

Figure S1: HZE induces persistent oxidative stress in Lgr5-GFP positive intestinal stem cells. (A) Sorted Lgr5-GFP ISC were stained for CellROX deep red to assess the oxidative stress. Stained cells were fixed, cytopsin onto a glass slide, and visualized under a microscope. Nuclei were co-stained with DAPI. Representative images show increased CellROX stain in irradiated samples at a 2-month time. (B) Immunofluorescent co-staining of β -catenin and Lgr5-GFP in intestine 2 months post irradiation. (C) Average tumor count per mouse in *Lgr5⁺Apc^{1638N/+}* mice. Scale bar, 20 μm . *, significant relative to control; **, significant relative to γ -rays. Statistical significance is set at $P < 0.05$, and error bars represent mean \pm SEM.

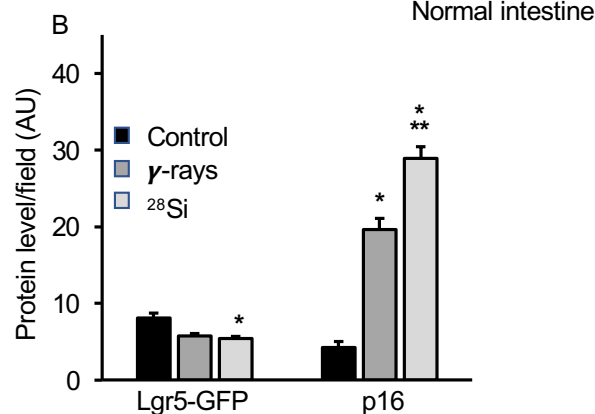
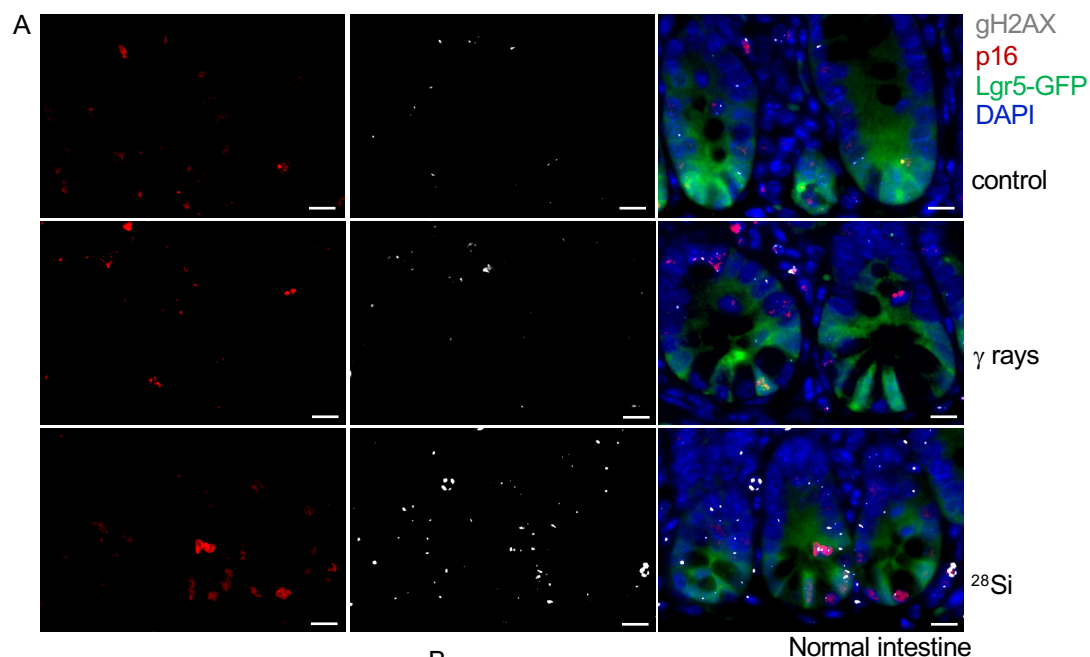


Figure S2: ^{28}Si exposure leads to persistent increased DNA damage and senescence after 5 months of radiation in non-tumor normal intestine from *Lgr5⁺Apc^{1638N/+}* mice.

