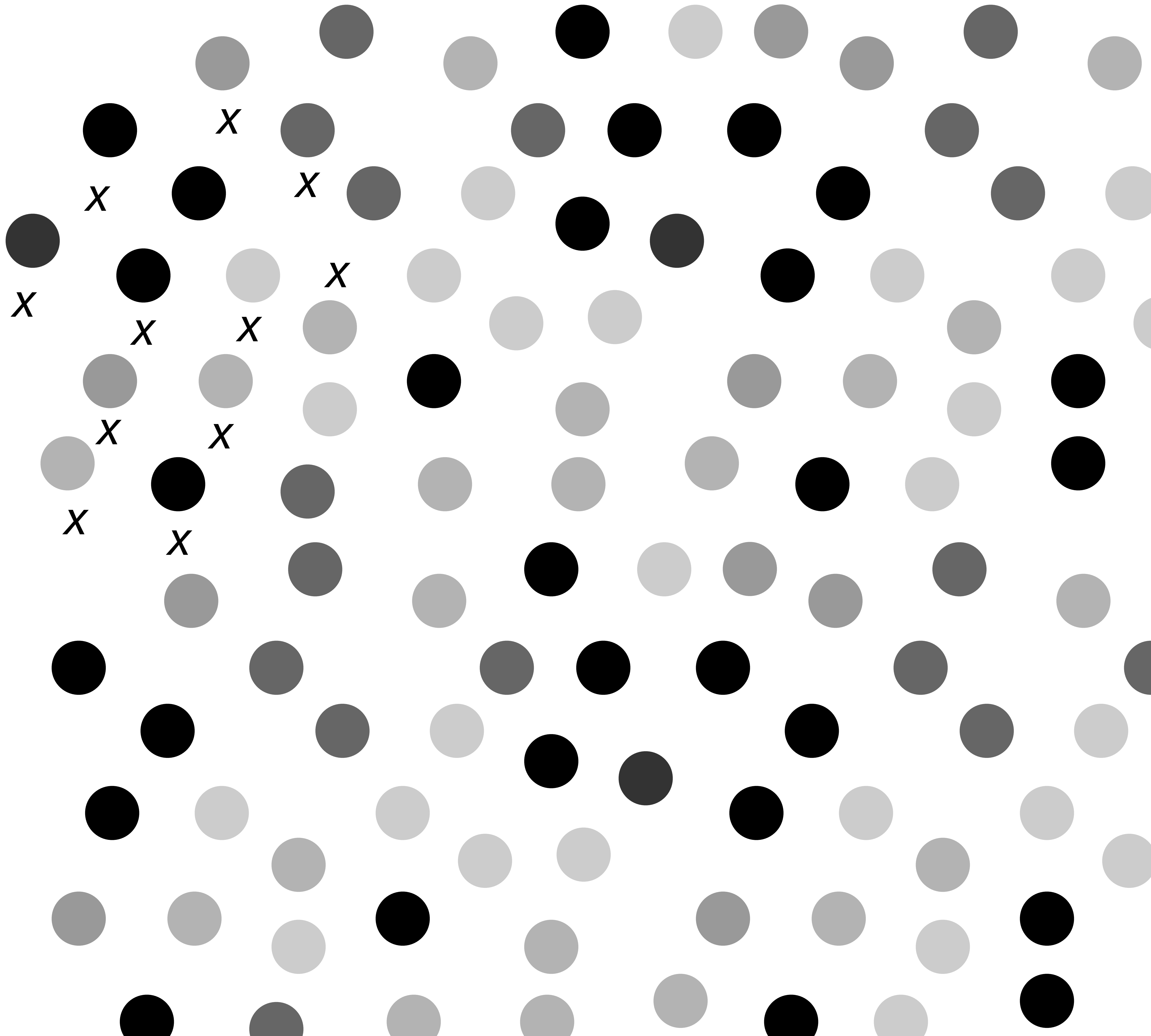
Evolution of life-history traits

Mutant fitness and reproductive success

- Consider a population monomorphic for trait x (e.g. size) at demographic equilibrium (under density-dependent regulation).



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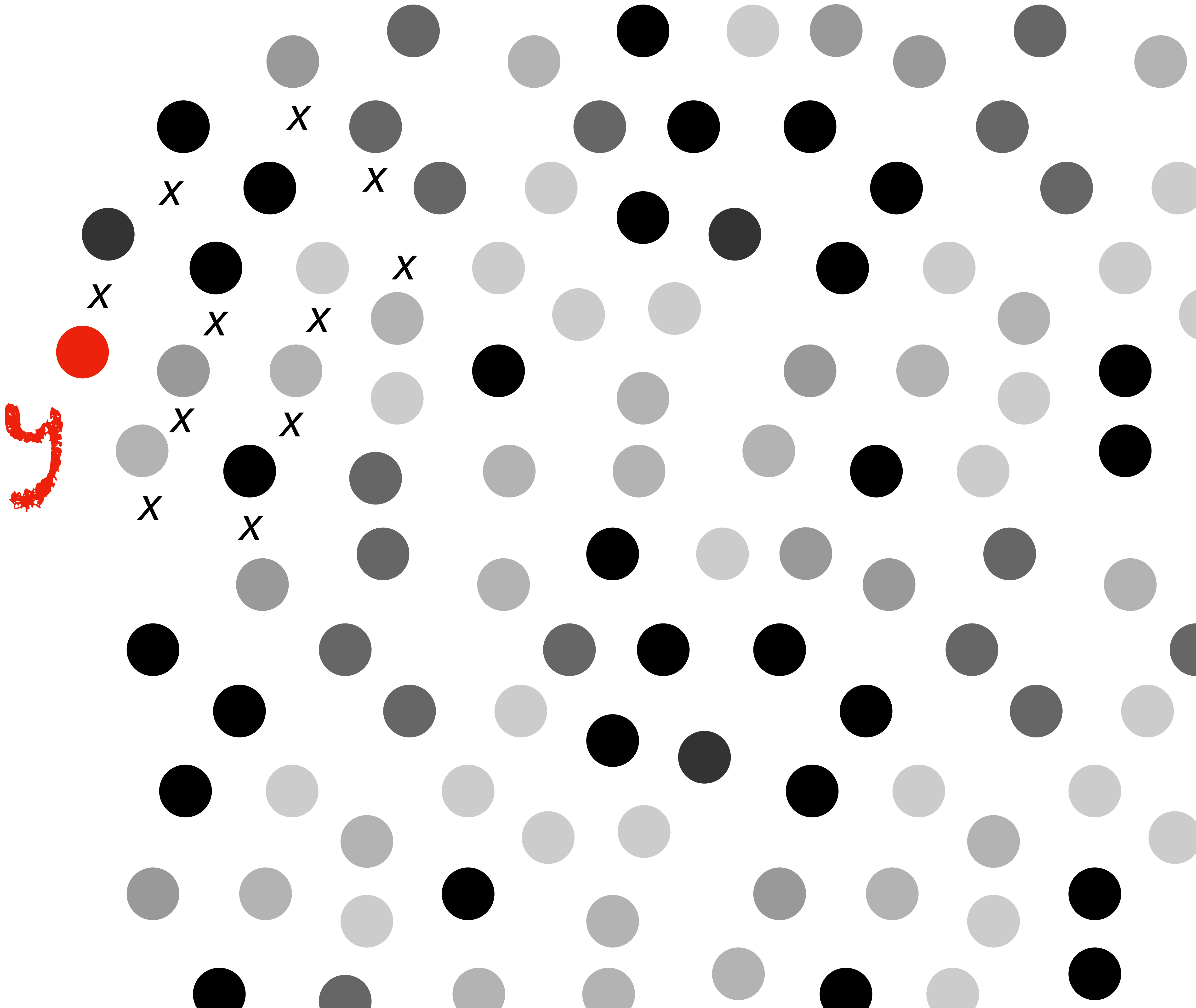

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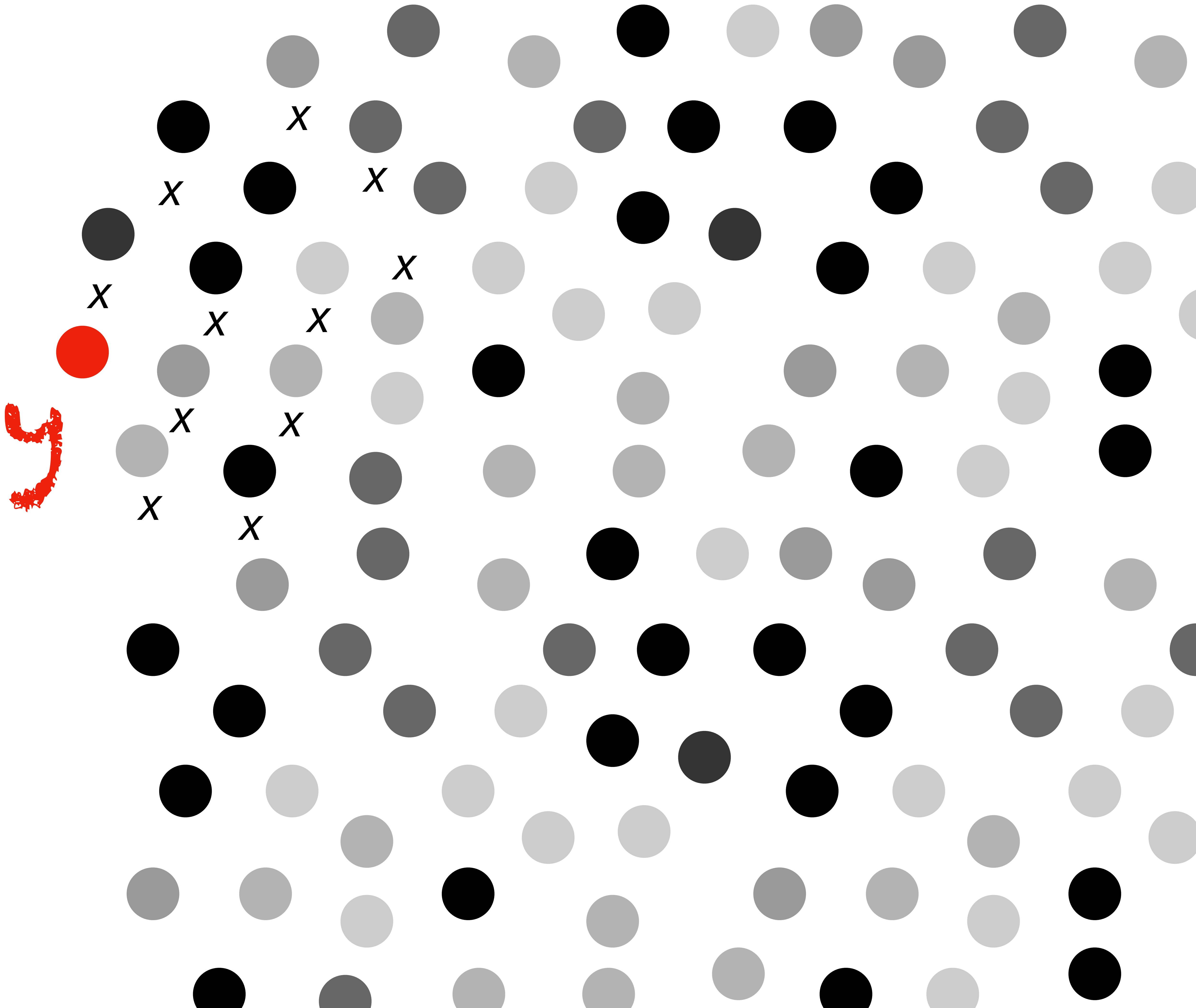

Is the mutant going to invade and replace the resident ?

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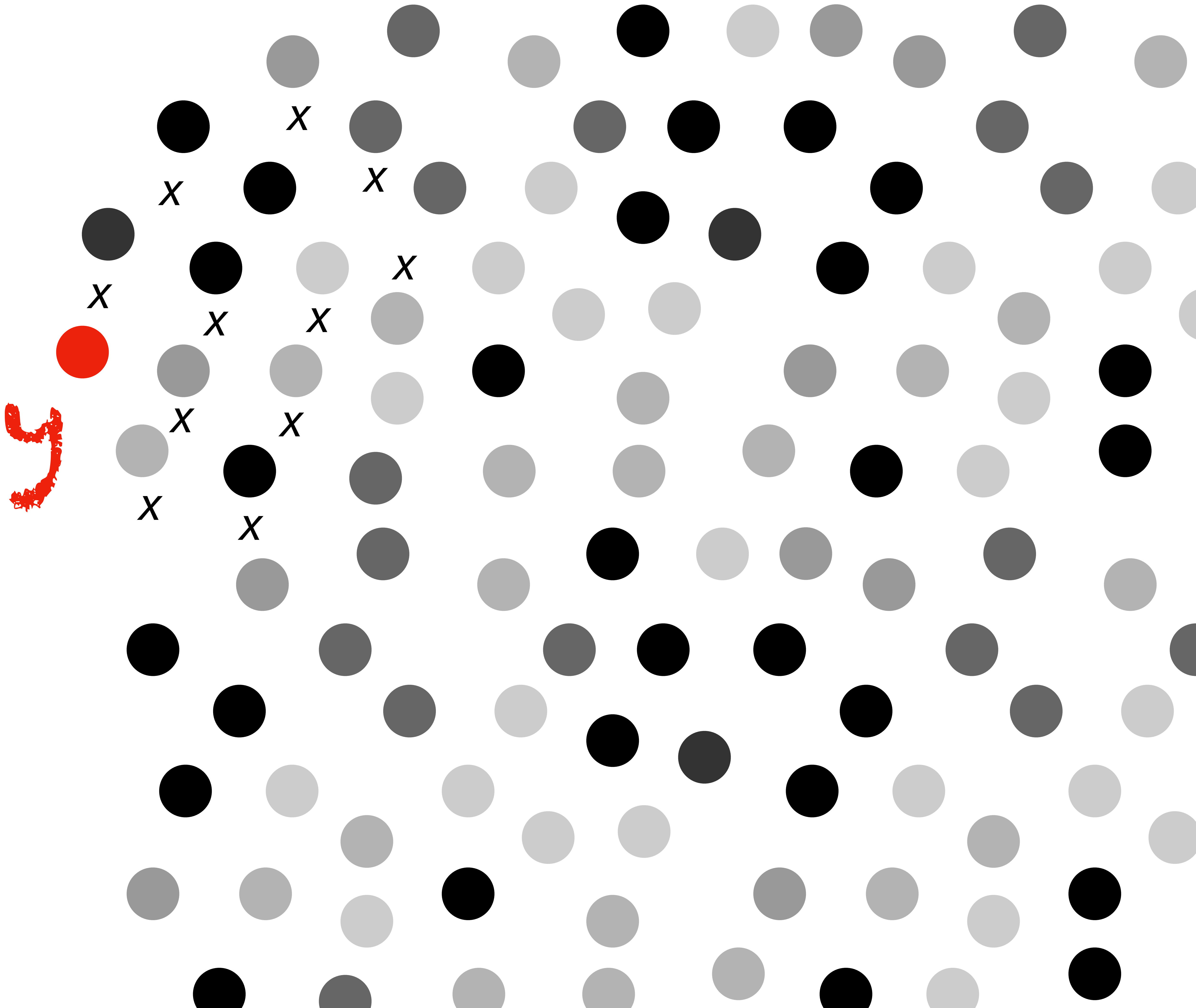
- In a large well mixed population, mutant invades only if

