The history of radiation induced mutagenesis in plants and WAM model.

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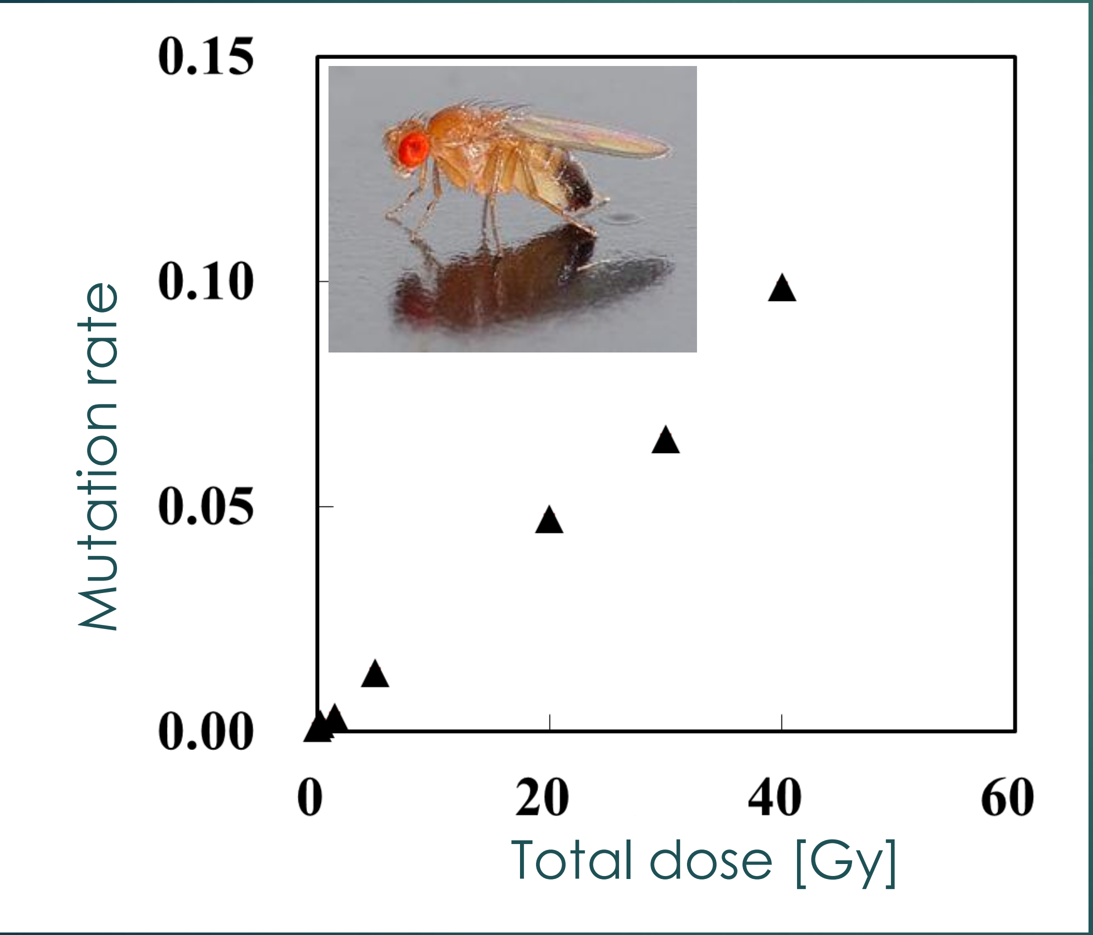
Hermann J. Muller (1890-1967)

the Nobel Prize in Physiology or Medicine in 1946

X-ray irradiated "*Drosophila*"



Hermann J. Muller

ARTIFICIAL TRANSMUTATION OF THE GENE

Most modern geneticists will agree that gene mutations form the chief basis of organic evolution, and therefore of most of the complexities of living things. Unfortunately for the geneticists, however, the study of these mutations, and, through them, of the genes

Science, 66, 84-87, 1927

Lewis John Stadler
(1896 - 1954)

	Total number of head progenies examined	Number segregating mutant seedling characters
X-ray treated:		
Higher voltage		
Heavy dose	210	6
Light dose	259	1
Lower voltage:		
Heavy dose	494	6
Light dose	280	1
Total X-rayed	1,243	14
Radium treated:		
Total for all doses	1,039	3
Untreated	1,341	0