Adjacent normal intestinal sections were co-stained with p16, γH2AX , and Lgr5-GFP to detect DNA damage response and senescence after 5 months of radiation exposure. (A) After radiation exposure, representative fluorescent images show increased p16 and γH2AX expression in non-tumor tissue sections. (B) γH2AX foci were counted and represented graphically, showing higher DNA damage response in irradiated samples relative to control. Graphical representation of Lgr5-GFP or p16 fluorescent intensity in the non-tumor intestine with or without radiation. Nuclei were visualized using DAPI. Scale bar, 10 μm . *, significant relative to control; **, significant relative to γ -rays. Statistical significance is set at $P < 0.05$, and error bars represent mean \pm SEM.

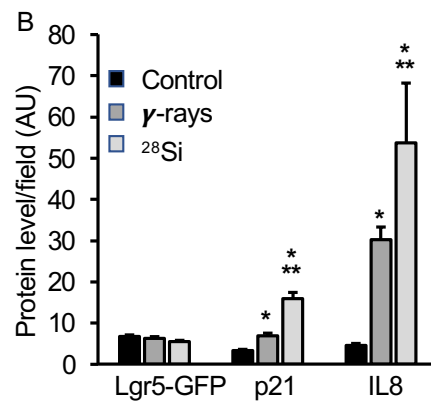
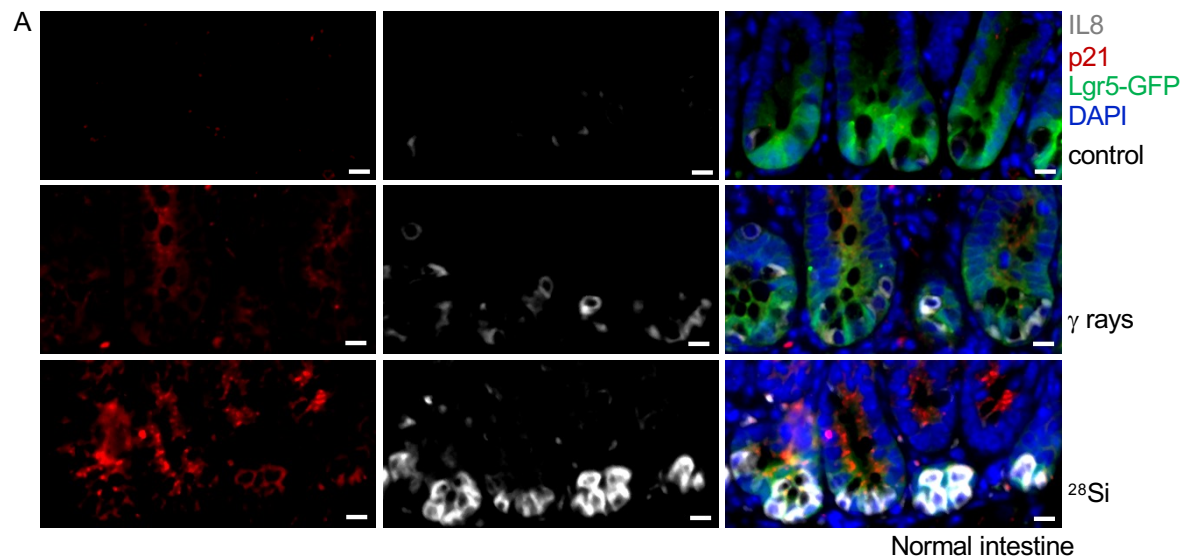


