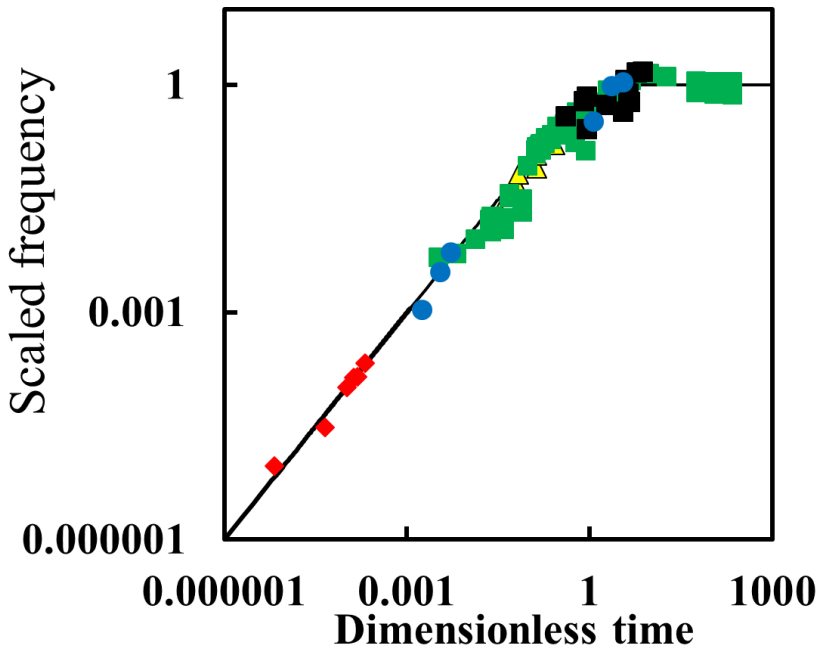
Whack-A-Mole Model



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Takahiro Wada, Kansai University
Issei Nakamura, Chinese Academy of Science
Hiroo Nakajima, Osaka University
Masako Bando, Jein & Kyoto University
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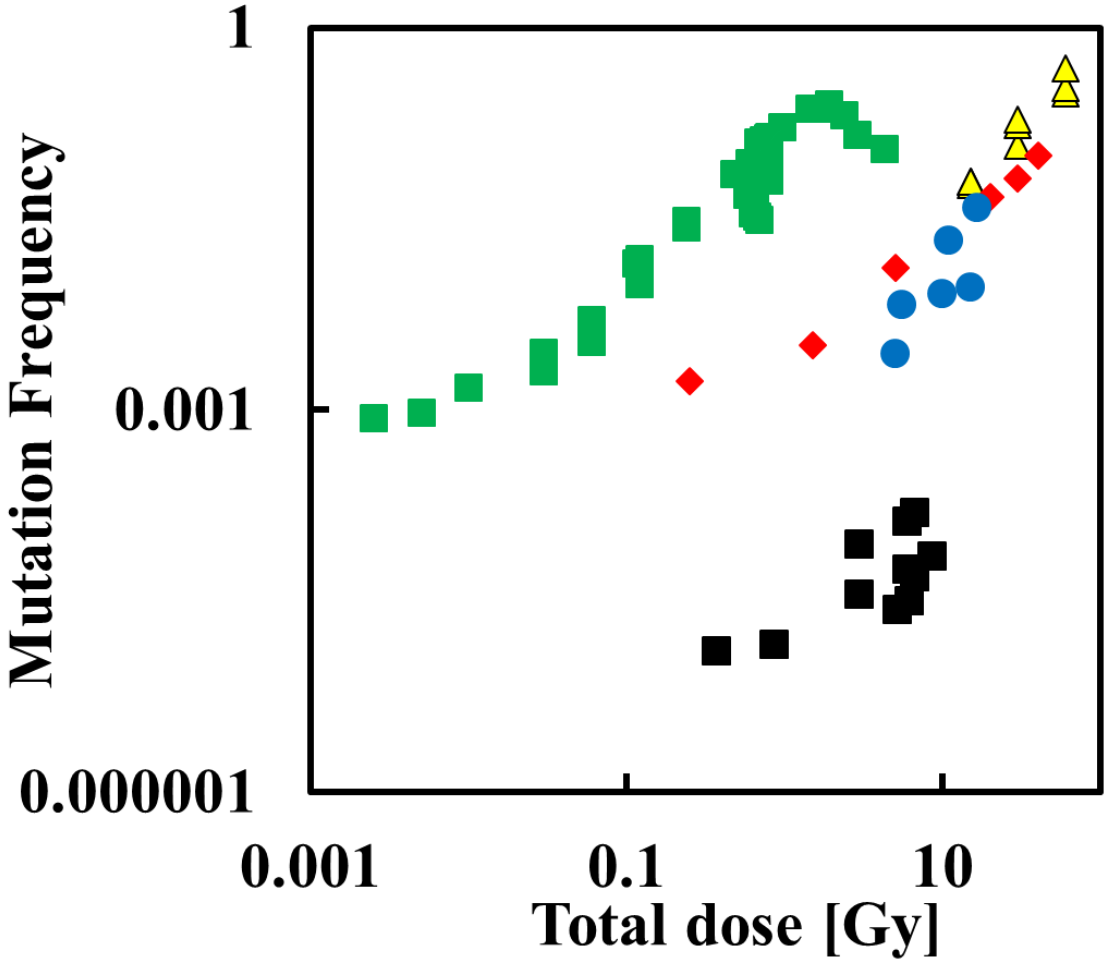
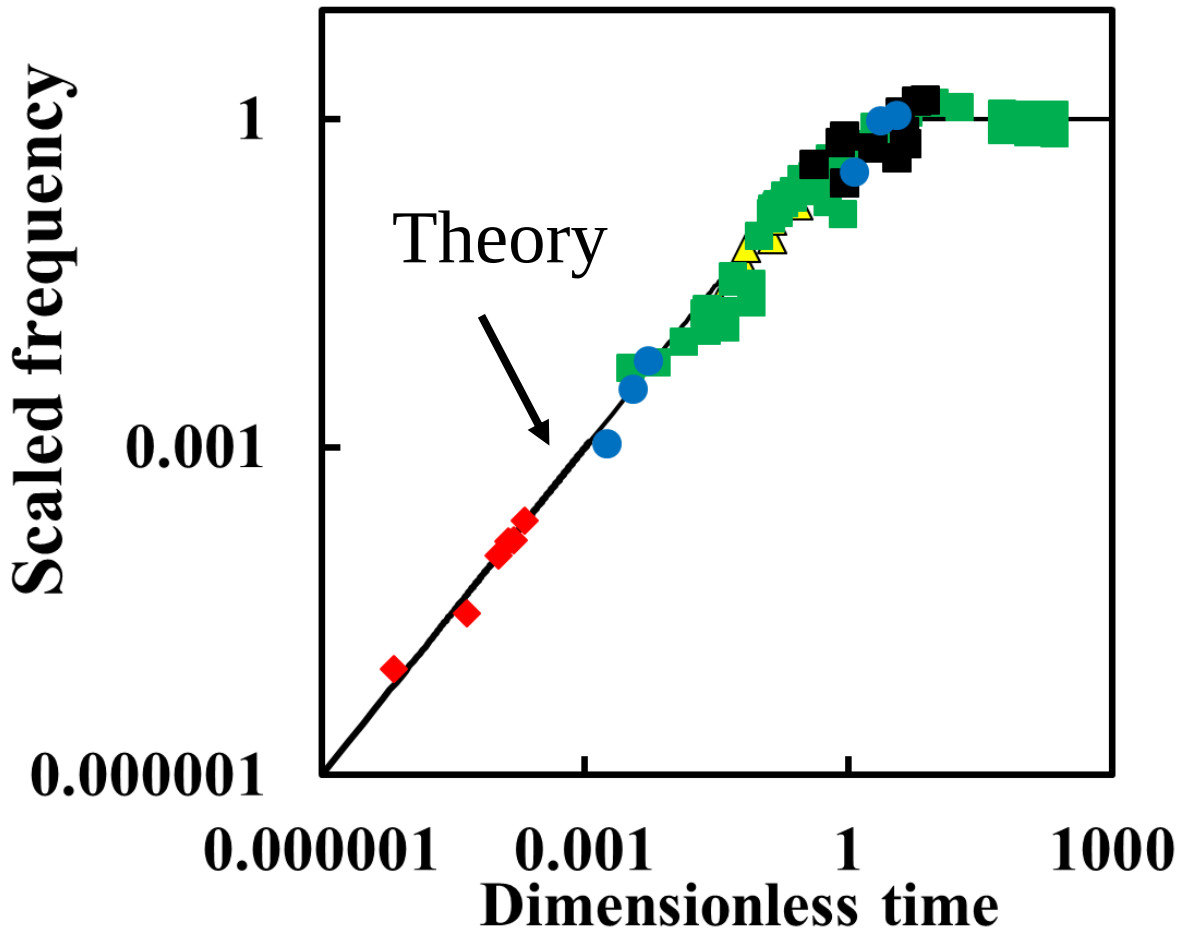
Conclusion



