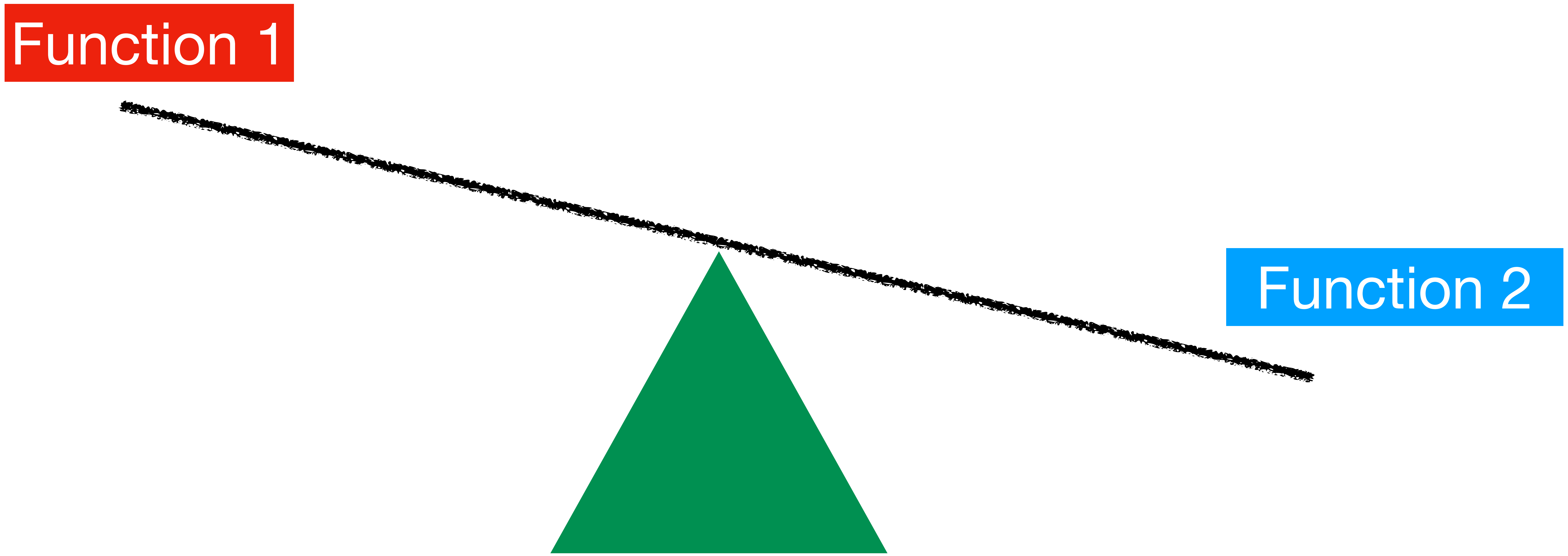
Life-history evolution

Trade offs

due to finite resources



Example

Fecundity *vs.* offspring survival

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- Individuals live one year and reproduce once.

- Females have access to same amount of resources. They invest share x into fecundity and 1-x into parental care that improves survival from age 0 to 1.

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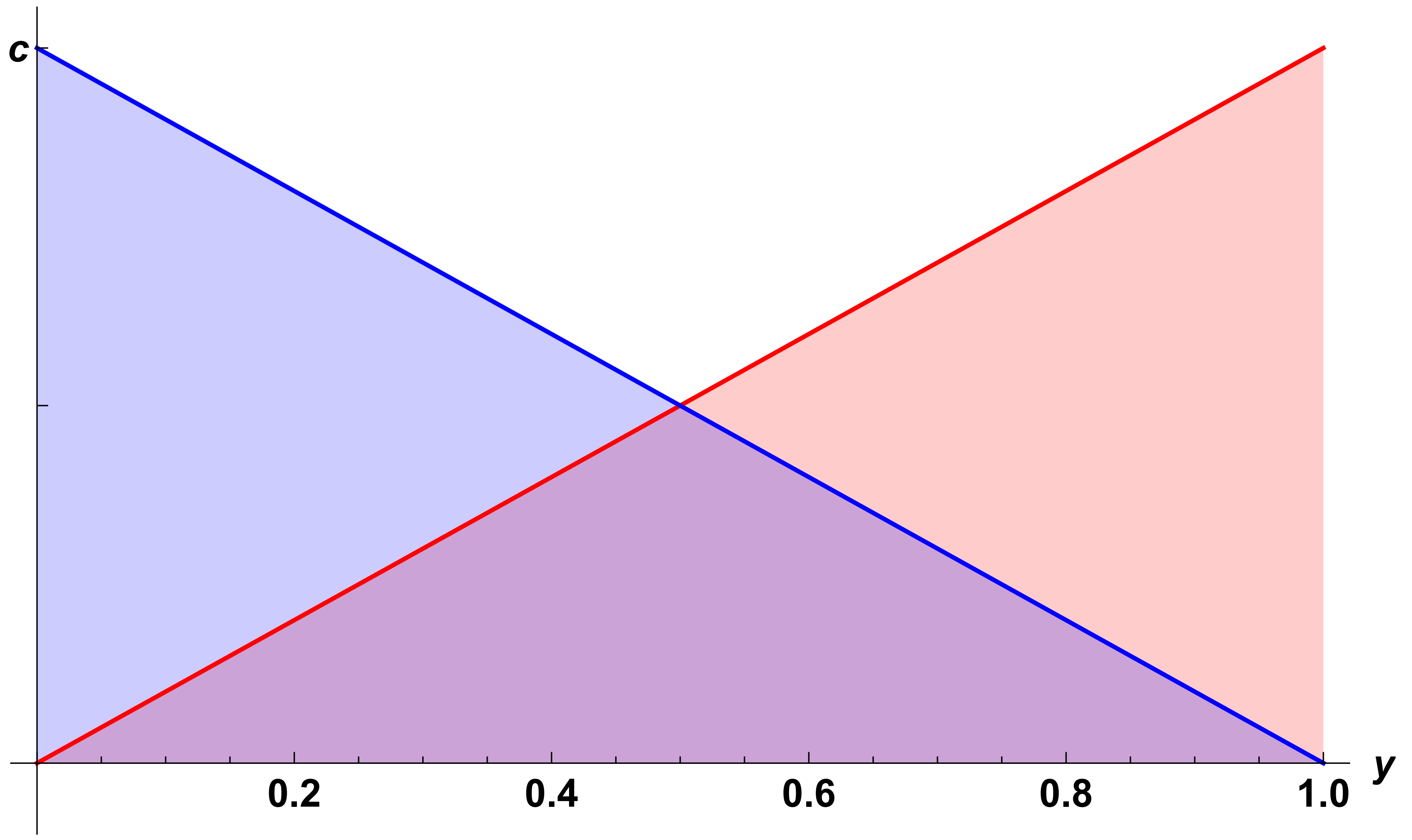
$$m_1(y, x) = cy$$

- Offspring survival from age 0 to 1:

$$p_0(y, x) = (1 - y)K(x)$$

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



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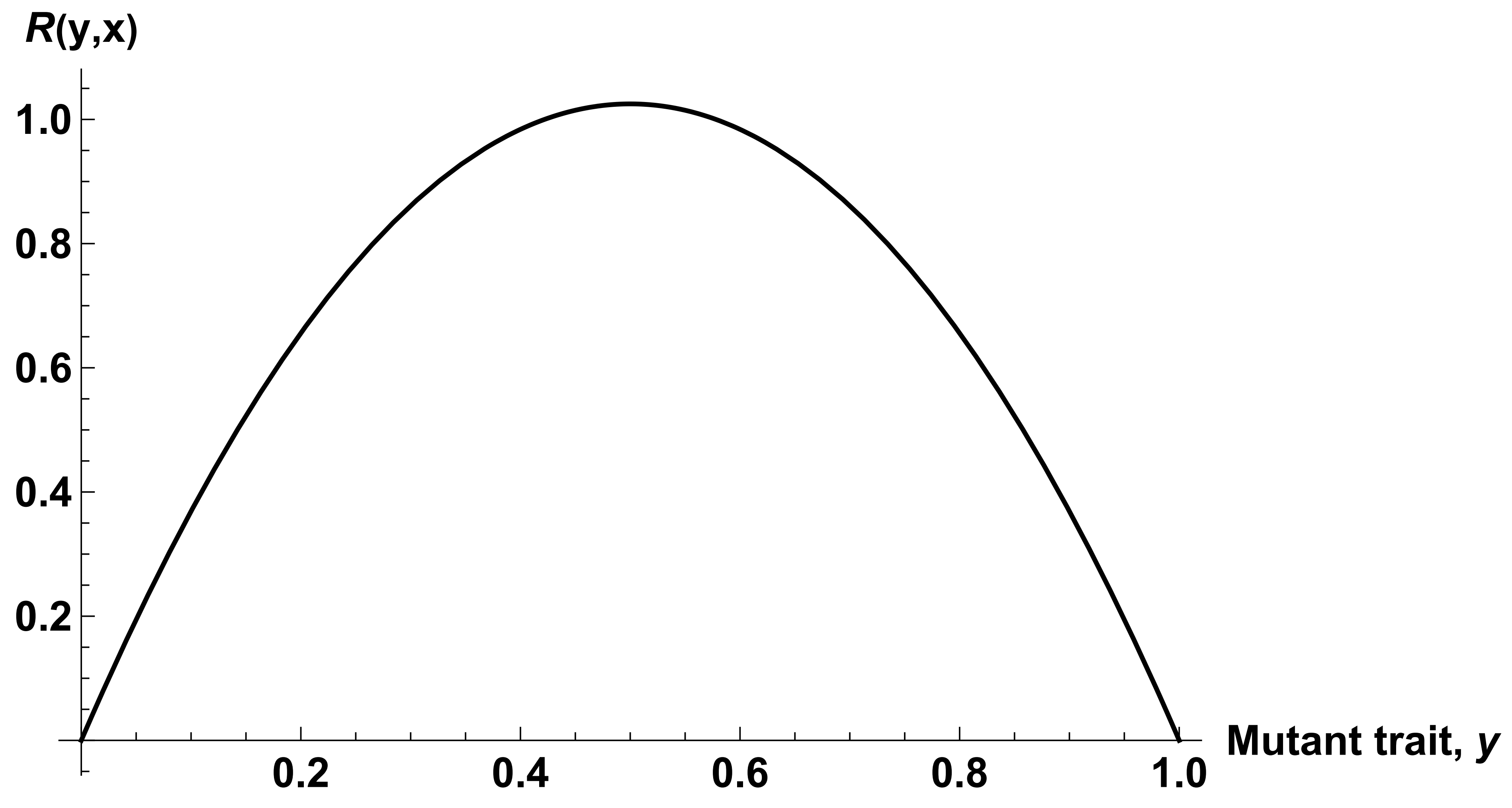

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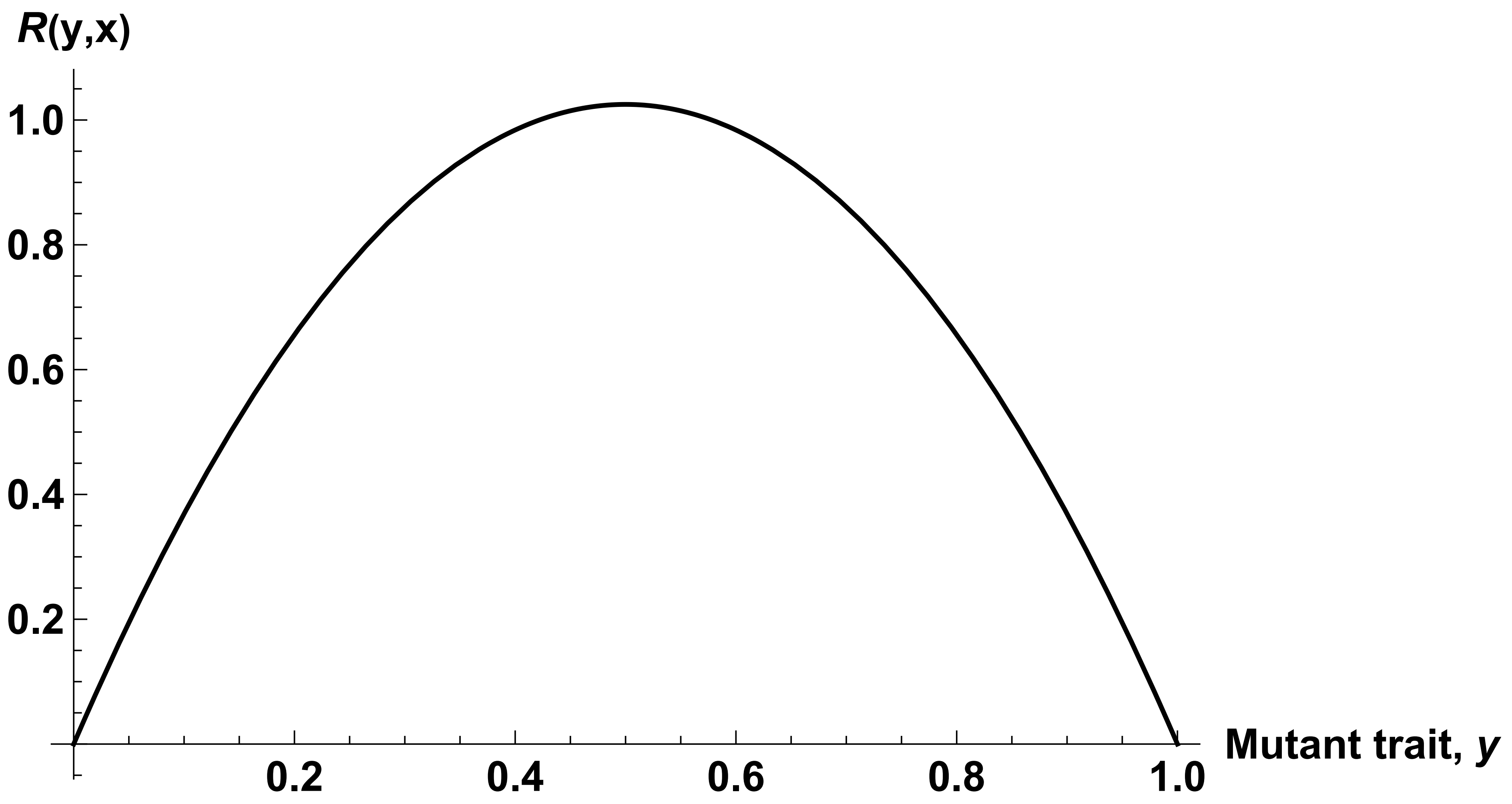
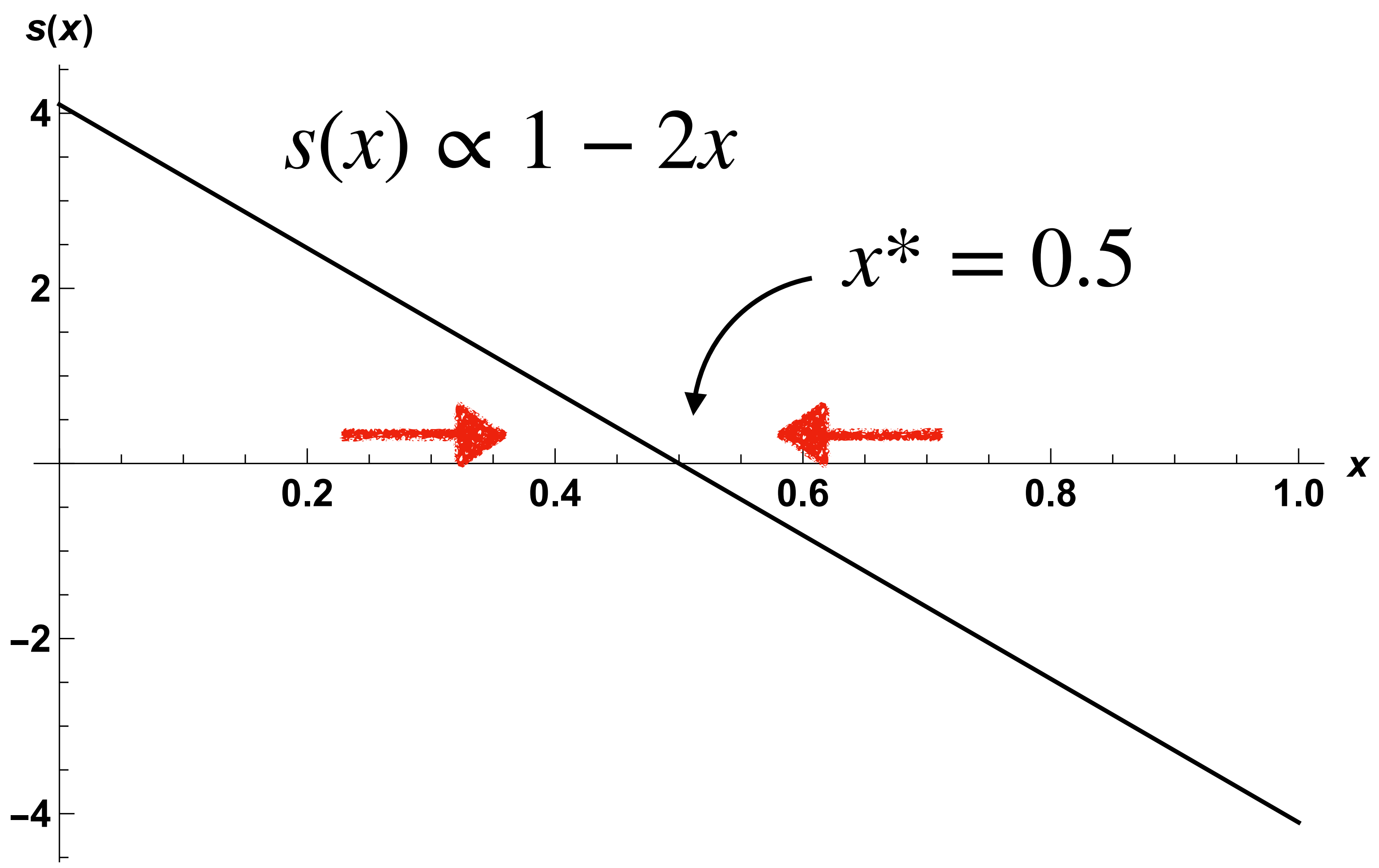




