Investigating the Biological Impact of Sub-Natural Background Radiation:

Insights from the REPAIR project

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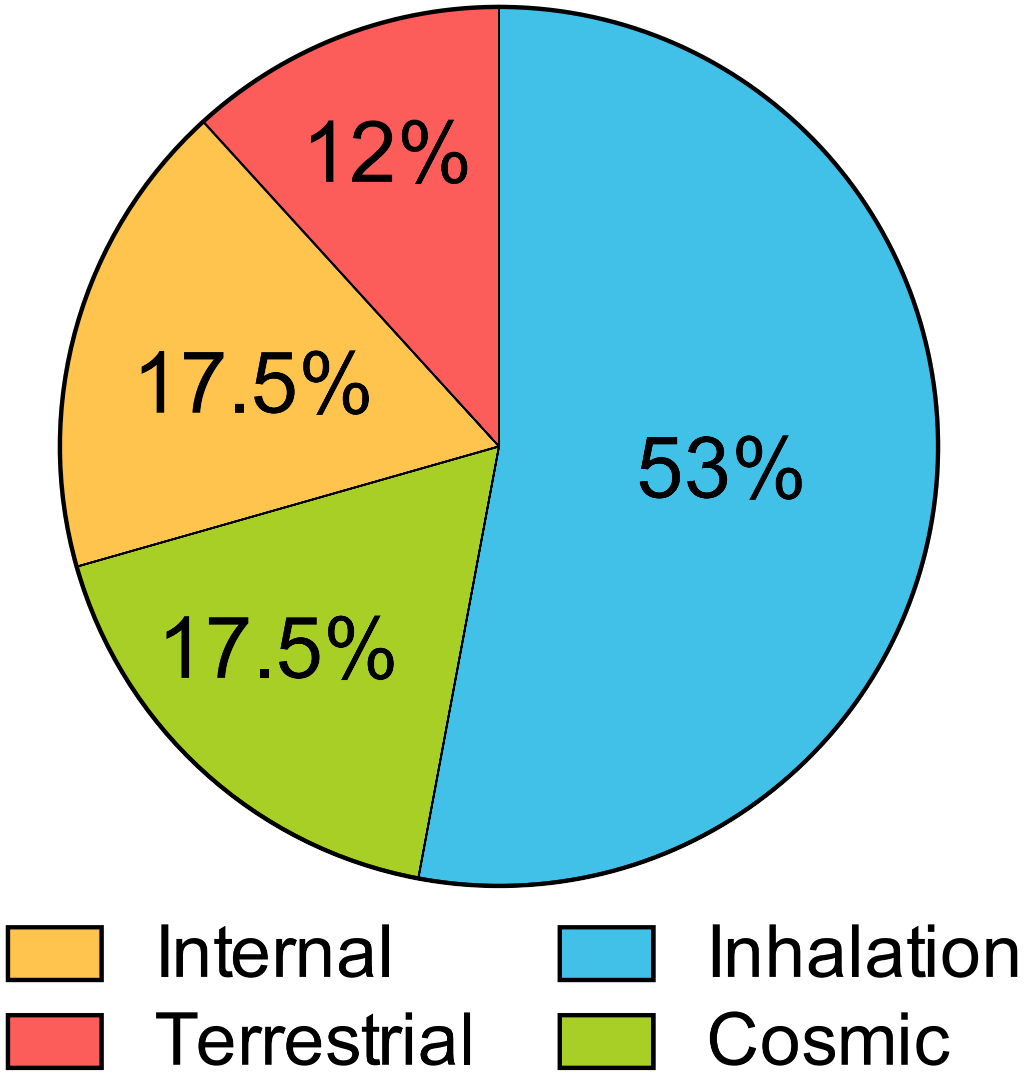
REPAIR:
Researching the Effects of the Presence and Absence of Ionizing Radiation