SPECIAL ARTICLES

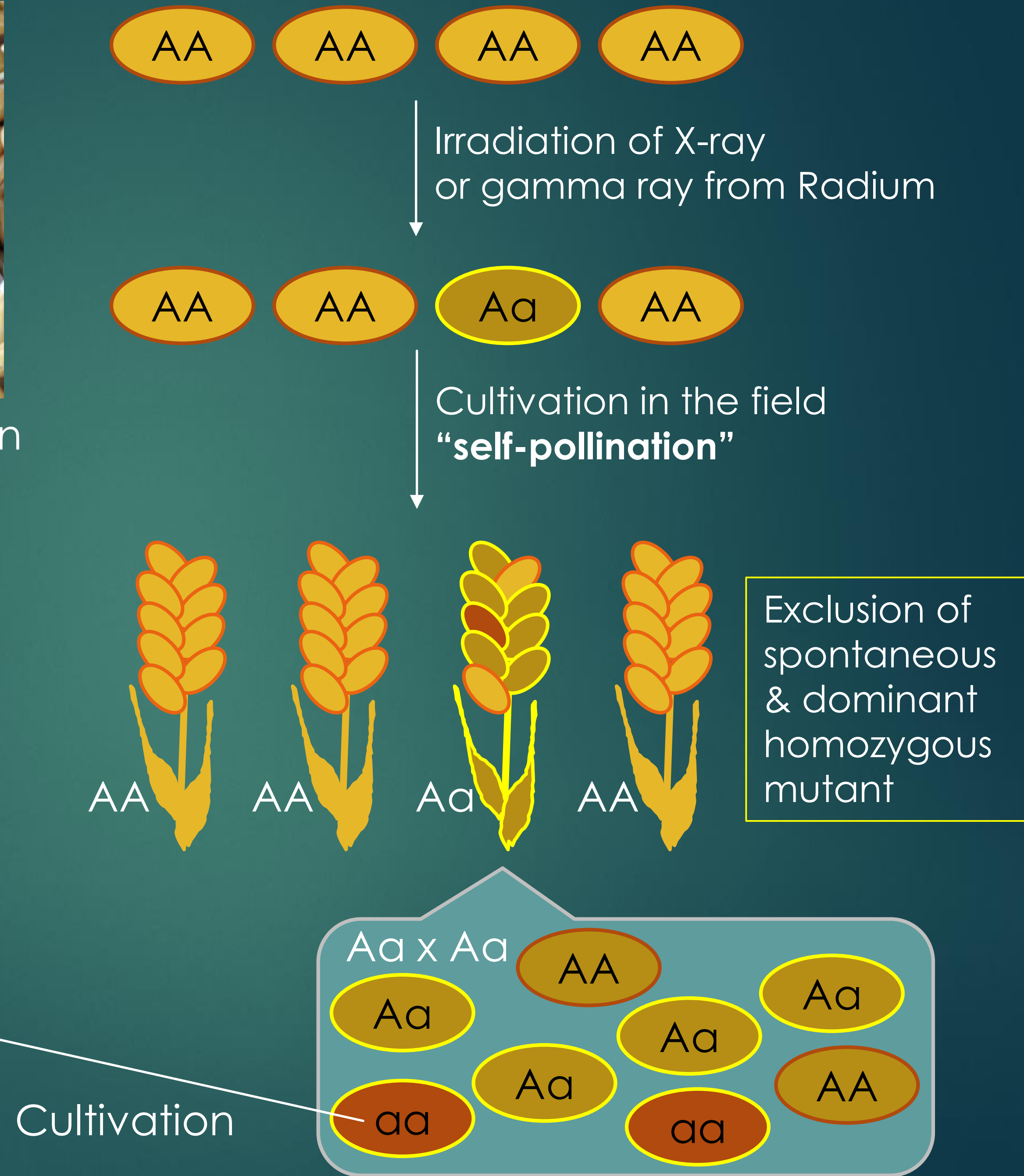
MUTATIONS IN BARLEY INDUCED BY X-RAYS AND RADIUM

At the Nashville meeting of the American Association last December I reported the occurrence of mutations in barley following X-ray treatment.[1] The experiments, which were independent of and coincident with those of Muller,[2] though by no means so comprehensive and thorough, confirm Muller's discovery of the power of X-rays to induce mutation and show its application to plants. They show also that mutations may be induced similarly by radium treatment.

were applied simultaneously, at target distances of 22.7 and 45.4 cm, respectively. The radiation passed through two samples of seed at shorter distances, and the filtering effect of the wet blotters and seeds must be considered in computing dosage. Ionization measurements made later showed that this reduced the intensity of the radiation at the higher voltage by about 52 per cent., and of that at the lower voltage by about 65 per cent. The relative ionizing intensity of the heavy and light treatments at the higher voltage and the heavy and light treatments at the lower voltage was in the ratio 100: 21: 50: 9. The so-called heavy doses were not heavy enough to reduce viability appreciably, but a dose of approximately three times this

Science,
67, 186-187, 1928

Barley seeds on germination

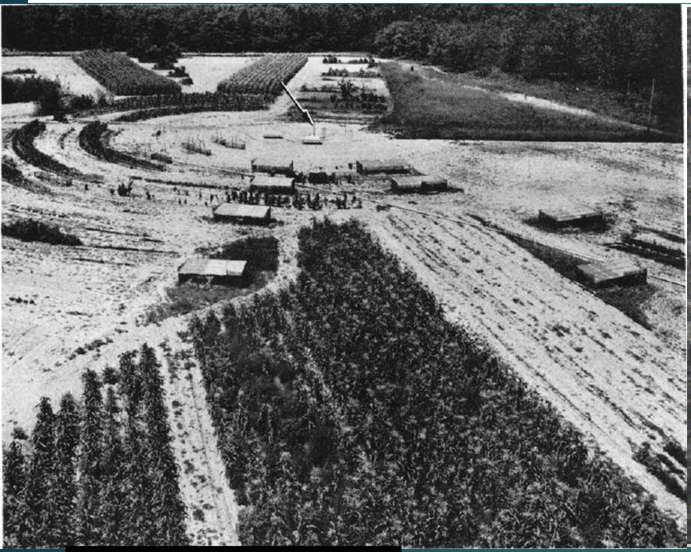


Gamma Irradiation facilities used for plant irradiation (1950's and 60's)

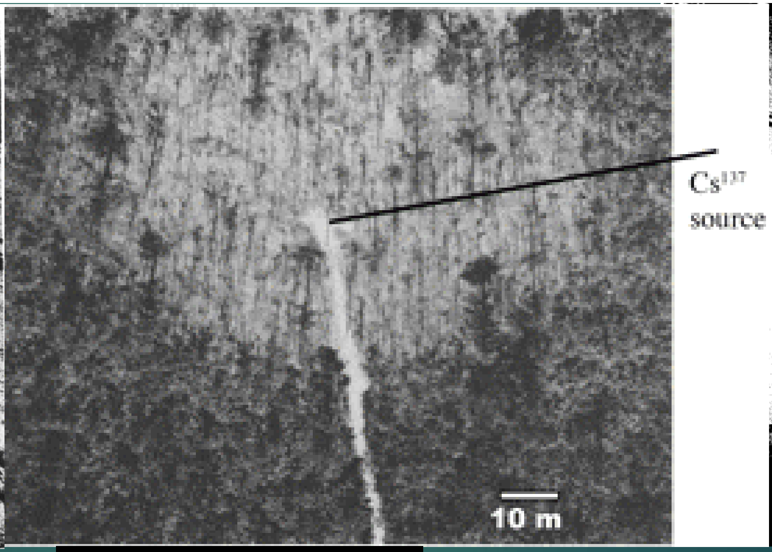
Country	Belongs to:	Nucleid	Intensity (Ci)	Facility	Area (m^2)	Operated since:
Australia	Division of Plant Industry	^{60}Co	100	Gamma room	30	?
Belgium	Ministere des Affaires Economiques et de L'Energie Commissariat a L'Energie Atomique	^{137}Cs	20	Gamma greenhouse	100	1962?
Costa Rica	Inter-American Institute of Agricultural Sciences	^{137}Cs	1400	Gamma field	25000	1961
Denmark	Research Establishment Riso	^{60}Co	100	Gamma field	2500	1957
Germany	Max-Planck-Institut fur Zuchtungsforschung	^{137}Cs	20000	Gamma room	95	1967
Hungary	Uni. of Agri. Sci.	^{60}Co	105	Gamma field	800	1966?
India	Ind. Agri. Res. Inst.	^{60}Co	200	Gamma field	12100	1960?
Italy	Laboratorio di Gentica Vegetale del Centro di Studi Nucleari della Cassaccia	^{60}Co	250	Gamma field	6300	1960
Netherlands	Inst. of. Atom. Sci. in Agri.	^{137}Cs	3000	Gamma room	140	1963
			300	Gamma greenhouse?		1963
Norway	Institutt for Arvelaere og Planteforedling	^{60}Co	50	Gamma field	10000	1956
Philippines	Phi. Atom. Res. Center	^{60}Co	630	Gamma field	38	1964
Spain	Instituto Nacional de Investigaciones Agronomicas	^{137}Cs	2250	Gamma field	1900	1961
Sweden	Fruit Breeding Station	^{60}Co	40	Gamma field	250	1952
	Royal Forestry College	^{137}Cs	1000	Gamma field	80000	1955
Thailand	Kasetsart University	^{137}Cs	100	Gamma greenhouse	80	1961
United Kingdom	Wantage Res. Lab.	^{60}Co	120	Gamma room	?	?
U.S.A.	Blandy Exp. Sta.	^{60}Co	200	Gamma field	100	1957
	Brookhaven Nat.Lab.	^{60}Co	3000	Gamma field	52000	1949
		^{60}Co	8.2	Gamma greenhouse	128	?
		^{60}Co	0.21		30	?
		^{137}Cs	9500	Gamma forest	500000	1961
	Emory University	Reactor		Gamma field	3800000	1958
		^{137}Cs	2500		?	1962
		^{60}Co	160		190	1959
		^{137}Cs	15000	Gamma forest	?	
	Oak Ridge Nat.Lab.Tenn.	^{60}Co	110	Gamma room	?	1956
	Uni.of Florida	^{60}Co	5900	Gamma field	66	1958