Before Scaling



After Scaling with dose rate

Process of mutation

Radiation exposure

Stimulus

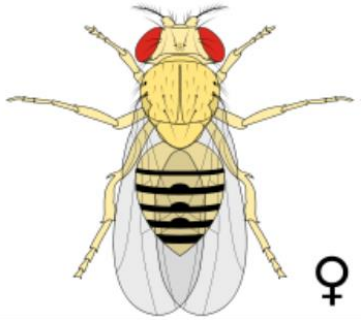
Mutation

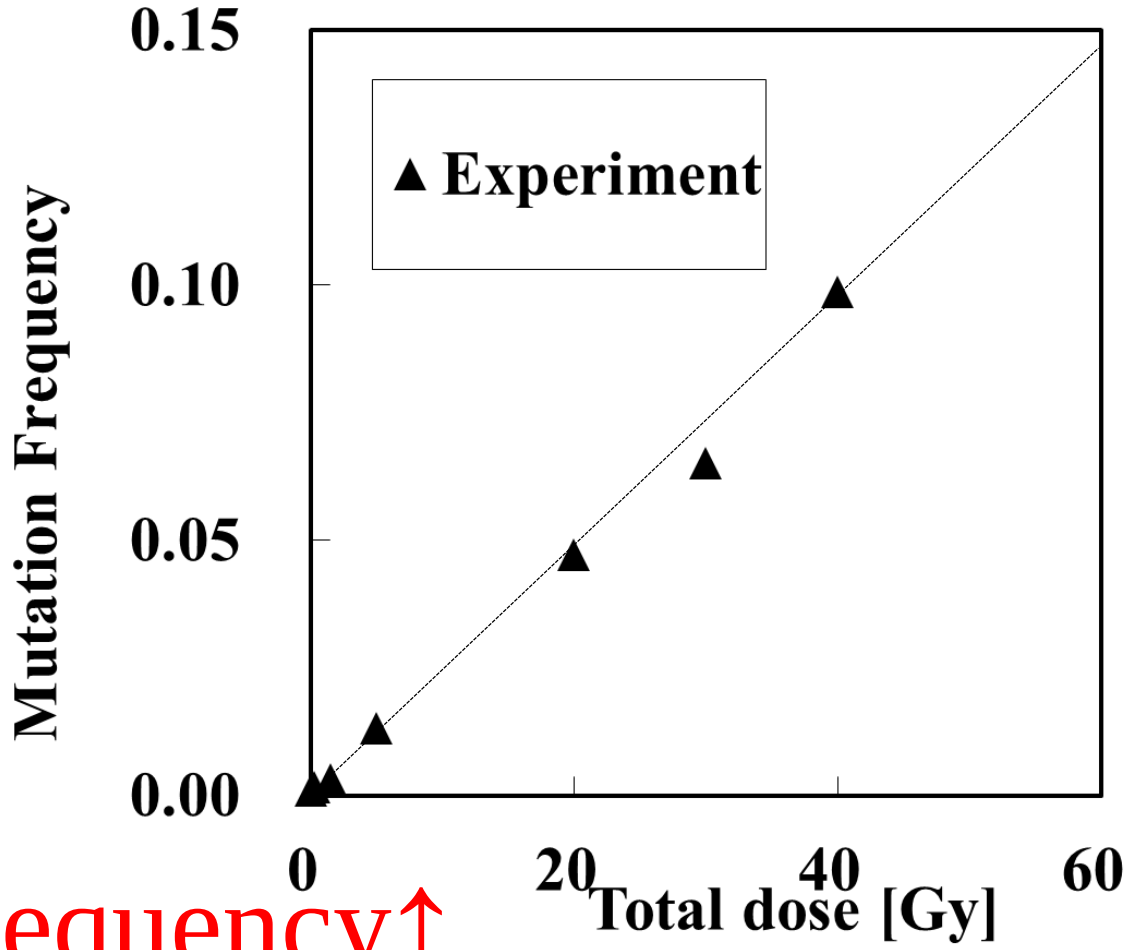
Response

Drosophila experiment of Muller

Science, Vol. 66, p. 84, 1927

X-ray

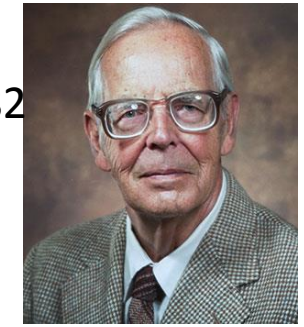




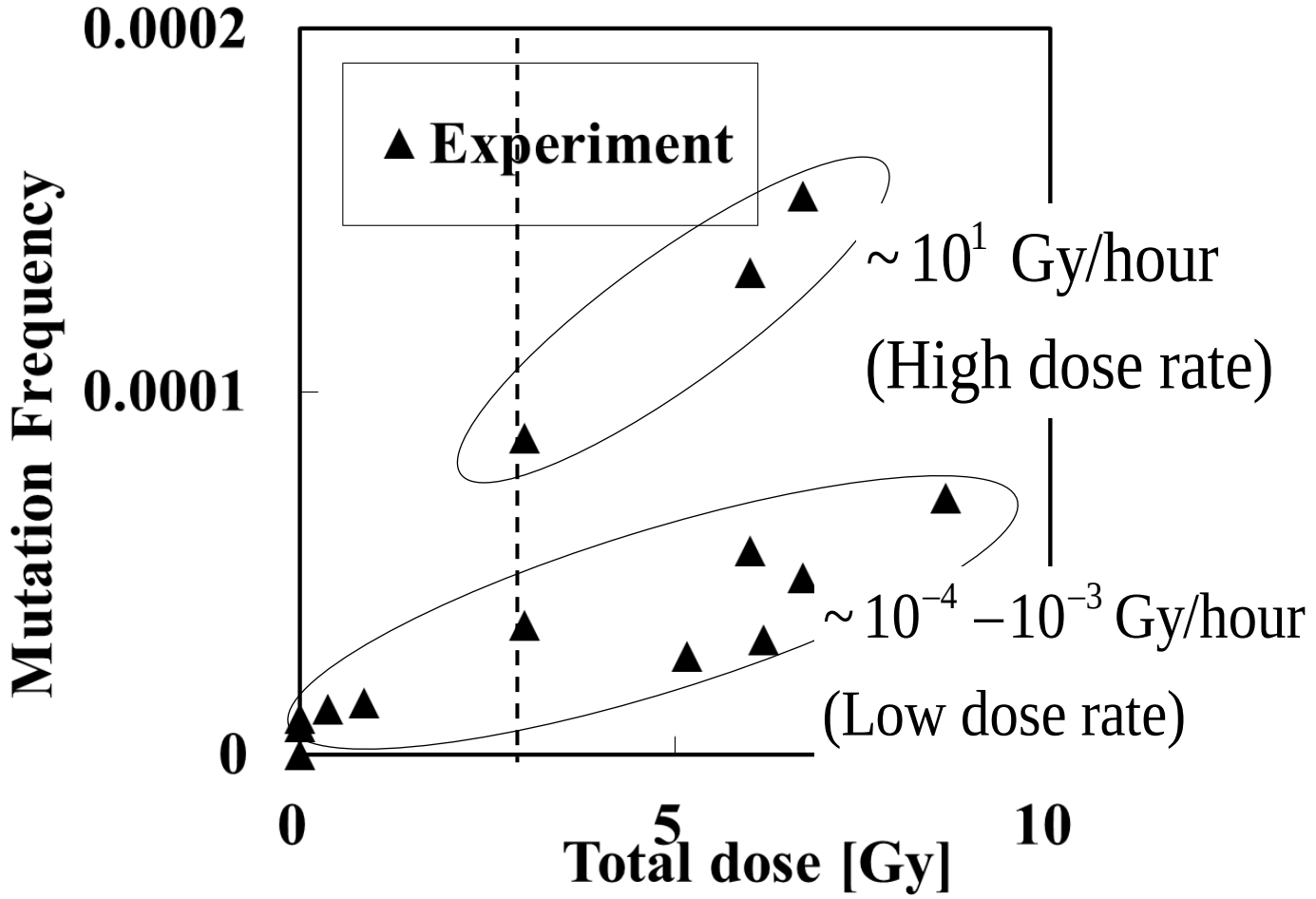
Total dose↑⇒Mutation frequency↑
= LNT（Linear non-threshold）