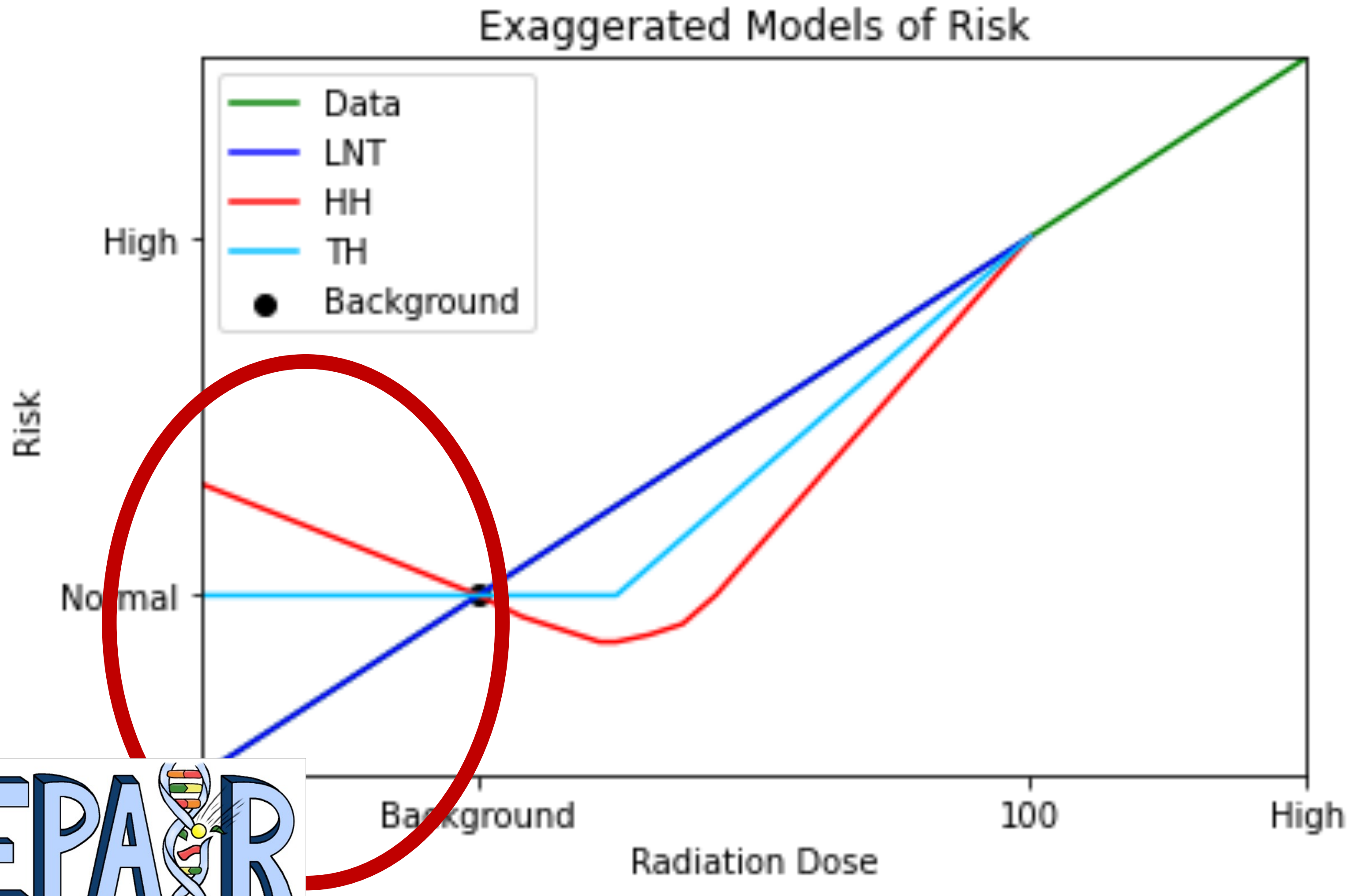
Natural background Radiation - Context

Location	Annual dose (mSv)
Ramsar, Iran	Up to 200
Guarapari, Brazil	Up to 40
Mamuju, Indonesia	Up to 32
Kerala, India	Up to 10
Yangjiang, China	Up to 6
World Average	**2.4**
Canadian Average	**2.2**

Natural background radiation



Why study natural background radiation?



