Part III - Foraging theory

resources

energy

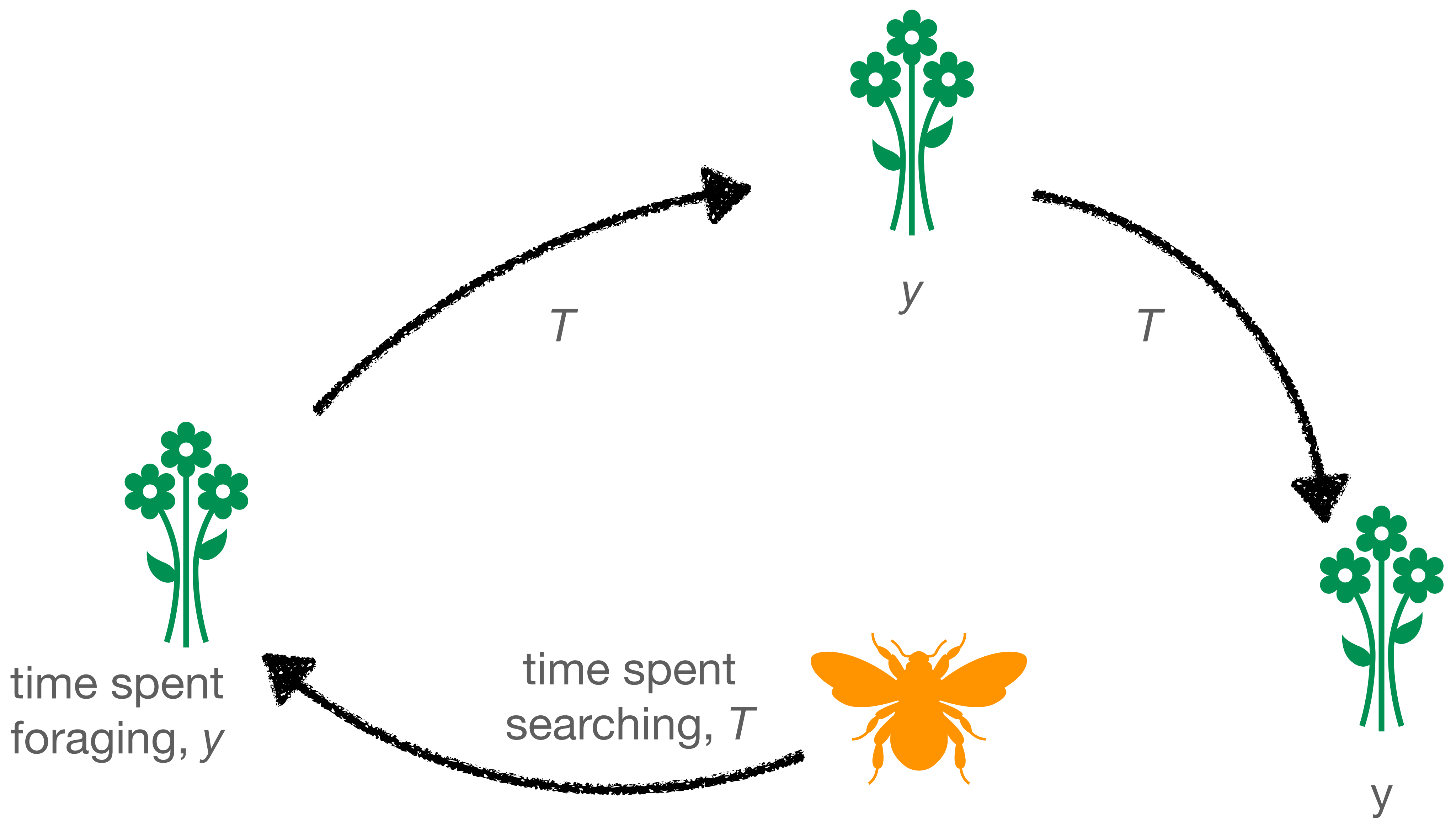
offspring

fitness

Foraging in patches

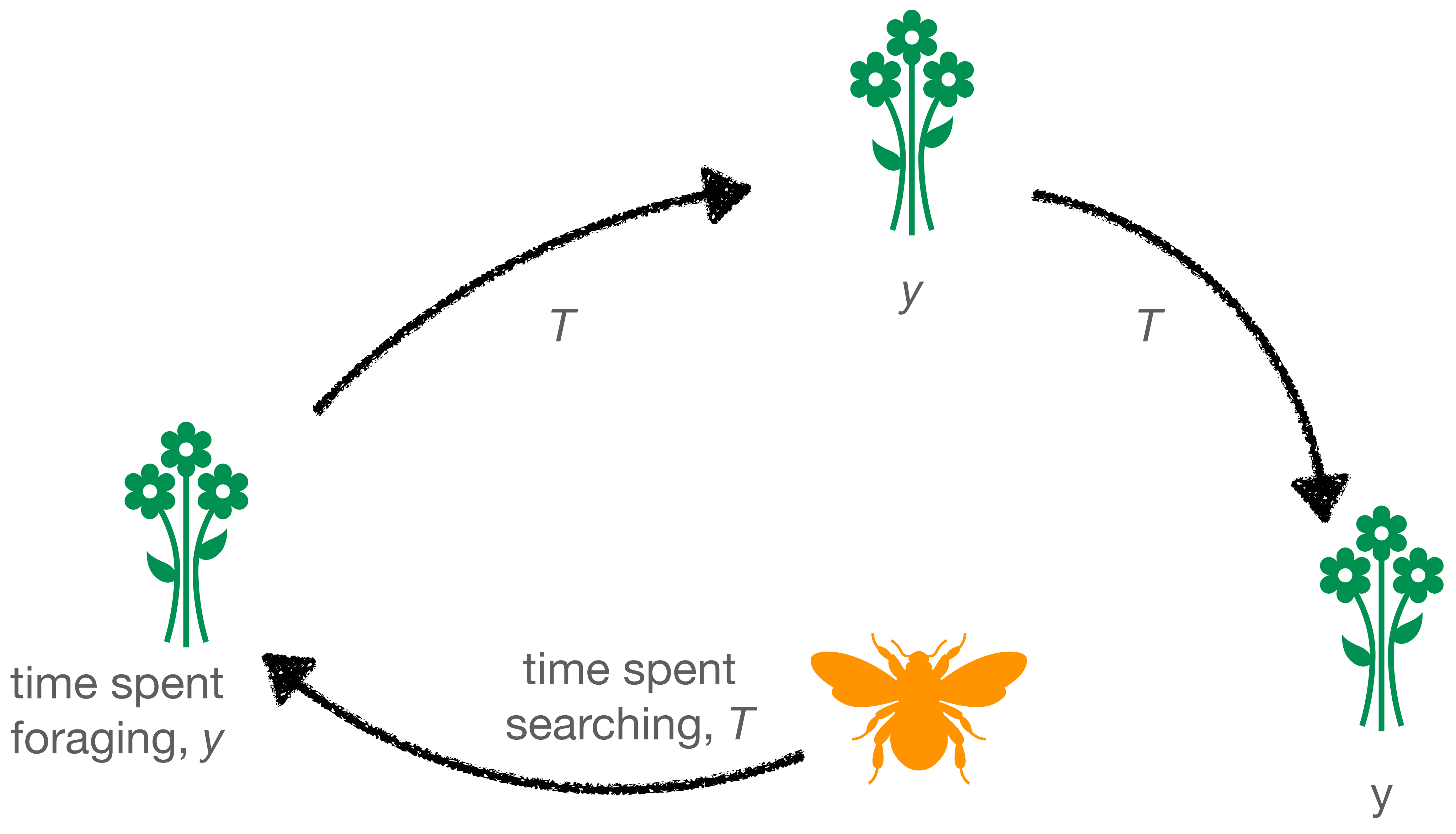
Foraging in patches

- Animal forages on multiple equivalent patches with finite amount of resources.



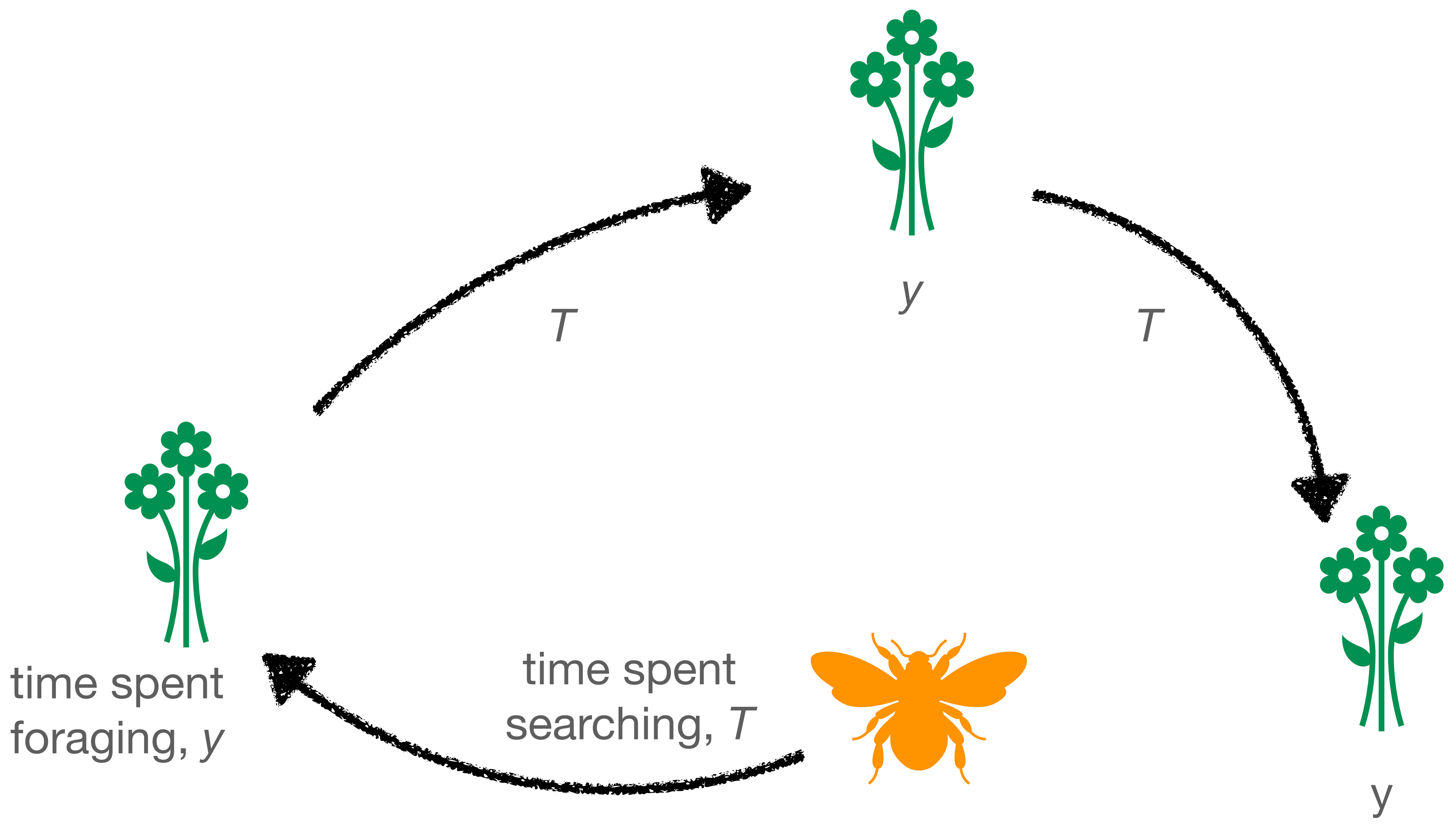
Foraging in patches

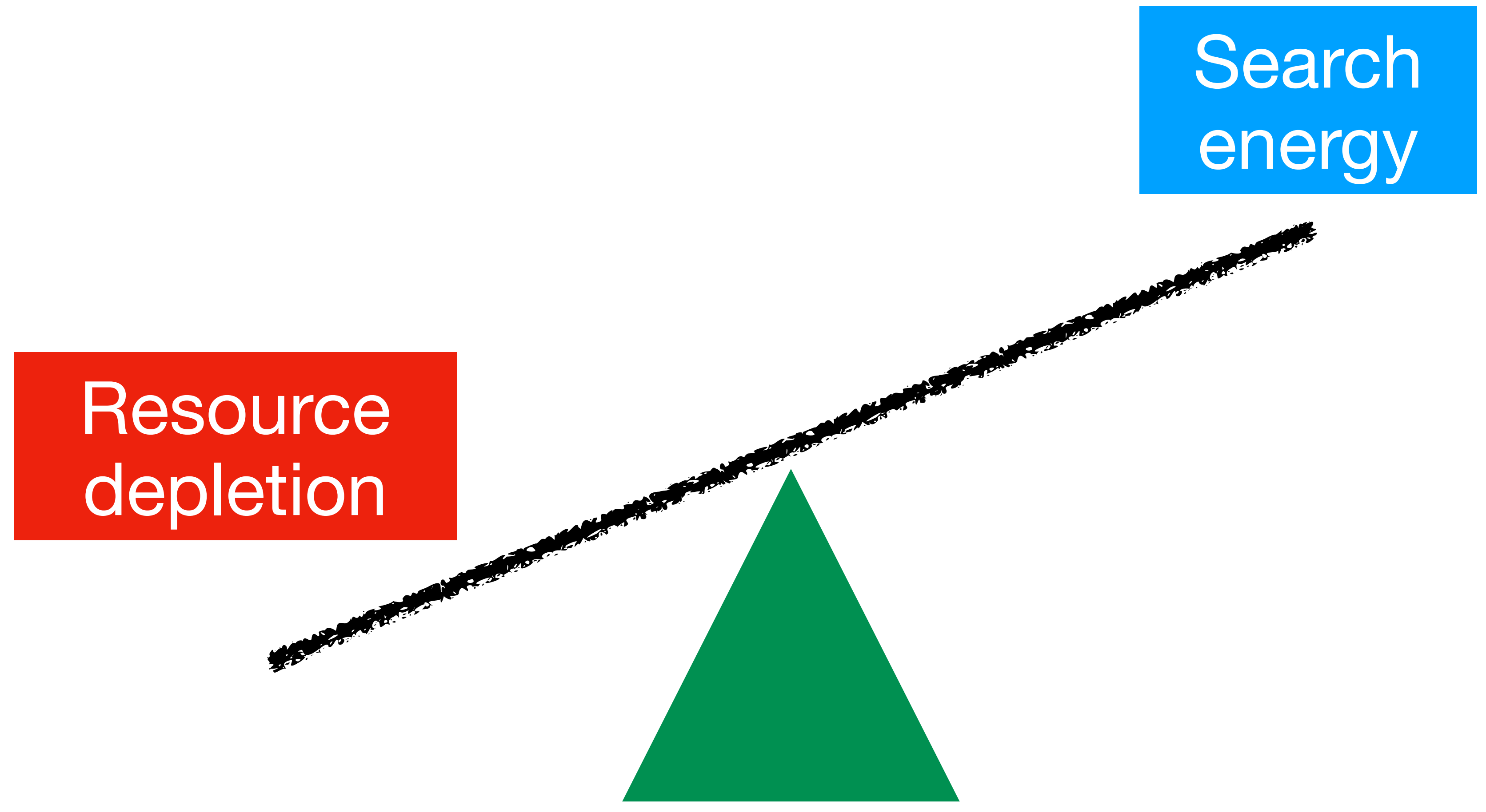
- Animal forages on multiple equivalent patches with finite amount of resources.
- How much time *y* should it spent foraging on a single patch when searching is costly?



Foraging in patches

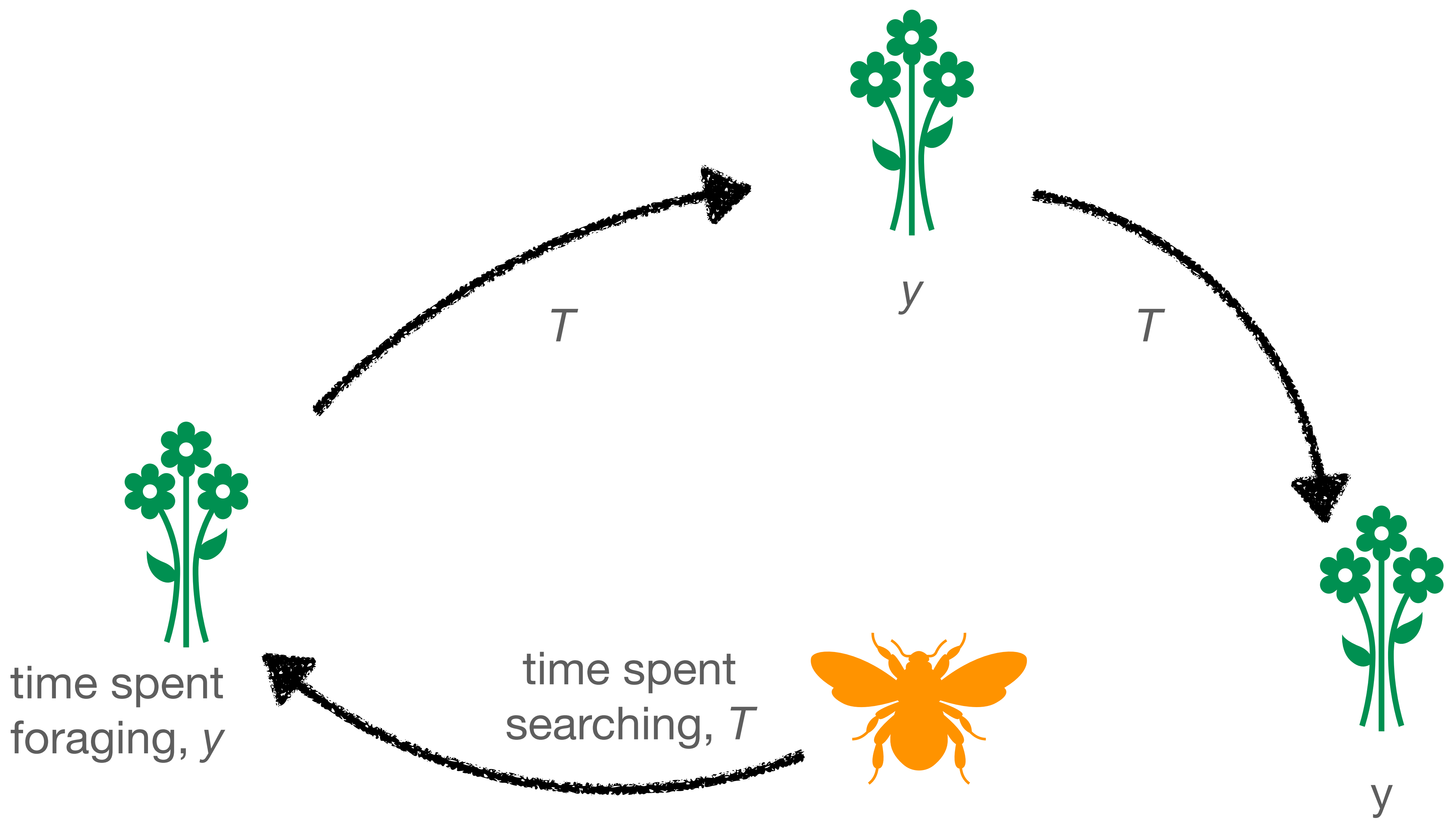
- Animal forages on multiple equivalent patches with finite amount of resources.
- How much time *y* should it spent foraging on a single patch when searching is costly?
- If it stays too long, resources get depleted; too short and it does not regain energy lost from search.