Table 1. Gamma sources in use in the facilities used primarily for plant irradiations in the Biology Department at the Brookhaven National Laboratory

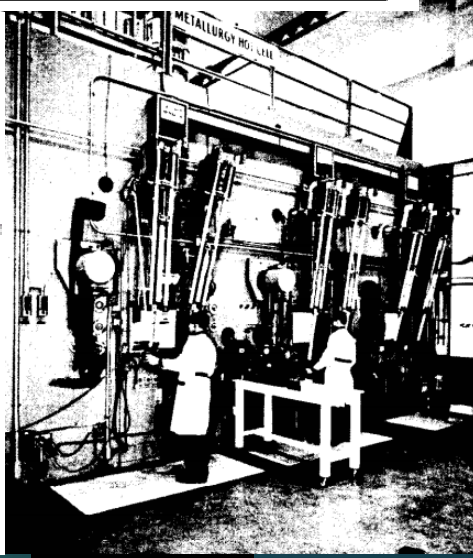
Installation	Isotope	No. effective curies	Exposure rate (R/hr at 1 M)	Lowest rate (R/hr)	Approx. radiation area
Field (cultivated)	Co^{60}	3160	4200	0·013	5·2 hectares
Forest	Cs^{137}	9500	3380	background	50 hectares
Greenhouse	Co^{60}	9	11	0·12	80 M^2
Fallout decay simulator	Cs^{137}	400	140	1·43	110 M^2
Hot cell	Co^{60}	60	80	12·50	1·44 M^2
Pool†	Co^{60}	50,000	10×10^6	4×10^4	500 cm^3



"Gamma Field"

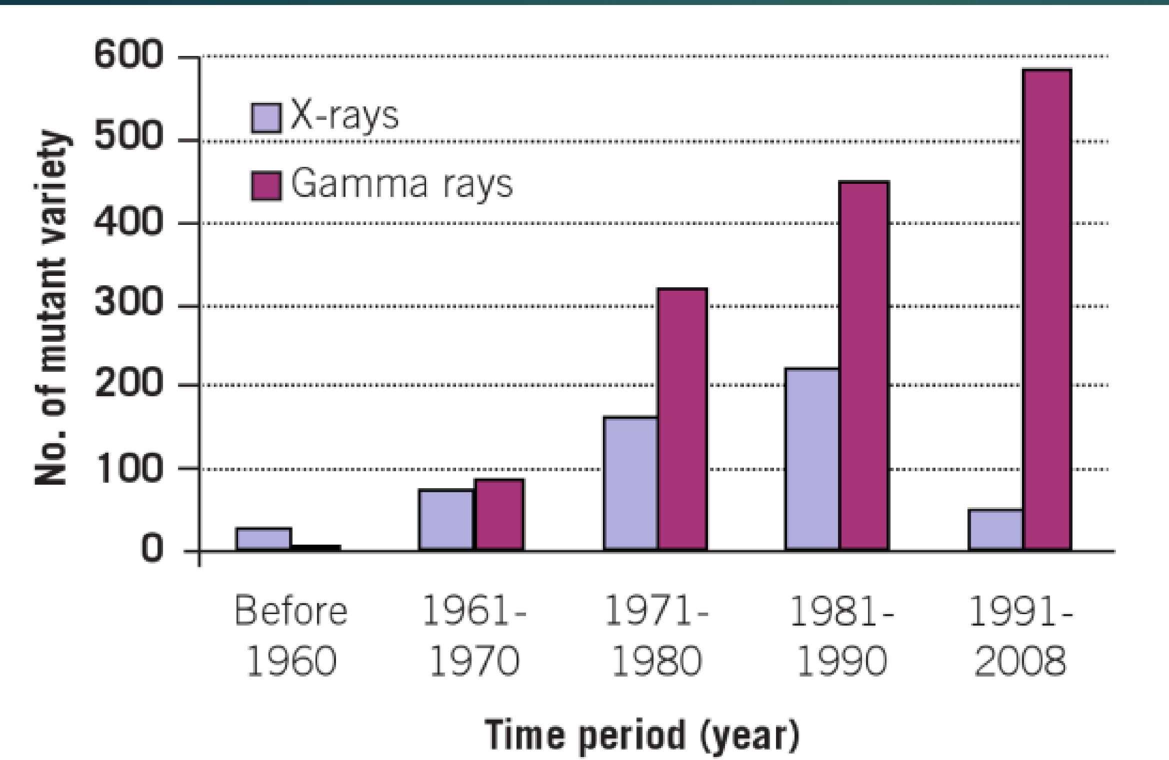


"Gamma Forest"



"Hot cell"

"Research uses of the gamma field and related radiation facilities at Brookhaven national laboratory "
Arnold H. Sparrow, Radiation Botany, 6(5), 377–380, 1966



The global development
of mutant crop varieties
by using X- and Gamma rays.
(IAEA, 2009)

Atomic seeds on sale

“Gammma Filed”
Institute of Radiation Breeding, Hitachiohmiya, Ibaraki, Japan

Co-60
88.8TBq

Plant species and radiation sensitivities

5 -330 R/20hr day (19 – 2900 mGy/day)

