Interactions Hôtes-Parasitoïdes

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Plan

- Biologie des parasitoïdes
- Dynamique des populations
- Persistance
- Aspects évolutifs

Parasitoïde

http://www.idw-online.de

cherchant des larves cachés

CPB Silwood Park

de *Drosophila melanogaster*

Oviposition

http://muextension.missouri.edu

Oviposition

http://www.anbp.org

Emergence

http://whatcom.wsu.edu

Importance

Parasitoïdes partout

- On estime que chaque espèce d'insecte est attaquée par au moins une espèce de parasitoïde
  - espèces spécialisées
  - espèces généralistes
- Facteur significatif biodiversité

Agriculture

- Beaucoup d'insectes ravageurs sont des espèces introduites
- qui ne sont pas abondantes dans leur aires d'origine
- et sont probablement souvent limitées par leurs parasitoïdes :
- potentiel pour la lutte biologique

Lutte biologique

- Beaucoup de « success stories »
  - Cassava mealy bug/*Apoanagyrus lopezi* en Afrique

Cassava mealy bug

http://www.duke.edu

Lutte biologique

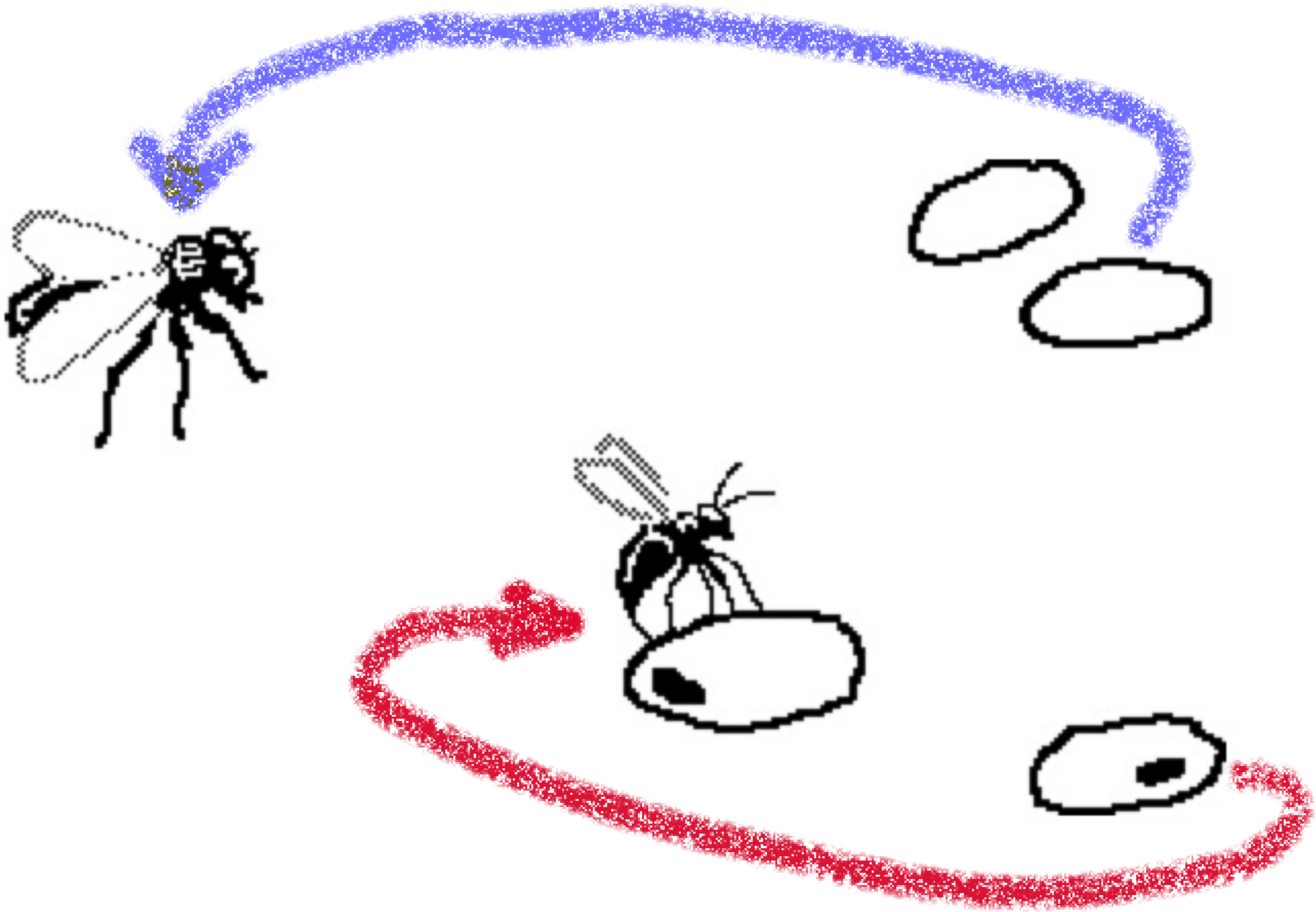
- Beaucoup de « success stories »
  - Cassava mealy bug/*Apoanagyrus lopezi* en Afrique
- Beaucoup de ratés
- Qu'est-ce qui détermine succes ?

Agriculture

- Dans l'agriculture souvent « pestes sécondaires » :
- insecticides contre une autre peste tuent aussi les parasitoïdes d'une espèce normalement contrôlée
- qui trouve donc le champs libre !