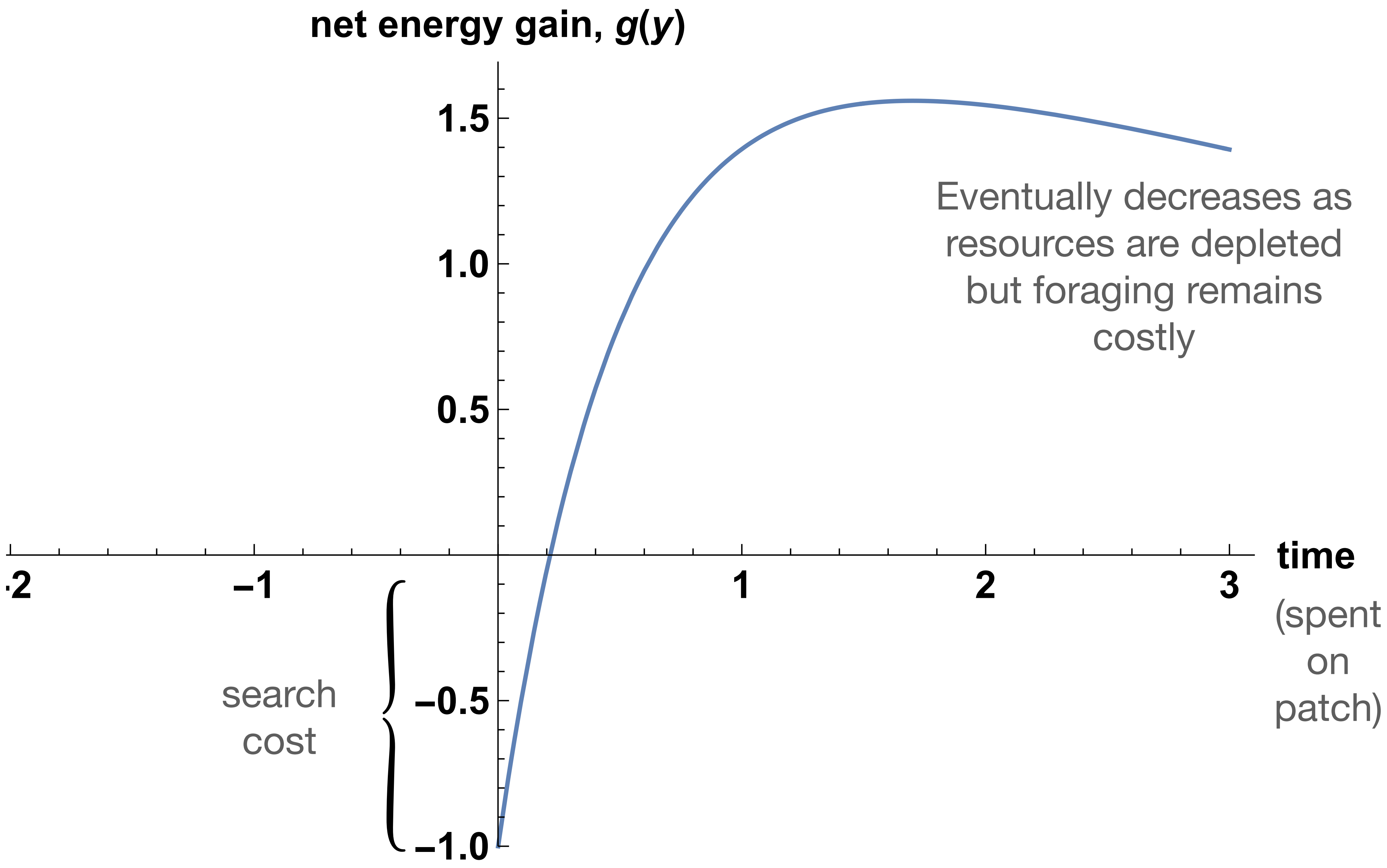




Energy gains

- $g(y)$: **net** energy gain from staying *y* in a patch

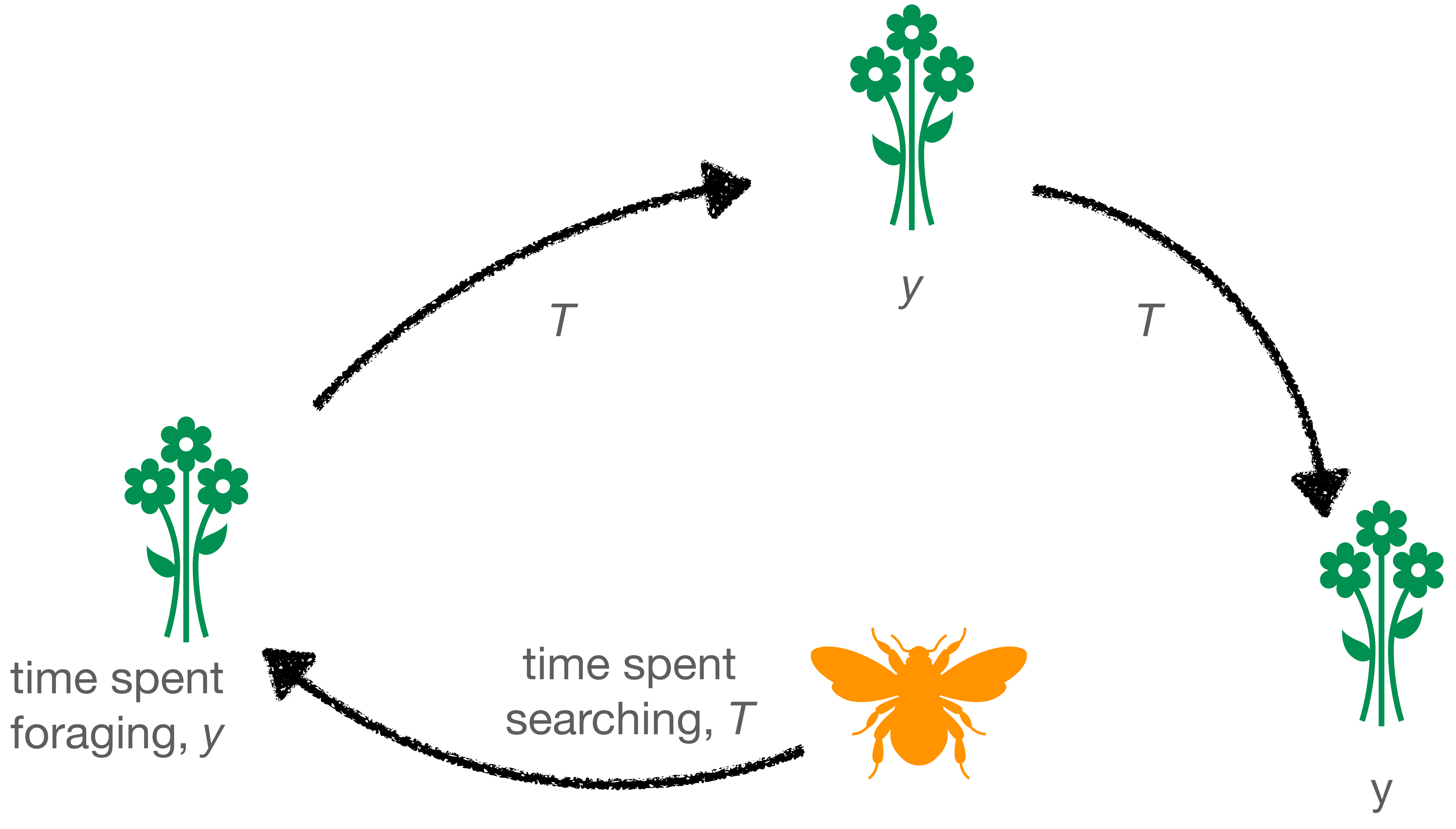


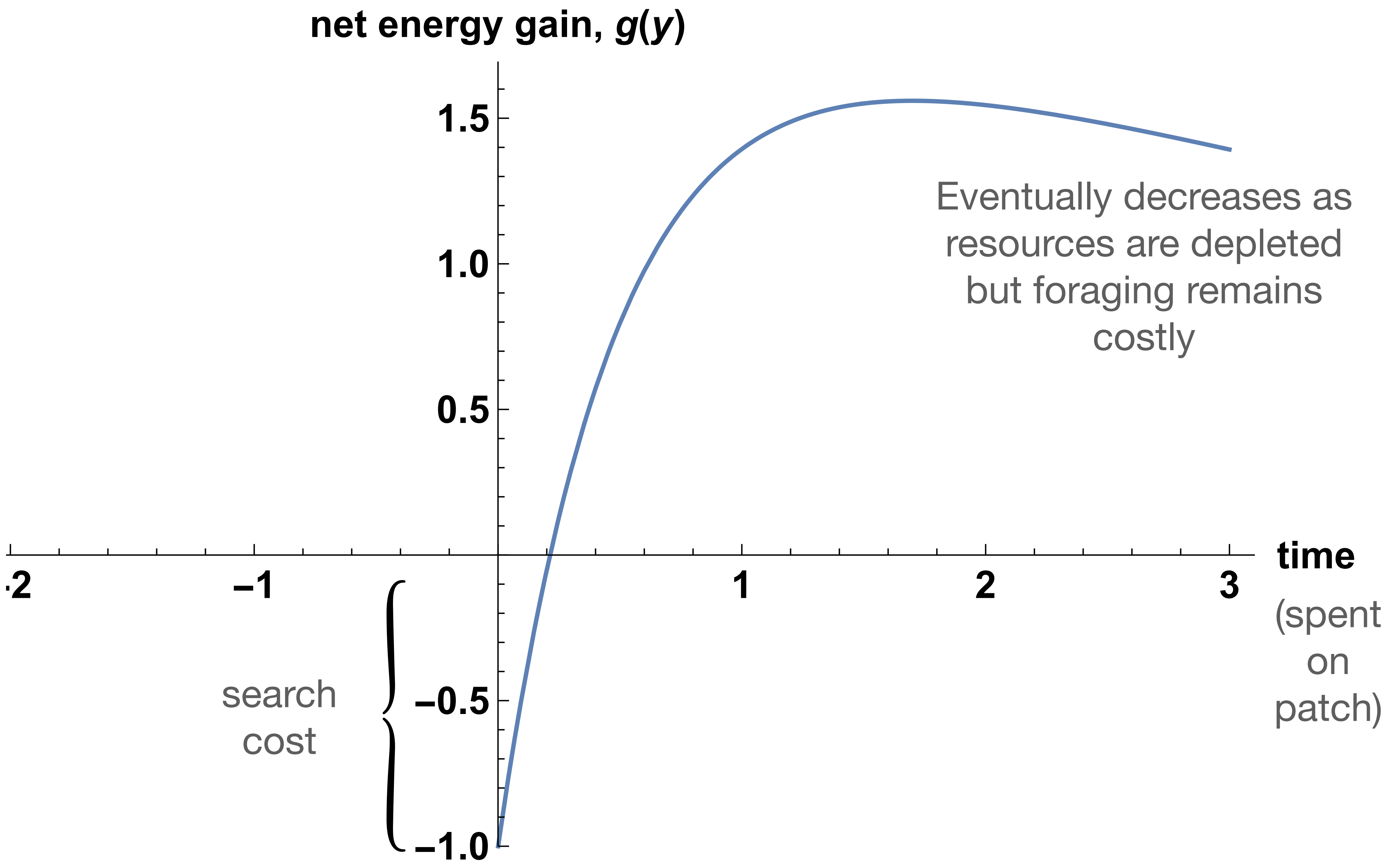


Energy gains

- $g(y)$: **net** energy gain from staying *y* in a patch
- Rate of energy gain from search + foraging :

$$R(y) = \frac{g(y)}{y + T}$$





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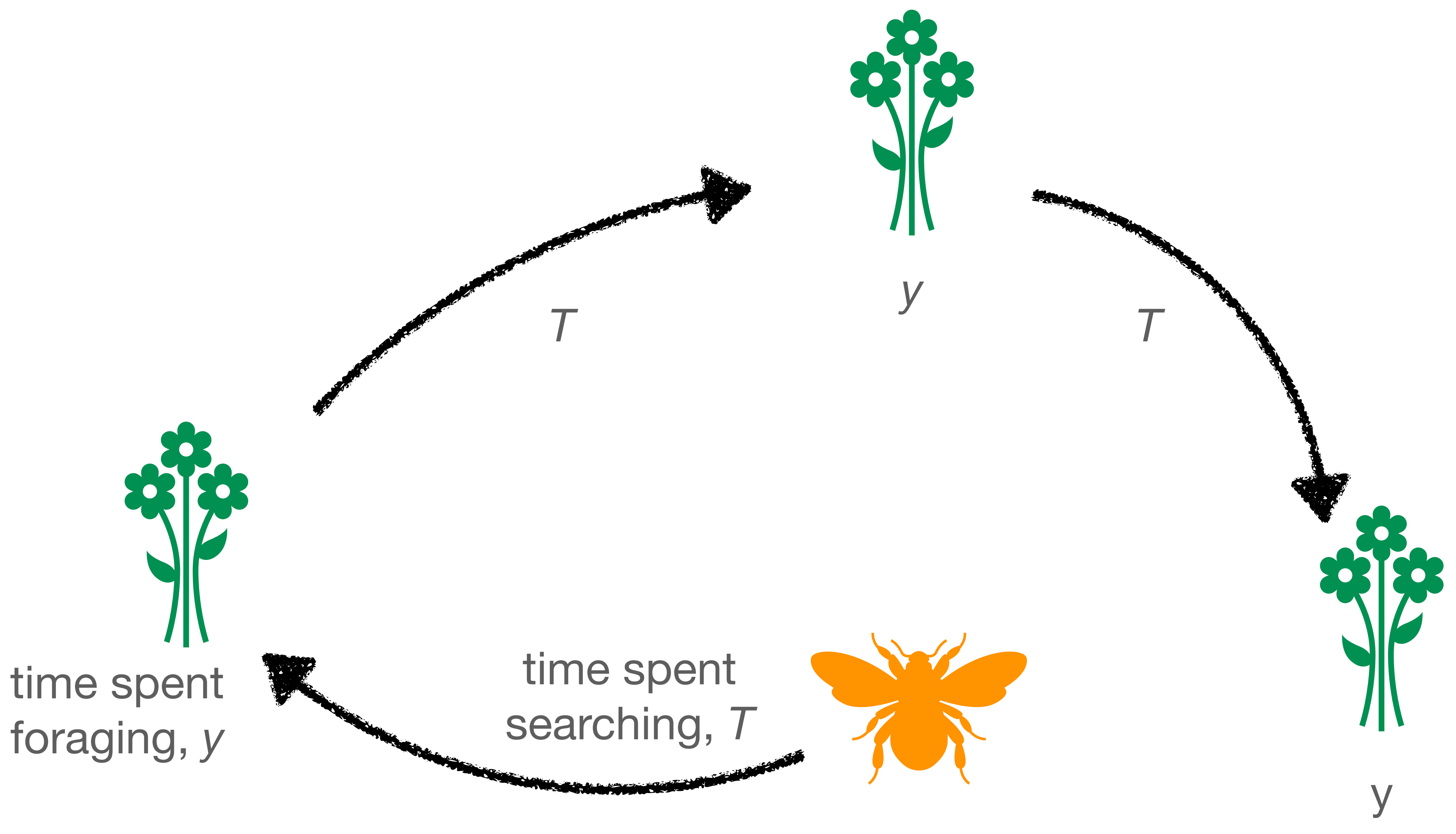

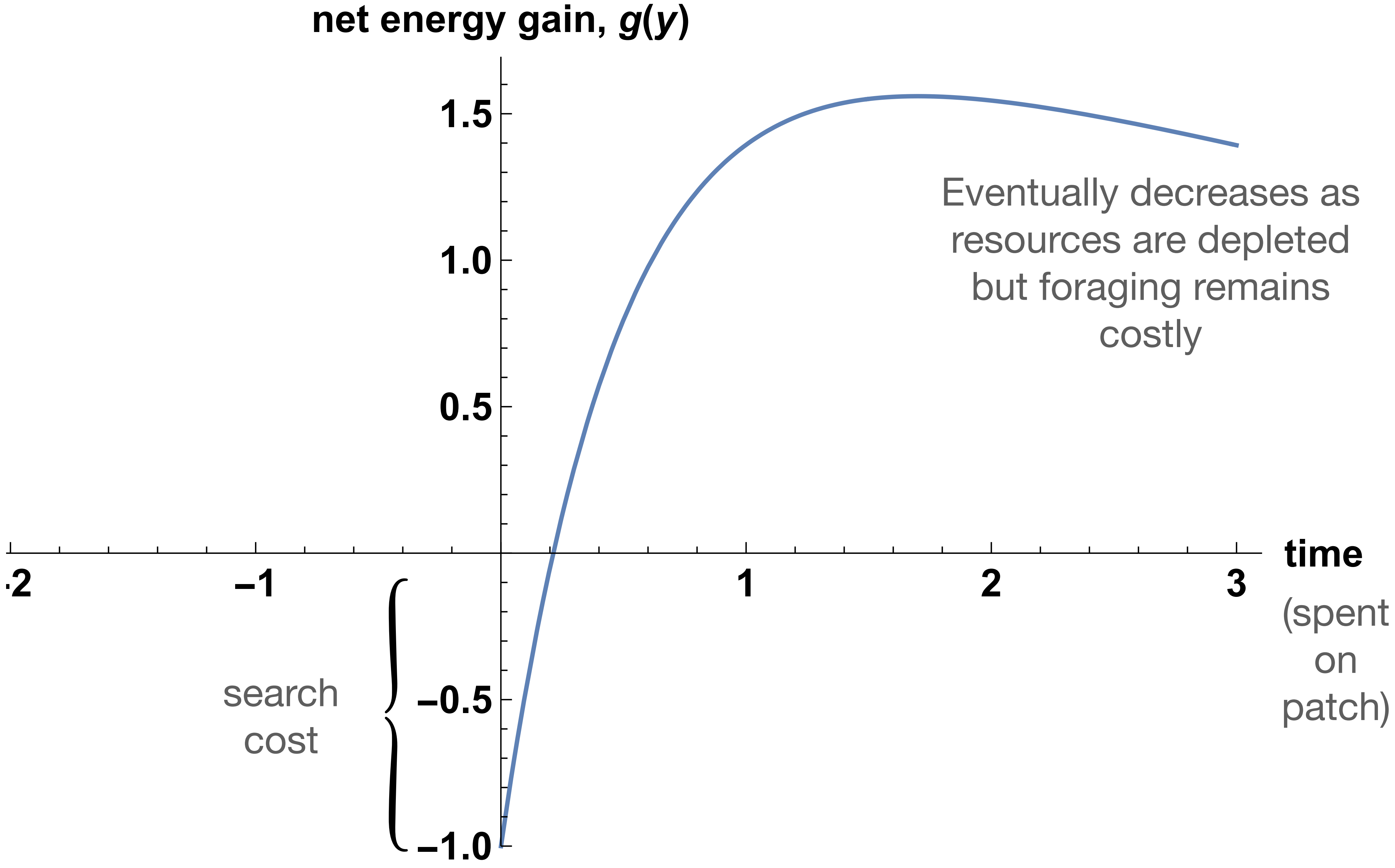

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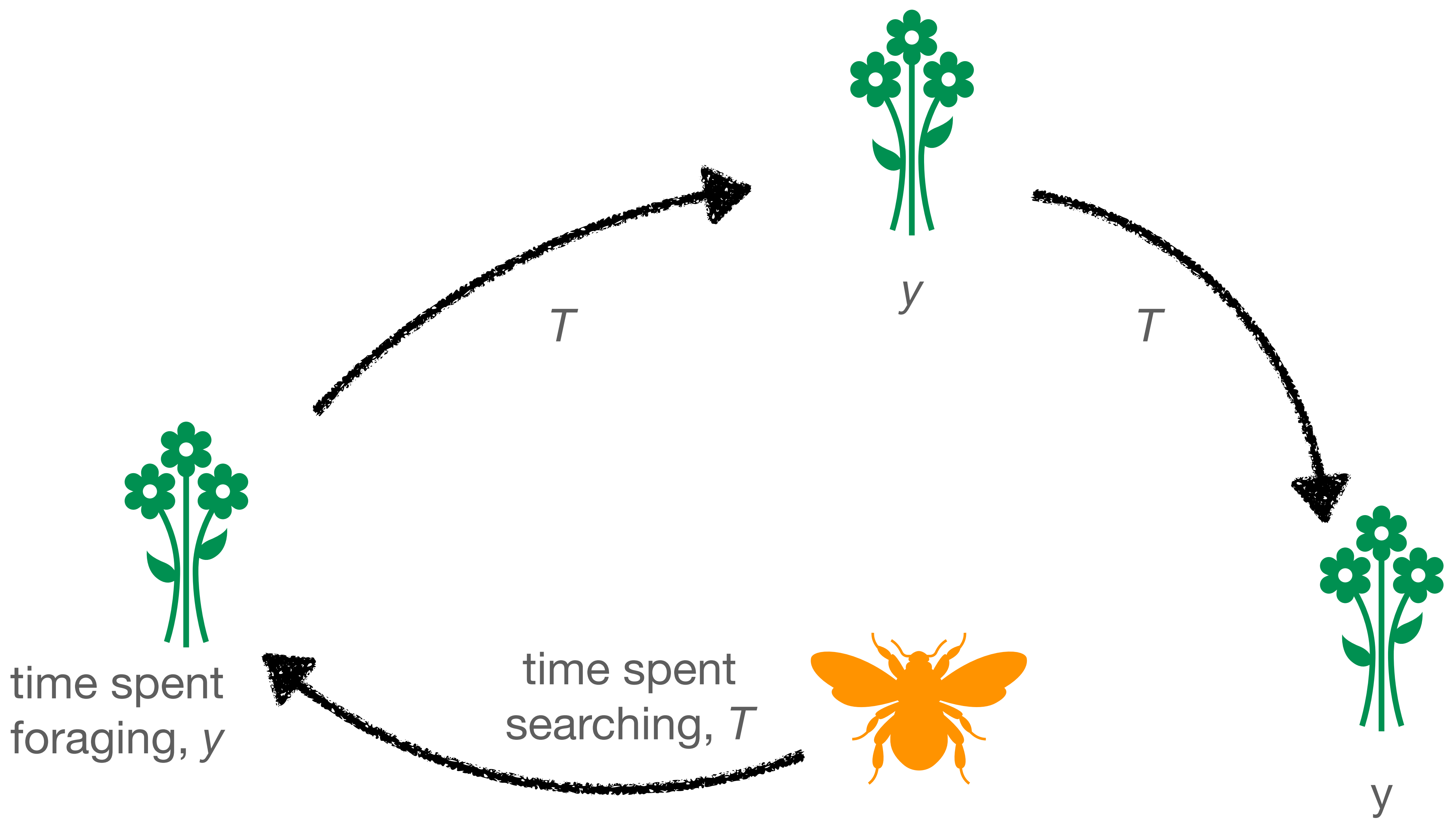
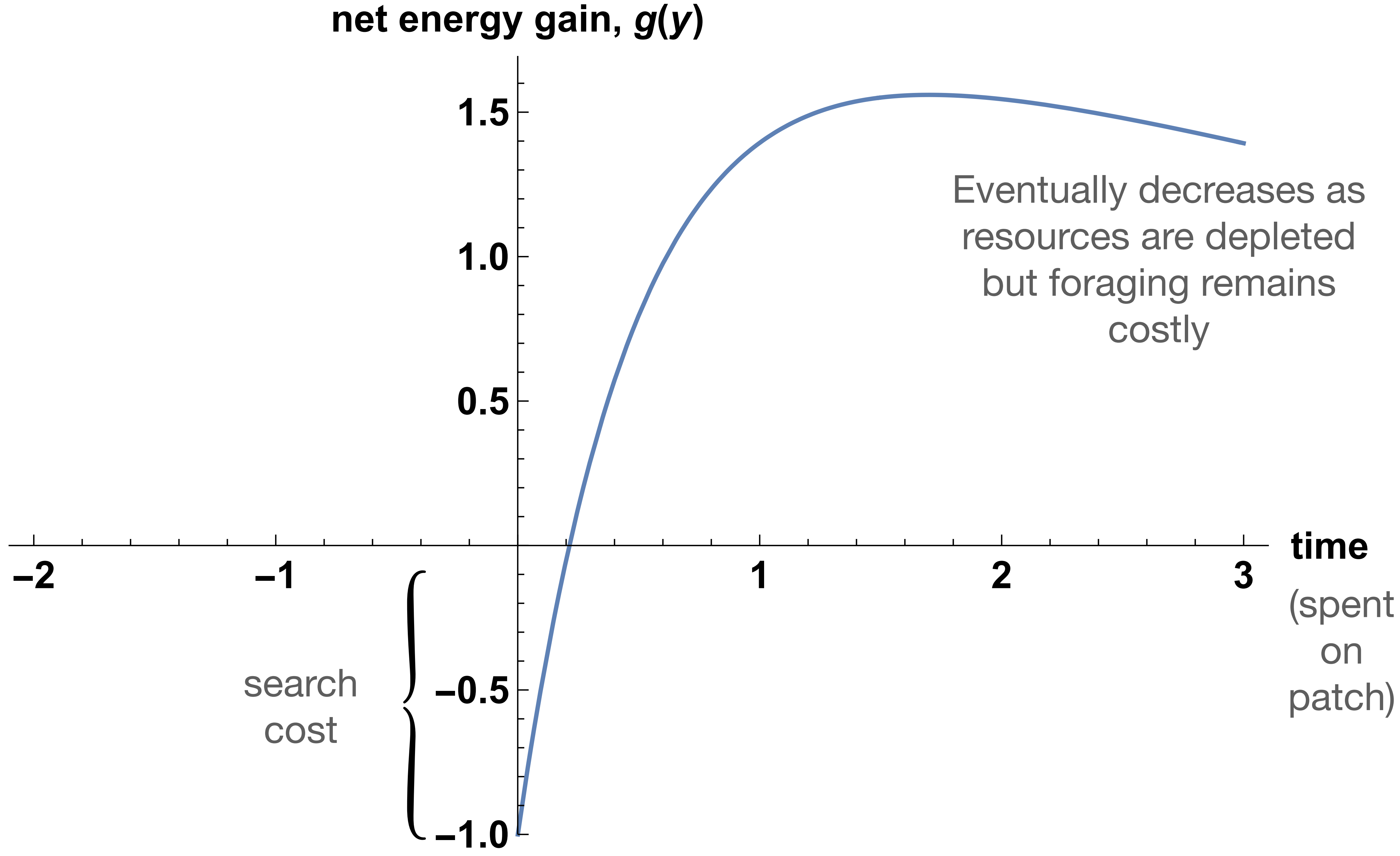
$$R(y) = \frac{g(y)}{y+T}$$