Iteroparity *vs.* semelparity

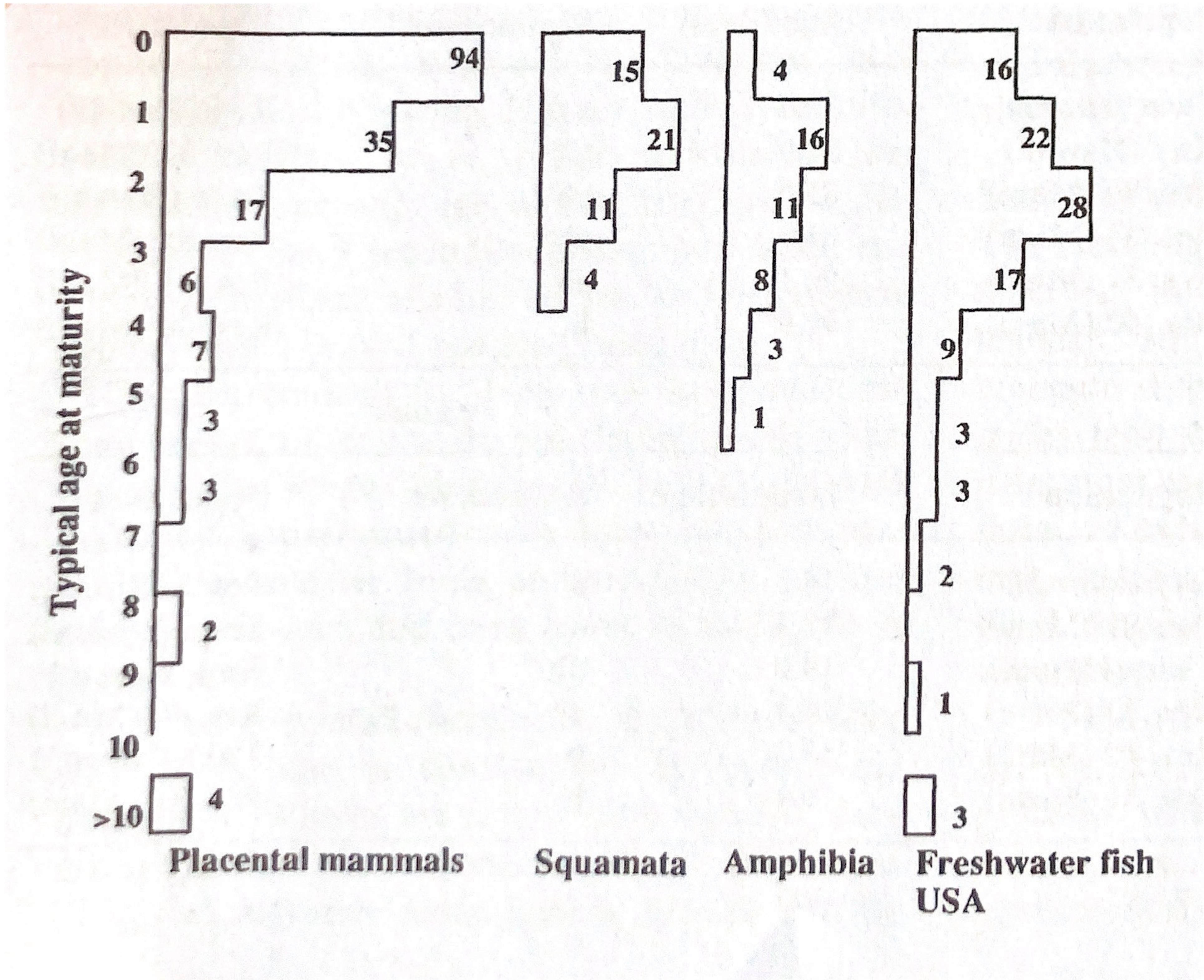
Exercise sheet - Trade off between adult survival and fecundity

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

- **Iteroparity**: Reproduce multiple times

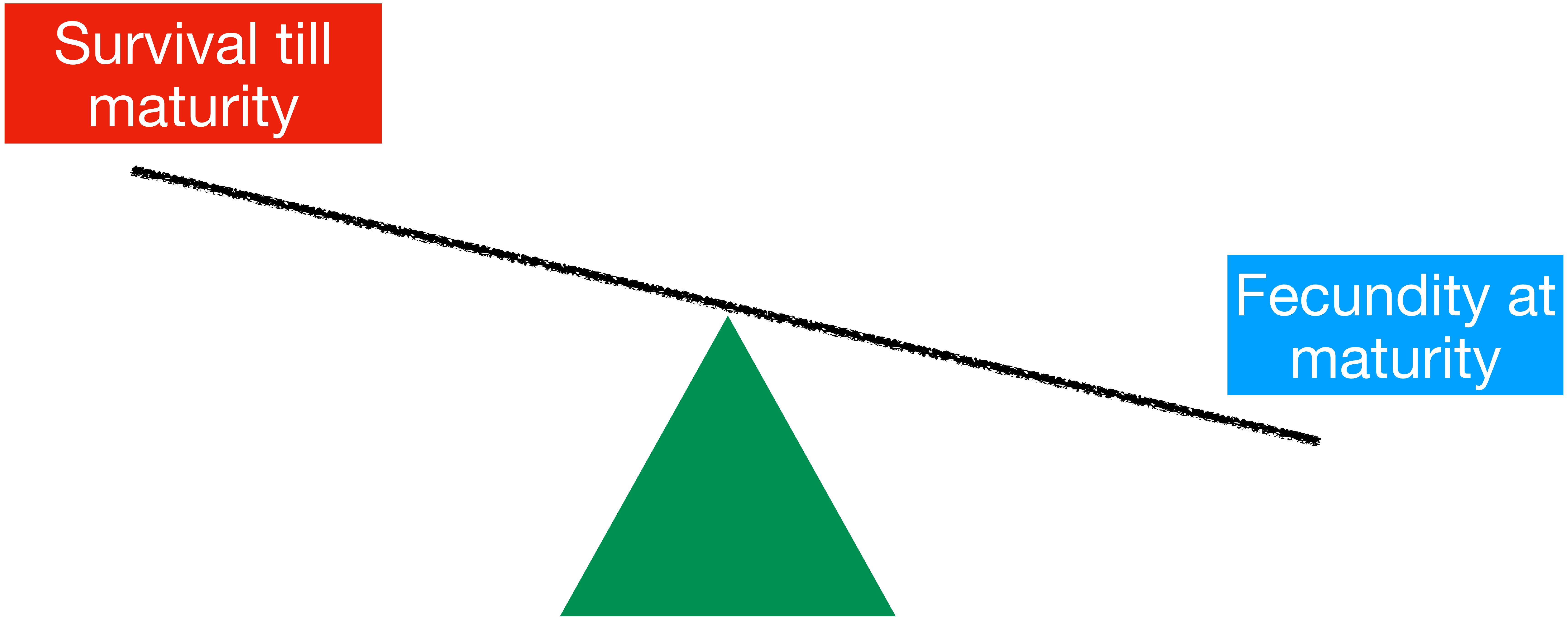
Age at maturity

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



Bell (1980) Am Nat
Stearns (1992)

Age at maturity



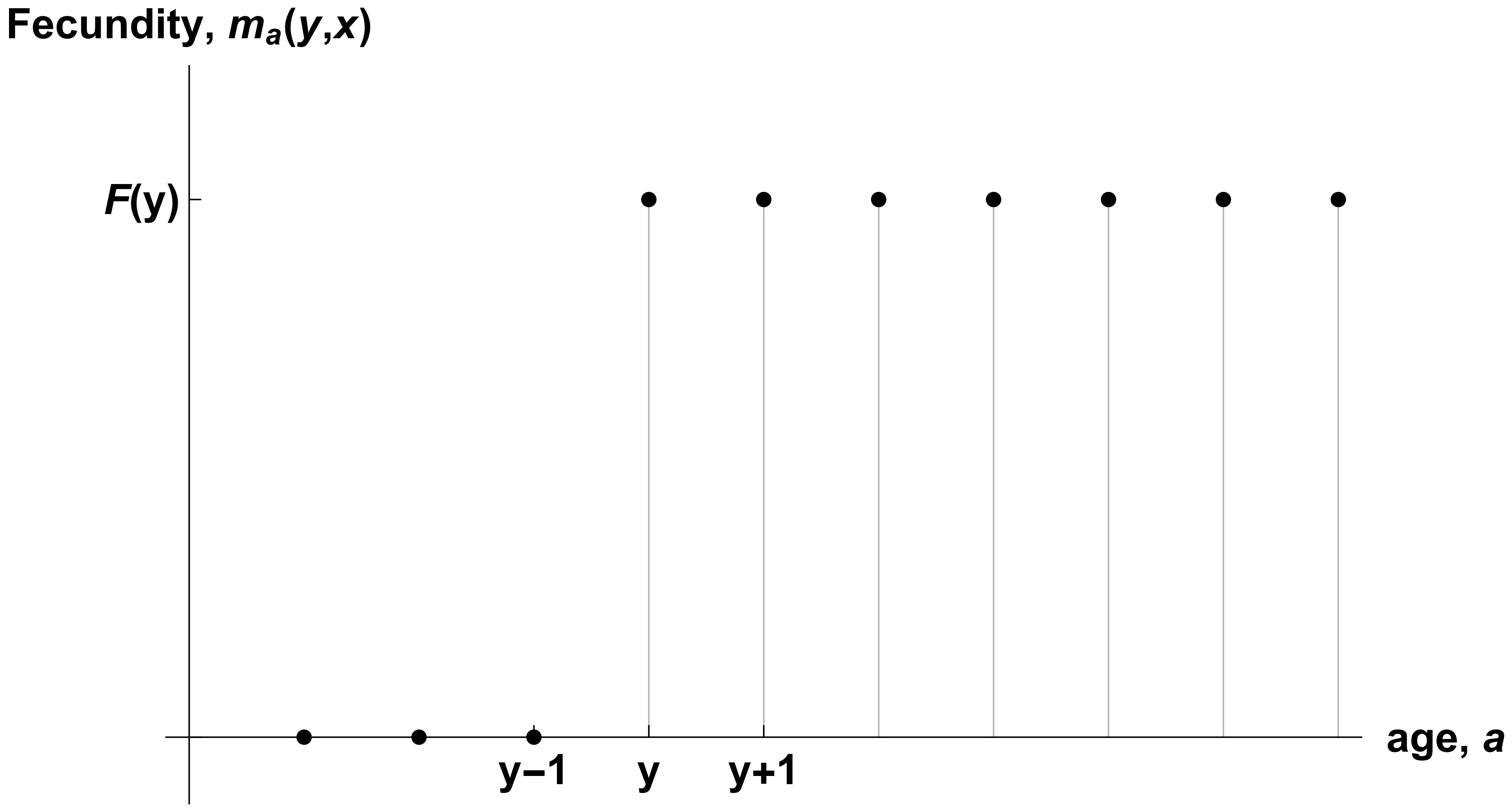
Age at maturity

A model

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

$$m_a(y,x) = \begin{cases} 0, & 1 \leq a < y \\ F(y), & y \leq a \end{cases}$$

where fecundity increases with age at maturity, $F(y)$.



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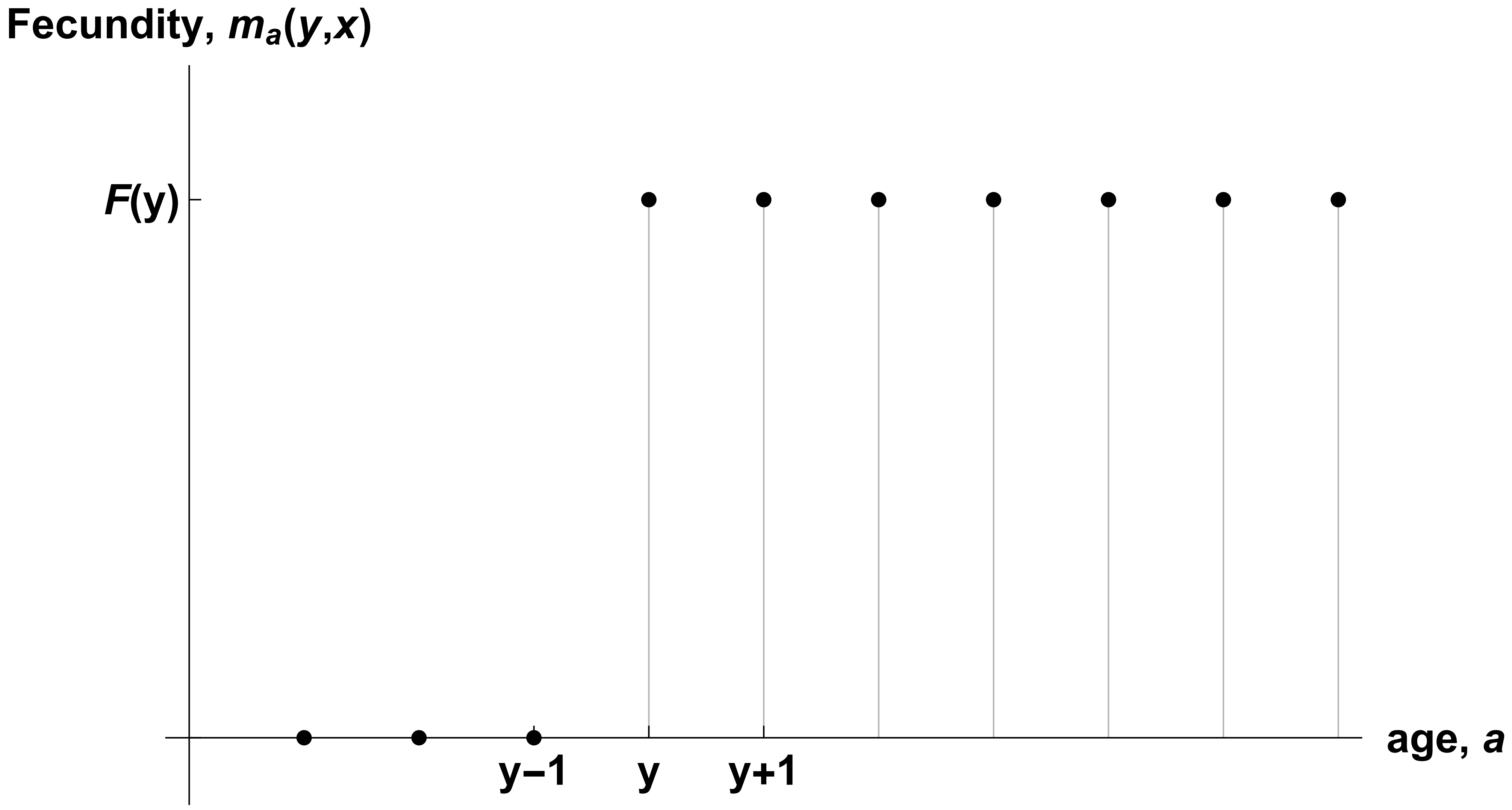

