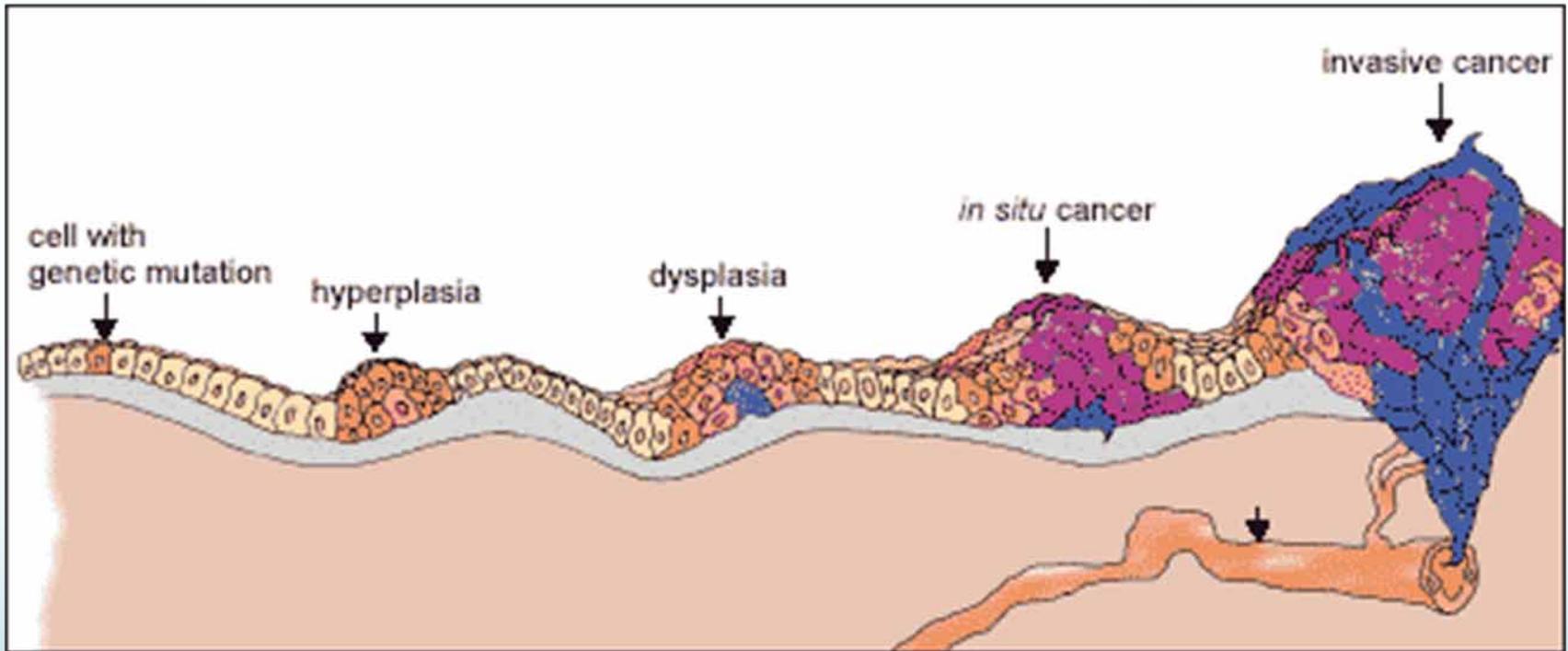
Total background radiation exposure: ~3 mSv/year (World), ~6 mSv/year (US)

Monoclonal Theory of Cancer Origin

Figure 4 - Two schemes by which tumors can develop. Most—if not all—human cancer appears to be monoclonal.



Intra-Tumor Heterogeneity



Linear No-Threshold, as a possible model of the real world, is *far from dead*. But the preponderance of new data requires a new look at the underlying assumptions of the model.



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Thank you!