Mega-mouse experiment of Russell

Pnas, Vol. 79(2), 542-544, 1982

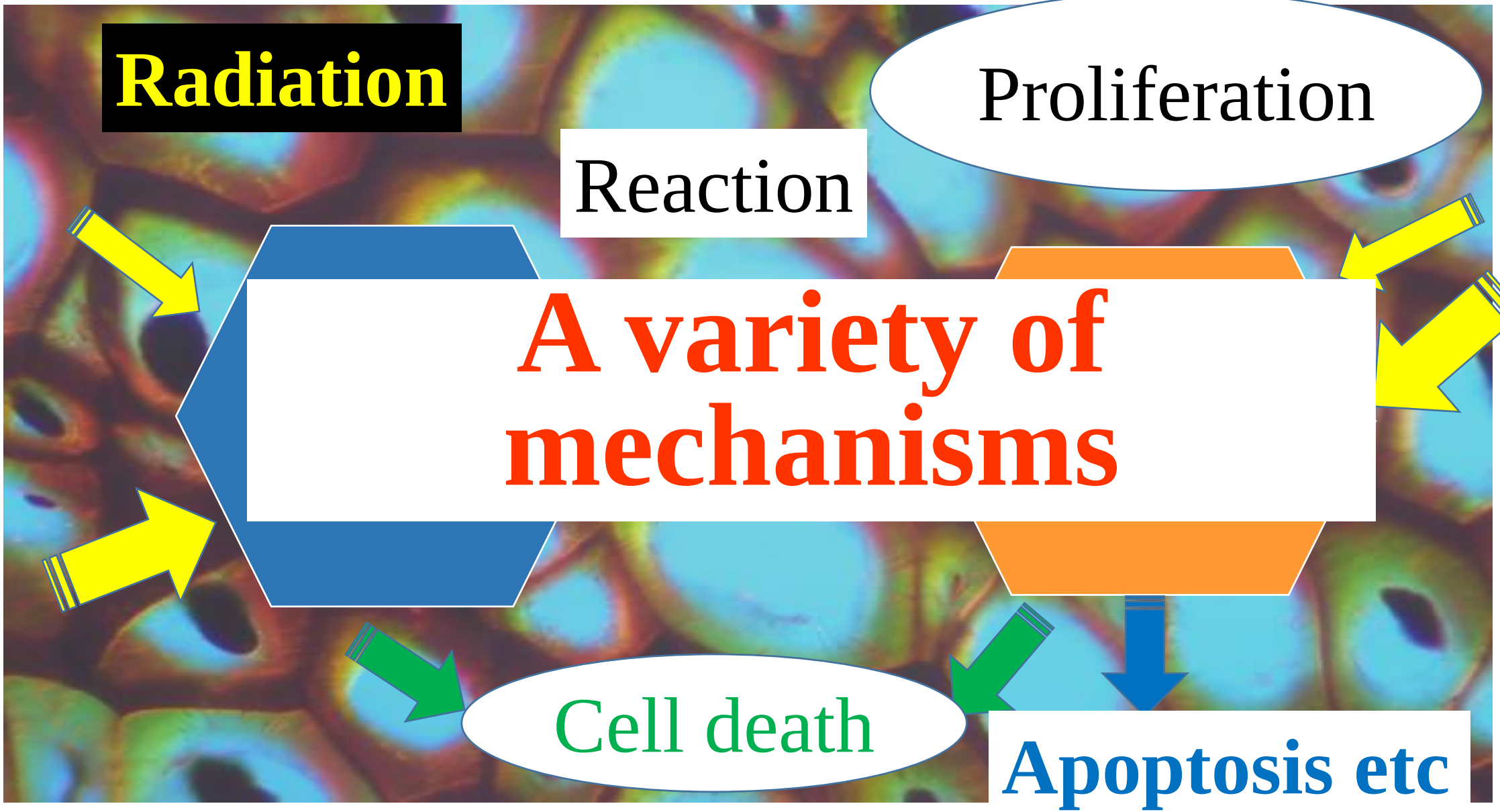


X-ray, γ-ray



Dose-rate↑⇒Mutation frequency↑

System consisting of cells



Basic equation of our theory

$$\frac{dN_n}{dt} = R_{nn}N_n$$

$$\frac{dN_m}{dt} = R_{mn}N_n + R_{mm}N_m$$

F:mutation frequency

d: Dose rate [Gy/hour]

D:Total dose [Gy]

Applied to mutation frequency F

$$F \equiv \frac{N_m}{N_n}, R_{mn} = a_0 + a_1 d, R_{mm} = b_0 + b_1 d$$

N_n : number of normal cell

N_m : number of mutated cell

Equation for mutation frequency

Preventative effects :
Mutation frequency is expressed as a differential equation with respect to time.

$$\frac{d}{dt}F(t) = (a_0 + a_1 d) - (b_0 + b_1 d)F(t)$$

$$\frac{dF}{dD} = c\frac{F_0}{D_0}$$

F:mutation frequency

d: Dose rate [Gy/hour]

D:Total dose [Gy]

Solution for mutation frequency

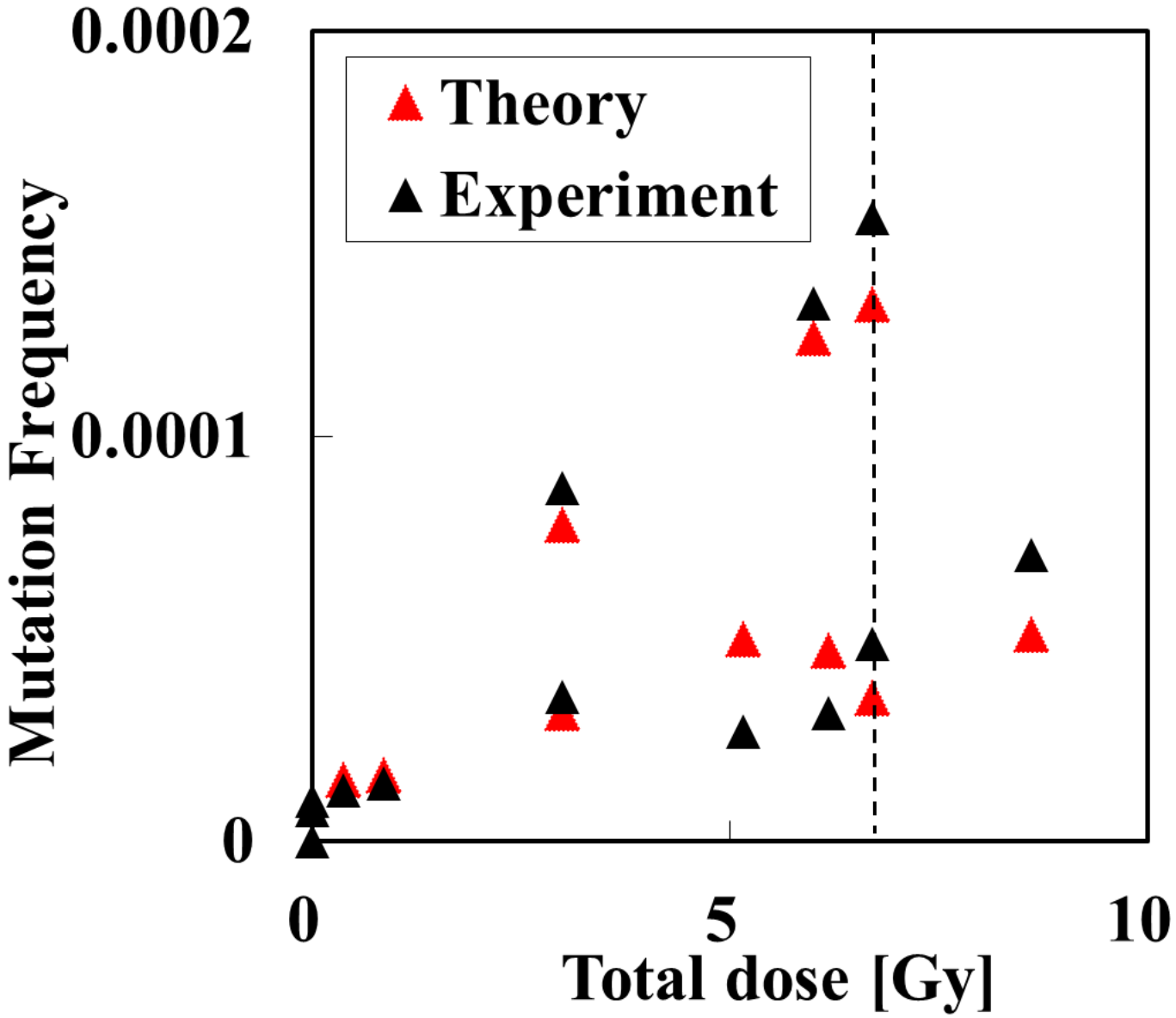
$$F(t) = F(\infty)\left(1 - \mathrm{e}^{-(b_0 + b_1 d)t}\right) + F(0)\,\mathrm{e}^{-(b_0 + b_1 d)t}$$