$$R_0(y,x) = \sum_{a=1}^{A} l_a(y,x) m_a(y,x) > 1$$

Pr survival to age *a* of a rare *y* mutant in a population of *x*

Fecundity of a rare *y* mutant of age *a* in a population of *x*



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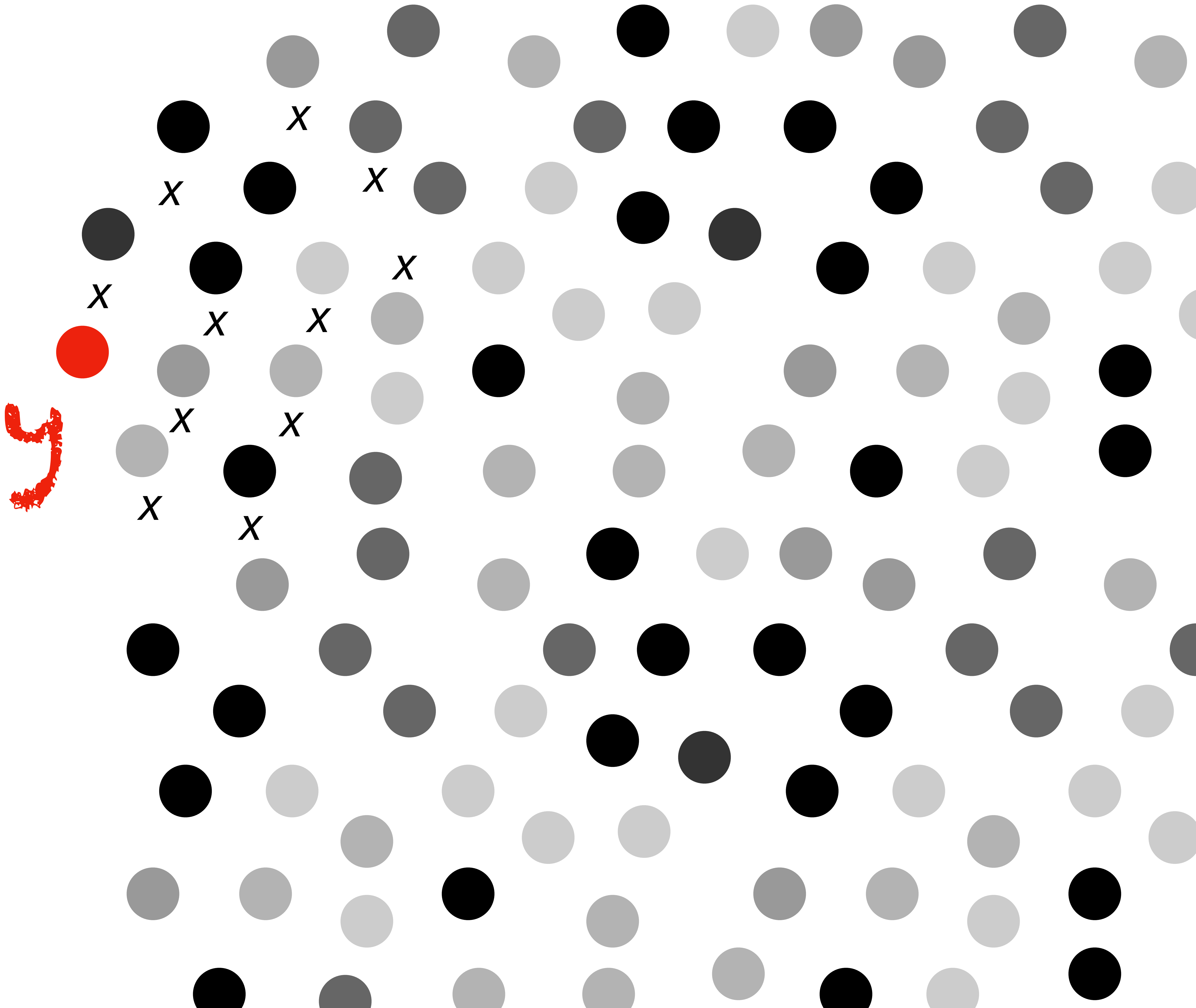
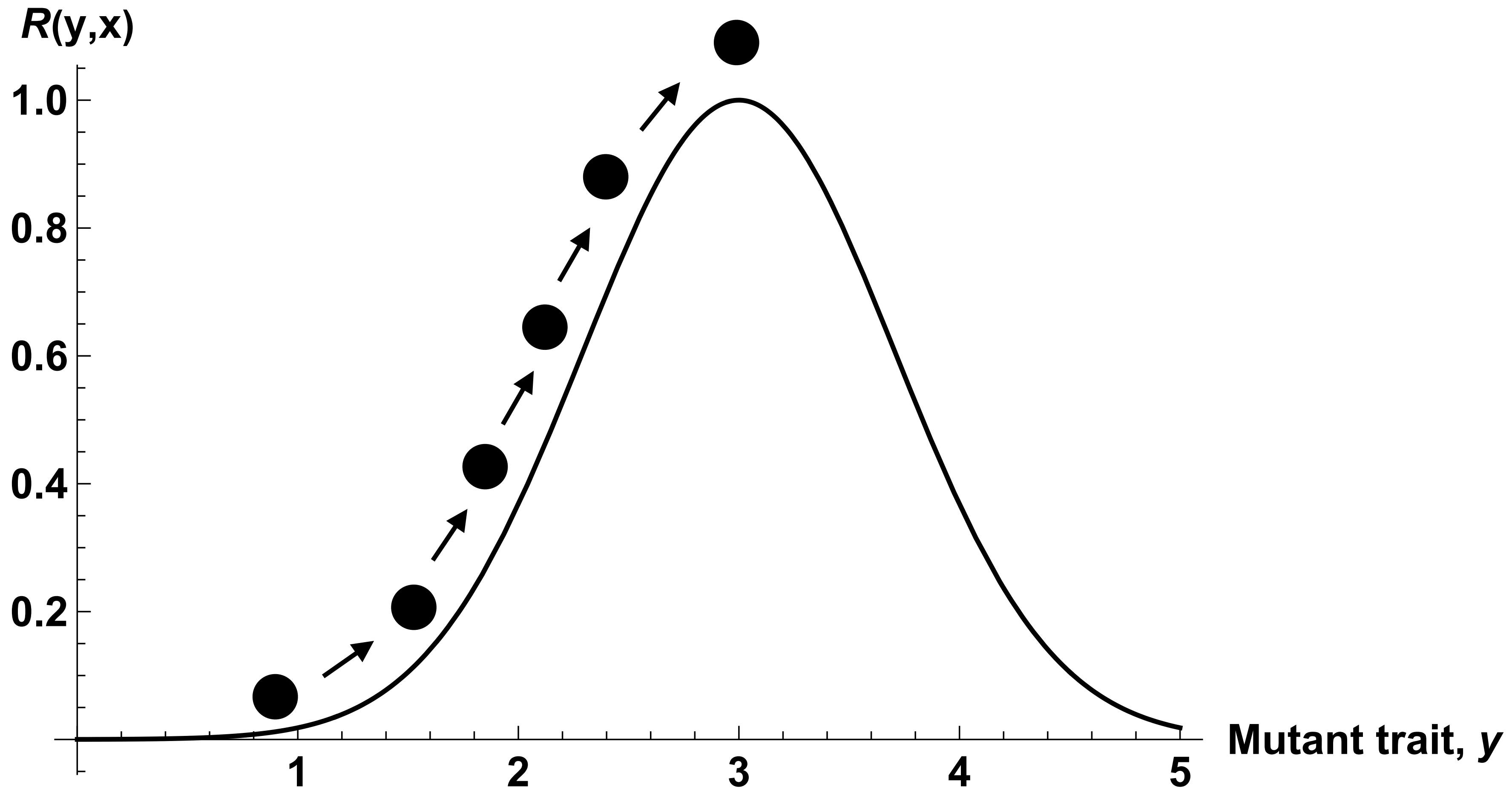
i.e. if a mutant on average has more than one offspring over its lifetime.



Evolutionary analysis

- For quantitative traits, mutant lifetime reproductive success $R_0(y, x)$ defines a **fitness landscape.**
- An evolving population population **climbs** this landscape to arrive to a maximum.



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- For quantitative traits, mutant lifetime reproductive success $R_0(y, x)$ defines a **fitness landscape.**
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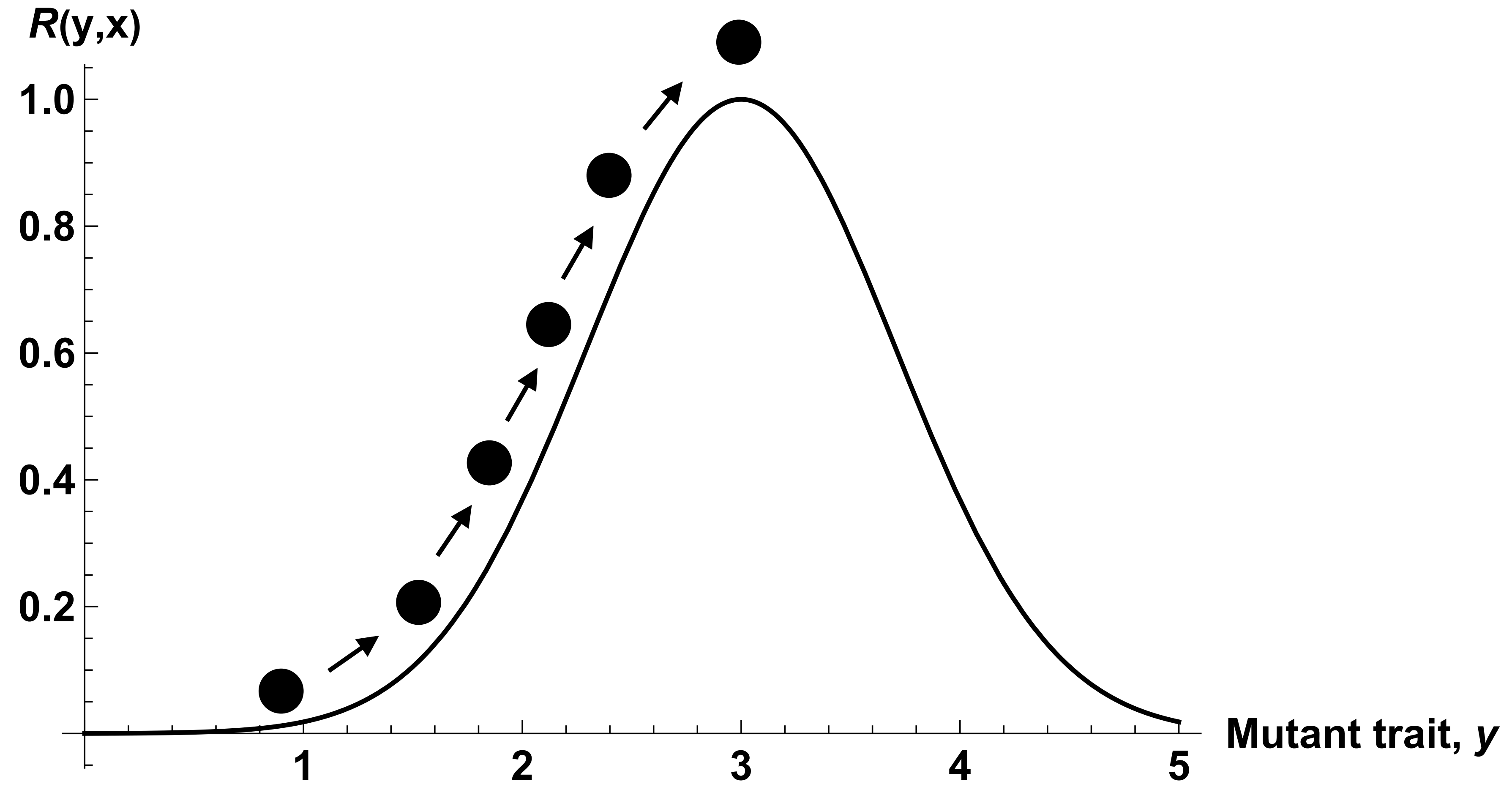
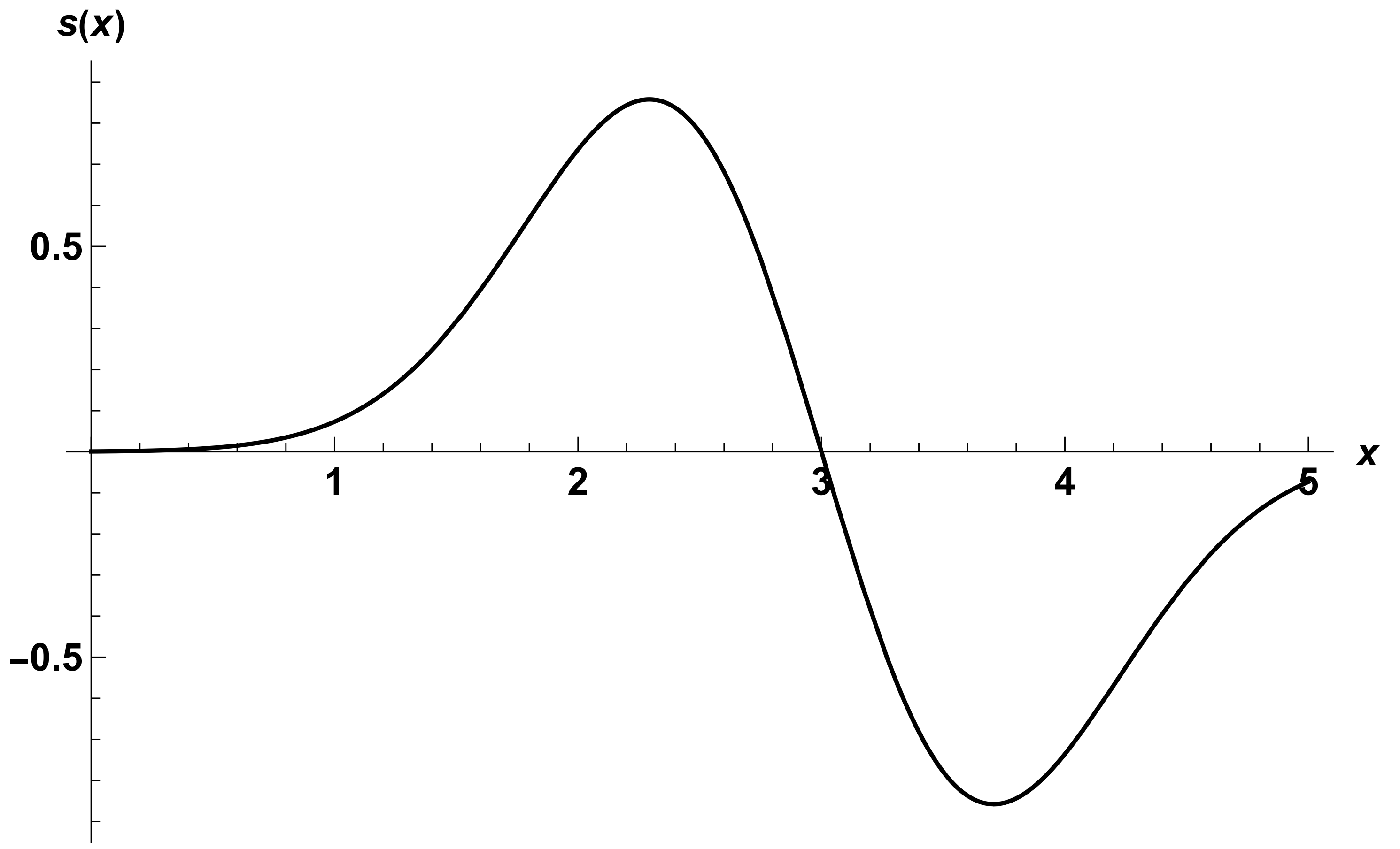
$$s(x) = \left. \frac{\partial R(y, x)}{\partial y} \right|_{y=x}$$





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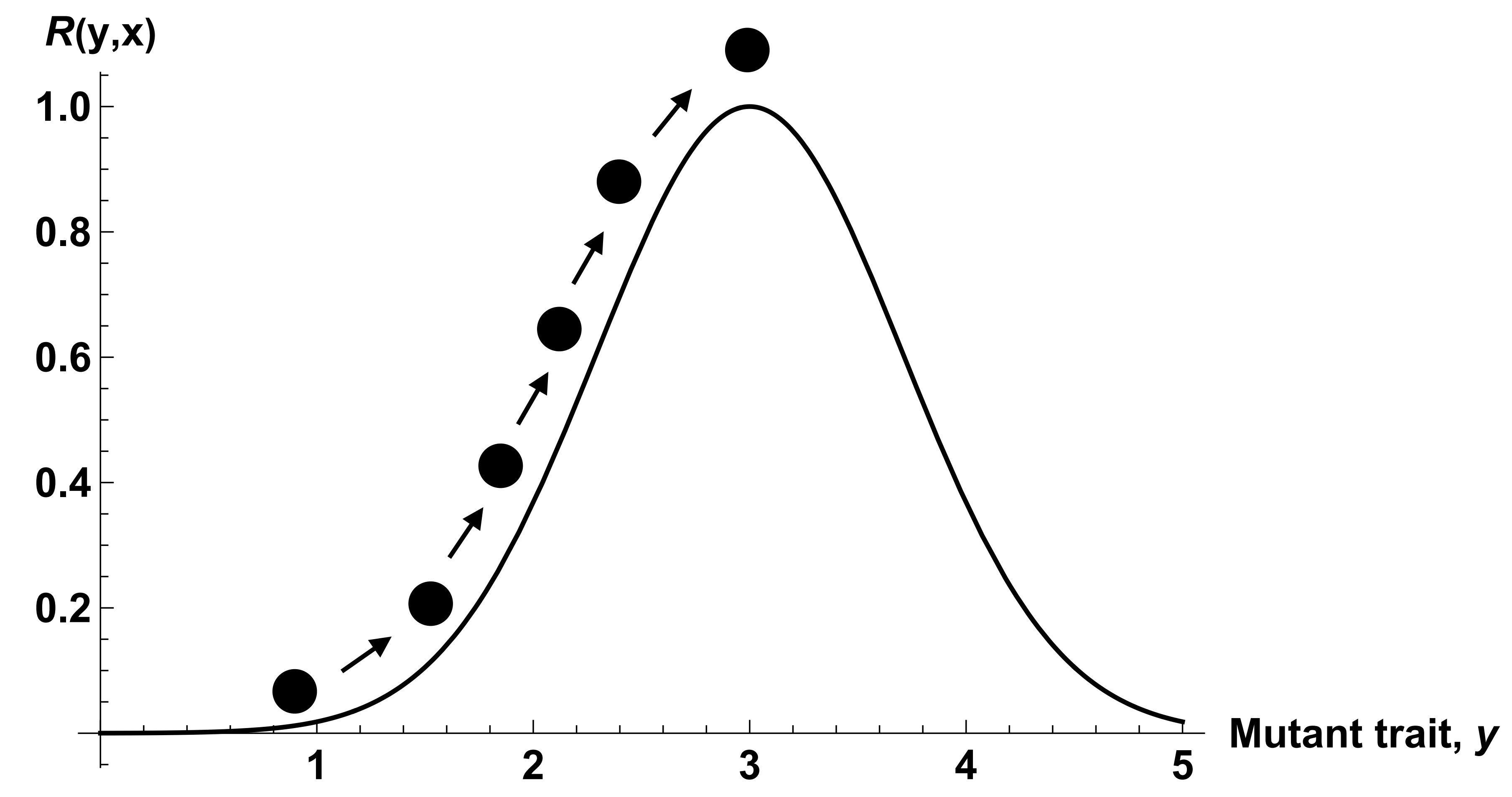
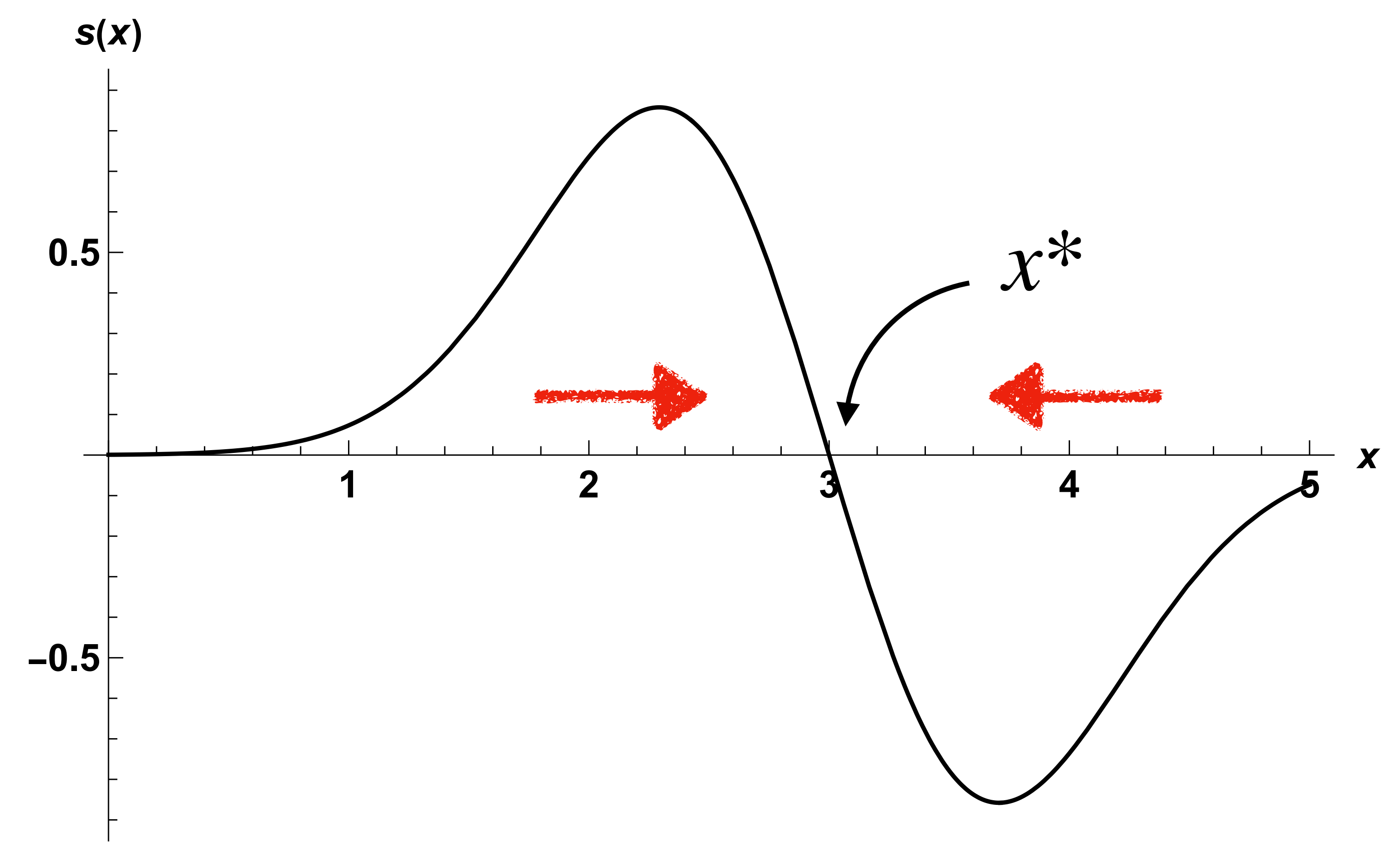
- A maximum x^* is such that

$$s(x^*) = 0$$

and

$$\left.\frac{\partial s(x)}{\partial x}\right|_{x=x^*} < 0$$





Example

Fecundity *vs.* offspring survival

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- Individuals live one year and reproduce once.