Life sciences laboratory

Life sciences laboratory

Creating a sub-NBR environment:

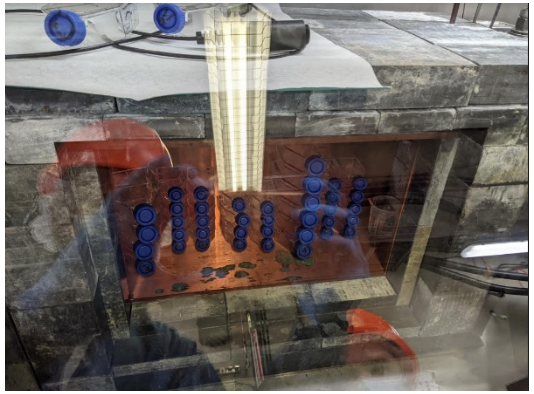
•Cosmic: SNOLAB

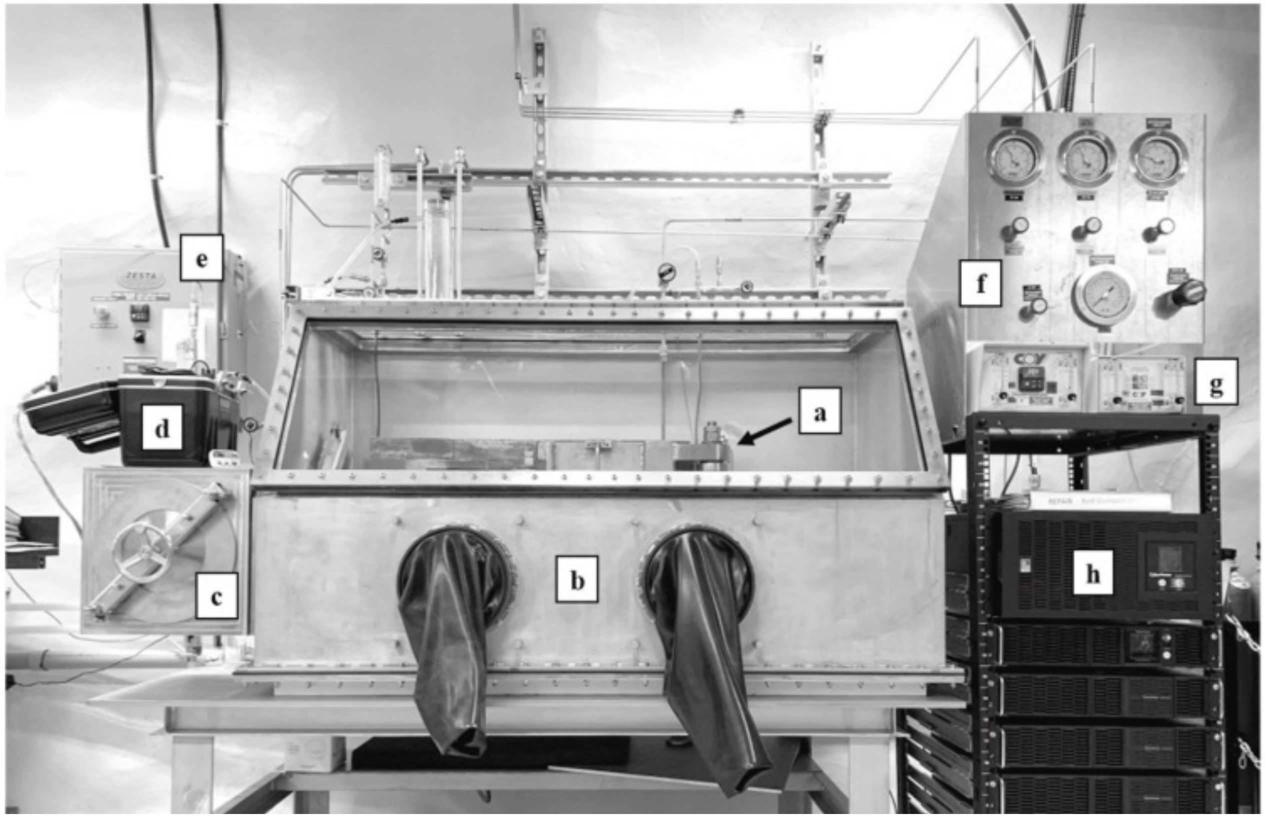
•Terrestrial (Gamma): Lead

•Inhalation (Radon): Air filtration

•Endogenous radioisotopes: Nutritional restriction*

Life sciences laboratory





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Cell Model (CGL1) Experiments

The CGL1 Cell Line

Hybrid human cell line:

- Cross between Hela (cancerous cells) and normal skin fibroblasts
- Normal phenotype
- Genetic damage causes cancerous phenotype transition (neoplastic transformation

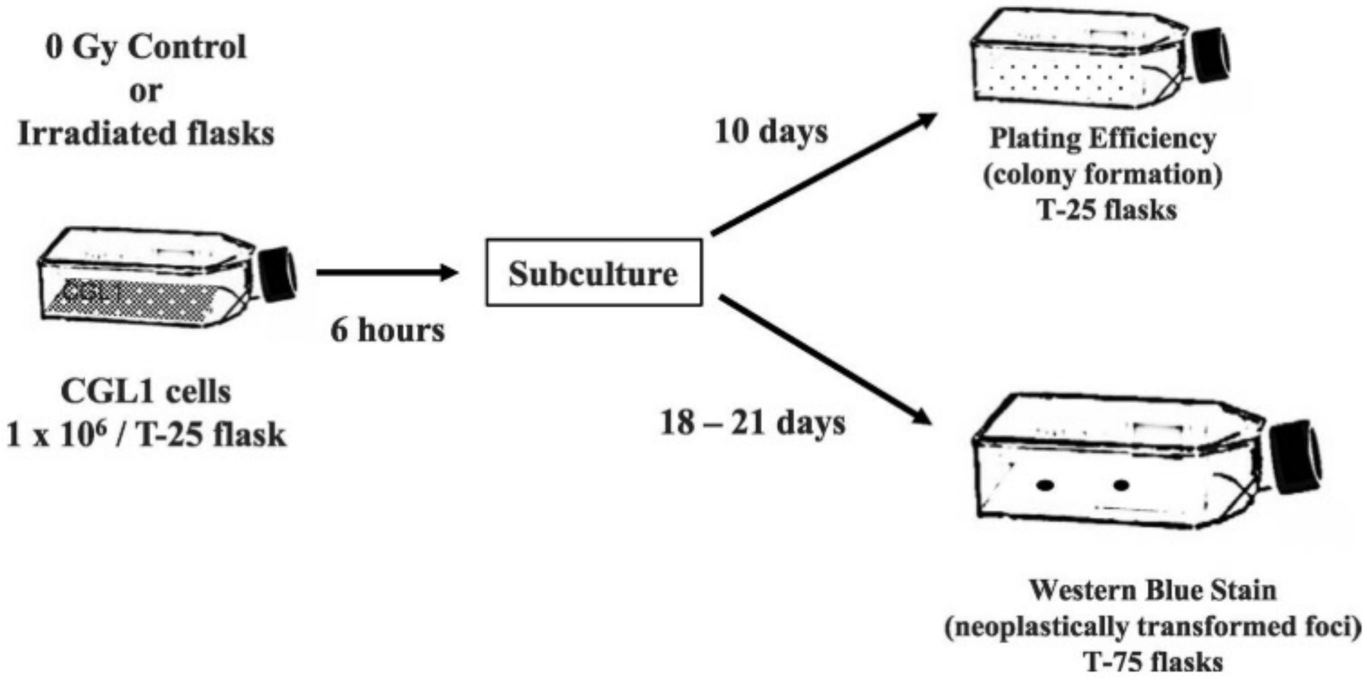


FIG. 1. A general timeline of the CGL1 neoplastic transformation assay.

