Part III - Foraging theory

resources

energy

offspring

fitness

Today

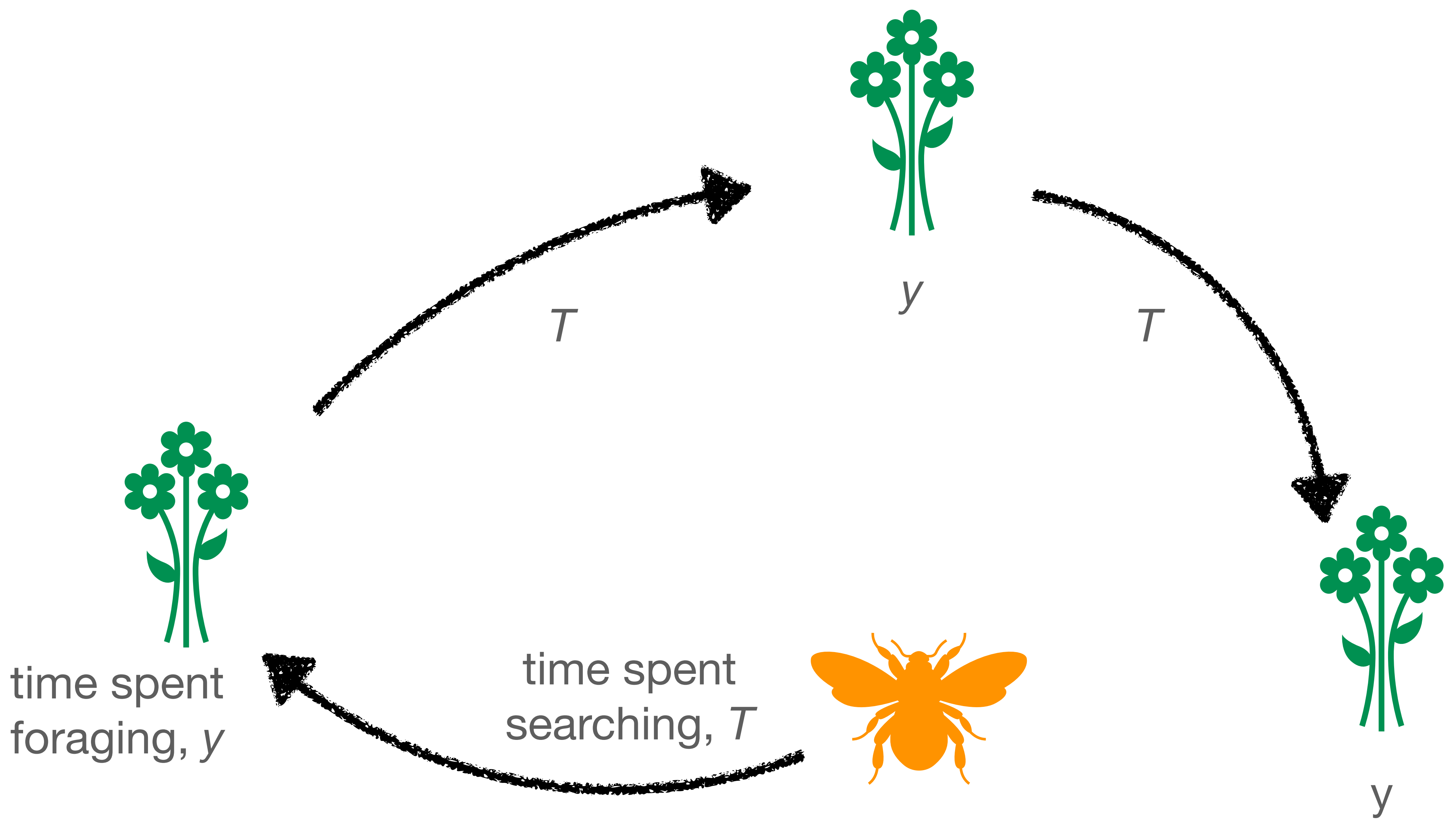
three topic in foraging theory

- Marginal Value theorem
- Risk taking
- Exploitation of natural resources

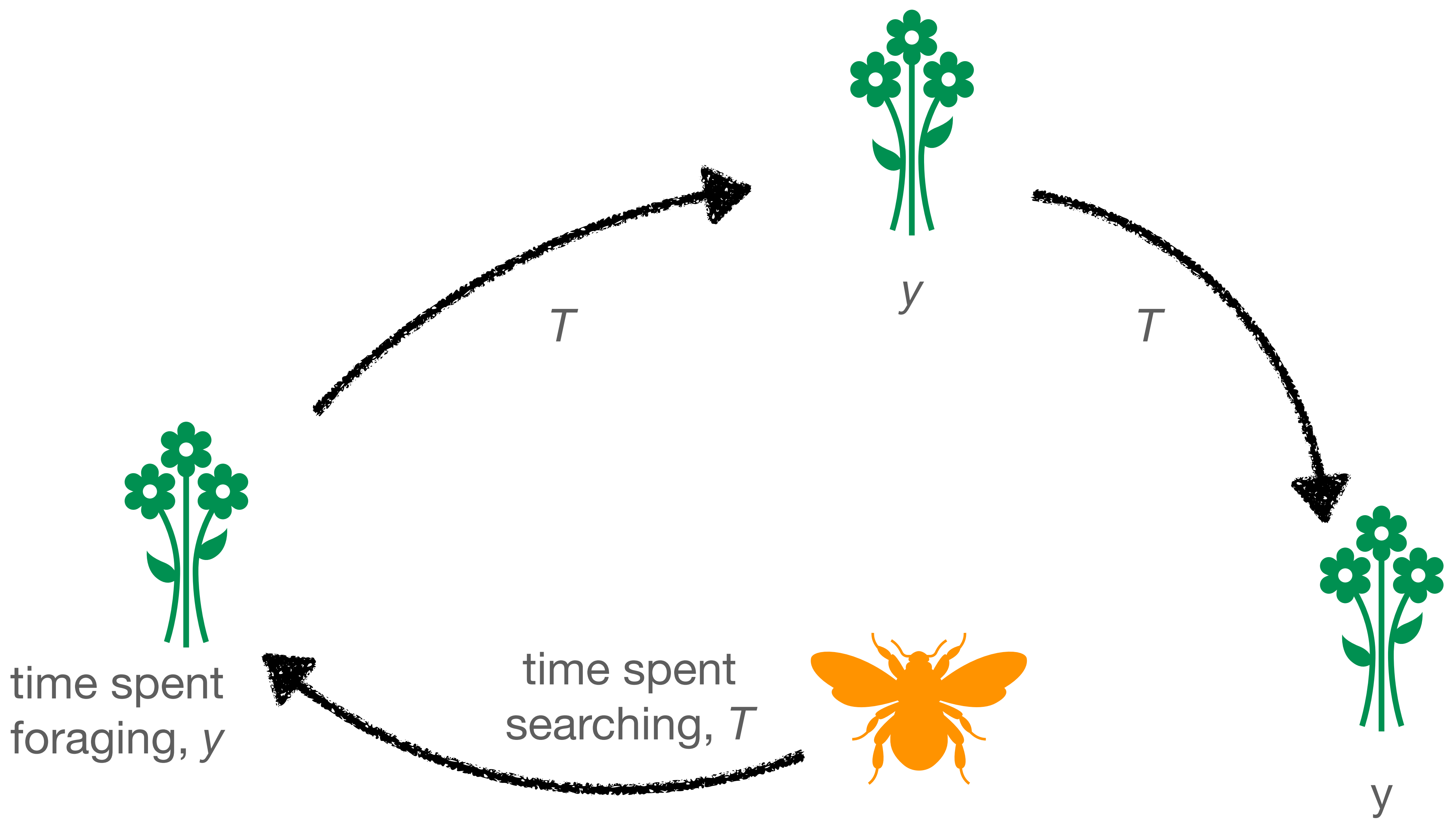
Foraging in patches

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.
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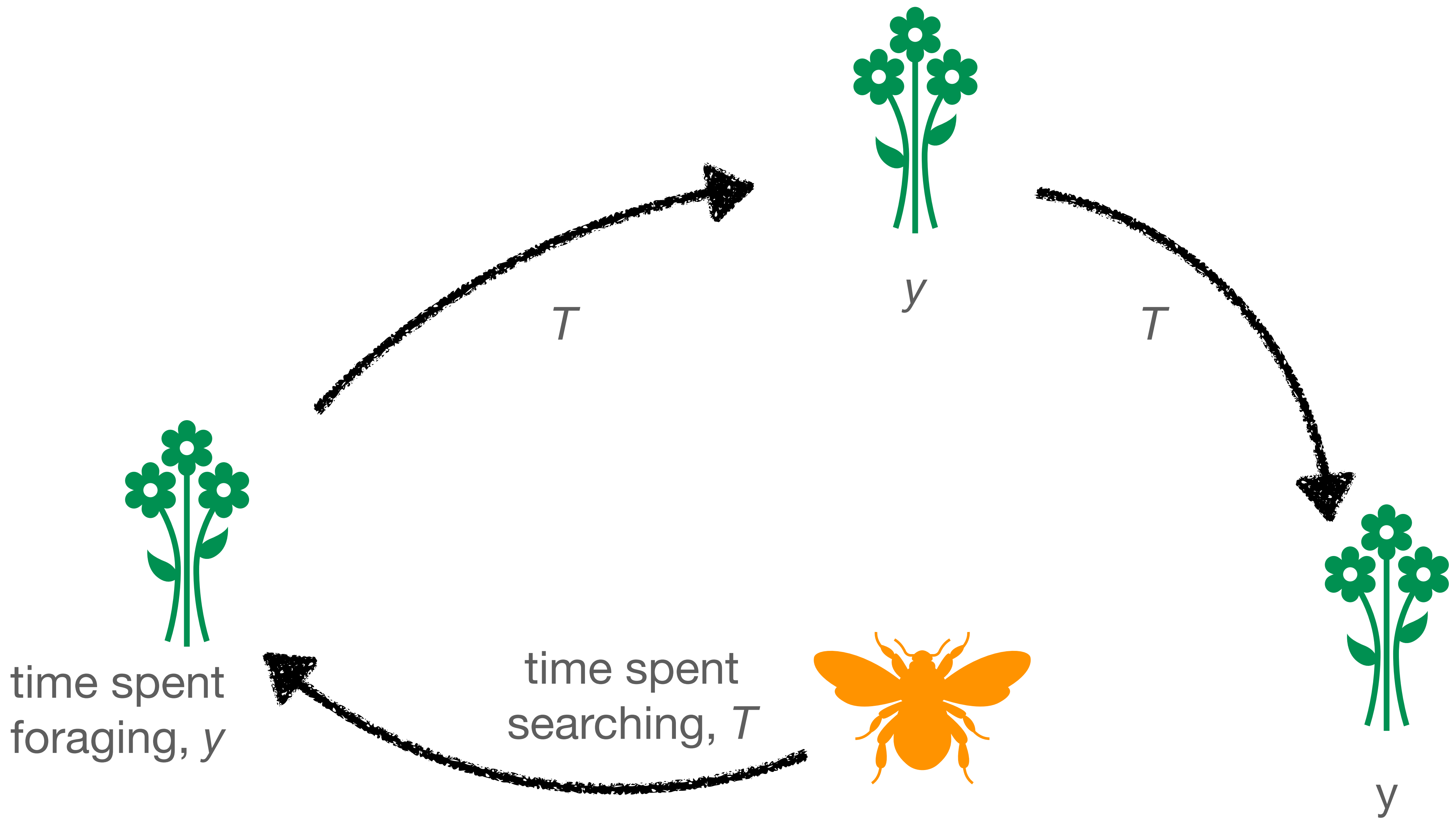
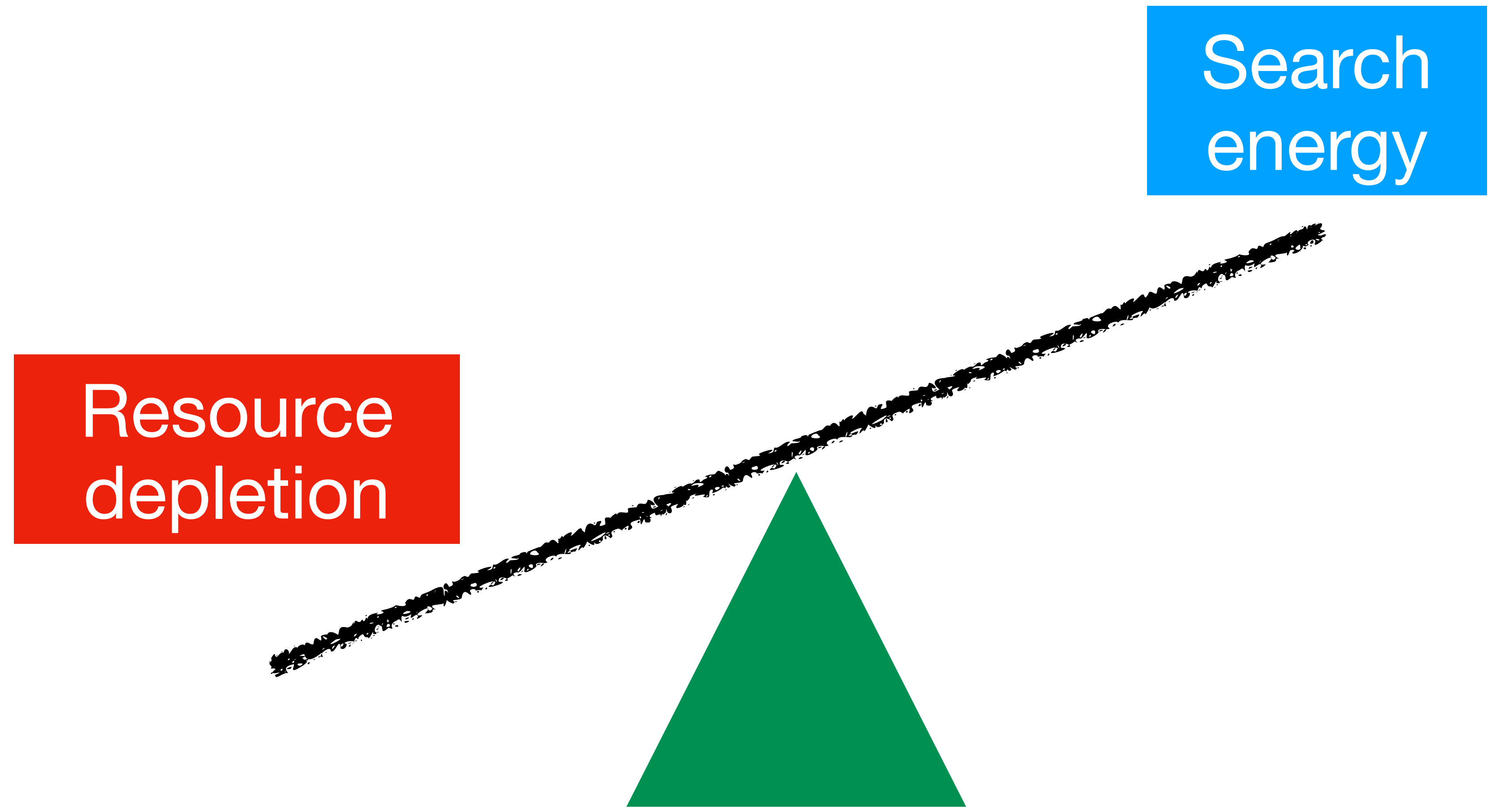
Foraging in patches

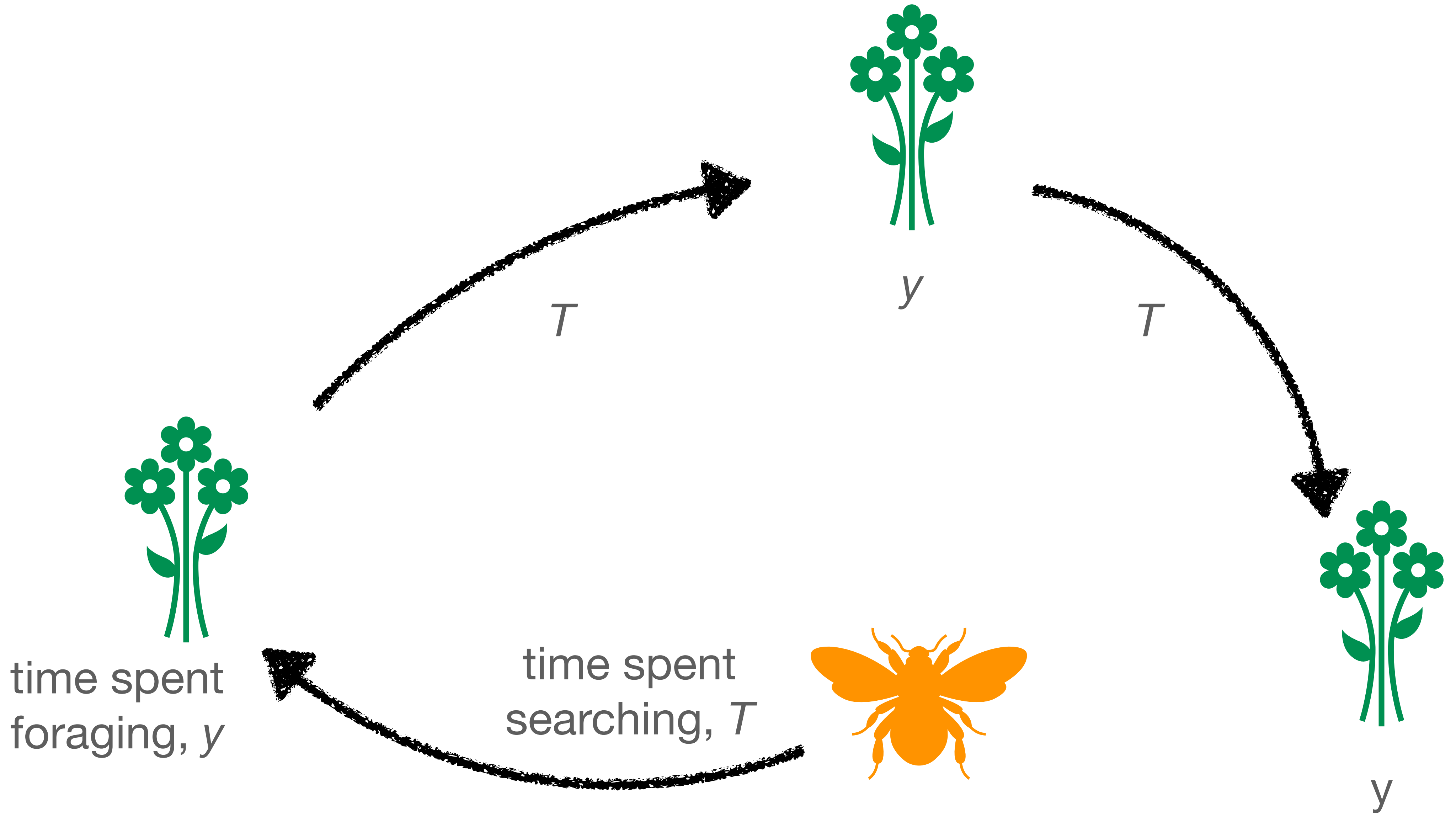
- Animal forages on multiple equivalent patches with finite amount of resources.
- How much time *y* should it spent foraging on a single patch when searching is costly?
- If it stays too long, resources get depleted; too short and it does not regain energy lost from search.

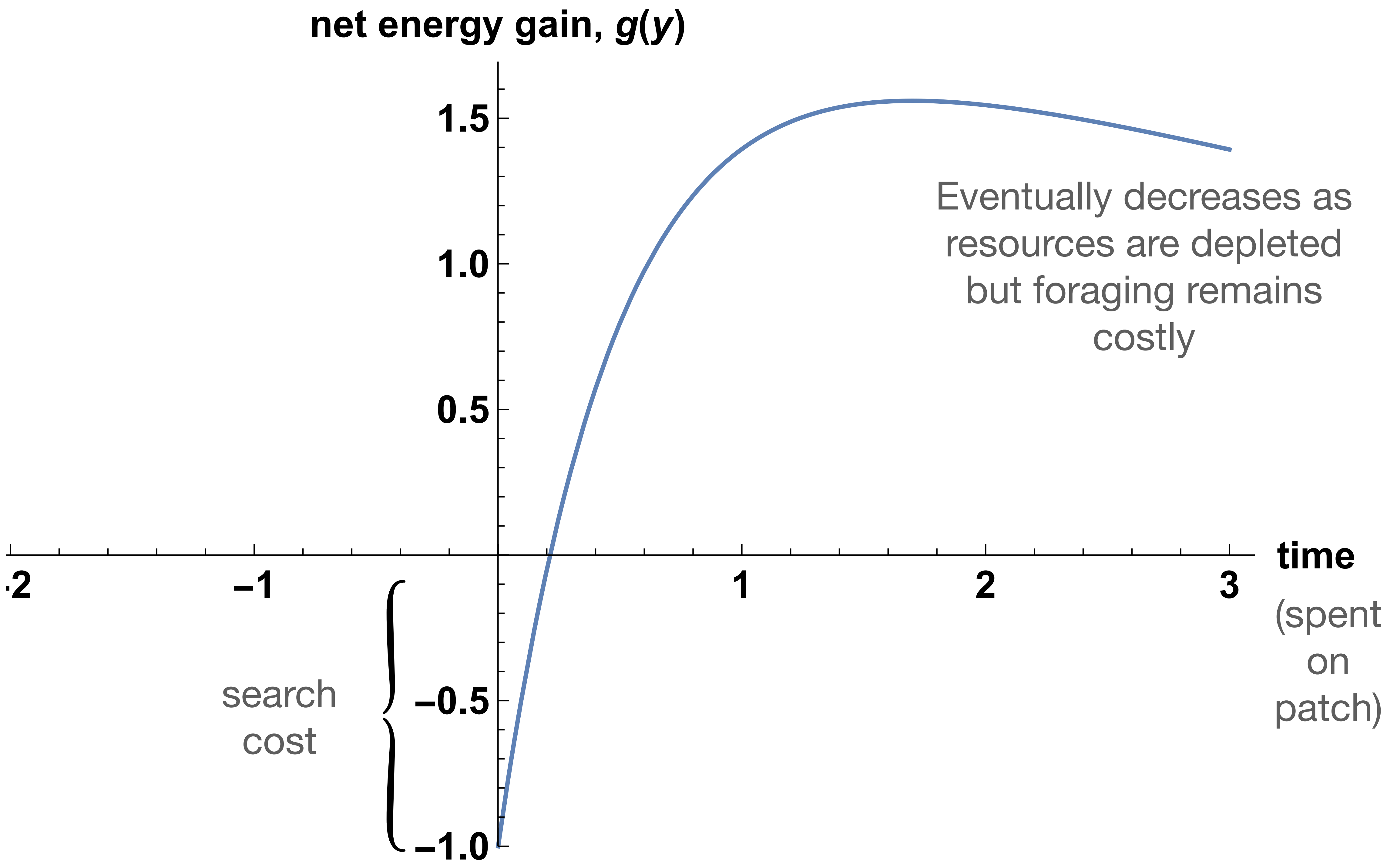




Energy gains

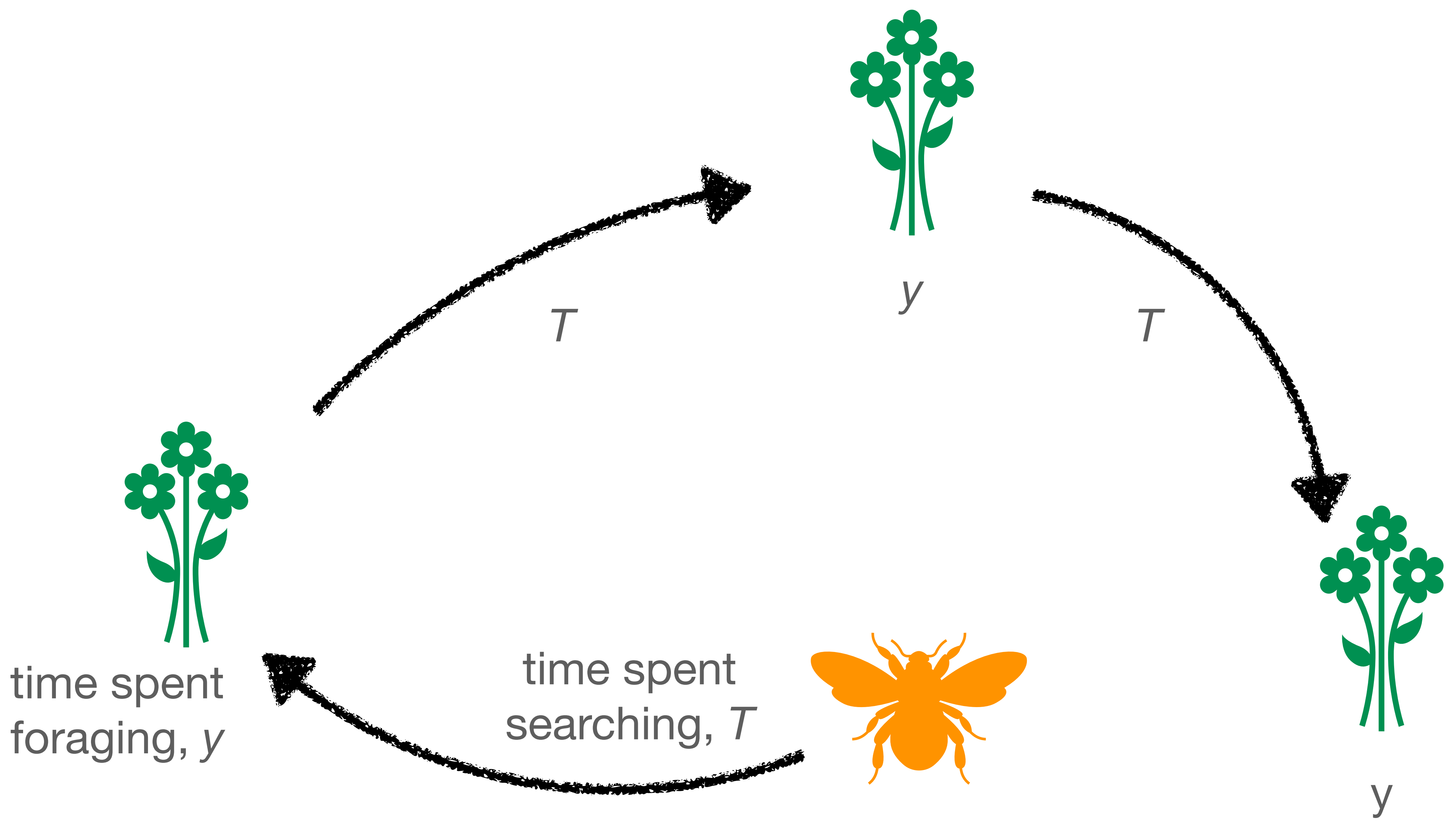
- $g(y)$: **net** energy gain from staying *y* in a patch