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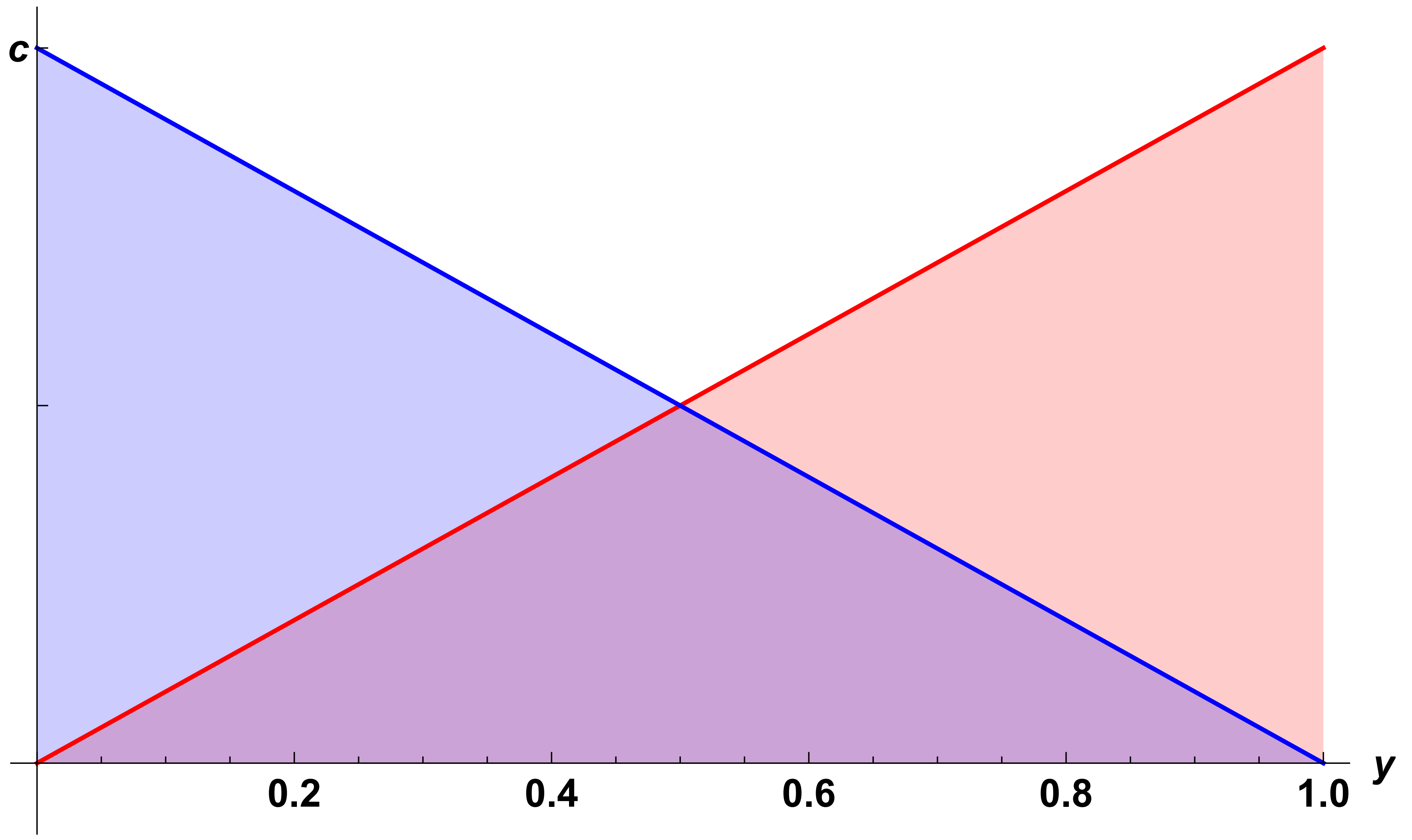
$K(x) > 0$
Density-dependent competition from resident



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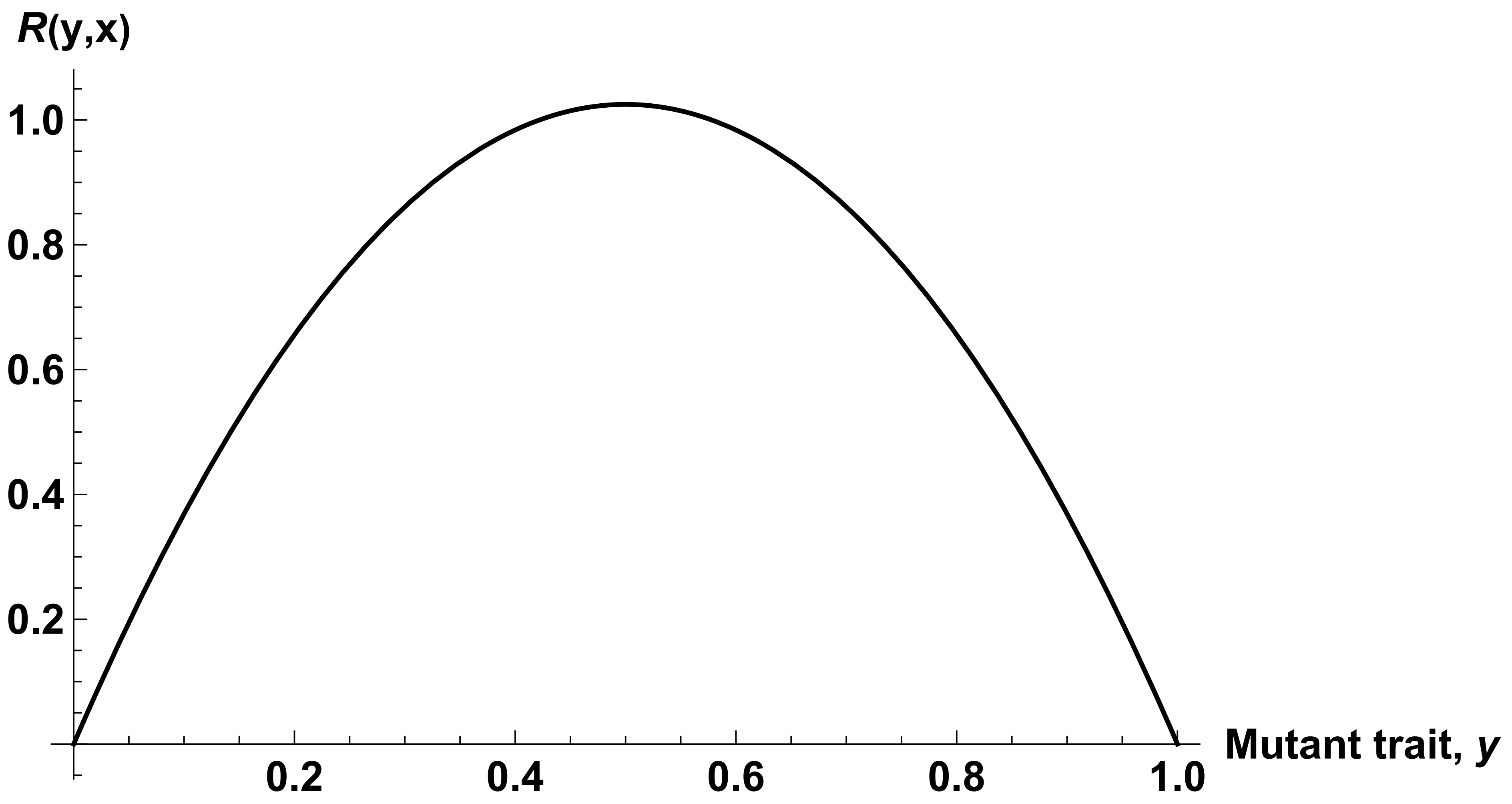

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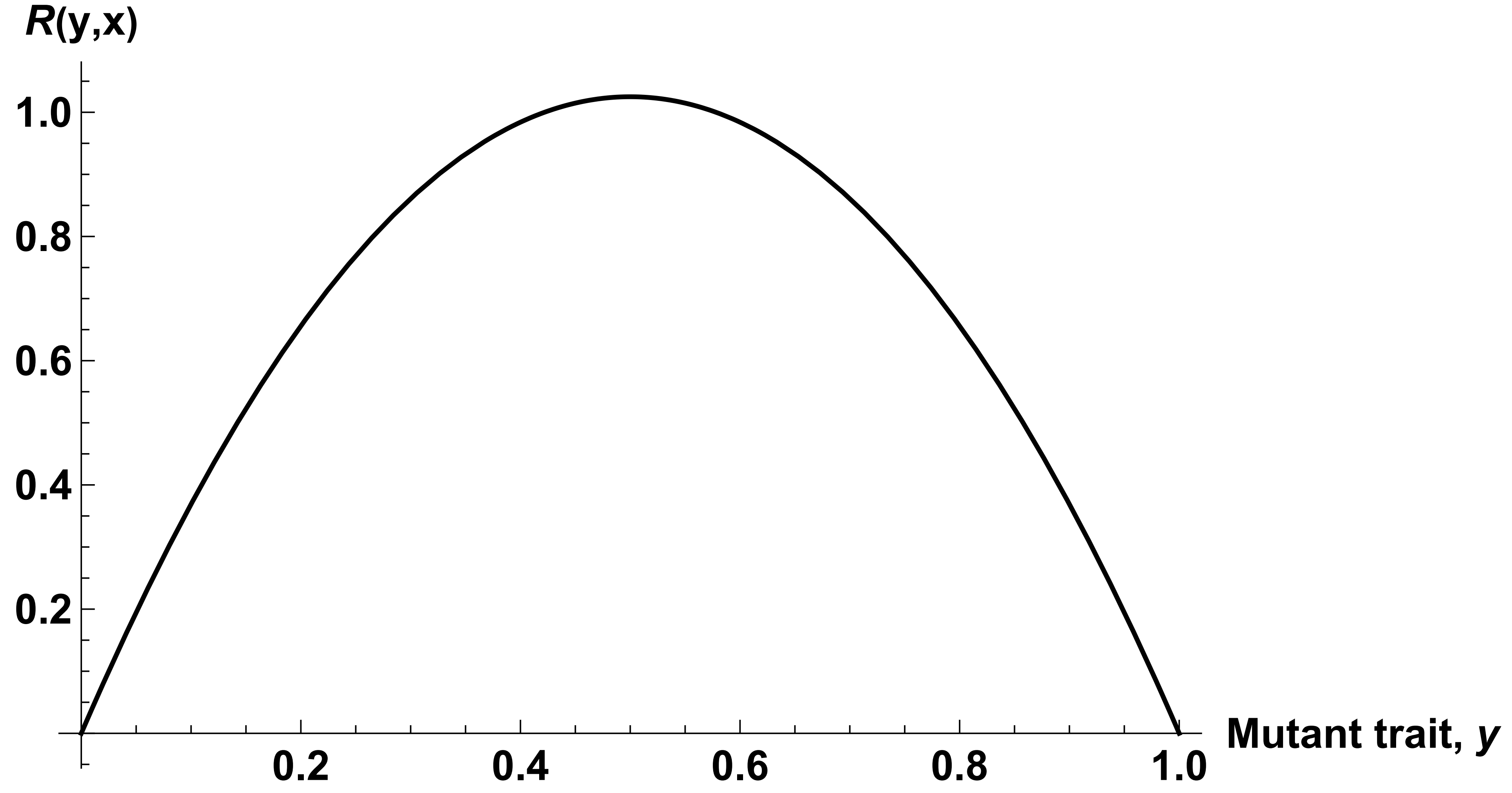
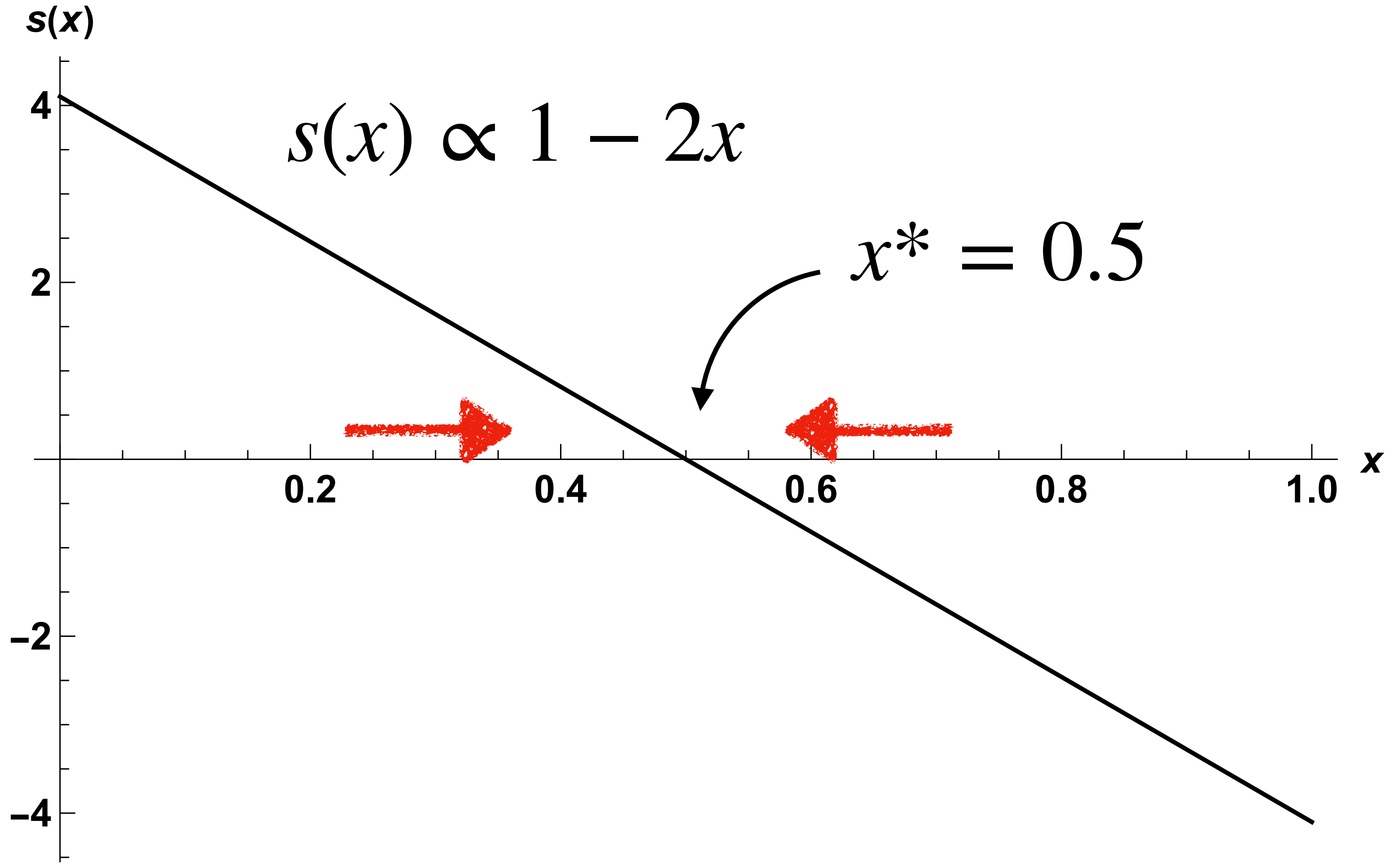
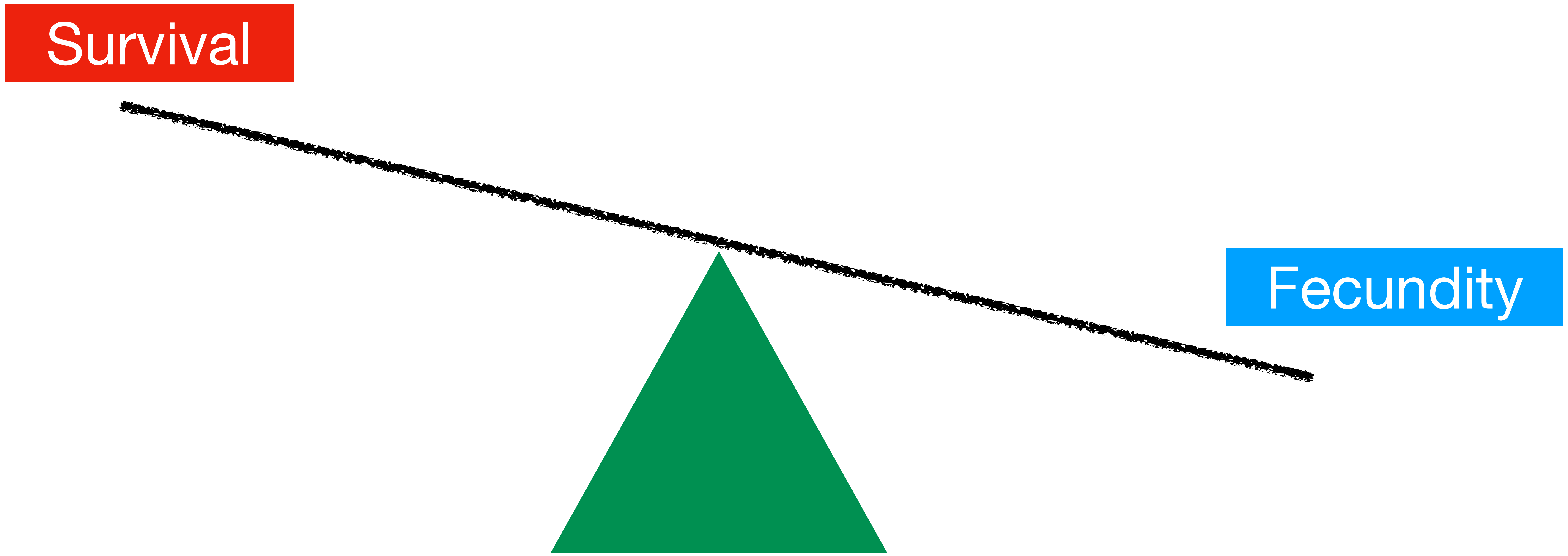