- Fitness : $w(y,x) \propto R(y)$
- Selection gradient :

$$s(x) \propto \frac{g'(x)}{x+T} - \frac{g(x)}{(x+T)^2}$$



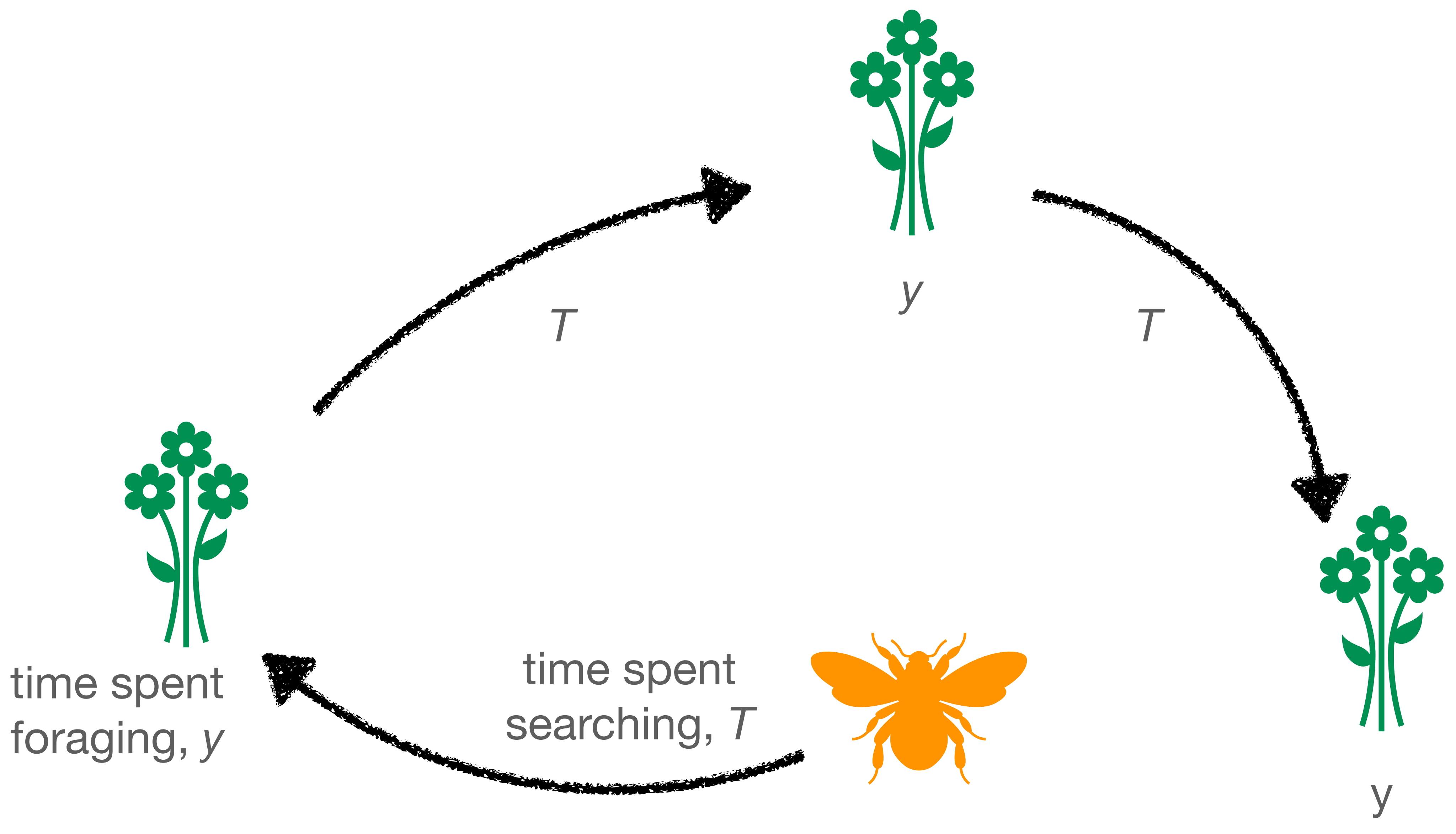


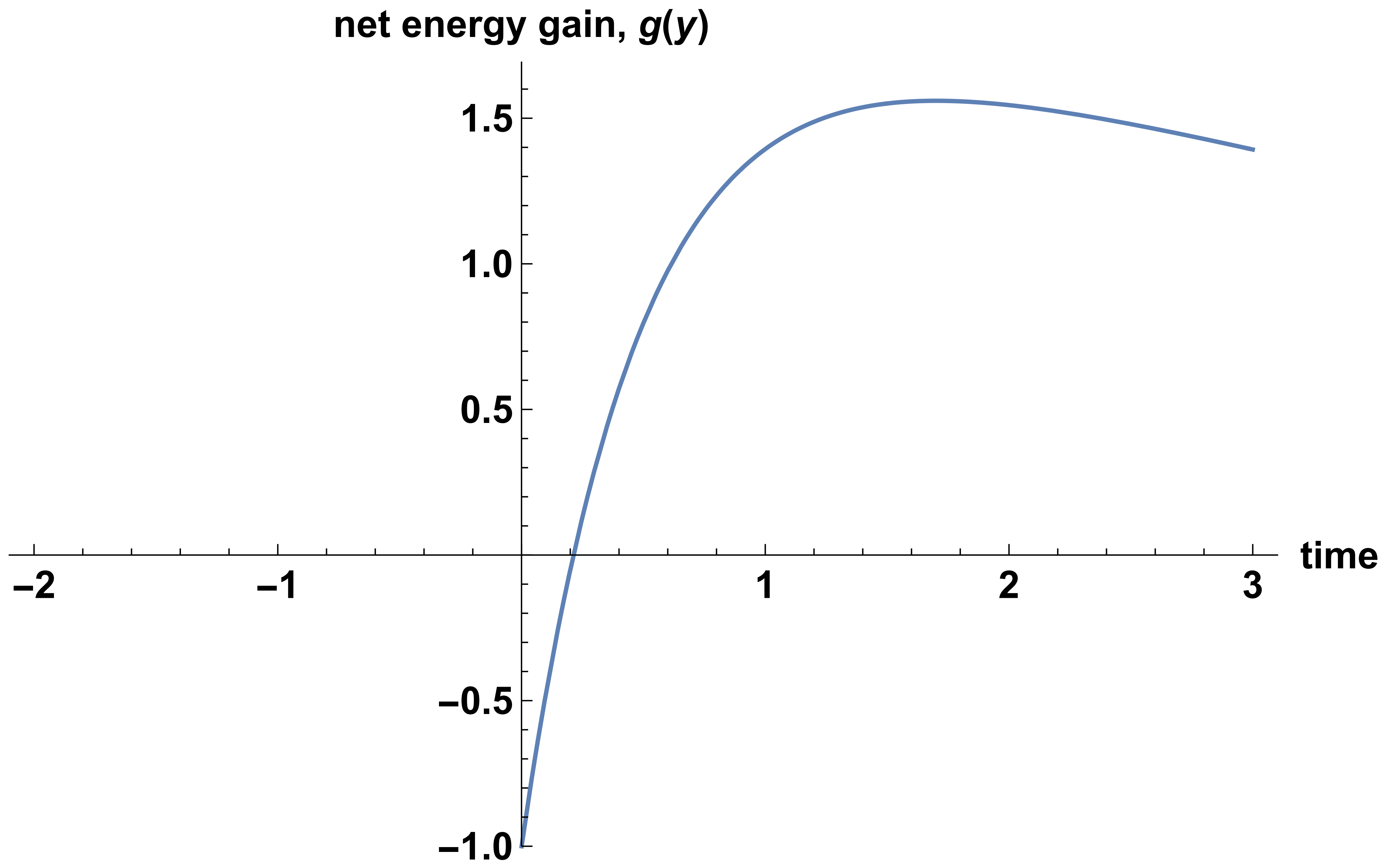
Marginal value theorem

Optimum x^* such that $s(x^*) = 0$,

i.e., such that

$$g'(x^*) = \frac{g(x^*)}{x^* + T} = R(x^*)$$





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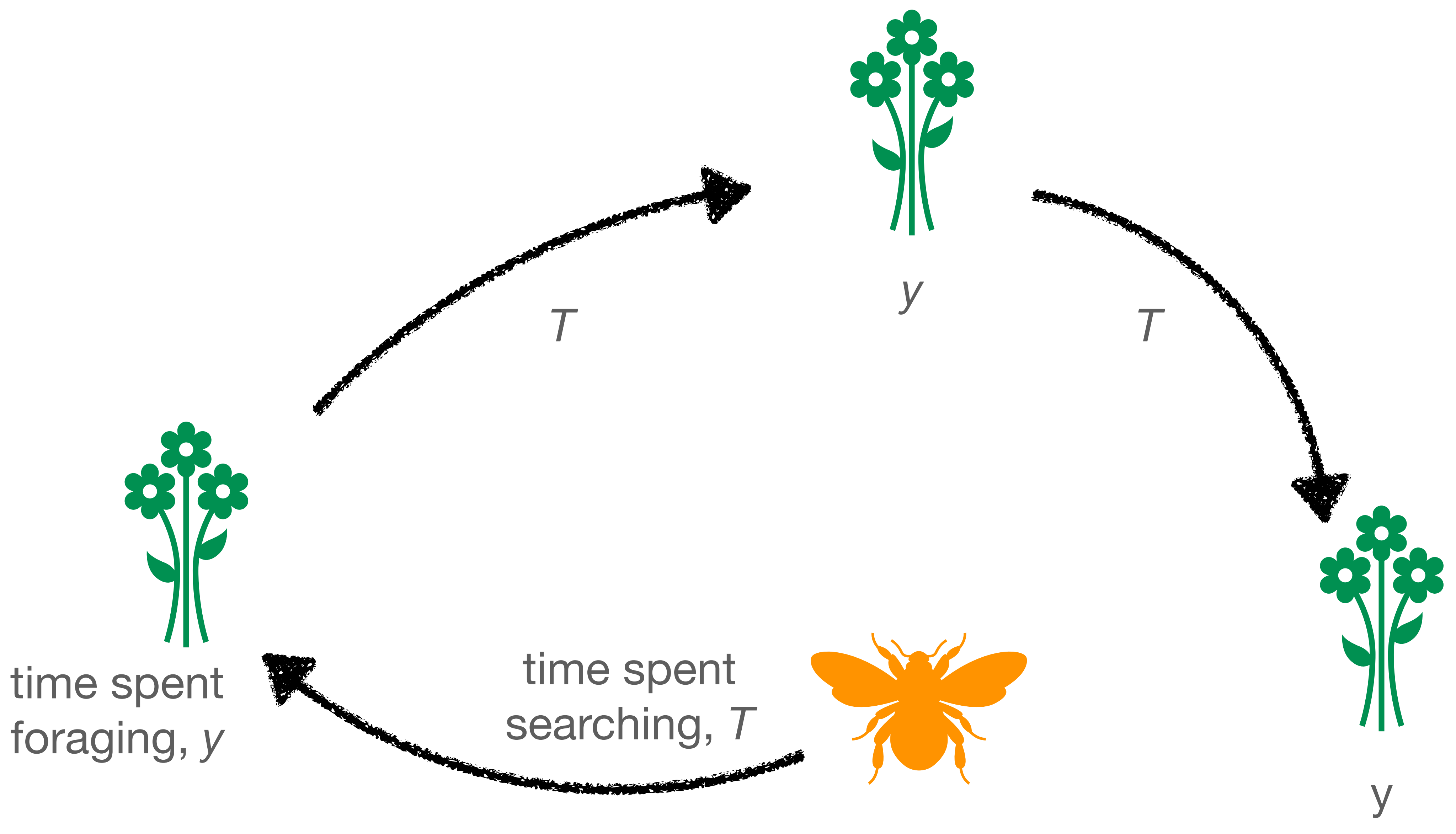