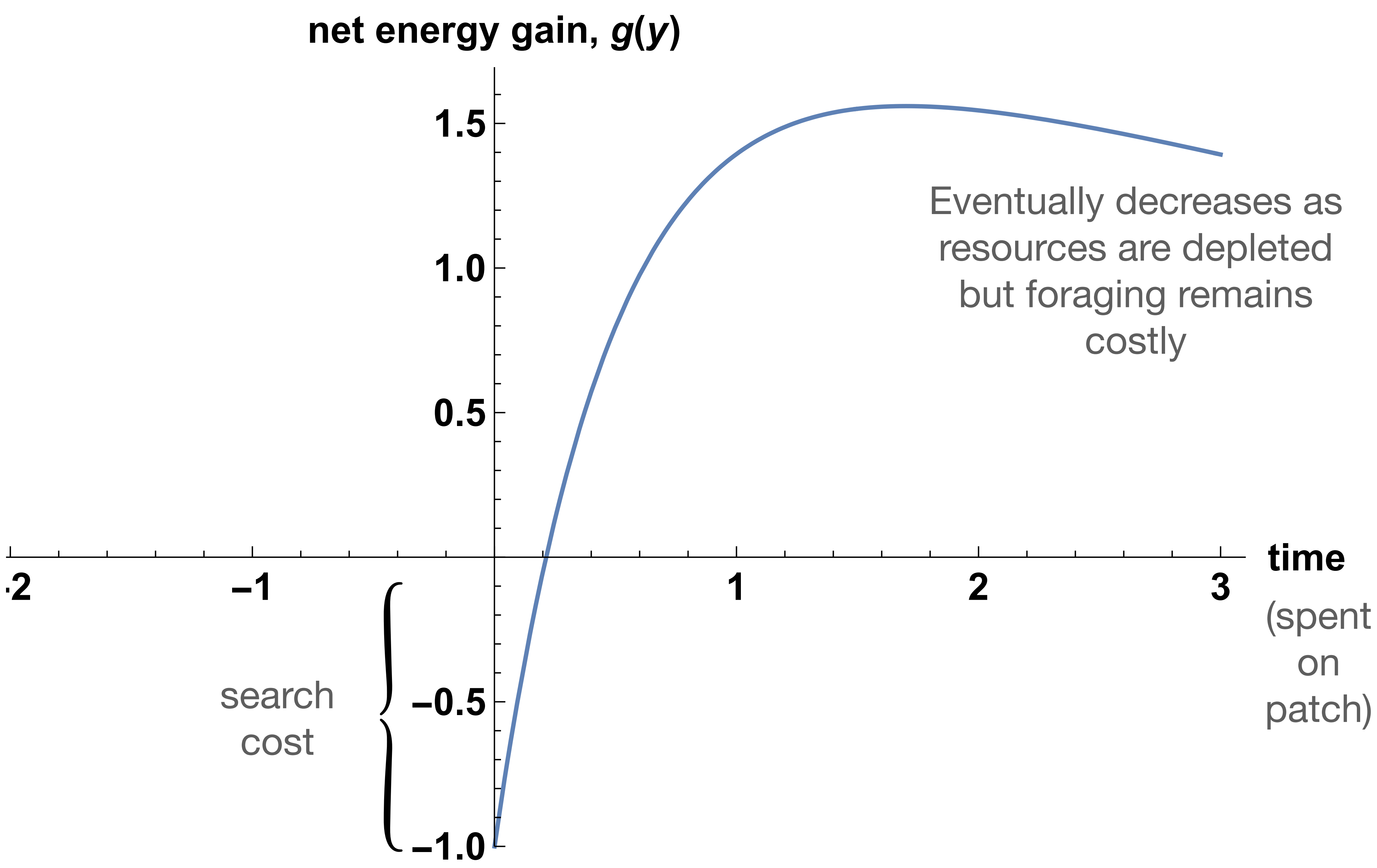




Energy gains

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





Energy gains

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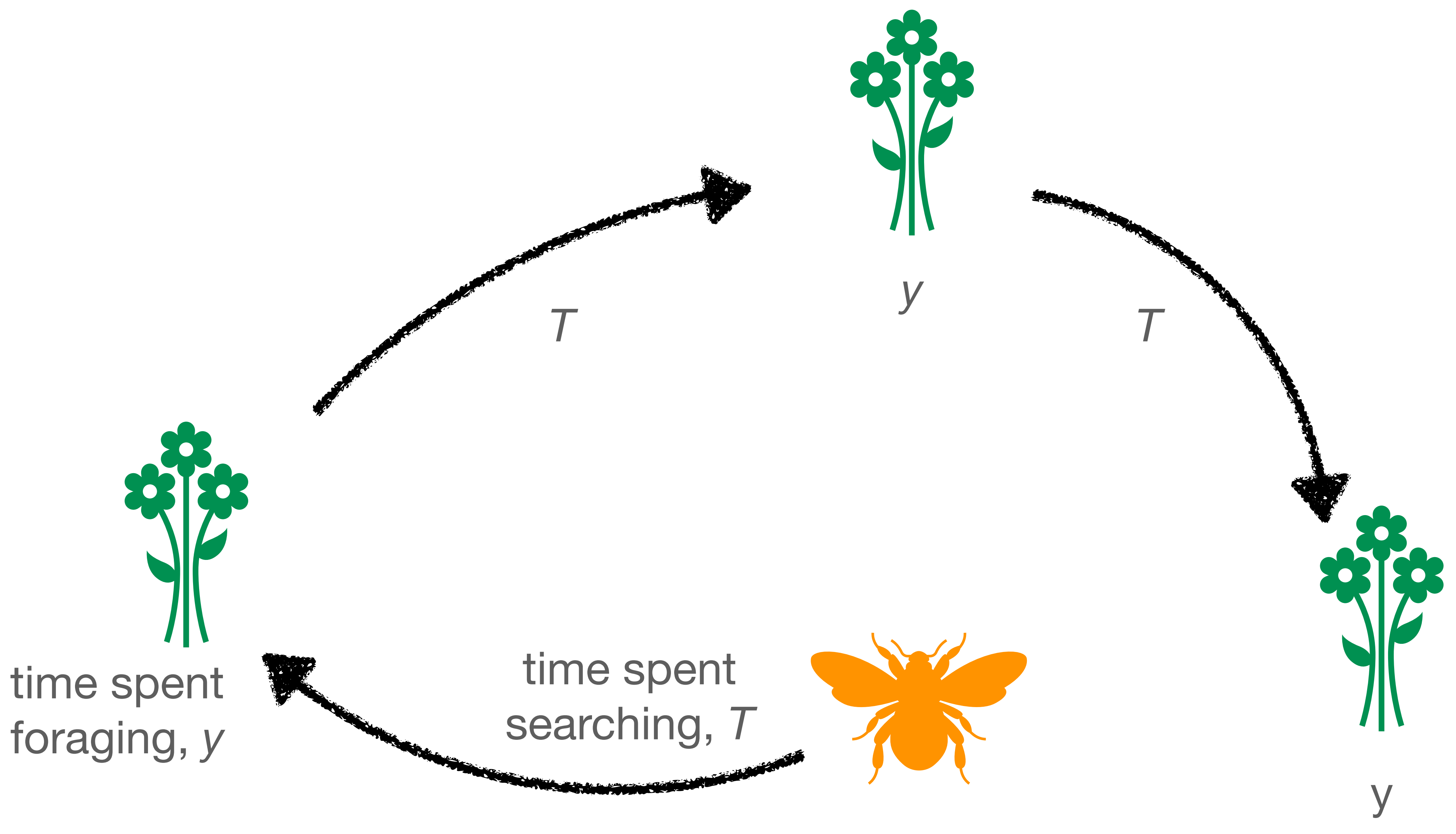
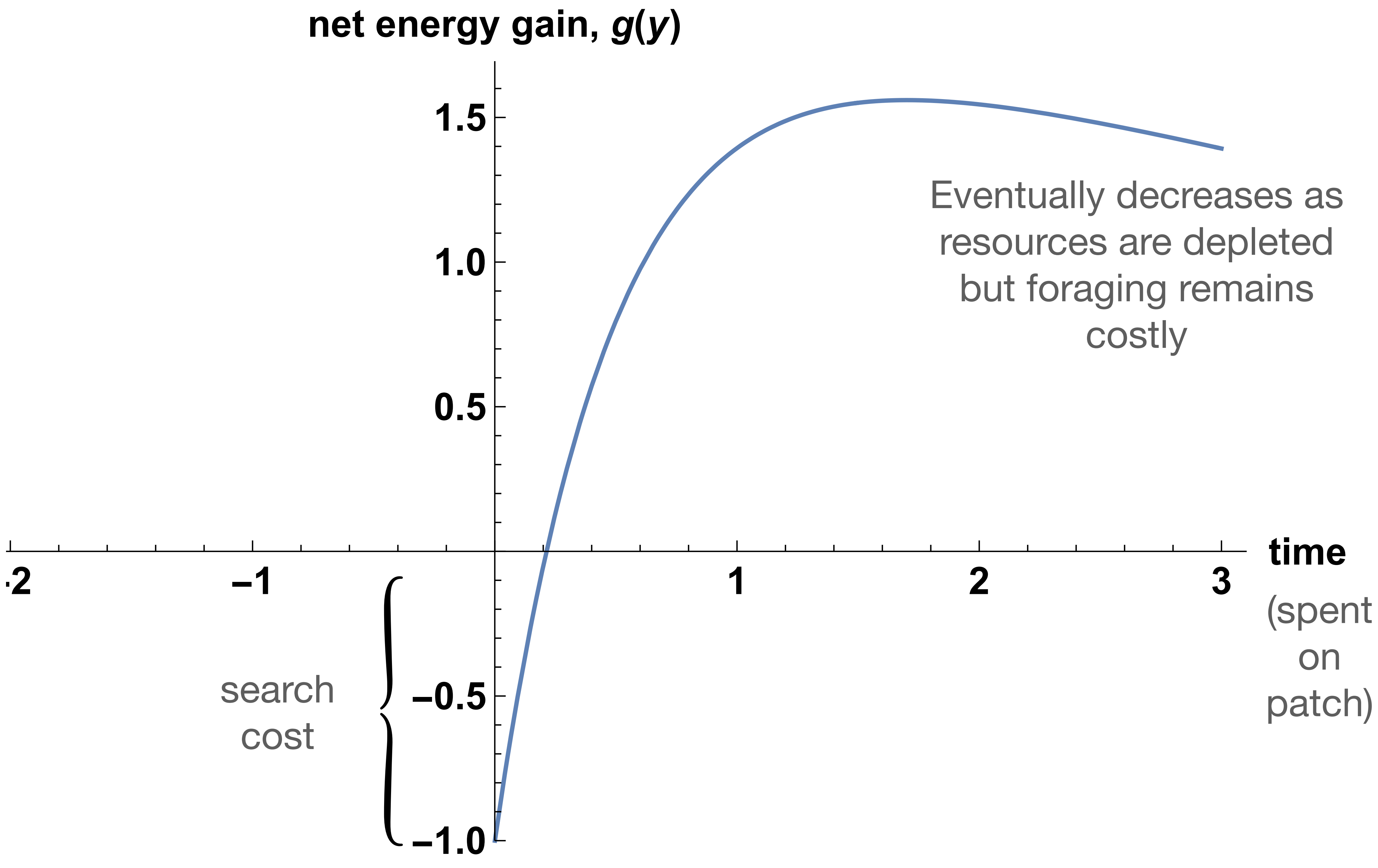
$$R(y) = \frac{g(y)}{y + T}$$





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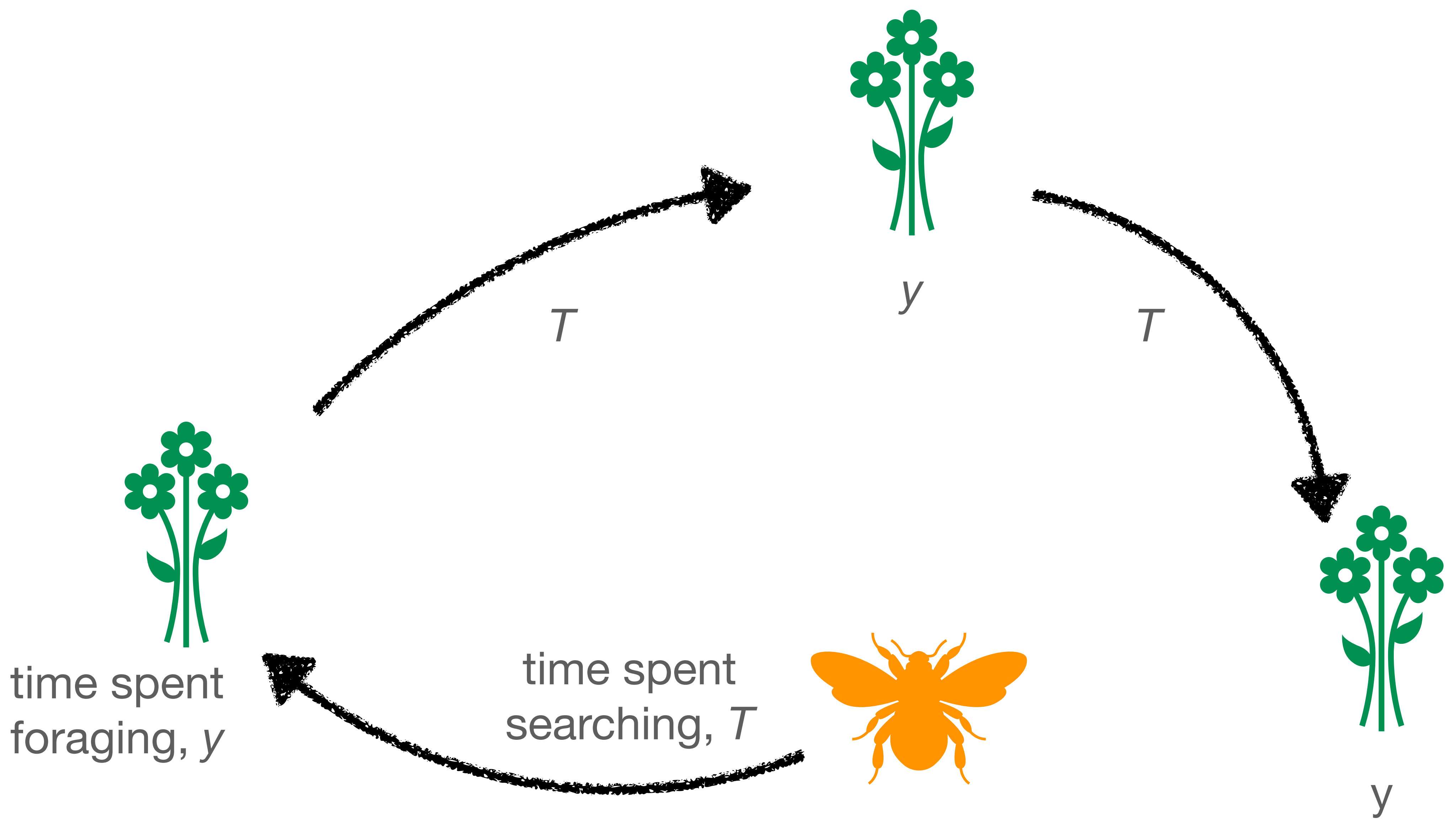

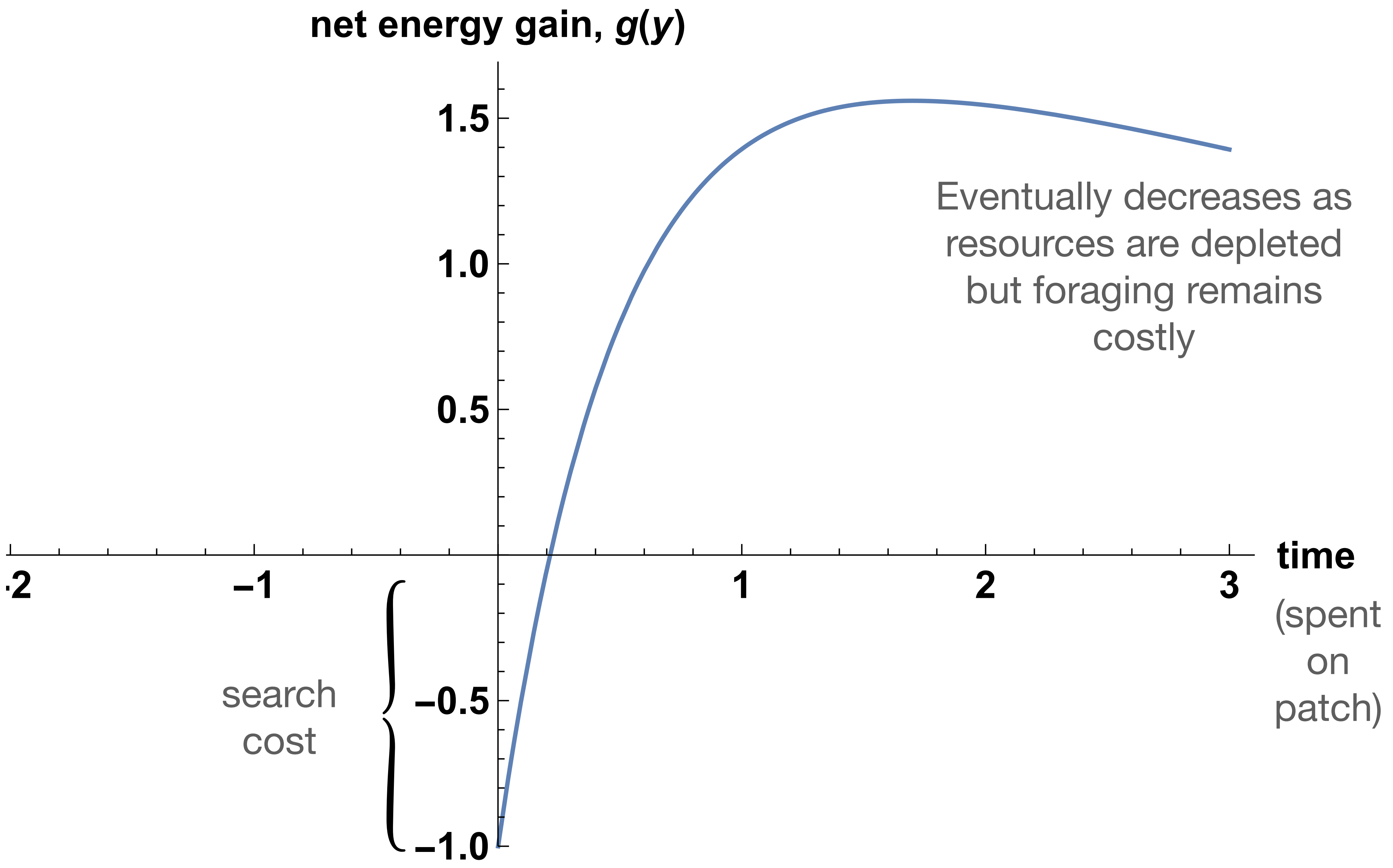

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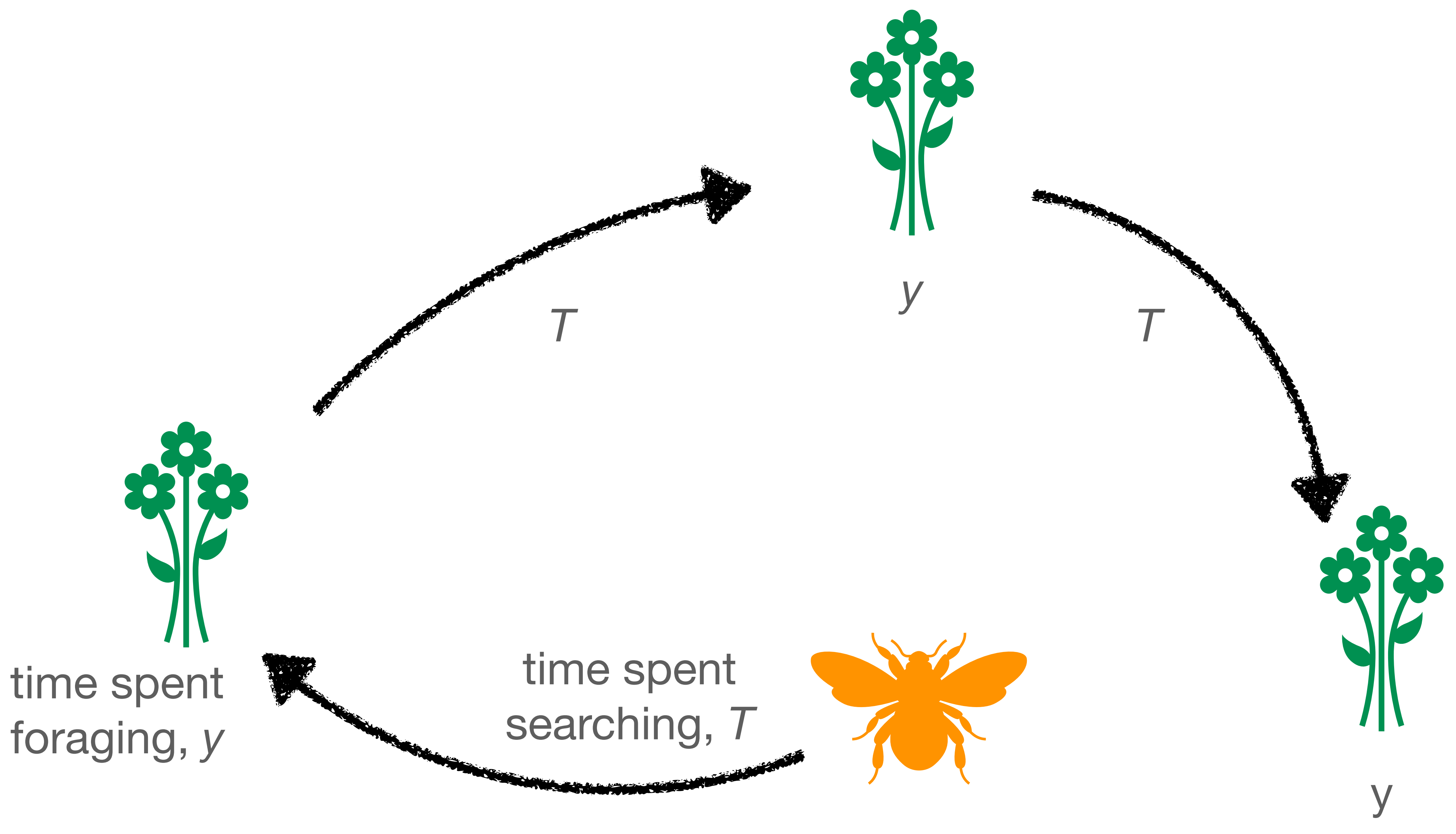