Trade offs

due to finite resources



Iteroparity *vs.* semelparity

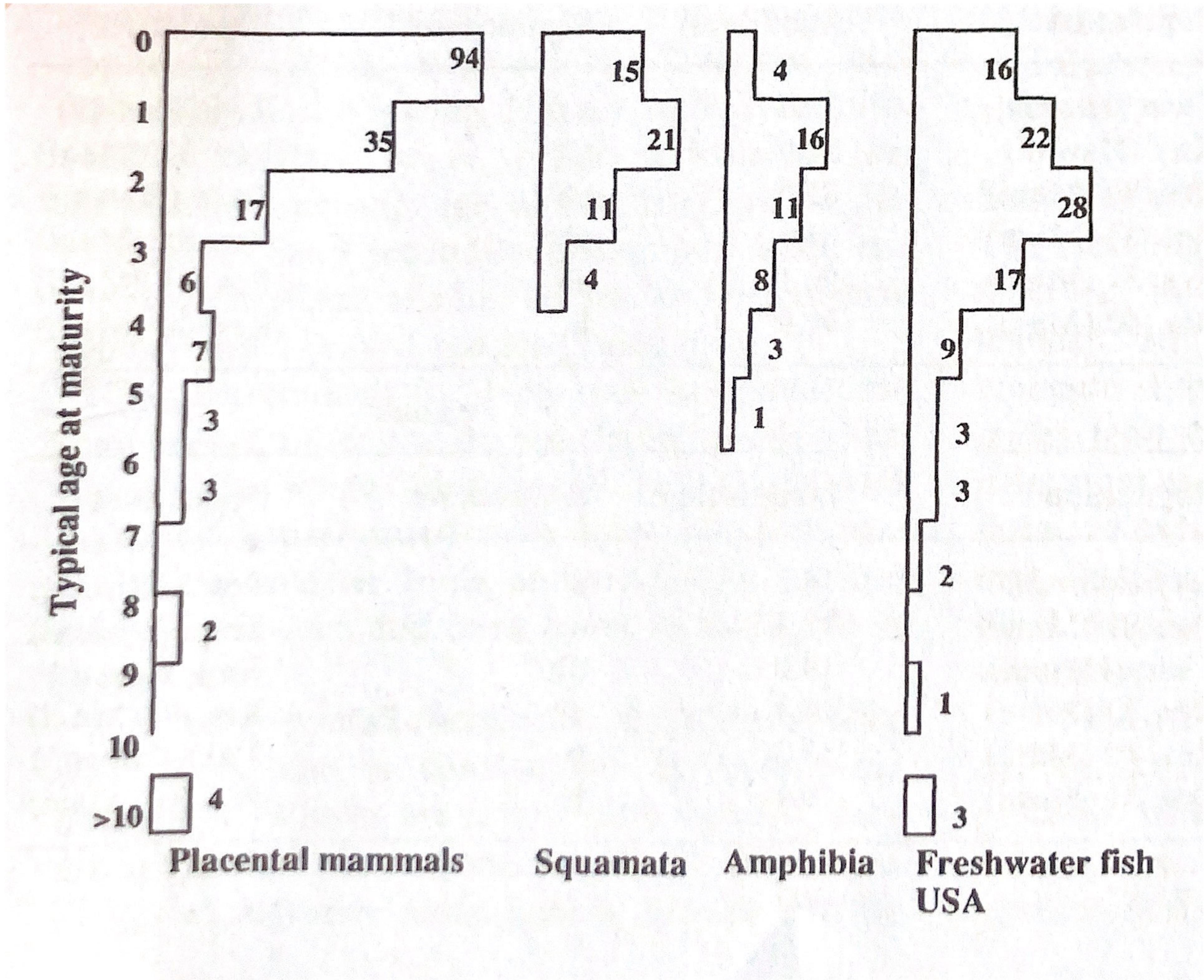
Exercise sheet

- **Semelparity**: Reproduce only once during one's lifetime

- **Iteroparity**: Reproduce multiple times

Age at maturity

- Age at which a juvenile body matures to become capable of sexual reproduction



Bell (1980) Am Nat
Stearns (1992)

Age at maturity

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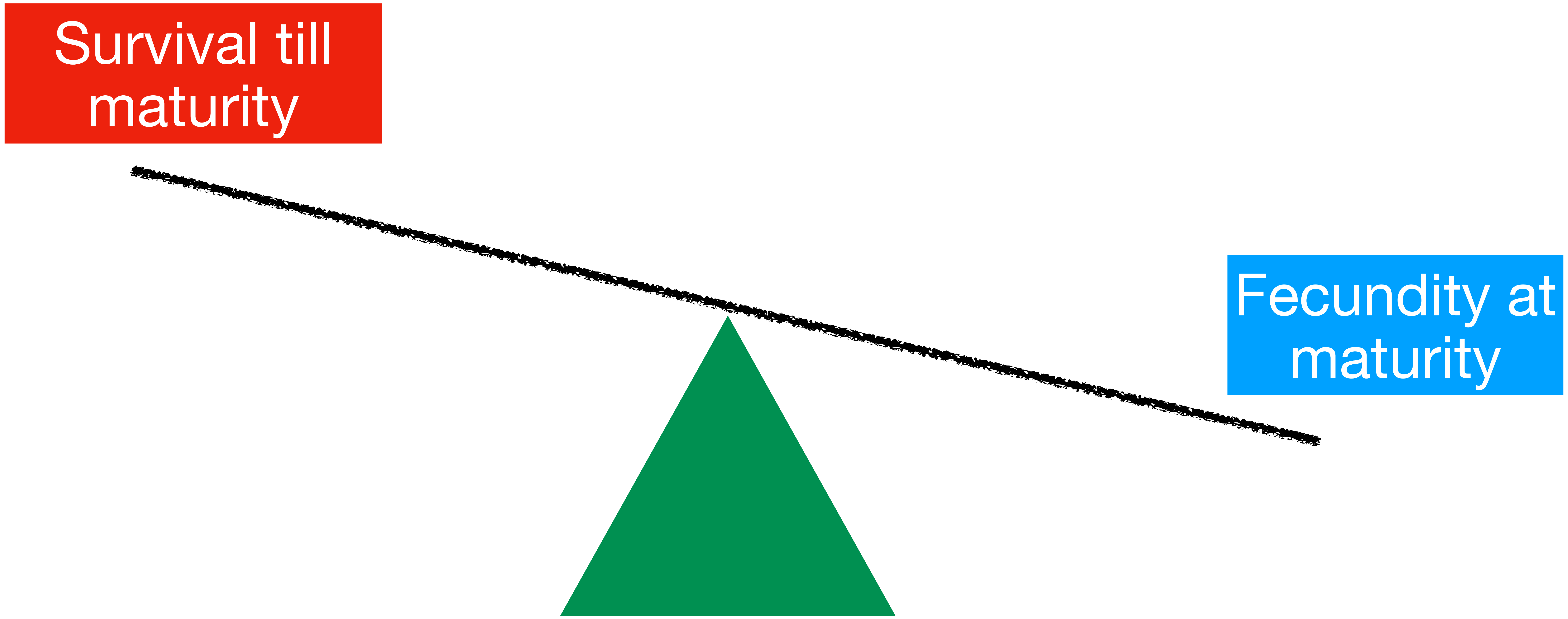

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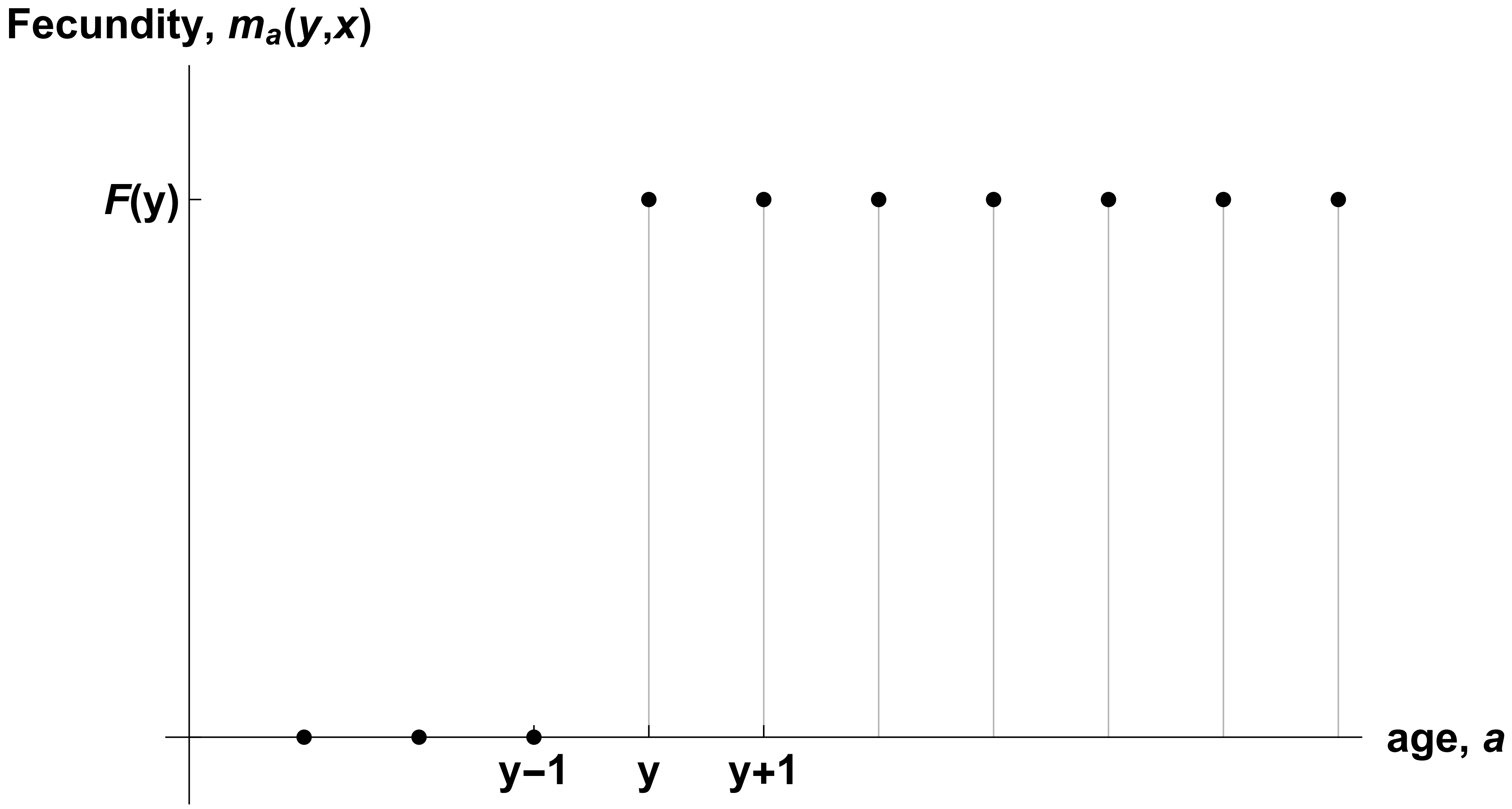

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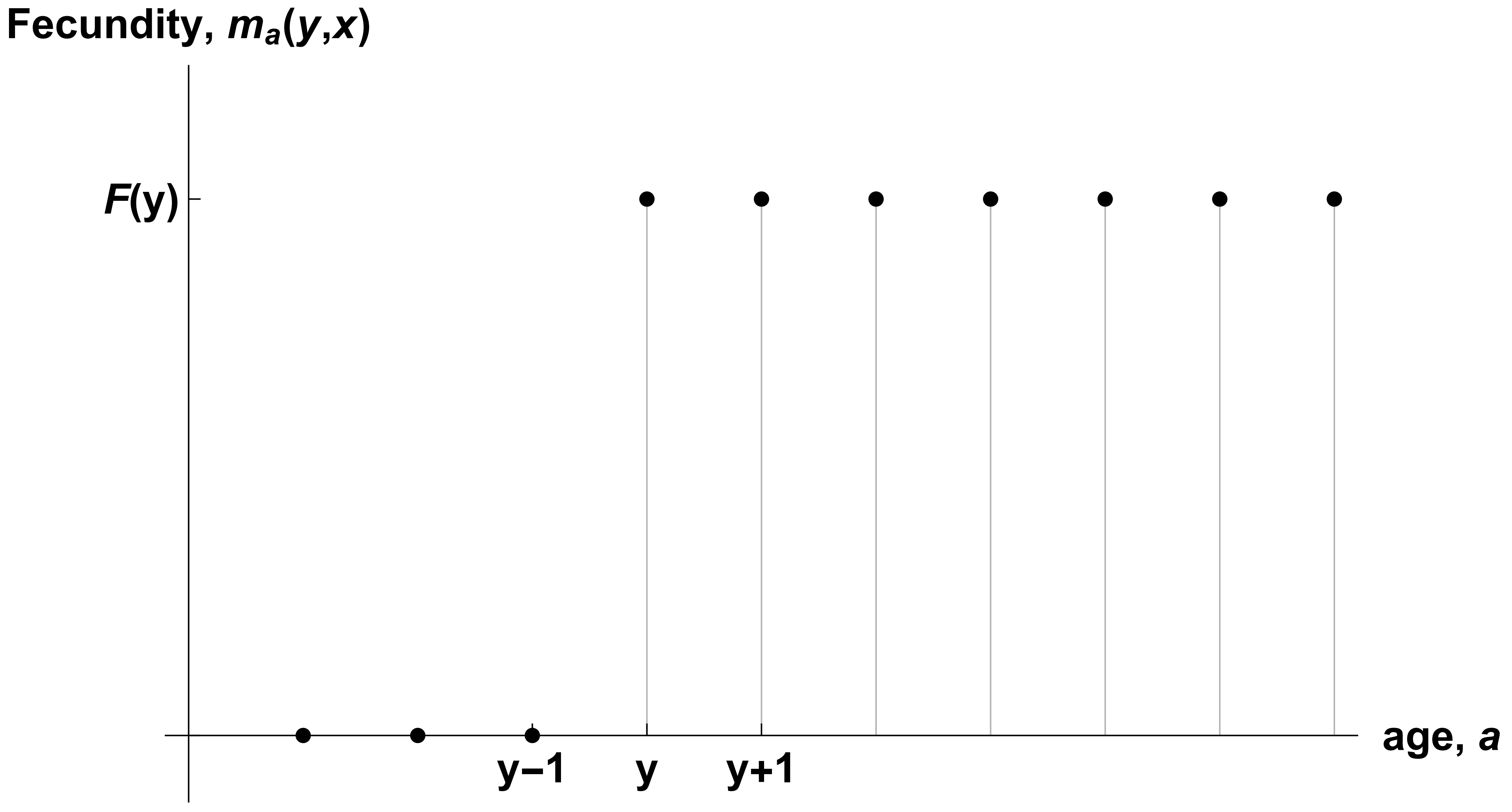