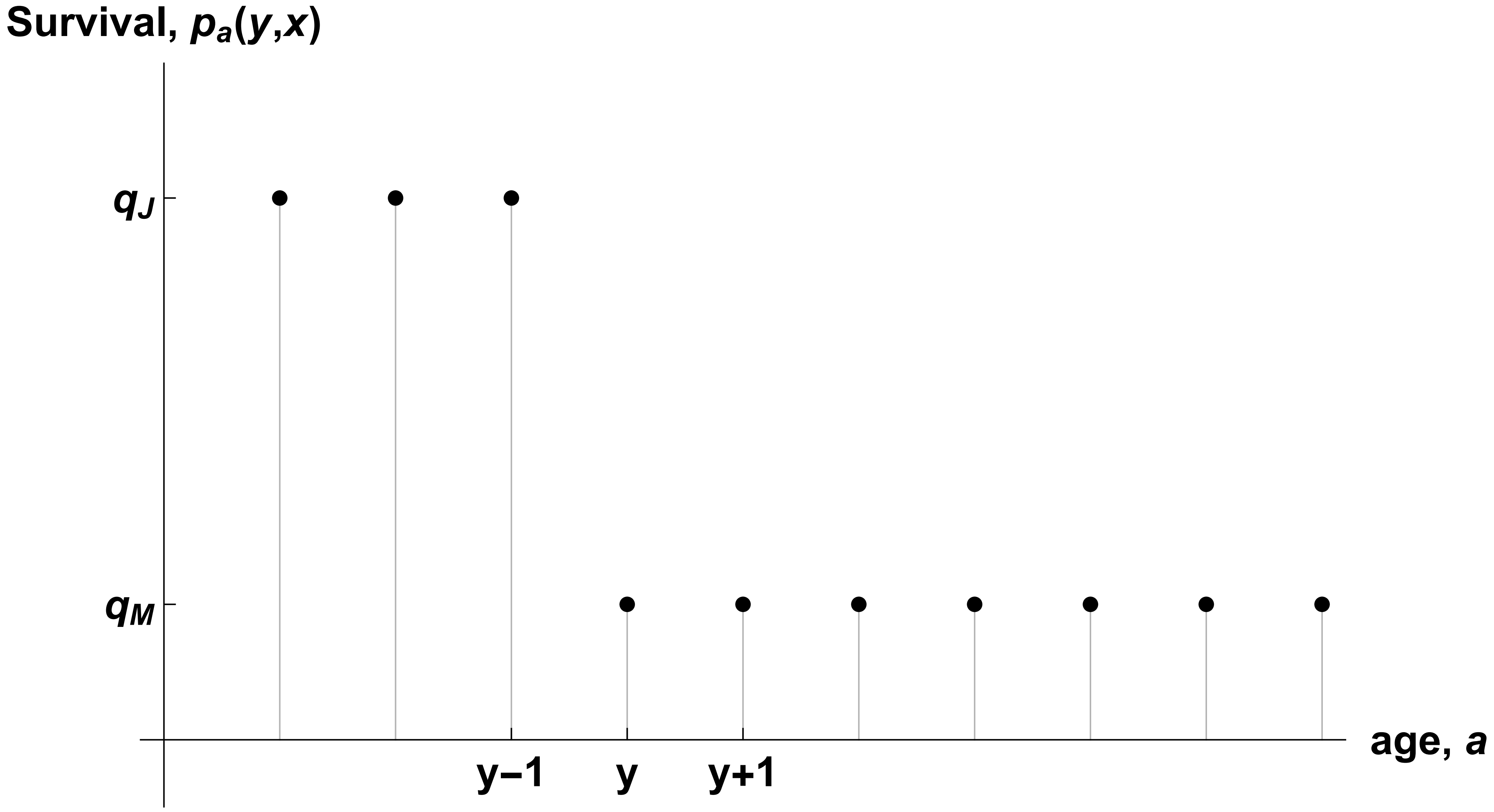

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such that
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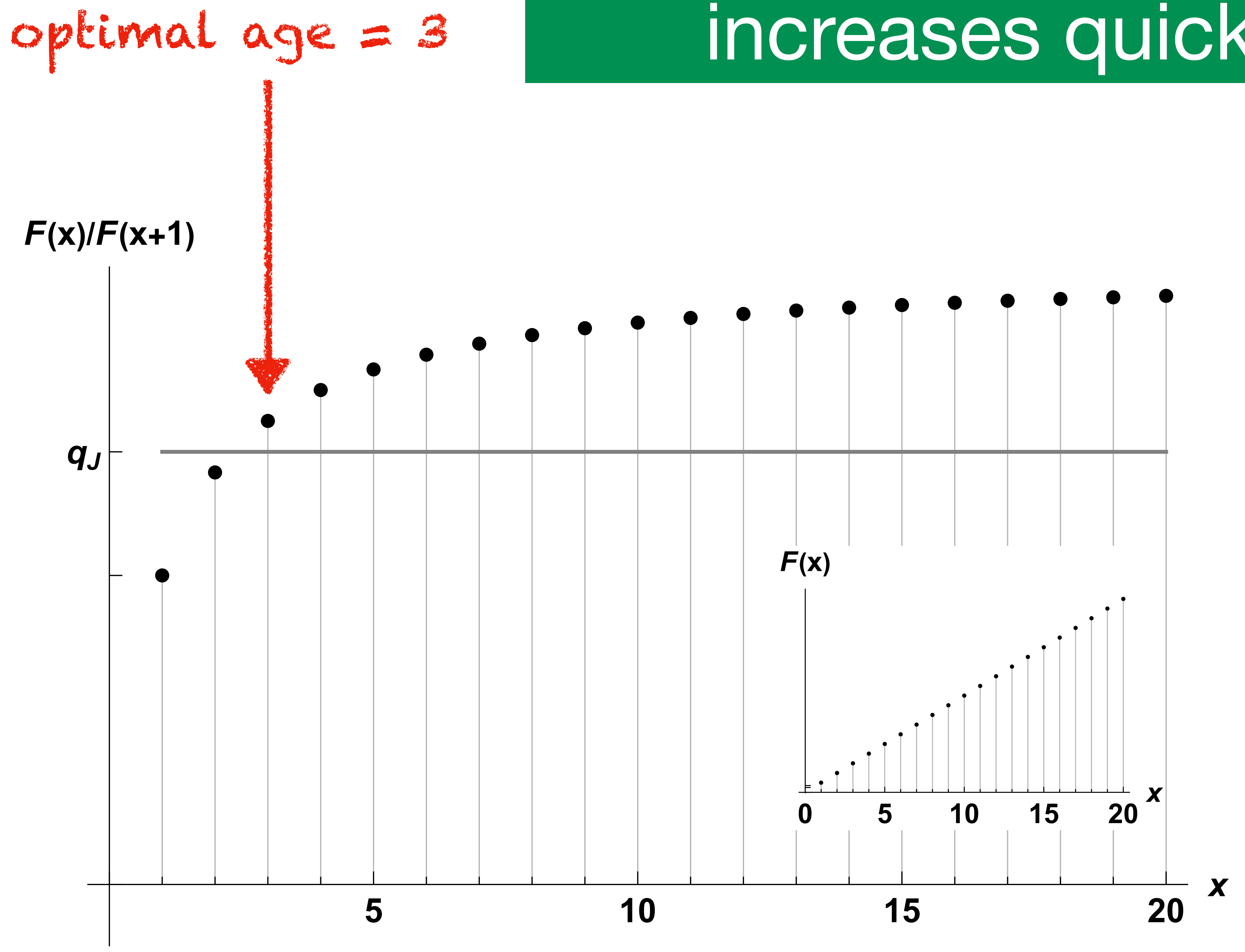

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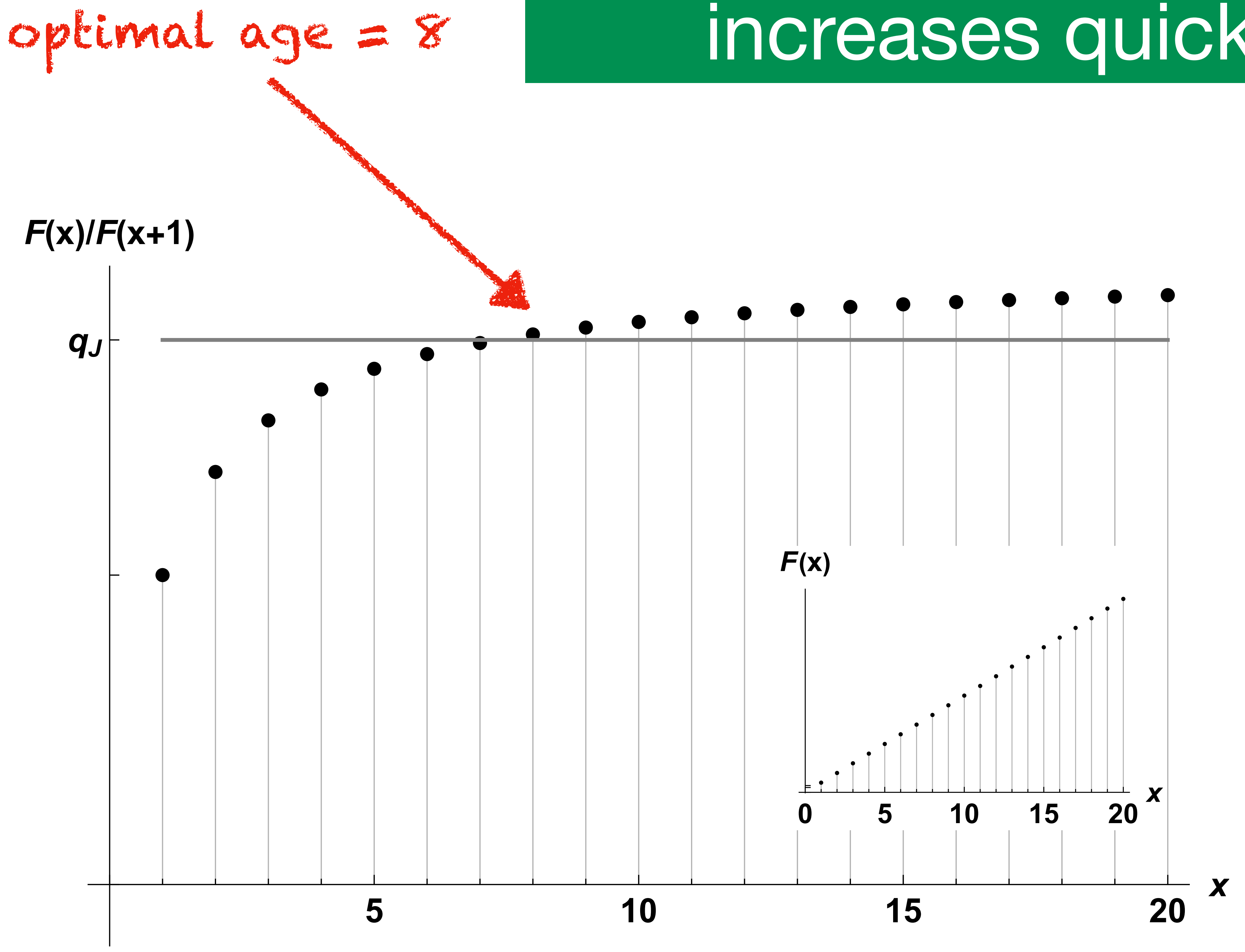

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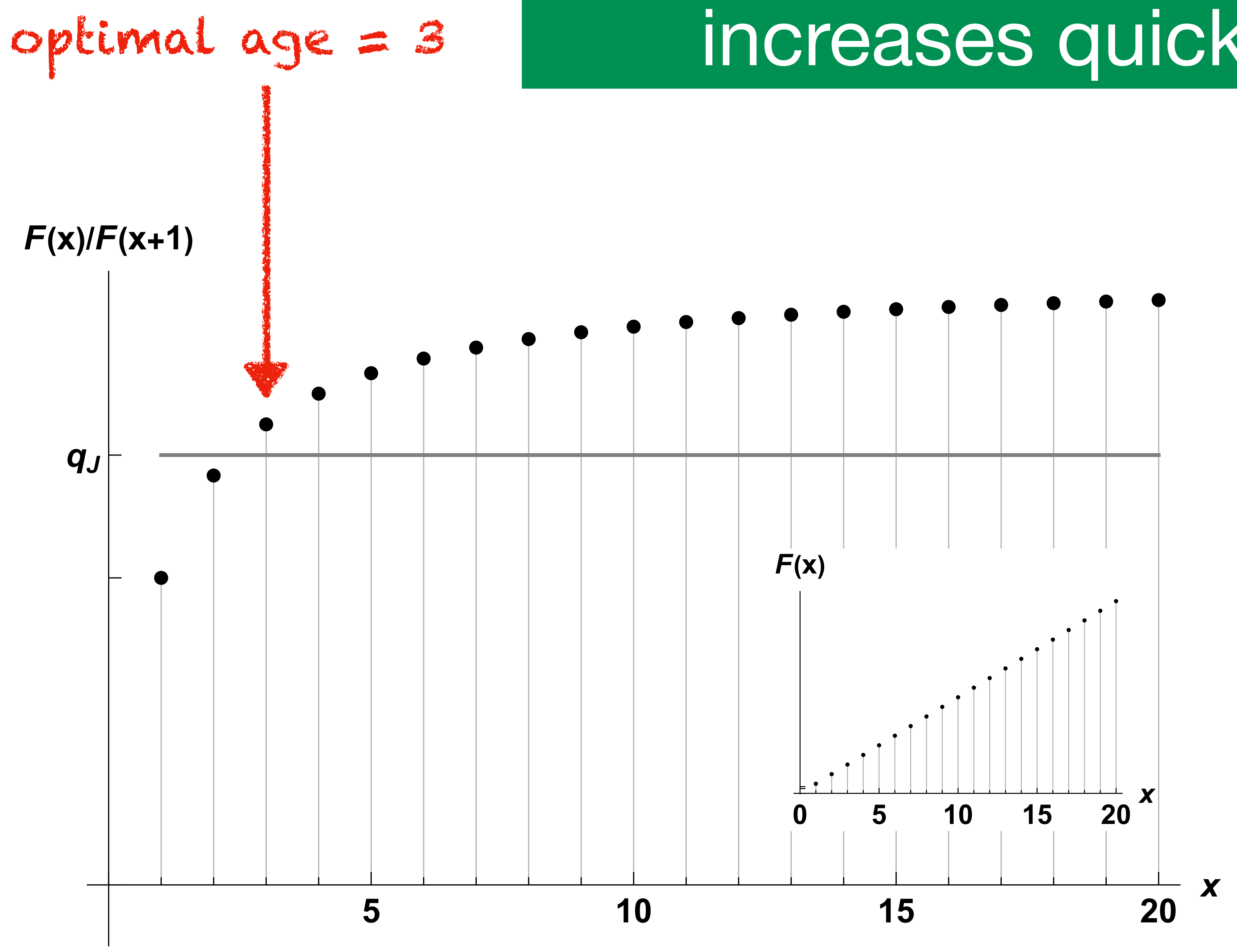

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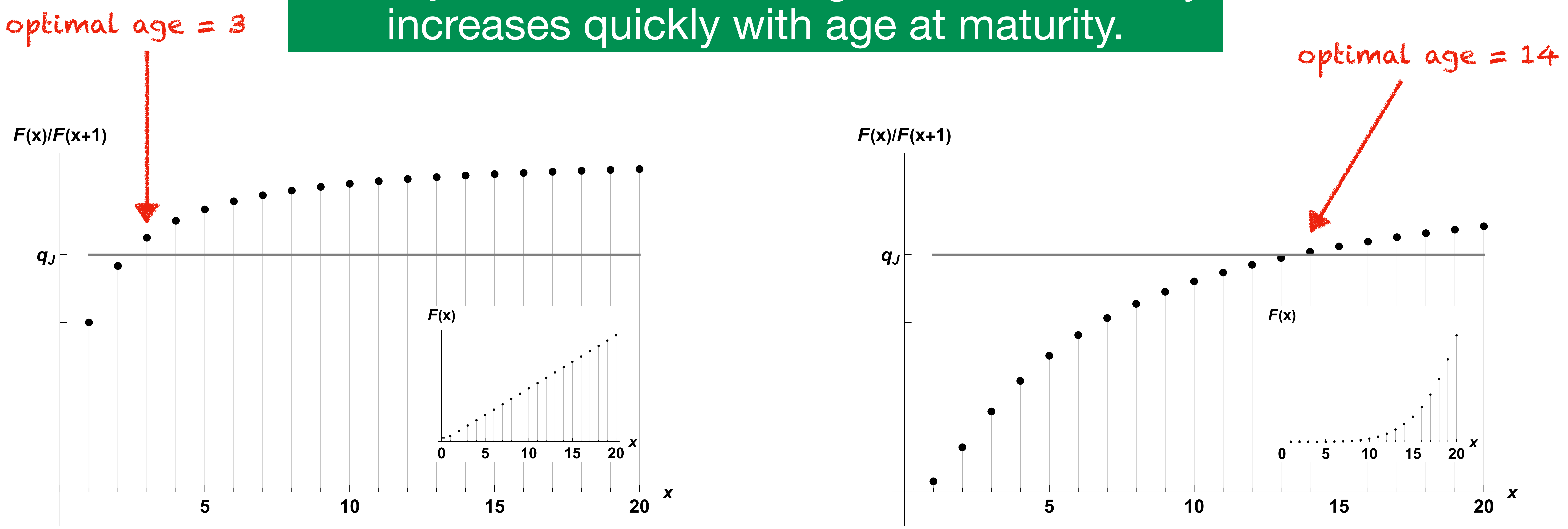
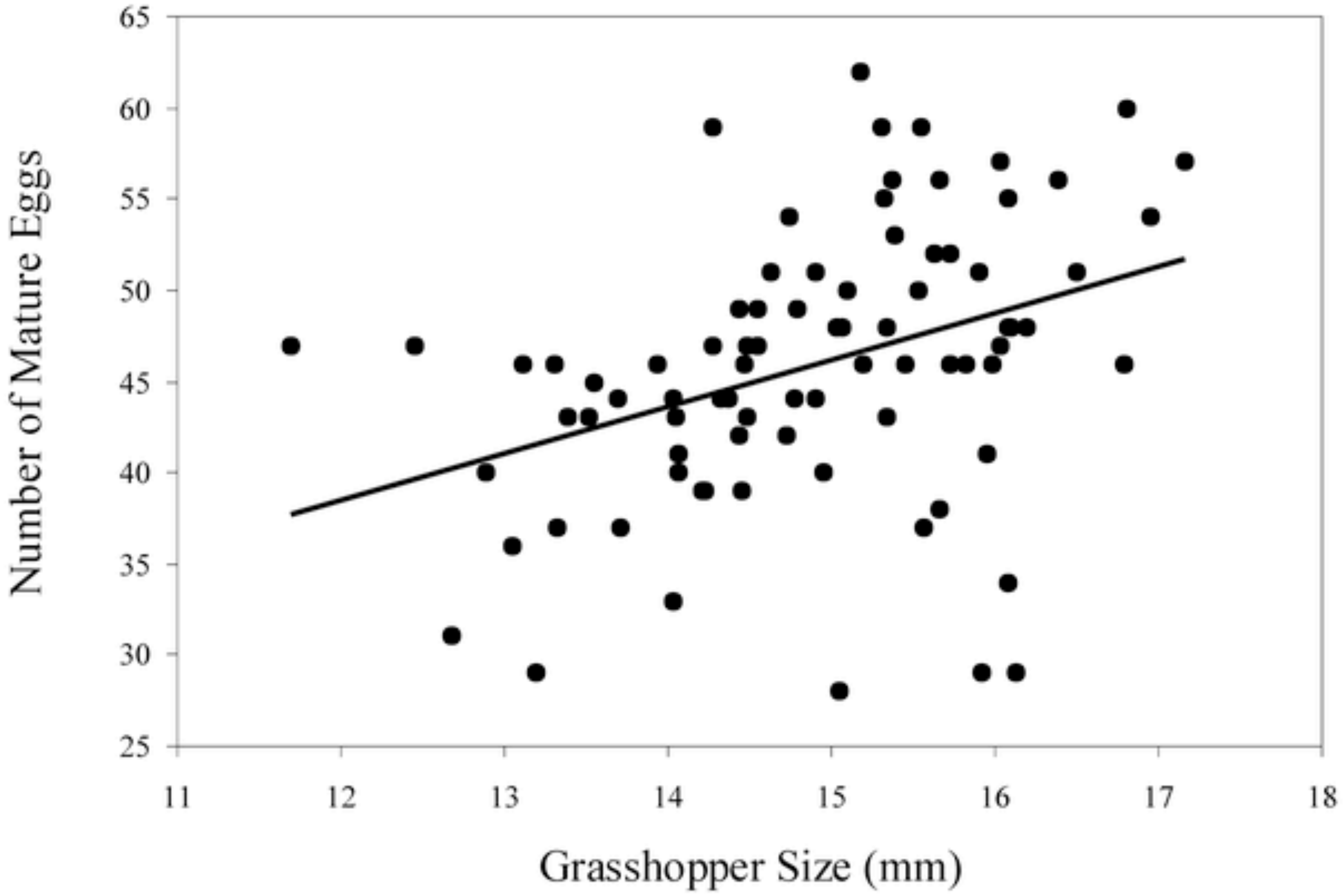