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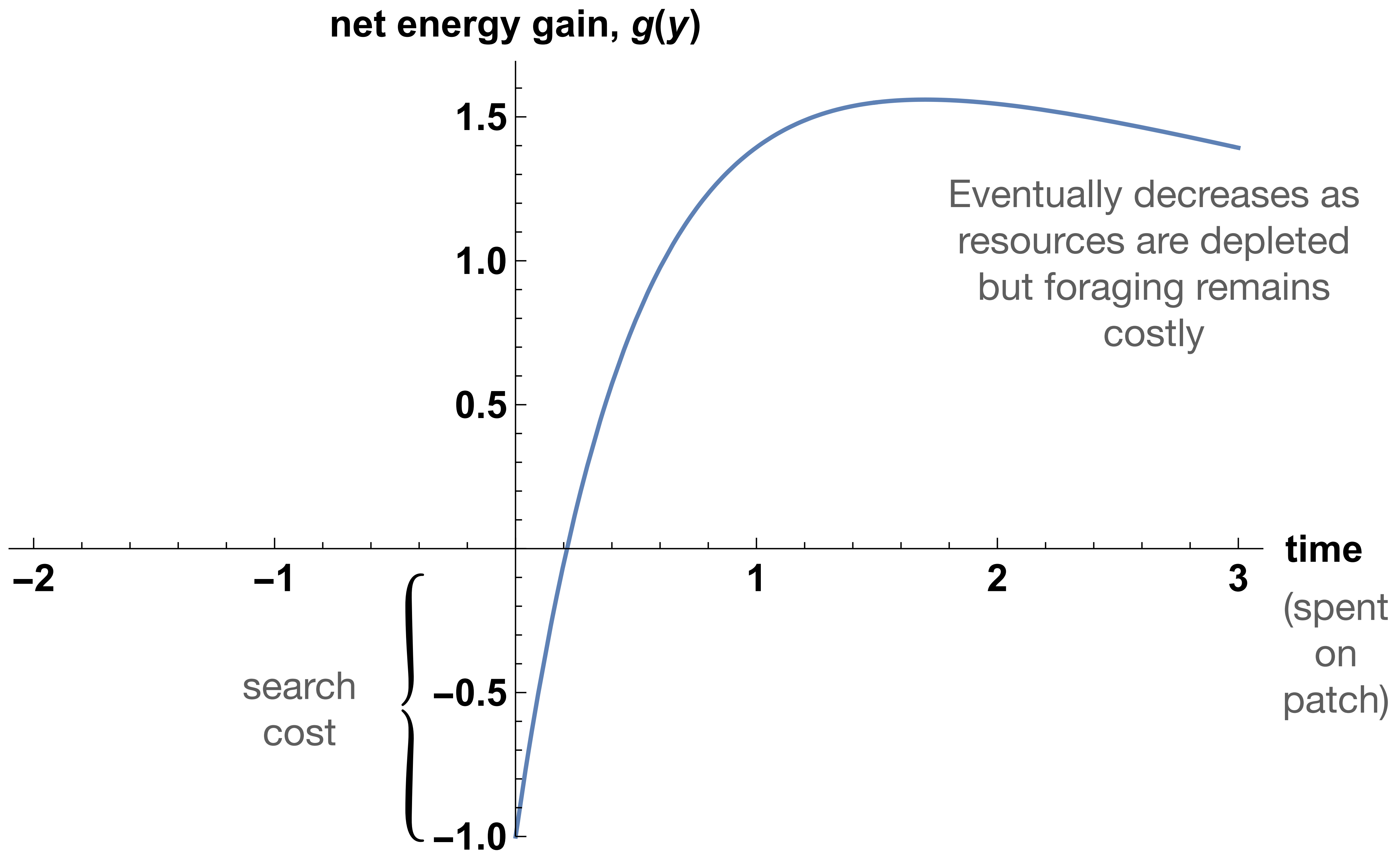
- Selection gradient :

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

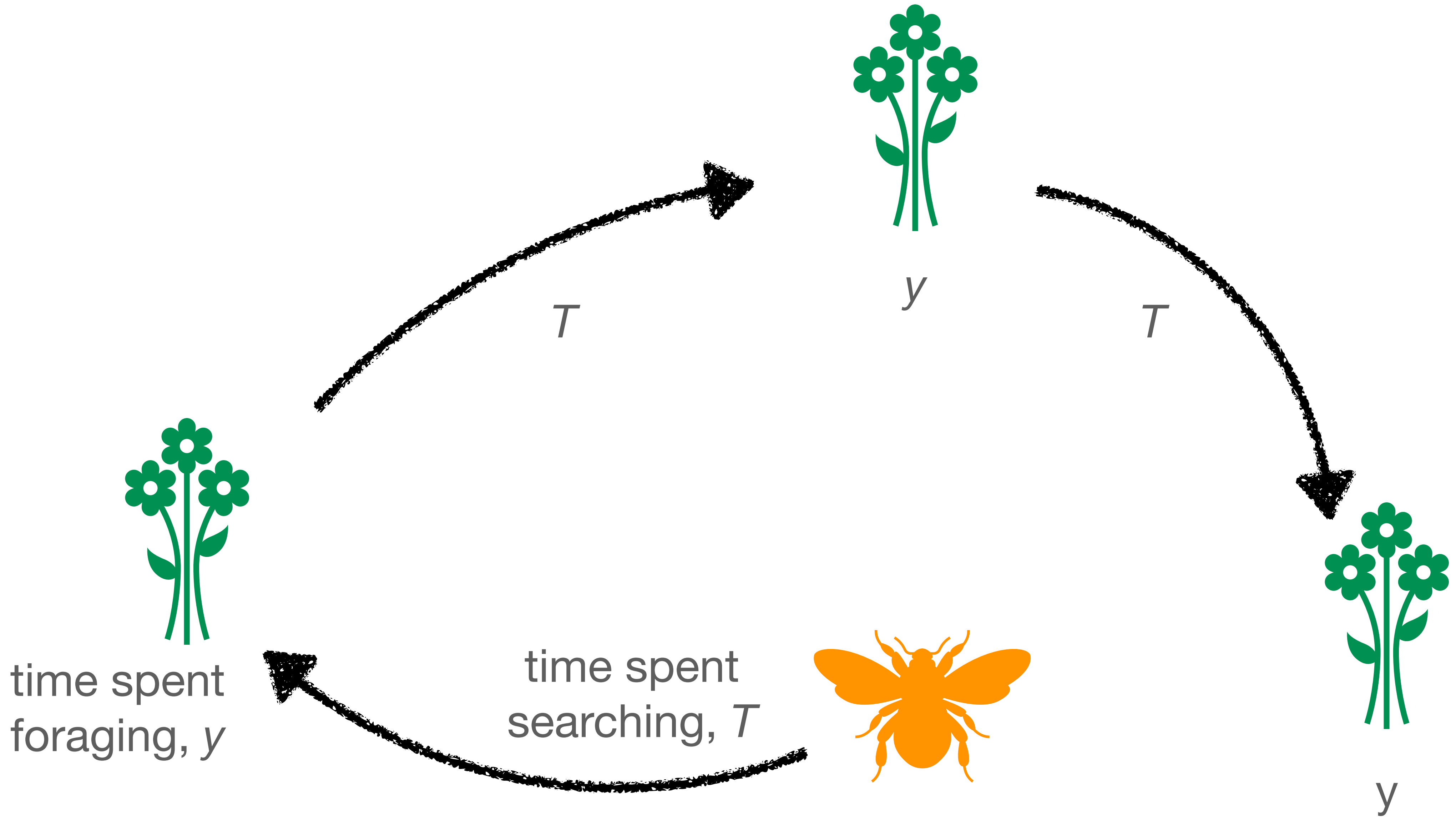


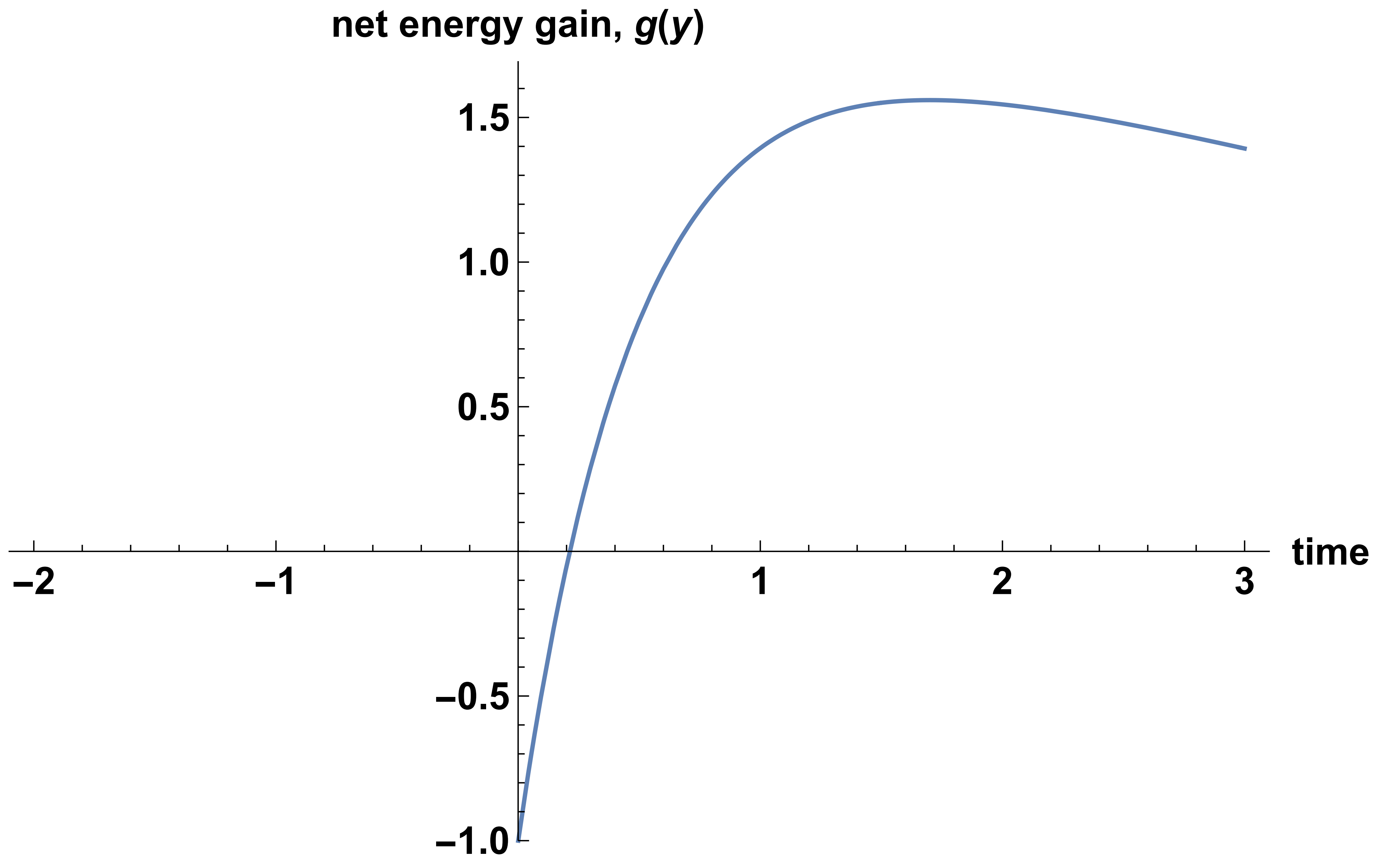
Marginal value theorem

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

i.e., such that

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





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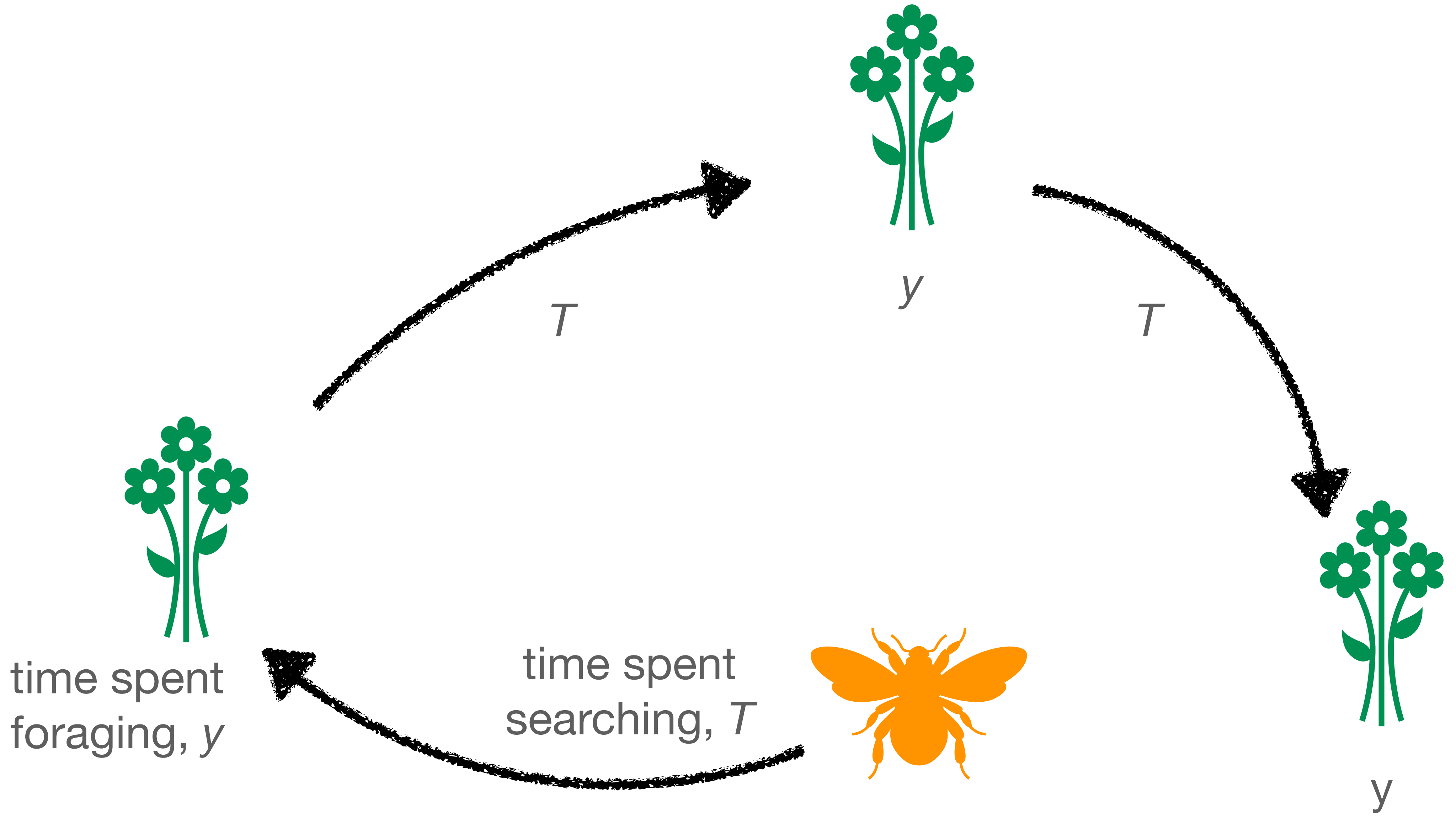

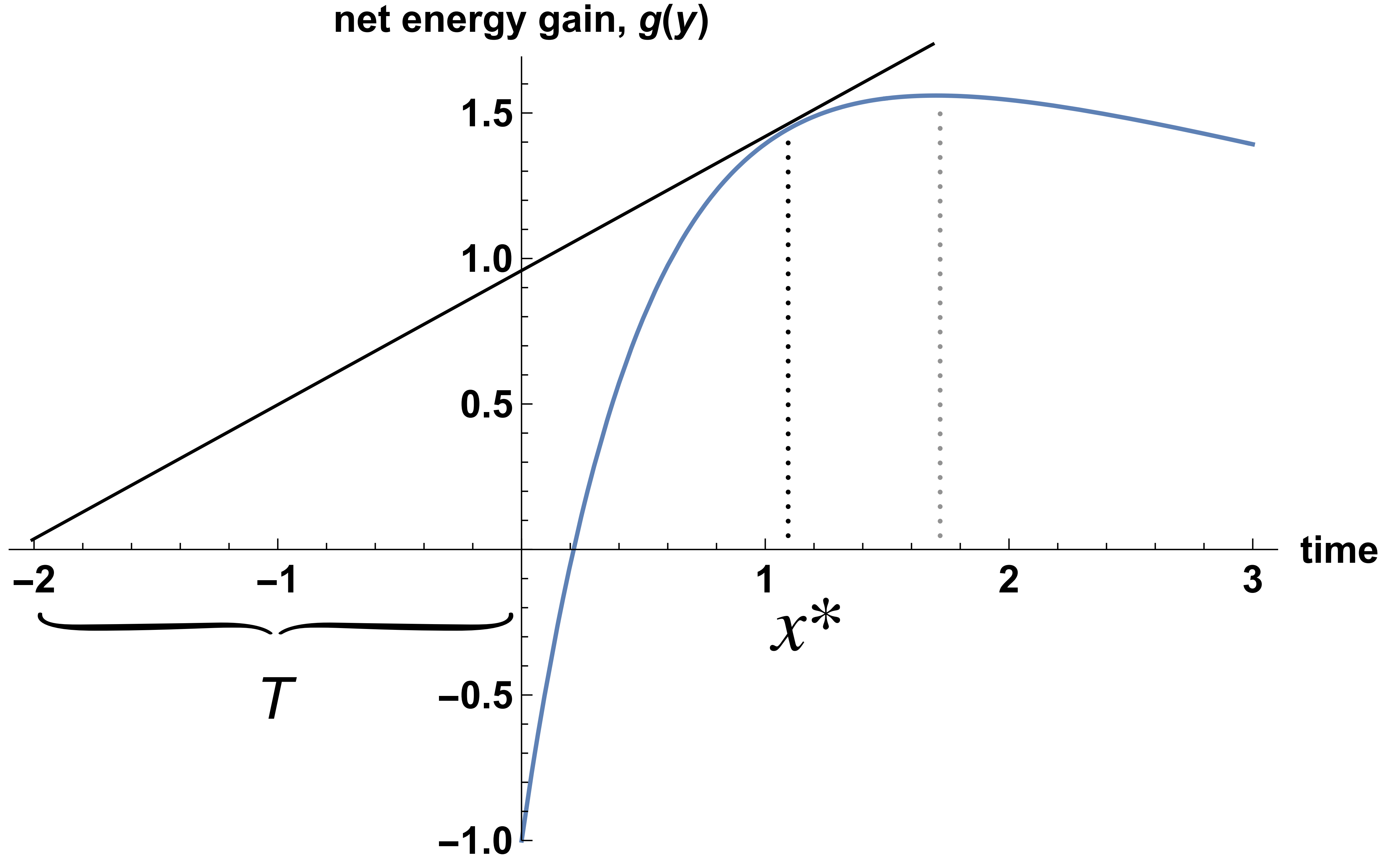

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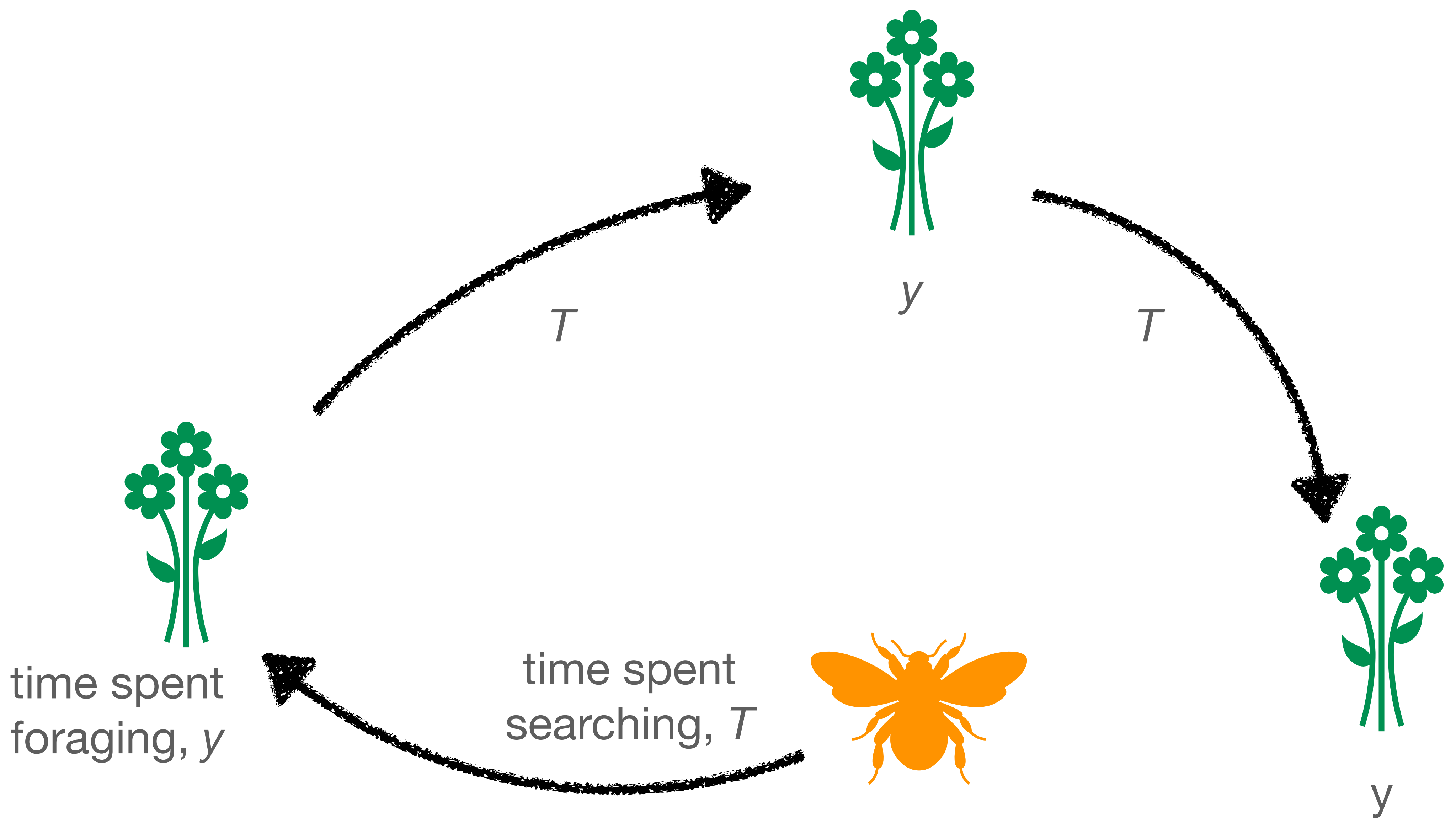