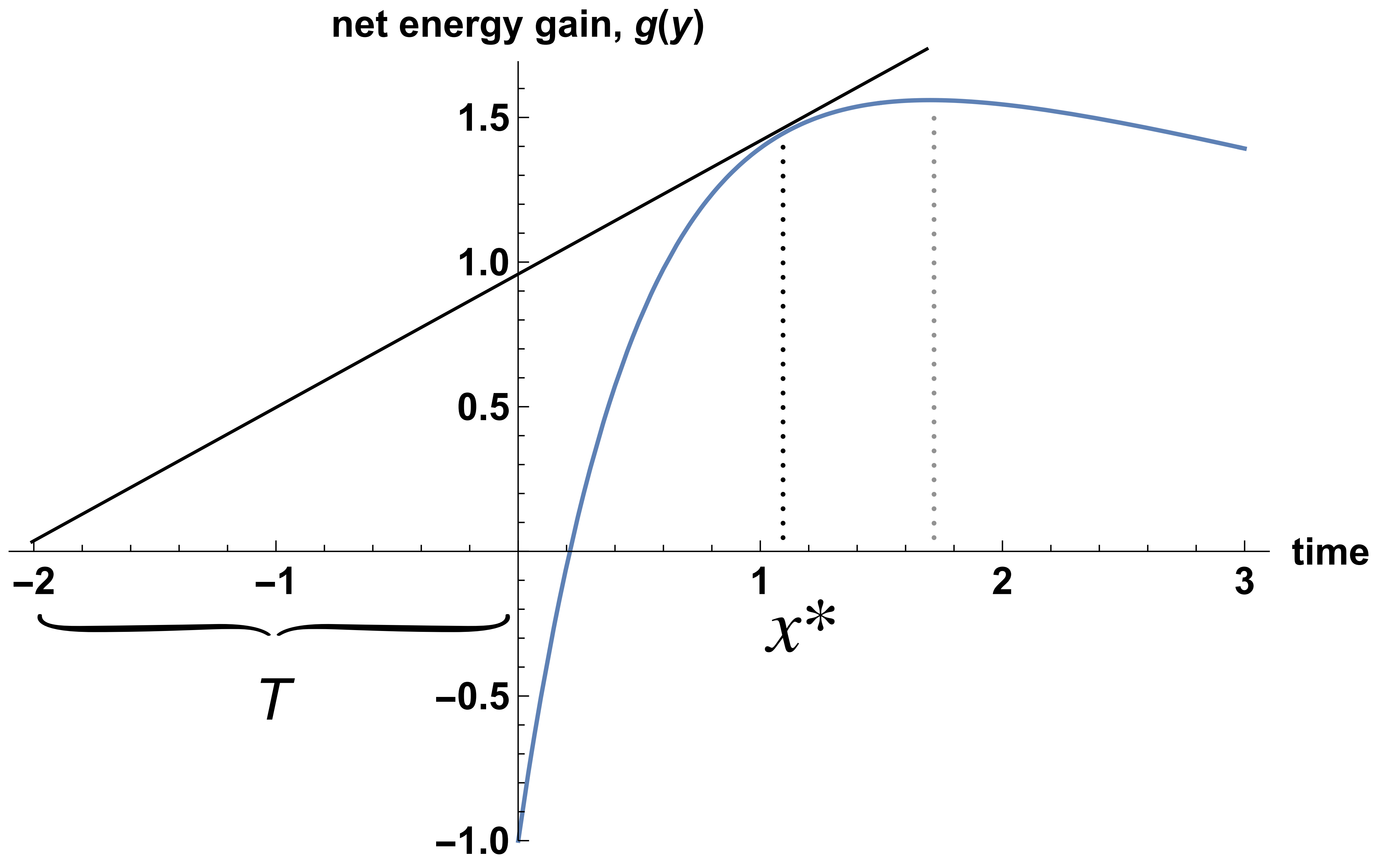

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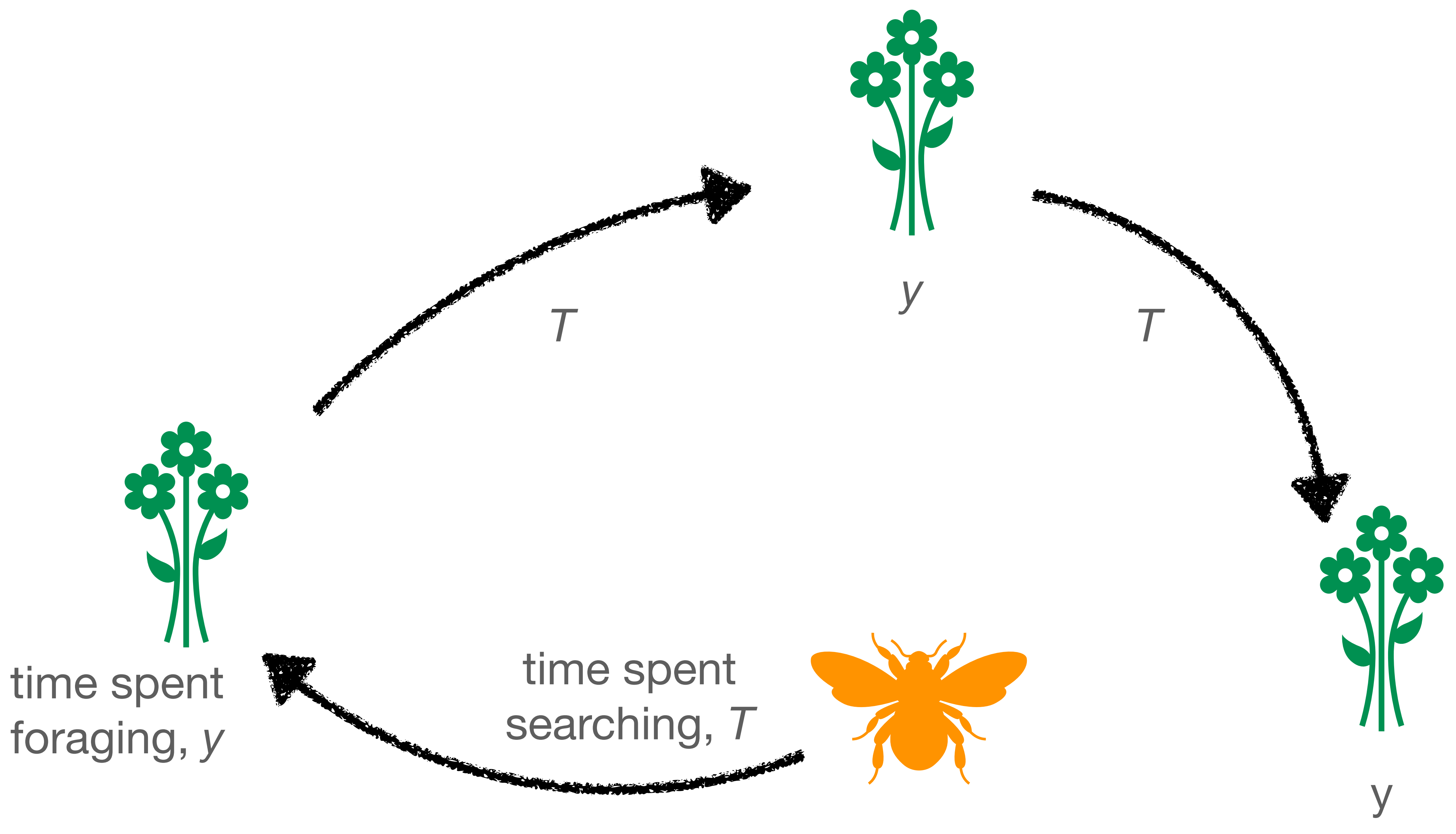
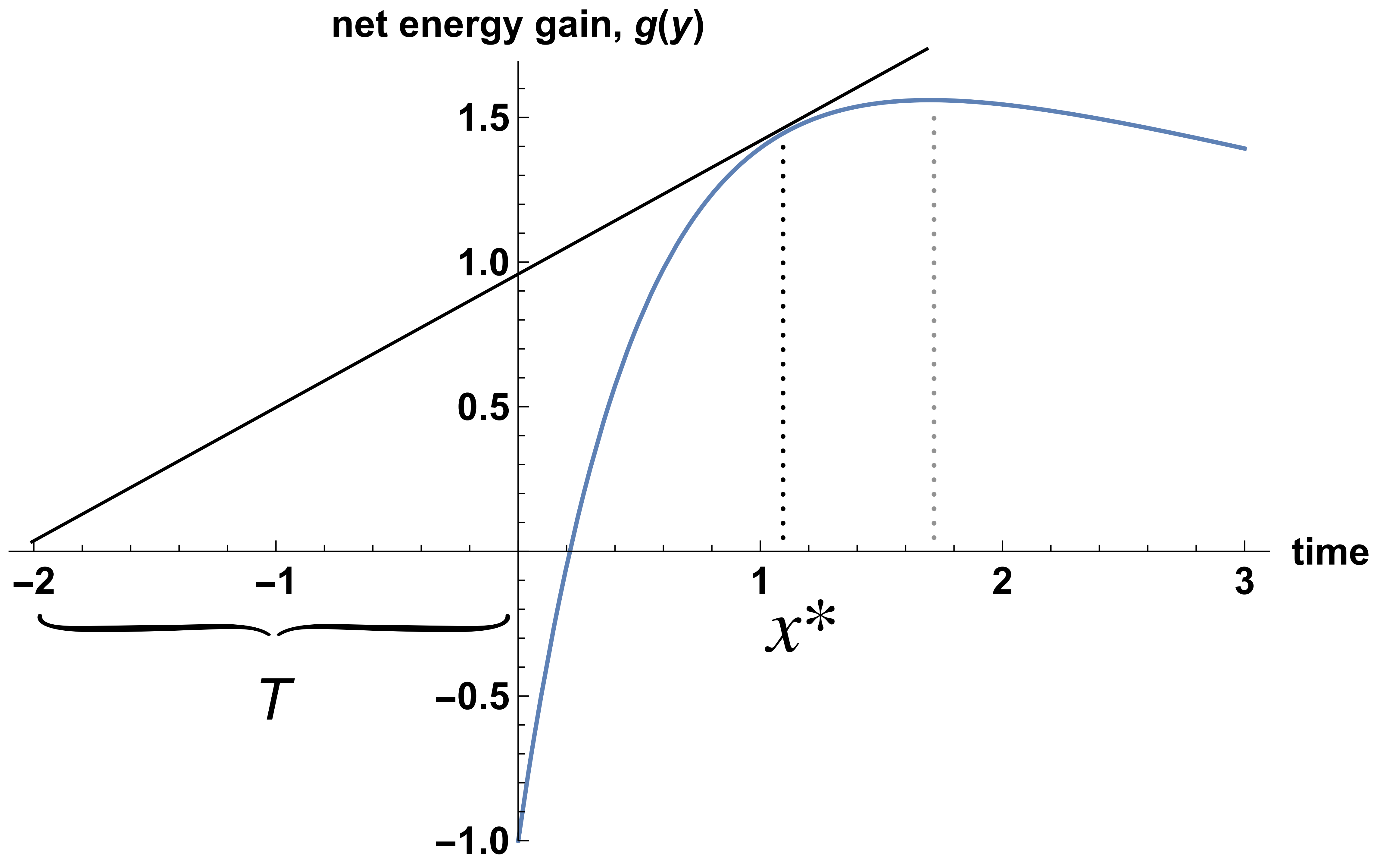
An animal should leave when the marginal (or instantaneous) rate of energy gain $g'(x^*)$ has fallen to the rate of energy gain $R(x^*)$





When selection favours risky foraging?

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Variation in relationship with uncertainty

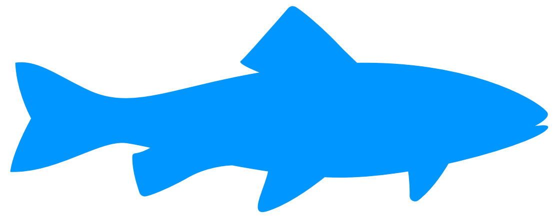
When selection favours risky foraging?

State-dependent payoffs and uncertainty

When selection favours risky foraging?

State-dependent payoffs and uncertainty

High condition
e.g., well-fed



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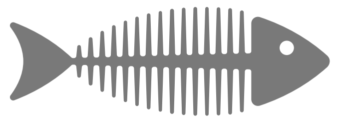

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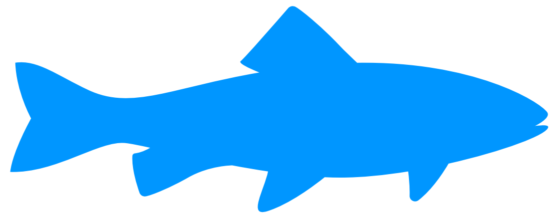

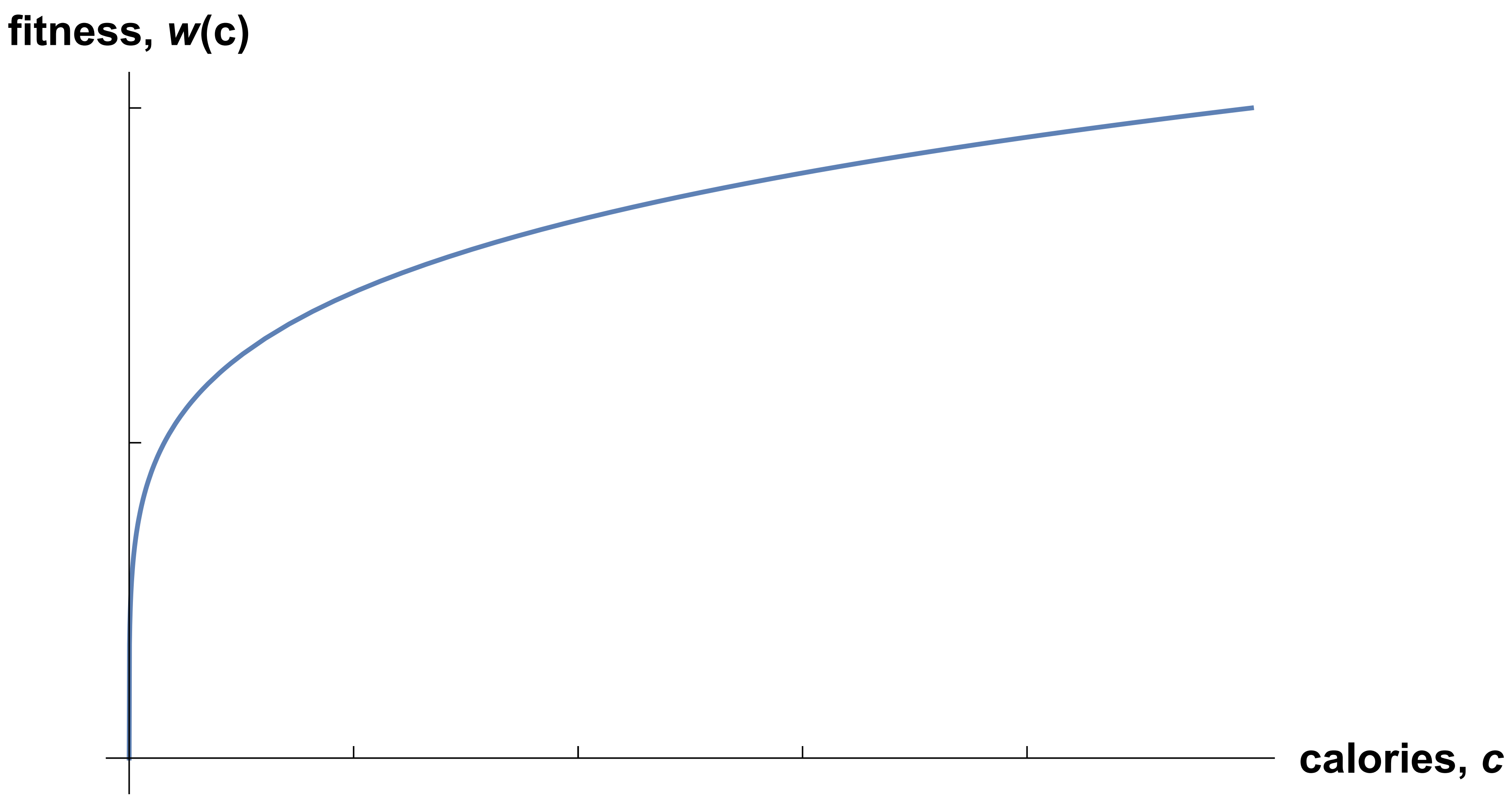

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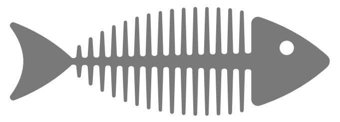

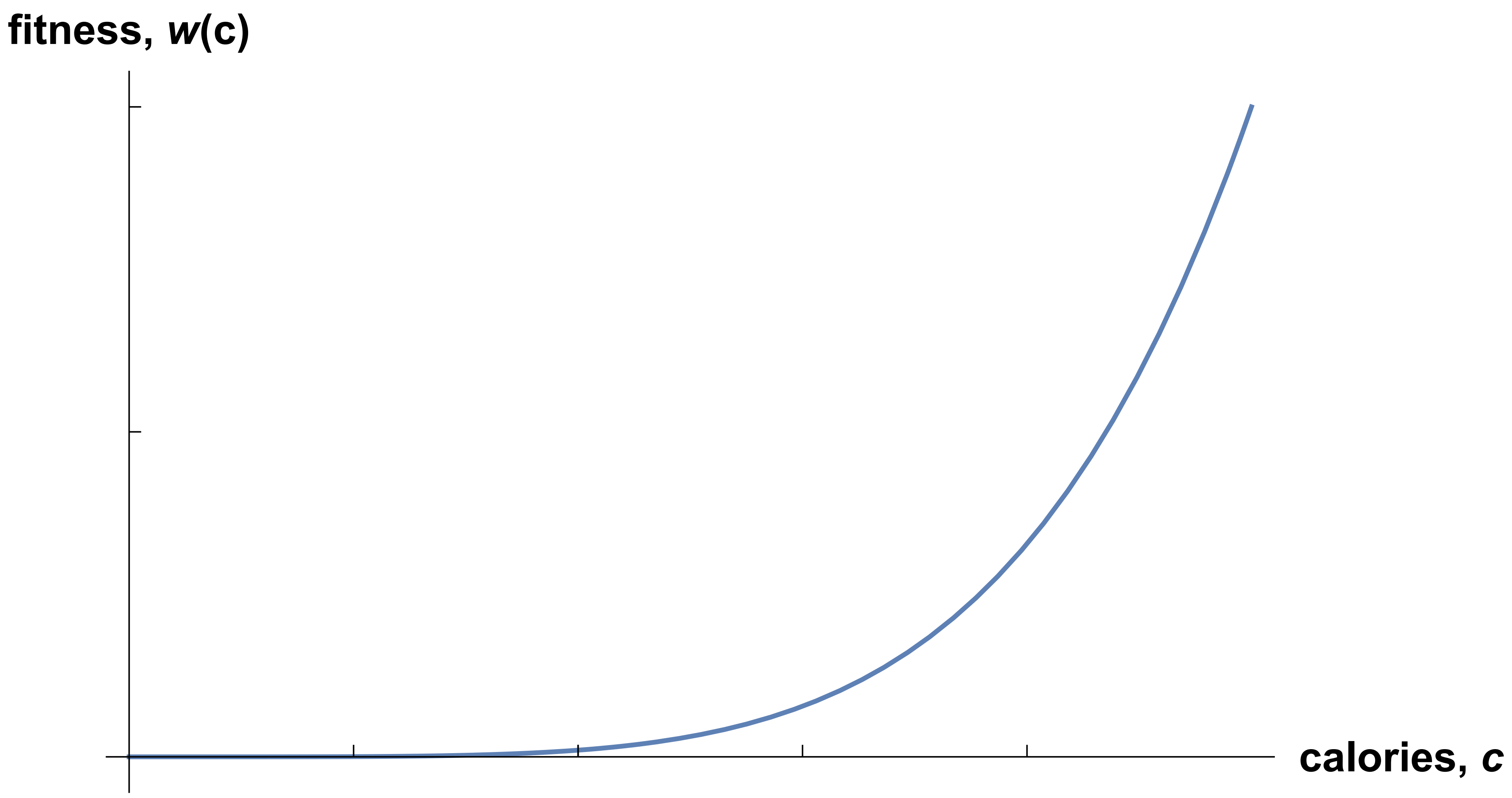

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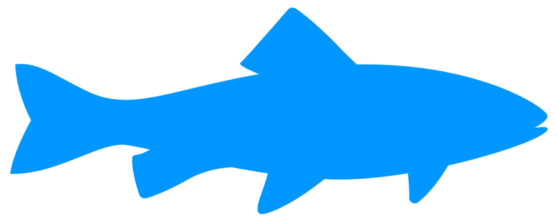

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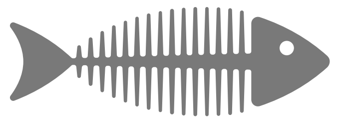

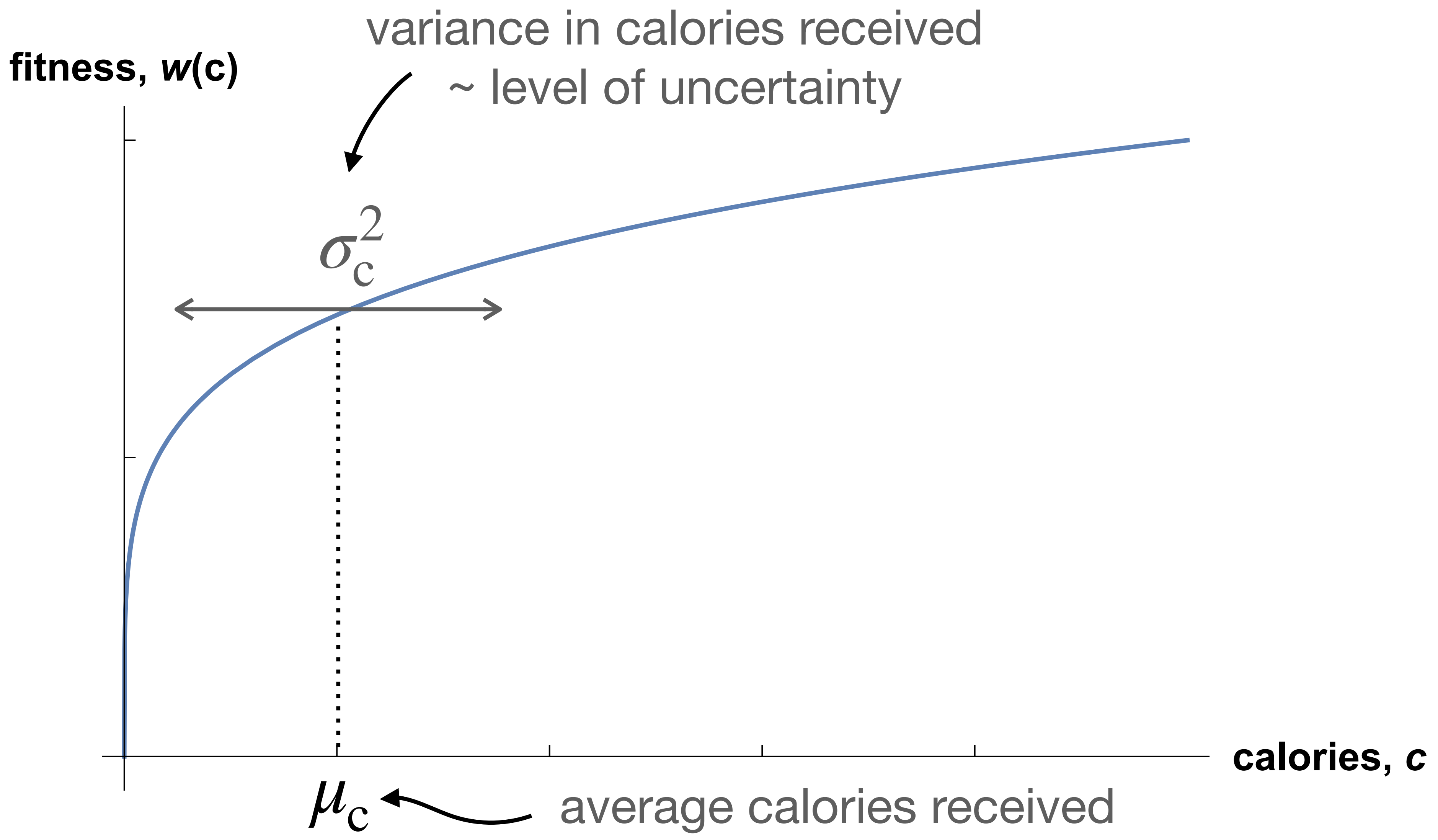

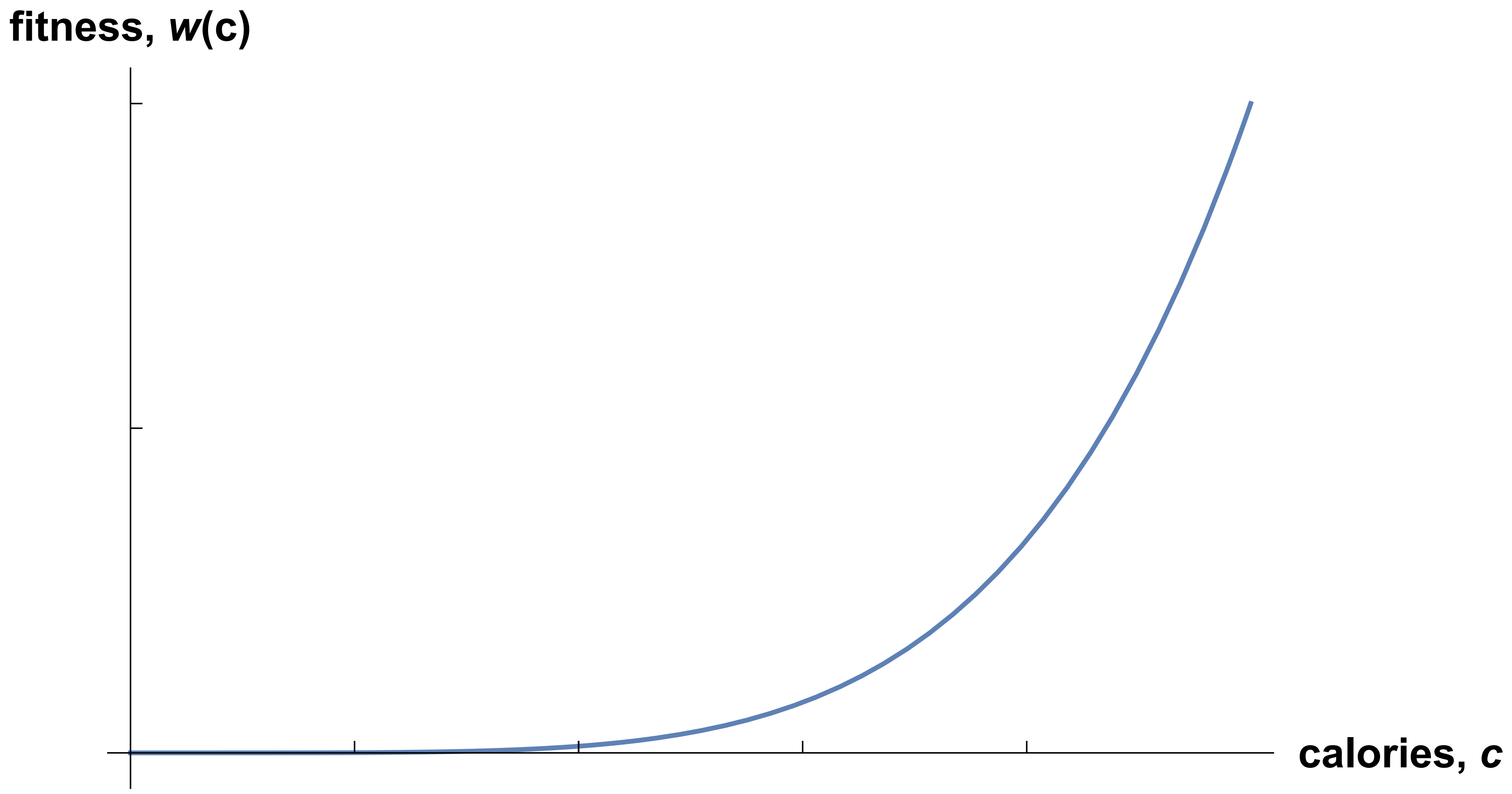

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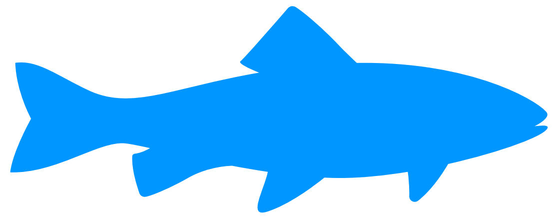