Ecologie

Cycle de vie

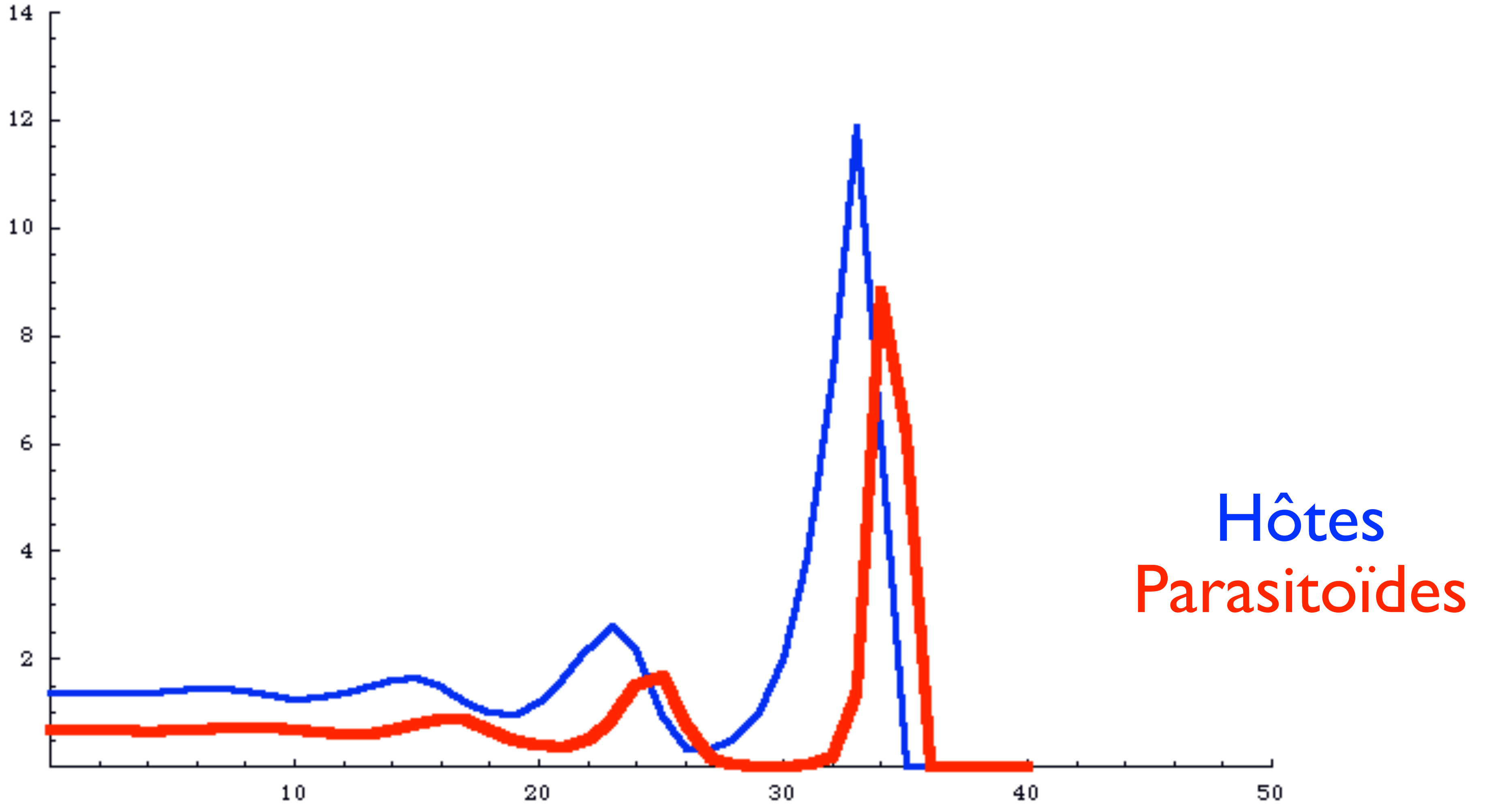


Nicholson-Bailey model

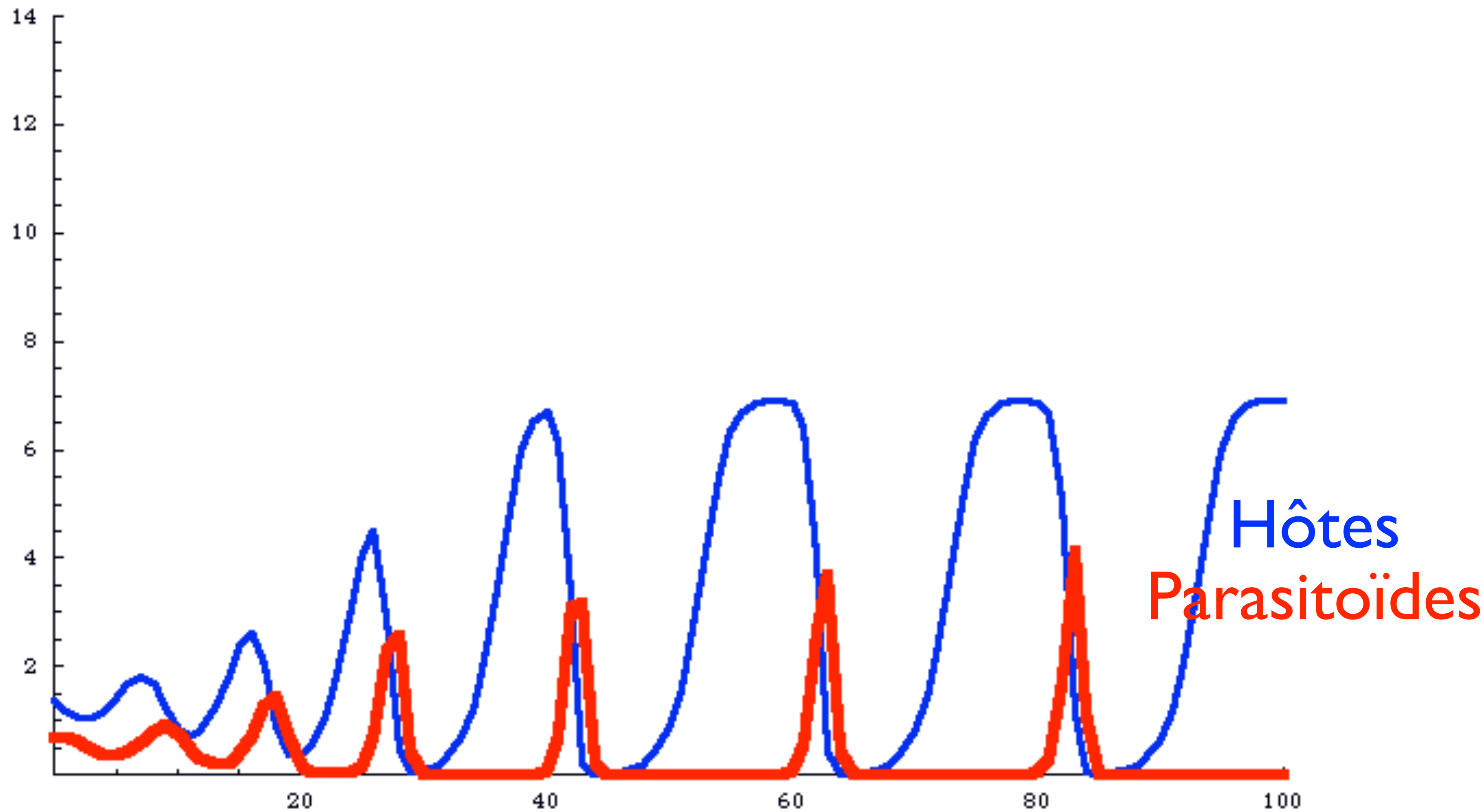
$$N_{t+1} = \lambda N_t e^{-aP_t}$$

$$P_{t+1} = cN_t(1 - e^{-aP_t})$$

Nicholson-Bailey



NB plus compétition



Hétérogénéité

Localisation

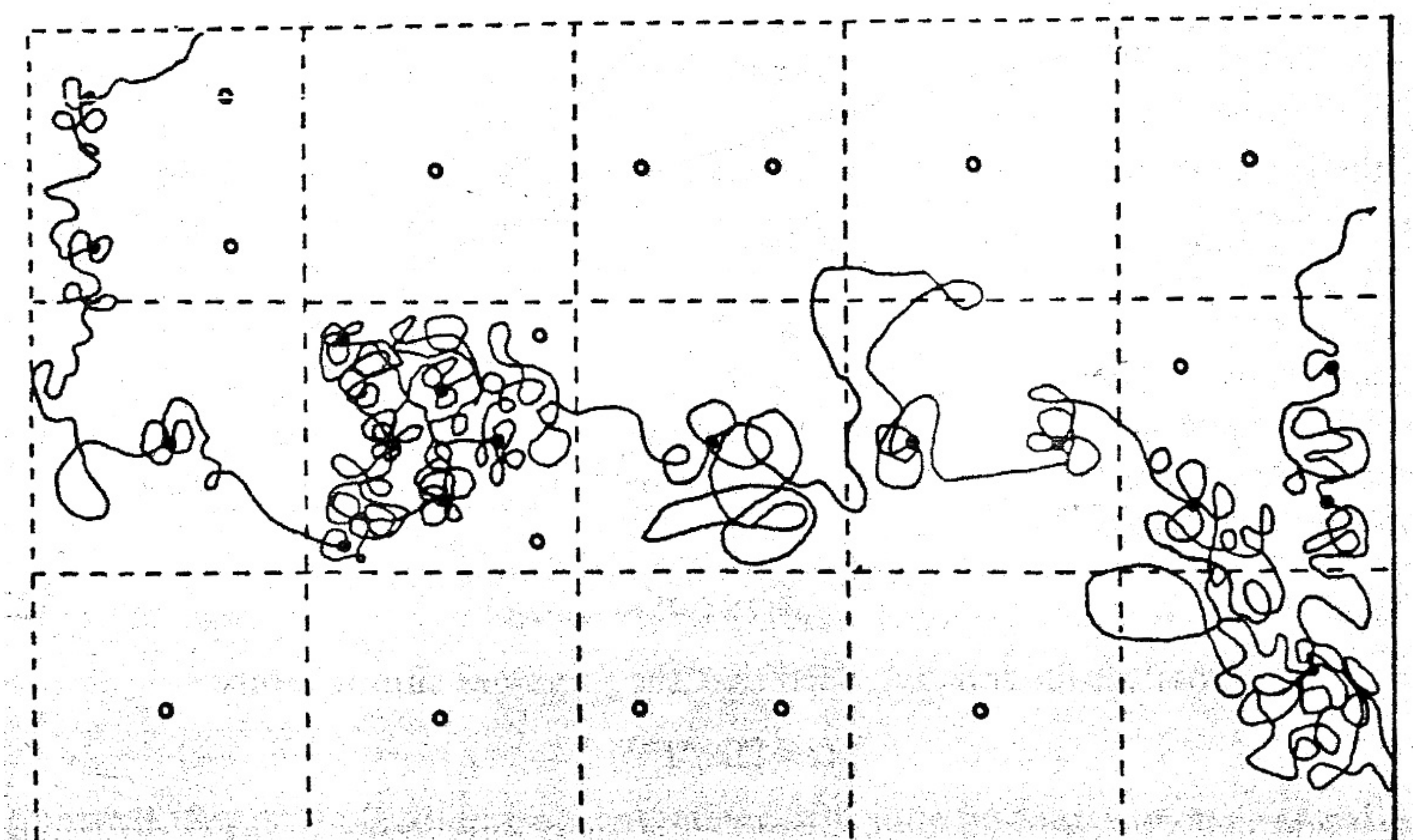


FIG. 9. Part of a track showing the movements of a tachinid parasite *Cyzenis albicans*, within an arena. The circles represent small drops of sugar solution upon which the parasite adults feed. The solid circles show where feeding occurred.