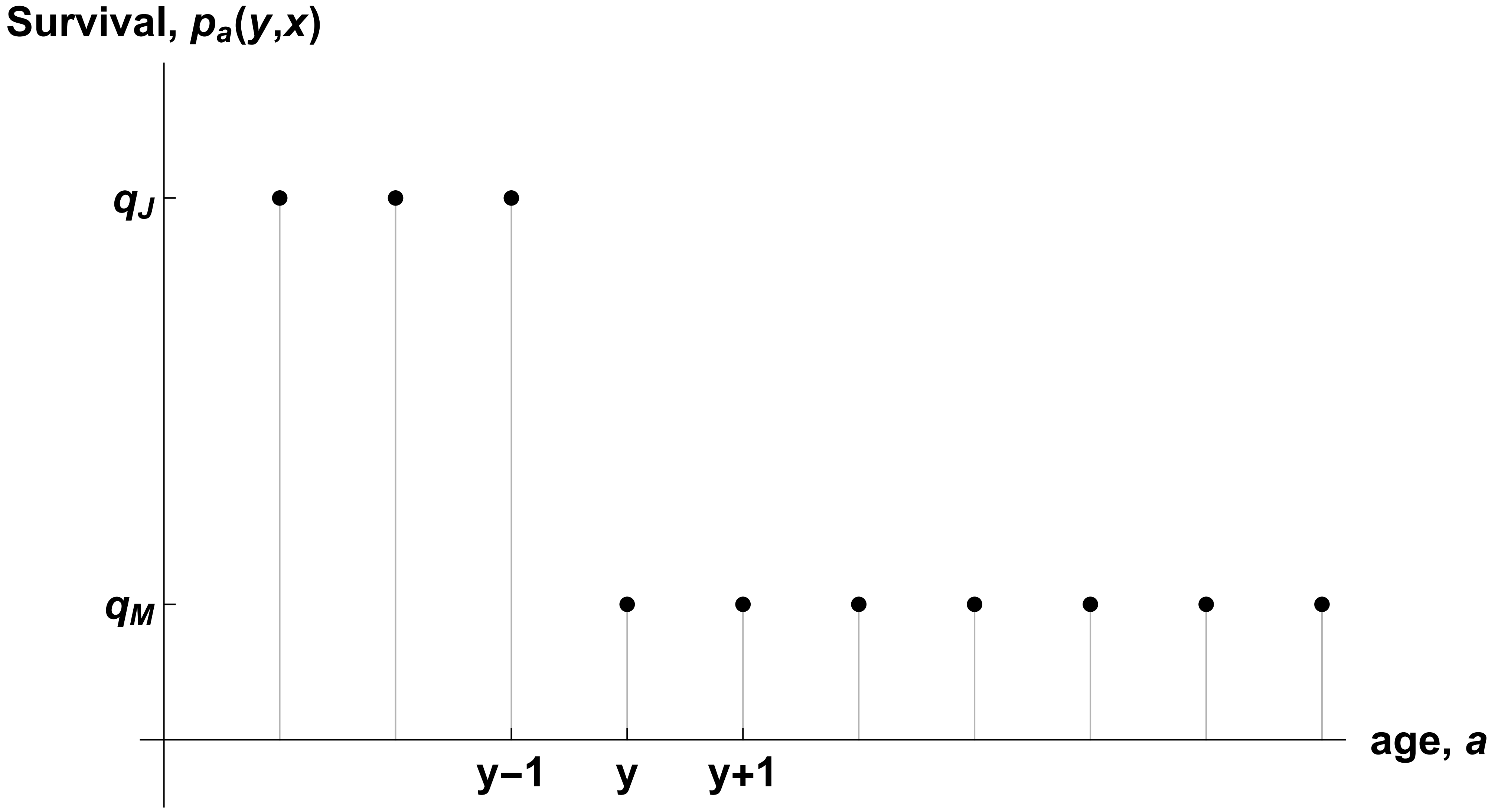

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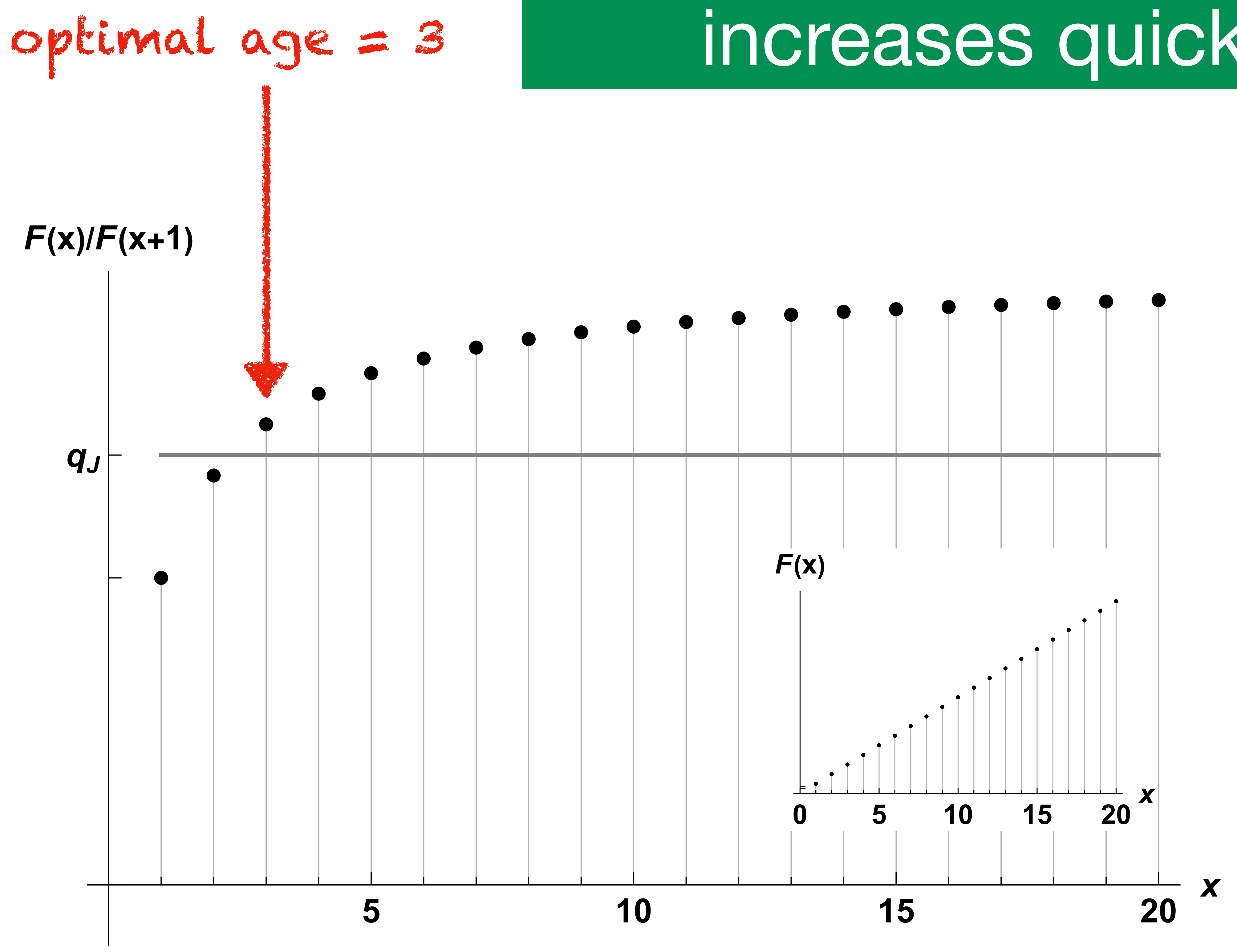

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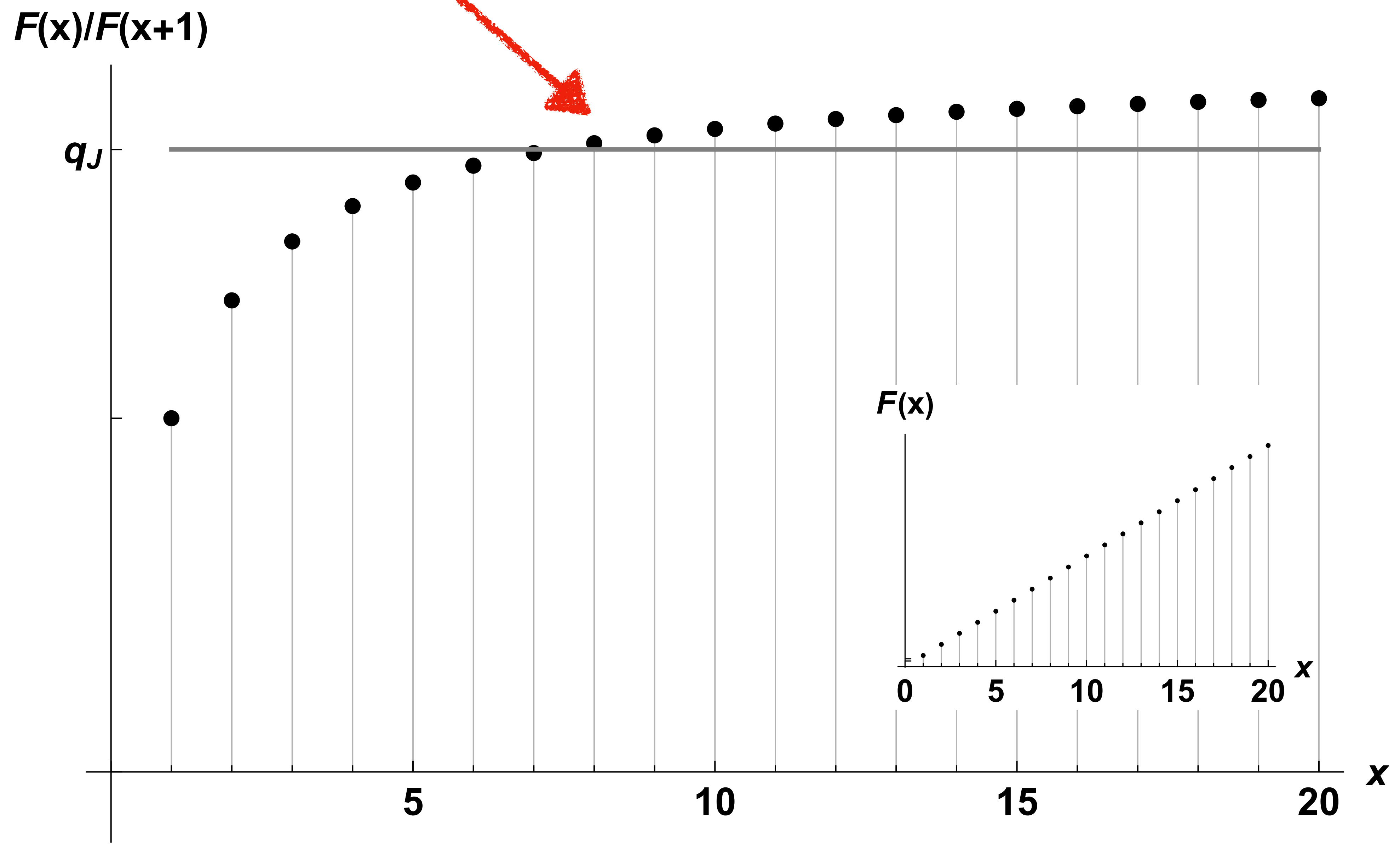
optimal age = 8



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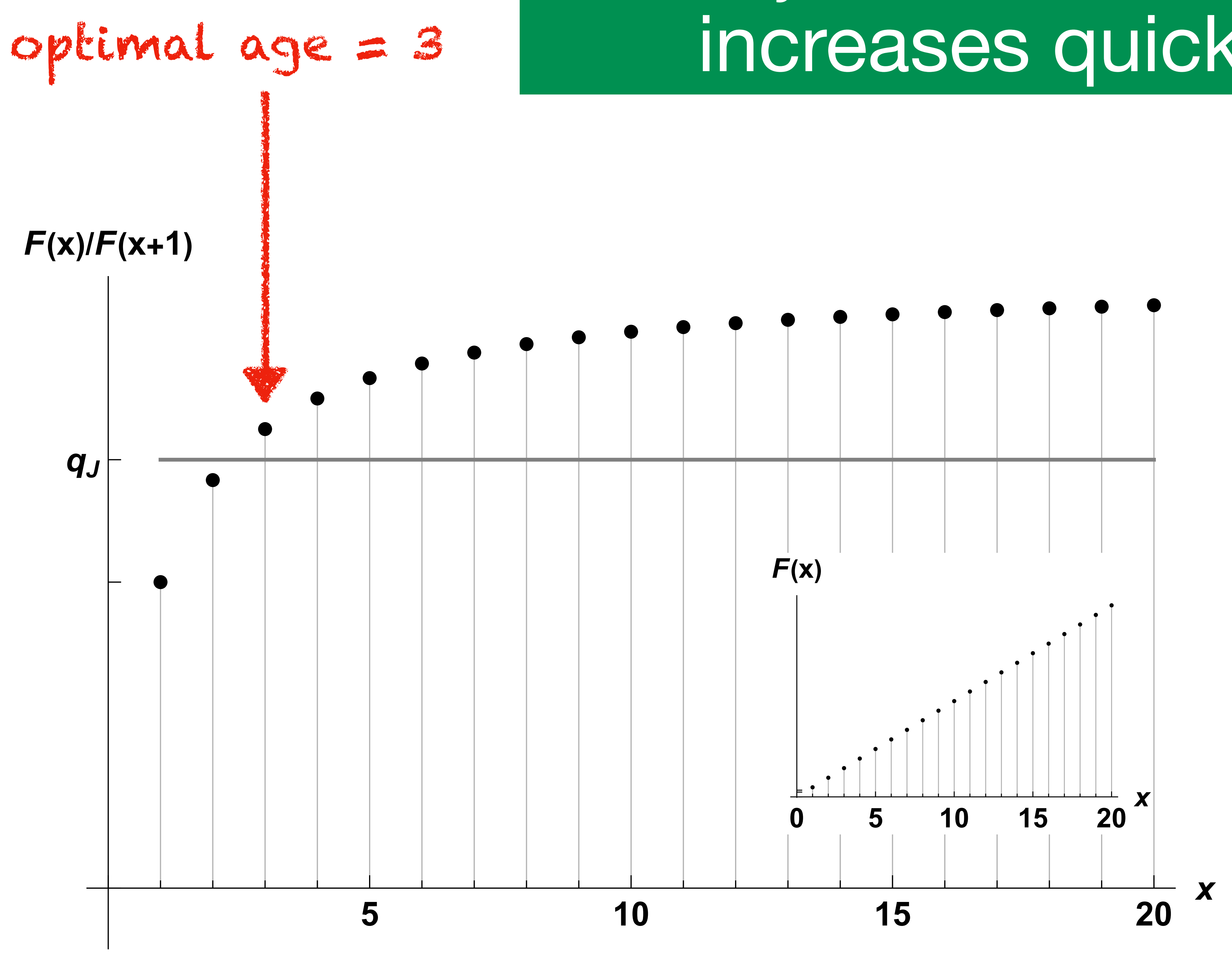