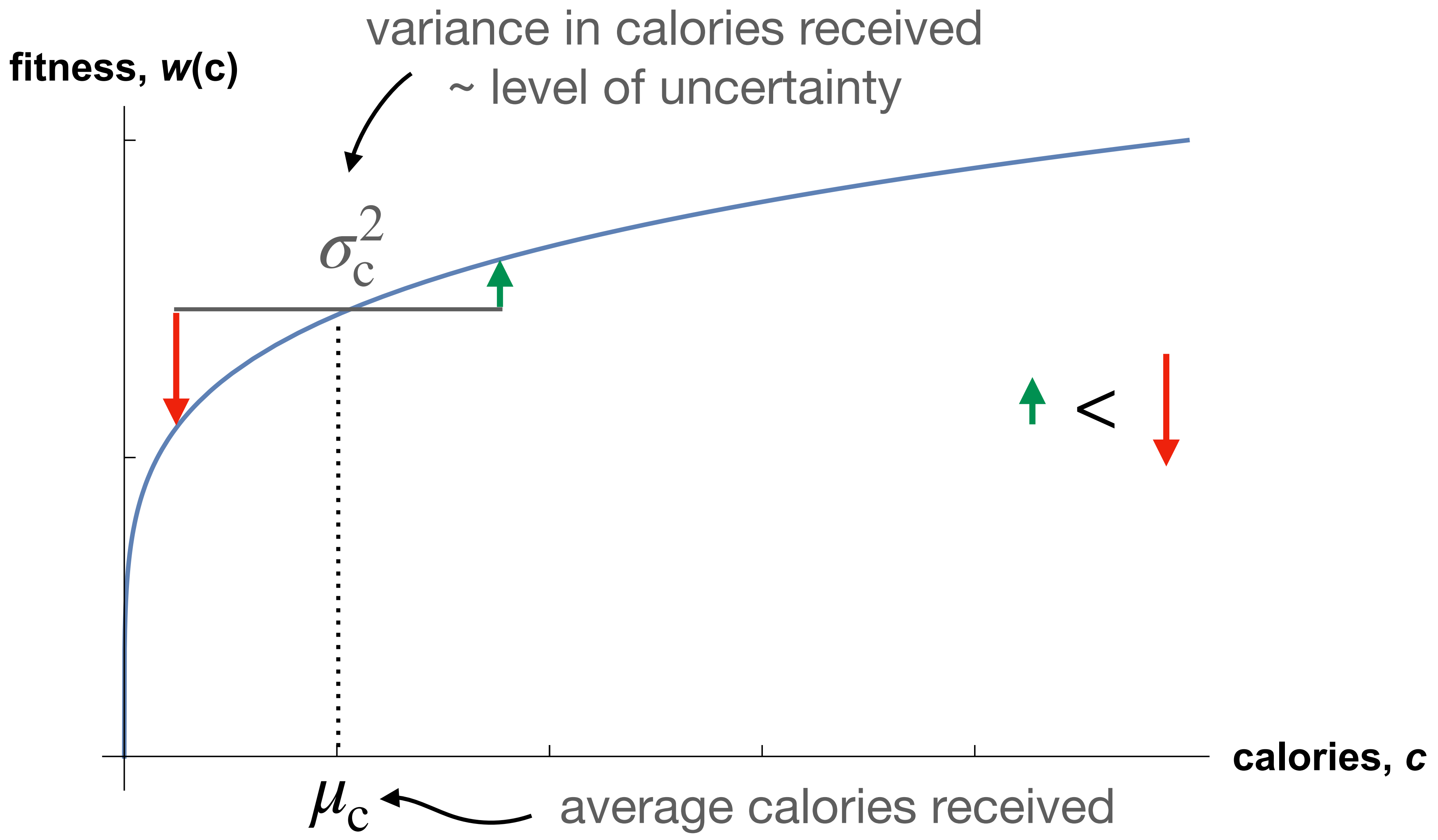

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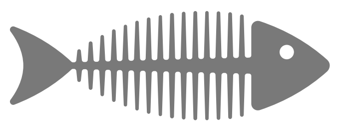

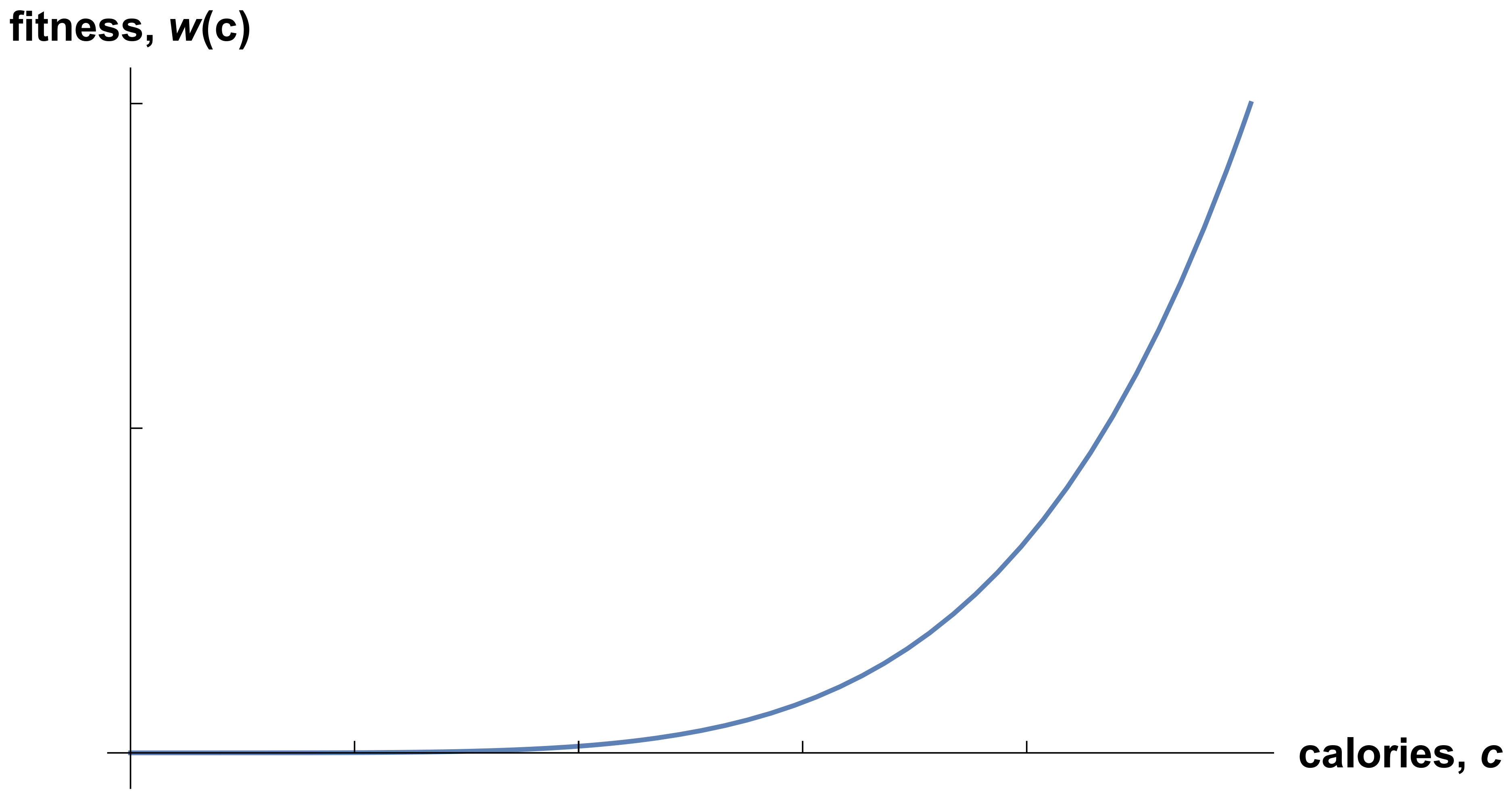

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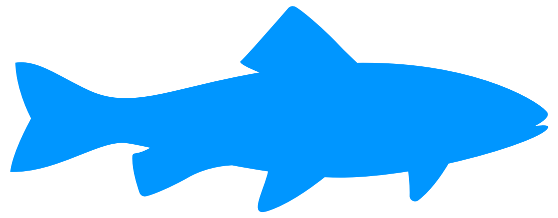

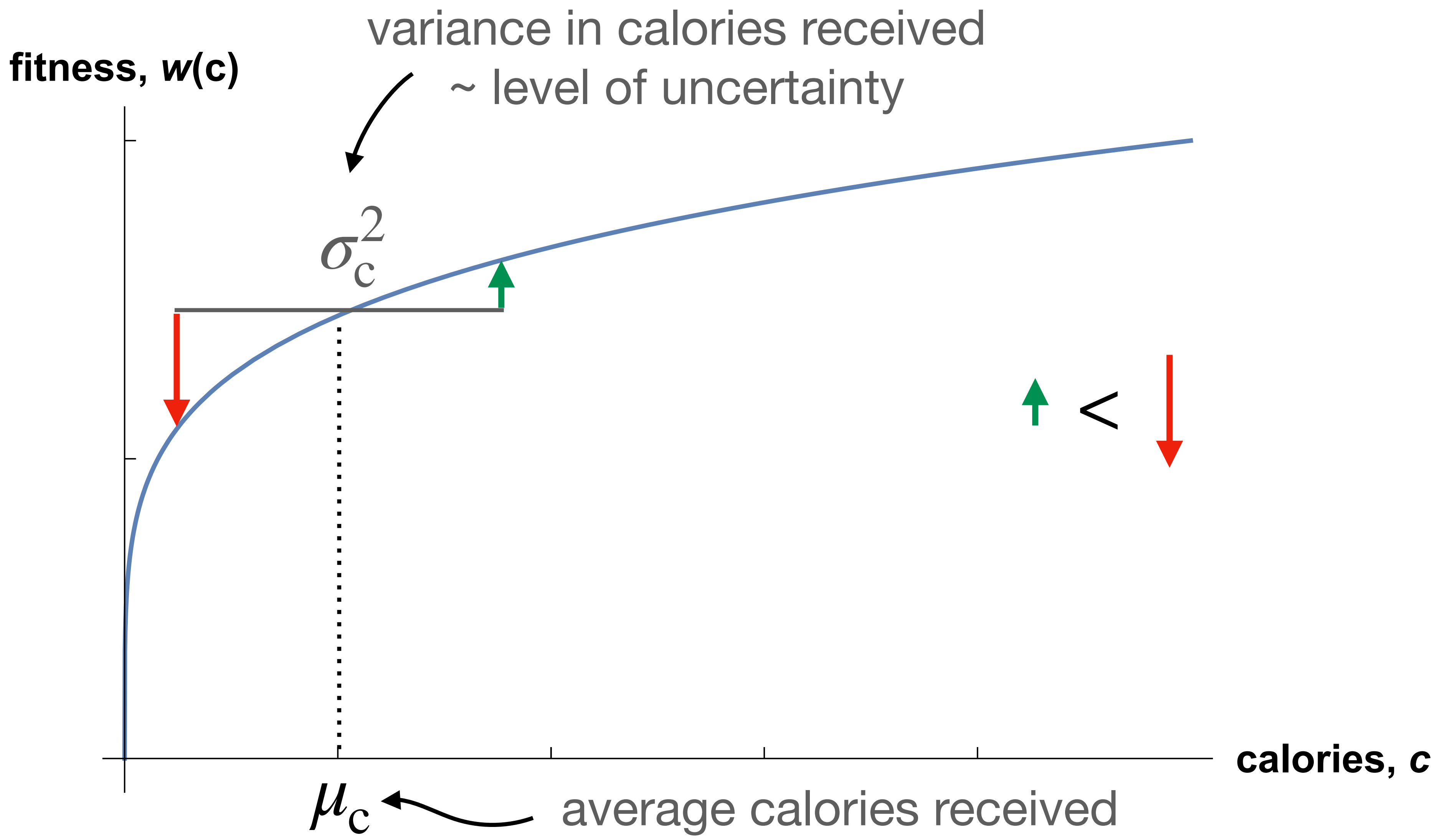

Risk not worth taking: fitness cost of bad times outweighs fitness benefits of good times

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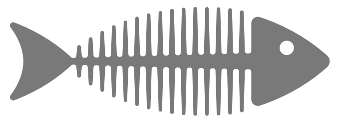

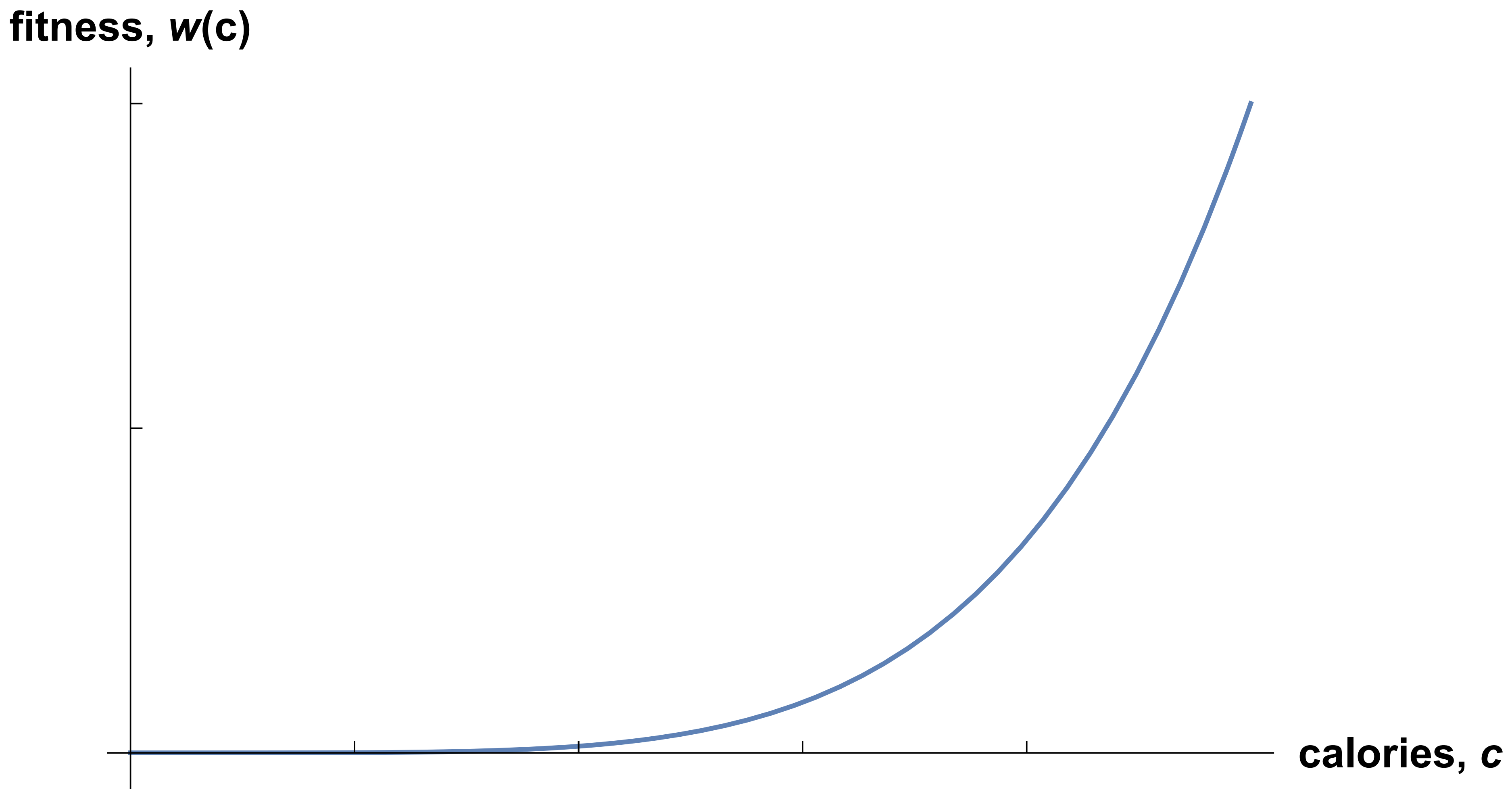

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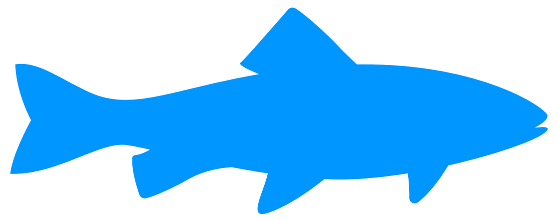

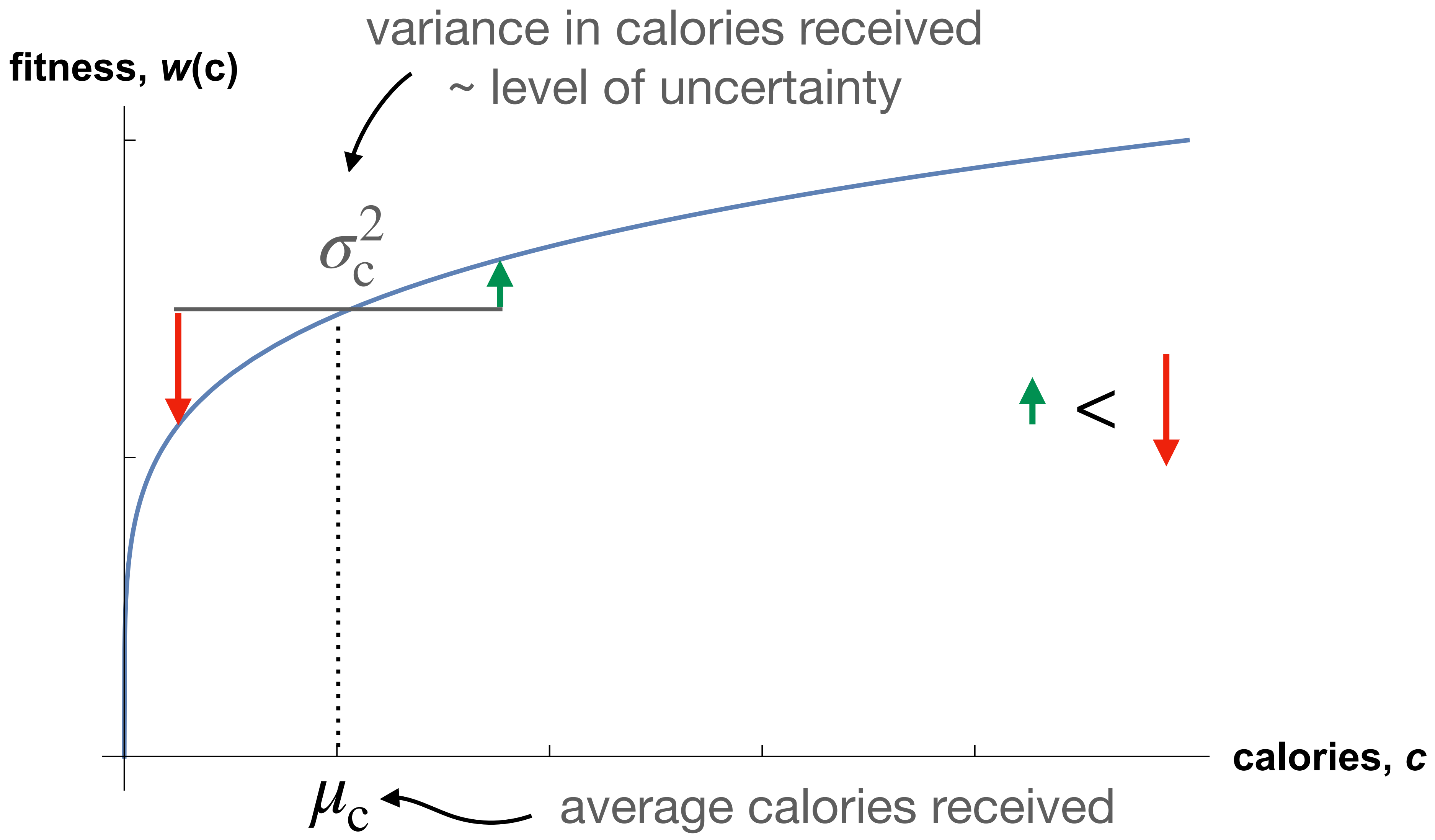

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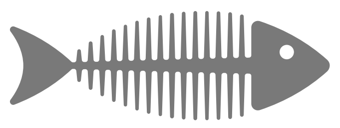