Figure S3: ^{28}Si exposure leads to increased senescence and SASP acquisitions after 5 months of radiation in non-tumor normal intestine derived from *Lgr5⁺Apc^{1638N/+}* mice. To detect senescence and secretory phenotype, in non-tumor normal intestinal sections were co-stained with p21, IL8, and Lgr5-GFP. Signals were detected, and images were captured under fluorescent microscopy. (A) Representative fluorescent images show enhanced expression of IL8 and p21 expression in intestinal non-tumor normal tissue. (B) The fluorescent intensity of IL8, p21, and Lgr5-GFP was quantified and represented as a bar graph. Nuclei were visualized using DAPI. Scale bar, 10 μm . *, significant relative to control; **, significant relative to γ -rays. Statistical significance is set at $P < 0.05$ and error bars represent mean \pm SEM.

Table S1: List of SASP and GI function primers used for qRT-PCR

S.No.	Gene	Primers
1	ATF5	Forward 5'-gggtcatttttagctctgtgagagaa; Reverse 5'-atttggcccataaccctaga
2	Bax	Forward 5'-atgcgtccaccaagaagctga; Reverse 5'-agcaatcatctctgcagctcc
3	CD40	Forward 5'-gcagtgtgttacgtgcagtg; Reverse 5'-ctgtgcagtggcttgctcagt
4	Cyclind1	Forward 5'-ttgactgccgagaagttgtg; Reverse 5'-ccacttgagcttggtcacca
5	CyclinD2	Forward 5'- caccgacaactctgtgaagc; Reverse 5'- tgctcaatgaagtctgtgagg
6	Cxcl1	Forward 5'-ctgggattcacctcaagaacatc; Reverse 5'-cagggtcaaggcaagcctc
7	Cxcl2	Forward 5'-ccaaccaccaggetacagg; Reverse 5'-gcgtcacactcaagctctg
8	Cxcl5	Forward 5'-tgcgtgtgtttgcttaaccg; Reverse 5'-agctatgacttccaccgtagg
9	Faim2	Forward 5'-ctcgagagaagacatcatgacc; Reverse 5'-ttctctccatttgctgtgtg
10	IL1 β	Forward 5'-gcactacaggtccgagatgaac; Reverse 5'-ttgtcgttgcttggttctcctgt
11	IL6	Forward 5'-caagaaagacaaagccagagtc; Reverse 5'-gaaattggggtaggaaggac
12	Lpo	Forward 5'-tgacctgtctccagactgc; Reverse 5'-ttgaccagaccttgacctc
13	Opg	Forward 5'-atgaacaagtggctgtgctg; Reverse 5'-tcacacaggagctgatgacc
14	p16	Forward 5'-gggtttcgccaacgccccga; Reverse 5'-tgcagcaccaccagcgtgtcc
15	P19arf	Forward 5'-gtcacacgactgggctgatt; Reverse 5'-gactccatgctgctccagat
16	p21	Forward 5'-tccacagcgatatccagaca; Reverse 5'-agacaacggcacactttgct
17	PLAT	Forward 5'-agtctctgctgggtgctgtc; Reverse 5'-cggggaccacctgtatgtt
18	PLA2G2a	Forward 5'-taagacaggaagagagctgagc; Reverse 5'-gtaccacatccacttttctccag
19	PTGES	Forward 5'-agcacactgttggtcatcaa; Reverse 5'-tccacatctgggtcactct
20	Sox17	Forward 5'-tgaaatatggcccactcaca; Reverse 5'-ctgtcttccctgtcttggttg
21	Tlr1	Forward 5'-ggacctacccttgcaaaca; Reverse 5'-tatcaggaccctcagcttgg
22	Troy	Forward 5'-cgctgccattctcttctac; Reverse 5'-tcgatccttgaattctgct
23	Gapdh	Forward 5'-gtggagtcatactggaacatgtag; Reverse 5'-aatggtgaaggctcggtgtg
24	Scl2a2	Forward 5'-cgaatttatccagcagcacaa; Reverse 5'-ggccatcaacatgatcttcac
25	Scl2a5	Forward 5'-tgatatagggcatccaggagat; Reverse 5'-tgaccatcctcacgatctttg
26	Scl5a1	Forward 5'-gataaaagaccccaccagcat; Reverse 5'-cttgggcctggatatatacttgg
27	Cck	Forward 5'-ccggtcacttattctatggct; Reverse 5'-cactgctagcgcgatacatc
28	Gip	Forward 5'-gcaagctaaggtcagagtc; Reverse 5'-gatgatgtgctgagagacctt
29	Scl9a3	Forward 5'-cctcatgctctgaagtcca; Reverse 5'-cggccaagctgtacaagag
30	Scl27a4	Forward 5'-gatgatgcgaccacca; Reverse 5'-catcctgtctttgtgtaccc
31	Npc1	Forward 5'-ccctccaaatttcgtaagtgtg; Reverse 5'-gcagccatataacgagagcat
32	Npc1I1	Forward 5'-gctagtttctctccagtagca; Reverse 5'-ctcaacctctgatcaccttg