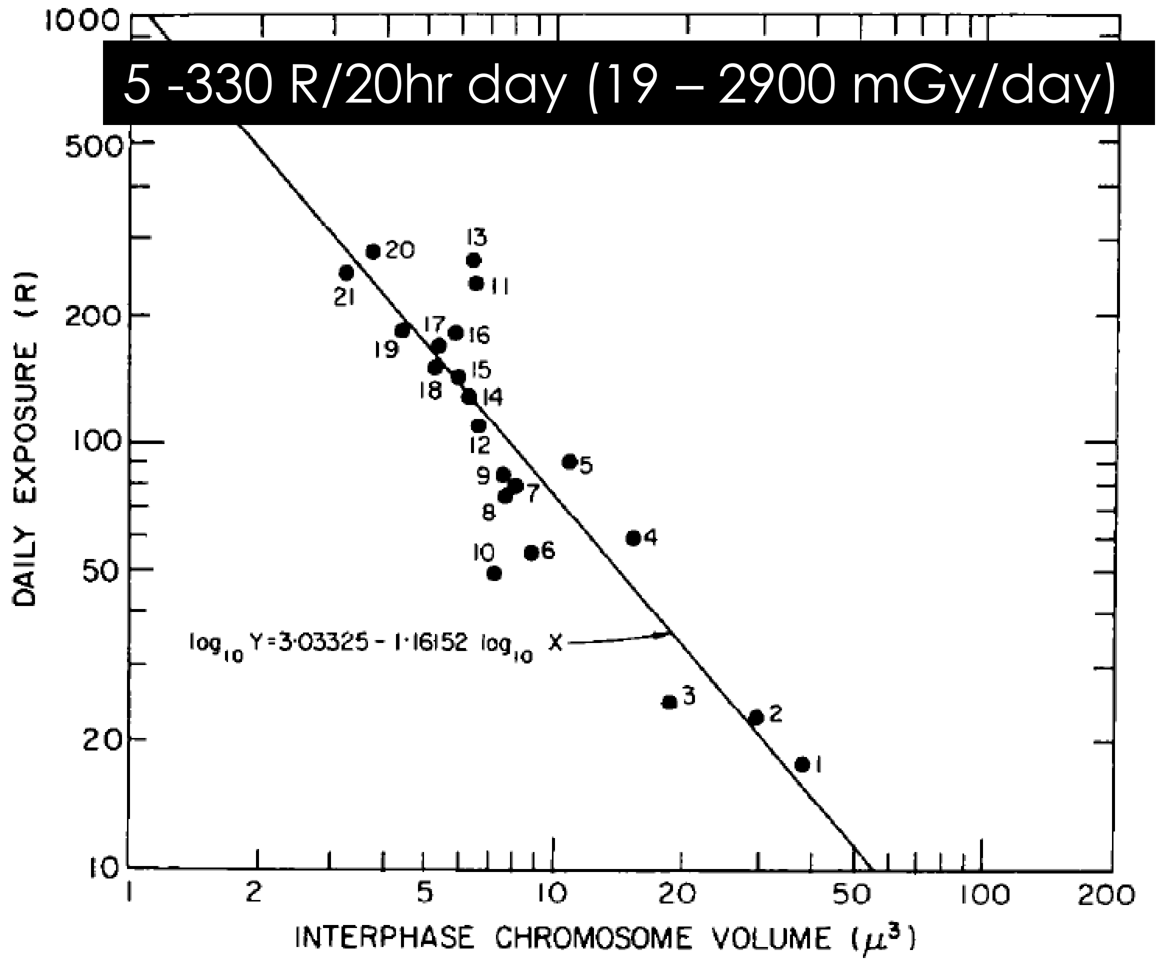


FIG. 5. Regression of daily exposure required to reduce seed set by 50 per cent plotted against interphase chromosome volume for 20 herbaceous diploid species.

1 : onion (タマネギ)
2 : welsh onion (ネギ)
3 : barley (オオムギ)
4 : pea (エンドウ)
5 : spinach (ホウレン草)
6,8 : kidney beans (インゲン豆)
7 : eggplant (ナス)
9 : tomato (トマト)
10 : celery (セロリ)
11 : cucumber (キュウリ)
12 : chili pepper (唐辛子)
13 : melon (メロン)
14 : sugar beet (テンサイ)
15 : cabbage (キャベツ)
16 : carrot (ニンジン)
17 : watermelon (メロン)
18 : radish (ハツカ大根)
19 : chinese cabbage (ハクサイ)
20 : pumpkin (セイヨウカボチャ)
21 : rice (稲)

Yamakawa K., Sparrow AH.
Radiation Botany, 5(6), 557-562 (1965)

New varieties created by the Gammma filed in Japan.

Figure 11. Six flower color mutant varieties registered in 1995 were obtained from pink color of the original variety "Taihei".
A. Haeno Hatsuyuki, B. Haeno Kirameki, C. Haeno Kurenai, D. Haeno Miyarabi, E. Haeno Yuugure, F. Haeno Kagayaki

Japanese pear "Gold Nijisseiki"
(梨、ゴールドニ十世紀)

15R/day（＝130mGy/day）
for 20years (1962-1981)

6 new *Chrysanthemum* cultivars
(観賞用菊の新品種)

250 – 1500mGy/day
for 100 days

Figure 2. Mutated sectors appeared on flower after chronic irradiation.

Figure 3. Floral petal culture and callus induction on the media.