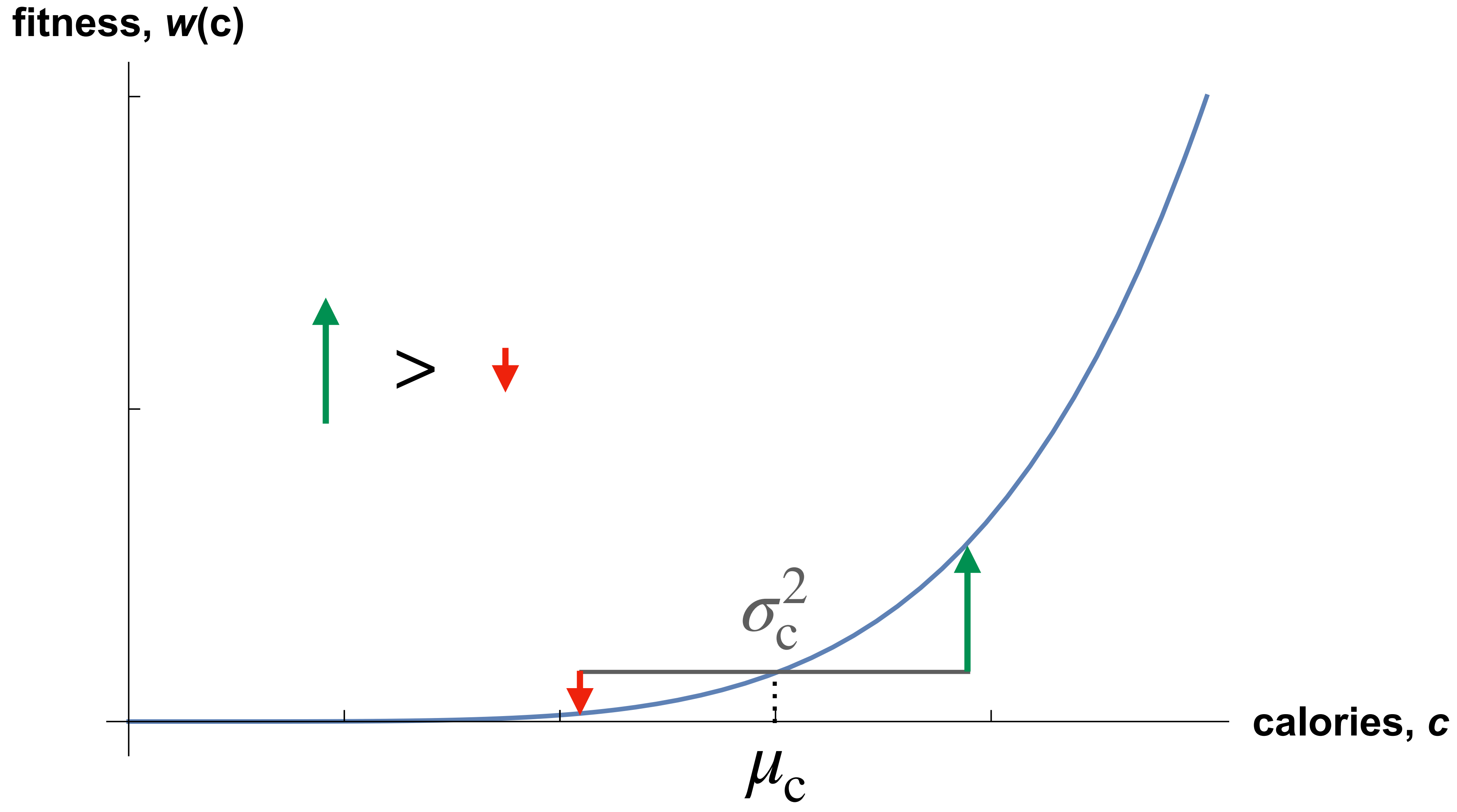

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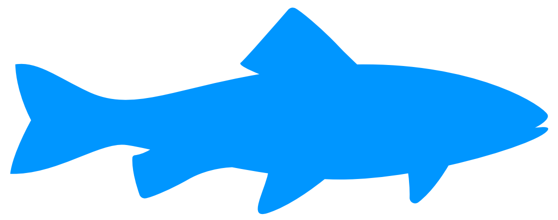

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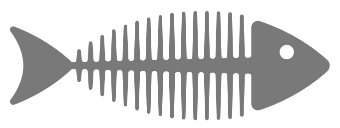

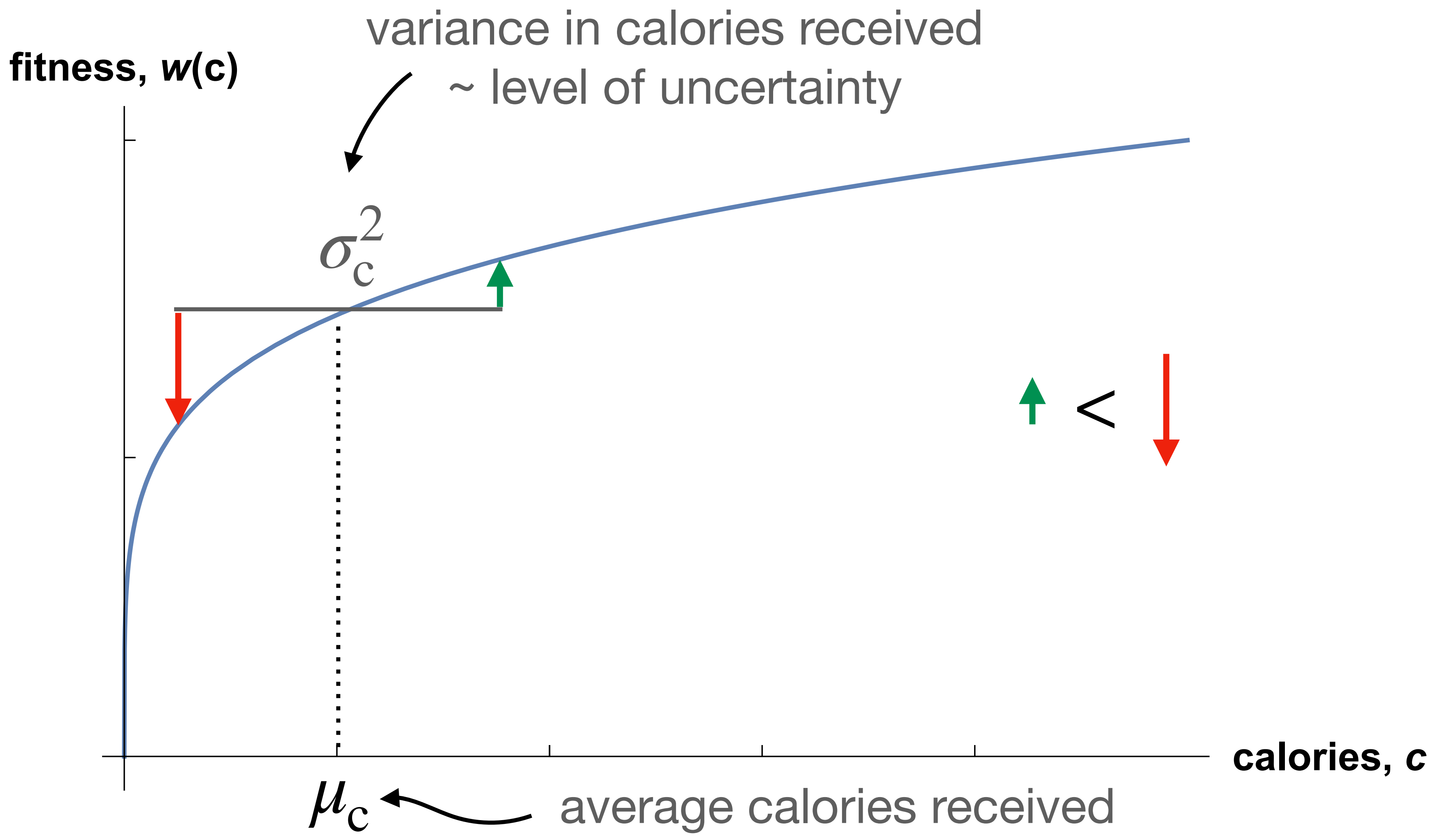

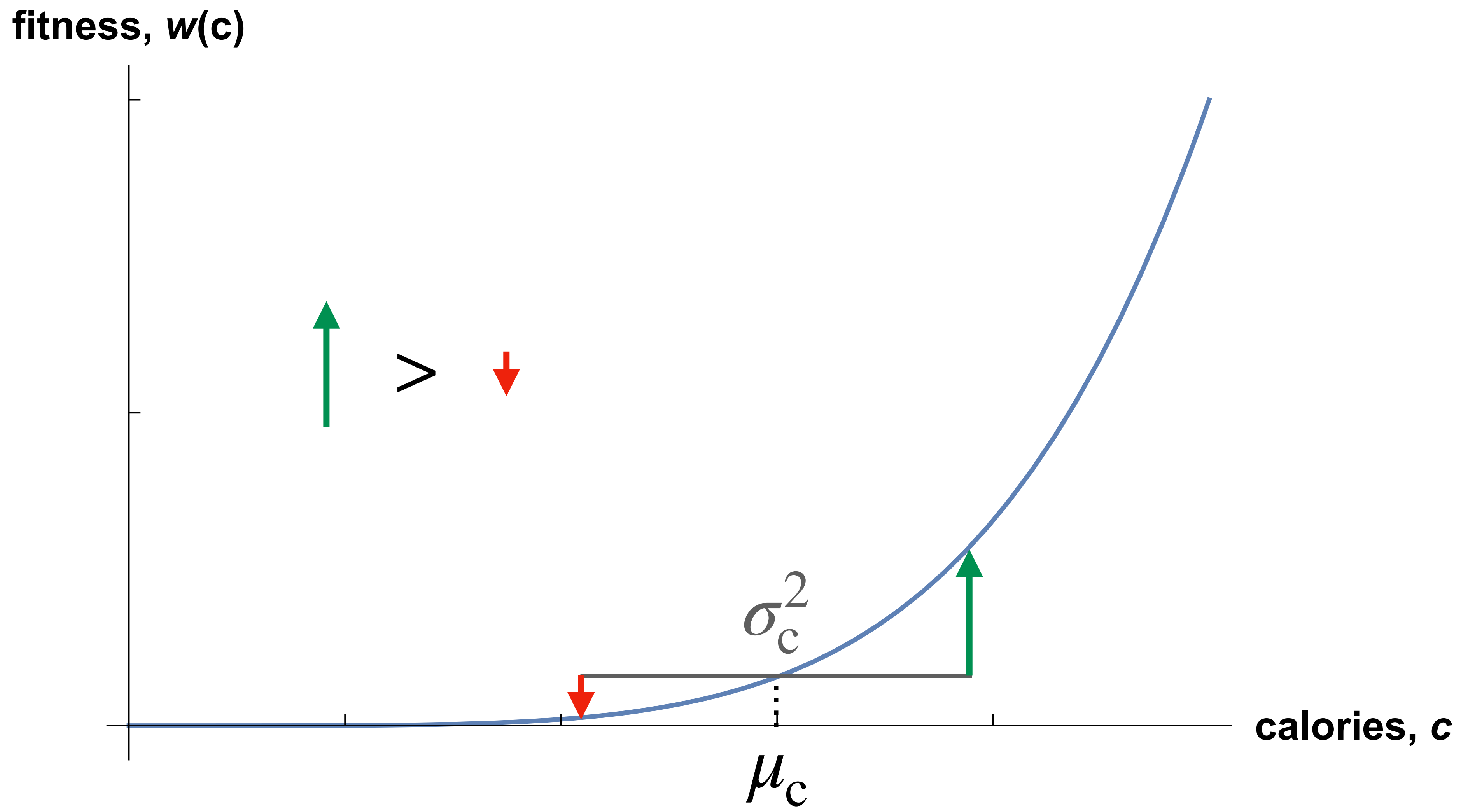

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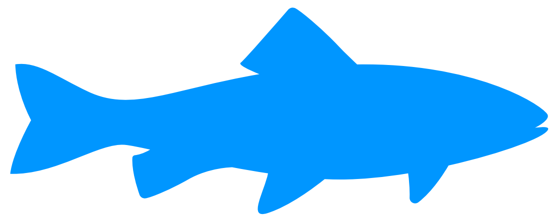

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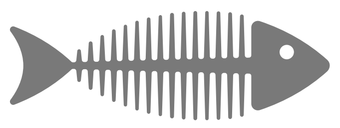
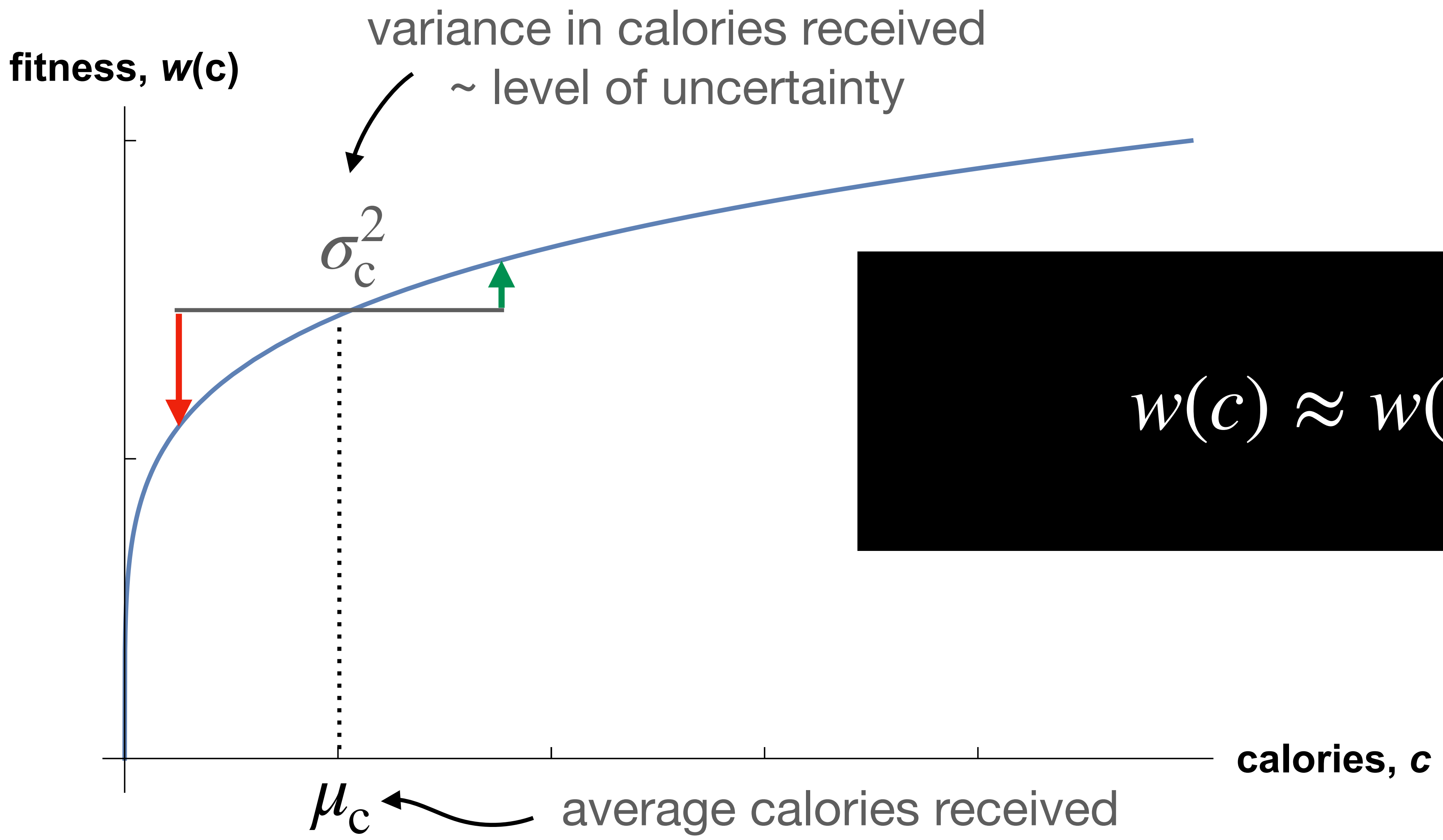
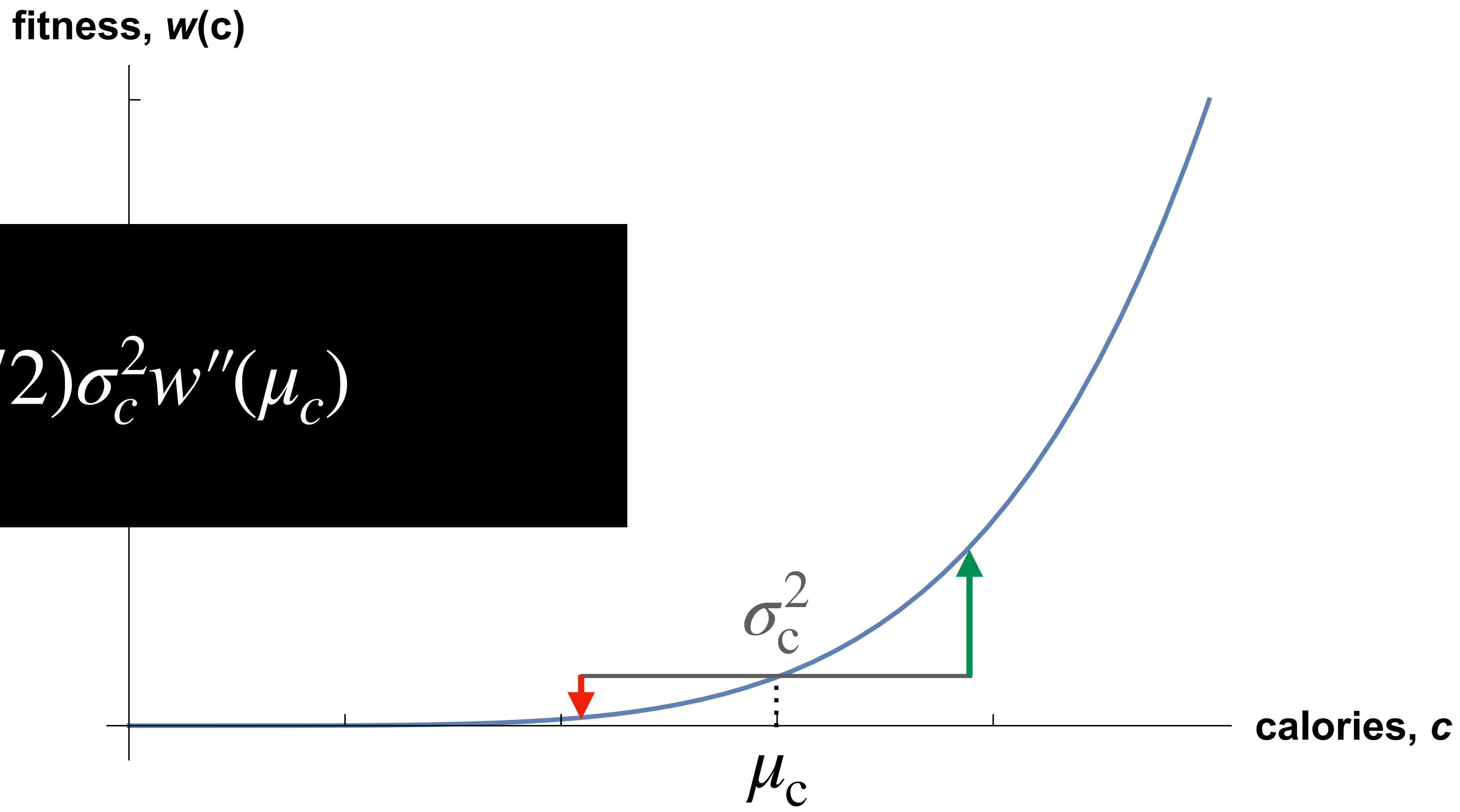




$$w(c) \approx w(\mu_c) + (1/2)\sigma_c^2 w''(\mu_c)$$



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The exploitation of renewable resources

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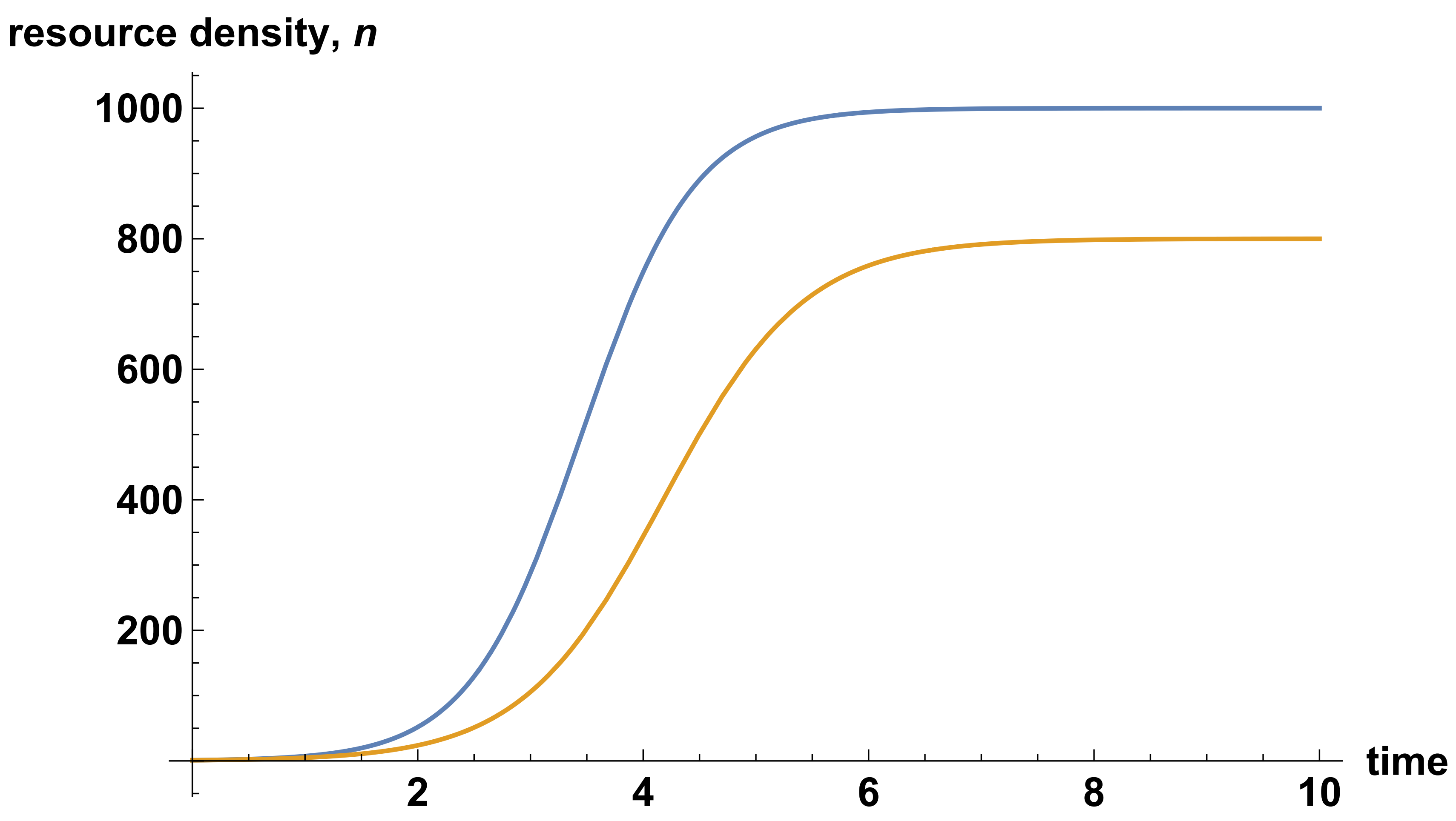
Shaefer's model