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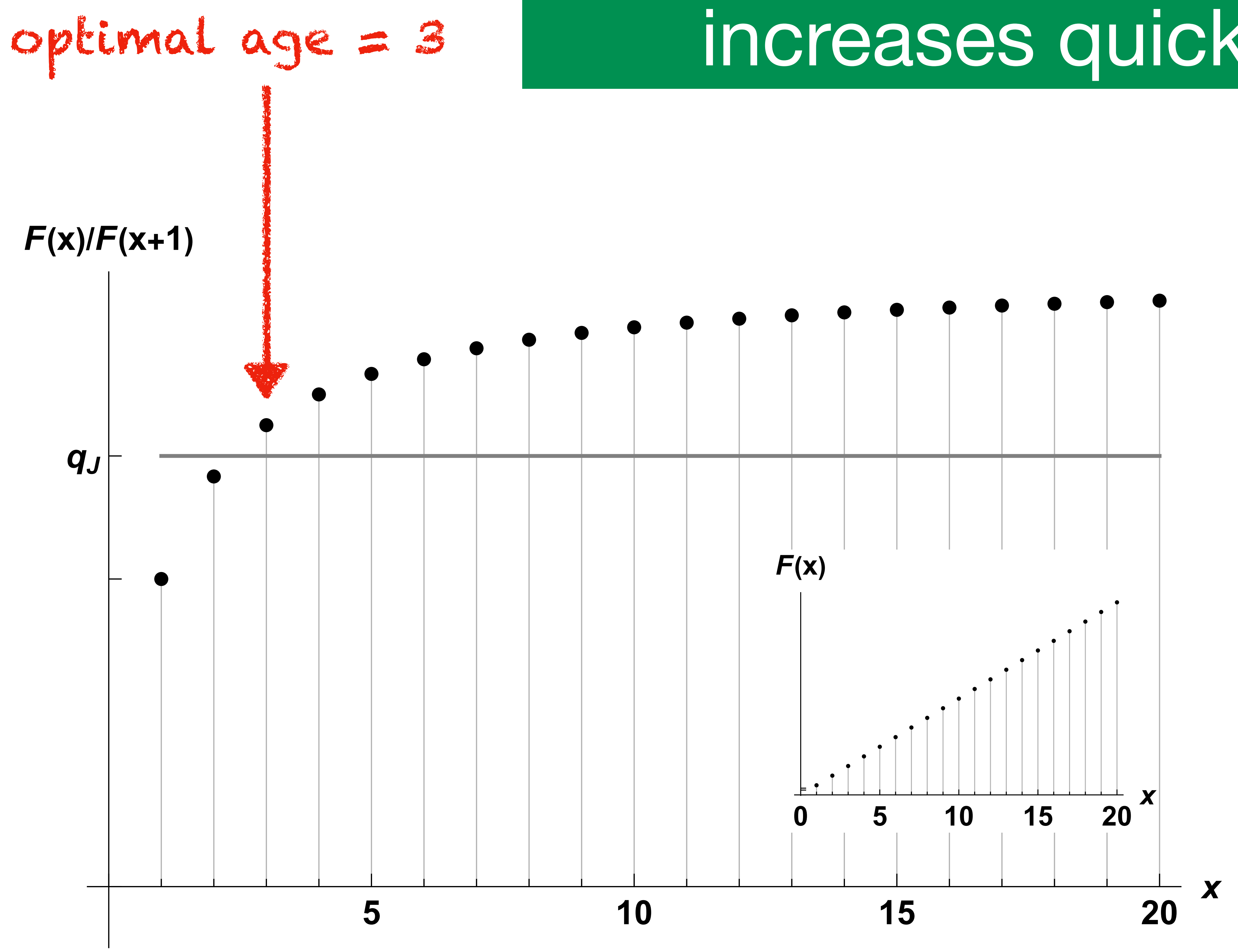
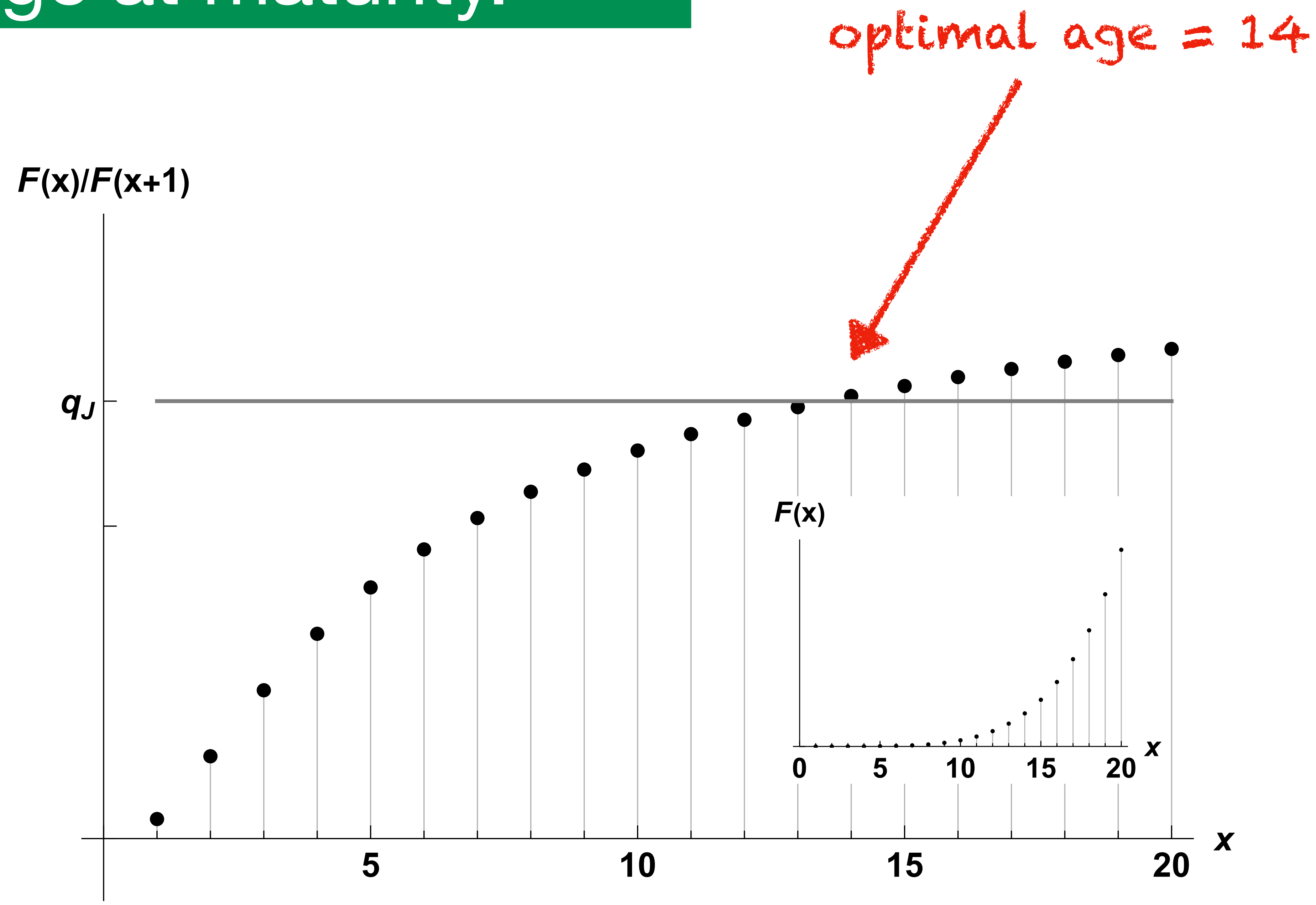
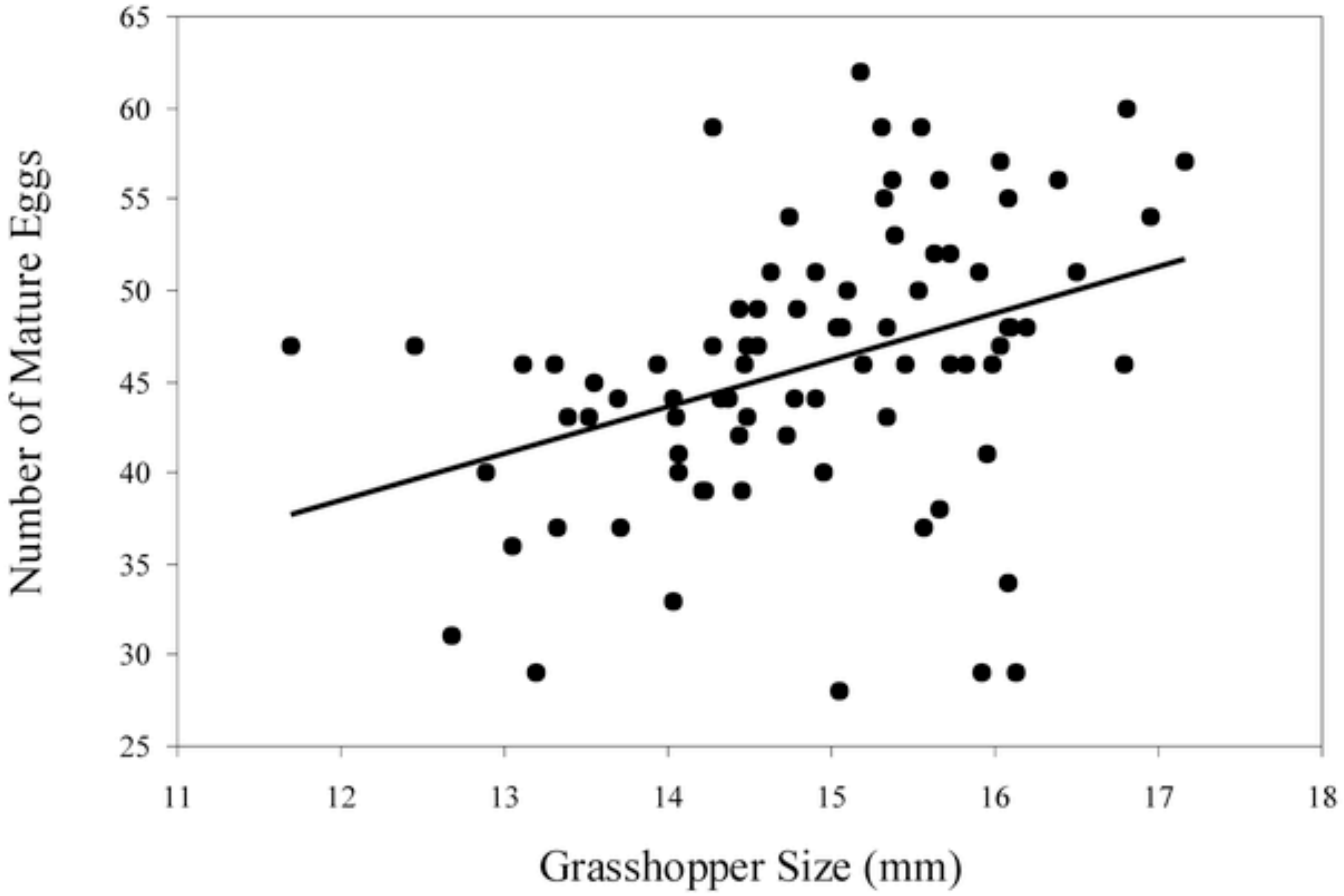




Effect of size at maturity

Fecundity associated with size in many species



J. of Orthoptera Research, 17(2):265-271 (2008)

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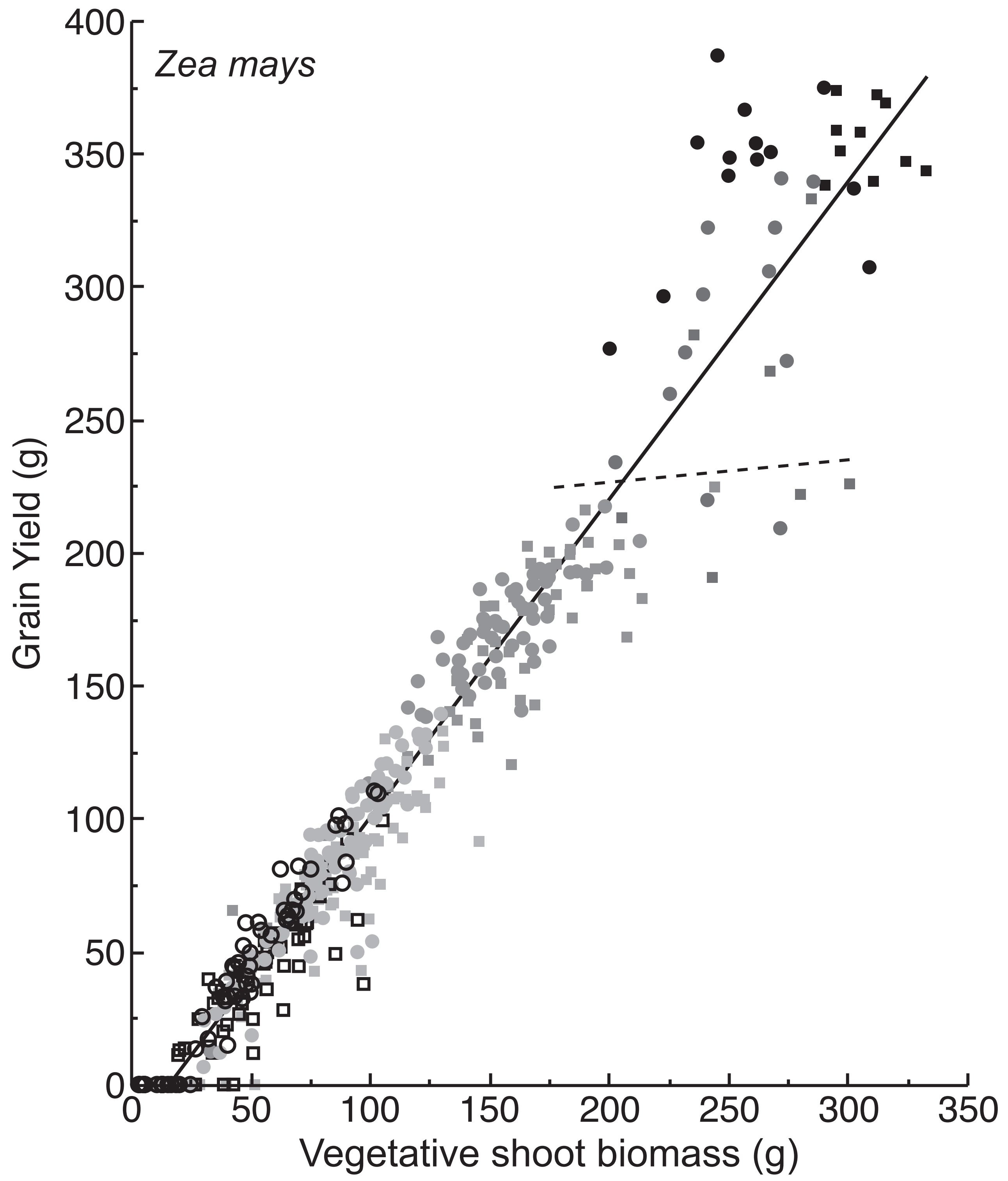
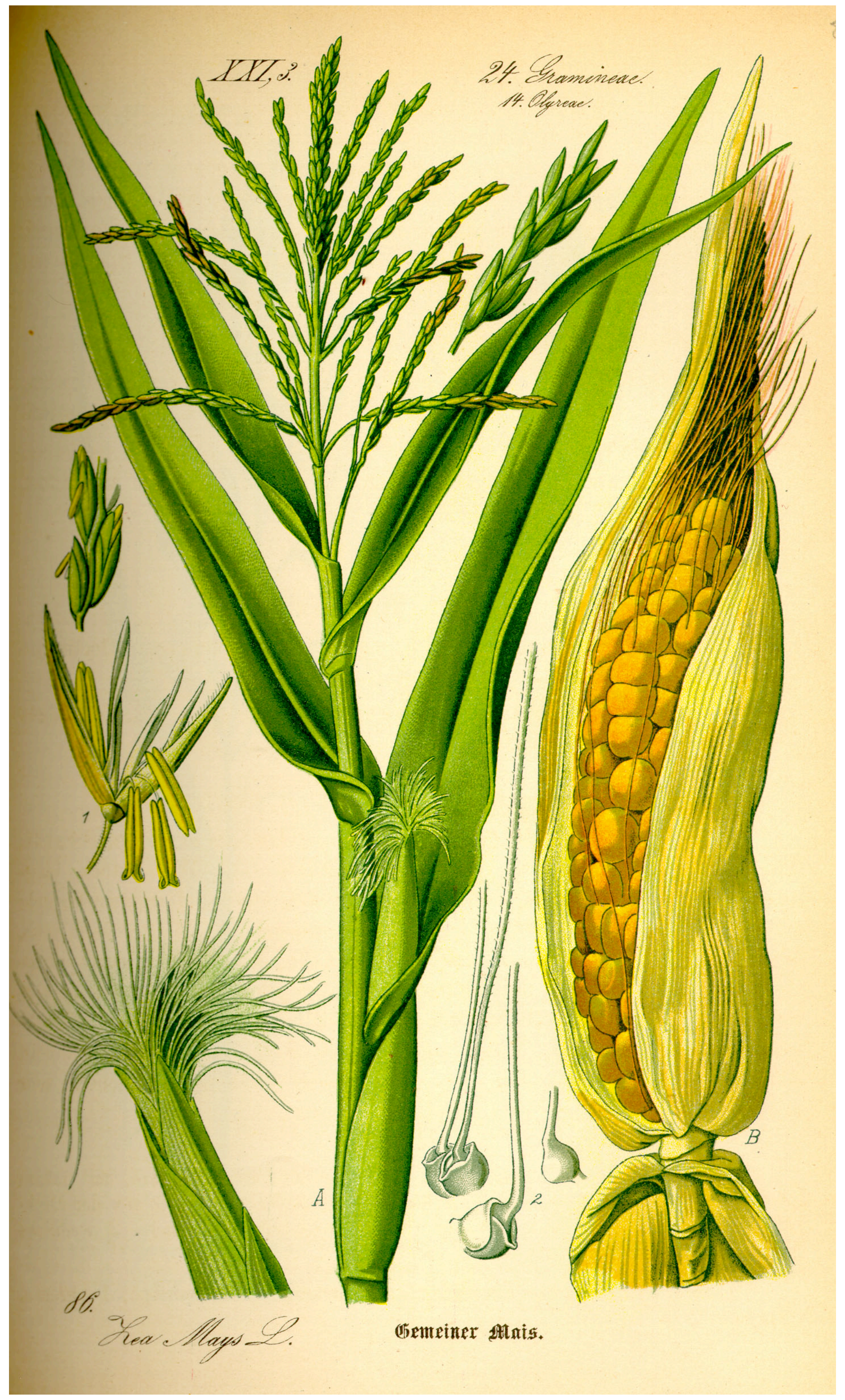
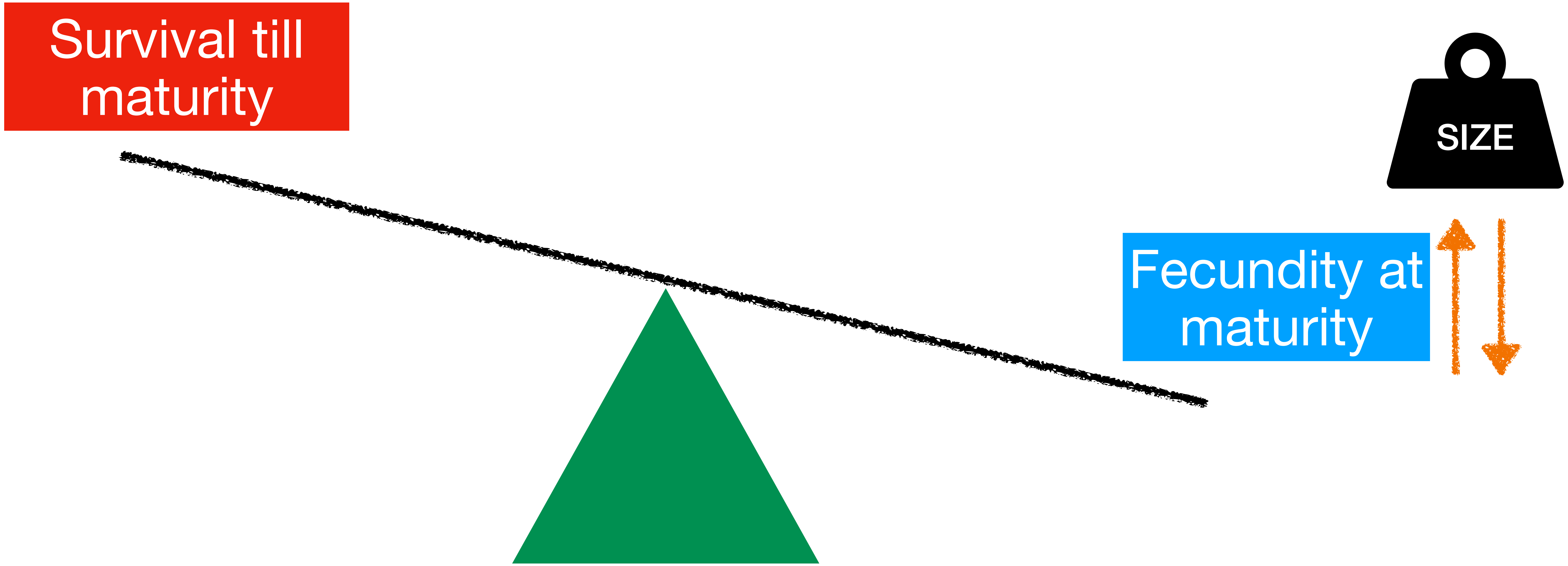


Weiner et al. Journal of Ecology 2009



Effect of size at maturity

Mediates the survival/fecundity trade-off



Effect of size at maturity

Roff’s model (adapted)

- Age at maturity, *y*, evolving trait:

$$m_a(y,x) = \begin{cases} 0, & 1 \le a < y \\ cL_a(y)^3, & y \le a \end{cases}$$