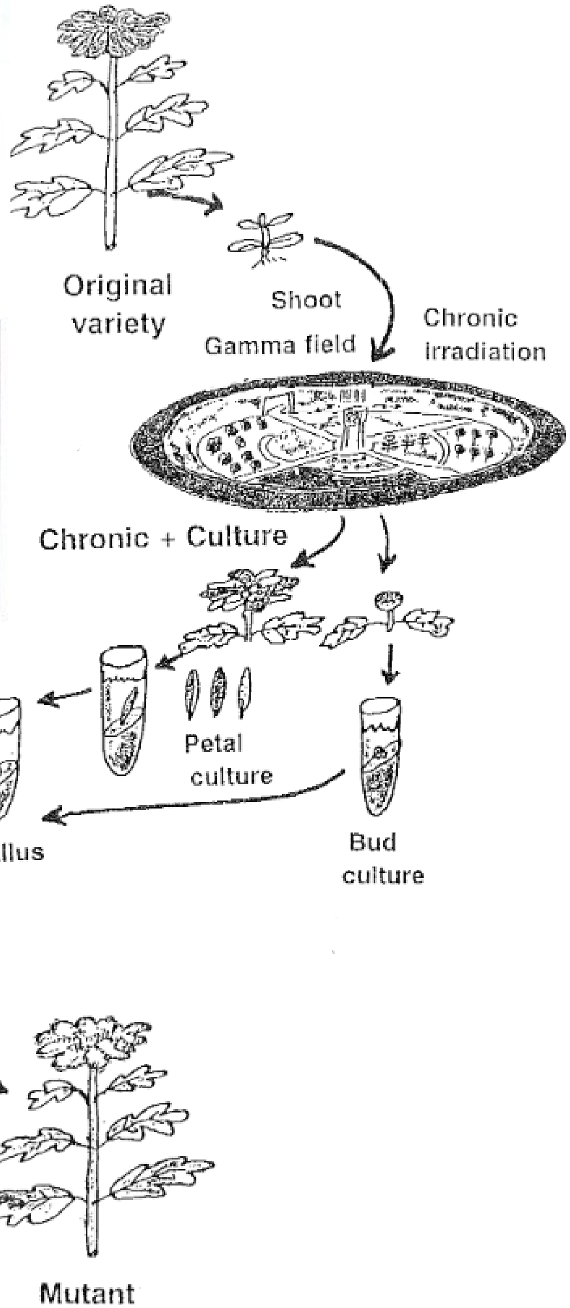
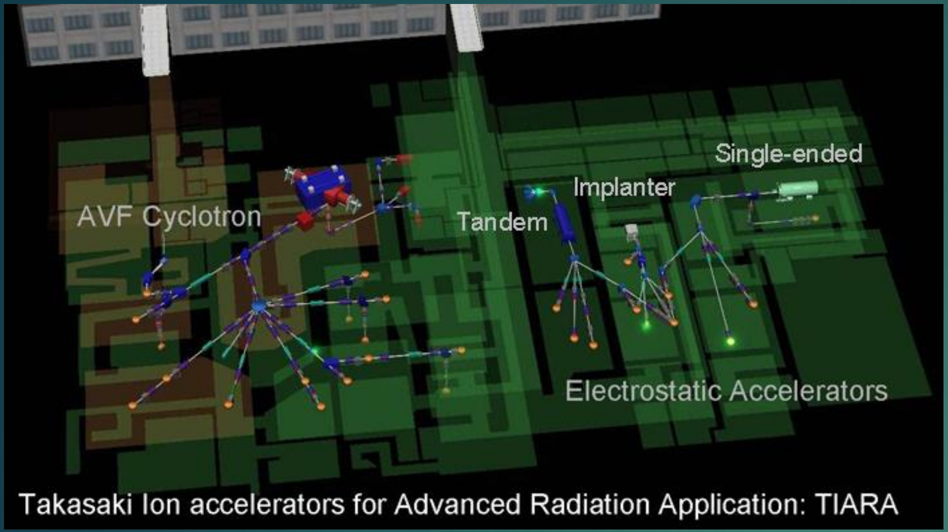


Figure 4. Flower color mutants derived from petal culture of chronic irradiated plants.
Originalvariety : upper right.

Figure 5. Flower shape and size mutants derived from petal culture of chronic irradiated plants.
Original variety : upper right.

Nagatomi S., Miyashita E. and Degi K.
Gamma Field Symposia, 35, 51-69, 1996

chrysanthemum mutants regenerated from $^{12}C^{5+}$ ion beam irradiated explants



Original "Taihei"

$^{12}C^{5+}$ ion beam 5Gy

$^{12}C^{5+}$ ion beam 20Gy

Ne^{+} ion beam 25Gy

Nagatomi S., Tanaka A., Watanabe H., Tano S., TIARA Annual Report, 48-50, 1996

William L. Russell (1910-2003)

the Enrico Fermi Award in 1976

William and Liane Russell in the early days of Oak Ridge National Laboratory's Mouse House. Liane Russell has published a history of the famed mammalian genetics facility.

X-ray or gamma-ray were irradiated to more than One million mouse
" **Mega-mouse project**"

PNAS, 79(2), 542-544, 1982

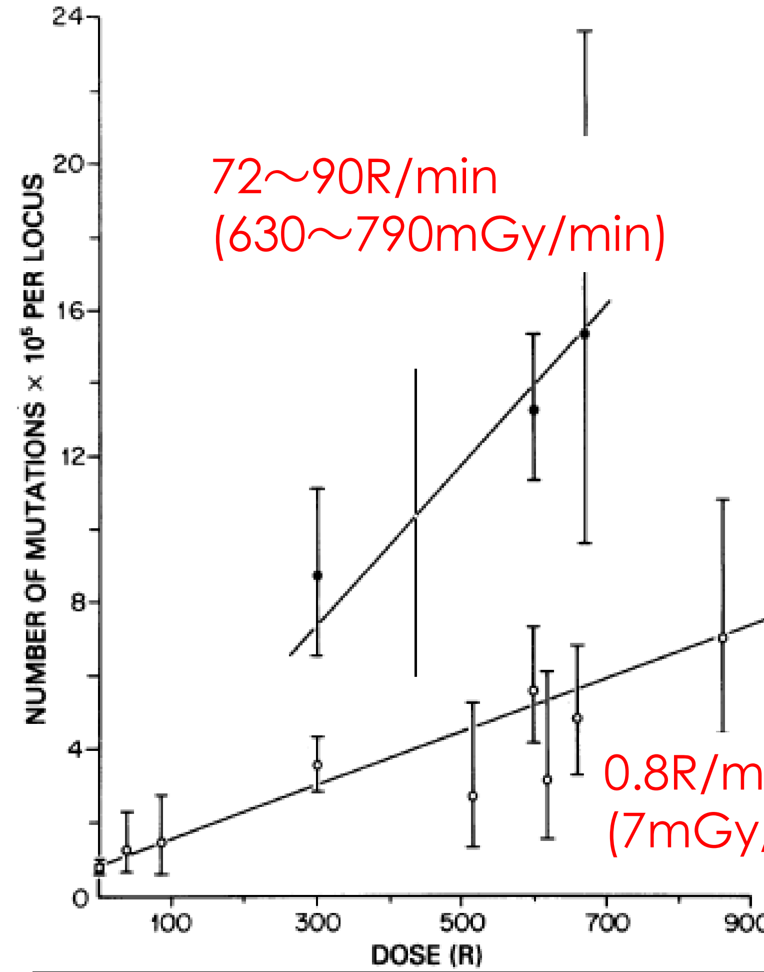
Mutation frequencies in male mice and the estimation of geneti hazards of radiation in men

(specific-locus mutations/dose-rate effect/doubling dose/risk estimation)