Effect of size at maturity

Fecundity associated with size in many species



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

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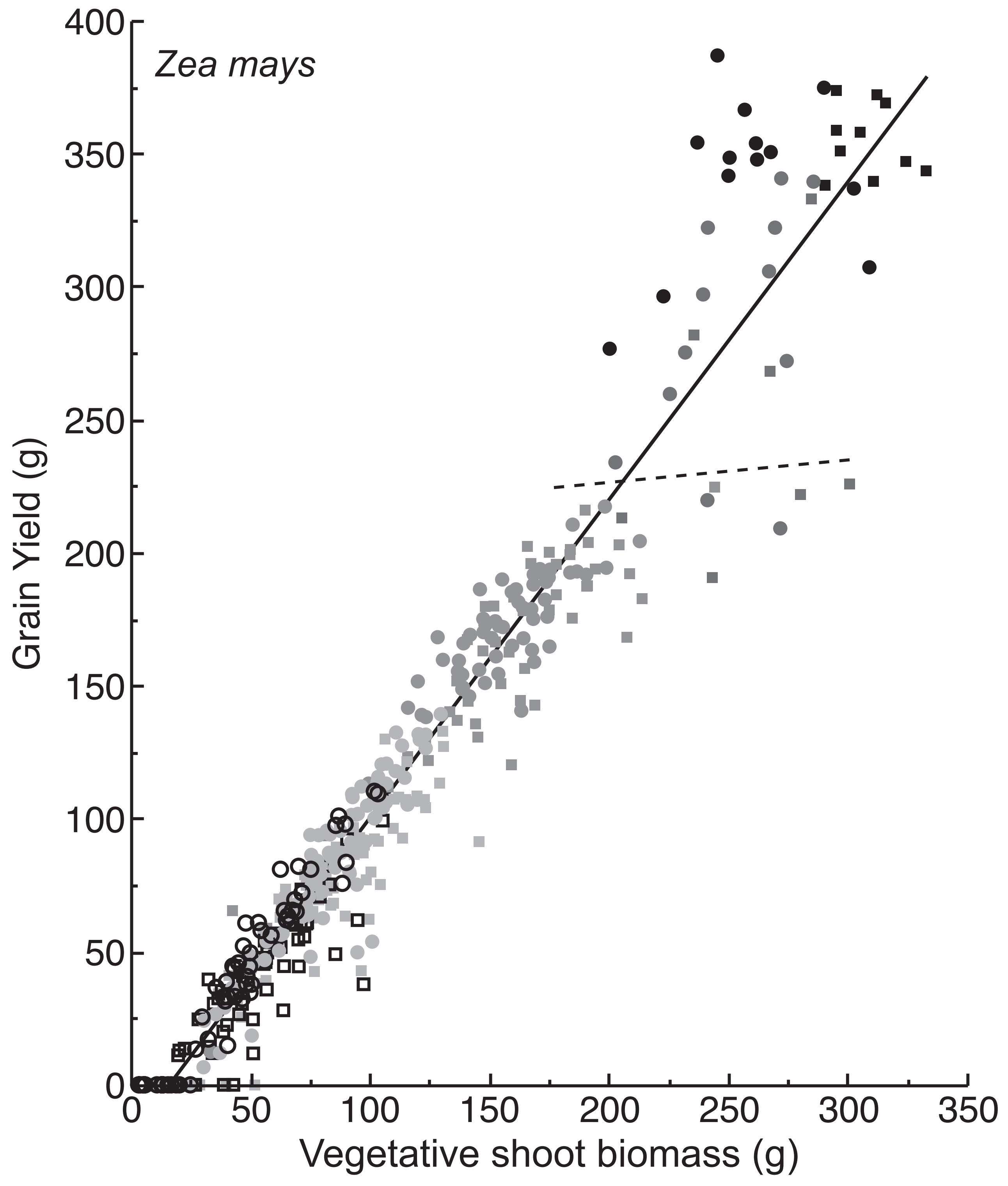
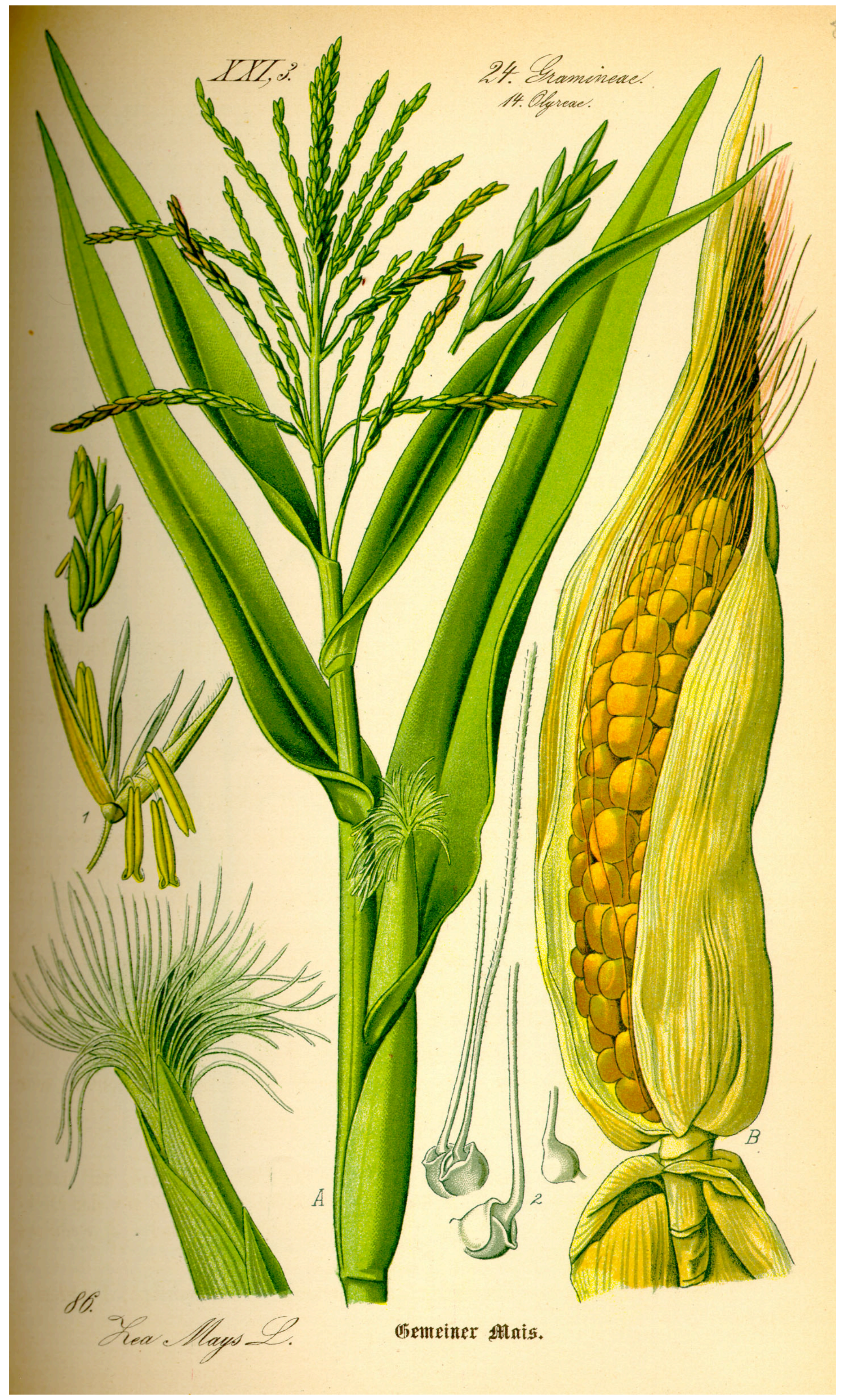
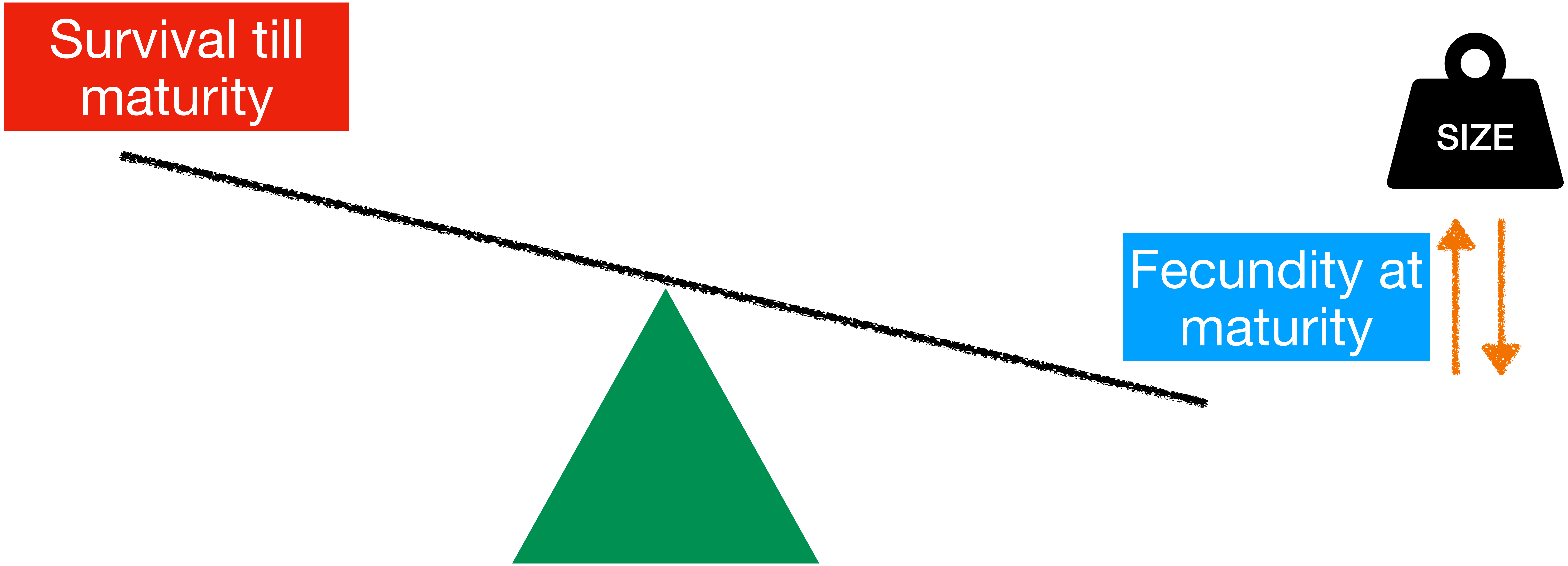


Weiner et al. Journal of Ecology 2009



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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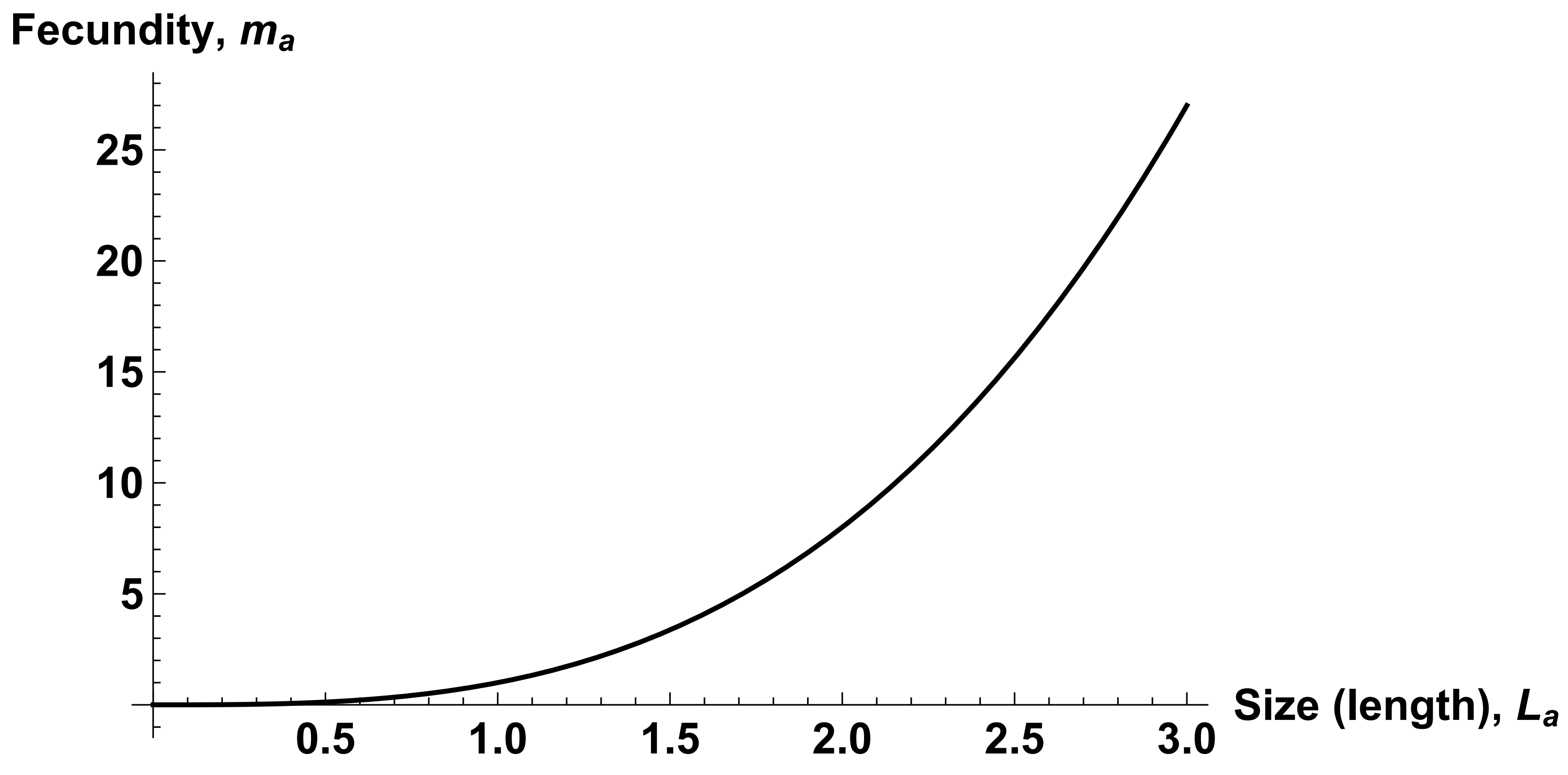

Von Bertalanffy growth equations

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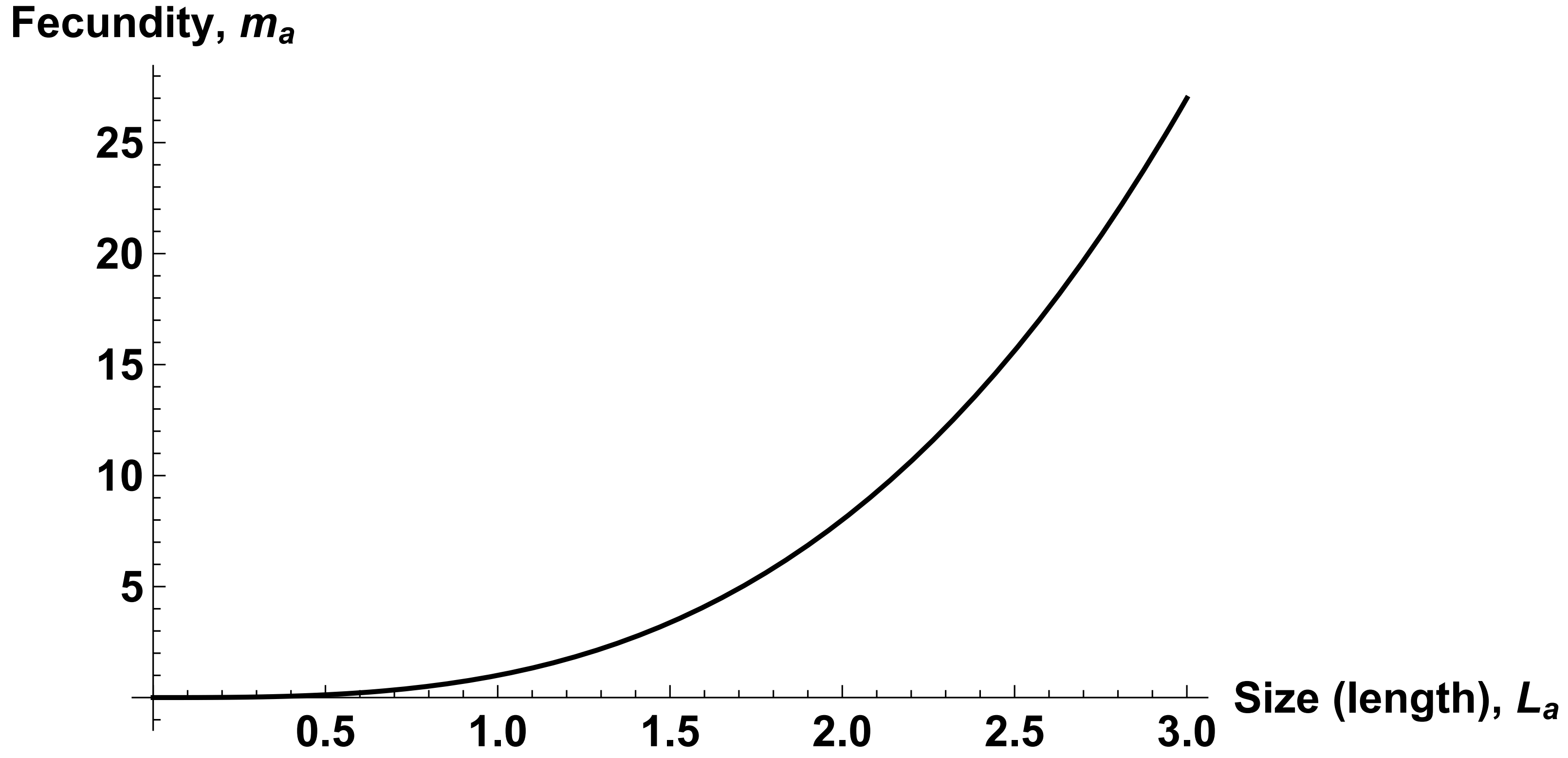

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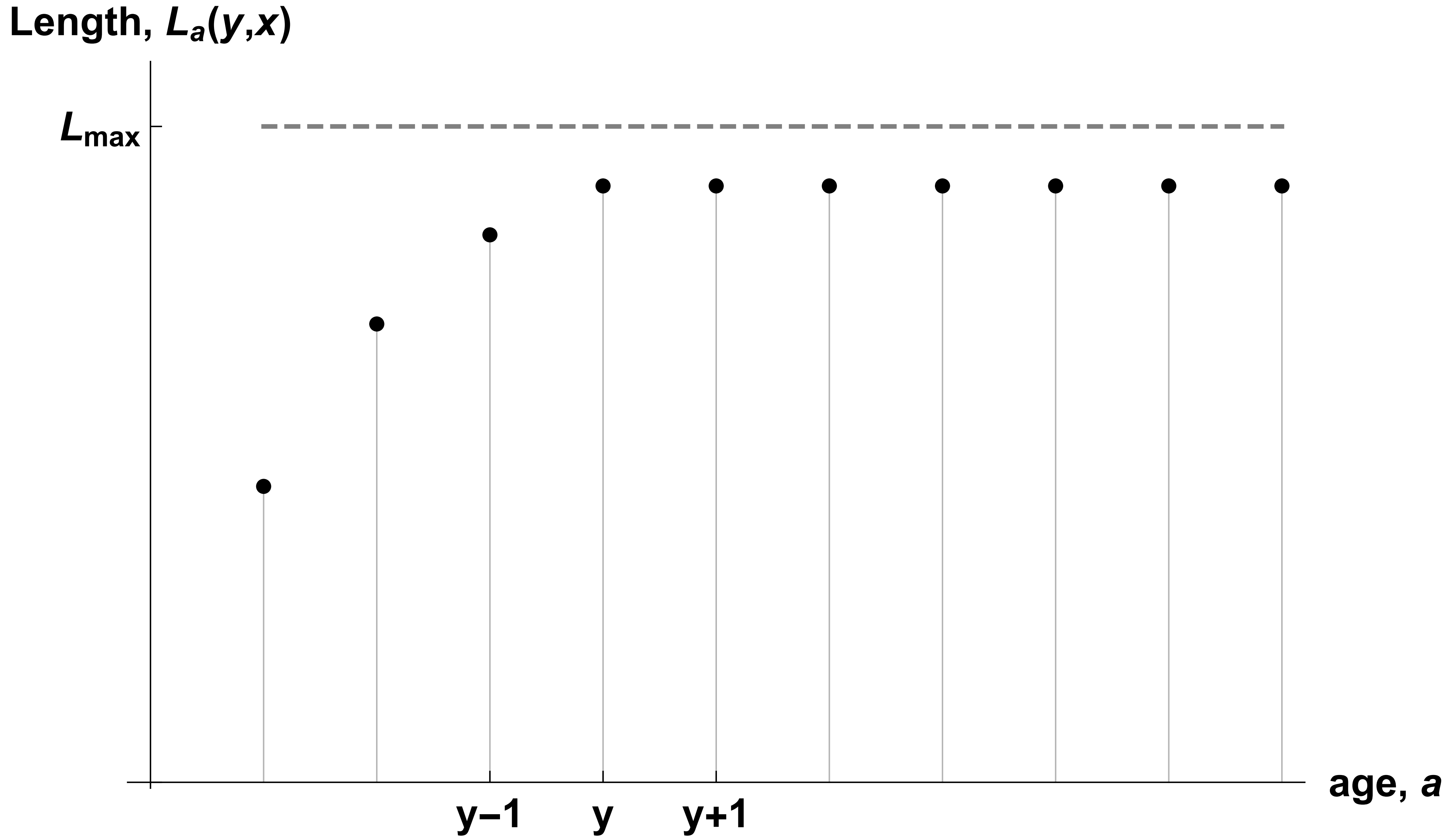