Hassell & May 1974

$$N_{t+1} = \lambda N_t \sum_{i=1}^{n} \alpha_i e^{-\beta_i P_t}$$

$$P_{t+1} = c N_t \sum_{i=1}^{n} \alpha_i \left(1 - e^{-\beta_i P_t}\right)$$

Hassell & May 1974

was divided between the n unit areas with a single area of high density and the remainder of equal low density. The distribution of predators was achieved by a single parameter characterization (μ) such that

$$\beta_i = c\alpha_i^{\mu} \quad (2)$$

where c is a normalization constant and μ is the 'relative aggregation index'.

Eqn (2) was not intended to be a realistic description of how predators aggregate. It was chosen for its simplicity and because it conveniently spans the behaviours of random search ($\mu = 0$) to complete aggregation in the highest density area, making the remainder

Aggregation

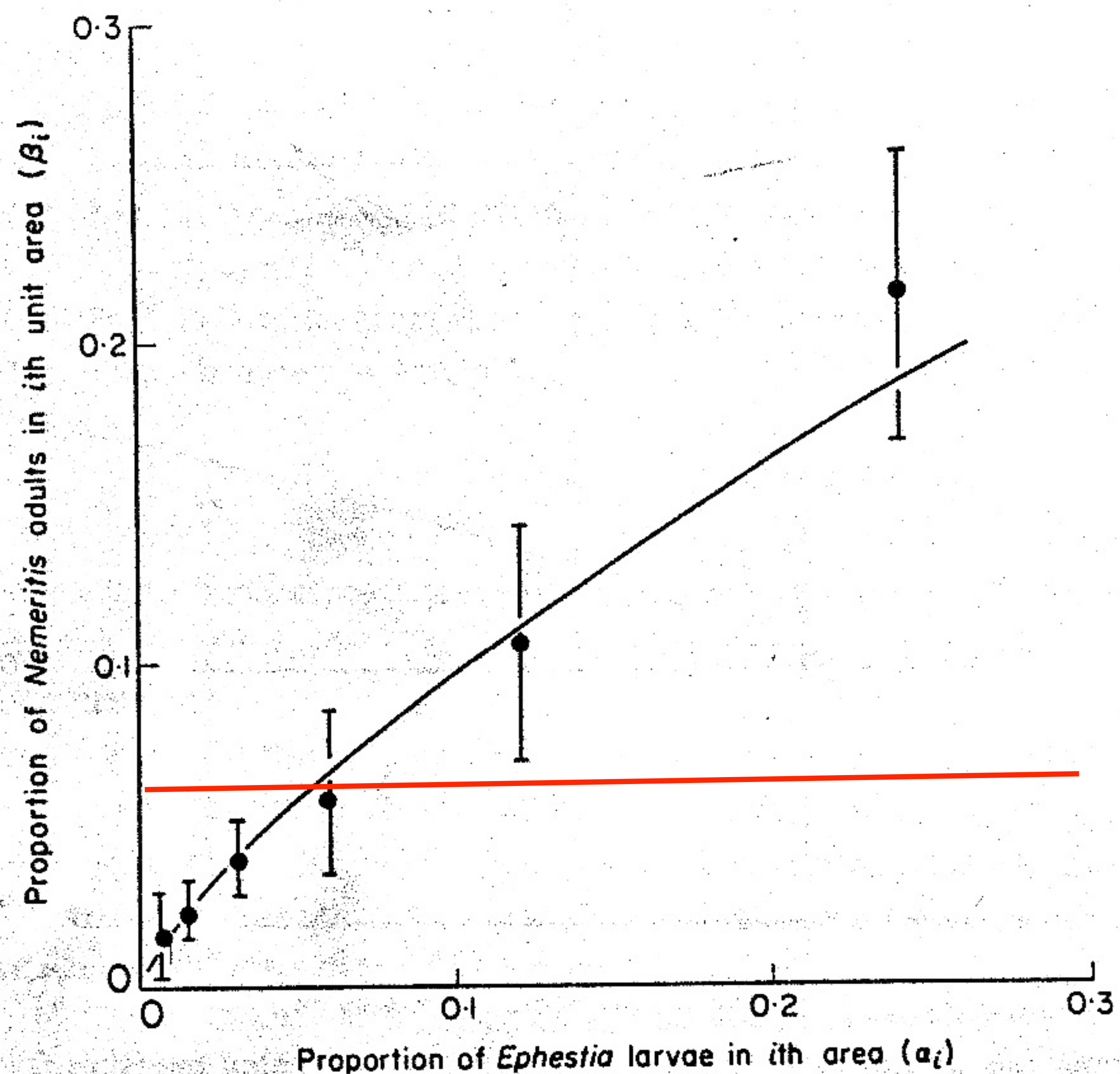
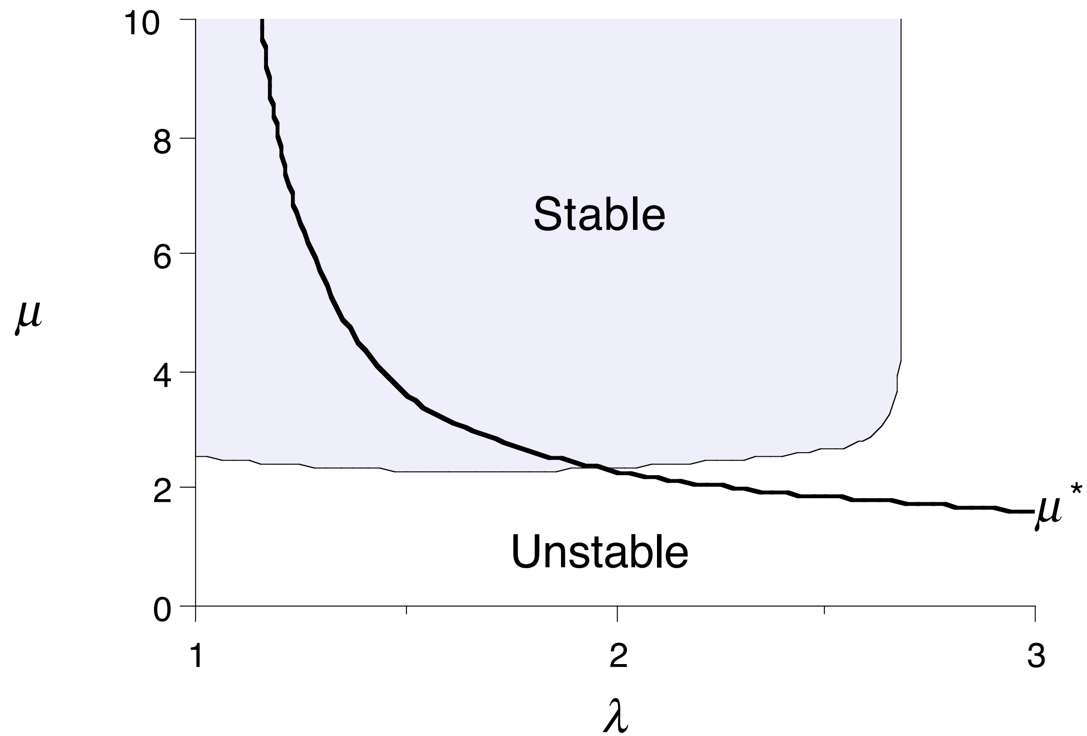


FIG. 11. The relationship between the proportion of searching *Nemeritis canescens* (β_i) and the proportion of *Ephestia cautella* larvae (α_i) per unit area from a laboratory interaction (Hassell 1971a, b). The fitted curve was derived by use of eqn (22). $\beta_i = 0{\cdot}53\ \alpha_i^{\ 0{\cdot}73 \pm 0{\cdot}04}$.