W. L. Russell and E. M. Kelly

Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830

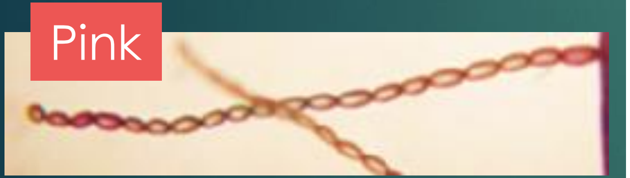
Contributed by William L. Russell, September 21, 1981



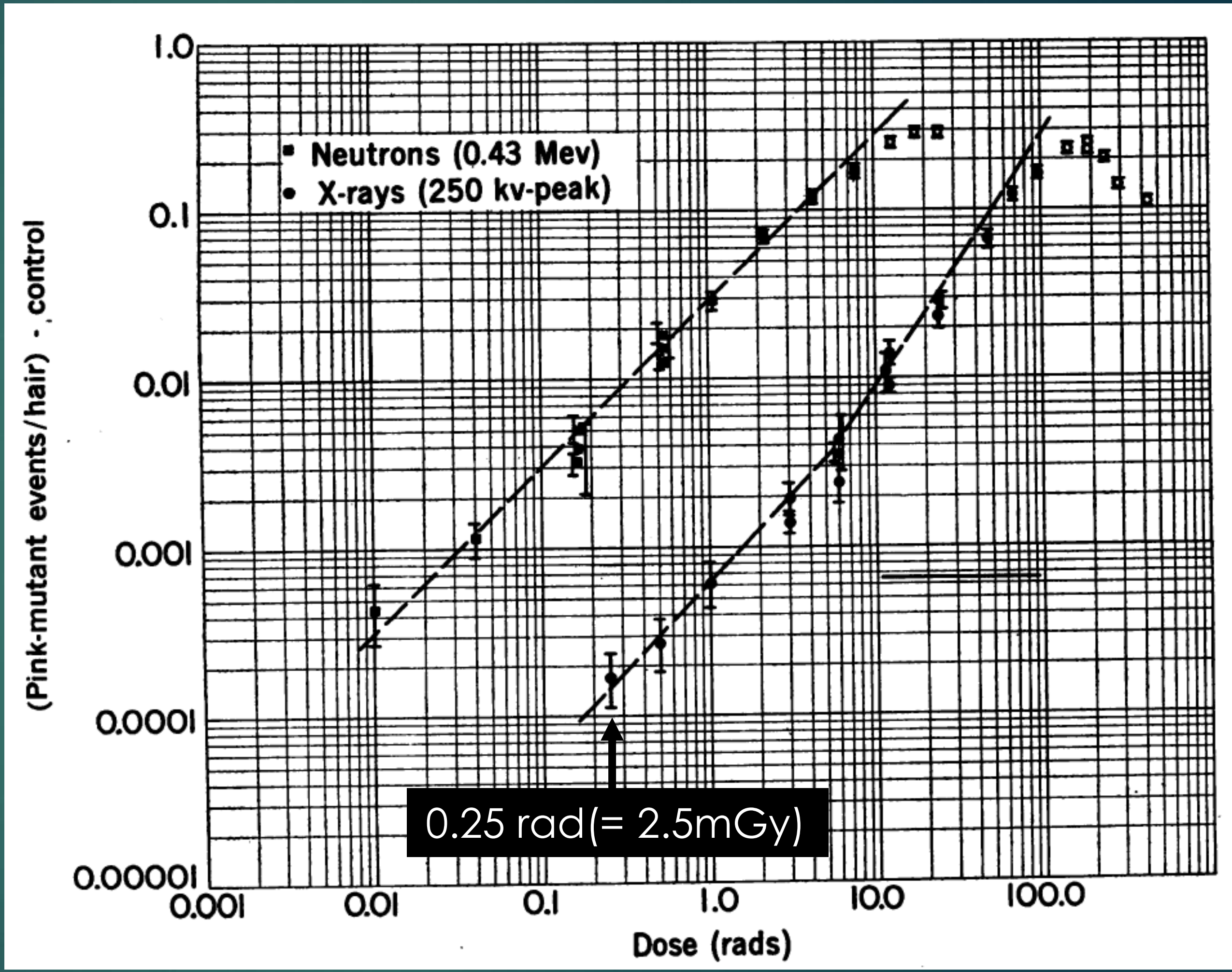
"Dose rate effect"

Dose-response for pink somatic mutations in *Tradescantia* stamen hairs

Tradescantia clone02

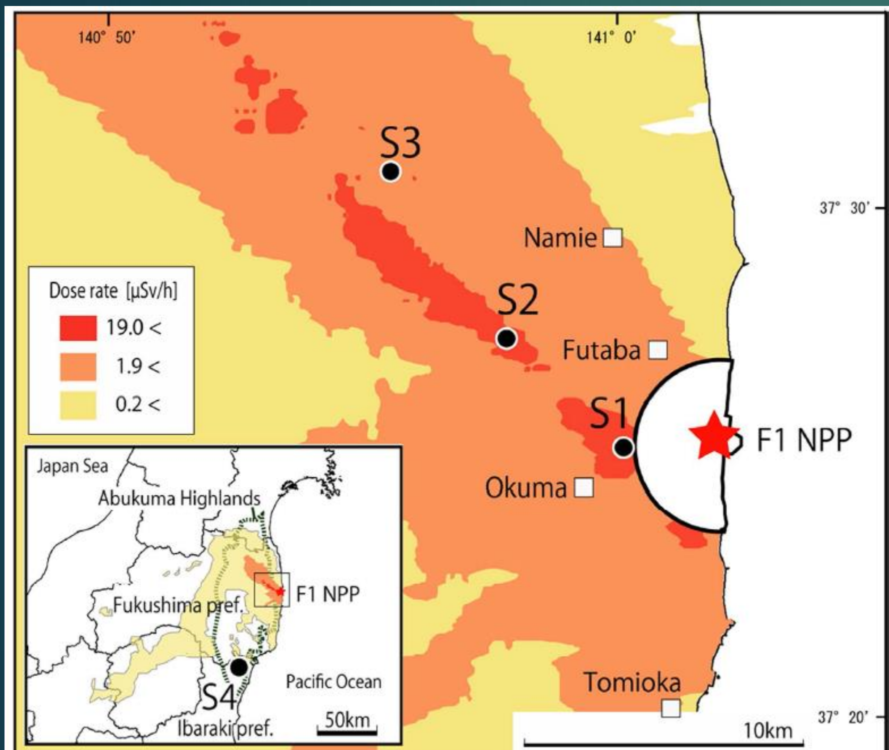


stamen hair
(おしべの毛)