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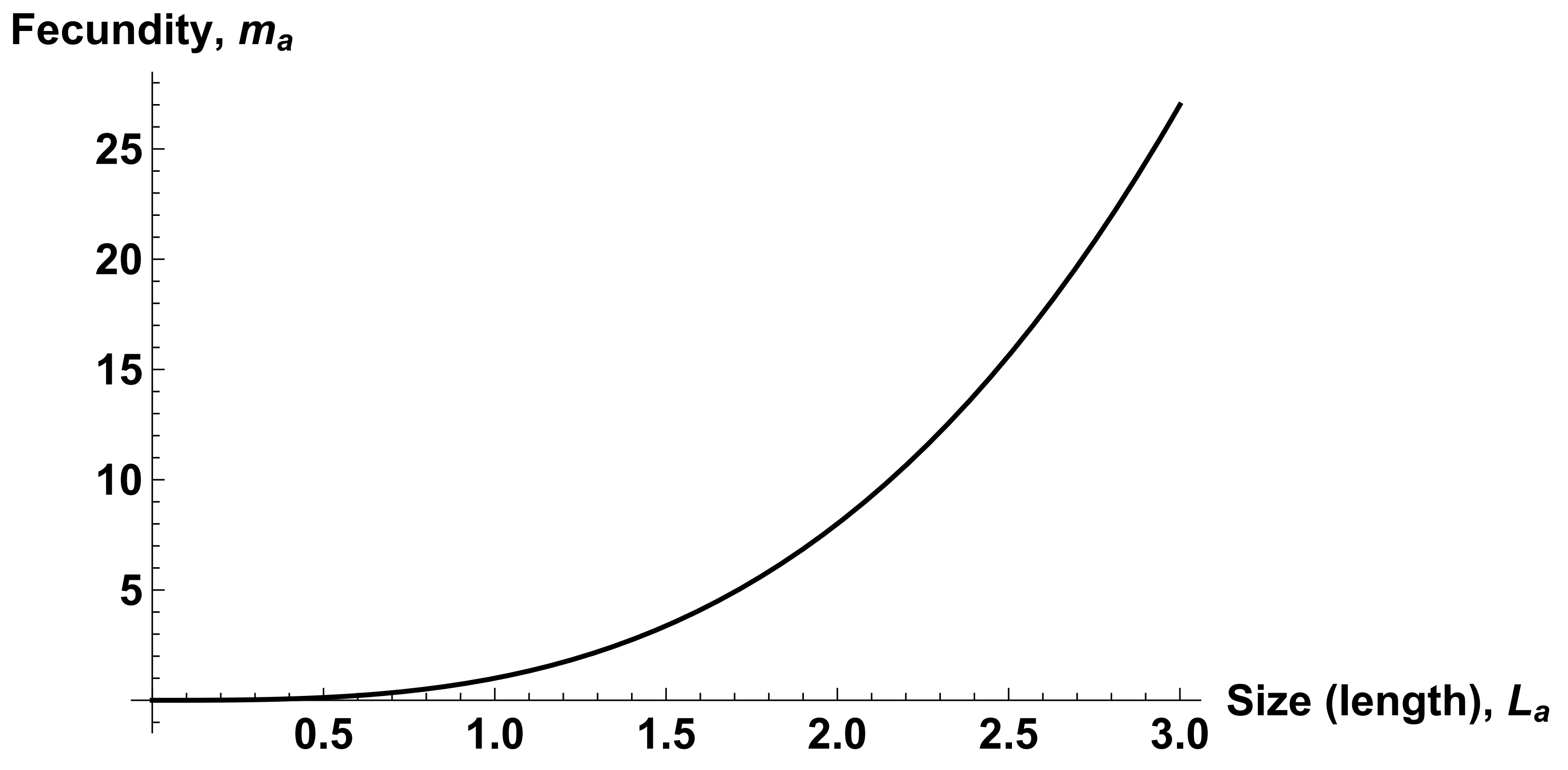

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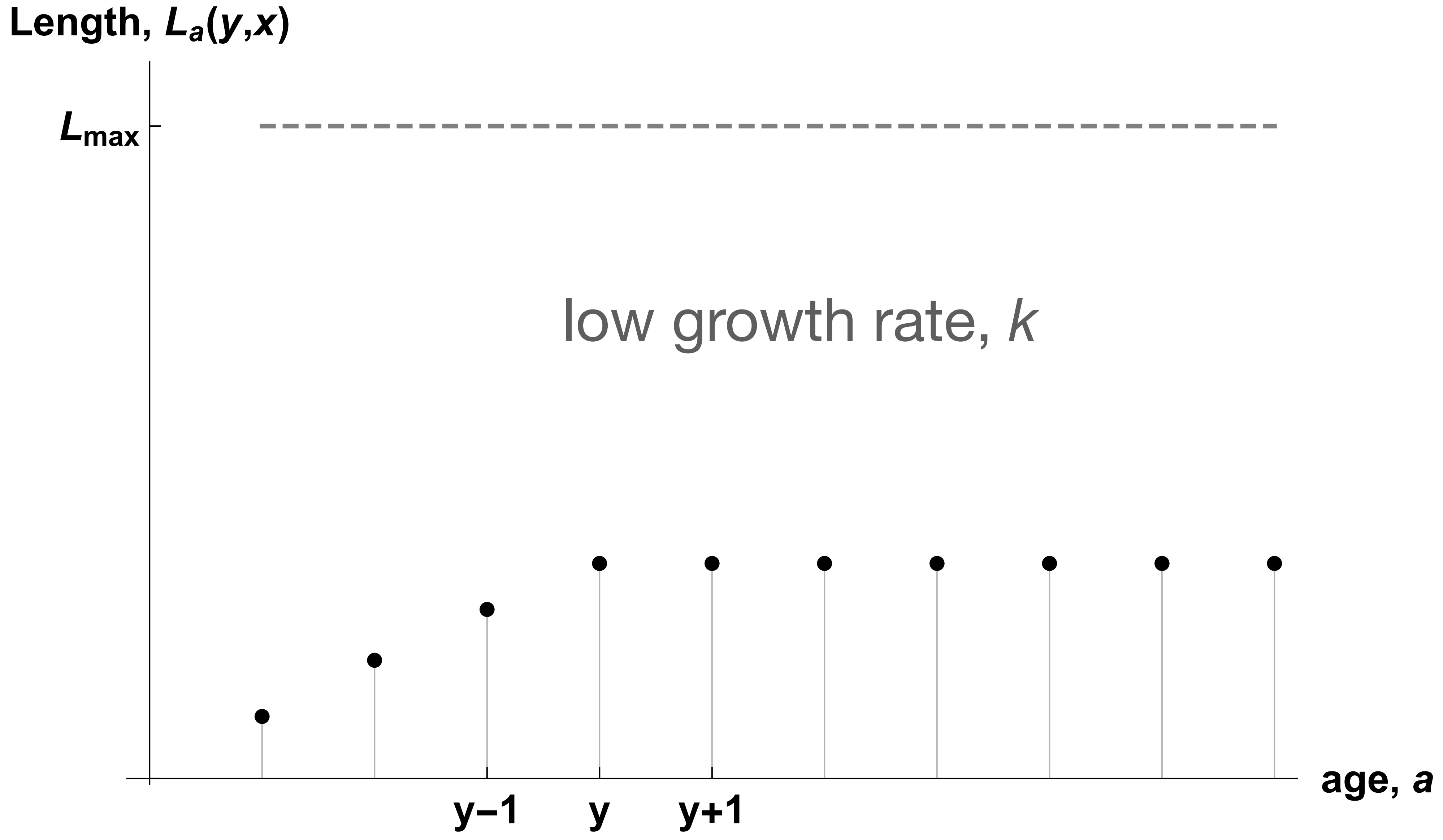

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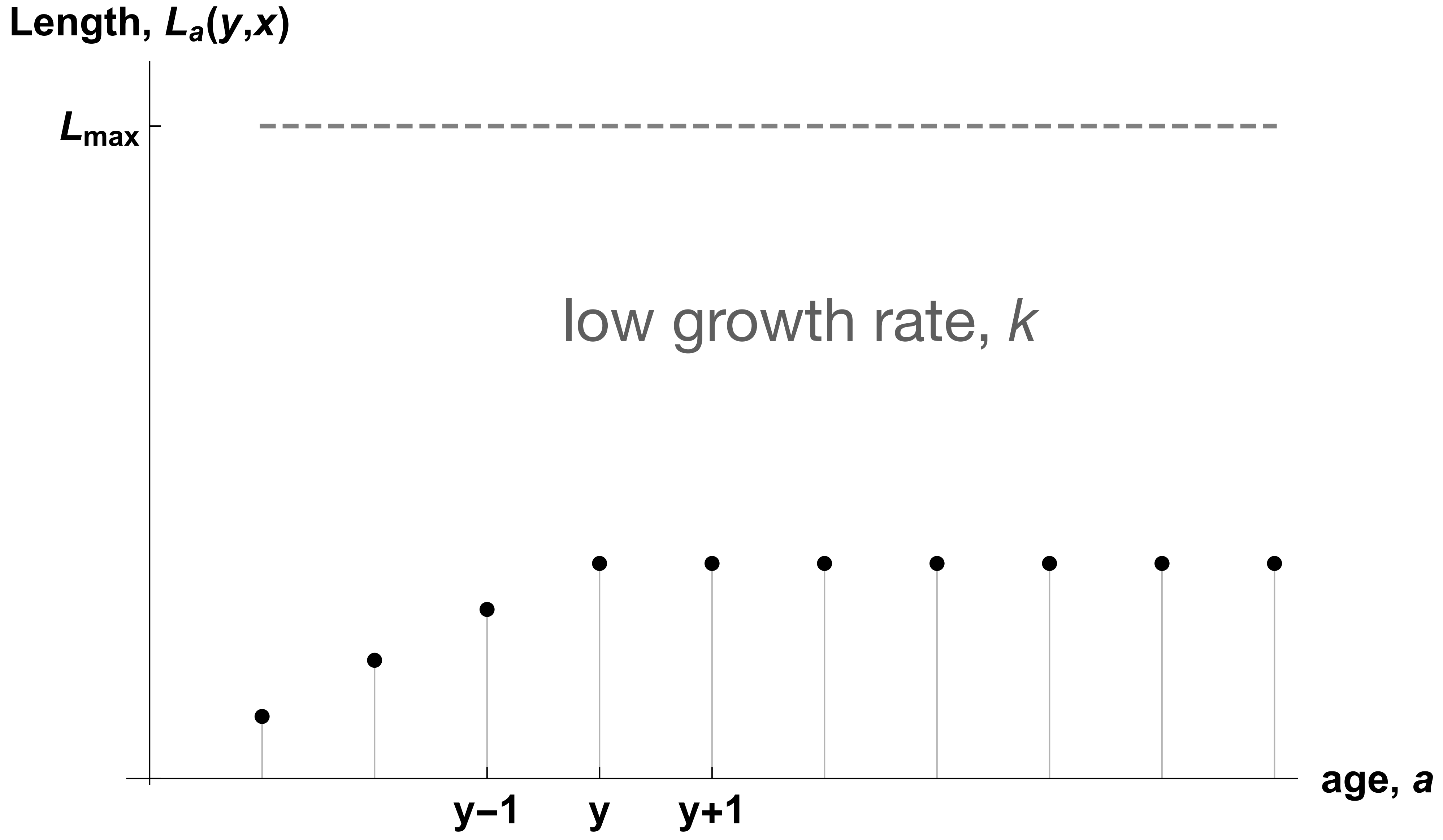

Mutant reproductive success

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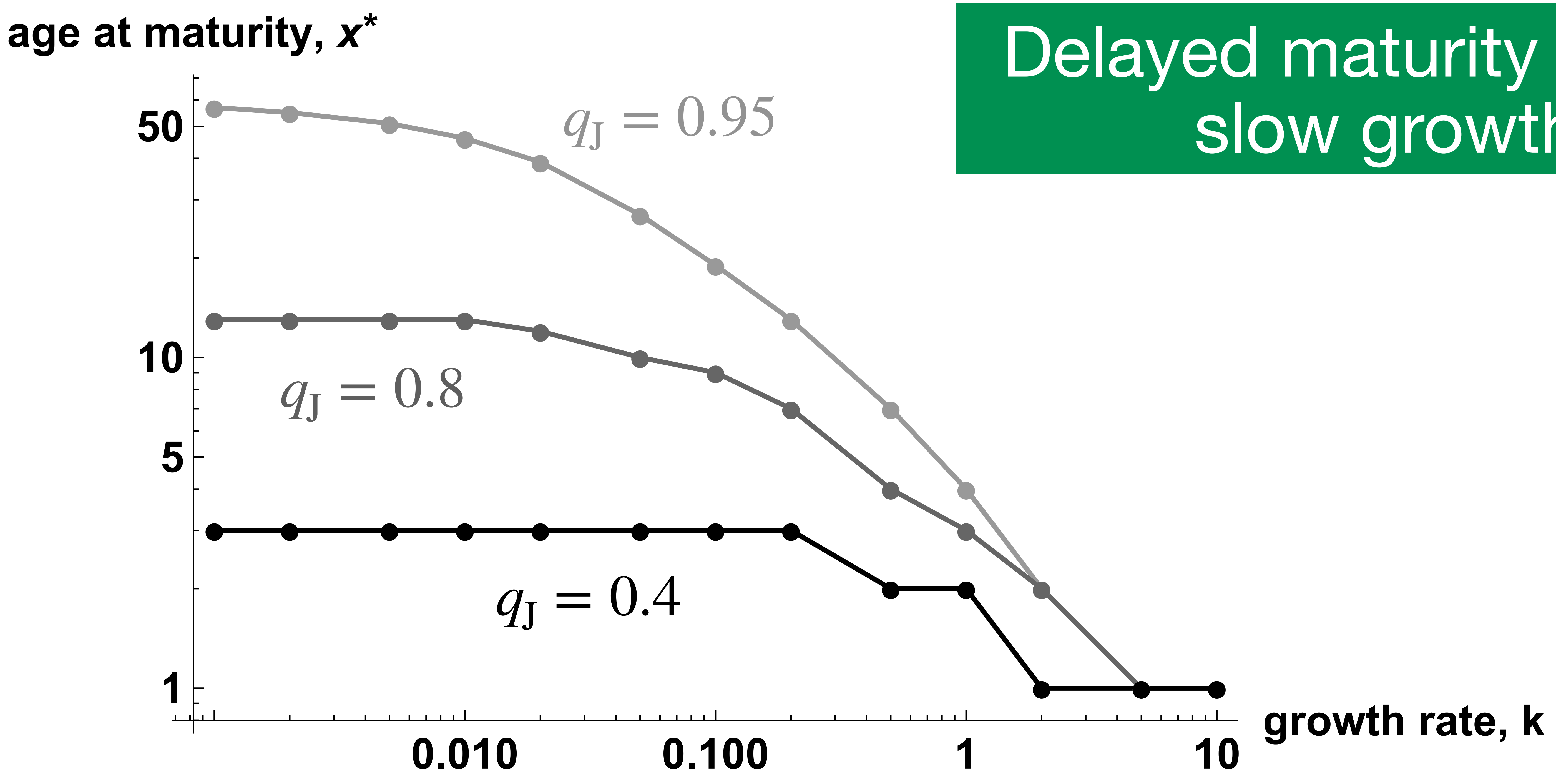
Optimal age at maturity