$$F(\infty) = \frac{a_0 + a_1 d}{b_0 + b_1 d}$$

$$a_0, a_1, b_0, b_1$$

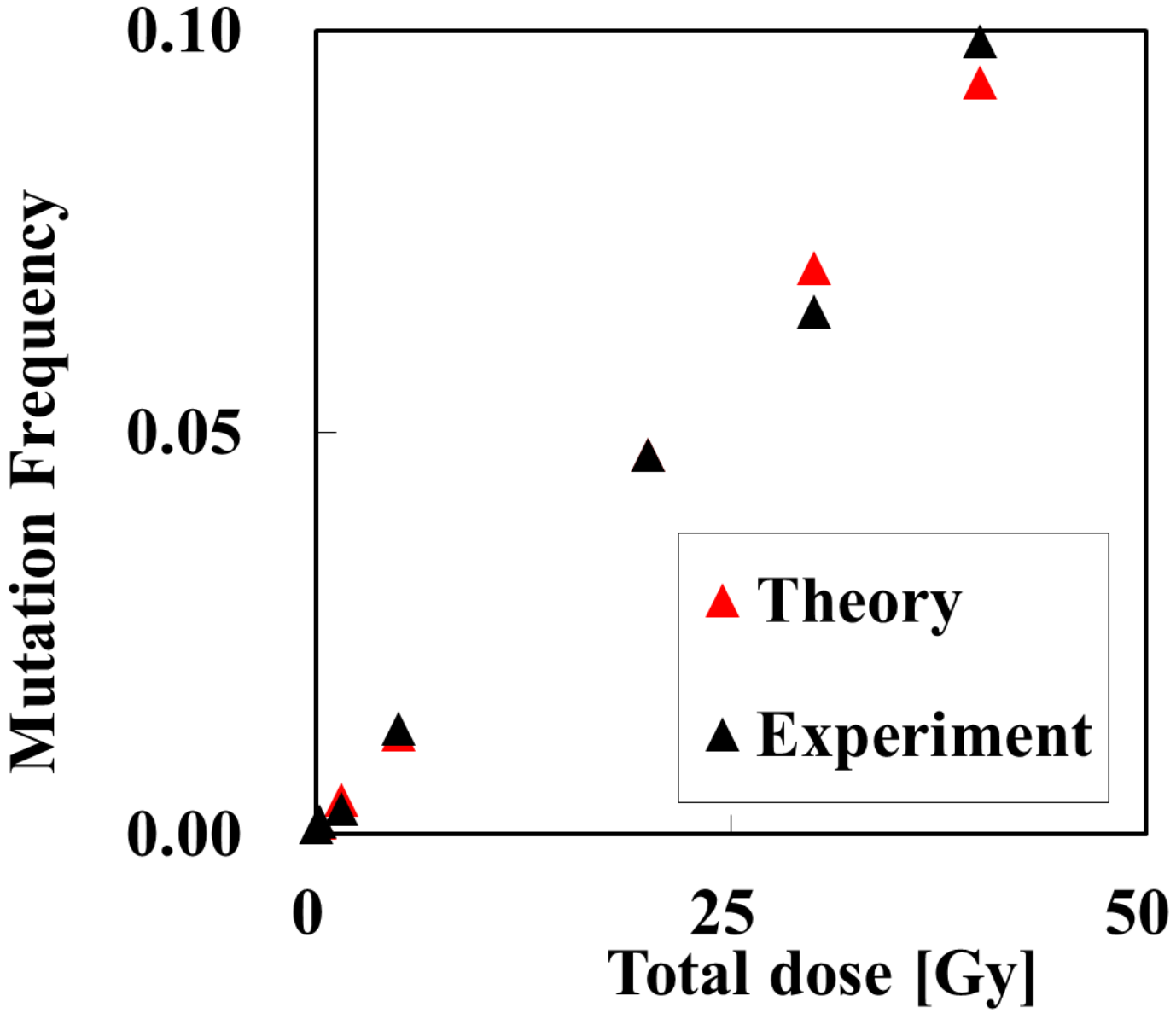
4 parameters

Comparison with experiment

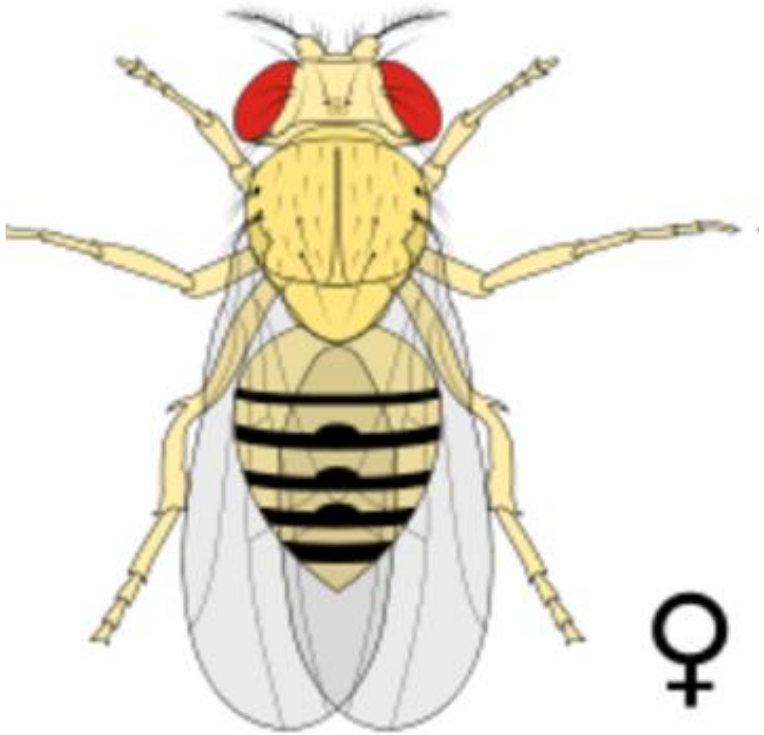


Mega-mouse

Comparison with experiment

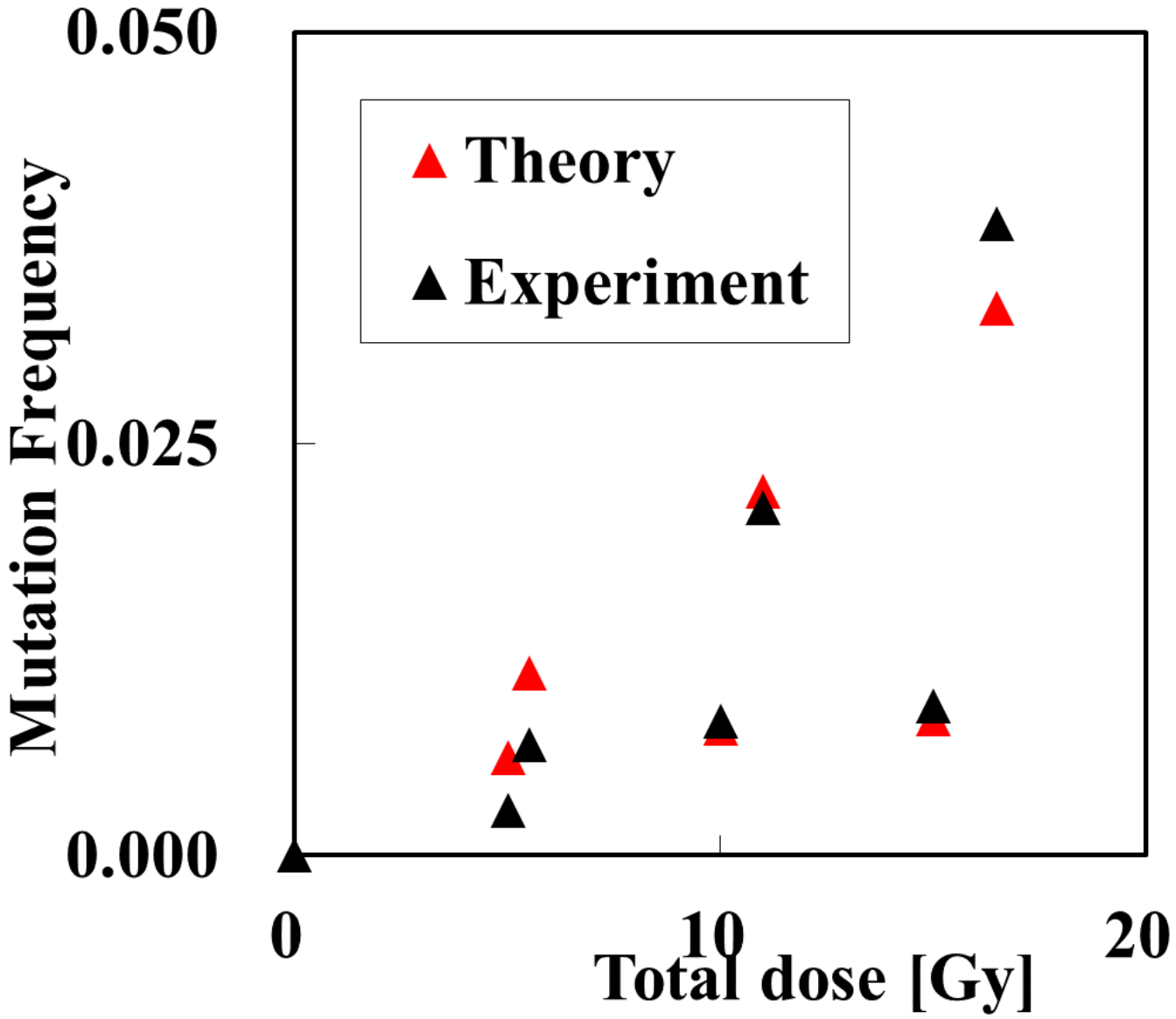


Drosophila



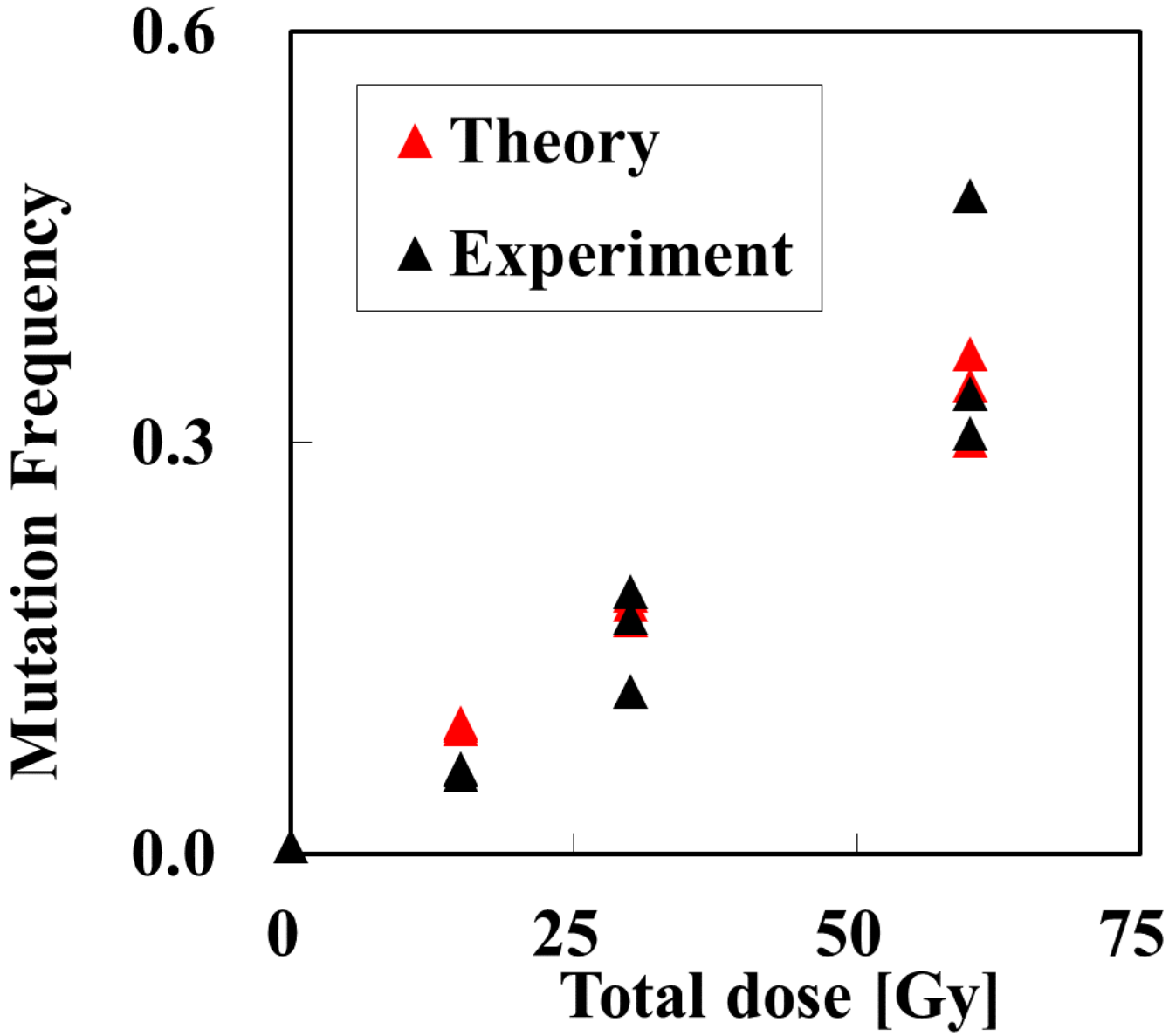
♀

Comparison with experiment



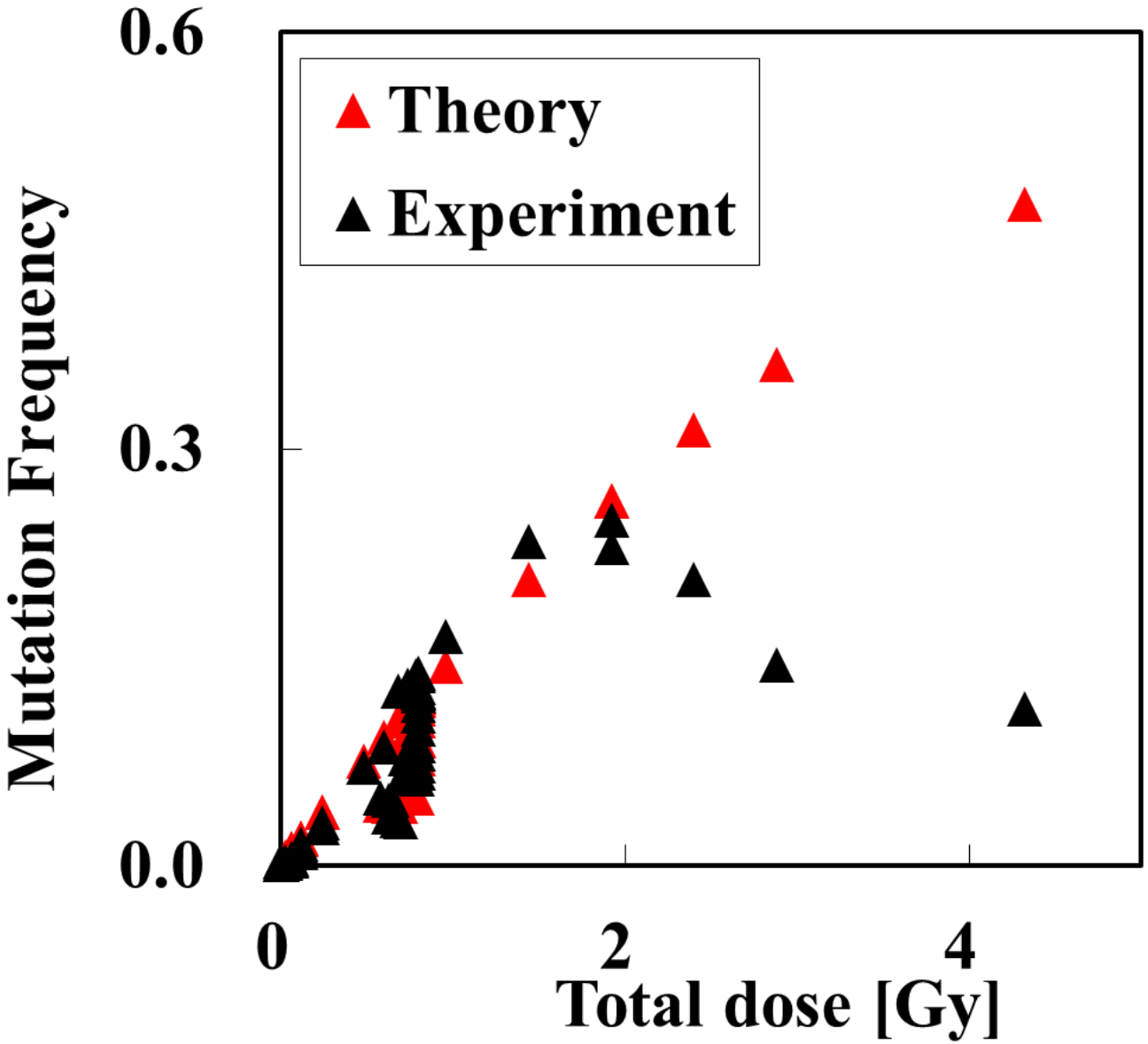
Corn

Comparison with experiment