REPAIR: CGL1 Experiment - 1

- 1 month
- 2 month
- 3 month
- 4 month

→

1. Baseline response
2. Radiation challenge

→

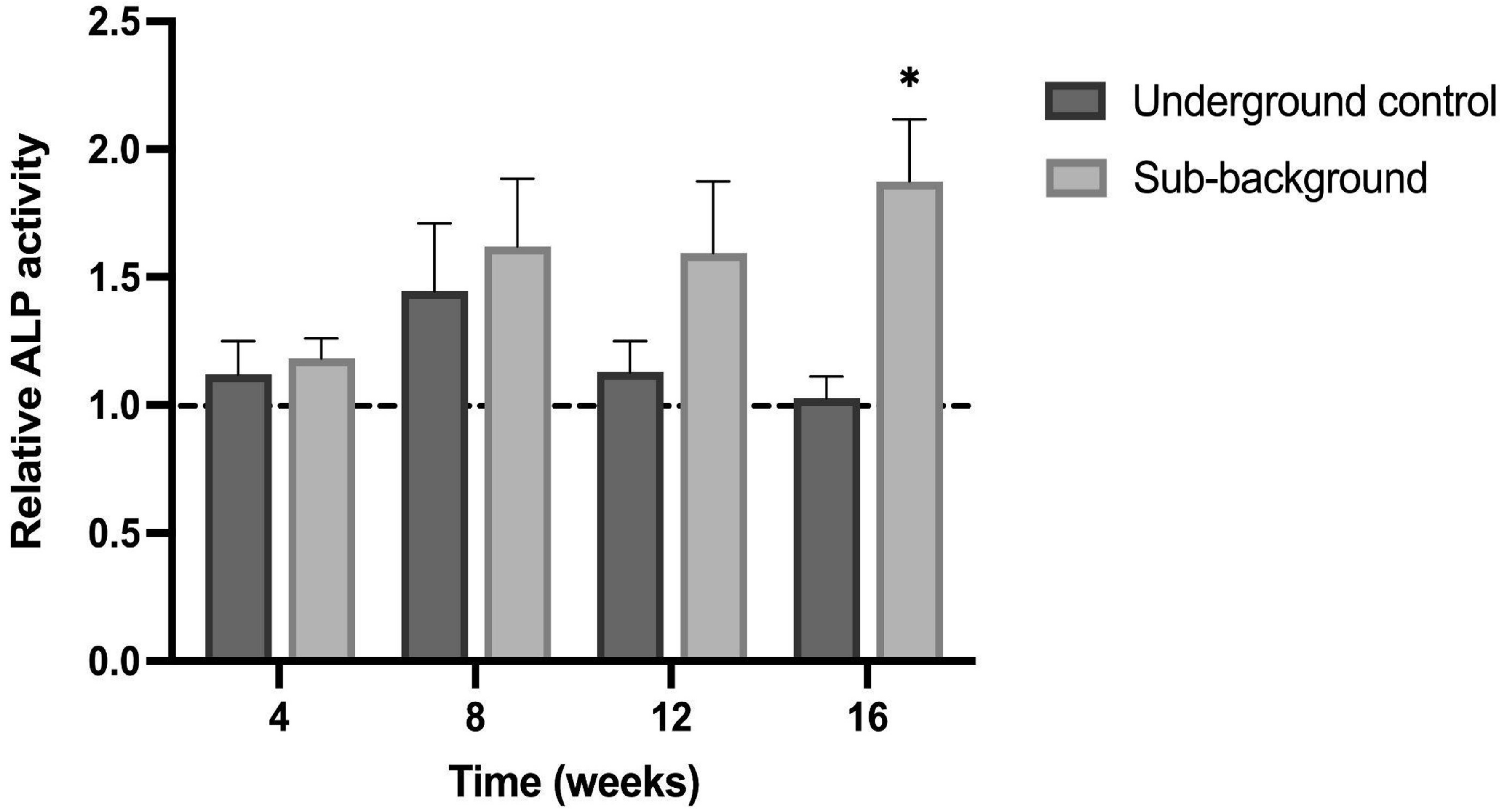
- Growth
- Survival
- Genomic damage
- Carcinogenesis

REPAIR: CGL1 Experiment

Particle type	Surface control (nGy hr^{-1})	Underground control (nGy hr-1)	Sub-Background (nGy hr-1)
Gamma	5.78 ± 0.03	7.67 ± 0.01	0.0427 ± 0.0013
Neutron	4.52 ± 0.04	0.0045 ± 0.0002	0.00169 ± 0.00002
Muon	55.27 ± 0.4	Negligible	Negligible
^{222}Rn	0.044 ± 0.014	1.45 ± 0.17	0.009 ± 0.011
^{40}K	2.41 ± 0.19	2.41 ± 0.19	2.41 ± 0.19
^{14}C	0.0175 ± 0.0001	0.0175 ± 0.0001	0.0175 ± 0.0001
Low LET[a]	63.48 ± 0.62	10.1 ± 0.2	2.47 ± 0.19
High LET[b]	4.56 ± 0.05	1.45 ± 0.17	0.01 ± 0.01
Total	68.04 ± 0.67	11.55 ± 0.37	2.48 ± 0.20
[a]Low LET = Gamma, Muon, ^{40}K, ^{14}C			
[b]High LET = Neutron, ^{222}Rn			