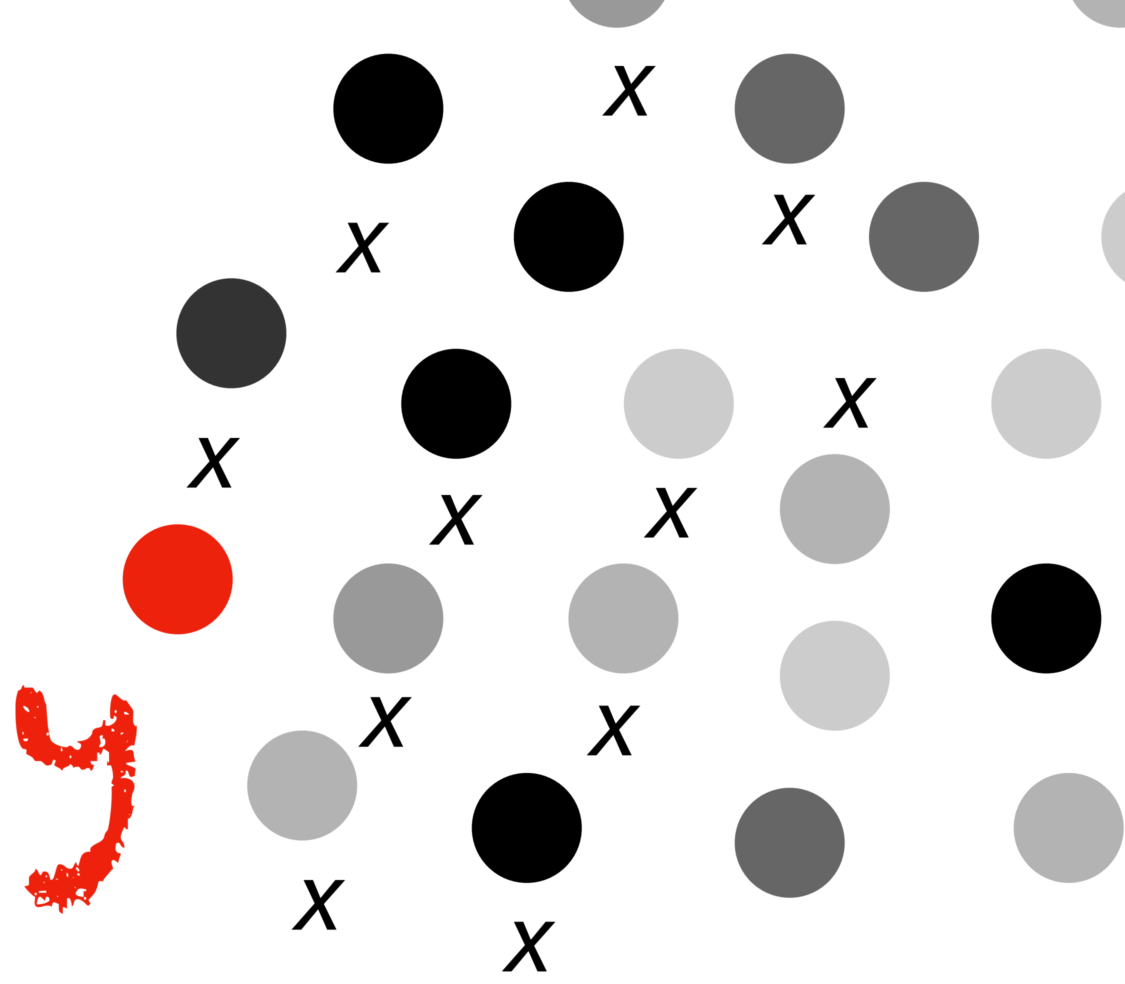


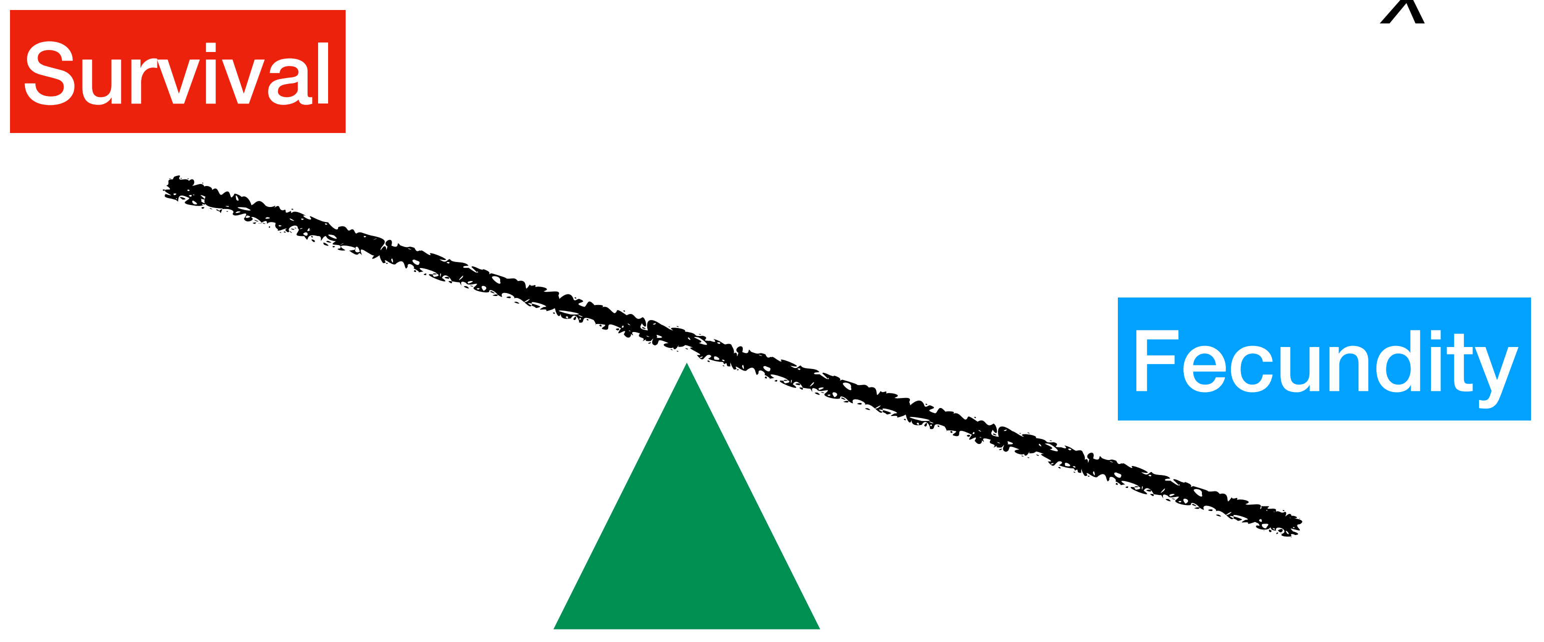
Delayed maturity favoured by slow growth rate.

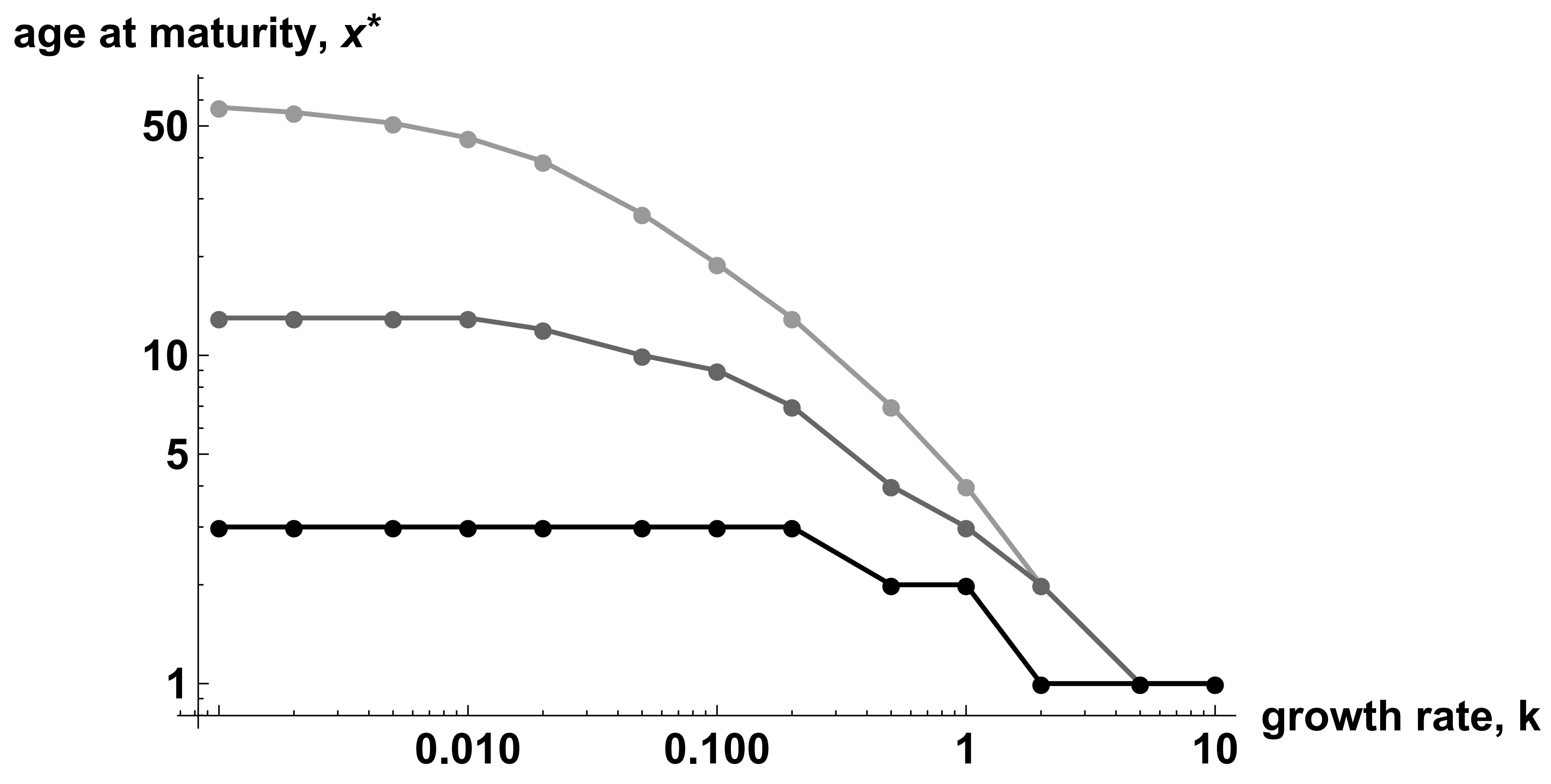
Summary

Life history evolution

- 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.



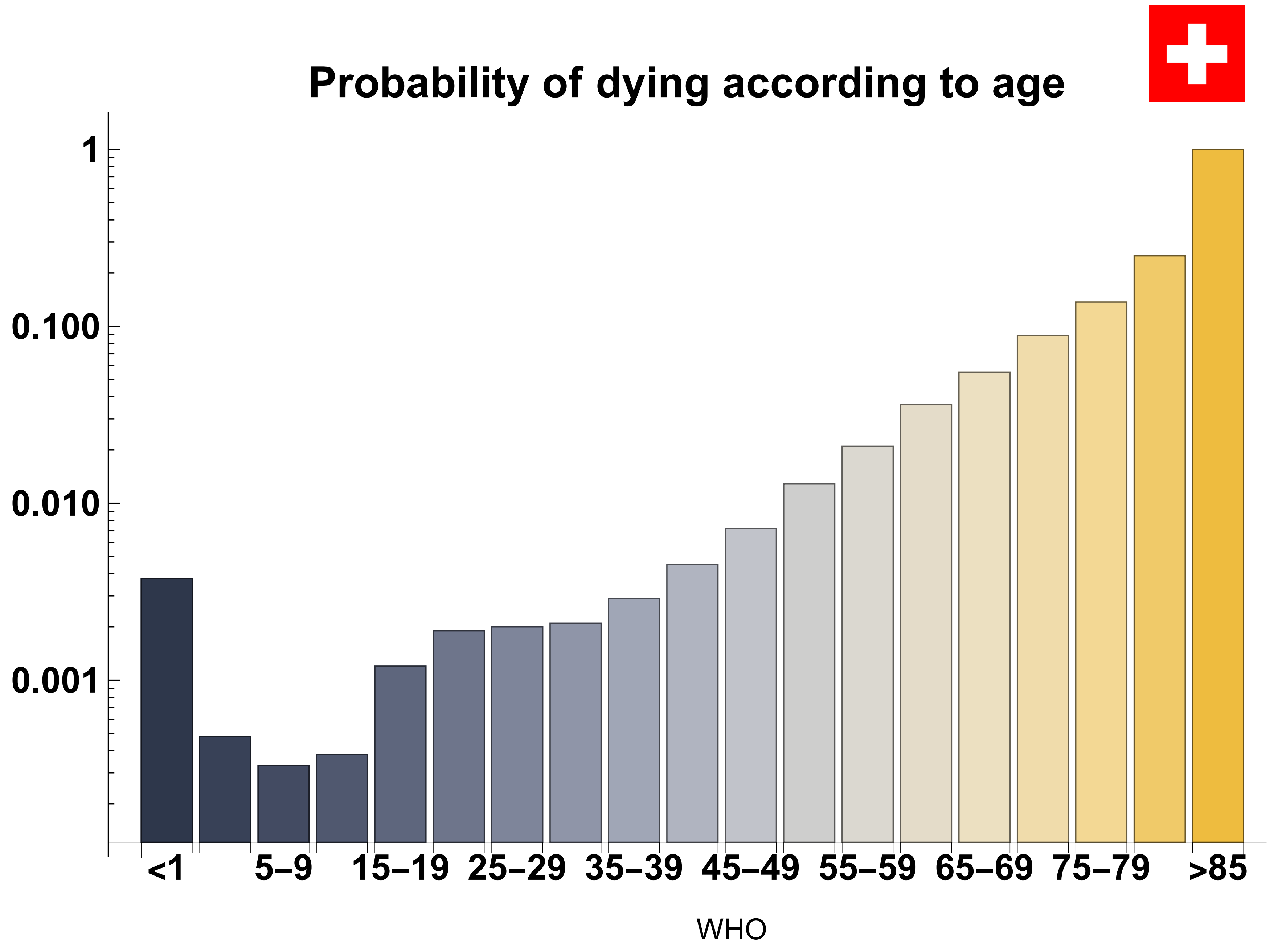


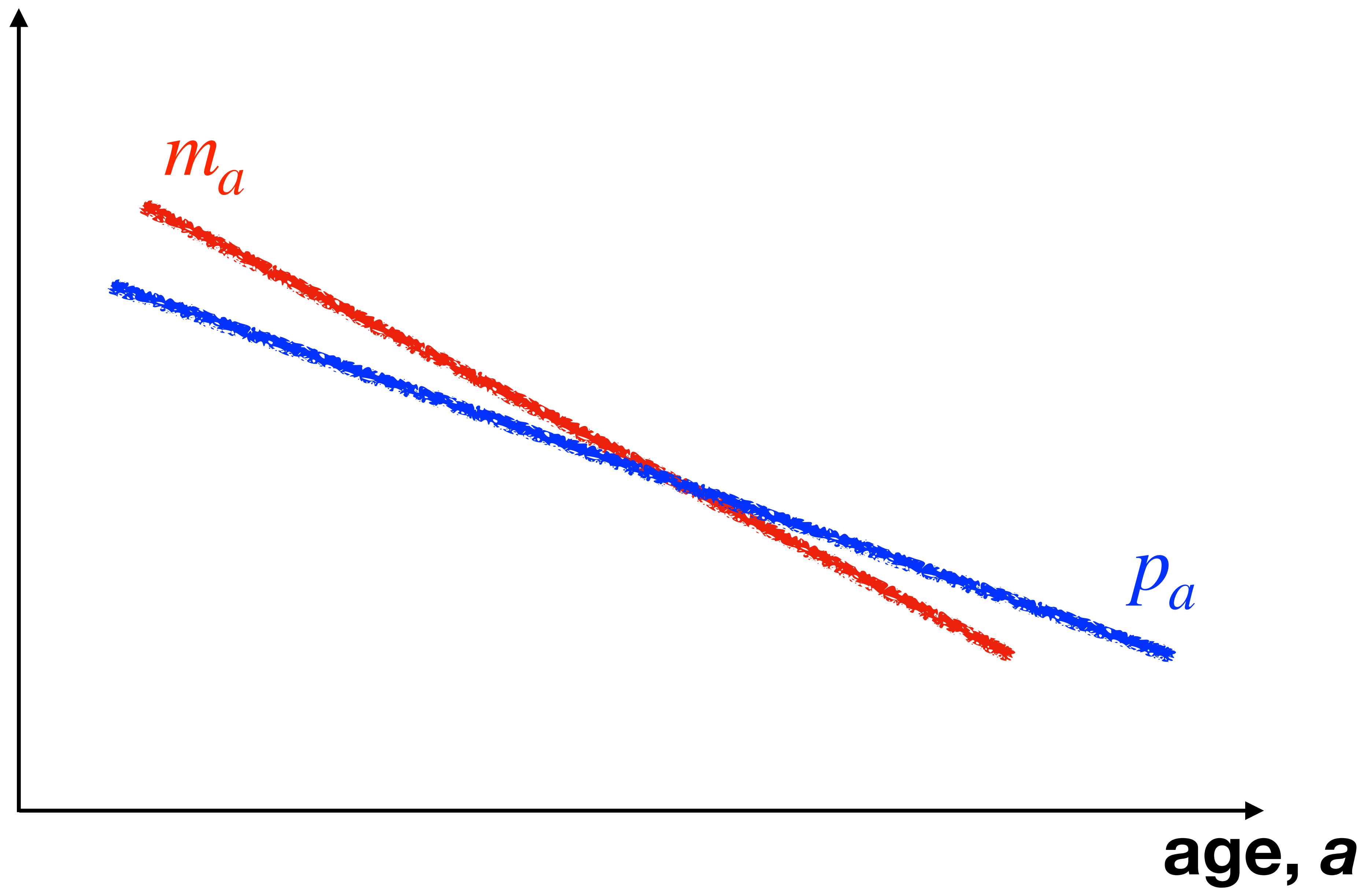


Evolution of ageing

Recap

- Gradual deterioration of function.
- Decrease in survival rate and/or fecundity with age.