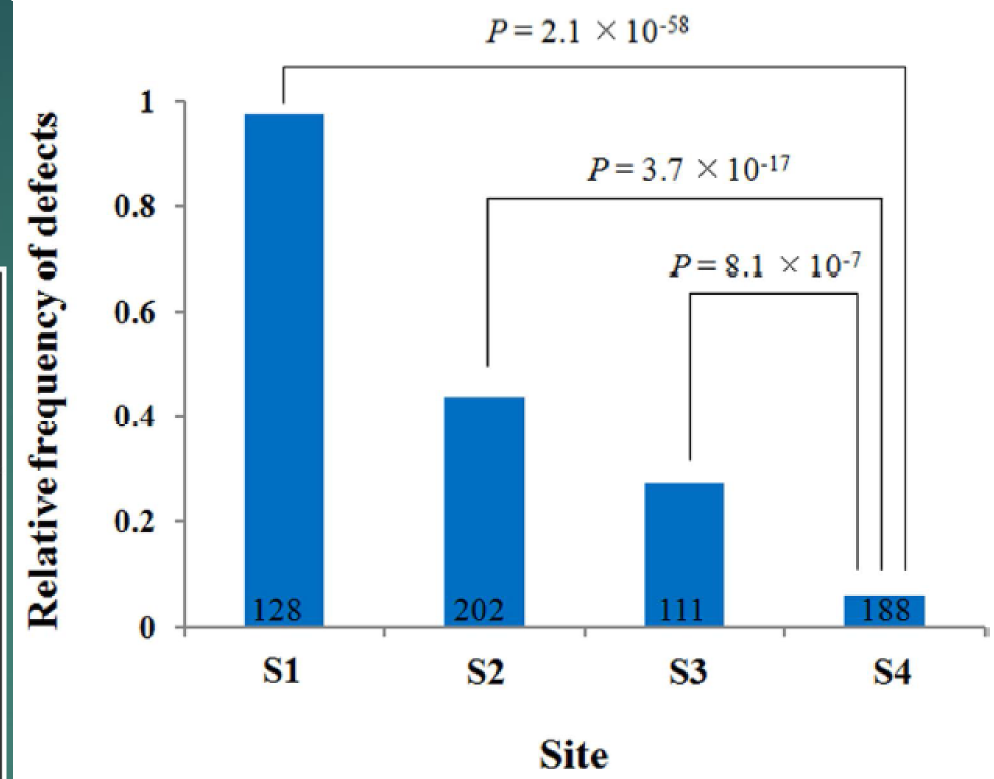


Sparrow AH., Underbrink AG., Rossi HH.
Science, 176, 916-918, 1972

Morphological defects in native Japanese fir trees around the Fukushima Daiichi Nuclear Power Plant



Relative frequency of main axis defects in Japanese fir trees from different sites.



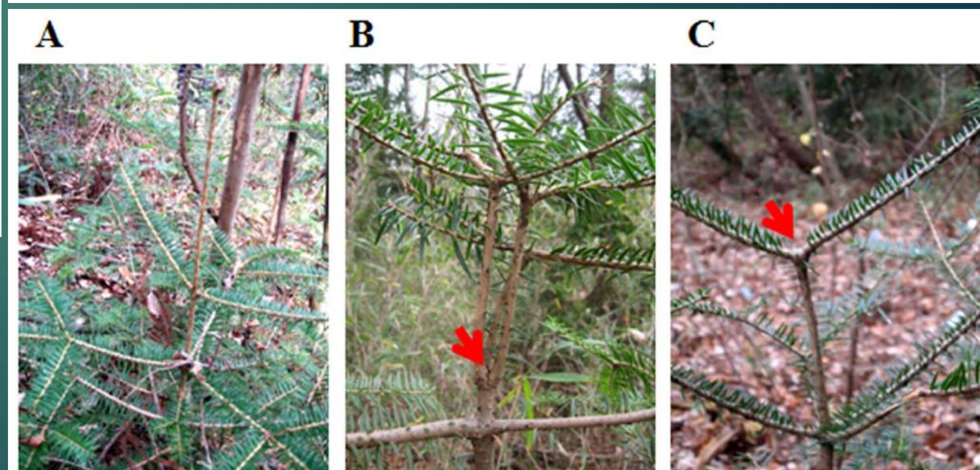
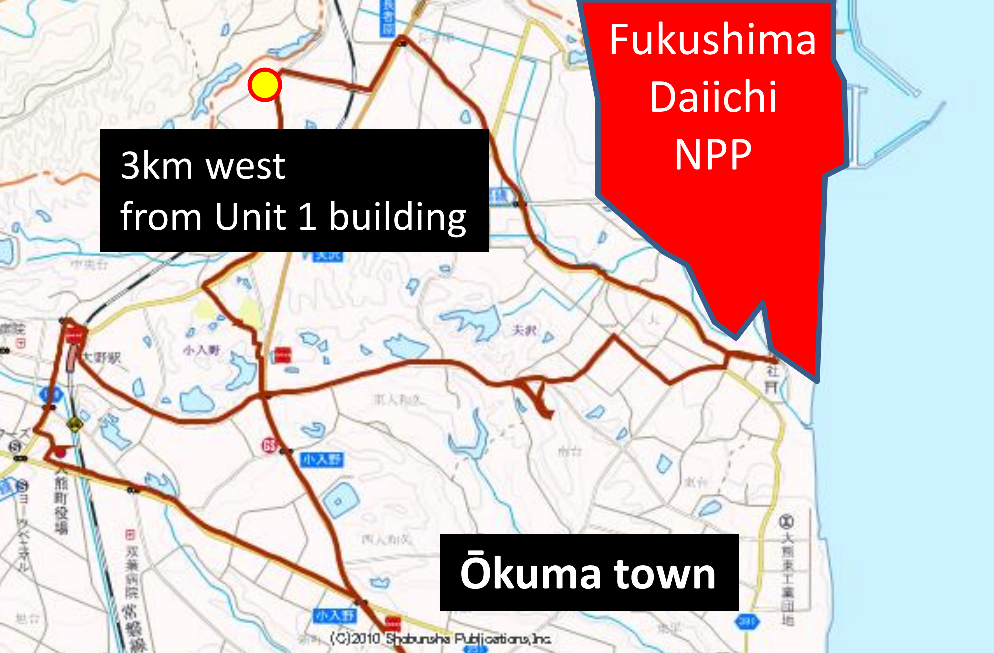


Figure 3. Representative morphological defects in Japanese fir trees. Arrowheads indicate the position of deleted leader shoot. (**A**) normal tree (S3), (**B**) defected tree (vertical forking, S1), (**C**) defected tree (horizontal forking, S2).