Aggregation stabilise ?

indice d'aggregation



fécondité hôte

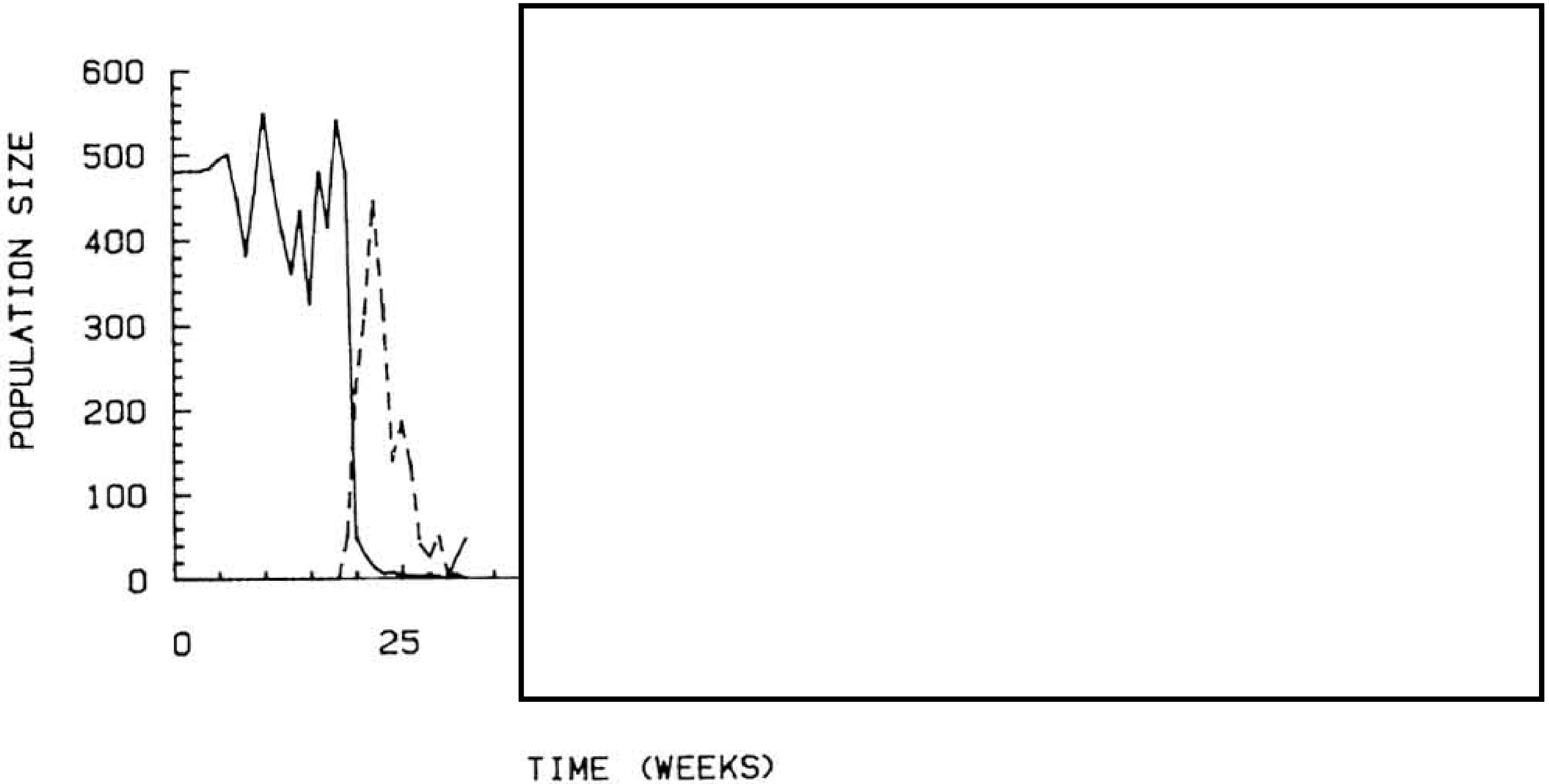


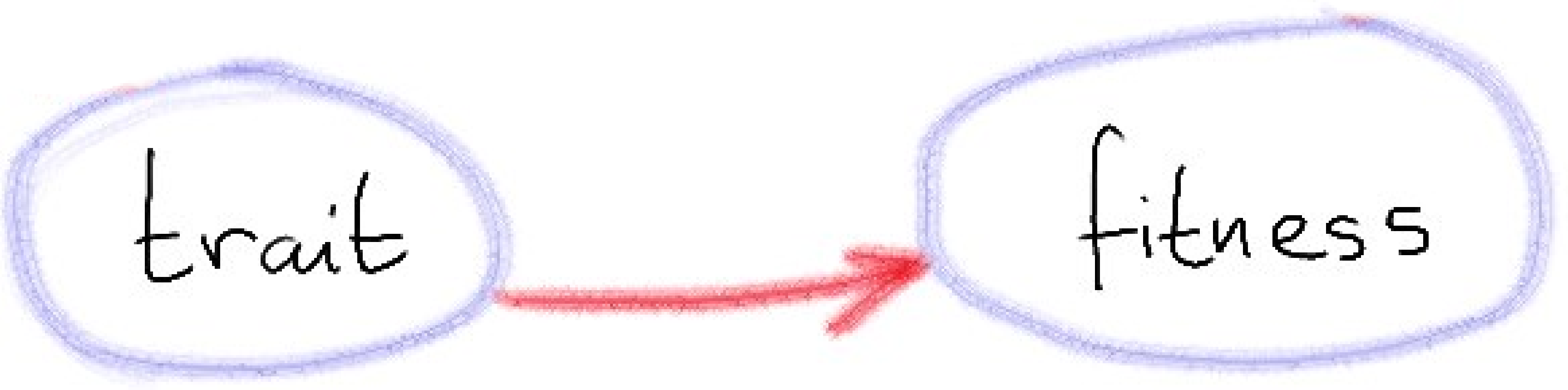
Fig. 1. Population dynamics of the bruchid beetle, *Callosobruchus chinensis* (——) feeding on black-eyed beans, and its pteromalid parasitoid, *Anisopteromalus calandrae* (- - - -), in a laboratory system. Left: 'non-patchy' – 50 beans uniformly distributed on floor of arena. Right: 'patchy' – 50 beans each in an individual container with restricted access to both hosts and parasitoids. In both cases the parasitoids were introduced to the arena once the host population was fluctuating around its carrying capacity (V. A. Taylor & M. P. Hassell, unpublished).