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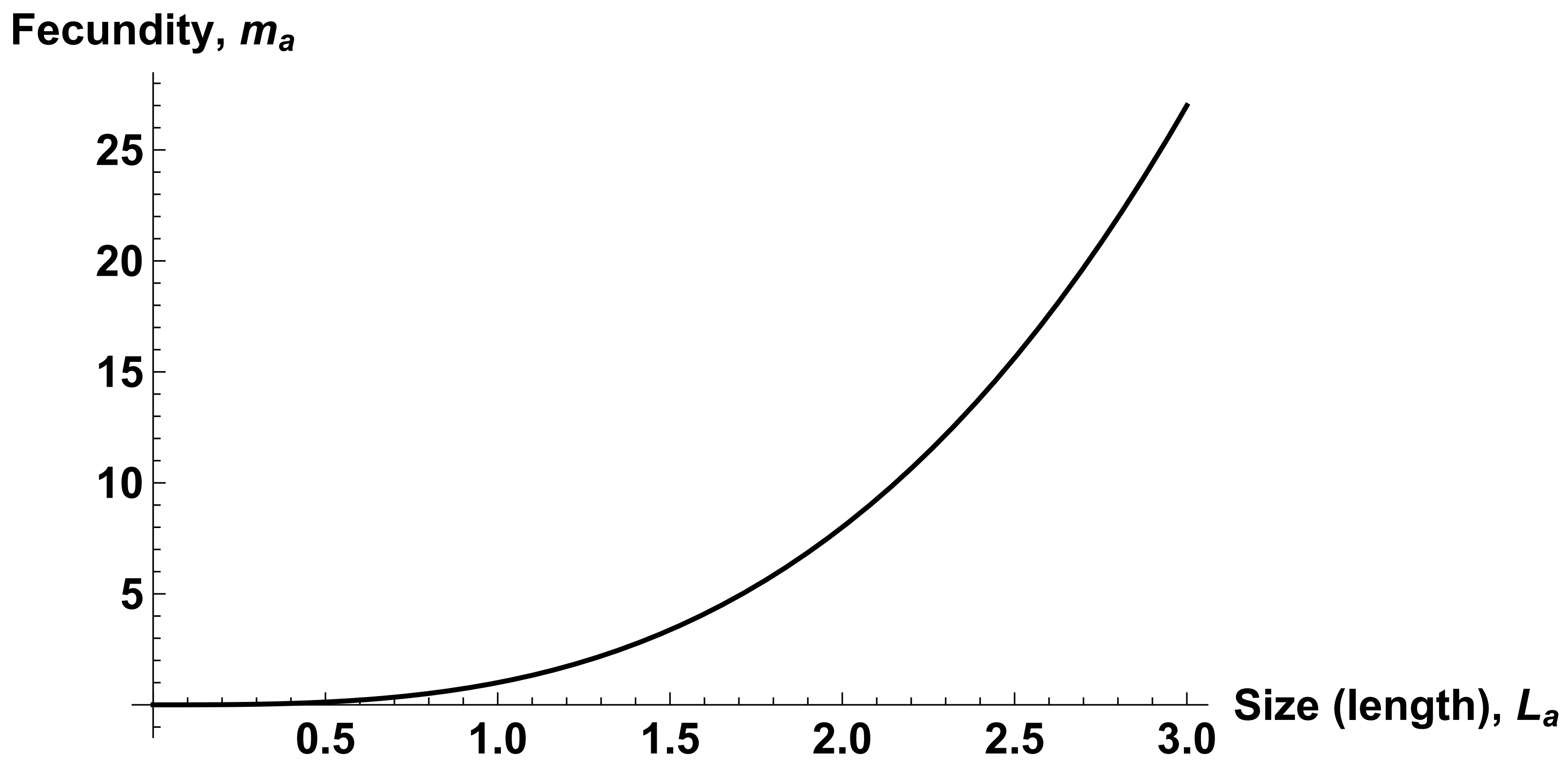

Von Bertalanffy growth equations

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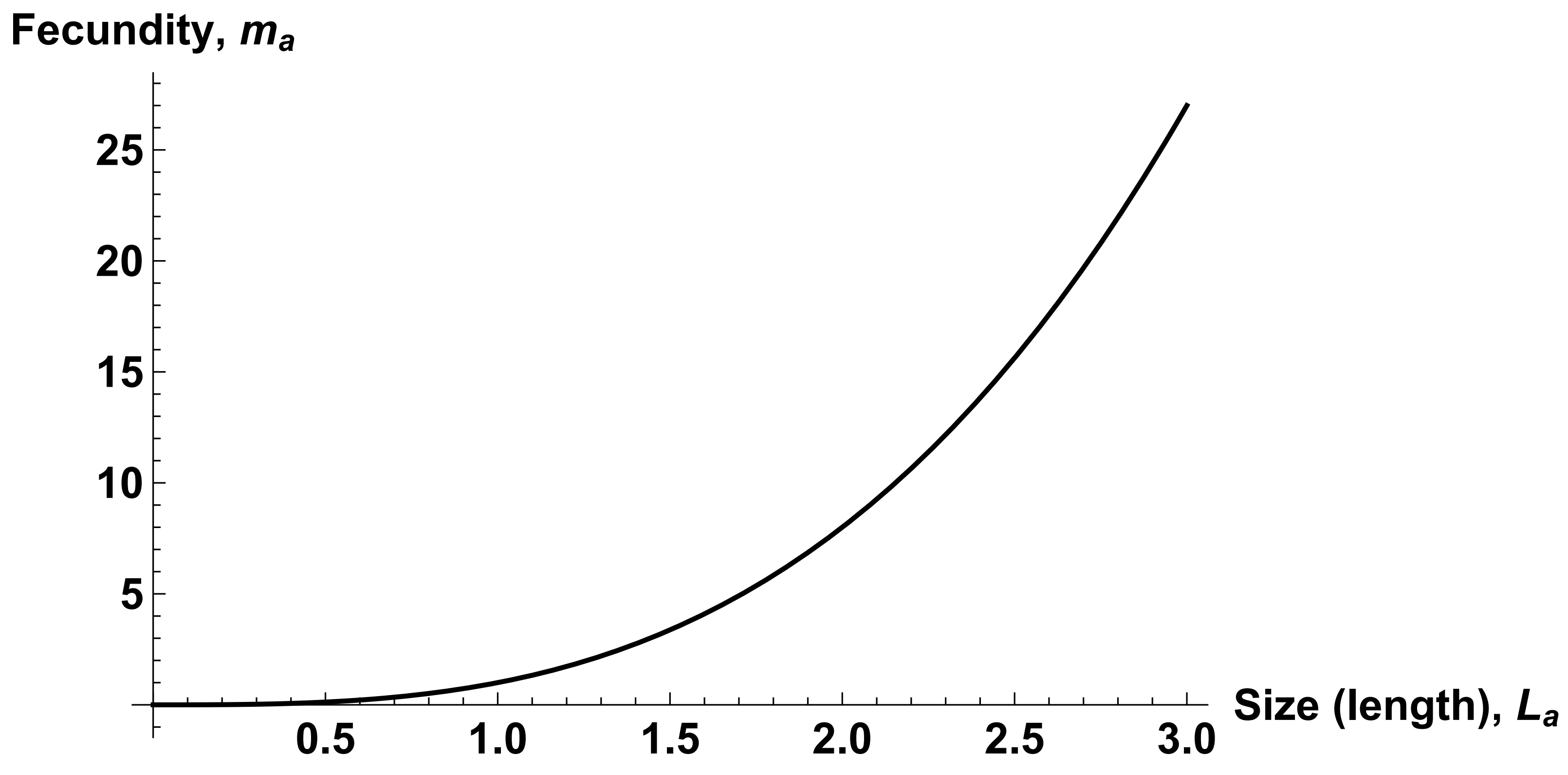

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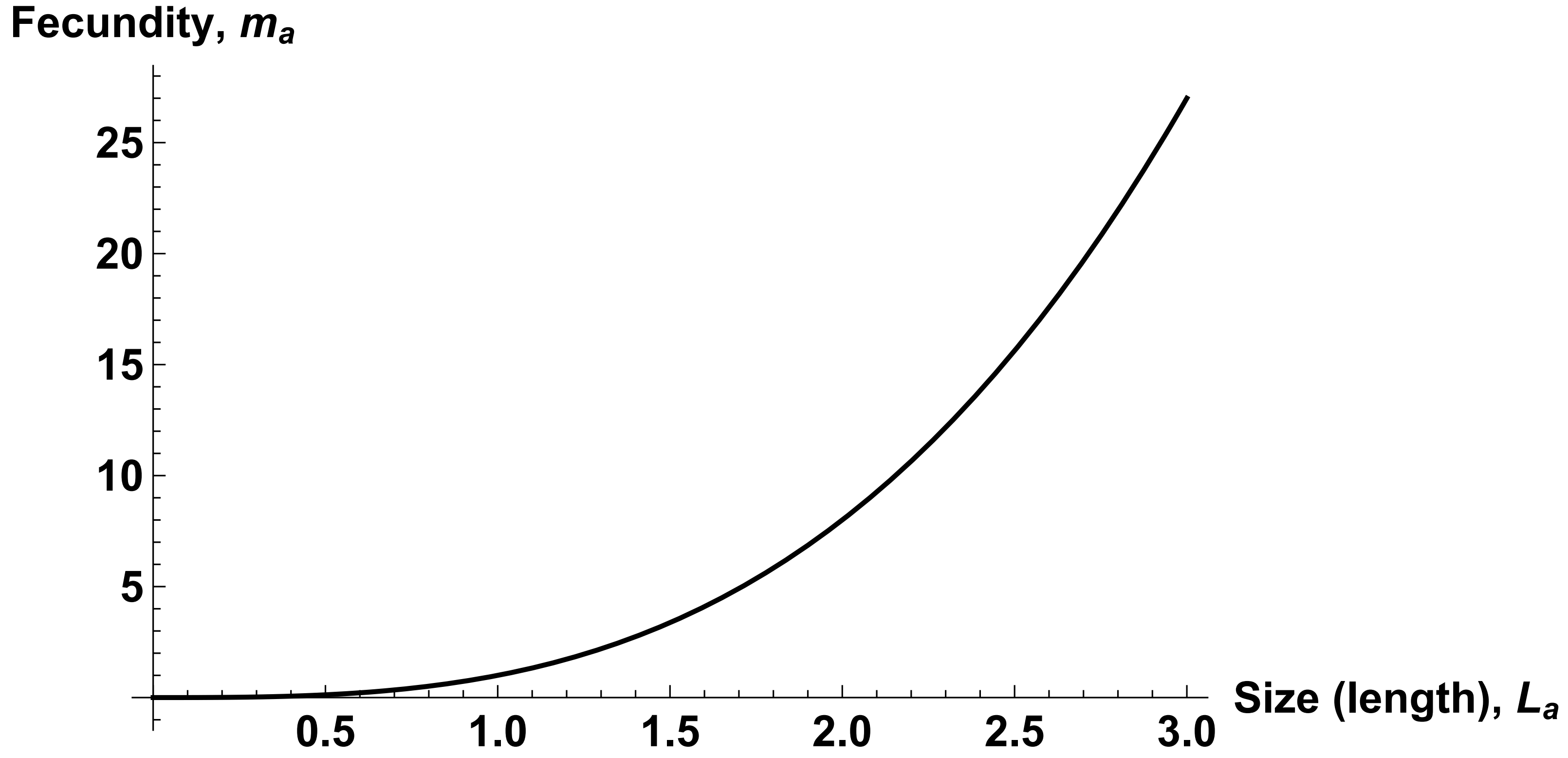

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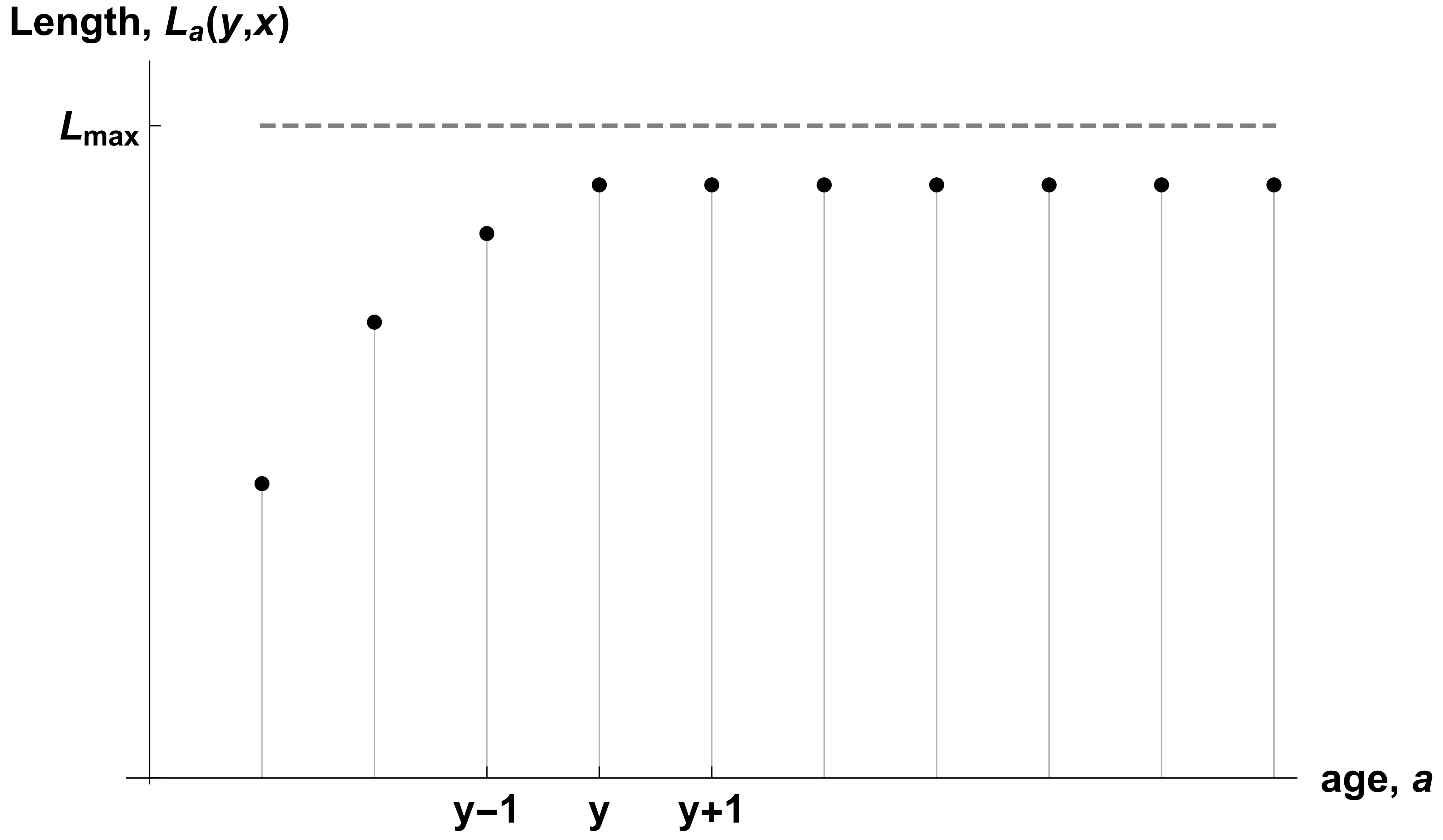

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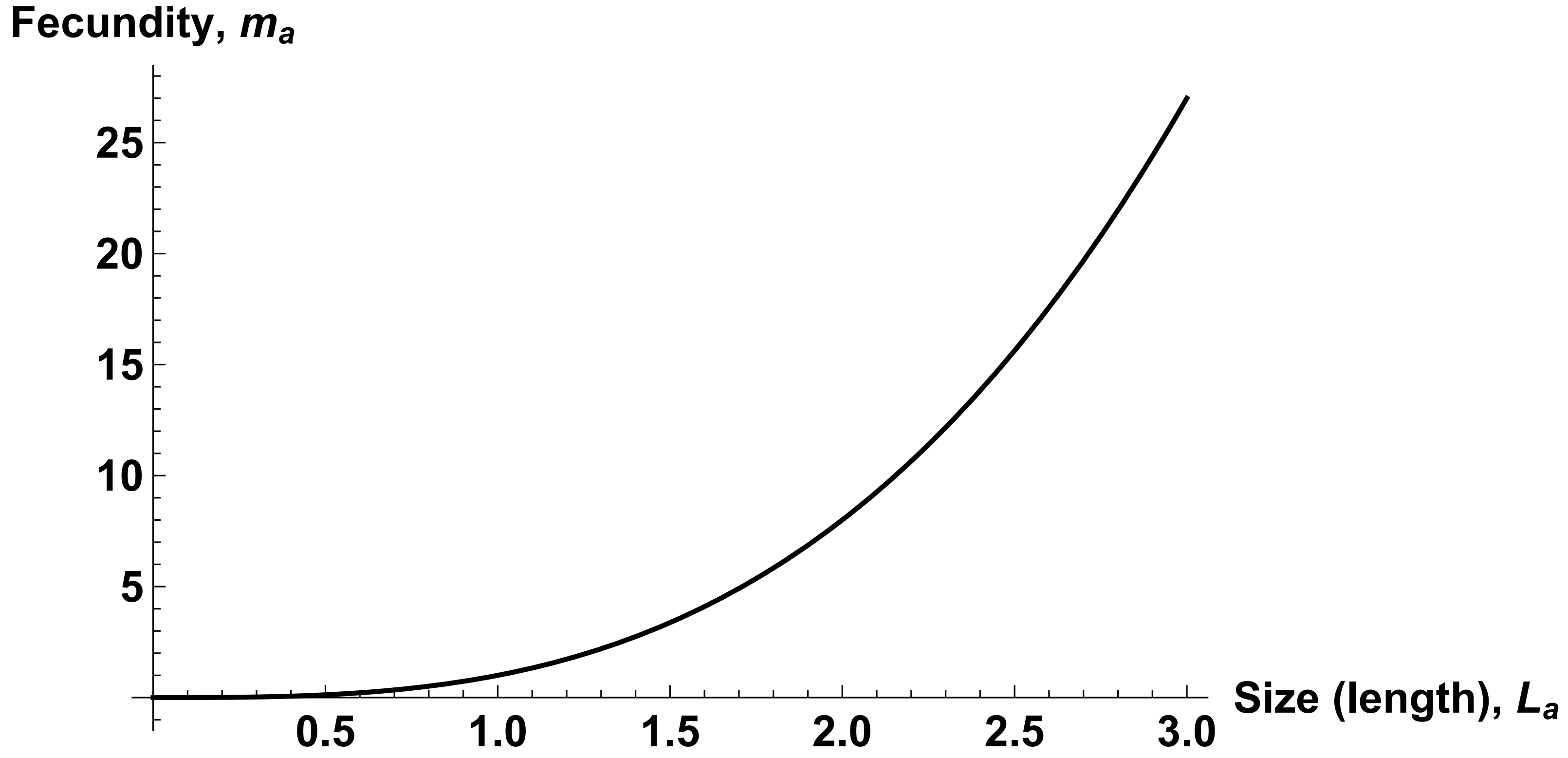