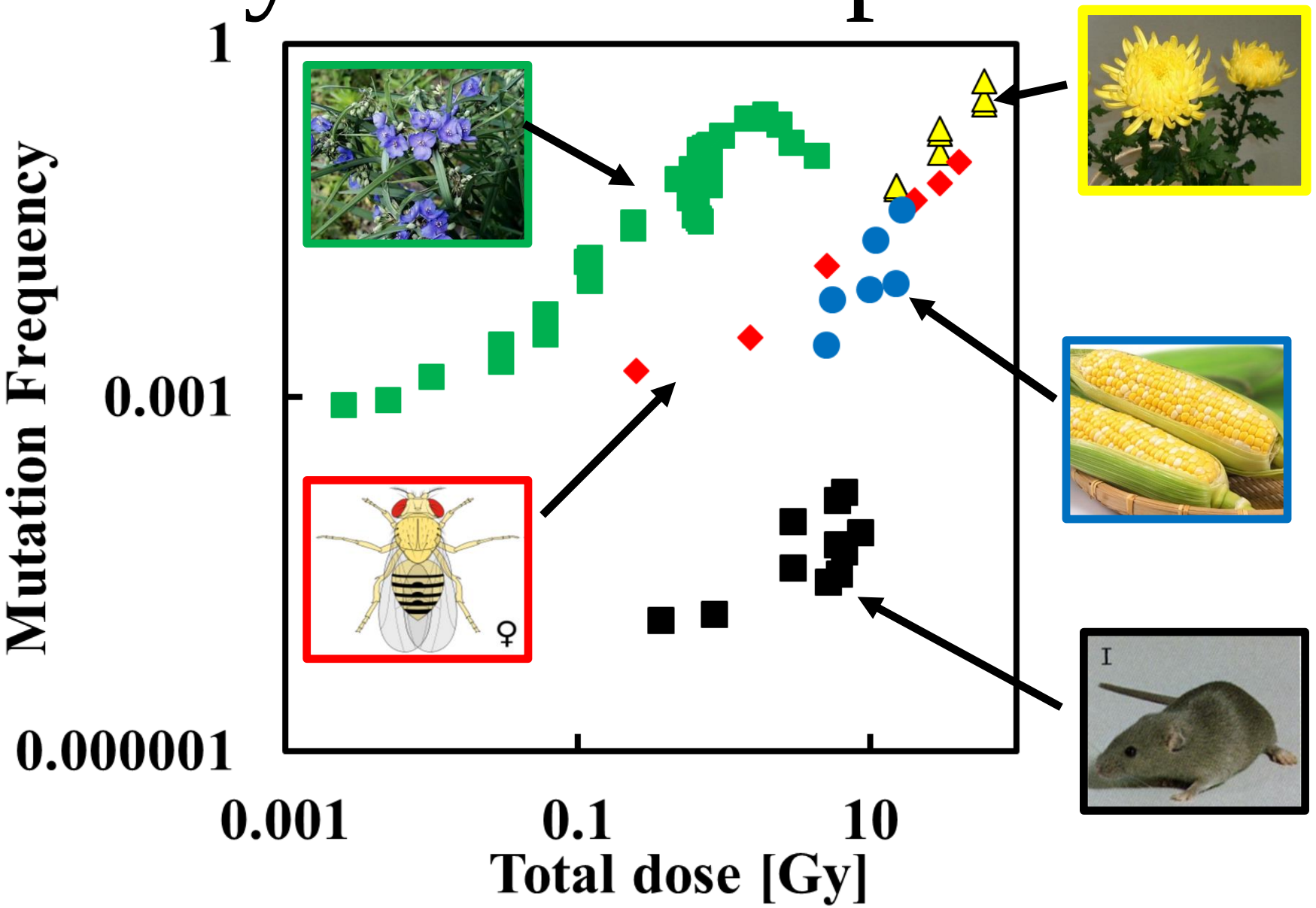
Chrysanthemum

Comparison with experiment



Tradescantia

Summary of the 5 experiments



We rewrite our solution by using scaling function

$$F(t) = F(\infty)\left(1 - \mathrm{e}^{-(\alpha+\beta d)t}\right) + F(0)\,\mathrm{e}^{-(\alpha+\beta d)t},$$

$$\Rightarrow \Phi(\tau) \equiv \frac{F(t) - F(0)}{F(\infty) - F(0)} = \left(1 - \mathrm{e}^{-\tau}\right), \qquad \tau \equiv (\alpha + \beta d)t$$