Evolution

Evolution

- Parasitoïdes evoluent
-

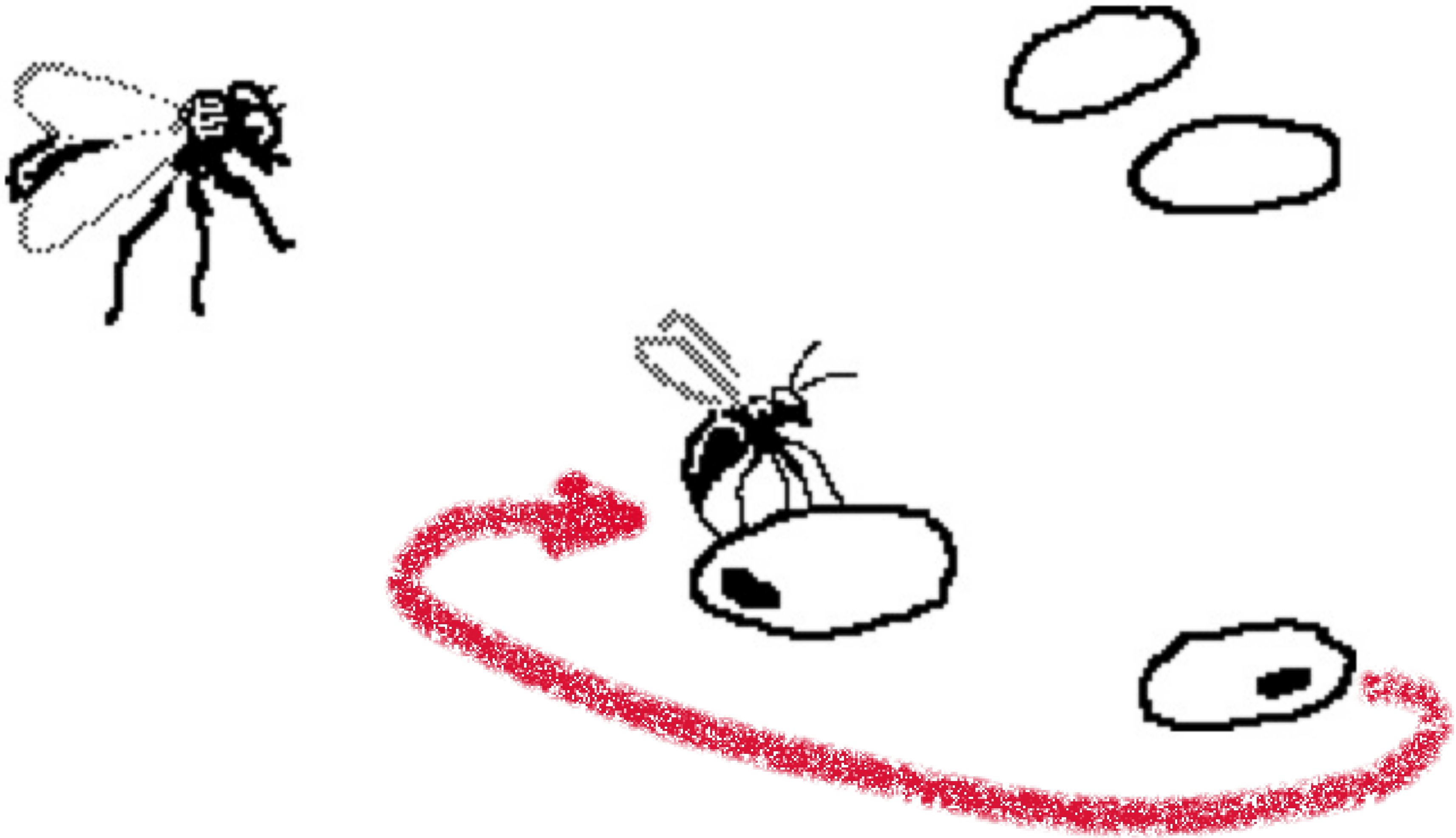
Biologie évolutive



Biologie évolutive

- Rélation « trait » – « fitness » très difficile à mésurer en général
  - p. ex. combien de proies doit un prédateur pour pouvoir se réproduire ?
  - quel rôle pour métabolisme ?
  - *etc.*, *etc.* …

Cycle de vie



Parasitoids attract theoreticians

Simple idea

1 host found = 1 parasitoid

Underlying many models

- Nicholson-Bailey model (+derivatives)
- Optimal Foraging Theory

Behavioural Ecology

Tinbergen's basic insight:

Behaviour evolves as do other traits:

- affects fitness
- determined by genetic factors
- shaped by natural selection

General Problem

How to test optimality of a given trait?

Two steps

- work out all alternative options
- calculate associated fitness

In the case of behaviour

- establish link behaviour $\rightarrow$ fitness

Fitness

What is fitness?

How to measure it?

How to assess link with a given trait?

Fitness, behaviour and life histories

Example: Foraging behaviour

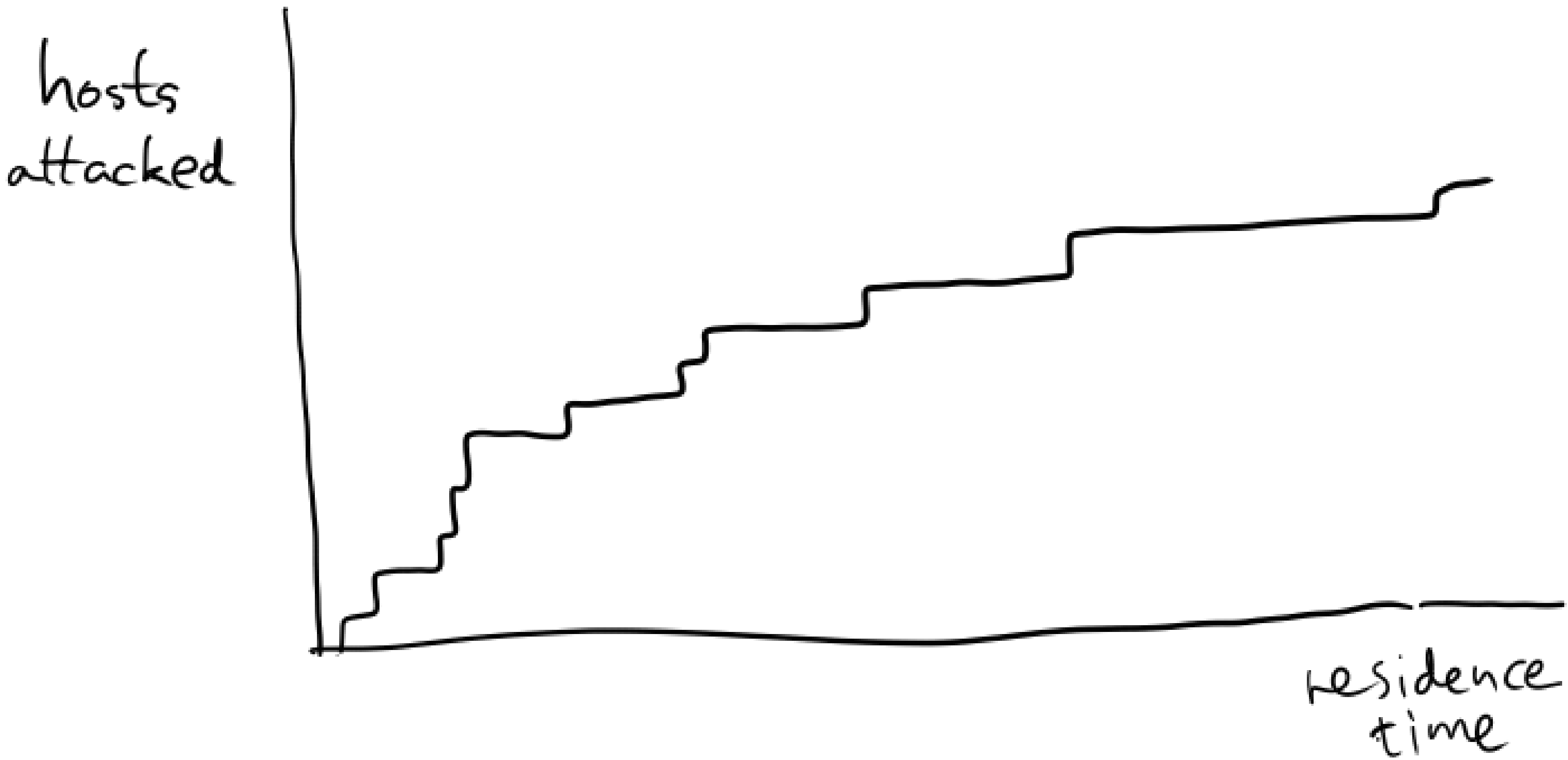
Which prey to hunt?

How long to stay?