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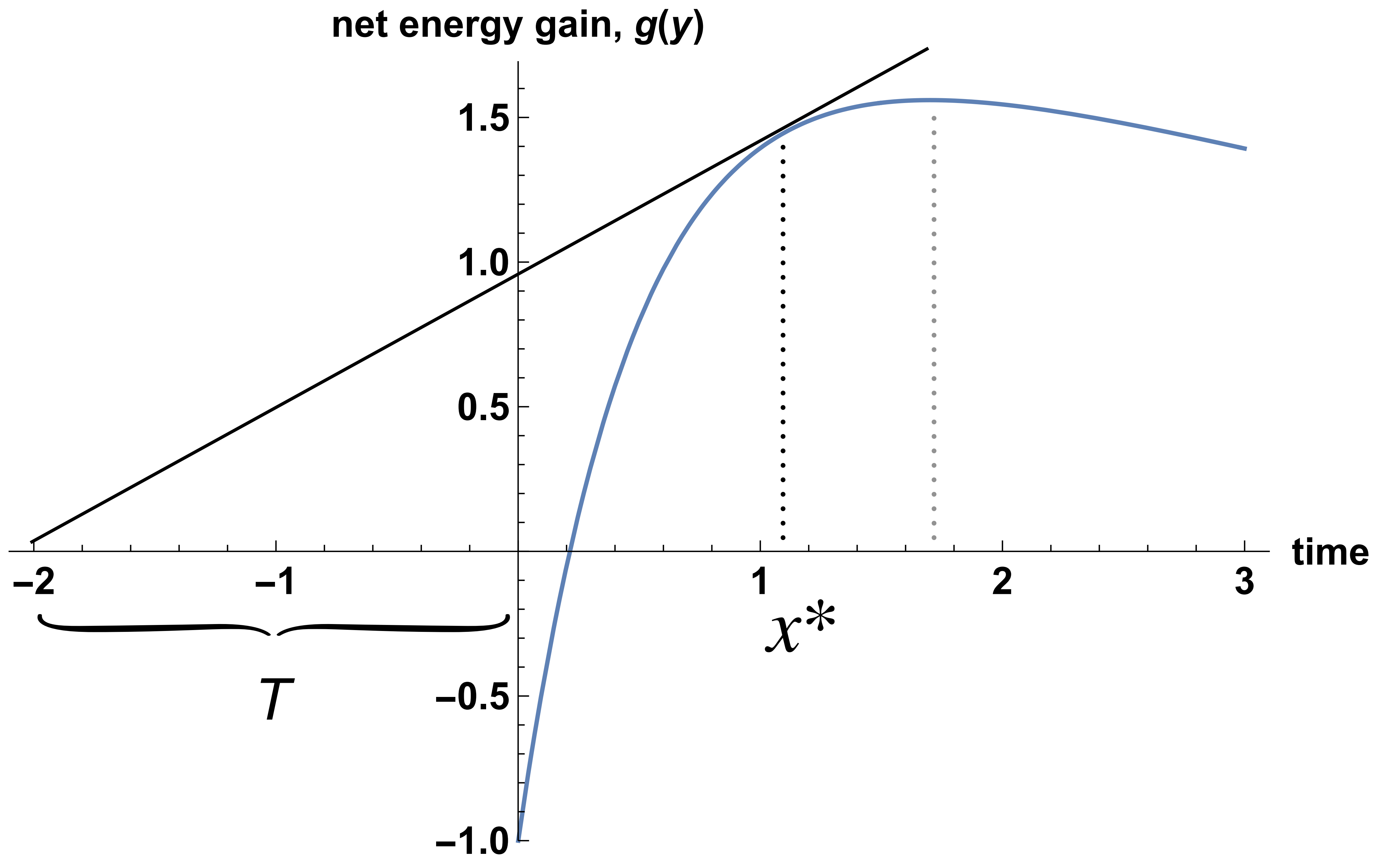

An animal should leave when the marginal (or instantaneous) rate of energy gain $g'(x^*)$ has fallen to the total rate of energy gain $R(x^*)$

When selection favours risky foraging?

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Variation in relationship with uncertainty

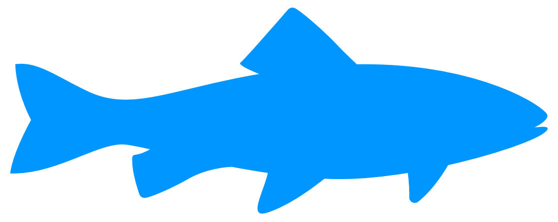
When selection favours risky foraging?

State-dependent payoffs and uncertainty

When selection favours risky foraging?

State-dependent payoffs and uncertainty

High condition
e.g., well-fed



Low condition
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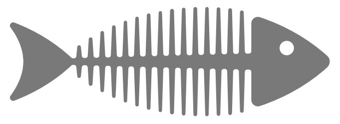

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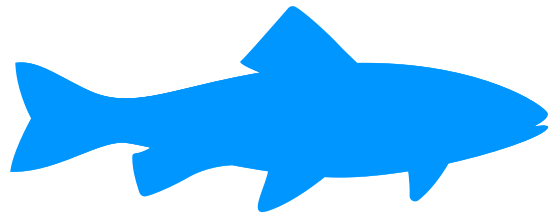

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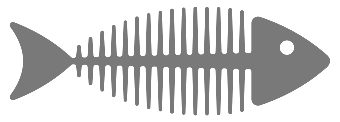

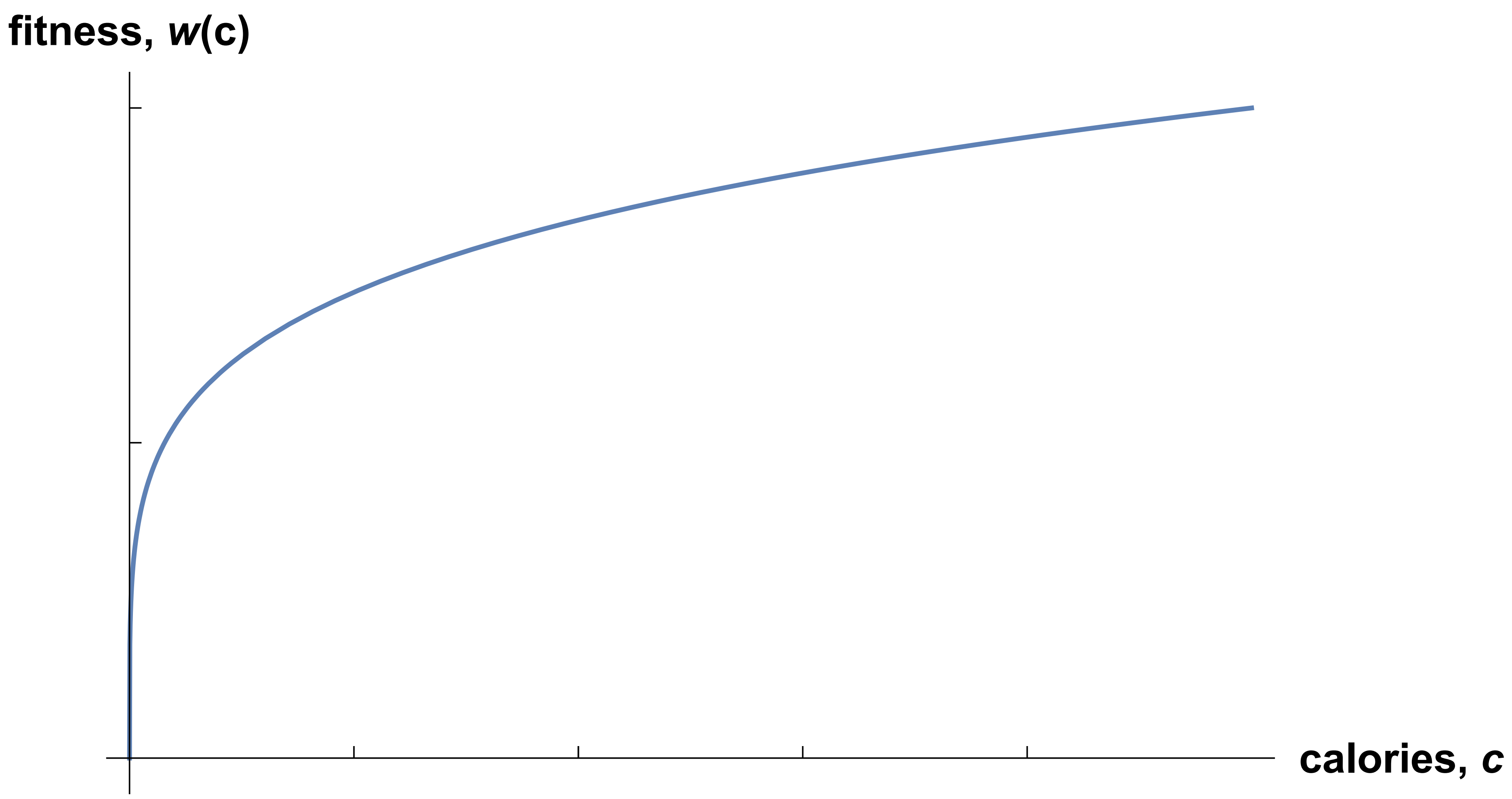

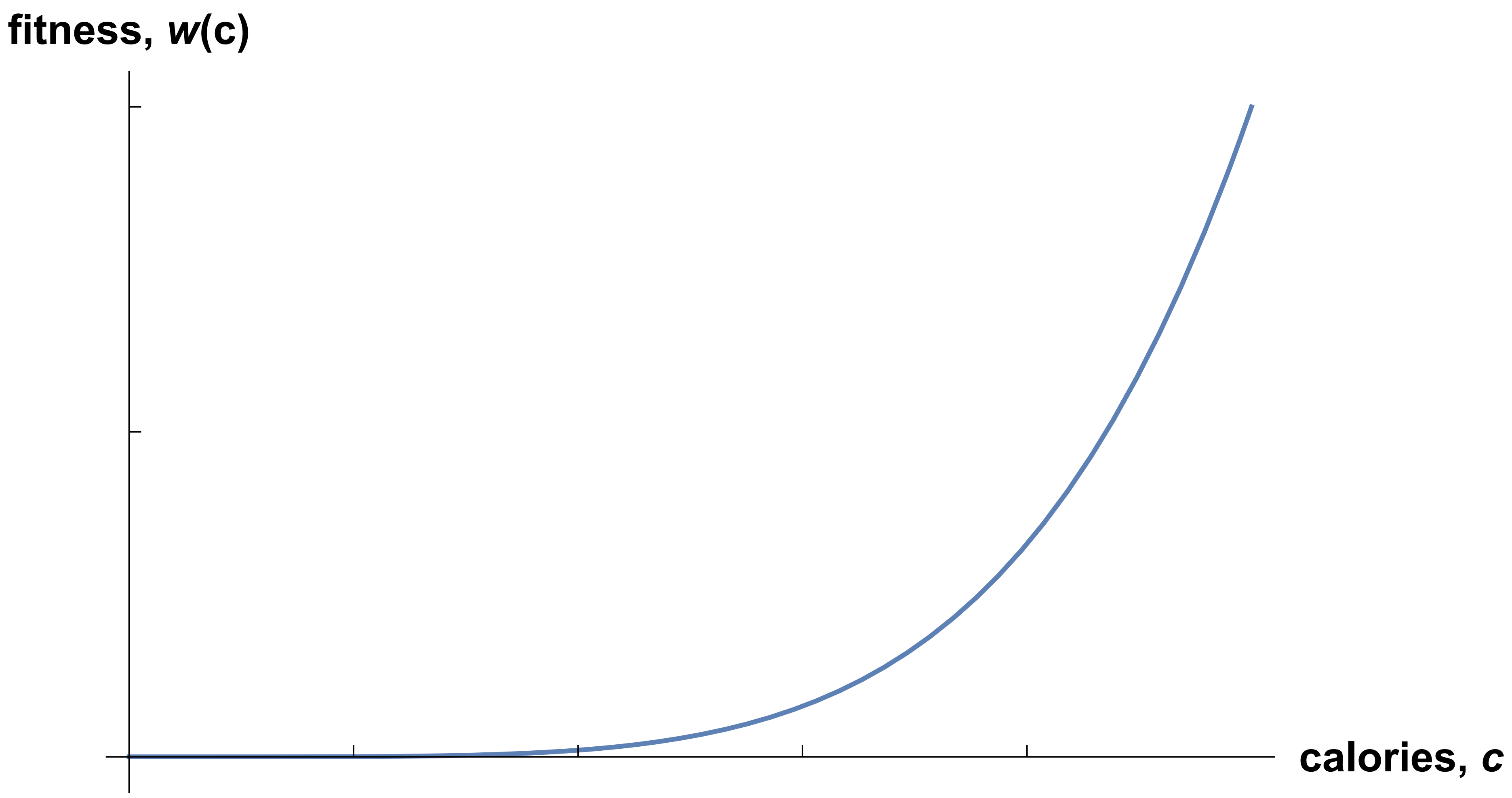

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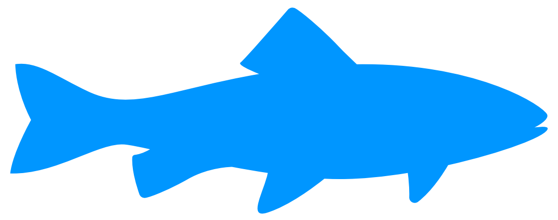

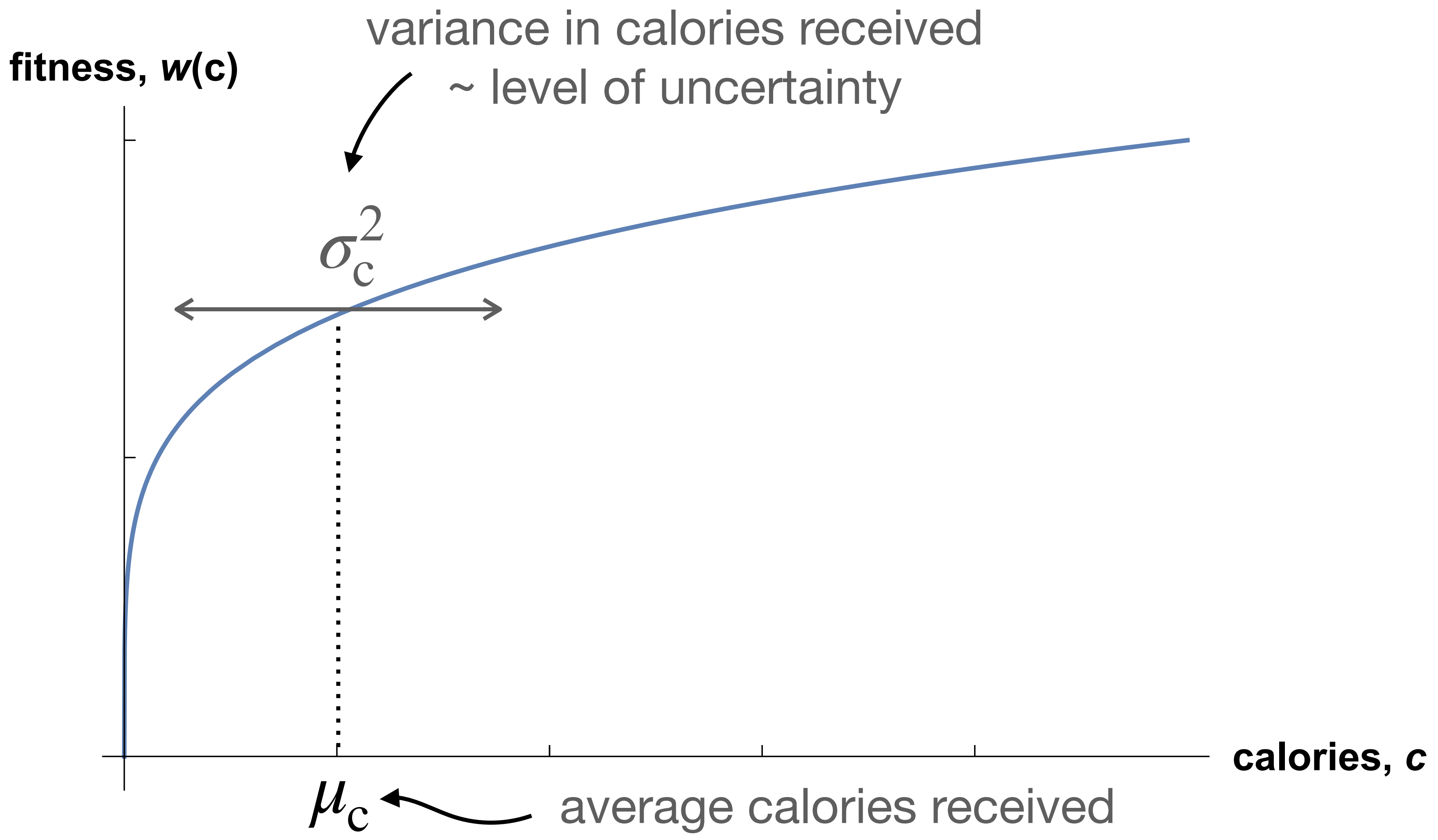

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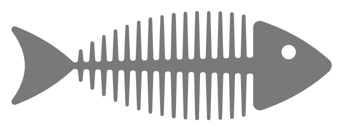

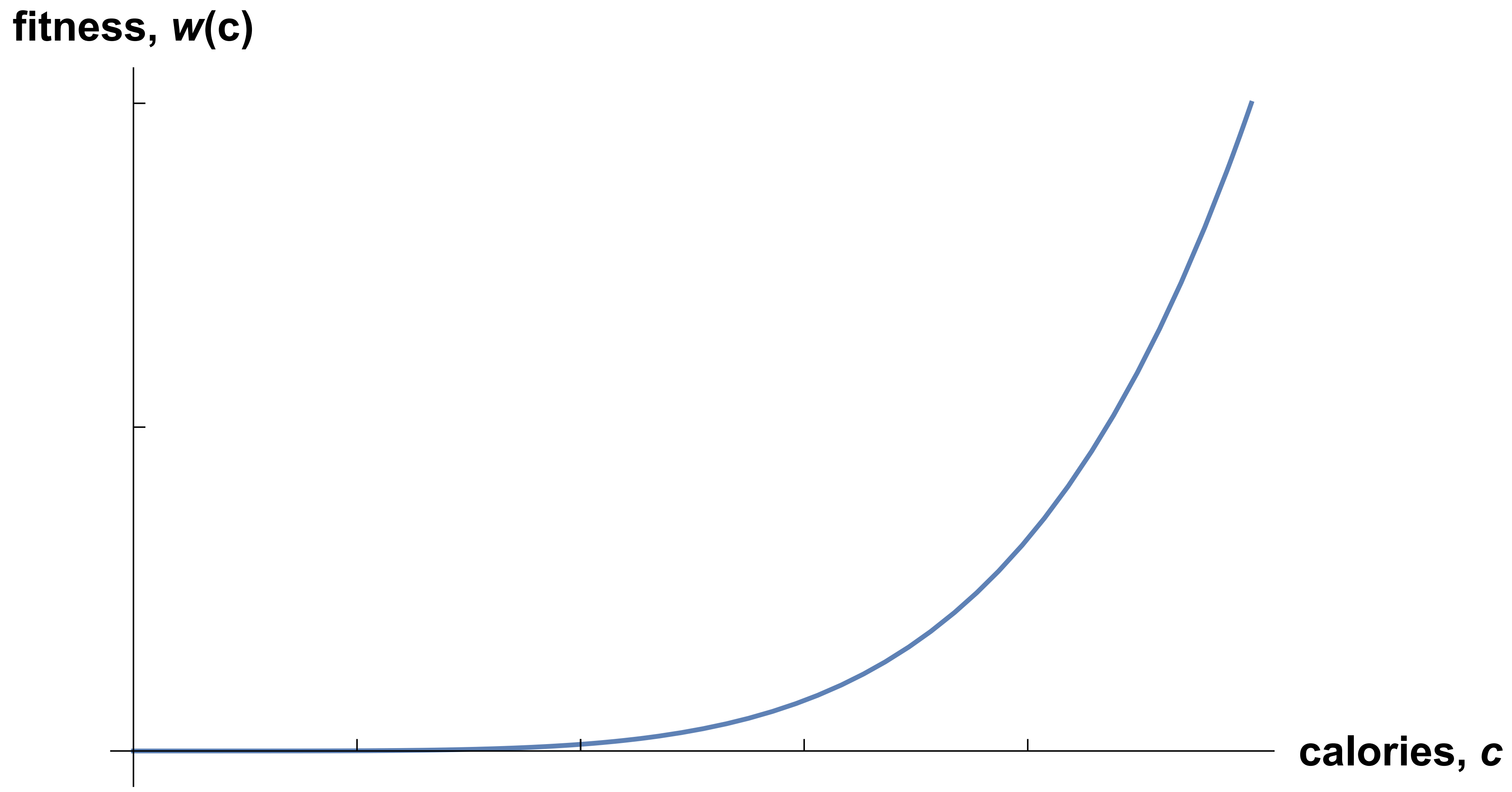

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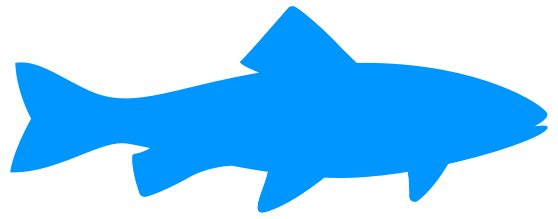

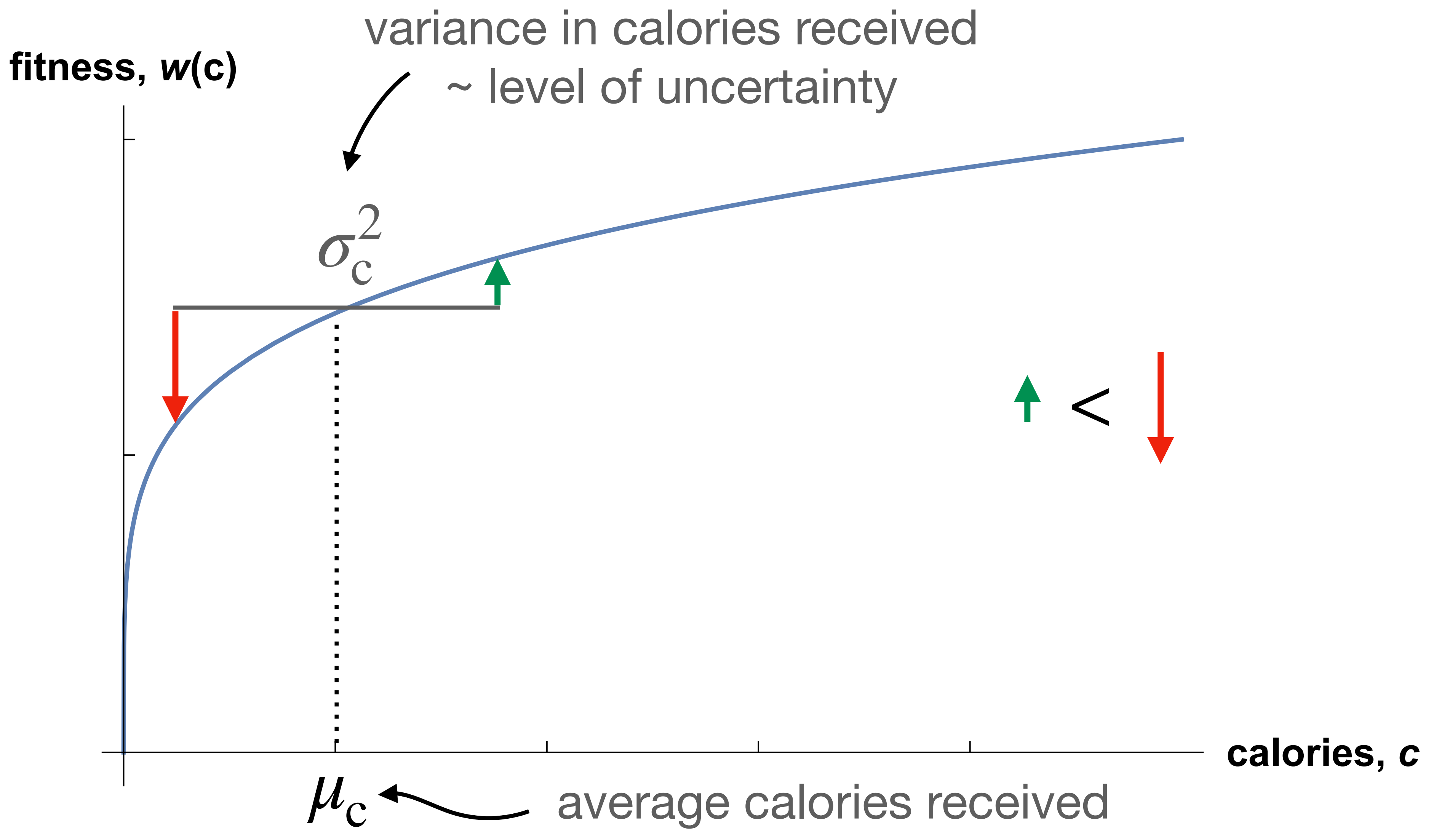

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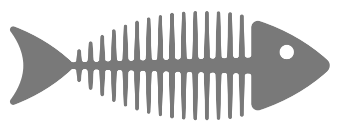