- Biotic resource with density n,

foraging function

$$\frac{dn}{dt} = \underbrace{r\left(1 - \frac{n}{K}\right)n}_{\text{logistic growth}} - \underbrace{n_c h(x) n}_{\text{harvesting by population of } n_c \text{ consumers with foraging effort } x}$$



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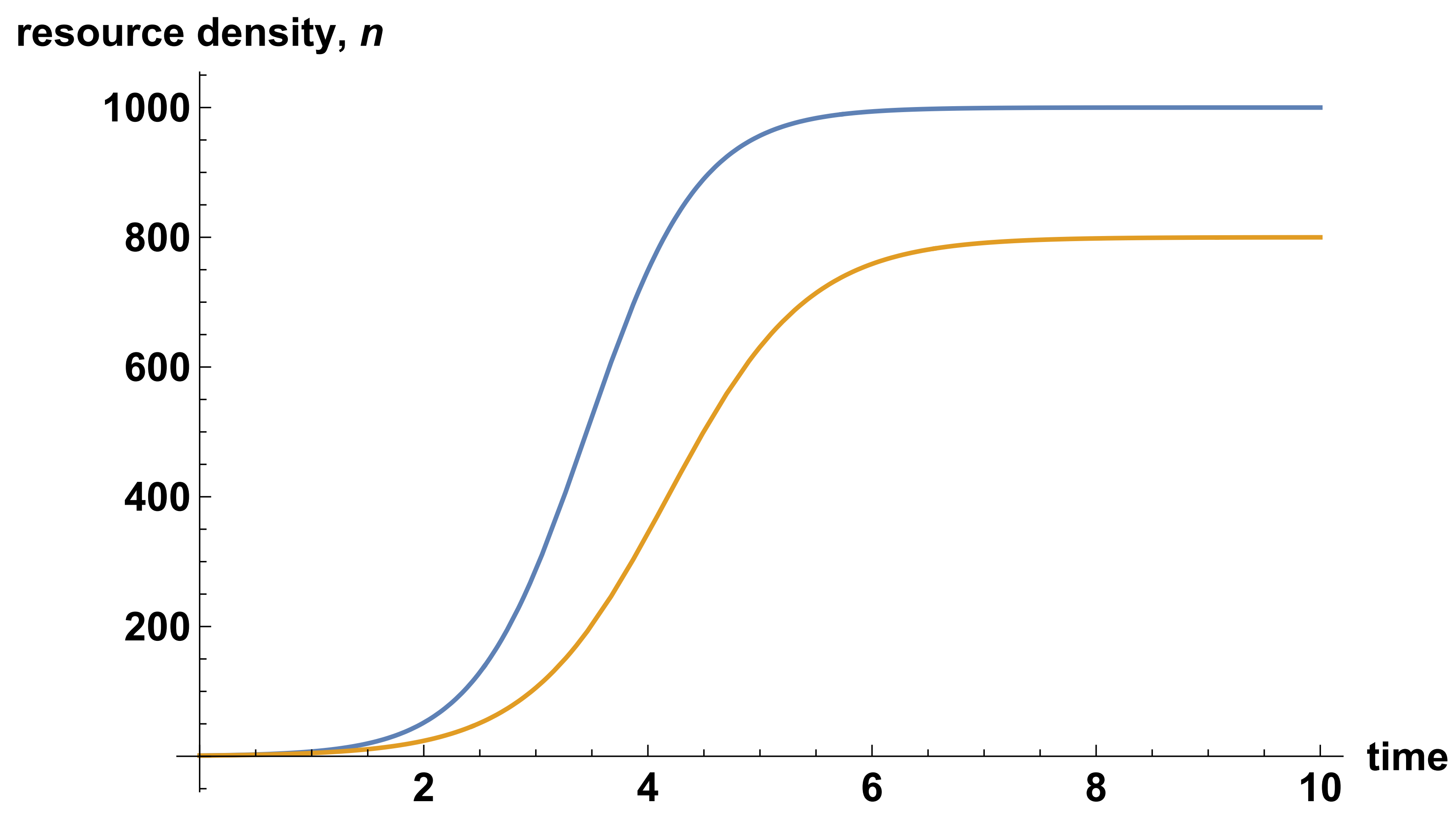

- Equilibrium resource density $\hat{n}(x)$ such that

$$\hat{n}(x) = K\left(1 - n_c \frac{h(x)}{r}\right)$$

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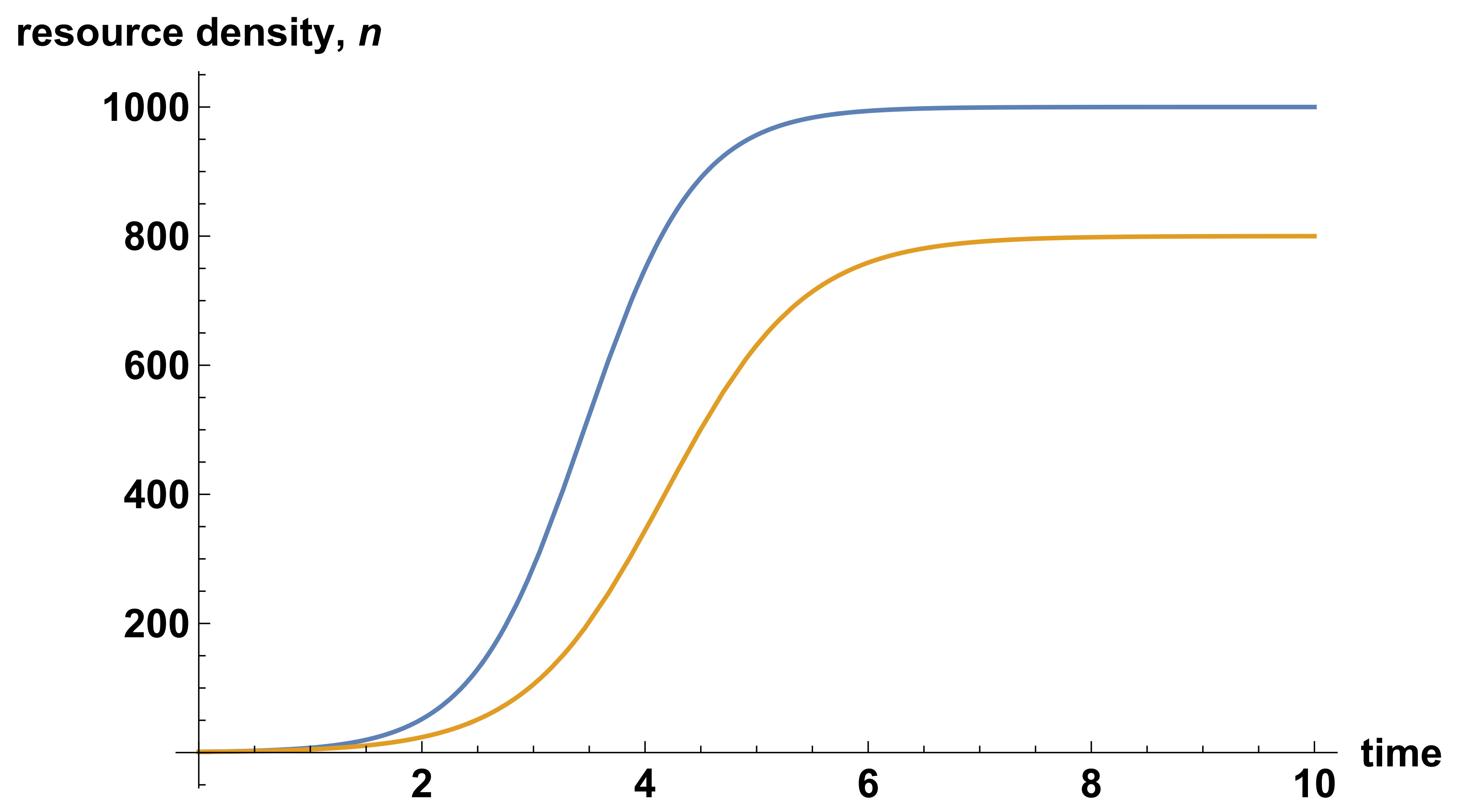

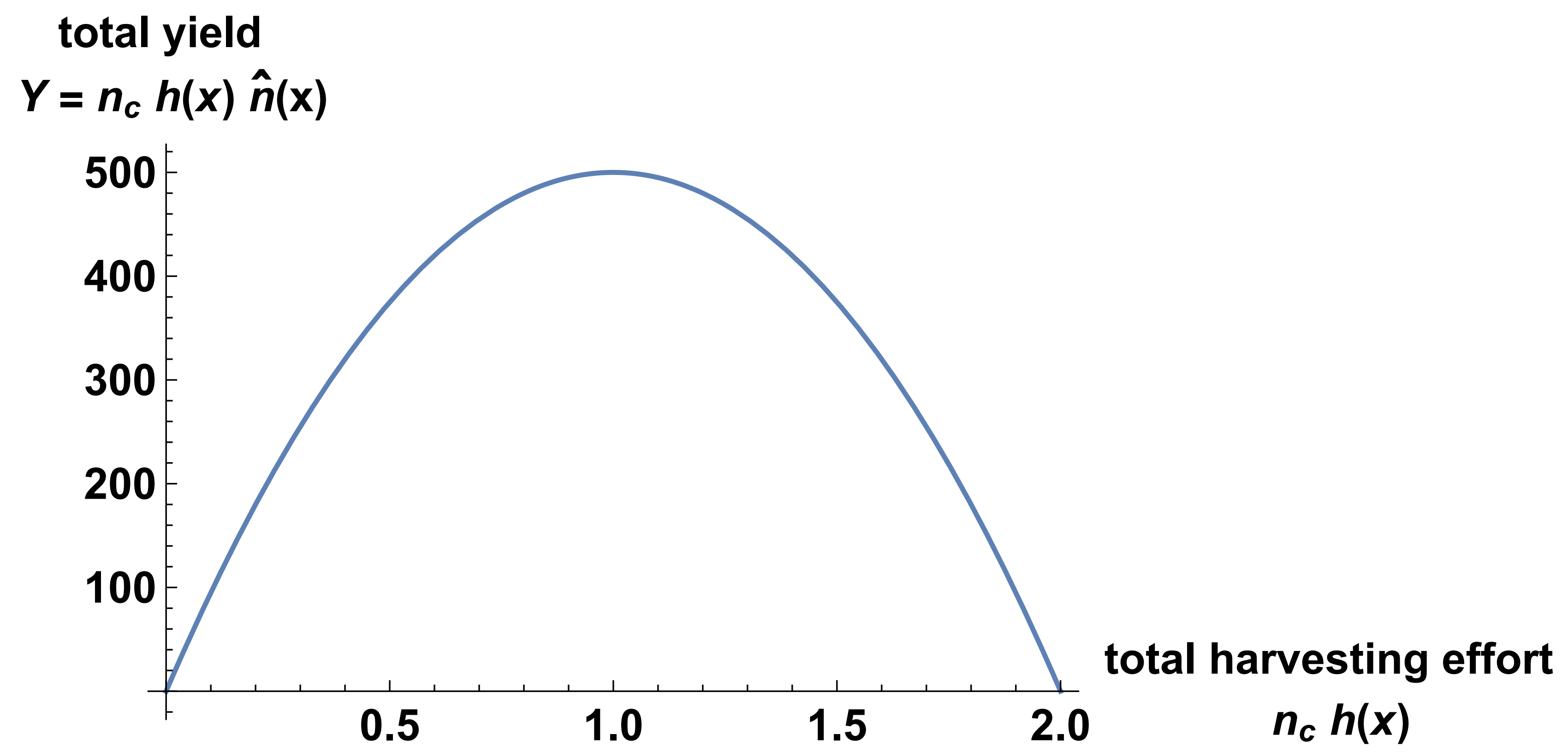

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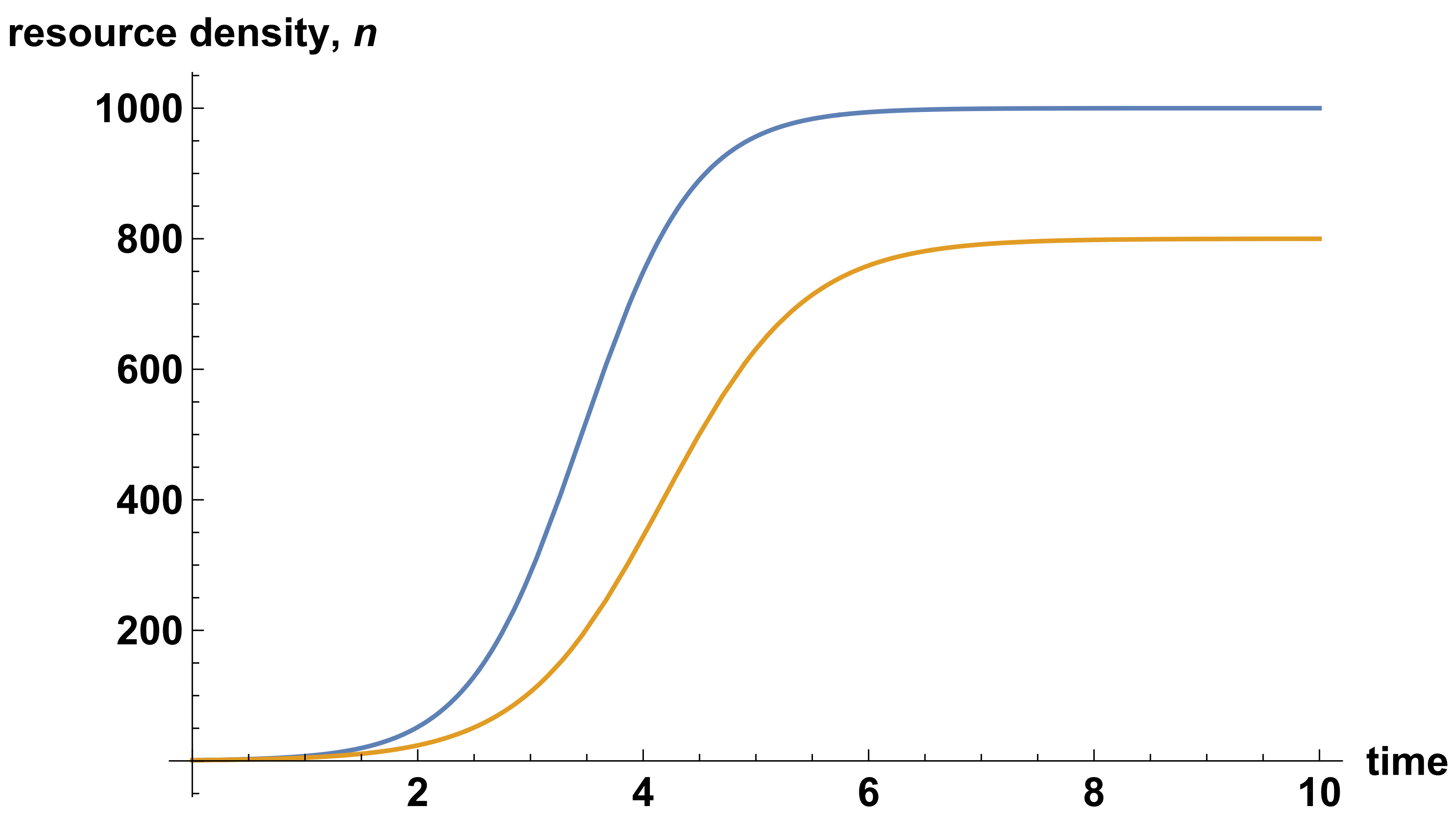
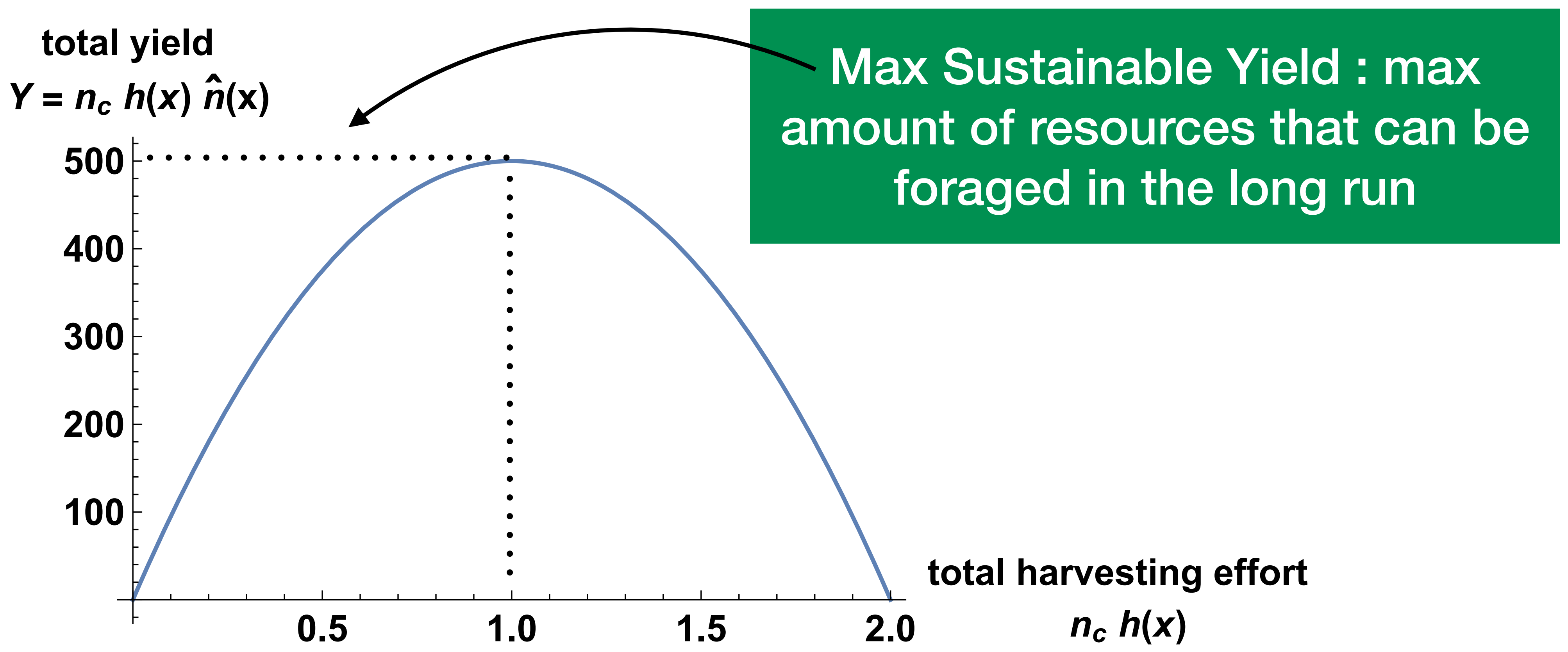
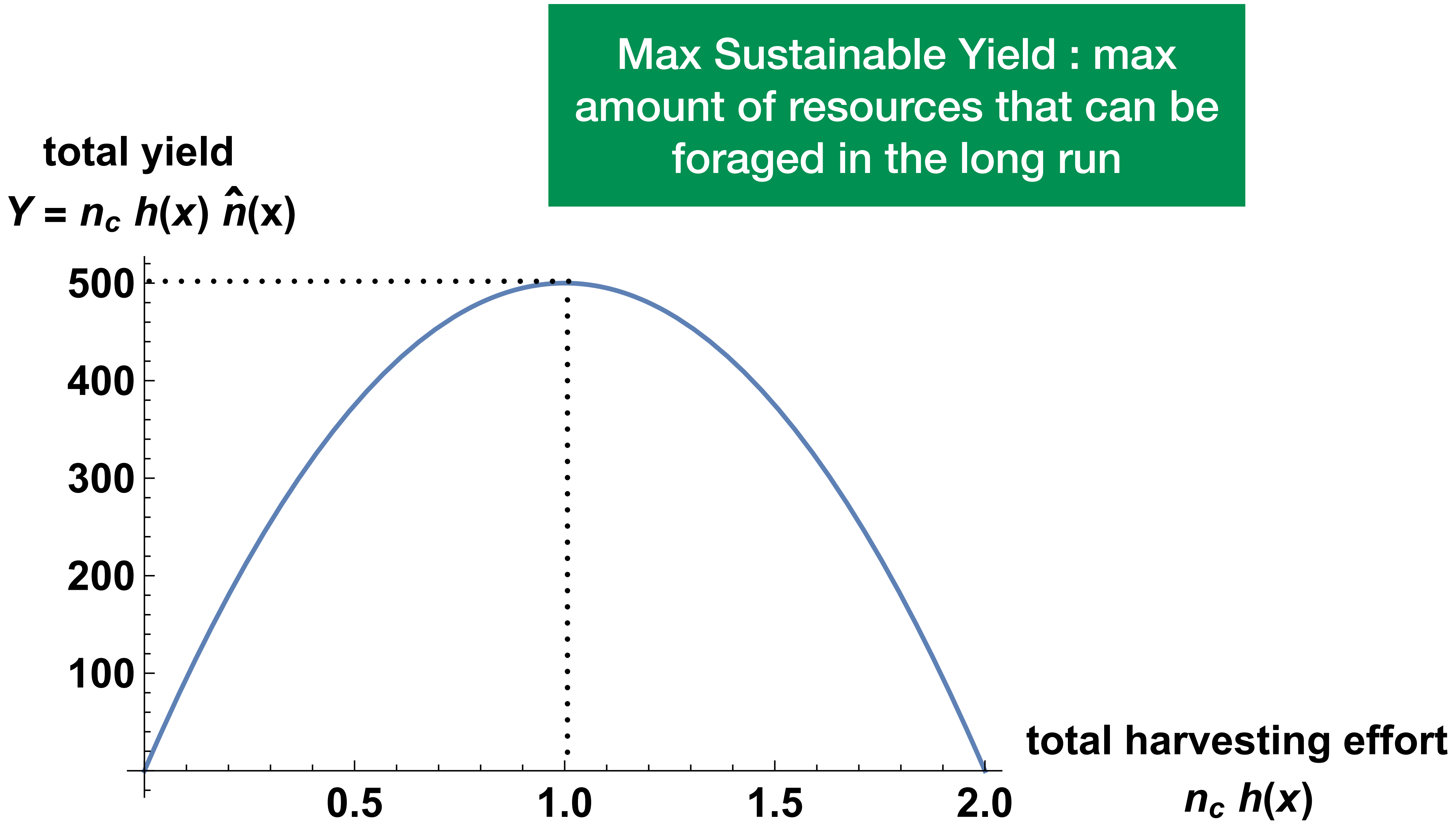