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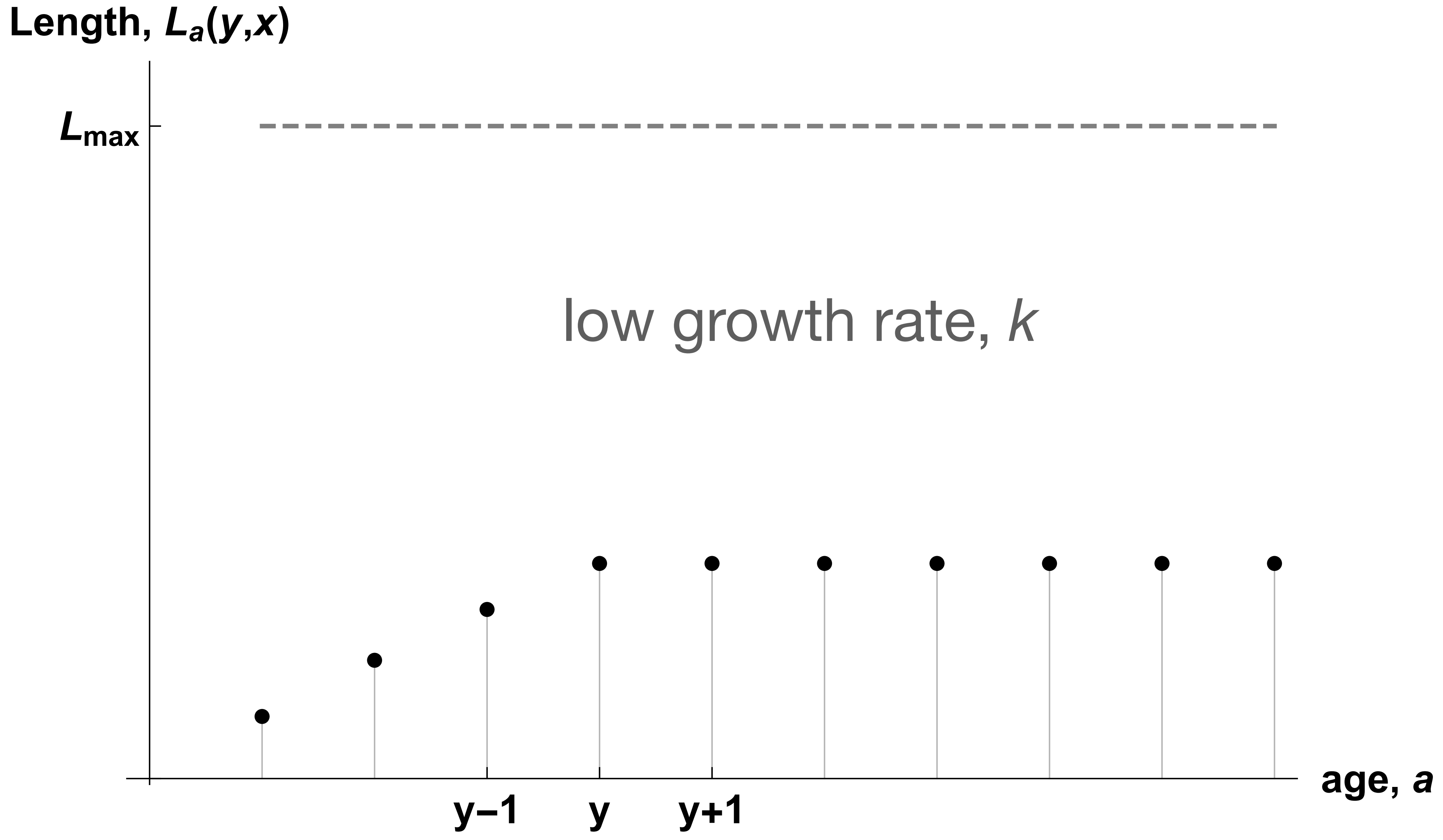

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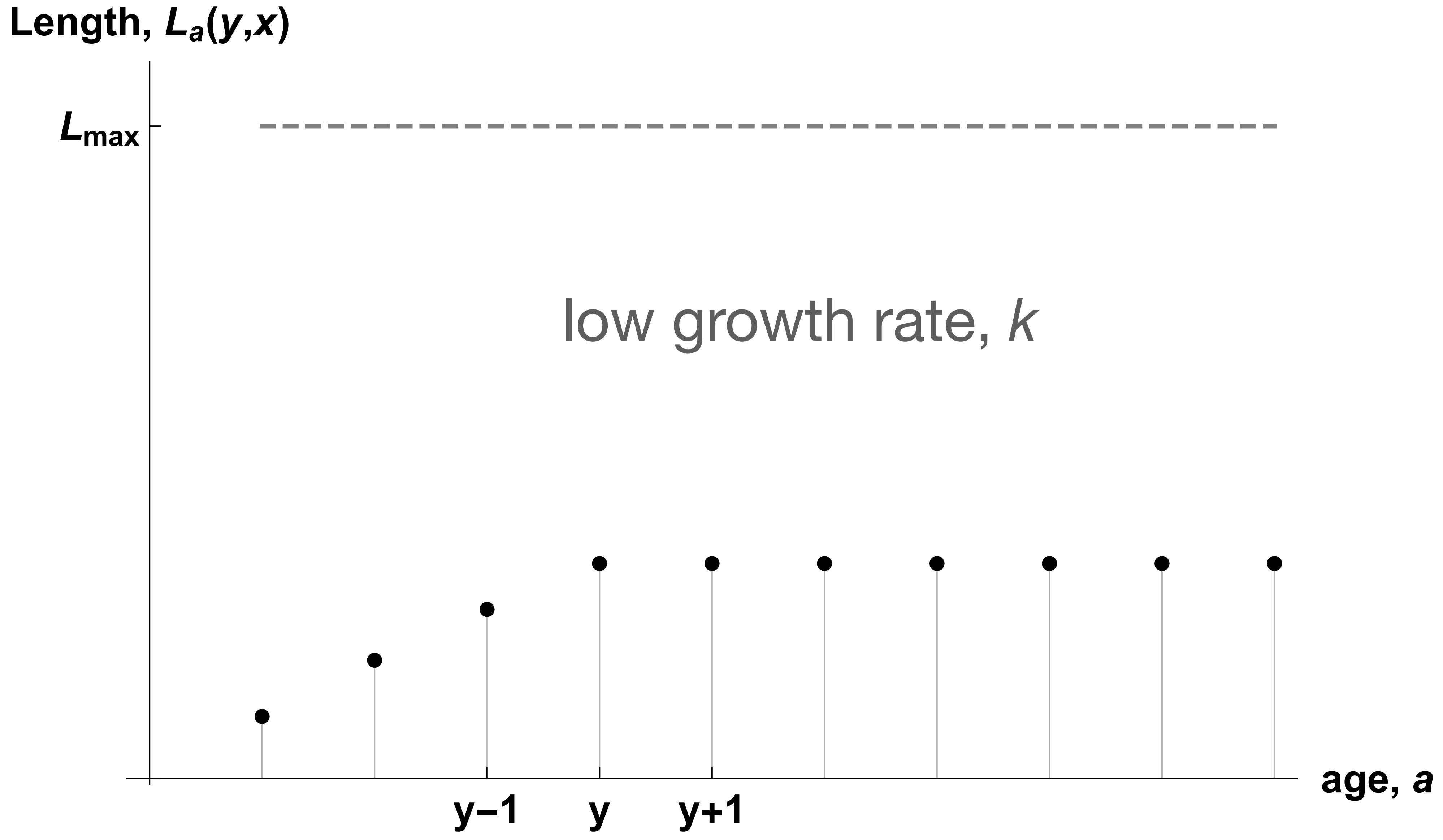

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- Differential survival among immature juveniles and mature adults:

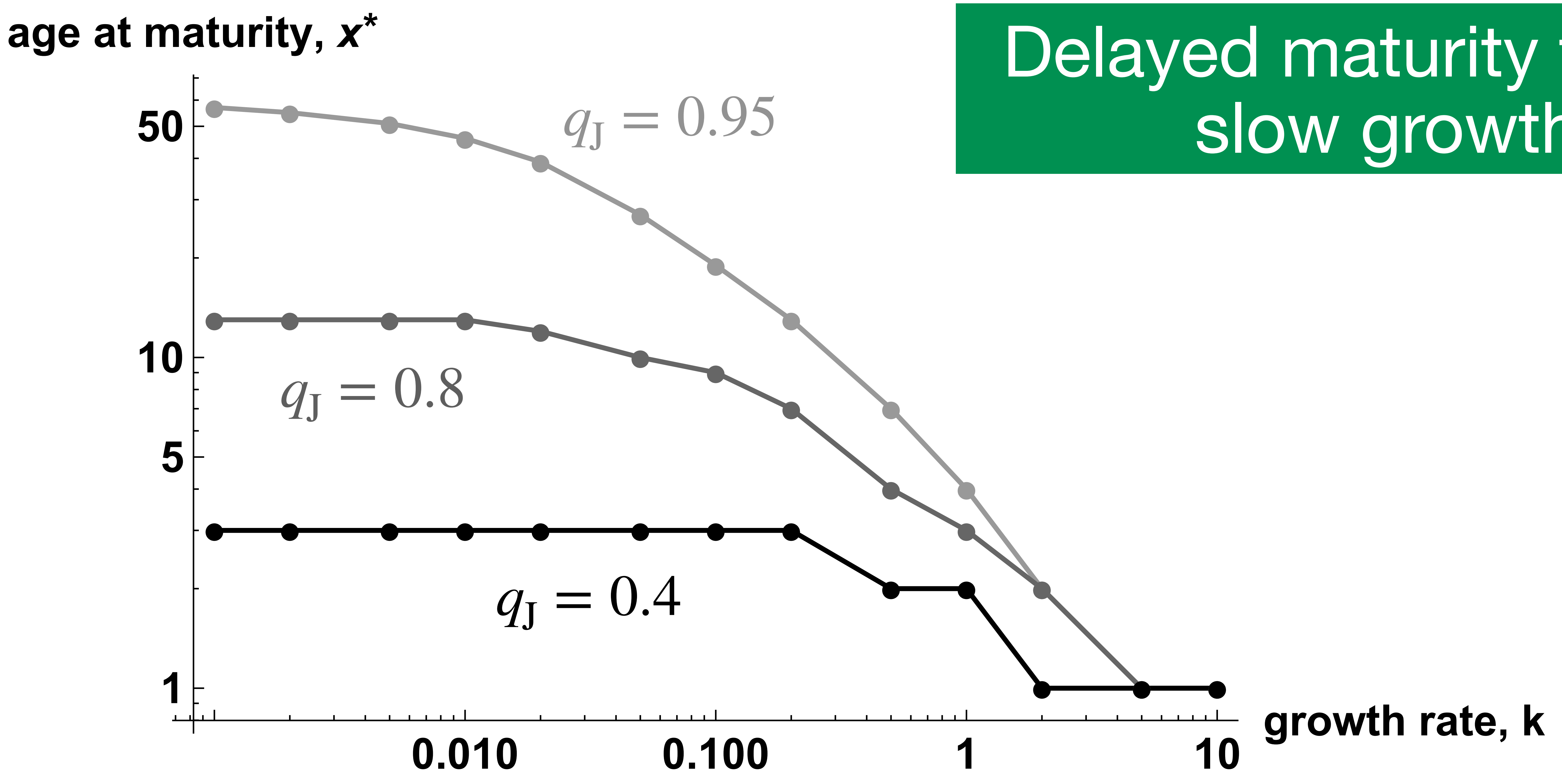
$$p_a(y,x) = \begin{cases} q_{\mathrm{J}}, & 1 \le a < y \\ q_{\mathrm{M}}, & y \le a \end{cases}$$

$$L_a(y) = \begin{cases} L_{\max}(1 - e^{-ka}), & 1 \le a < y \\ L_{\max}(1 - e^{-ky}), & y \le a \end{cases}$$

$$R_0(y,x) = \sum_{a=y}^{\infty} K(x) q_{\mathrm{J}}^{y-1} q_{\mathrm{M}}^{a-y} \times cL_a(y)^3$$

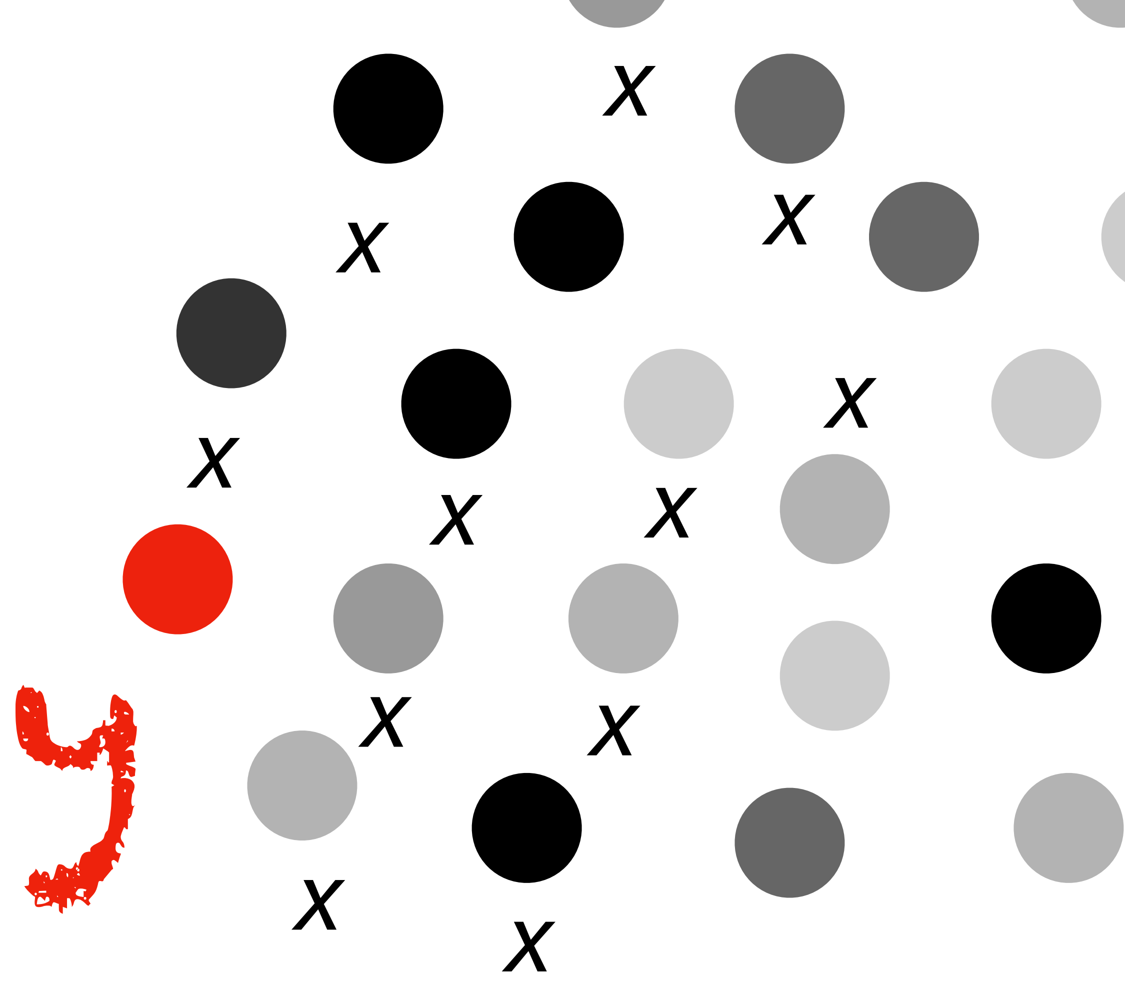
$$= q_{\mathrm{J}}^{y-x} \times \frac{\left(1 - e^{-ky}\right)^3}{\left(1 - e^{-kx}\right)^3}$$

Optimal age at maturity

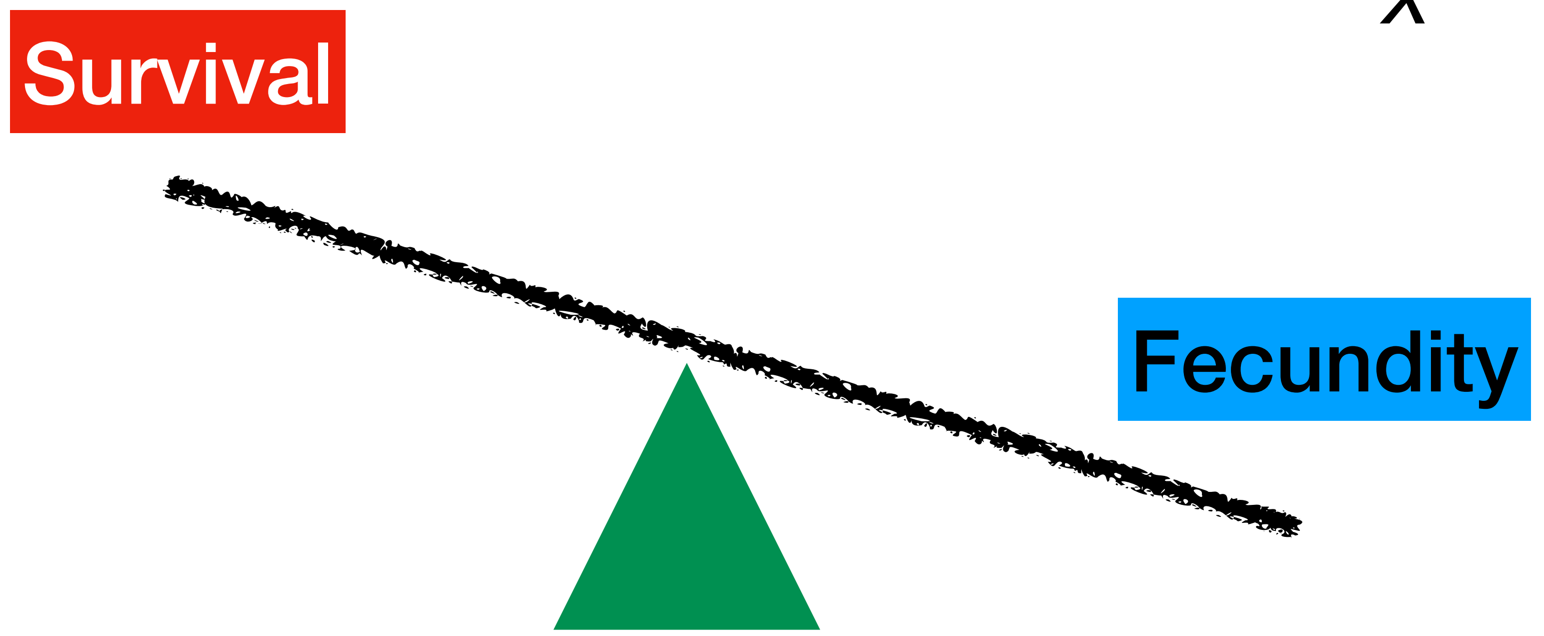


Delayed maturity favoured by slow growth rate.

Summary



- A rare mutant y invades a x population at demographic equilibrium when mutant reproductive success $R_0(y, x) > 1$.



- Evolution of life history traits determined by **trade-offs** due to finite resources.
- Delayed maturity favoured by high survival till maturity and rapidly increasing fecundity.
- Fecundity is often mediated by size (rather than age) so that delayed maturity favoured by slow growth.