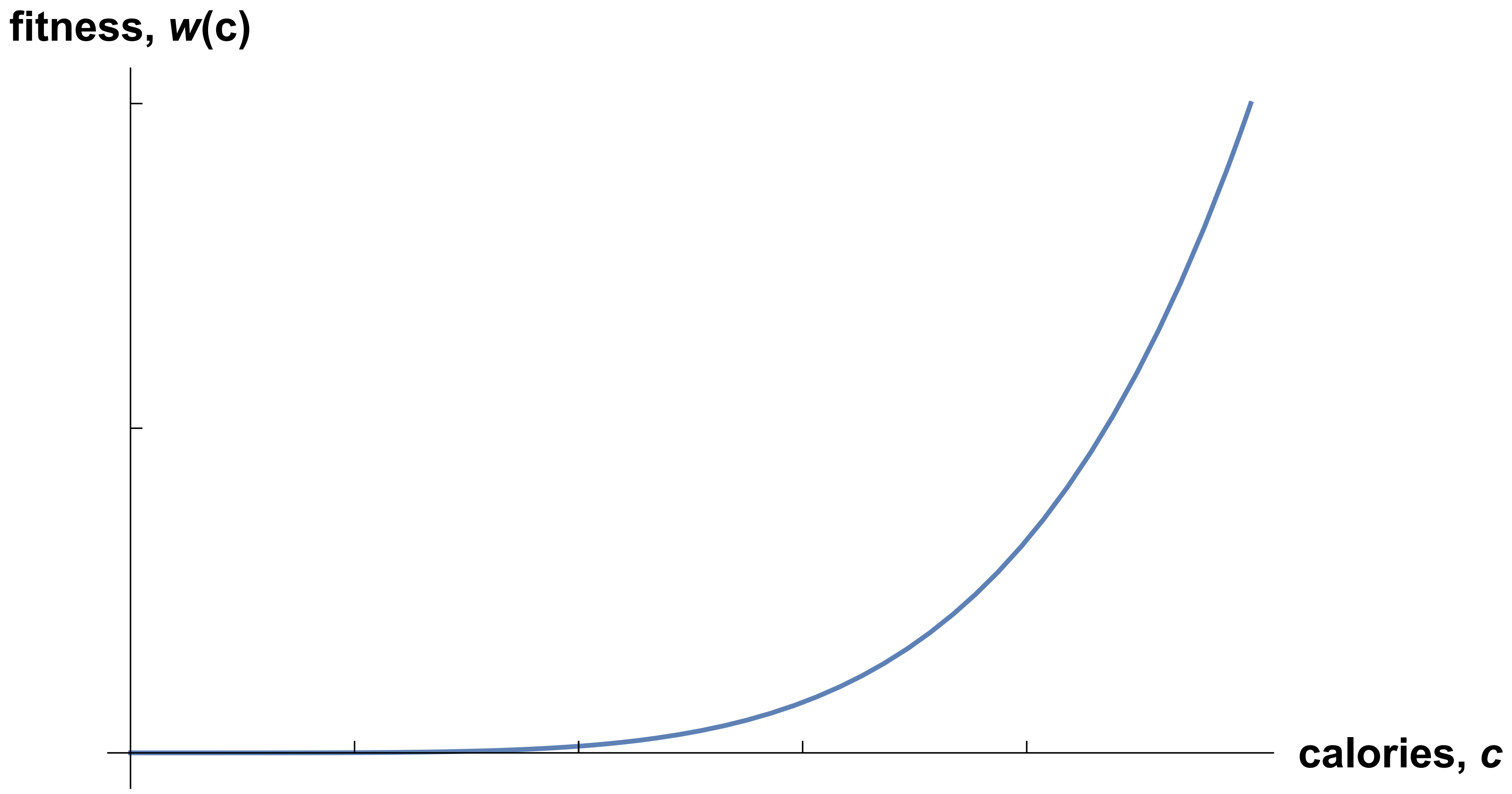

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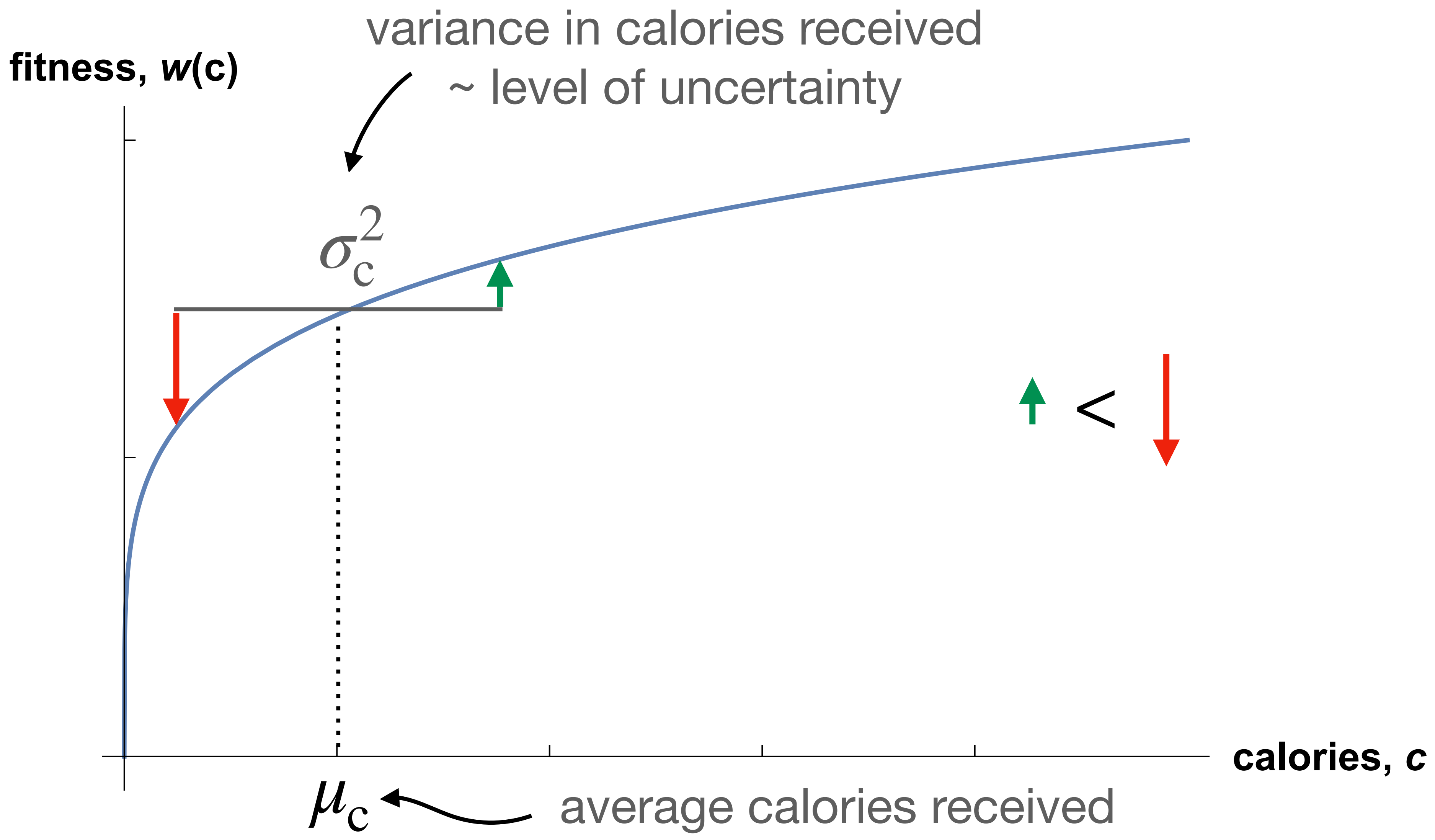

Risk not worth taking: fitness cost of bad times outweighs fitness benefits of good times

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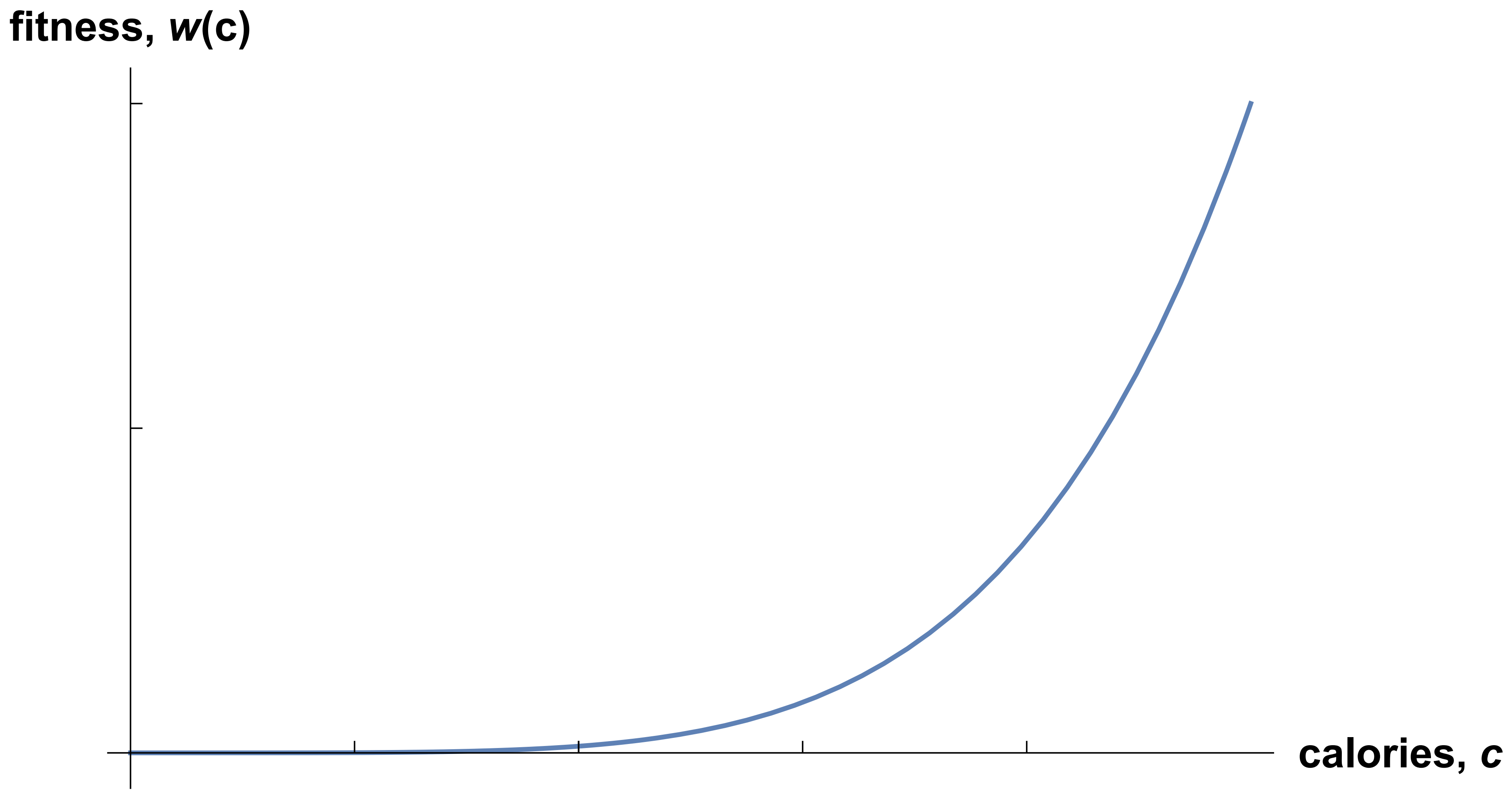

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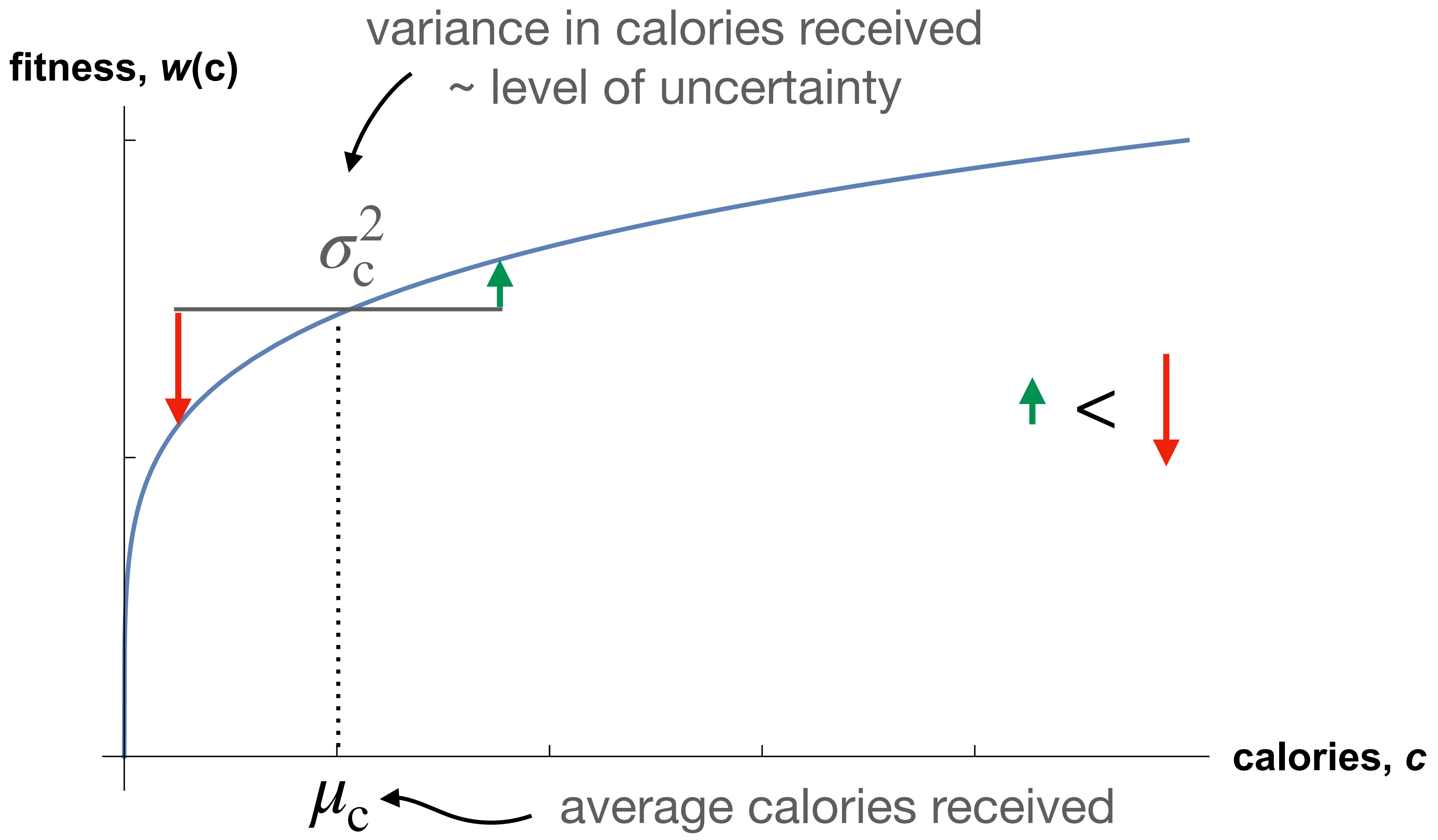

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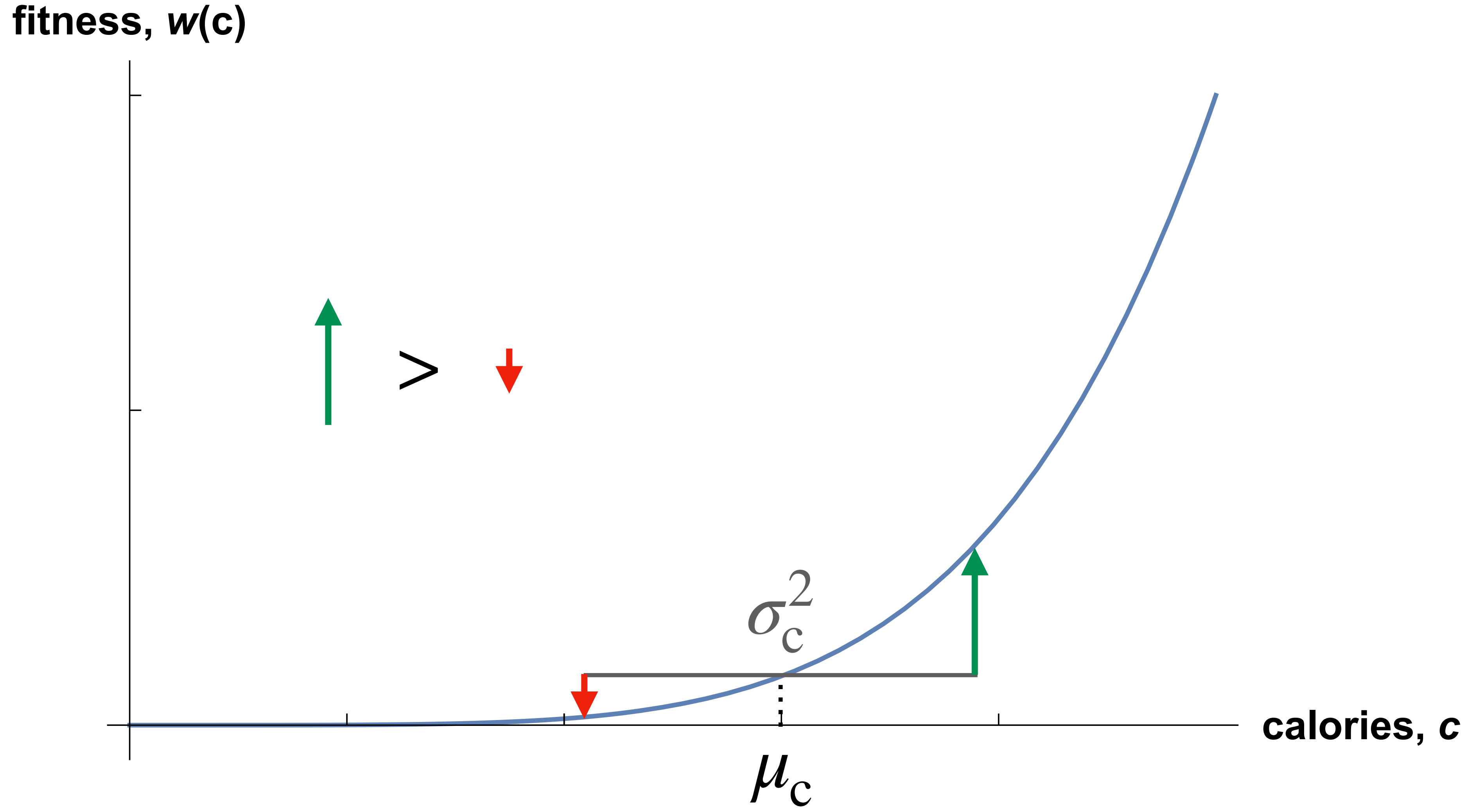

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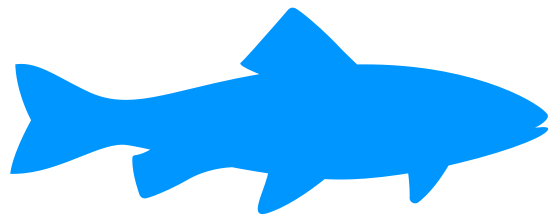

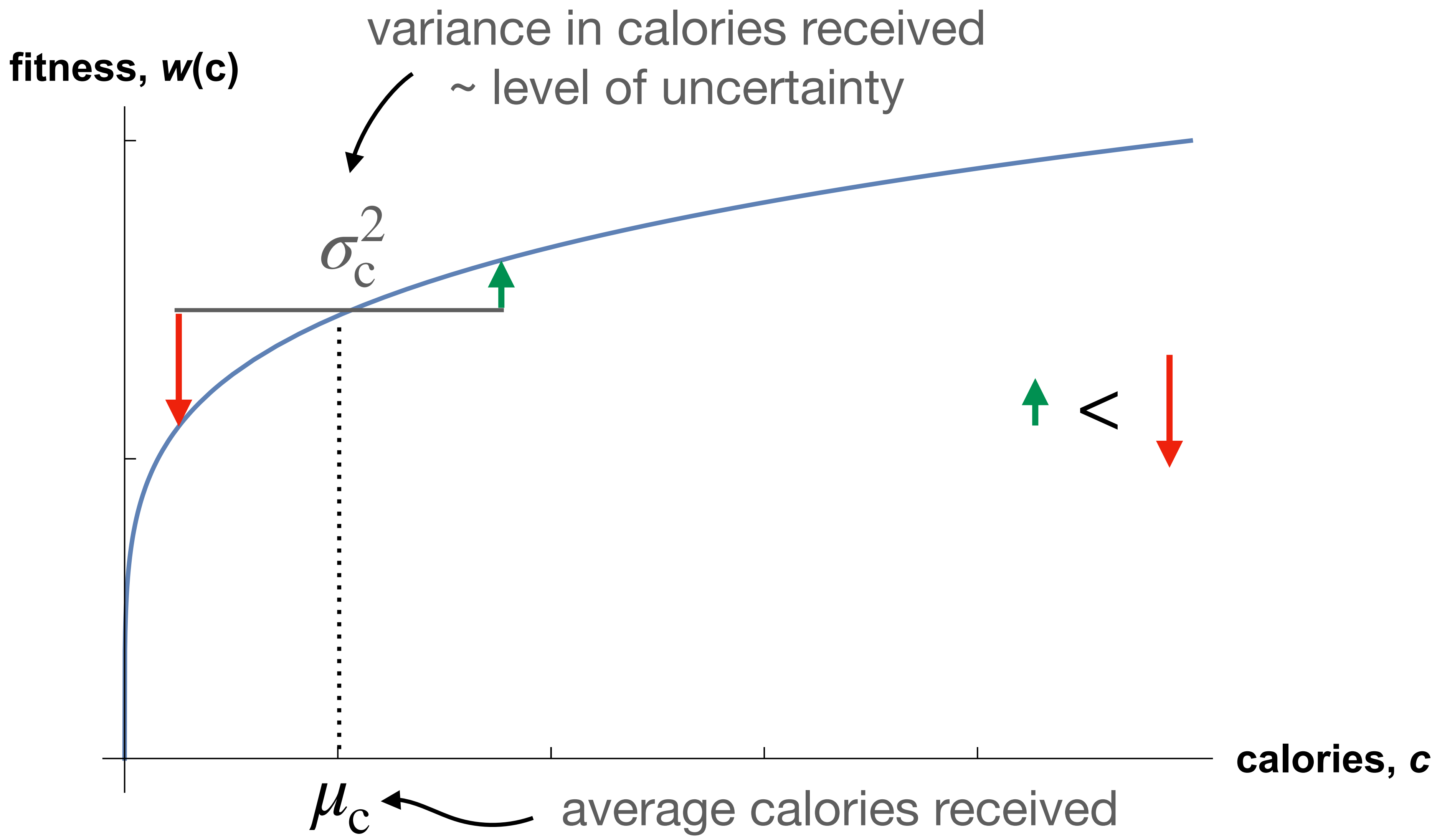

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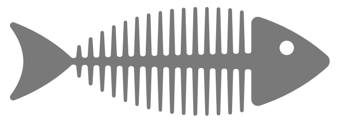