The exploitation of renewable resources

MSY and over-consumption



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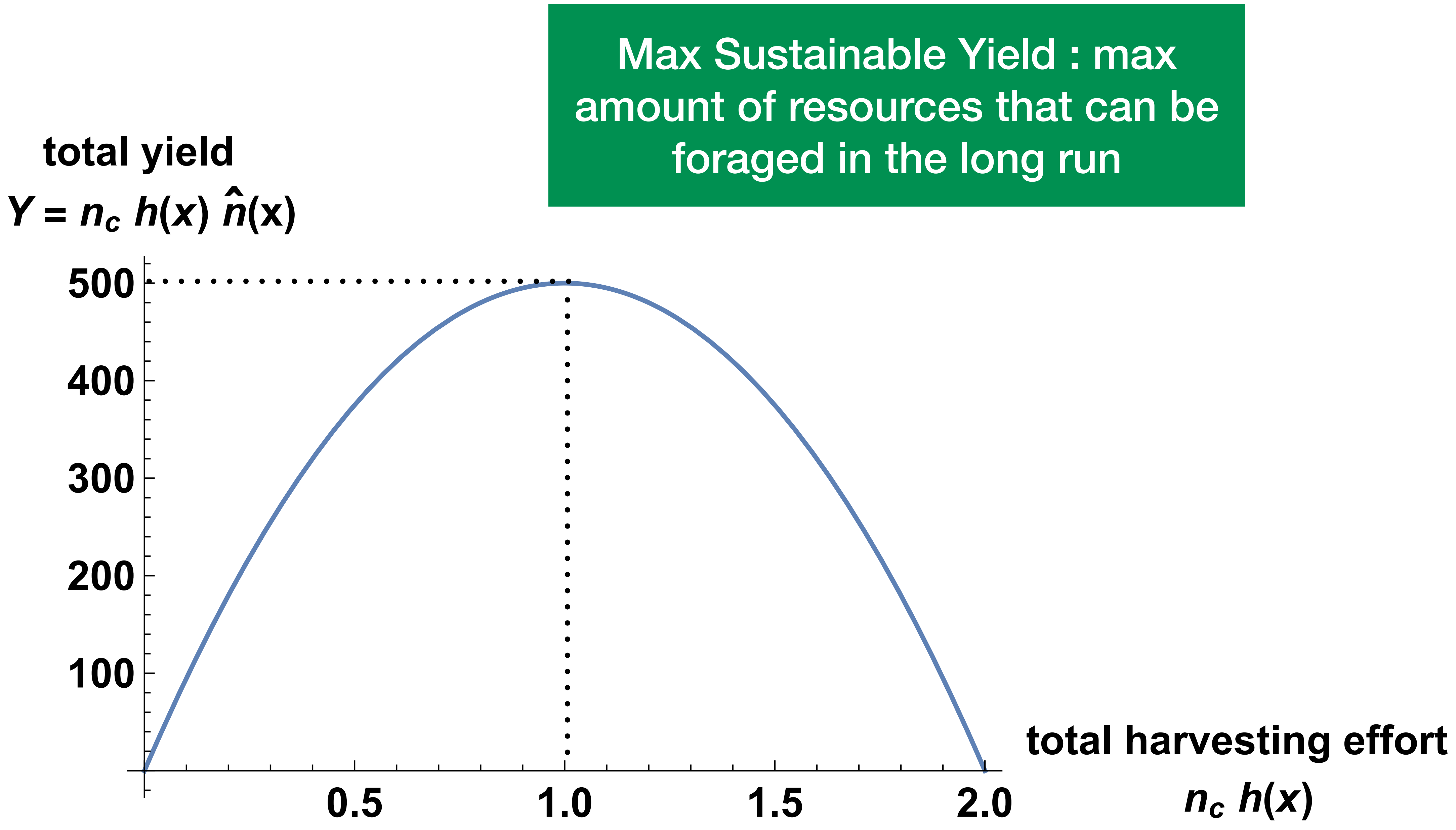

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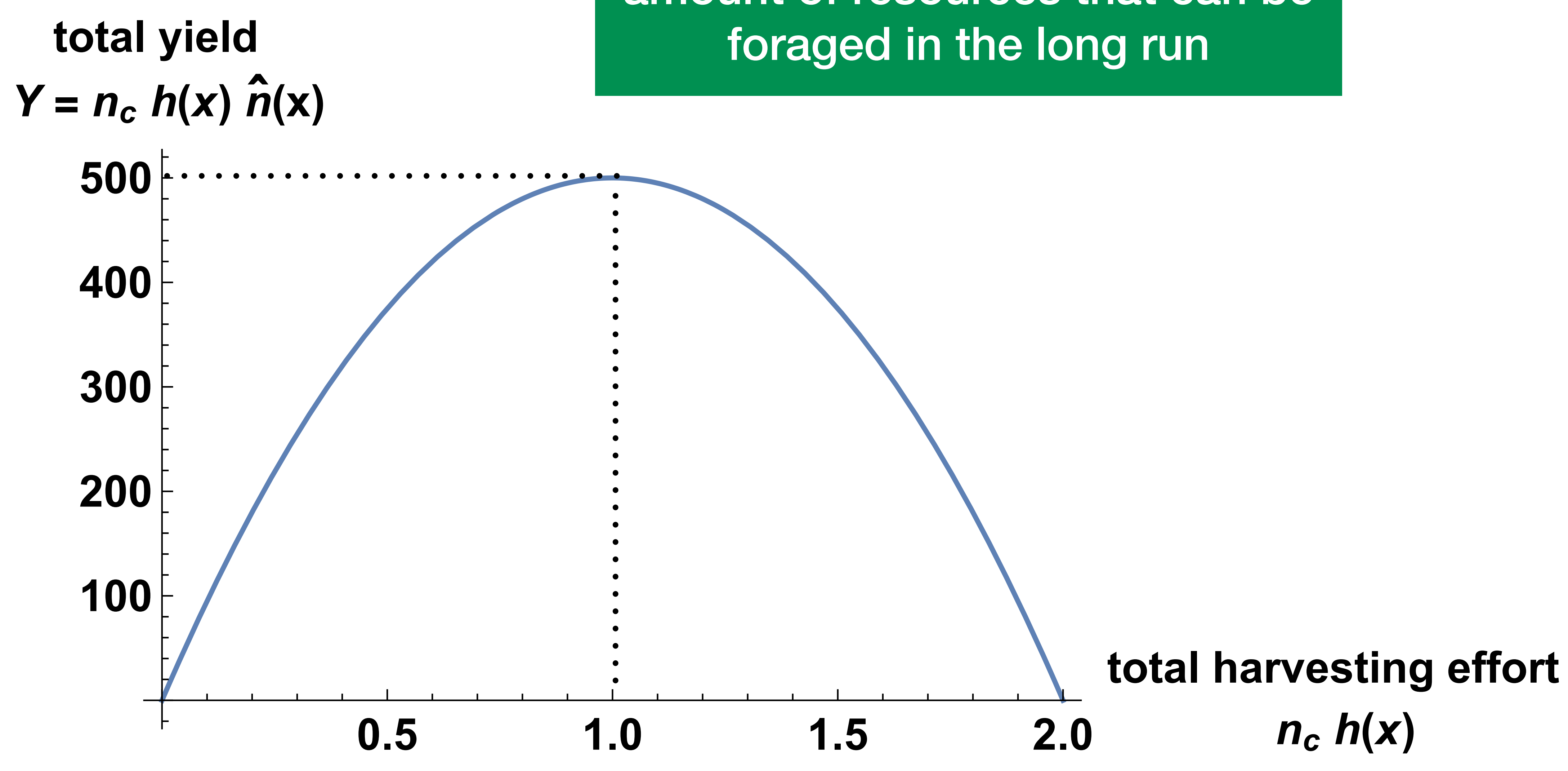
$$x_{\mathrm{MSY}} = \frac{1}{n_c}\frac{r}{2}$$

- MSY = $n_c h(x_{\mathrm{MSY}}) \times \hat{n}(x_{\mathrm{MSY}}) = \frac{Kr}{4}$
- Resource density = $\hat{n}(x_{\mathrm{MSY}}) = \frac{K}{2}$

Max Sustainable Yield : max amount of resources that can be foraged in the long run



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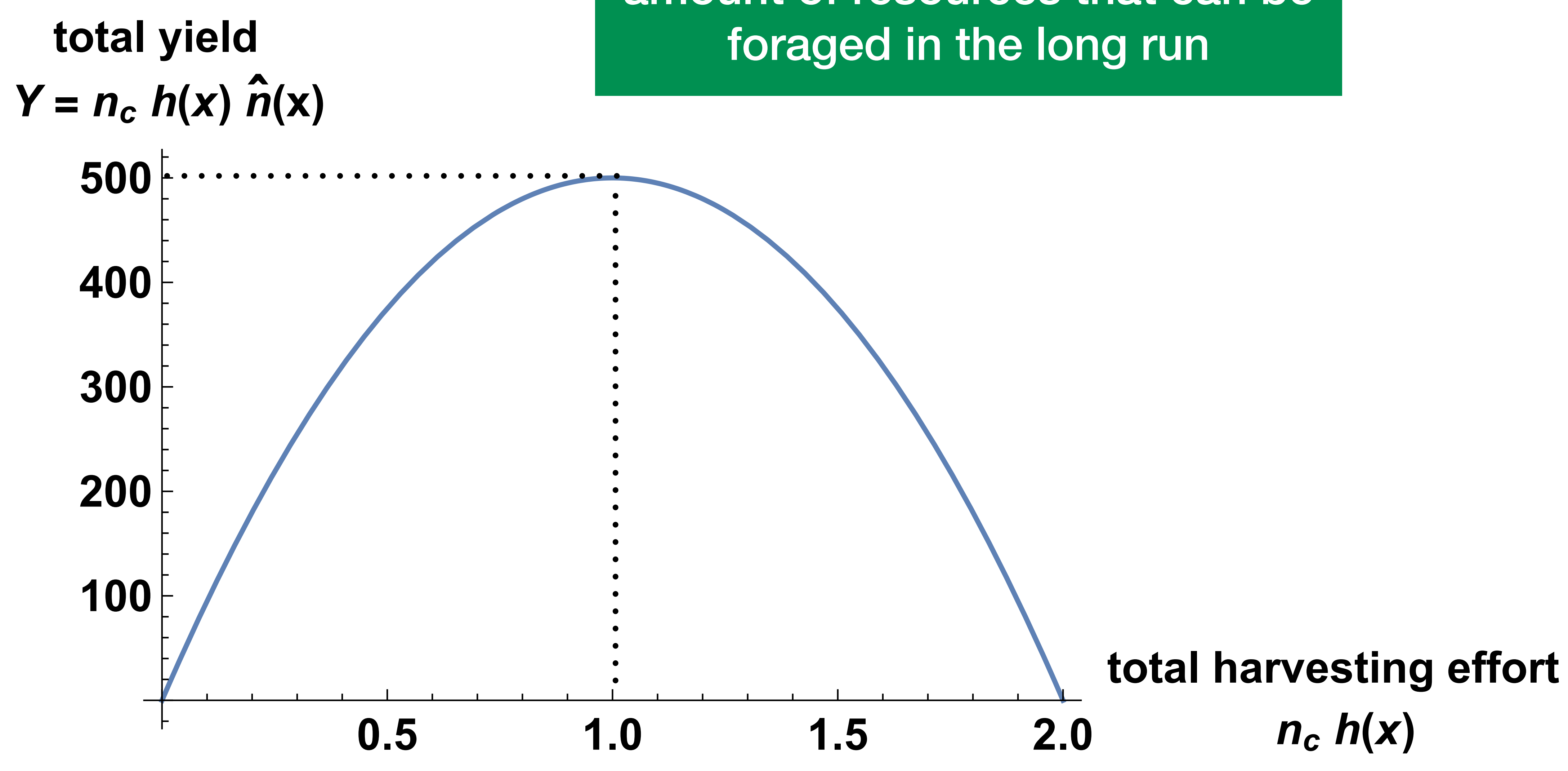
- Resource density = $\hat{n}(x_{\text{MSY}}) = \frac{K}{2}$
- Any effort above x_{MSY} amounts to over-exploitation.

Max Sustainable Yield : max amount of resources that can be foraged in the long run



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When cost is large, $c_0 \geq \dfrac{Kn_{\mathrm{c}}}{r}$ then $x^* \leq x_{\mathrm{MSY}}$.

Otherwise, $x^* > x_{\mathrm{MSY}}$.

When $c_0 = 0$, evolution leads to resource extinction.

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Due to competition, evolution typically leads to over-exploitation and lower yield than if individuals were coordinated.

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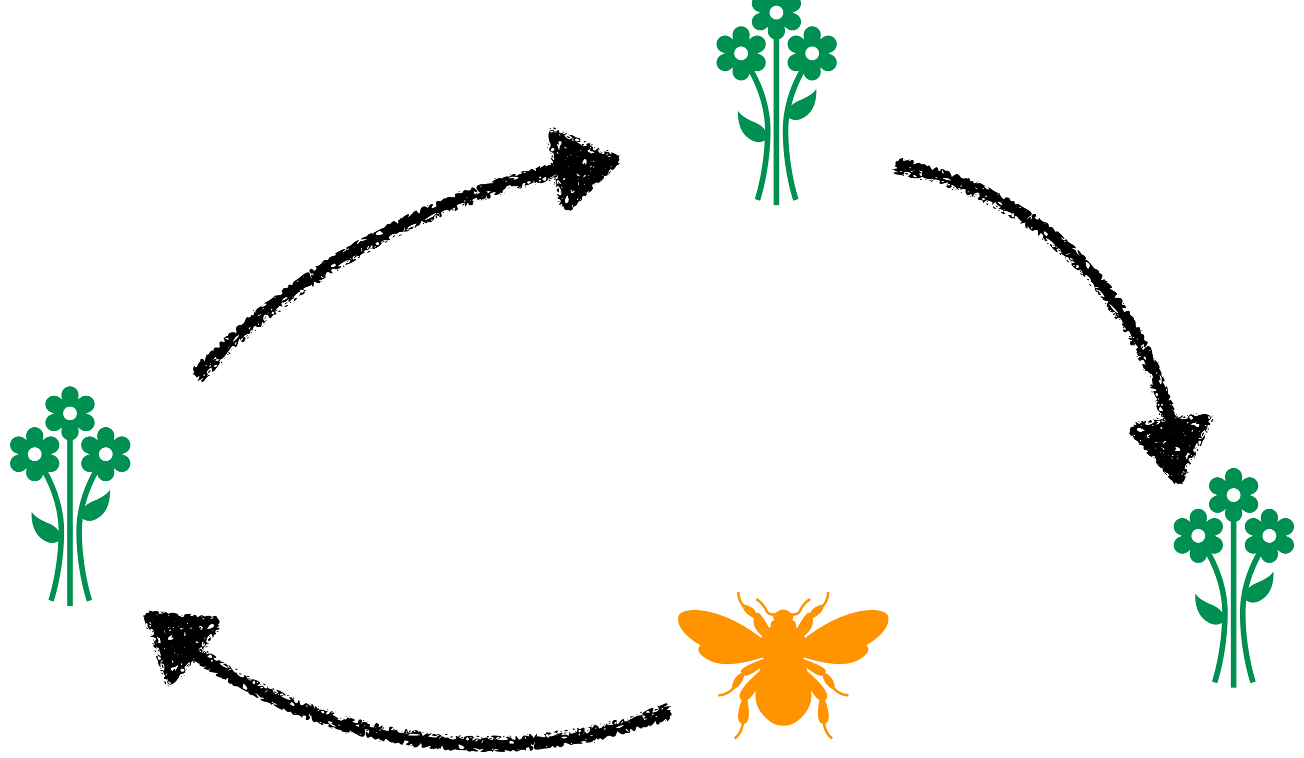
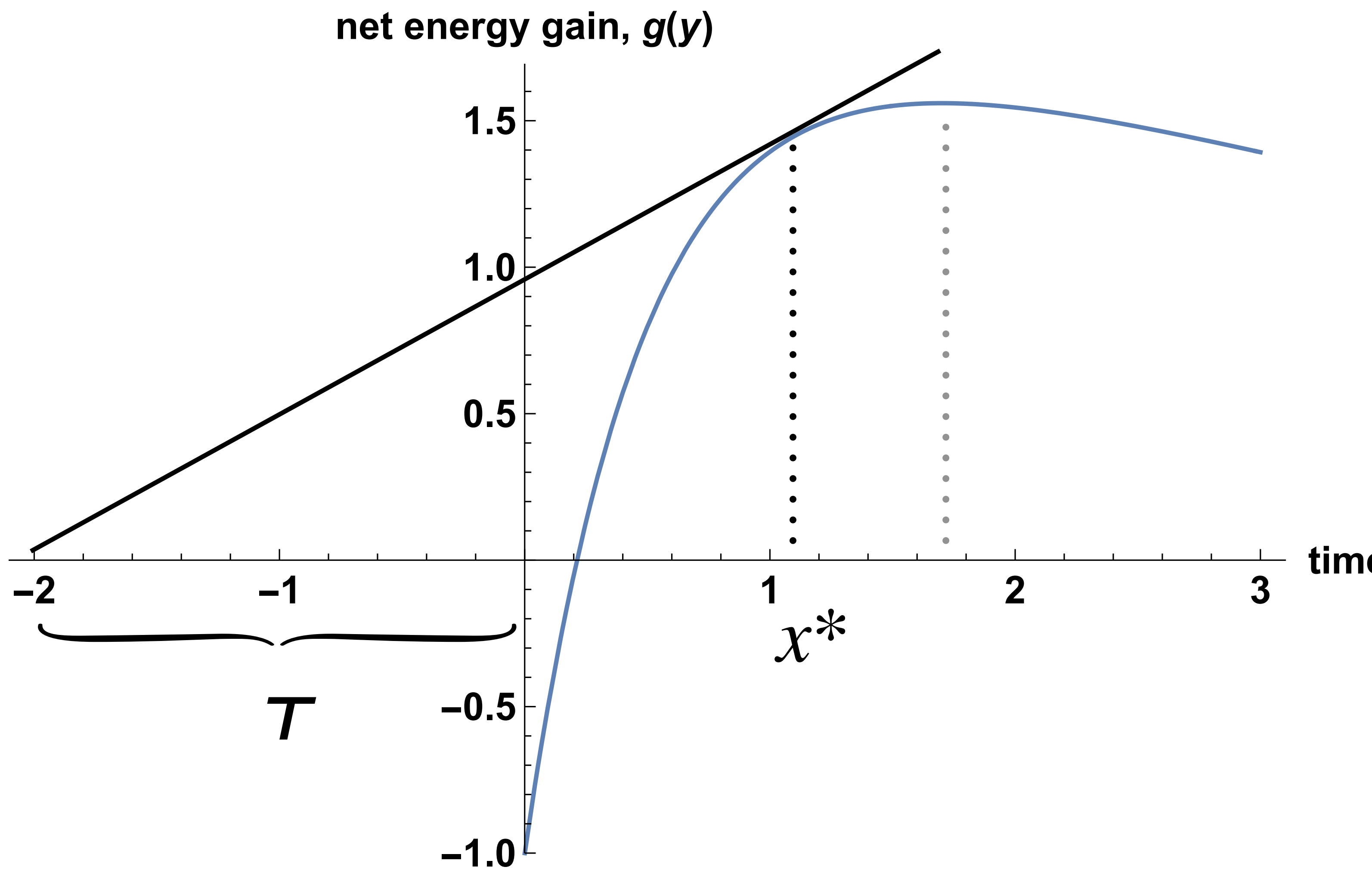
Summary





- Marginal value theorem allows to understand when an organism should leave for new pastures: leave when the *marginal* rate of energy gain has fallen to the total rate of gain.

- Risky foraging behaviours can be explained from state dependent payoffs where the fitness of low condition individuals accelerates with energy.

- For biotic resources, there may exist a foraging effort such that yield is maximised and resources are maintained. Due to competition, however, natural selection tends to favour over-consumption.