Table S2: Oxidative stress PCR array in Lgr5-GFP positive cells 60-day post radiation exposure

Gene Symbol	Gene Name	γ rays Fold change \pm SE	^{28}Si Fold change \pm SE
Sod1	Superoxide dismutase 1, soluble	4.99 \pm 0.44	5.62 \pm 0.23
Prdx6	Peroxiredoxin 6	4.91 \pm 0.31	6.81 \pm 0.31
Noxo1	NADPH oxidase organizer 1	4.86 \pm 0.18	4.06 \pm 0.23
Gpx2	Glutathione peroxidase 2	4.78 \pm 0.23	3.32 \pm 0.28
Epx	Eosinophil peroxidase	2.94 \pm 0.39	3.13 \pm 0.32
Ercc6	Excision repair cross-complementing rodent repair deficiency, complementation group 6	3.78 \pm 0.22	4.07 \pm 0.25
Gpx5	Glutathione peroxidase 5	2.92 \pm 0.39	4.14 \pm 0.34
Park7	Parkinson disease (autosomal recessive, early onset) 7	2.86 \pm 0.25	2.53 \pm 0.23
Ercc2	Excision repair cross-complementing rodent repair deficiency, complementation group 2	2.69 \pm 0.23	2.83 \pm 0.23
Nqo1	NAD(P)H dehydrogenase, quinone 1	2.62 \pm 0.23	2.87 \pm 0.32
Sod2	Superoxide dismutase 2, mitochondrial	2.6 \pm 0.26	2.68 \pm 0.19
Ccs	Copper chaperone for superoxide dismutase	2.6 \pm 0.23	2.81 \pm 0.25
Il19	Interleukin 19	2.51 \pm 0.41	2.44 \pm 0.04
Xpa	Xeroderma pigmentosum, complementation group A	2.46 \pm 0.26	2.49 \pm 0.22
Gss	Glutathione synthetase	2.35 \pm 0.19	2.60 \pm 0.19
Als2	Amyotrophic lateral sclerosis 2 (juvenile) homolog (human)	2.20 \pm 0.19	2.55 \pm 0.23
Hmox1	Heme oxygenase (decycling) 1	2.01 \pm 0.42	3.00 \pm 0.28
Cygb	Cytoglobin	-2.74 \pm 0.31	2.44 \pm 0.22
Fancc	Fanconi anemia, complementation group C	7.61 \pm 0.23	8.29 \pm 0.24
Atr	Ataxia telangiectasia and rad3 related	7.25 \pm 0.33	3.05 \pm 0.26
Slc38a1	Solute carrier family 38, member 1	2.7 \pm 0.24	2.36 \pm 0.30
Ift172	Intra-flagellar transport 172 homolog (Chlamydomonas)	2.29 \pm 0.22	2.67 \pm 0.22
Duox1	Dual oxidase 1	2.3 \pm 0.20	2.29 \pm 0.22
Txrnd3	Thioredoxin reductase 3	4.57 \pm 0.29	4.48 \pm 0.24
Prdx4	Peroxiredoxin 4	2.19 \pm 0.23	2.49 \pm 0.21
Apc	Adenomatosis polyposis coli	2.08 \pm 0.22	2.25 \pm 0.22
Ehd2	EH-domain containing 2	-2.07 \pm 0.39	-2.53 \pm 0.12
Mpo	Myoglobin	-14.86 \pm 0.31	-2.47 \pm 0.31
Fmo2	Flavin containing monooxygenase 2	-2.29 \pm 0.28	-2.42 \pm 0.24
Aox1	Aldehyde oxidase 1	-5.87 \pm 0.14	-2.67 \pm 0.31