$\Phi(\tau)$: scaled frequency

τ : dimensionless time

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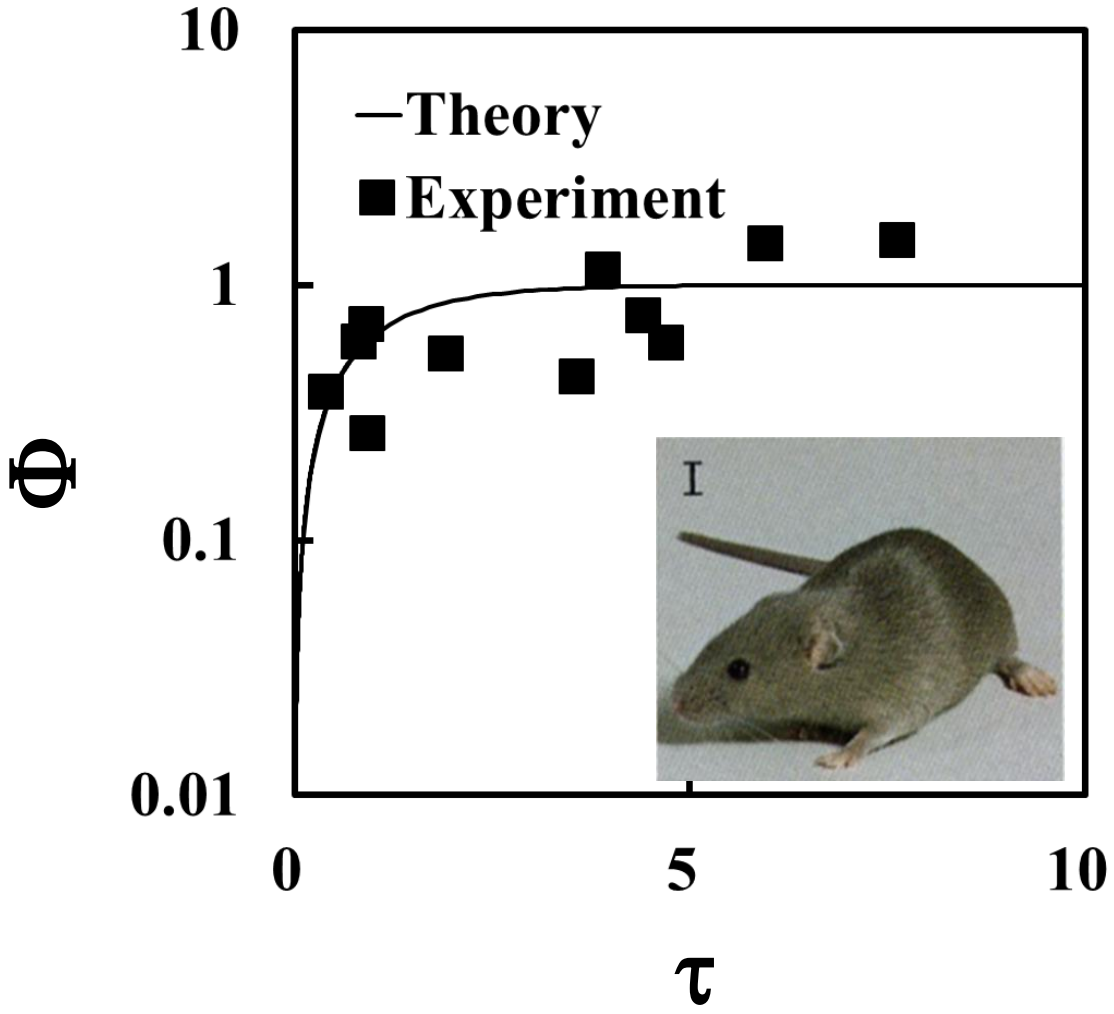
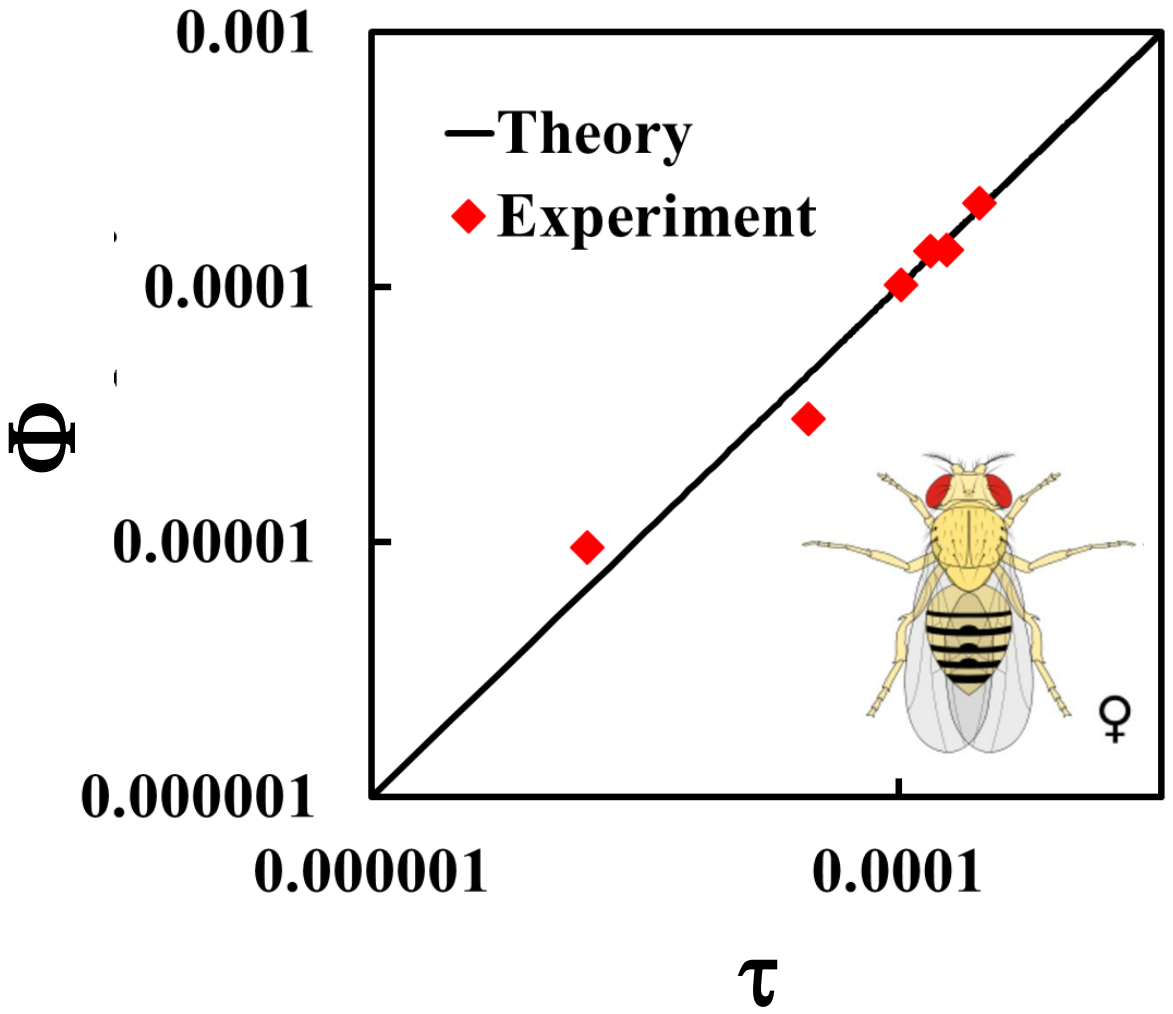
Comparison with experiment