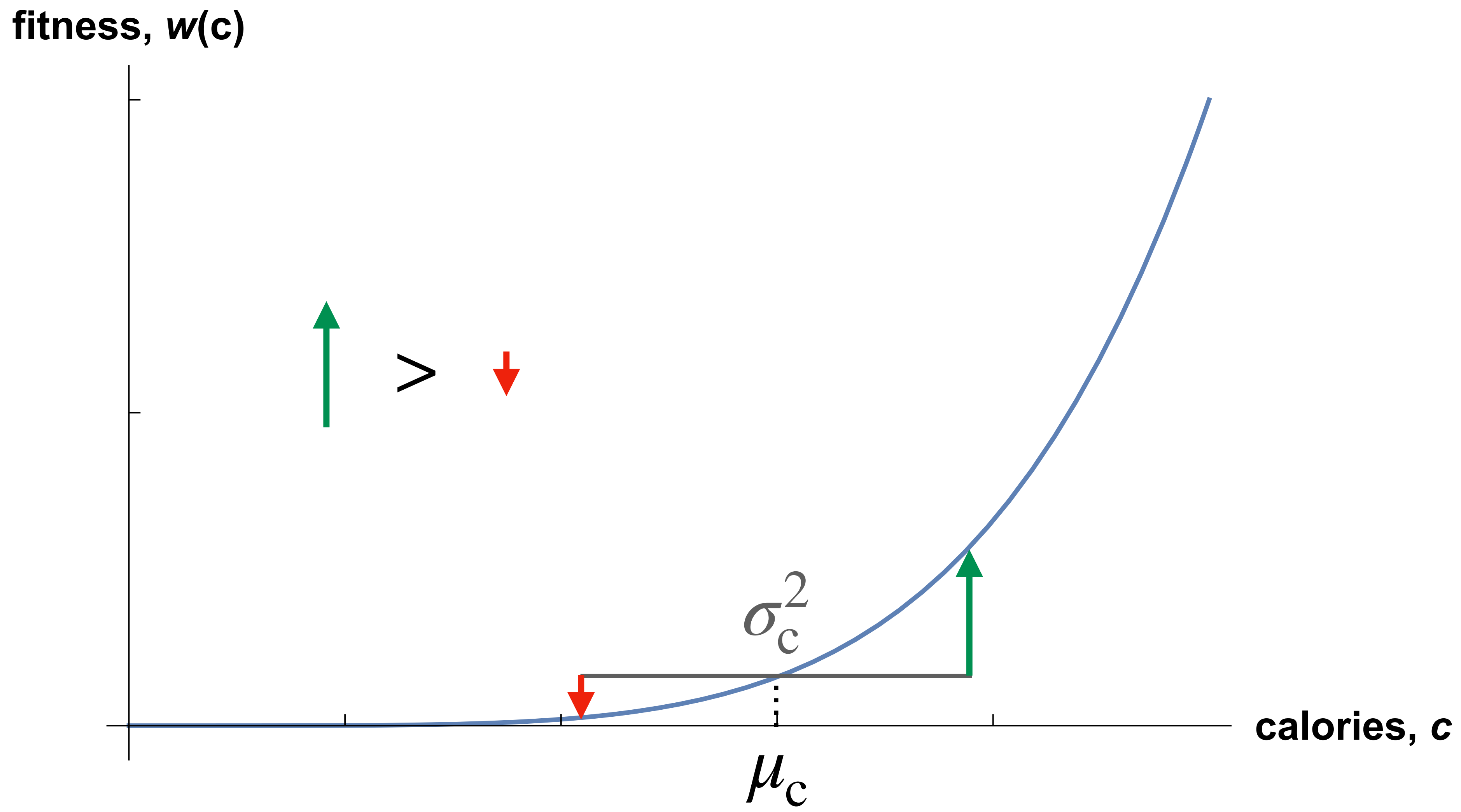

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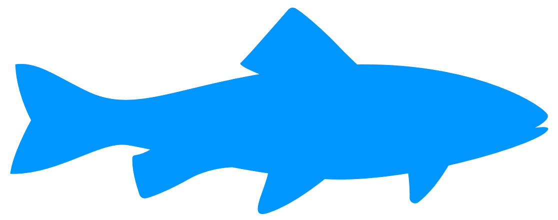

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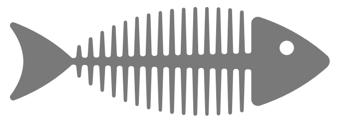
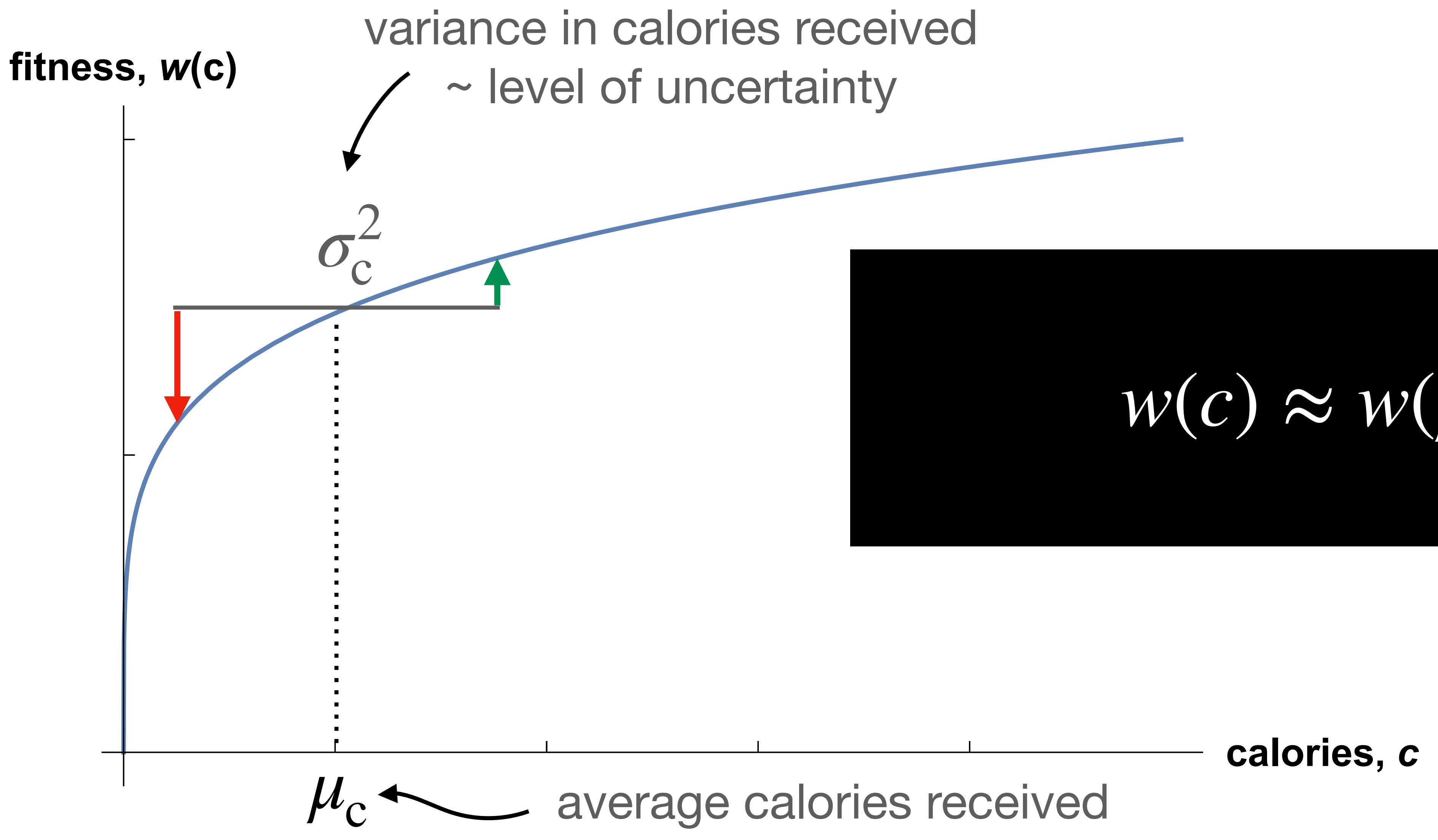
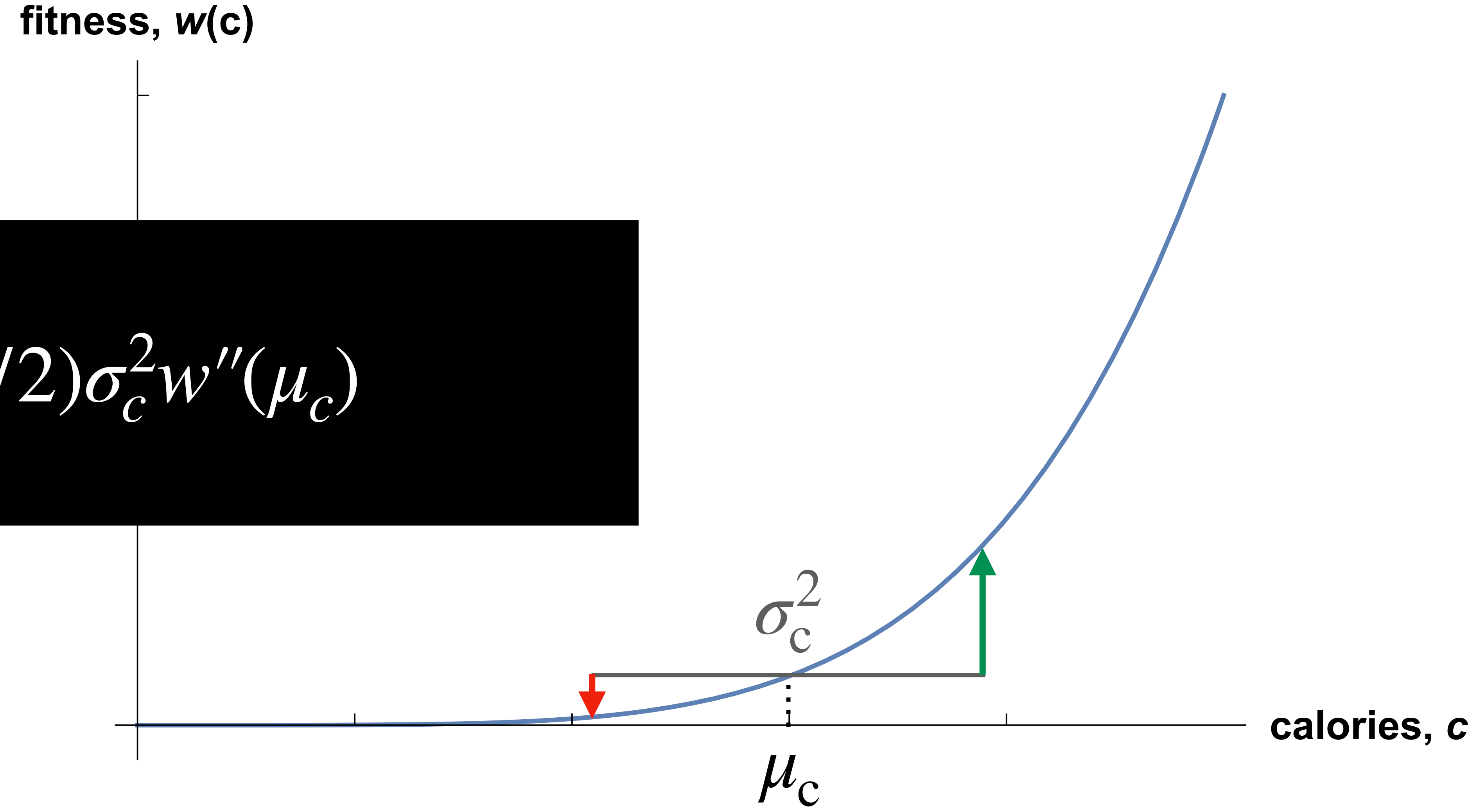




$$w(c) \approx w(\mu_c) + (1/2)\sigma_c^2 w''(\mu_c)$$



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The exploitation of renewable resources

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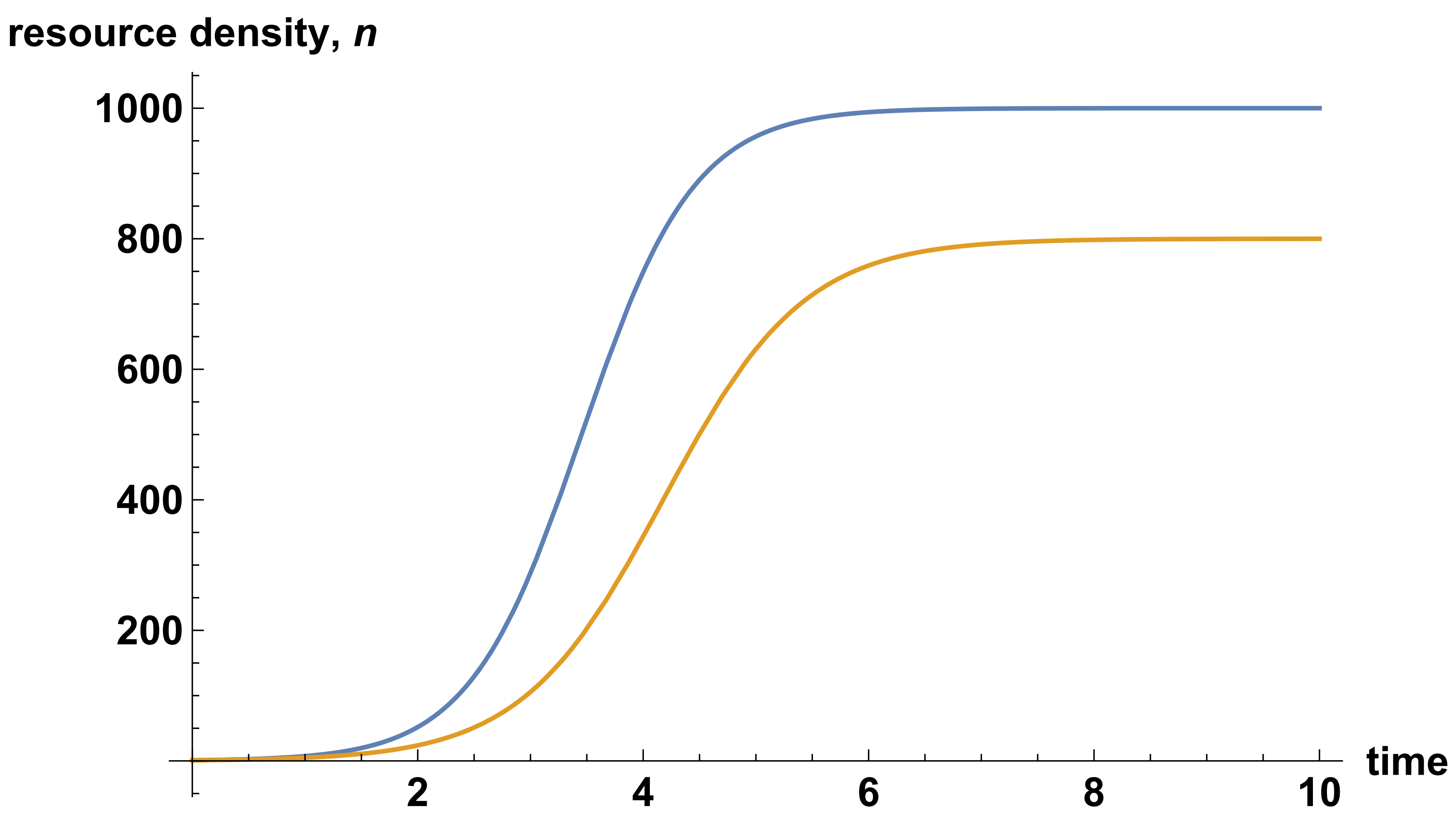
Schaefer's model

- Biotic resource with density *n*,

foraging function

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



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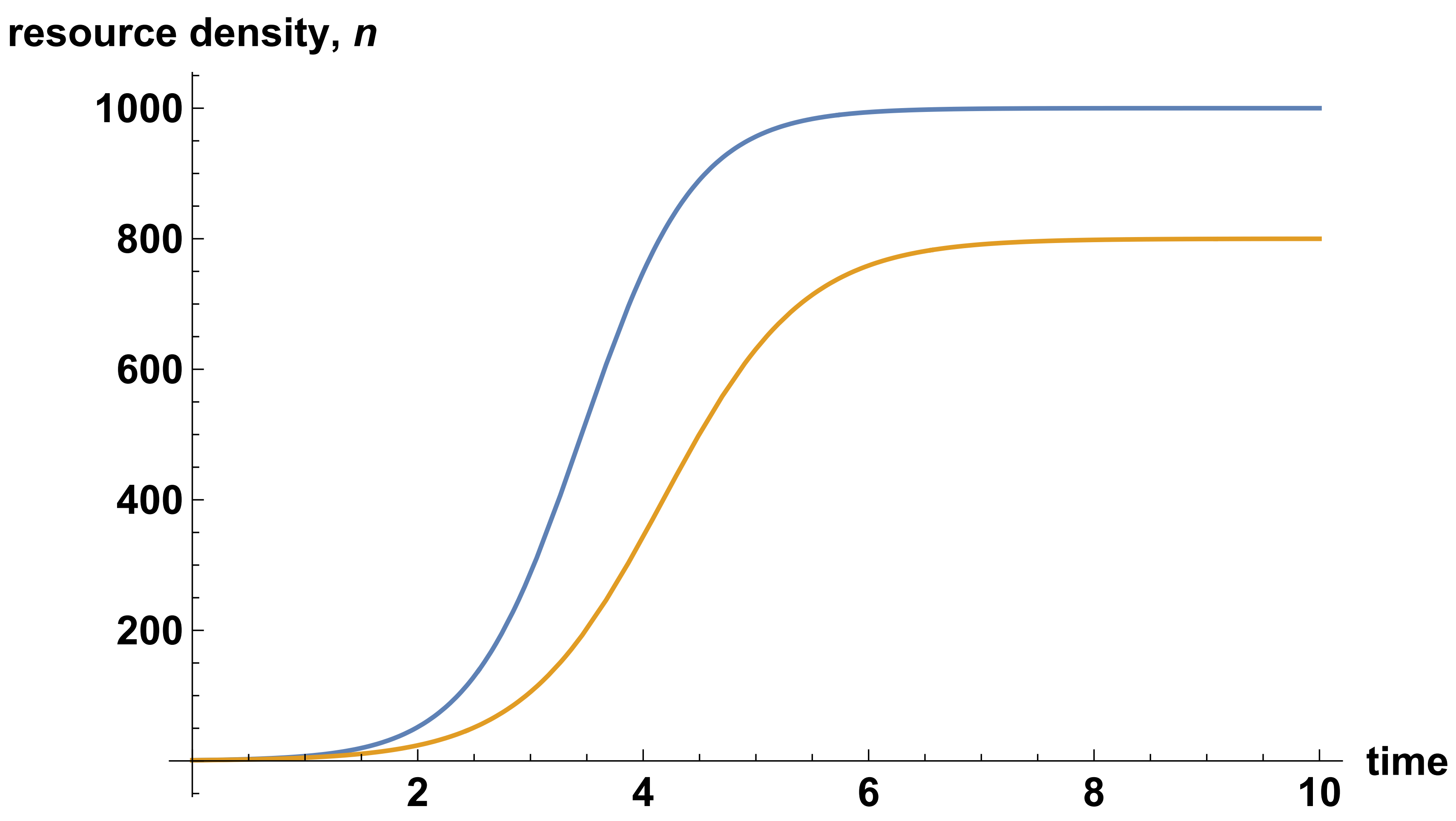

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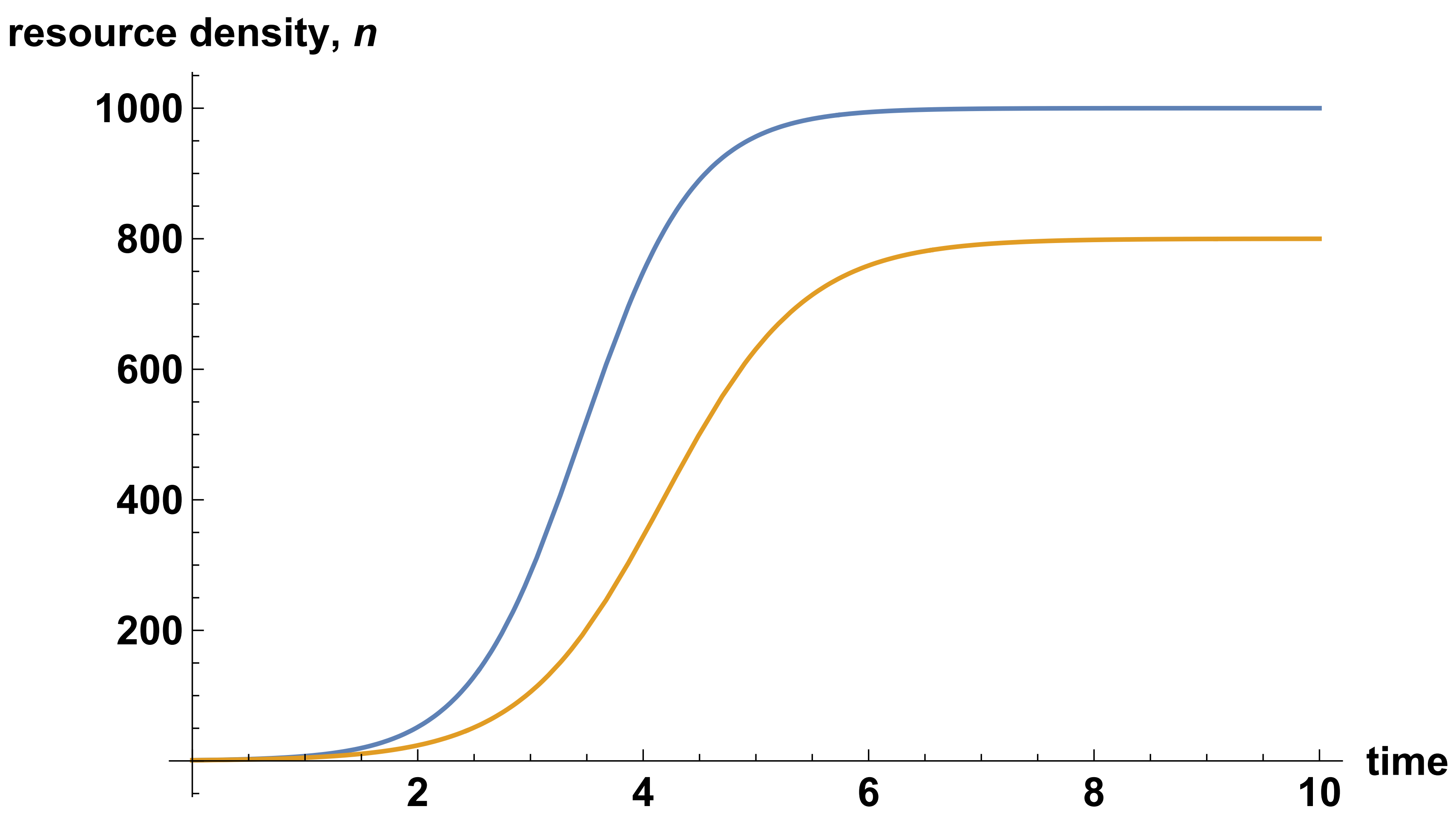