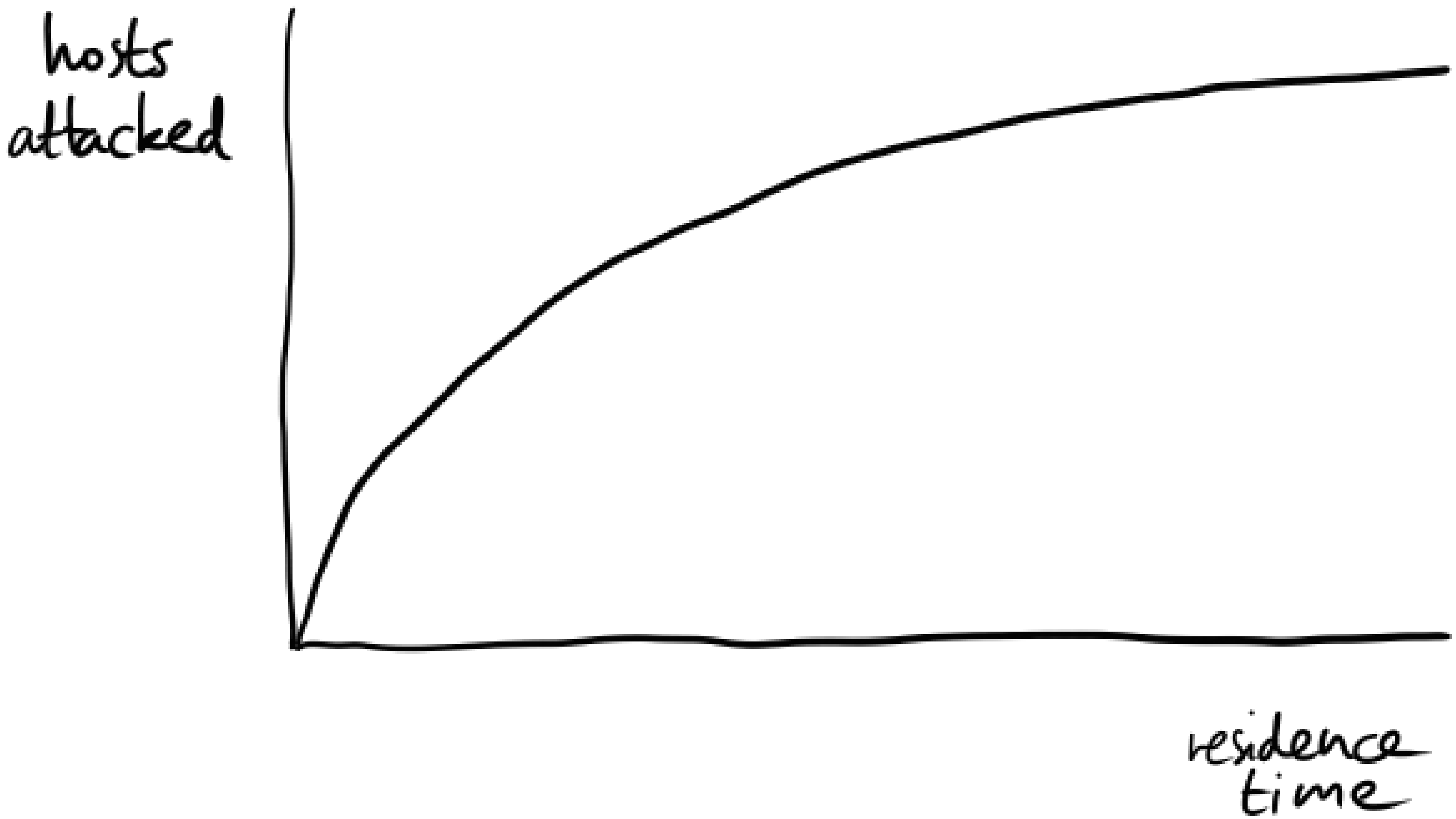
Fitness of predators

- assess prey capture rate
- link food intake rate to reproduction rate
- integrate reproduction rate over life-time

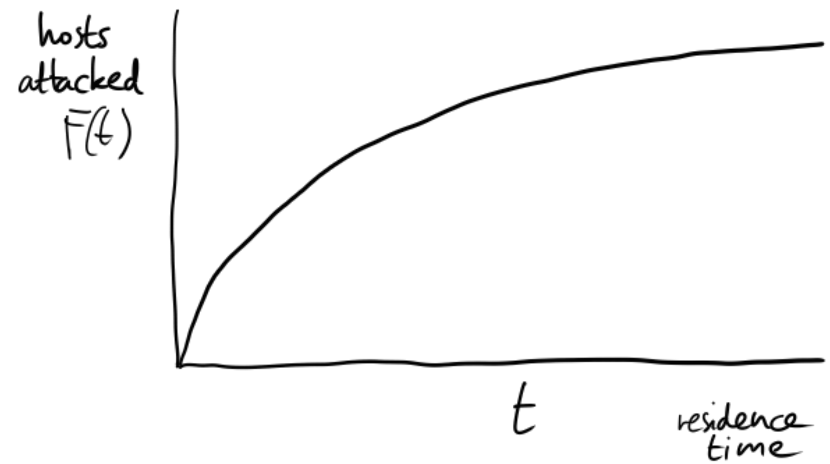
How long to stay?



Idealisation



Fitness = gain rate



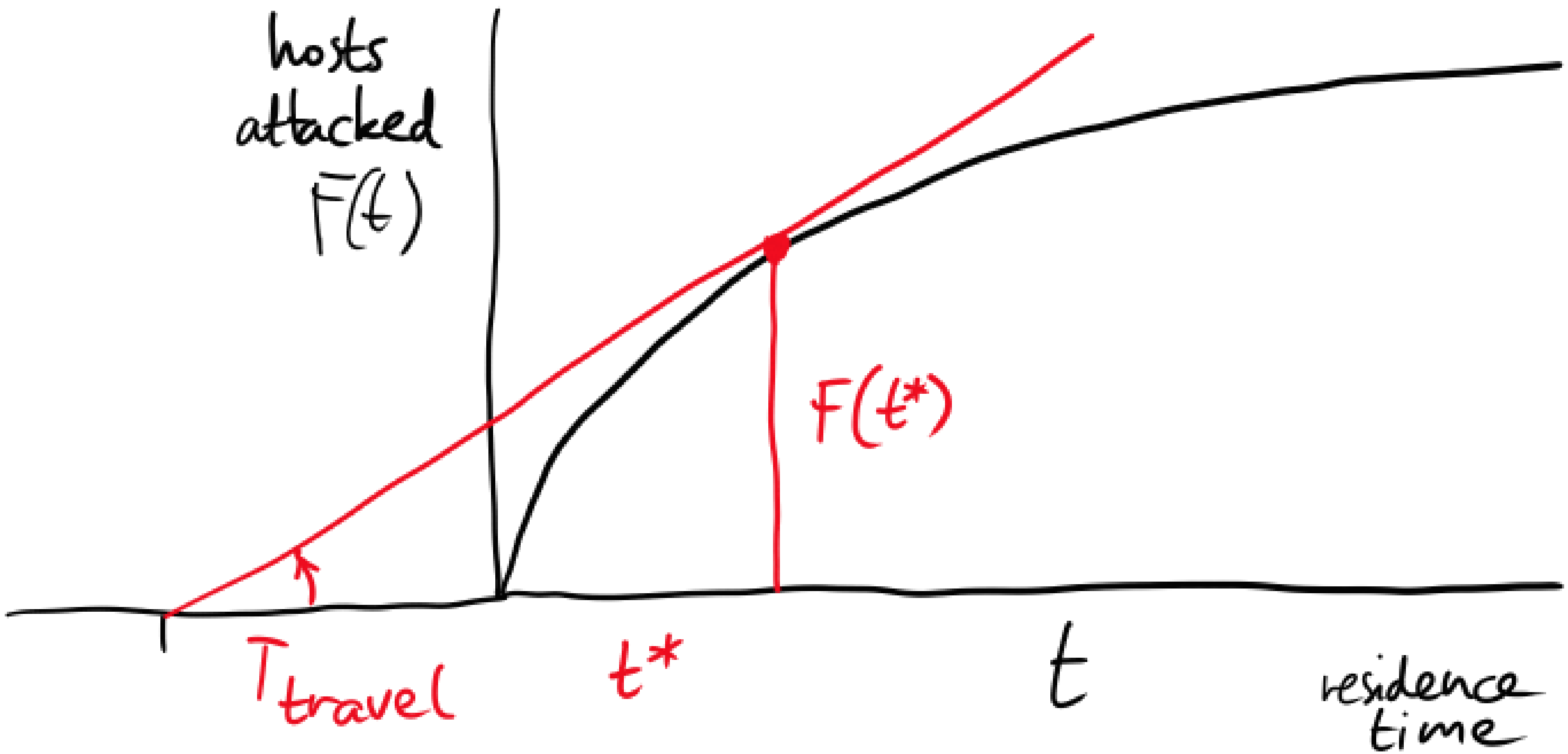
$$G = \frac{F(t)}{T_{travel} + t}$$

G : rate of hosts attacked per unit time (Gain)