27-fold decrease

REPAIR: CGL1 Experiment - 1



REPAIR: CGL1 Experiment - 1

Conclusions:

- Sub-NBR exposure did not significantly alter:
    - growth rates,
    - cell survival,
    - induction of DNA double strand breaks following high dose irradiation
- Sub-NBR exposure did result in significantly increased ALP activity, suggestive of increased neoplastic transformation rates

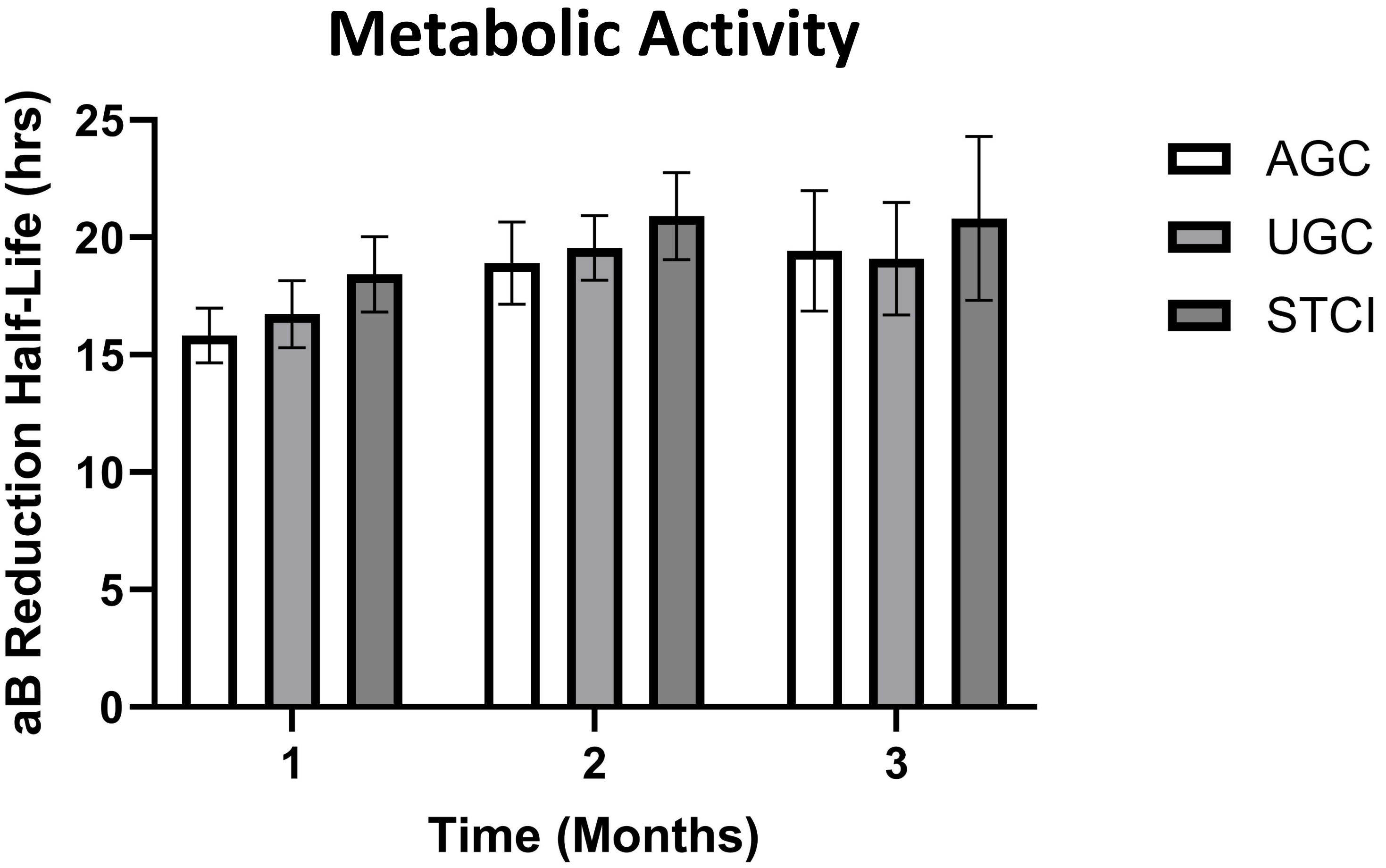
REPAIR: CGL1 Experiment - 2

- 1 month
- 2 month
- 3 month
- 4 month

1. Baseline response

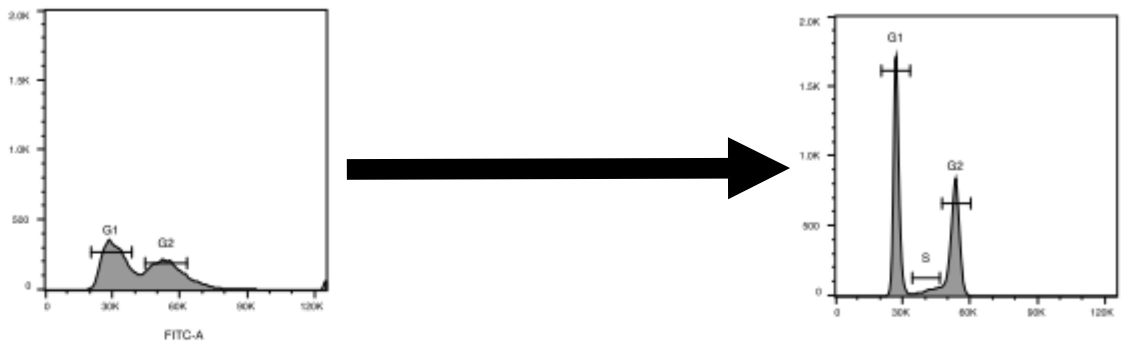
- Metabolic activity (alamarBlue)
- Transcriptomics (NGS)

REPAIR: CGL1 Experiment - 2



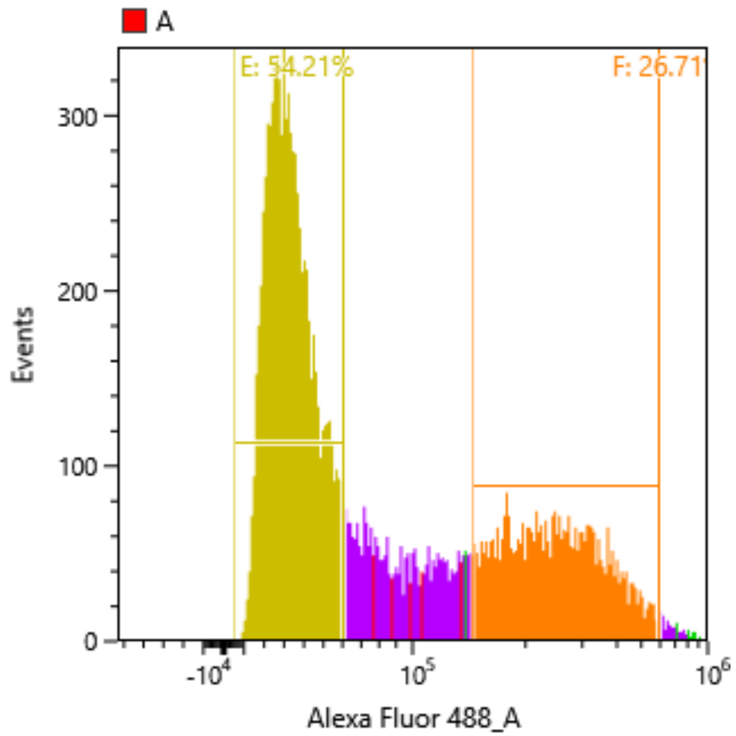
REPAIR: CGL1 Next Steps

- Development of a flow-based assay for cellular iALP activity
  - Comparison with conventional transformation assay for validation
  - Detect baseline transformation (~28/1,000,000)



REPAIR: CGL1 Next Steps

- Development of a flow-based assay for cellular iALP activity



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Literature cited

Available upon request

Dose Definitions

Absorbed Dose

Absorbed dose is the amount of energy deposited by radiation in a mass.

The mass can be anything: water, rock, air, people, etc.

Absorbed dose is expressed in milligrays (mGy).

Equivalent Dose

Equivalent dose is calculated for individual organs.