Mouse

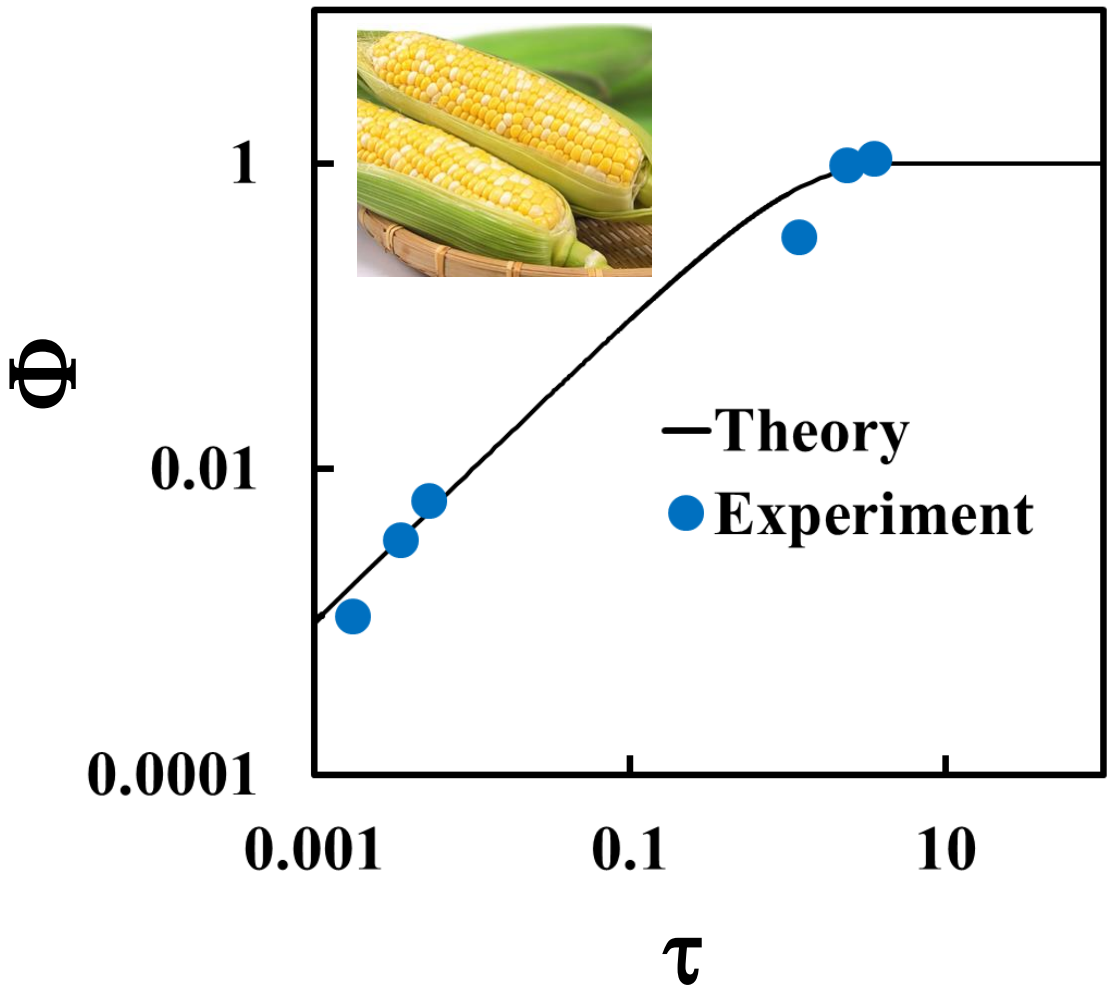


Drosophila

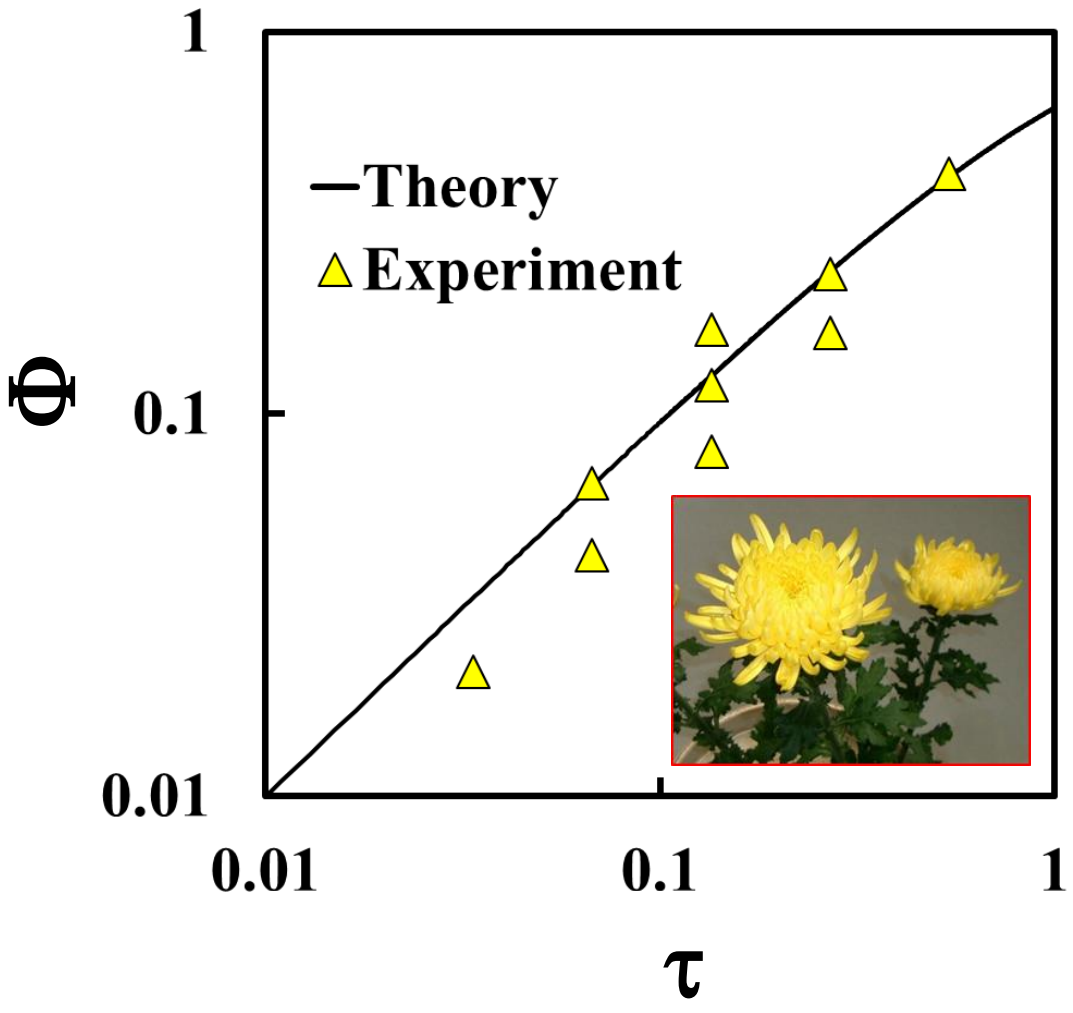


Comparison with experiment

Corn

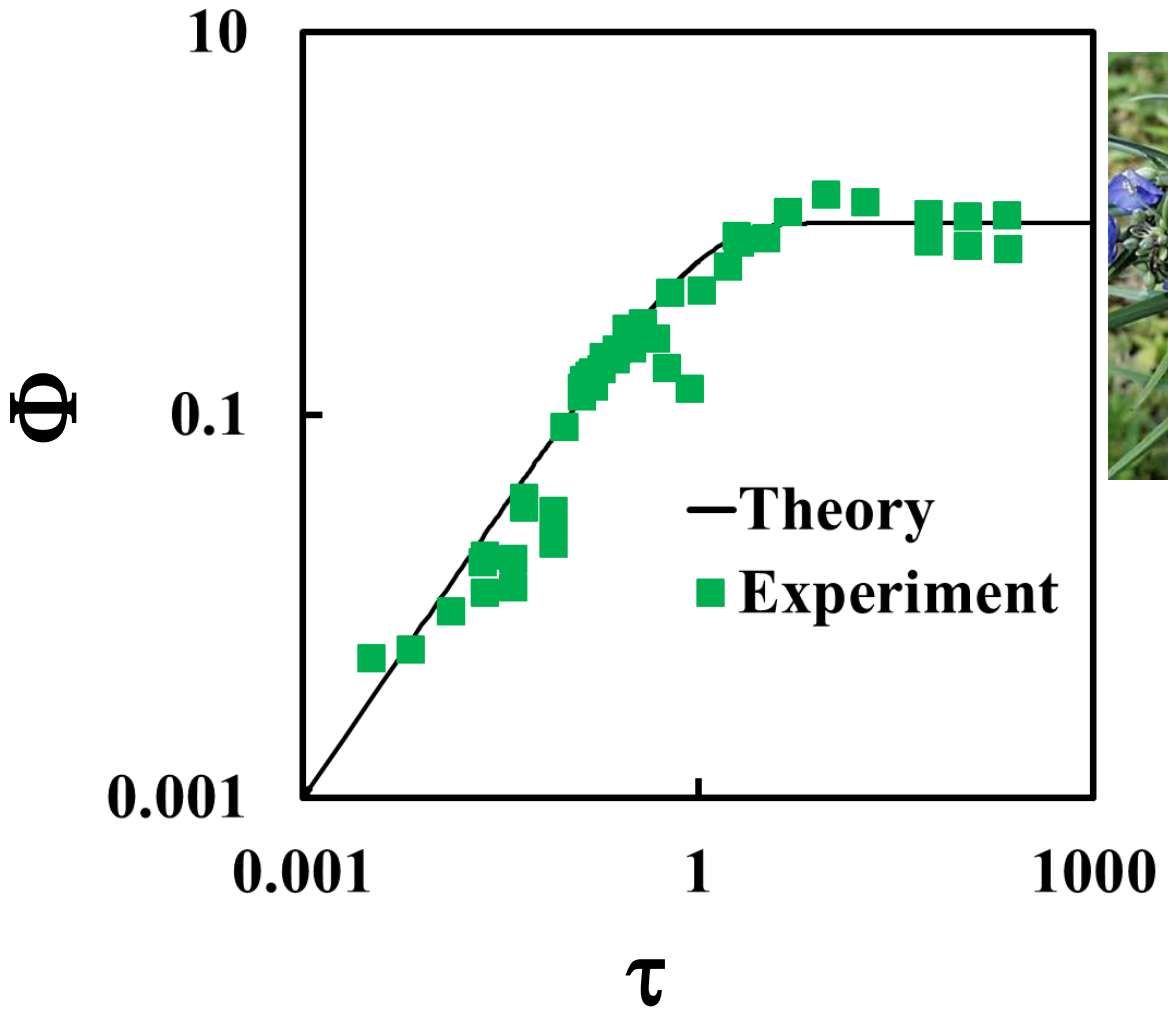


Chrysanthemum

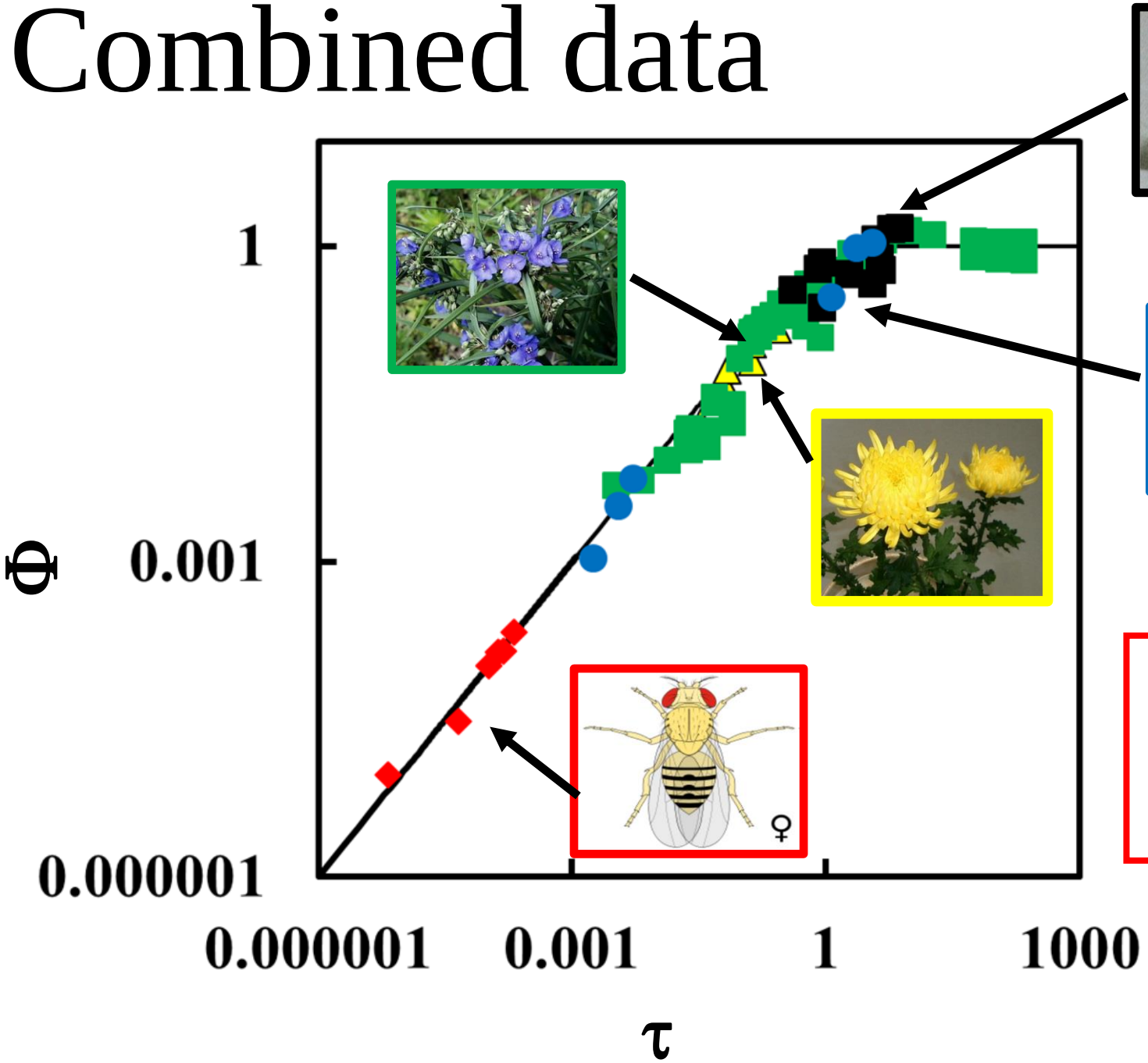