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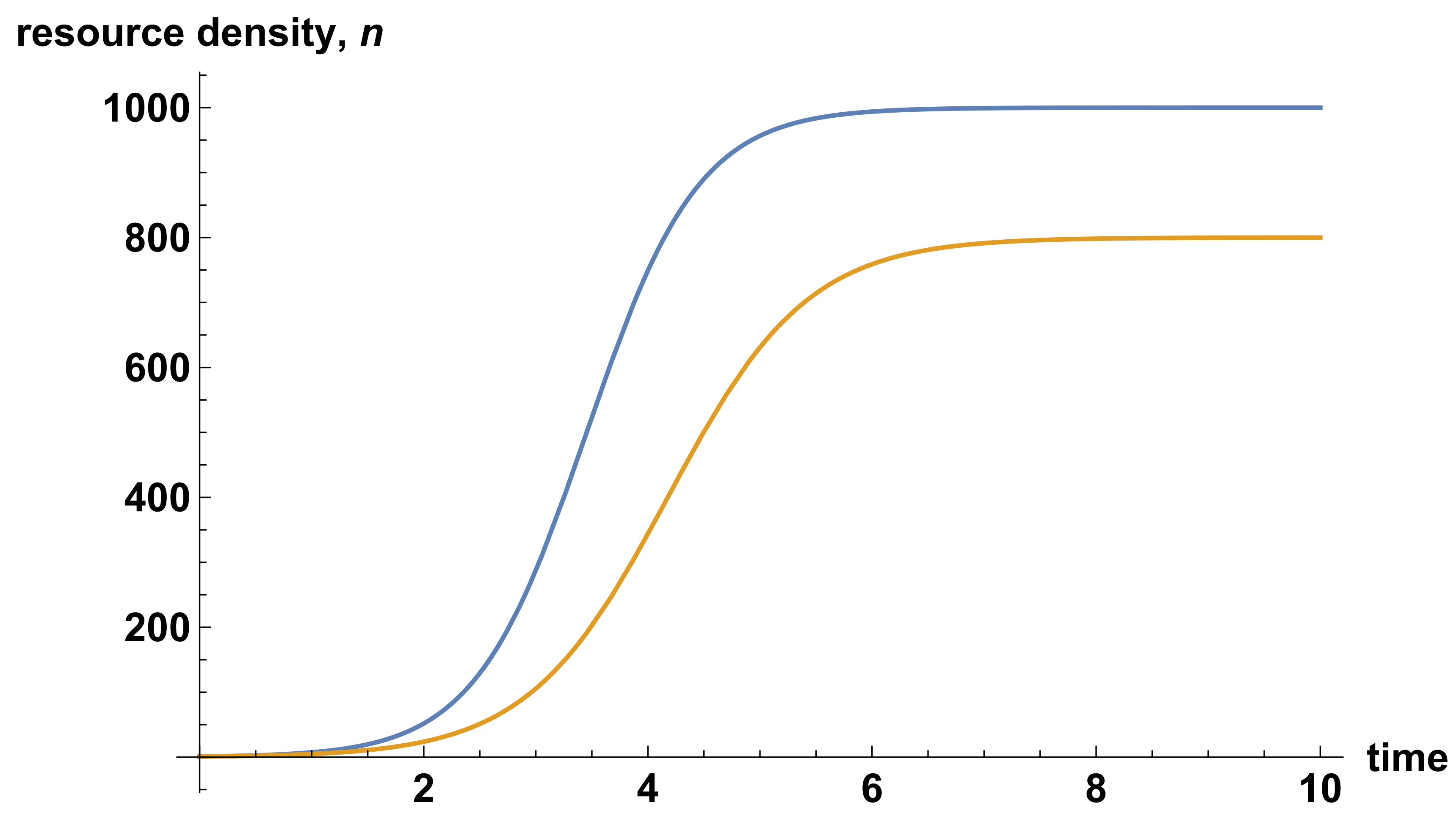

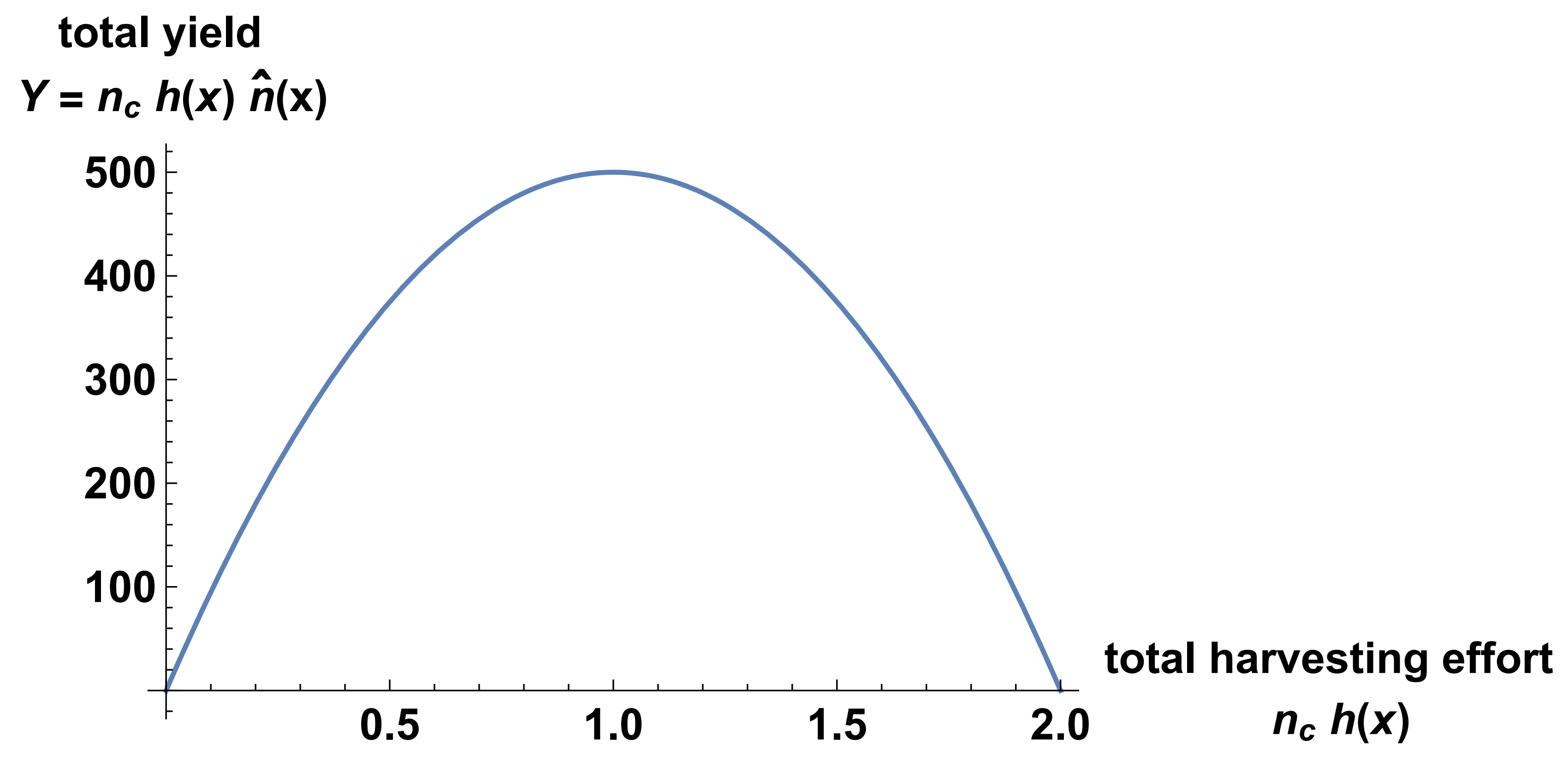

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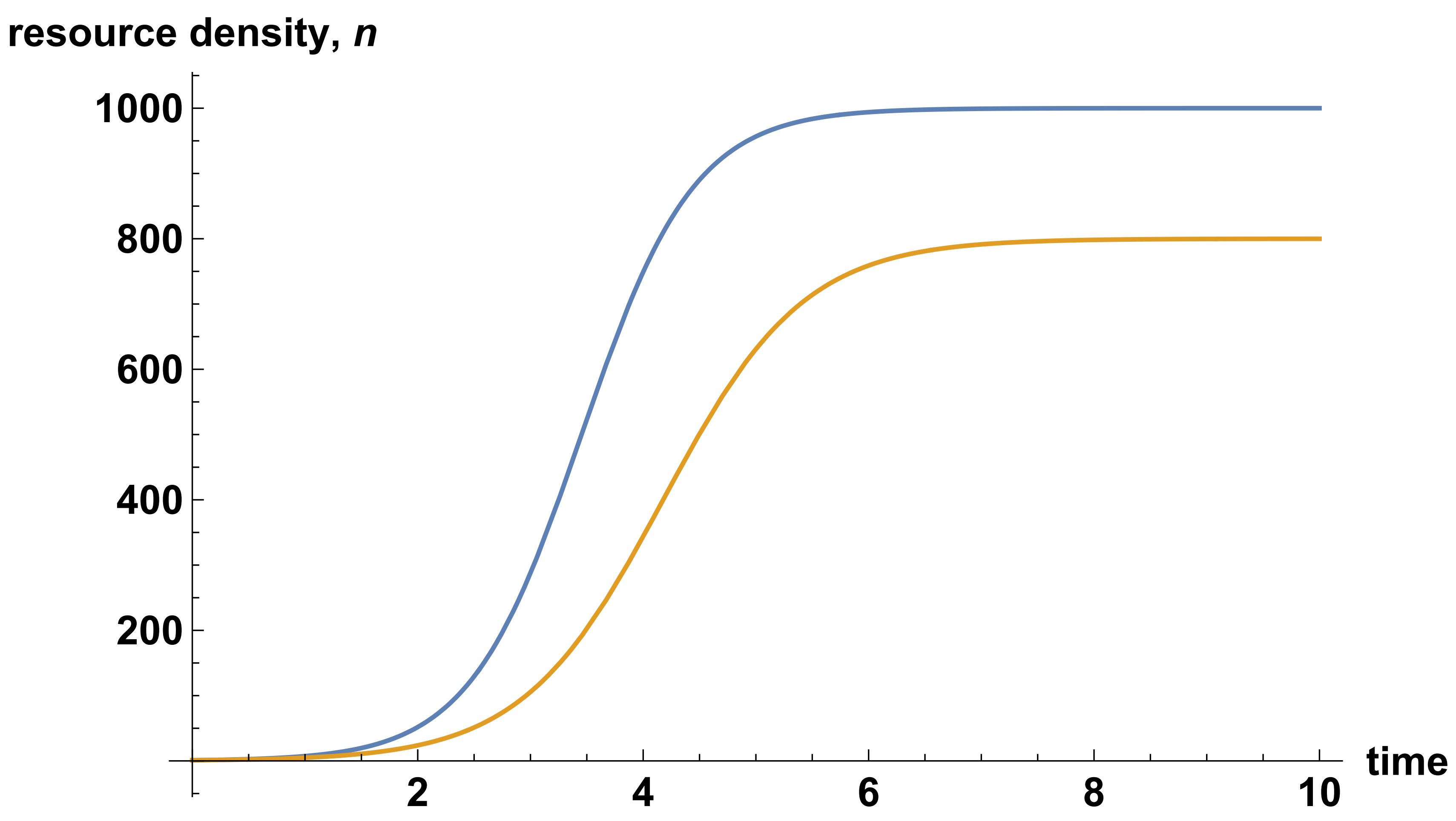
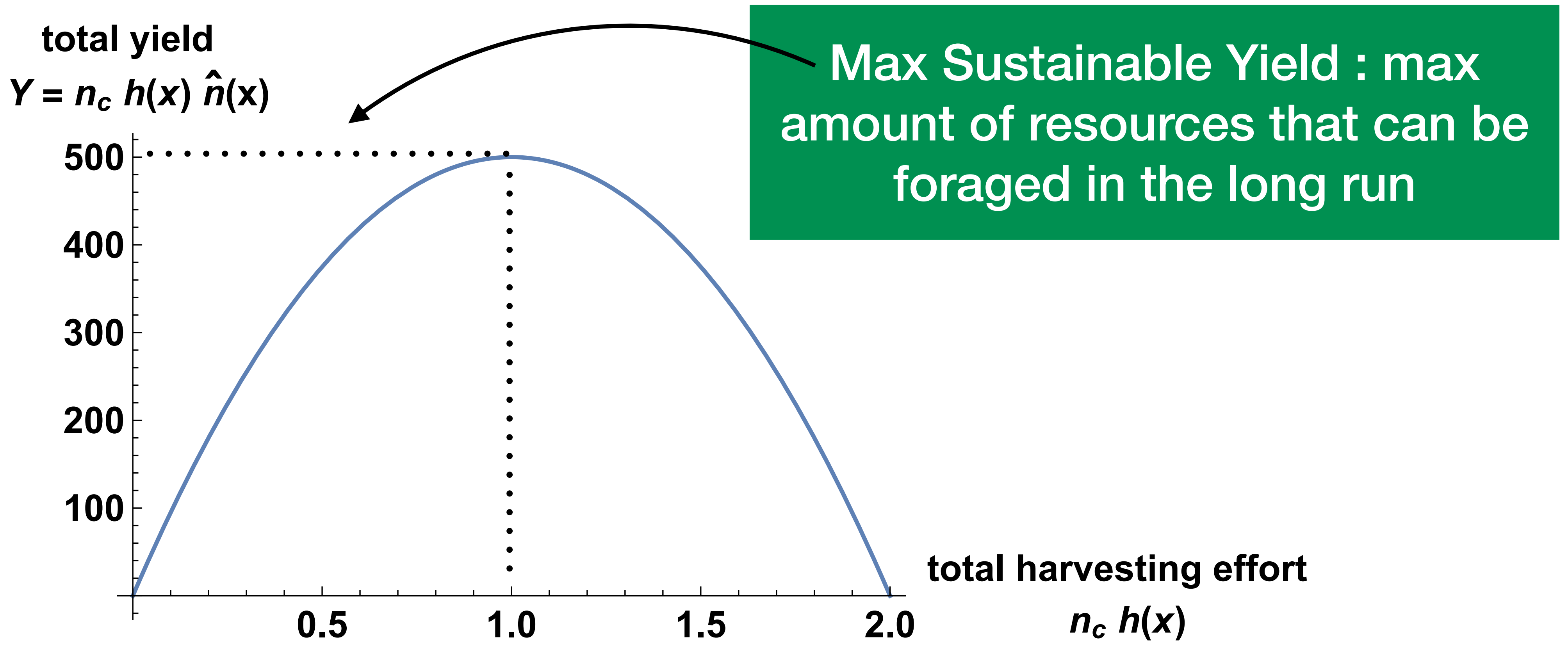
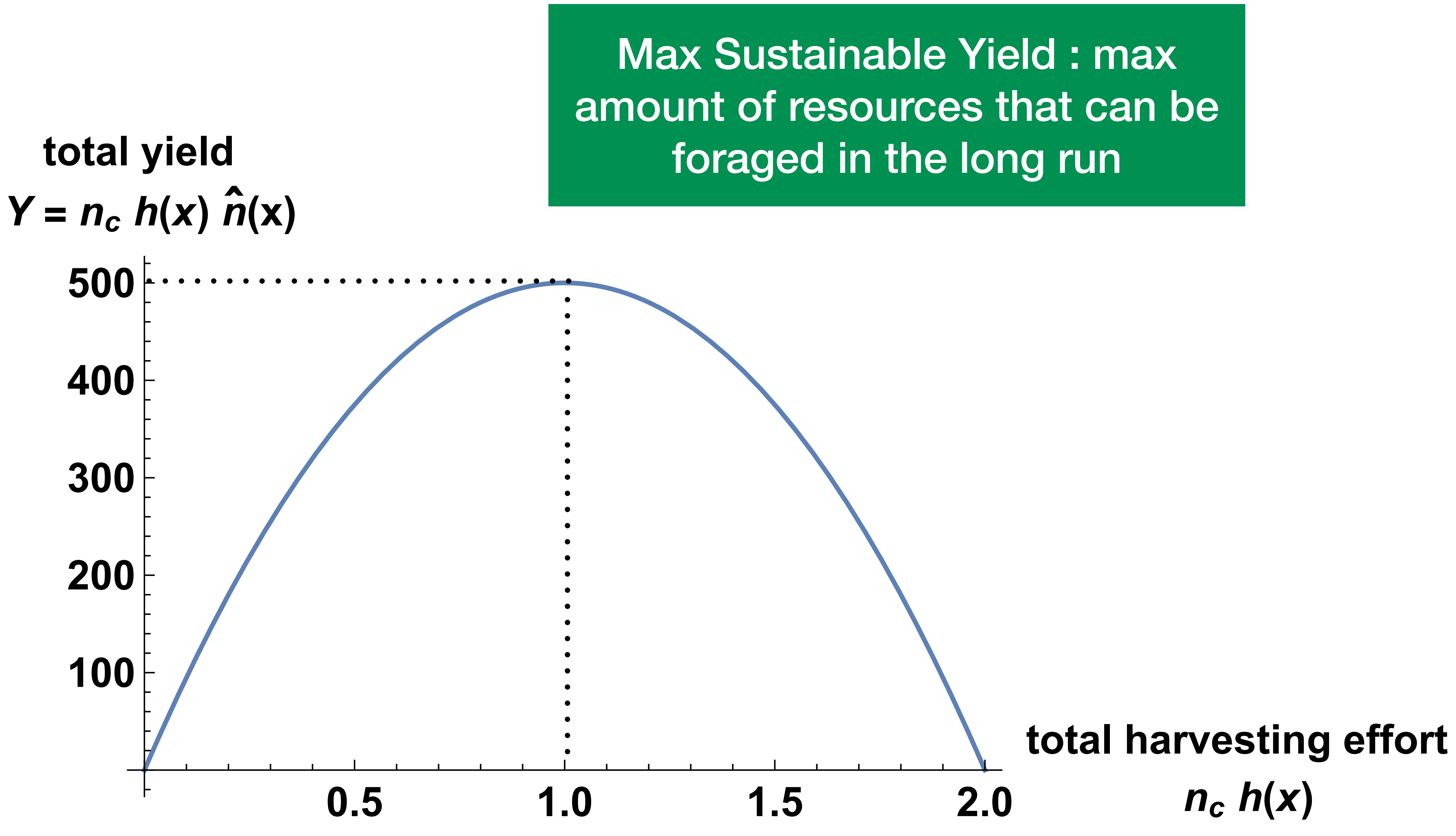




The exploitation of renewable resources

MSY and over-consumption



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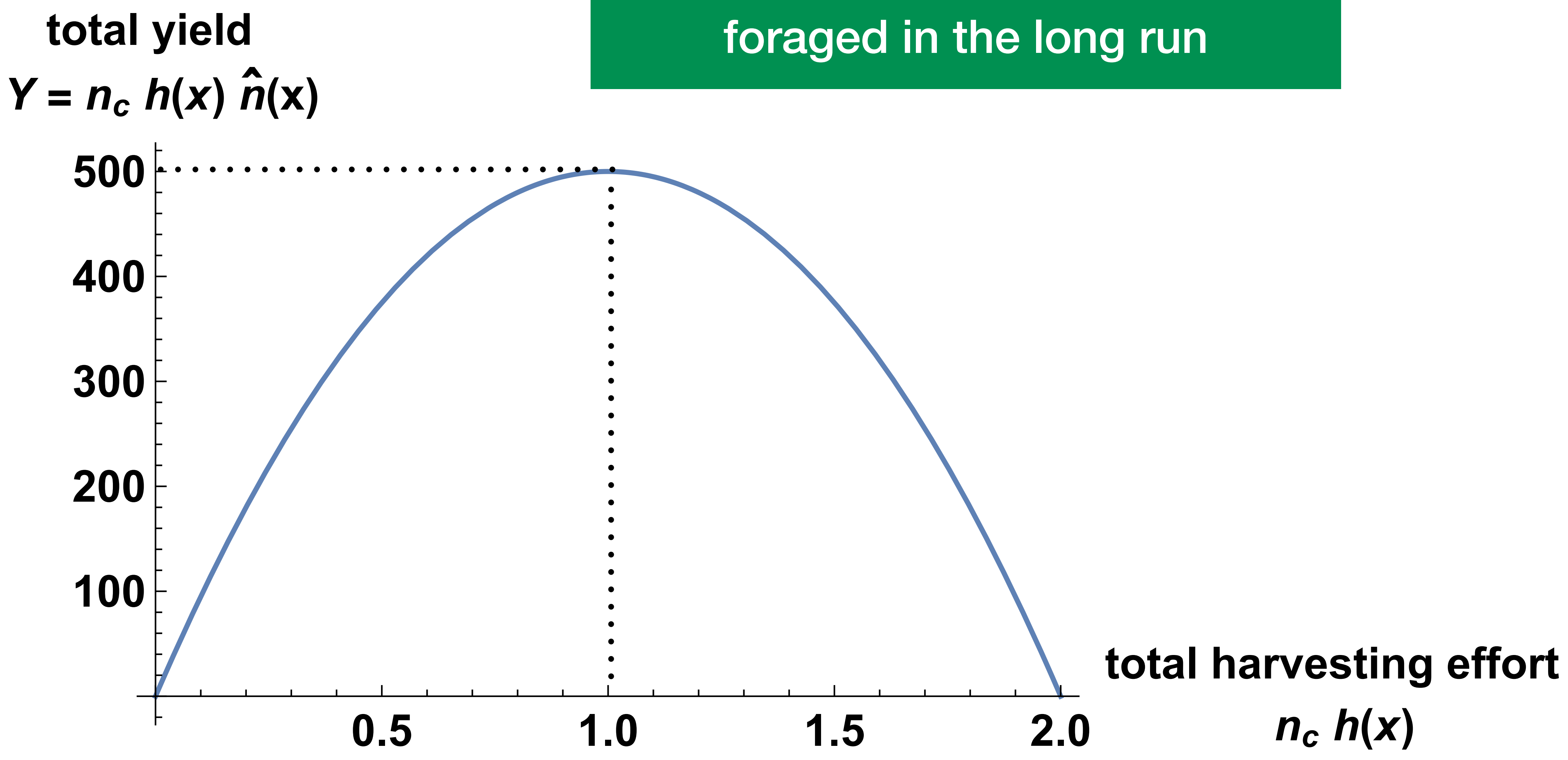
- Total yield = $n_c h(x) \times \hat{n}(x) = n_c x \times K\left(1 - n_c \frac{x}{r}\right)$

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



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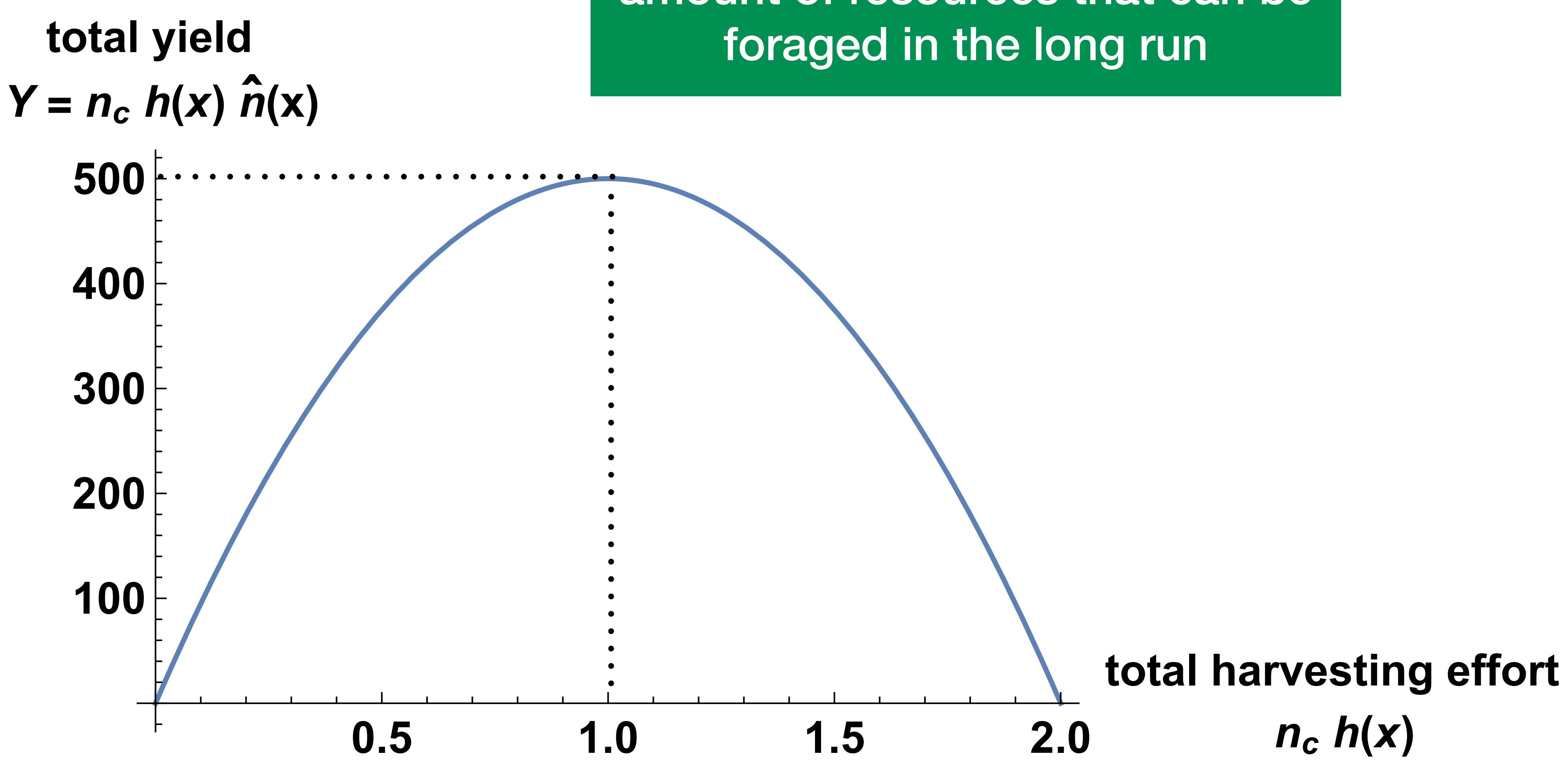