It is based on the absorbed dose to an organ, adjusted to account for the effectiveness of the type of radiation.

Equivalent dose is expressed in millisieverts (mSv) to an organ.

Effective Dose

Effective dose is calculated for the whole body.

It is the addition of equivalent doses to all organs, each adjusted to account for the sensitivity of the organ to radiation.

Effective dose is expressed in millisieverts (mSv).

High-NBR areas and life expectancy

Correlative links between natural radiation and life expectancy in the US population

Elroei David · Roy Bitan · Sharona Atlas · Marina Wolfson · Vadim E. Fraifeld

Table 1 Pairwise and partial correlations of life expectancy with background radiation and ^{222}Rn

Correlation coefficients with LE	Males		Females	
	Background radiation	^{222}Rn	Background radiation	^{222}Rn
r (p-value)	0.27 (5.8E−54)	0.31 (2.5E−68)	0.26 (8.3E−48)	0.32 (6.7E−73)
r_p (p-value)	0.21 (5.6E−32)	0.26 (2.8E−49)	0.19 (2.0E−26)	0.27 (1.0E−54)

The number of counties was n = 3124 for both sexes

r Pearson's correlation coefficient, r_p Partial correlation coefficient

Table 3 Stepwise multivariate regression analysis of relative impacts of terrestrial radiation, cosmic radiation and ^{222}Rn on life expectancy

Variables	Males		Females	
	Std. Beta	p-value	Std. Beta	p-value
^{222}Rn	0.25	< 0.0001	0.27	< 0.0001
TR	0.10	< 0.0001	0.11	< 0.0001
CR	0.22	< 0.0001	0.15	< 0.0001
^{222}Rn-TR interaction	–	> 0.3	–	> 0.4
^{222}Rn-CR interaction	–	> 0.08	−0.06	< 0.02
TR-CR interaction	−0.09	< 0.005	–	> 0.13

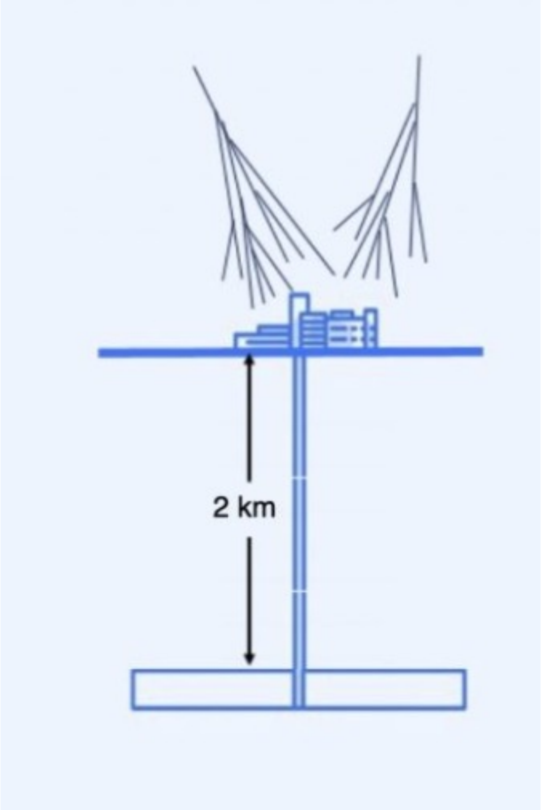
Table 2 Stepwise multivariate regression analysis of relative impacts of background radiation and ^{222}Rn on life expectancy

Variables	Males		Females	
	Std. Beta	p-value	Std. Beta	p-value
BR	0.21	< 0.0001	0.21	< 0.0001
^{222}Rn	0.26	< 0.0001	0.27	< 0.0001

The number of counties was n = 3124 for both sexes

Std. Beta standardized beta coefficients

Shielding at SNOLAB



- 2km of rock shielding decreases the muon flux by a factor of 50 million.
- About 60 billion solar neutrinos pass through your thumb nail every second, only two neutrinos will collide with your whole body in your lifetime.

Background

Sources:

- Radon (73%)
  - Alpha decay
- Galactic cosmic radiation (GCR) (11%)
  - Muons production
- Endogenous/internal radiation sources (9%)
  - Beta emitters: C-14 and K-40
- Terrestrial sources (7%)
  - Uranium+Thorium decay series from the soil