Table S3: Expression of SASP and SIR genes in Lgr5-GFP cells 60-day post radiation expression

Gene	Functions	γ rays Fold change \pm SE	^{28}Si Fold change \pm SE
ATF5	Tumor suppressor, enhances radio resistance	1.09 \pm 0.11	1.44 \pm 0.31
Bax	Proapoptotic signaling	-1.42 \pm 0.03	-1.61 \pm 0.06
CD40	Induce ROS and NO level in cell with activated CD40	-1.42 \pm 0.9	1.08 \pm 0.18
Cyclind1	G1/S phase transition and entry into the S-phase	1.47 \pm 0.25	2.23 \pm 0.25
CyclinD2	Regulates cell-cycle during G (1)/S transition.	1.22 \pm 0.27	1.74 \pm 0.24
Cxcl1	Mitogenic, chemo-attractant for neutrophil	1.22 \pm 0.06	1.08 \pm 0.18
Cxcl2	Immunoregulatory and inflammatory processes	1.95 \pm 0.17	1.49 \pm 0.09
Cxcl5	Stimulates chemotaxis of neutrophil	1.09 \pm 0.24	1.74 \pm 0.24
Faim2	Fas apoptotic inhibitory molecule 2	1.05 \pm 0.26	2.07 \pm 0.39
IL1 β	Mediator of inflammatory response, involved in a cell proliferation, differentiation, and apoptosis	2.94 \pm 0.5	3.3 \pm 0.2
IL6	Inflammatory response cytokine	2.73 \pm 0.2	3.4 \pm 0.2
Lpo	A oxidoreductase, acts as a natural antibacterial agent	-1.26 \pm 0.19	1.38 \pm 0.37
Opg	TNF signaling	-1.09 \pm 0.09	1.21 \pm 0.12
p16	Cyclin dependent kinase inhibitor	1.90 \pm 0.2	2.6 \pm 0.3
P19arf	Induces cell cycle arrest in G1 and G2 phases	1.87 \pm 0.3	3.5 \pm 0.1
p21	Cyclin dependent kinase inhibitor	1.46 \pm 0.2	2.0 \pm 0.2
PLAT	Secreted serine protease that converts proenzyme plasminogen to plasmin,	-1.01 \pm 0.32	1.88 \pm 0.54
PLA2G2a	Inflammatory response and tissue regeneration, regulate phospholipid metabolism in bio membrane	-1.26 \pm 0.09	2.15 \pm 0.27
PTGES	Prostaglandin E synthase, induced by IL1beta, TP53. Medi pain during acute inflammatory response	1.08 \pm 0.26	2.55 \pm 0.19
Sox17	Transcriptional regulator of protein involved in development and in the determination of cell fate	1.10 \pm 0.25	1.91 \pm 0.14
Tlr1	pathogen recognition and activation of innate immunity.	-1.13 \pm 0.43	1.57 \pm 0.13
Troy	Activates JNK signaling	1.22 \pm 0.35	1.37 \pm 0.18