Watanabe Y. *et al.*
Scientific Reports 5 : 13232
doi: 10.1038/srep13232 (2015)


Fukushima
Daiichi
NPP
3km west
from Unit 1 building
Ōkuma town
(C)2010 Shobunsha Publications,Inc


in front of an individual residence


>70µSv/h
Cs-137:
154,000Bq/kg
（Oct., 2012）
ALOKA
µSv/h
70.8


morning glory (朝顔)

Whack-A-Mole Model

Please See posters No.17, 18 &19

Masako BANDO

Takahiro WADA

Yuichiro MANABE

Issei NAKAMURA

Hiroo NAKAJIMA

Yuchi TSUNOYAMA

Y. Manabe et al., J. Phys. Soc. Jpn. 84, 044002 (2015)

「放射線誘発突然変異頻度の線量･線量率応答への数理モデル
～Whack-A-Moleモデル～の適用」
真鍋勇一郎, 和田隆宏, 中村一成, 角山雄一, 中島裕夫, 坂東昌子
放射線生物研究, 50(3), 211-225, 2015

THINK × ACT
大阪大学 OSAKA UNIVERSITY 関西大学 KANSAI UNIVERSITY 中国科学院 CHINESE ACADEMY OF SCIENCES 京都大学 KYOTO UNIVERSITY

Whack-A-Mole Model

The differential equation
with respect to "time", "not to total dose"

$$\frac{dF(t)}{dt} = A - BF(t)$$

$F(t)$: mutation rate

$$A = a_0 + a_1 D_r$$
$$B = b_0 + b_1 D_r$$

D_r : dose rate

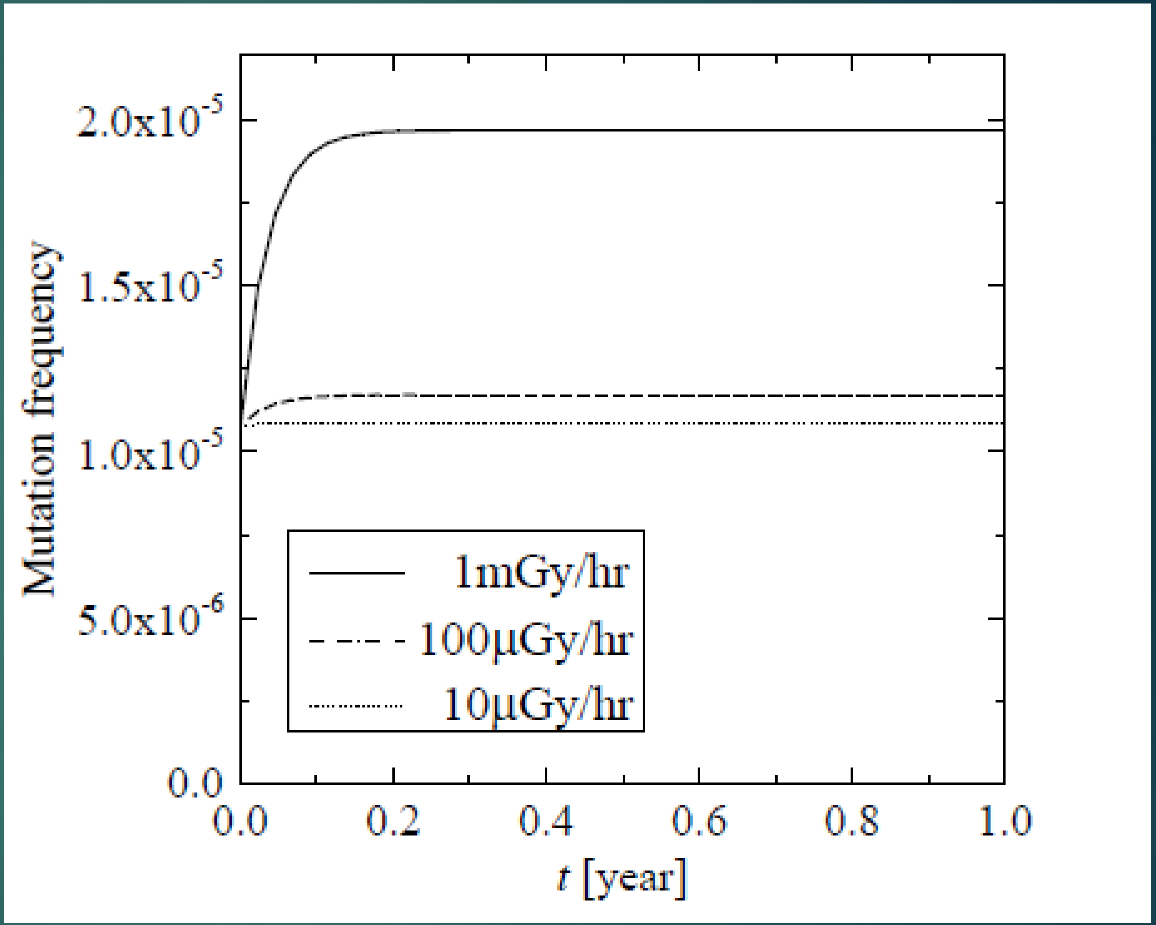
a_0 = mutation by natural environmental factors
a_1 = mutation by the radiation (additional)

b_0 = natural recovery (independent of the radiation strength)
b_1 = the effects of repair, proliferation, and apoptosis, etc. against to radiation exposure

WAM model prediction for the excess mutation frequency

	Mouse
a_0 [1/hour]	3.24E-08
a_1 [1/Gy]	2.94E-05
b_0 [1/hour]	3.00E-03
b_1 [1/Gy]	1.36E-01

The parameter sets are given from the “mouse” data.



0.1μGy/h, 1μGy/h : the effects are too small to see in this graph.


Thank you!
ふくしまから
はじめよう。
Future From Fukushima.

Assessing of parameters

Drosophila

Mouse

Maize

Chrysanthemum

Tradescantia

experimental data → χ^2 test

parameter sets (a_0, a_1, b_1, b_2)

$$\frac{dF(t)}{dt} = A - BF(t)$$

$$A = a_0 + a_1 d$$
$$B = b_0 + b_1 d$$

	Drosophila	*Mouse*	*Maize*	*Chrysanthemum*	*Tradescantia*
a_0 [1/hour]	3.5E-05	3.2E-08	*N.D.*	*N.D.*	2.9E-02
a_1 [1/Gy]	2.0E-03	3.0E-05	2.0E-03	6.5E-03	1.6E-01
b_0 [1/hour]	1.4E-02	3.0E-03	1.8E-01	4.5E-03	6.9E-01
b_1 [1/Gy]	1.0E-04	1.4E-01	*N.D.*	*N.D.*	1.6E-01