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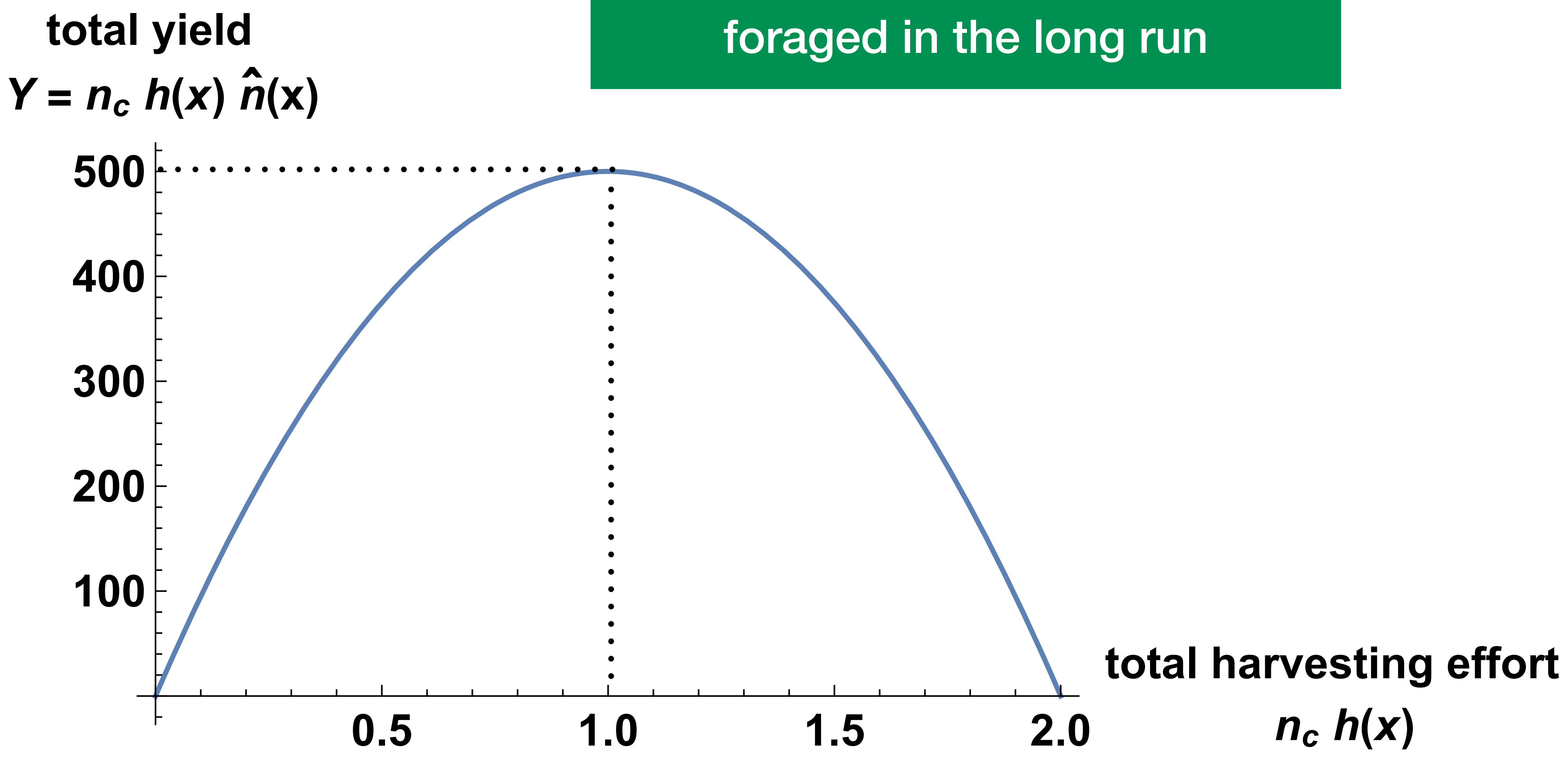

The exploitation of renewable resources

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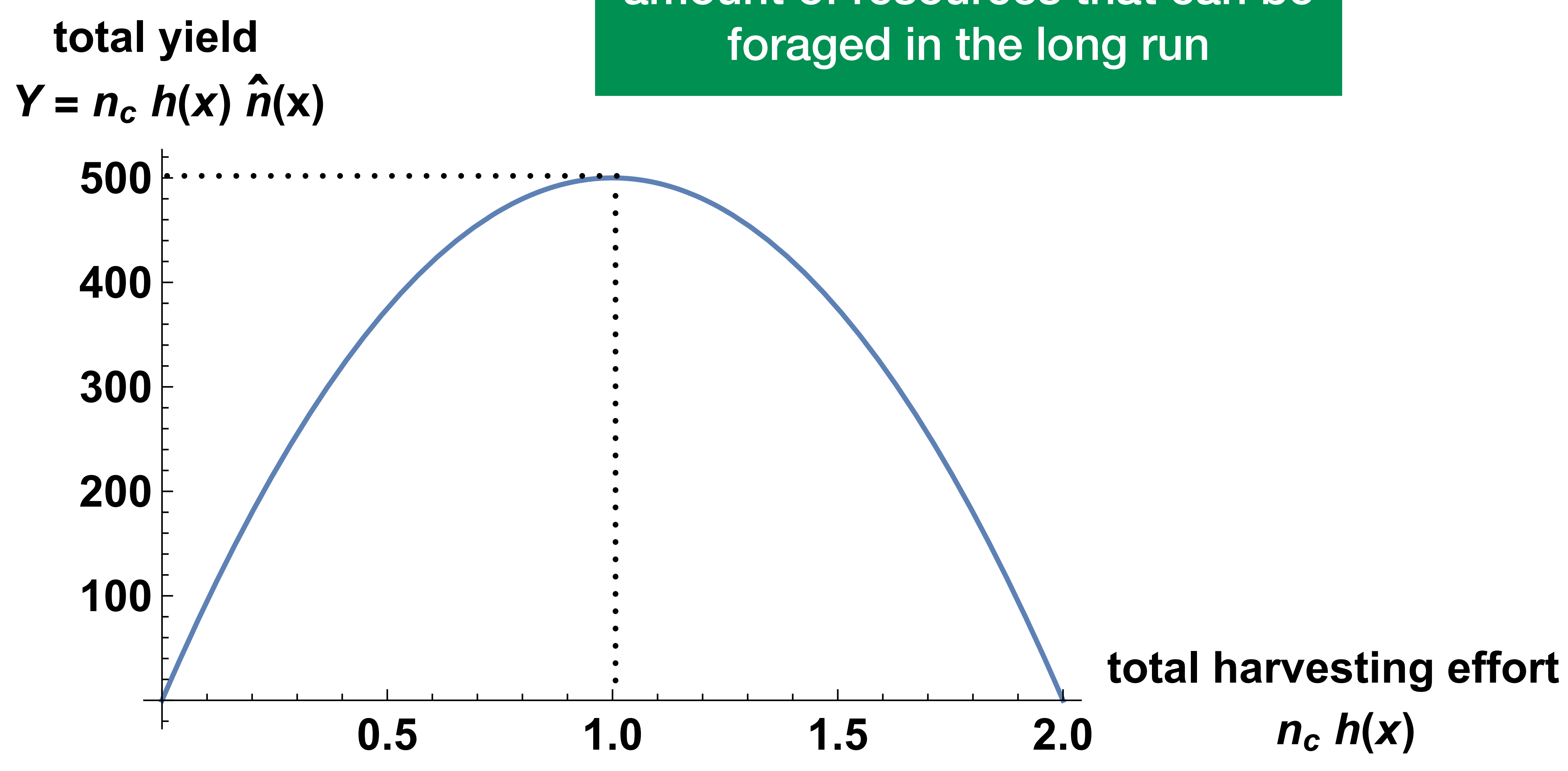

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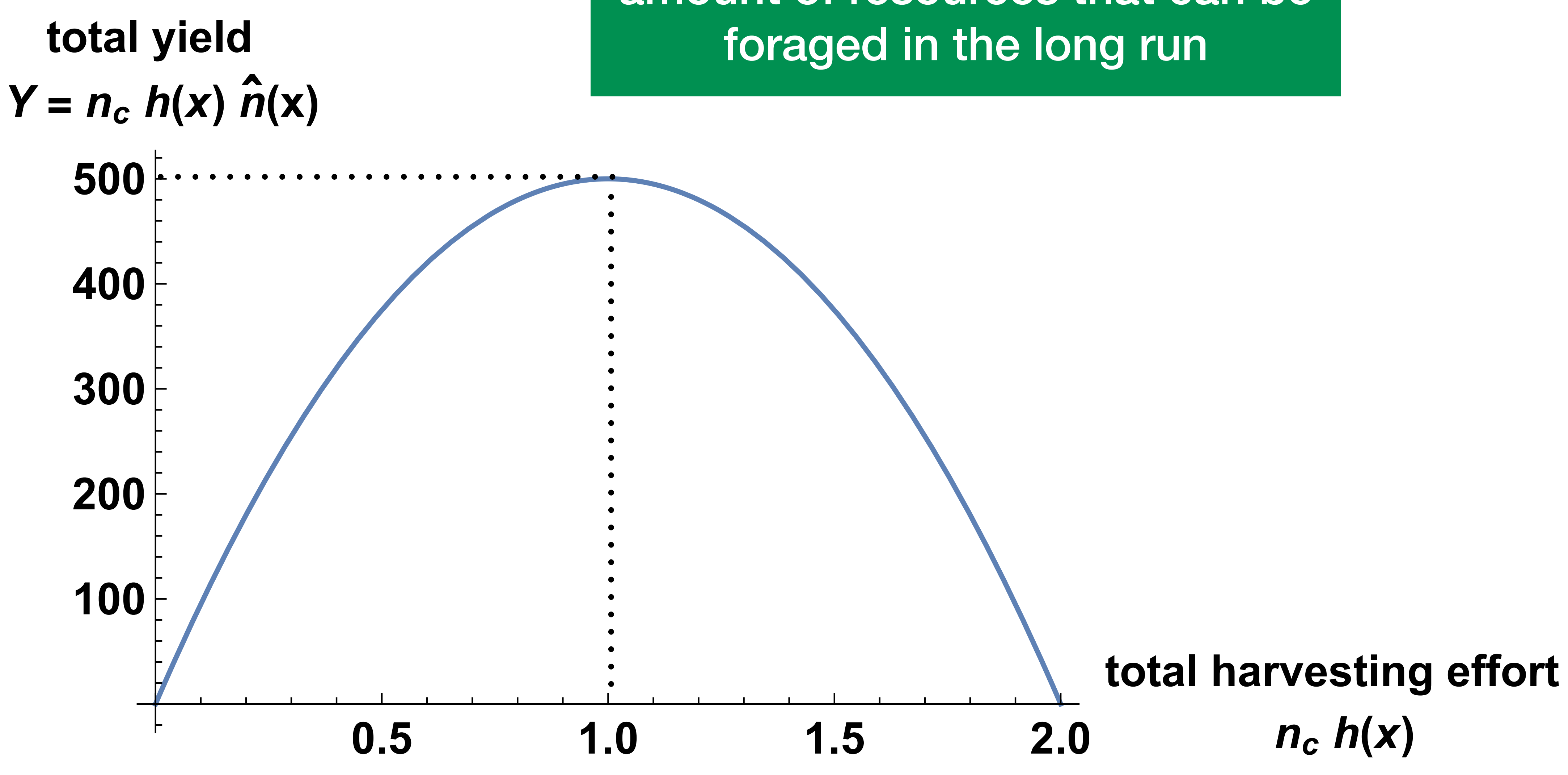

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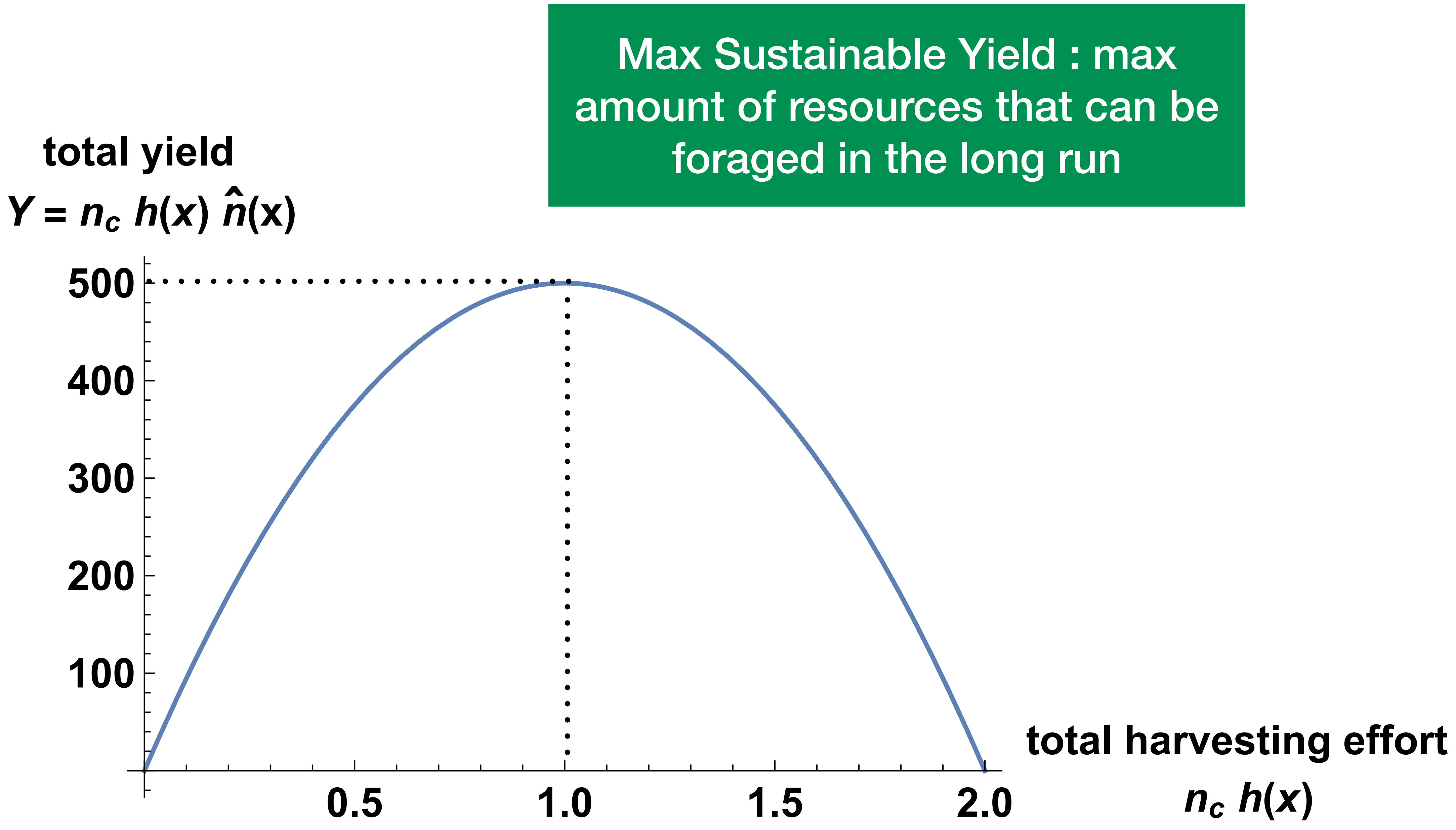
- Any effort above x_{MSY} amounts to over-exploitation.



The exploitation of renewable resources

How evolution shapes foraging of biotic resources

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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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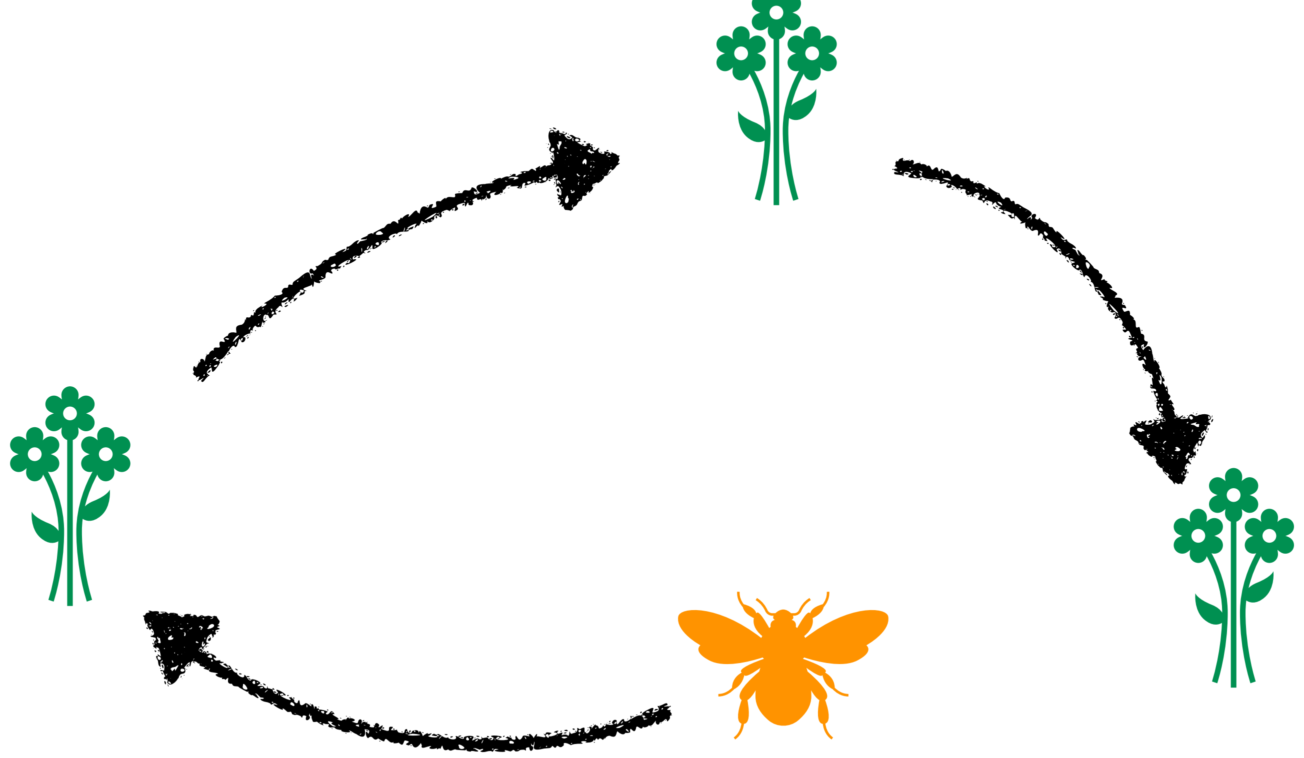
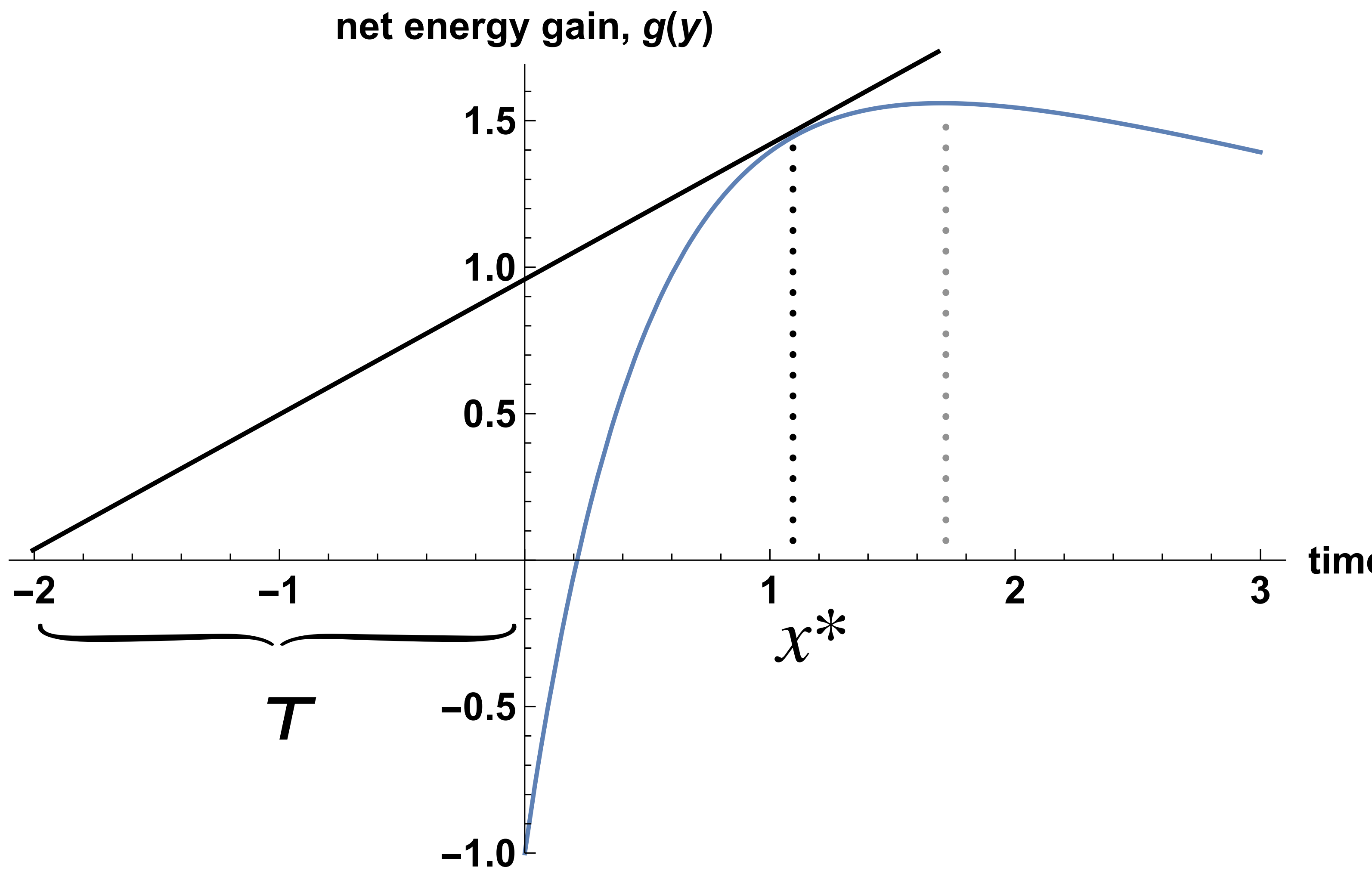
Summary





- 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.