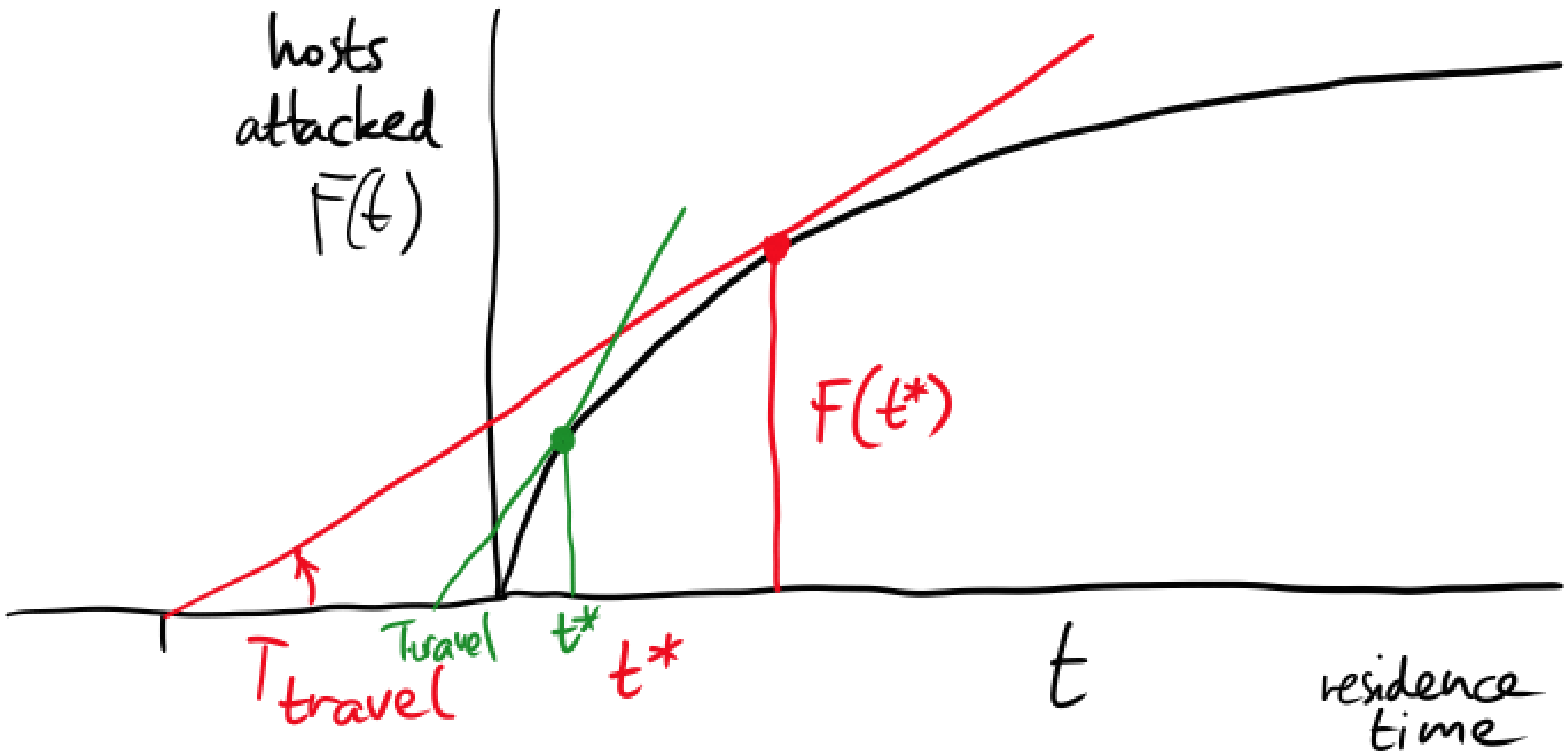
find the optimal patch residence time *t** that maximises *G*

...

Gain rate optimisation



Gain rate optimisation



If $T_{travel} < T_{travel}$ then $t^* < t^*$

If it is easy to find new patches leave sooner!

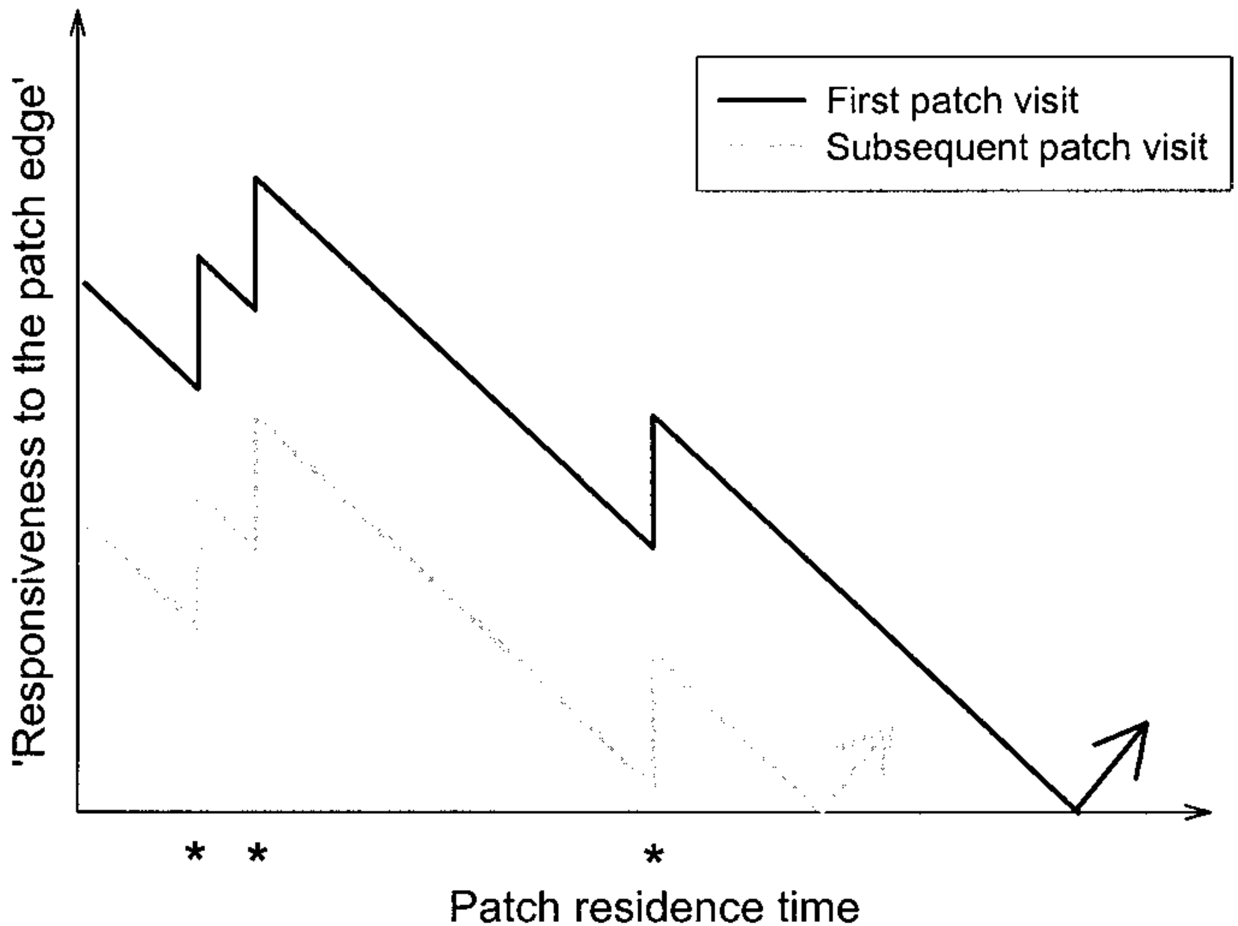


Figure 2
A mechanistic model to explain the way in which parasitoids might respond to information on patch availability within their environment. The 'responsiveness to the patch edge' decreases with the time spent on the patch but increases with each oviposition, indicated by an asterisk. When it declines to zero, the patch is abandoned. The experience of a short time interval between patch visits possibly reduces a parasitoid's initial "responsiveness" (black line) to a lower level (gray line), which results in earlier patch leaving, even when oviposition experiences on the patch are similar.

Miracle solution

Parasitoids:

- one host parasitized = one offspring
- host localisation = fitness increment!
- direct link behaviour and fitness

Optimal Foraging Theory (OFT)

Many many studies since 1970s
- using parasitoids

Support for the validity of the idea

But also many puzzling discrepancies

Puzzling fact

Parasitoids often refuse to oviposit

No oviposition = no offspring

Voluntary reduction in fitness?!?