Comparison with experiment

Tradescantia



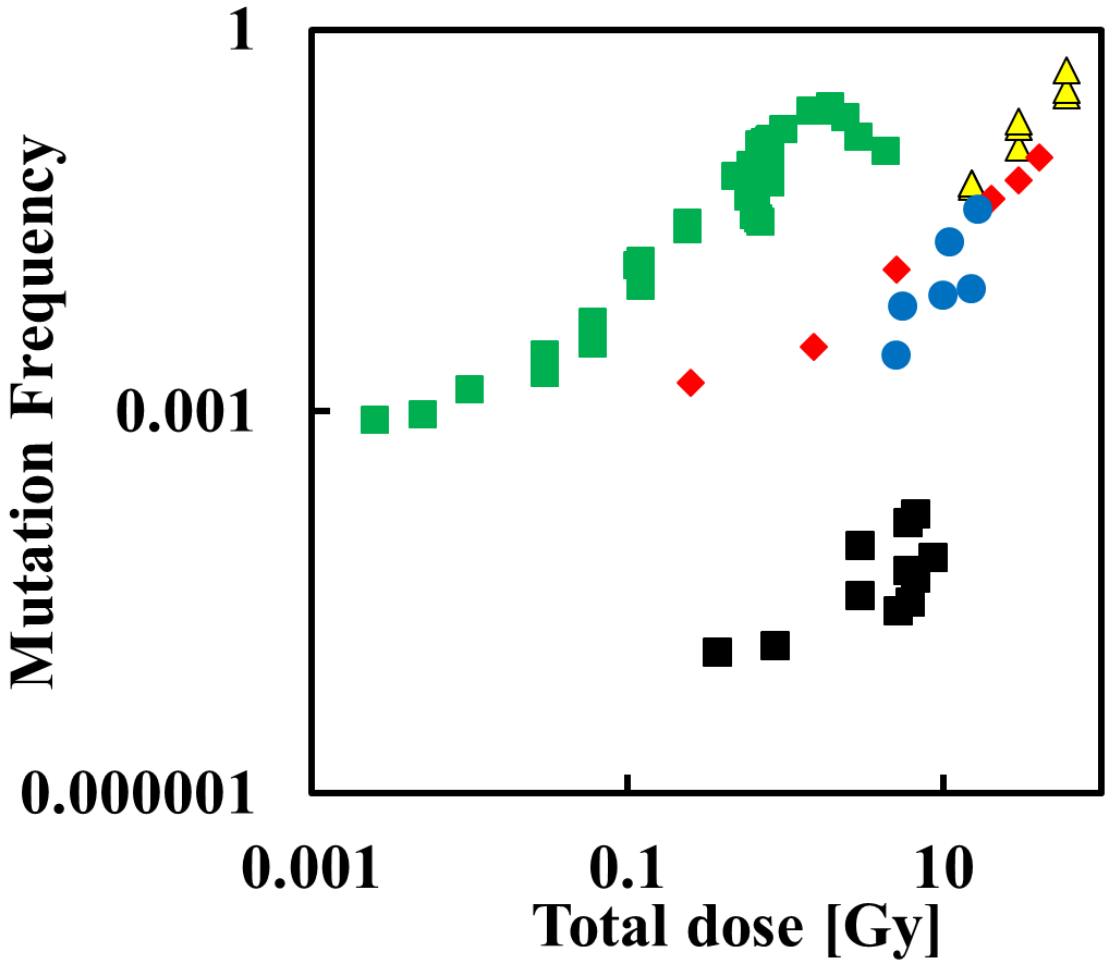
Combined data



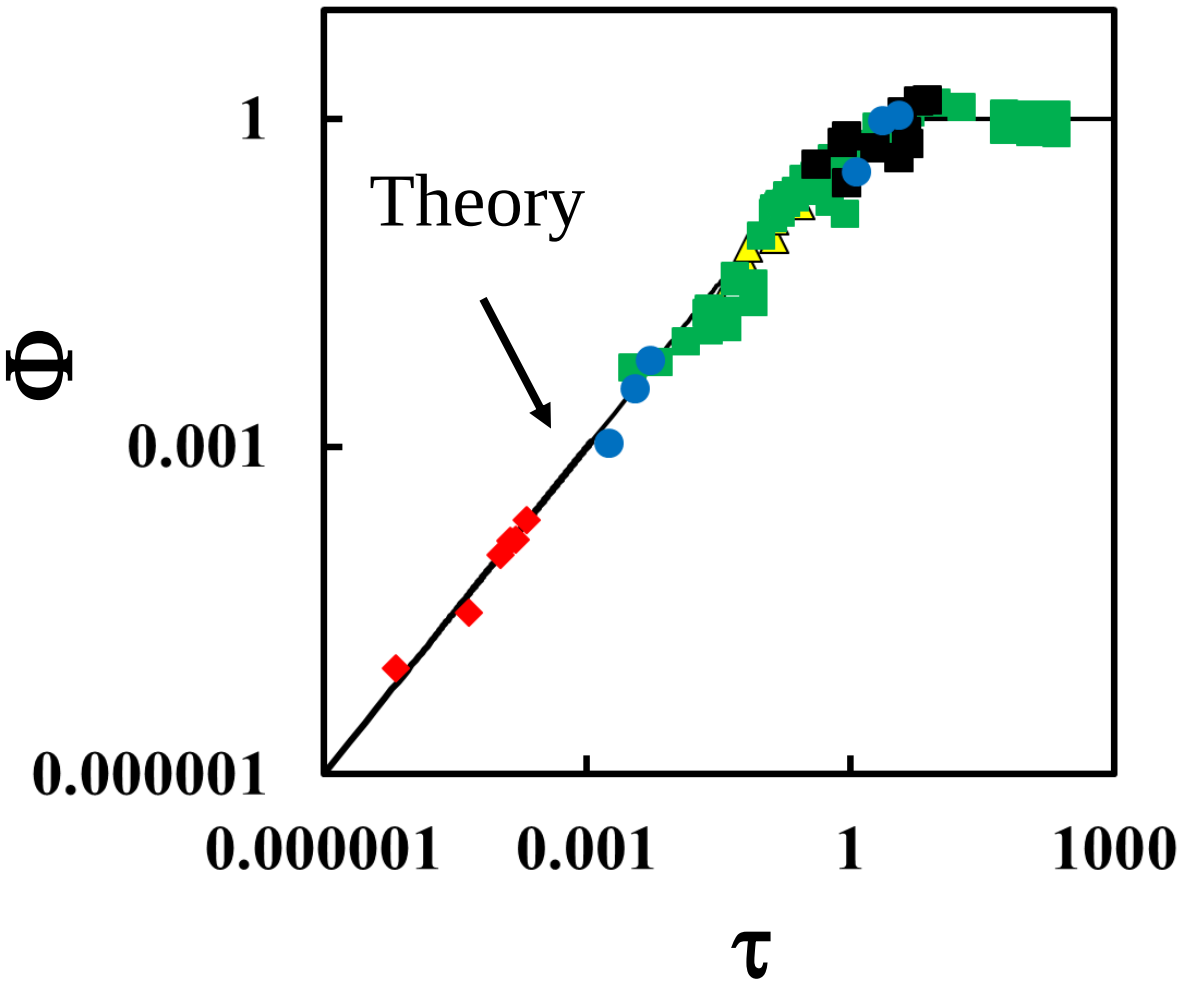
$\Phi(\tau)$: scaled frequency

τ : dimensionless time

Conclusion



Before Scaling



After Scaling