Strength of selection on age specific traits

Hamilton 1966

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

$$l_a(y,x) = p_0(y,x)p_1(y,x)\ldots p_{a-1}(y,x)$$

$$s(x) = \left.\frac{\partial R_0(y,x)}{\partial y}\right|_{y=x}$$

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$$s(x) = \left.\frac{\partial R_0(y,x)}{\partial y}\right|_{y=x} = \sum_{a=0}^{\infty} l_a(x)\left[\left.\frac{\partial m_a(y,x)}{\partial y}\right|_{y=x} + \left.\frac{\partial p_a(y,x)}{\partial y}\right|_{y=x} v_{a+1}(x)\right]$$

reproductive value of age a+1, i.e. expected number of offspring given survival till age a+1 = $v_{a+1}(x) = \sum_{b=a+1}^{\infty} \frac{l_b(x)}{l_{a+1}(x)} m_b(x)$

Strength of selection decreases with age

Hamilton 1966

$$s(x) = \sum_{a=0}^{\infty} l_a(x) \left[\left. \frac{\partial m_a(y,x)}{\partial y} \right|_{y=x} + \left. \frac{\partial p_a(y,x)}{\partial y} \right|_{y=x} v_{a+1}(x) \right]$$

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selection on survival proportional to reproductive value

Strength of selection decreases with age

Gray squirrel example (with fecundity scaled so that $R_0 = 1$)

Age *a* (years)	p_a	m_a	f_a
0	0.25		
1	0.46	1.15	0.32
2	0.77	2.05	0.57
3	0.65	2.05	0.57
4	0.67	2.05	0.57
5	0.64	2.05	0.57
6	0.88	2.05	0.57
7		2.05	0.57

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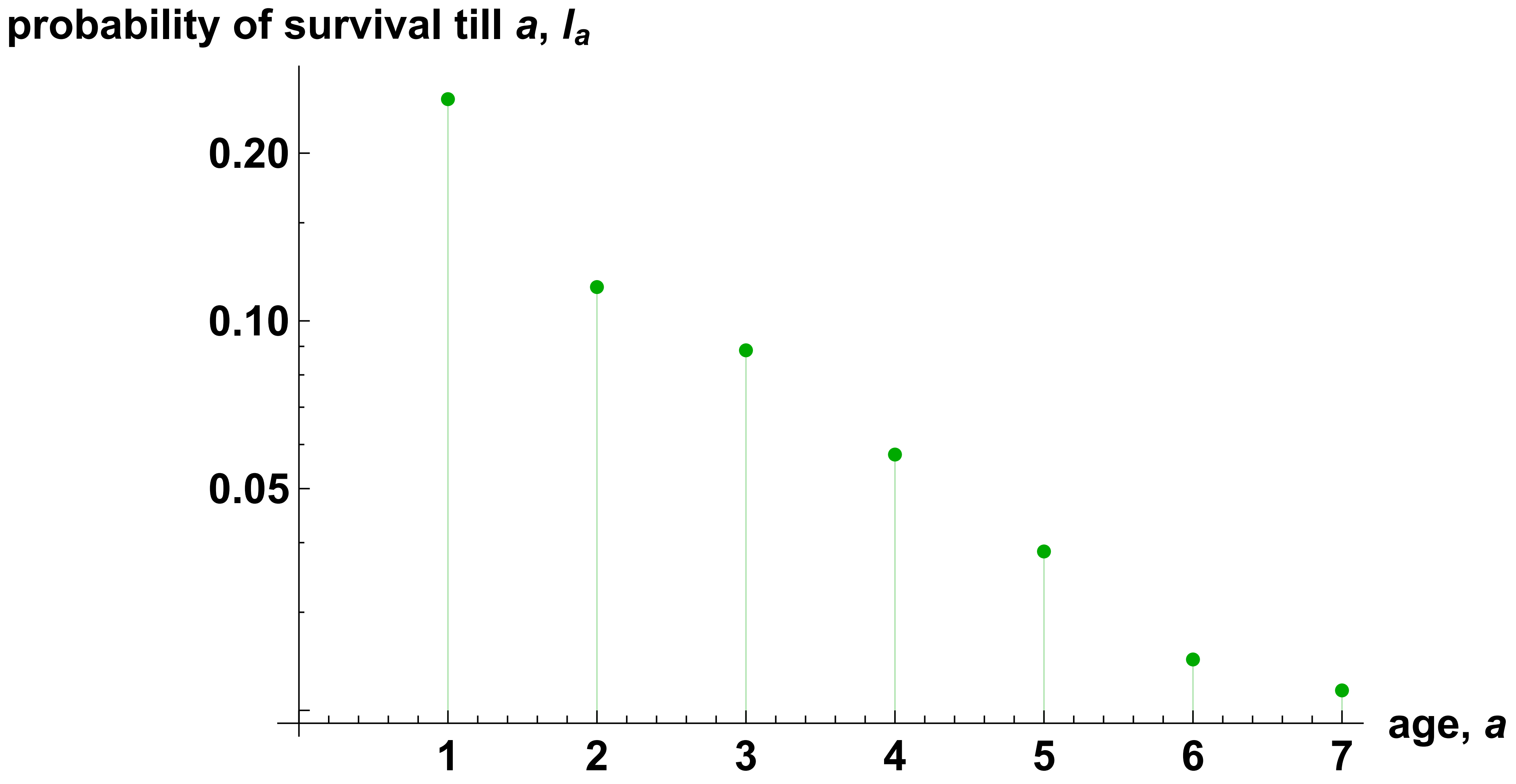

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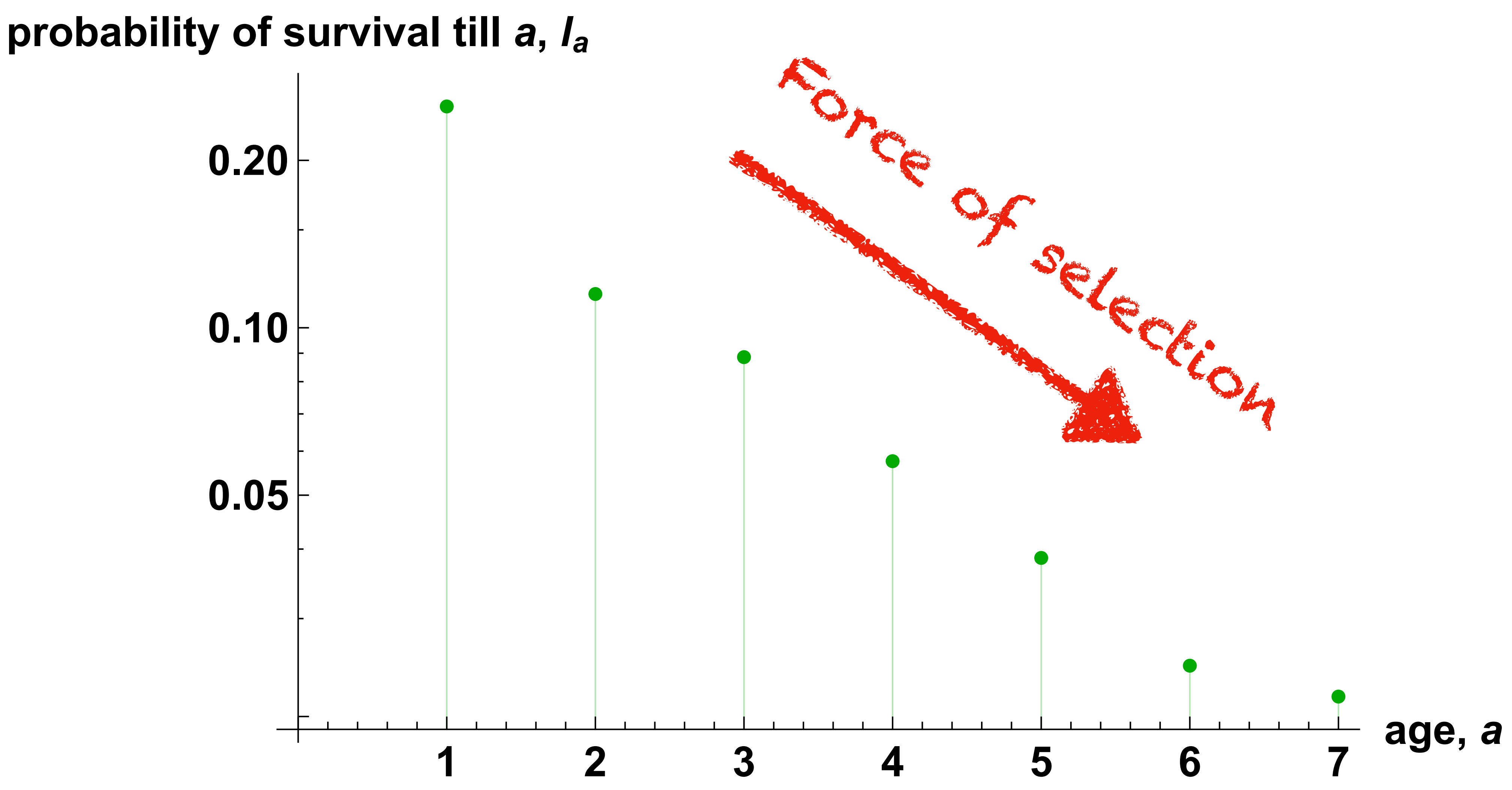
Age a (years)	p_a	m_a	f_a
0	0.25		
1	0.46	1.15	0.32
2	0.77	2.05	0.57
3	0.65	2.05	0.57
4	0.67	2.05	0.57
5	0.64	2.05	0.57
6	0.88	2.05	0.57
7		2.05	0.57



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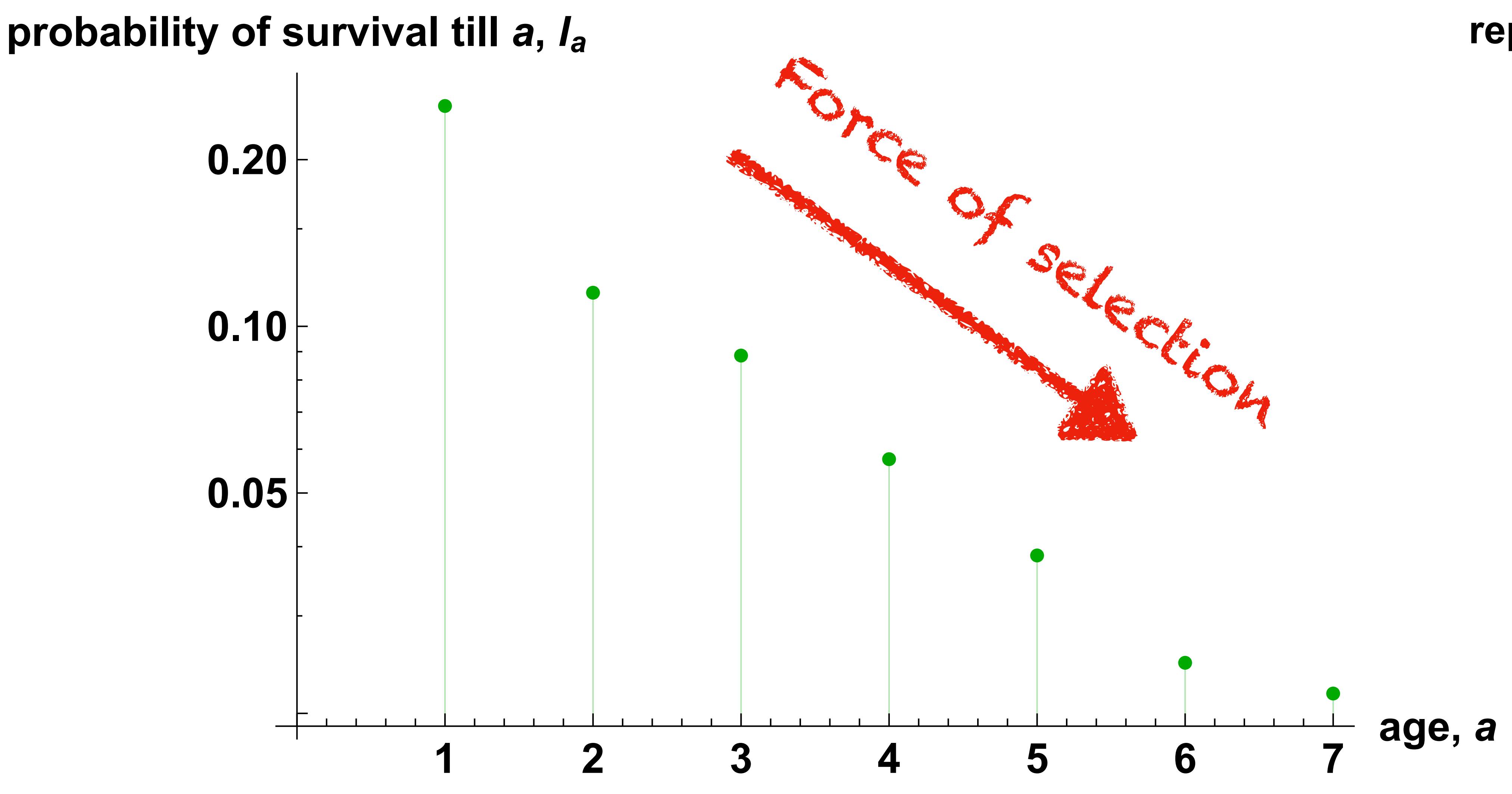
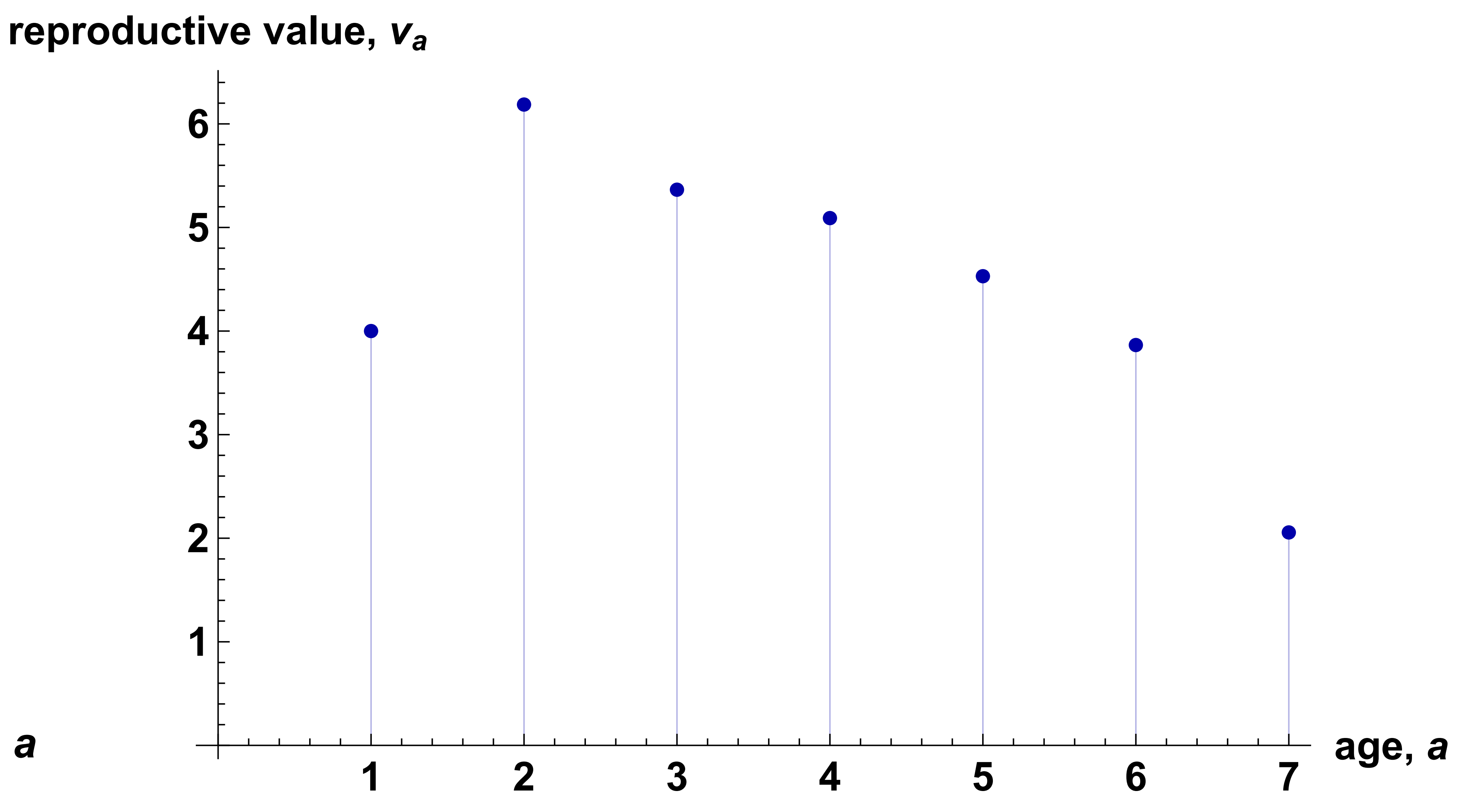




selection on fecundity decreases with age

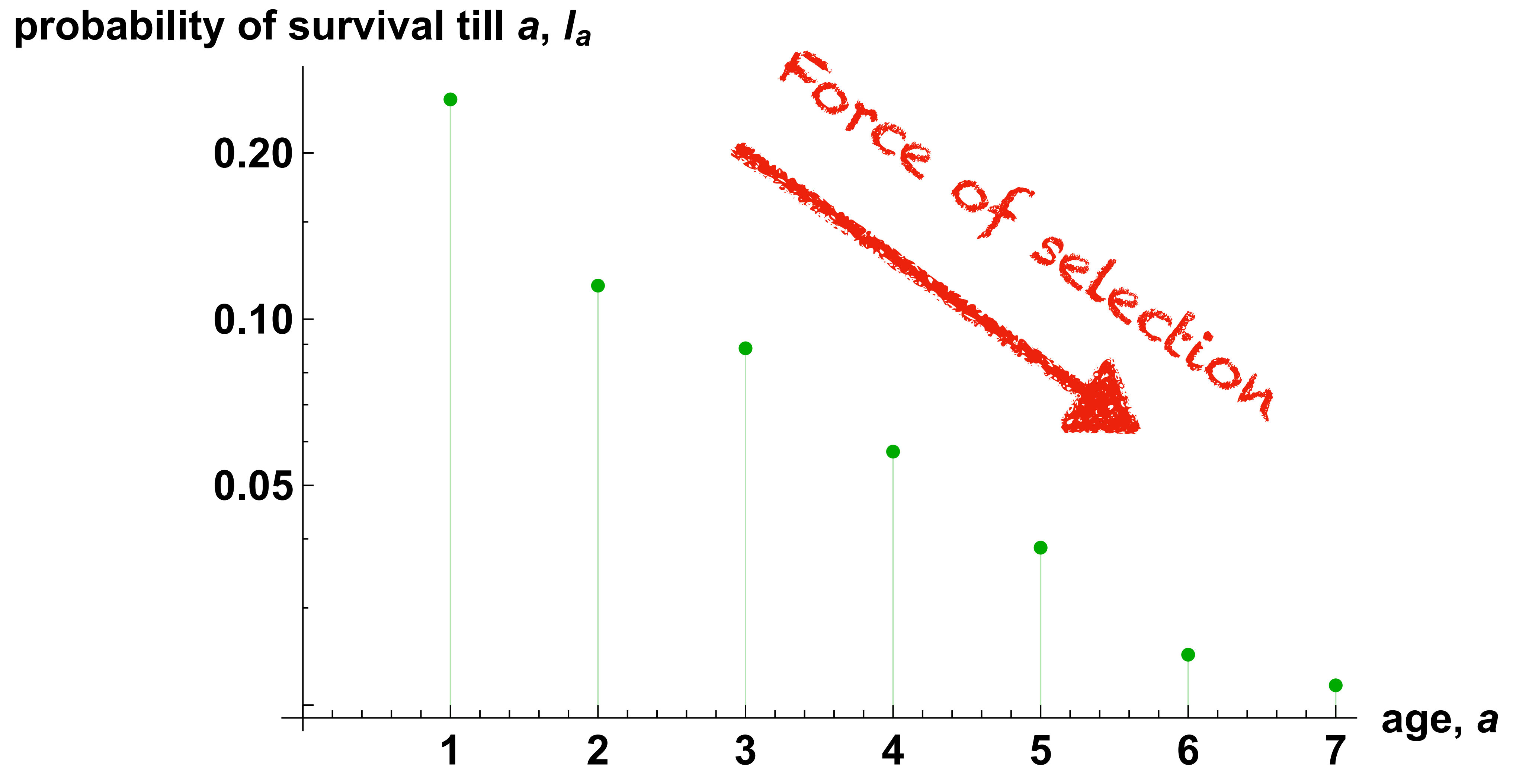
selection on survival biased towards ages with greatest perspective of reproduction