Maladaptation…

Modification

Missing aspect: cost of behaviour

Oviposition = Fitness Increment – Cost

What costs? How to assess?

Costs

Time
- differences in handling time

Quality
- differences in hatching probability

Risk
- differences in adult survival

Opportunity
- differences in encounter rate

Costs: eggs

Standard assumption

- host found = fitness increment
- implies unlimited eggs

In reality eggs do not come cheap

- eggs should not be wasted
- optimum decisions not obvious

Coevolution!
(encapsulation)

Monotonicity

Not always sufficient

– nonlinearity

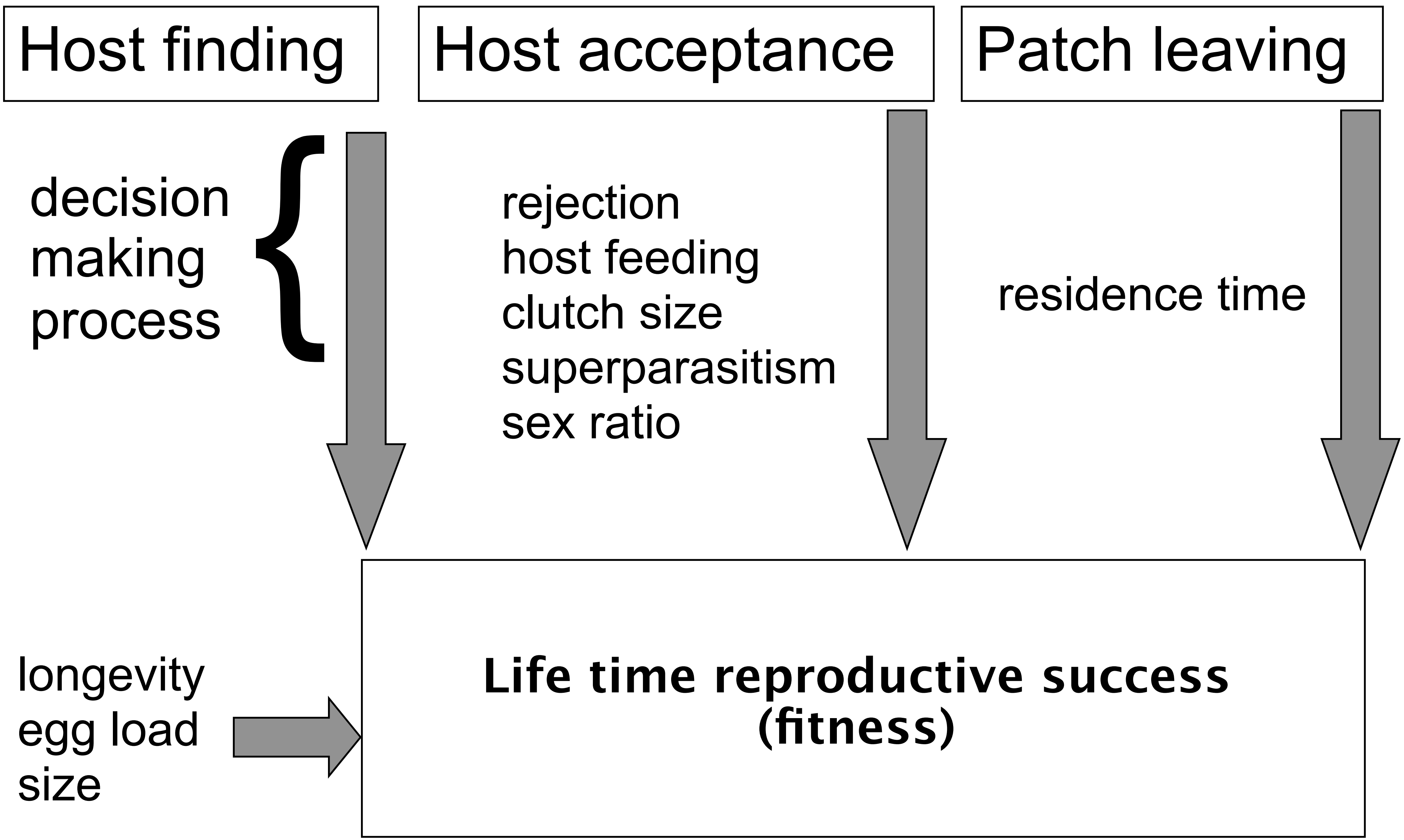
Often outright problematic

– costs & benefits expressed differently

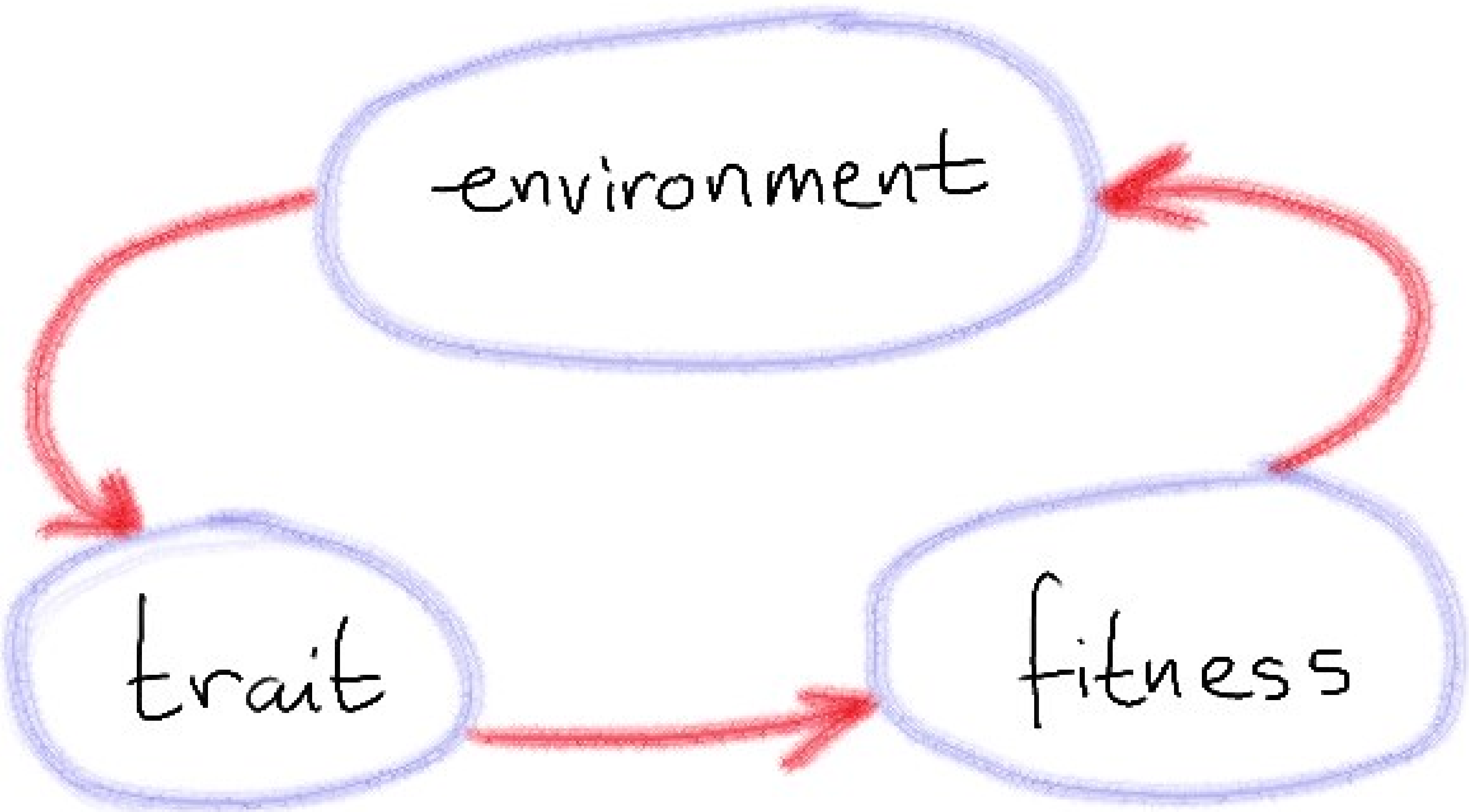
Need a way to integrate

Parasitoid fitness measure!

Life history integrates



Adaptive Dynamics



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