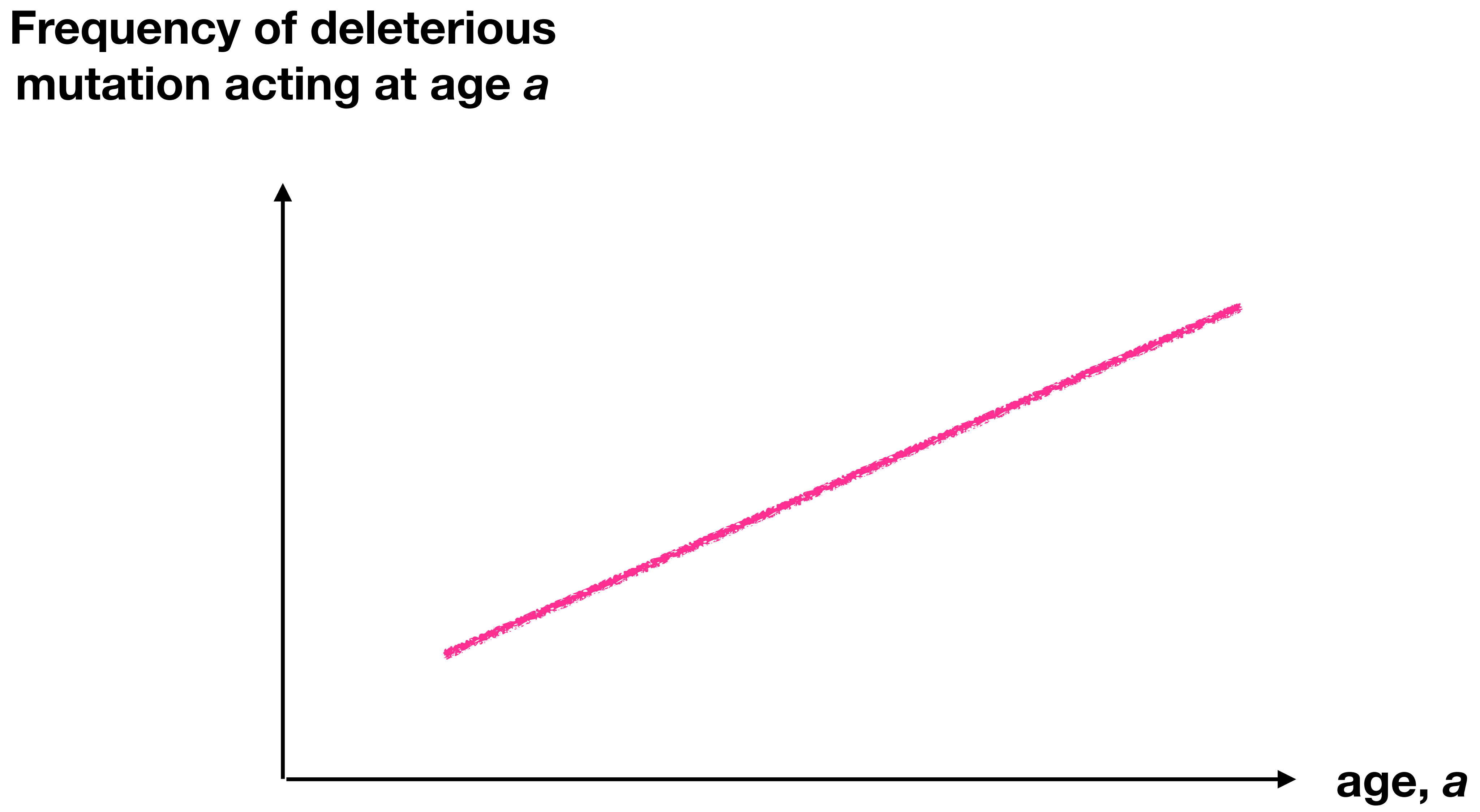
Mutation accumulation

Medawar 1952

- Deleterious, late-acting mutations accumulate with little resistance as selection weakens with age of action.

- Causes a reduction in vital rates with age.





Antagonistic pleiotropy
Williams 1957

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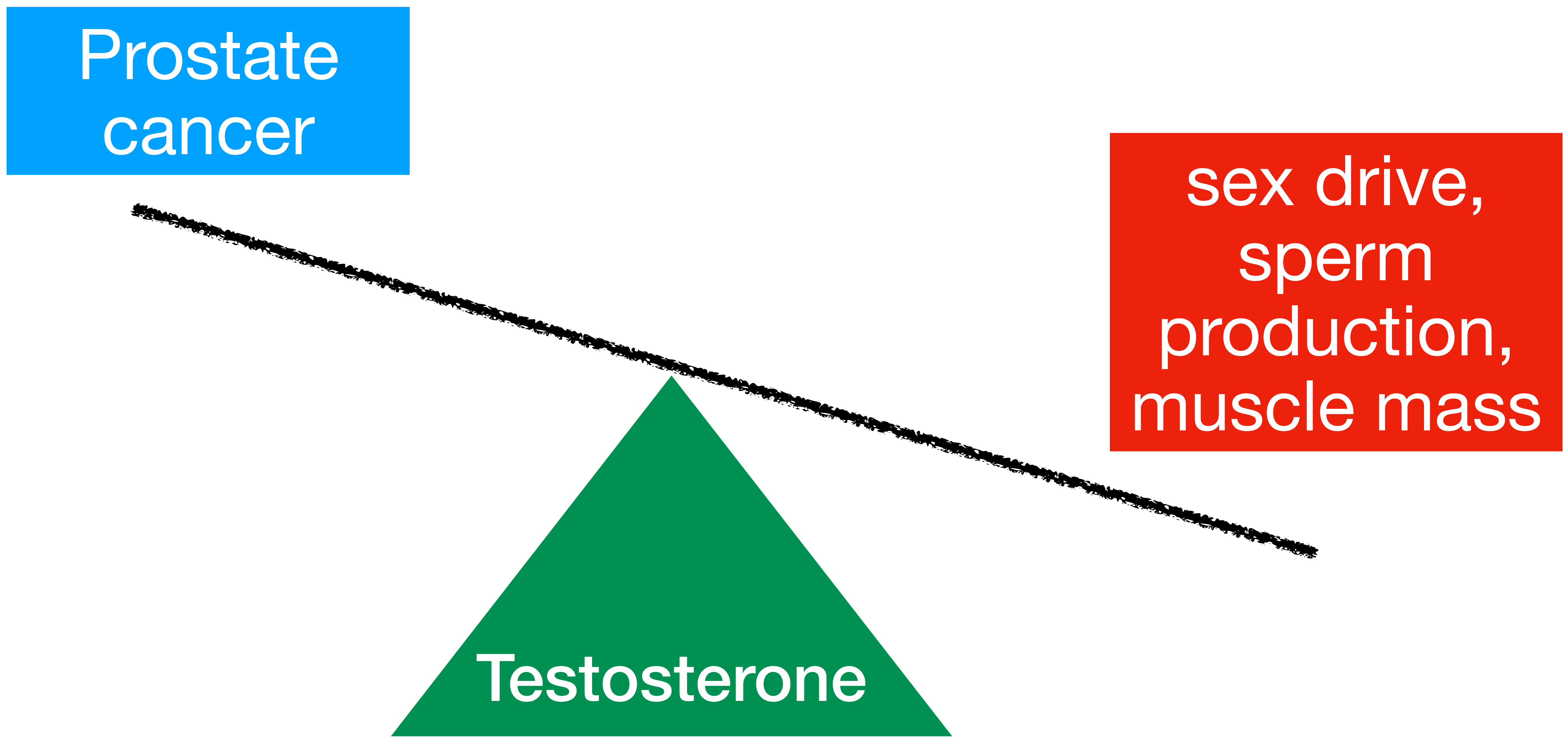

Disposable soma theory

Kirkwood 1977

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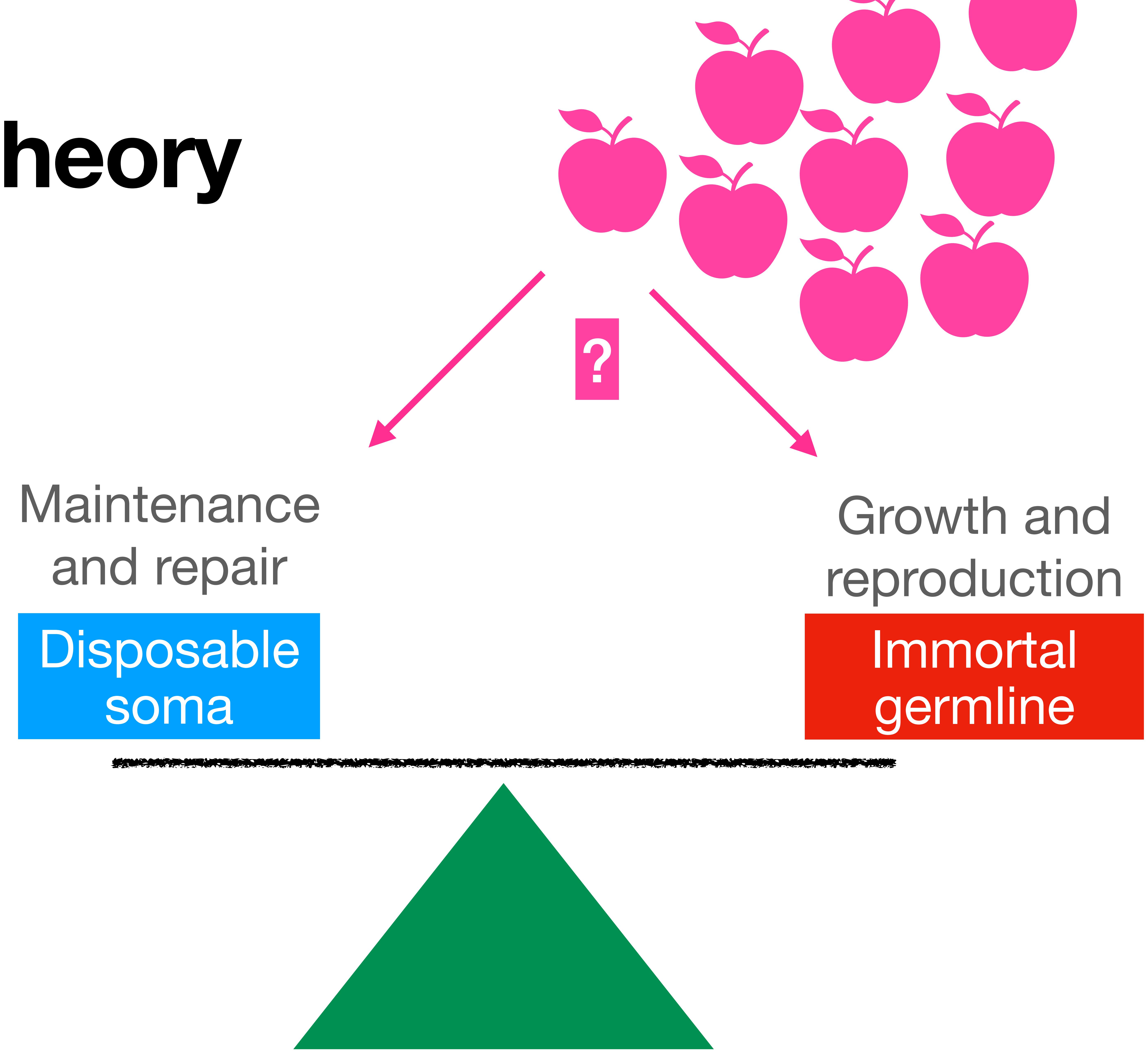

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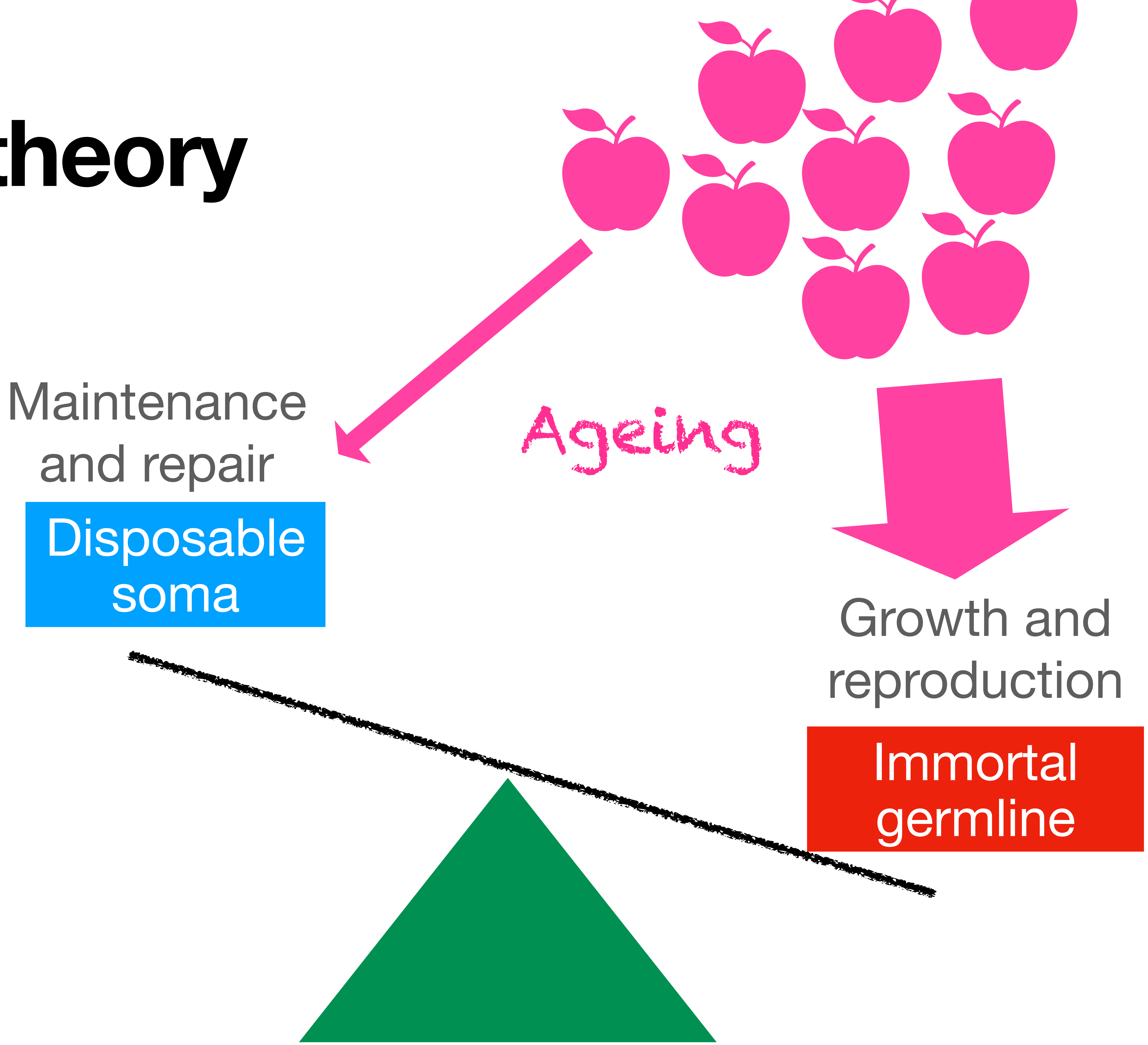

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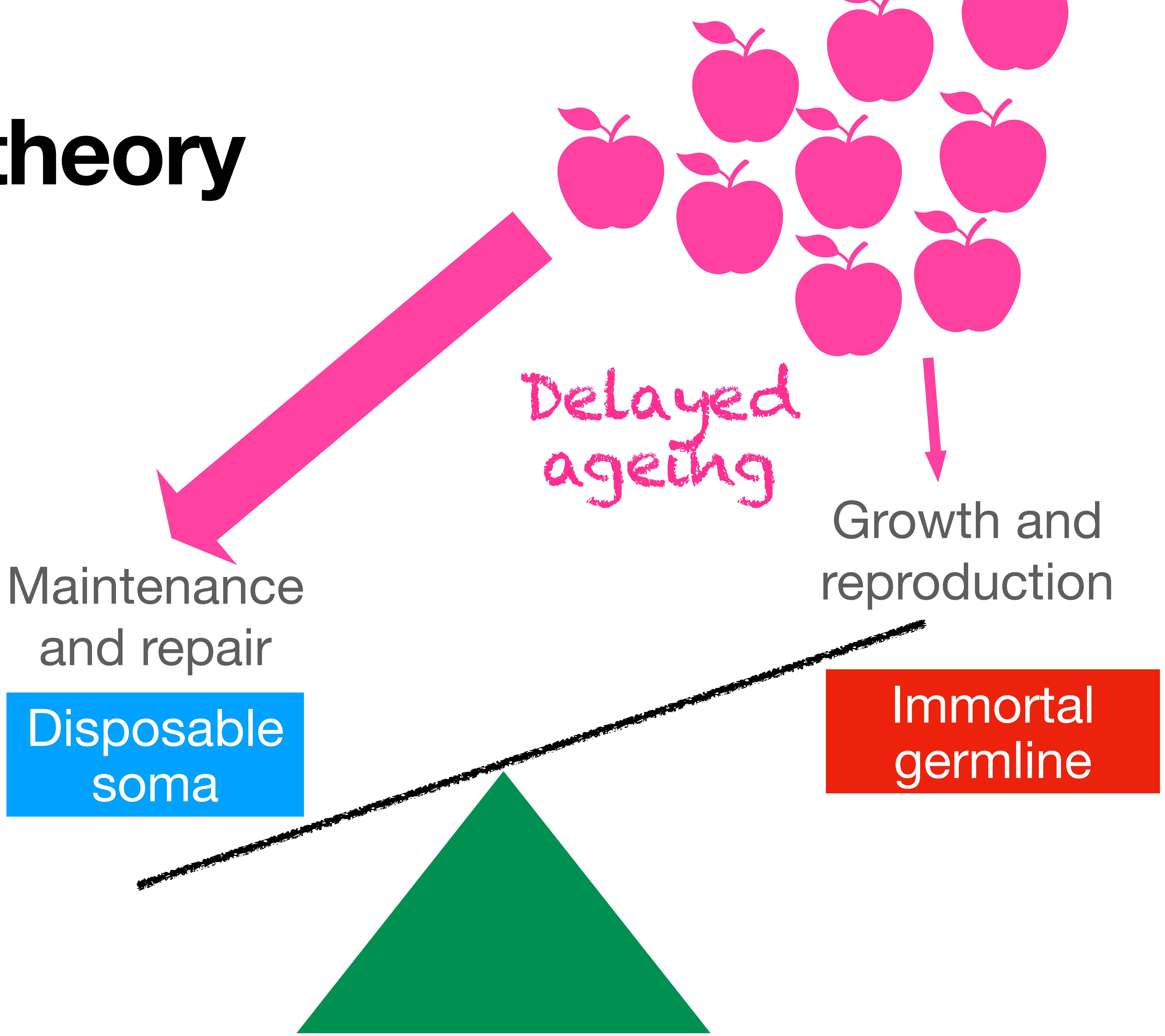

Summary

selection on senescence

- Strength of selection on traits with age-specific effects declines with age (proportional to probability of surviving till relevant age)
- Selection on traits influencing age-specific survival also proportional to reproductive value
- Two non-exclusive theories for ageing:
    - Mutation accumulation (selection too weak to purge detrimental mutations with late effects)
    - Antagonistic pleiotropy (favours early effects at the expense of later effects)