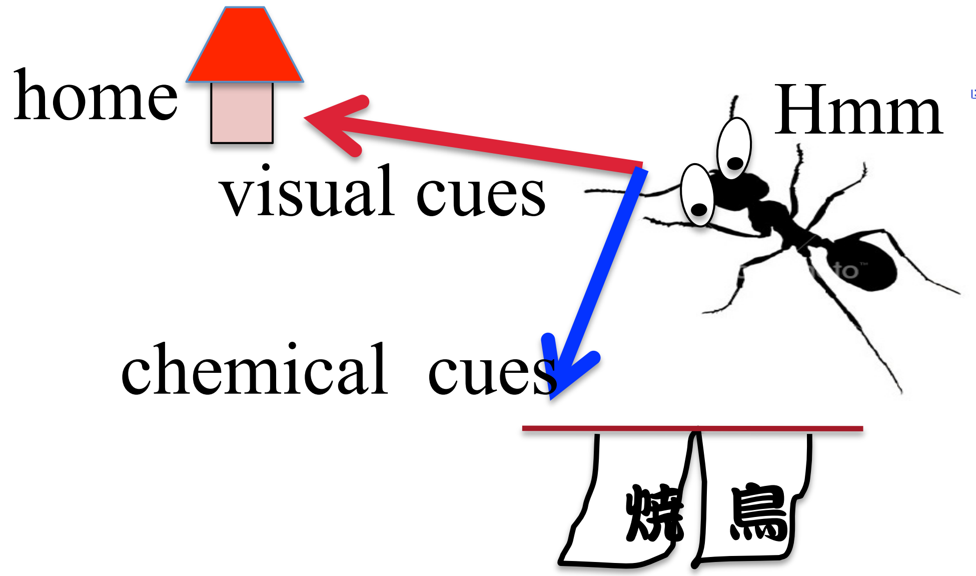
アリの採餌における意思決定とゆらぎ
Decision-making and Stochasticity of Foraging Ants



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--Motivation 1--

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Probabilistic Behaviour in Ants: A Strategy of Errors?

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Animal behaviour is probabilistic. This is exemplified by the communication behaviour of ants during food-searching. Experimental evidence

--Motivation 1--

Assay (Trail--following experiment) for two species of ants: Tetramorium impurum and Tapinoma erraticum (シワアリ)

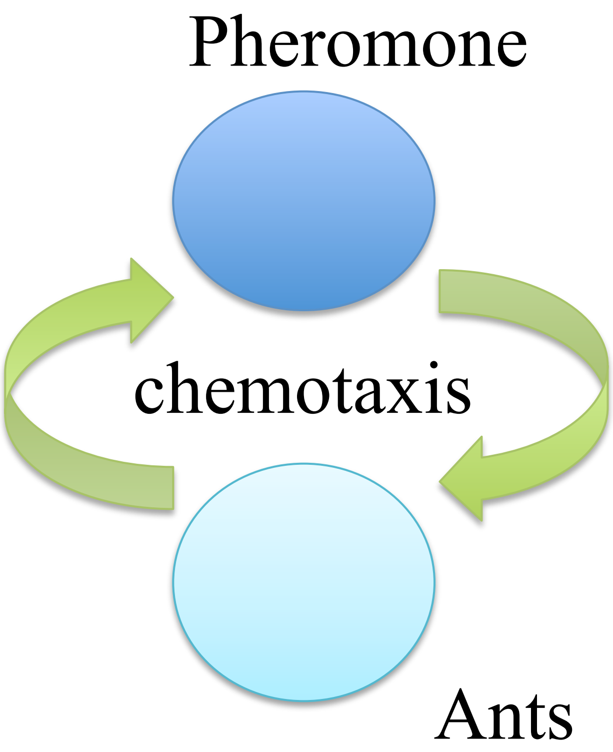
TABLE 1

Comparison between recruitment accuracy in two ant species

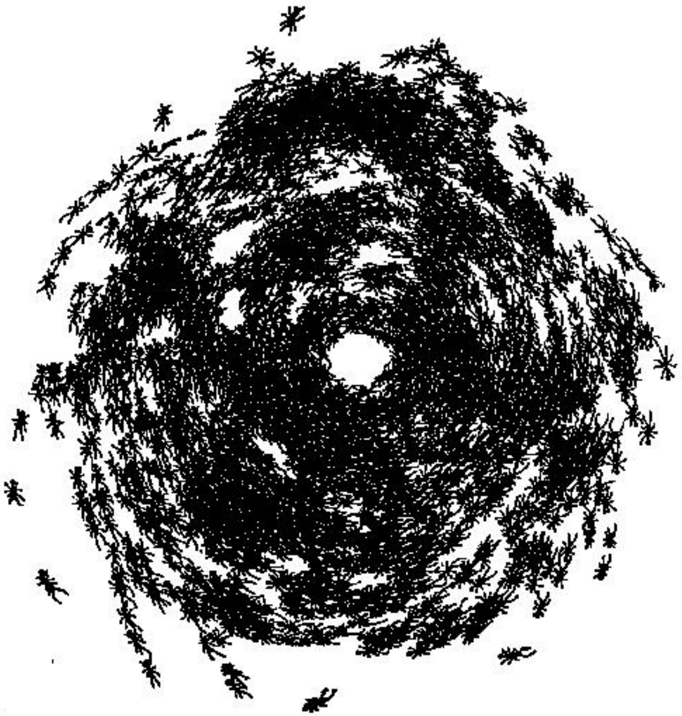
		Tetramorium impurum	*Tapinoma erraticum*
Length (%) of single recruitment trails actually followed by recruit		17 (40)	67·7 (47)
Percentage of recruits reaching the food source	Alone	8·9 (45)	73·6 (216)
	In group	60 (10)	—
	Total	18·2 (55)	73·6 (216)

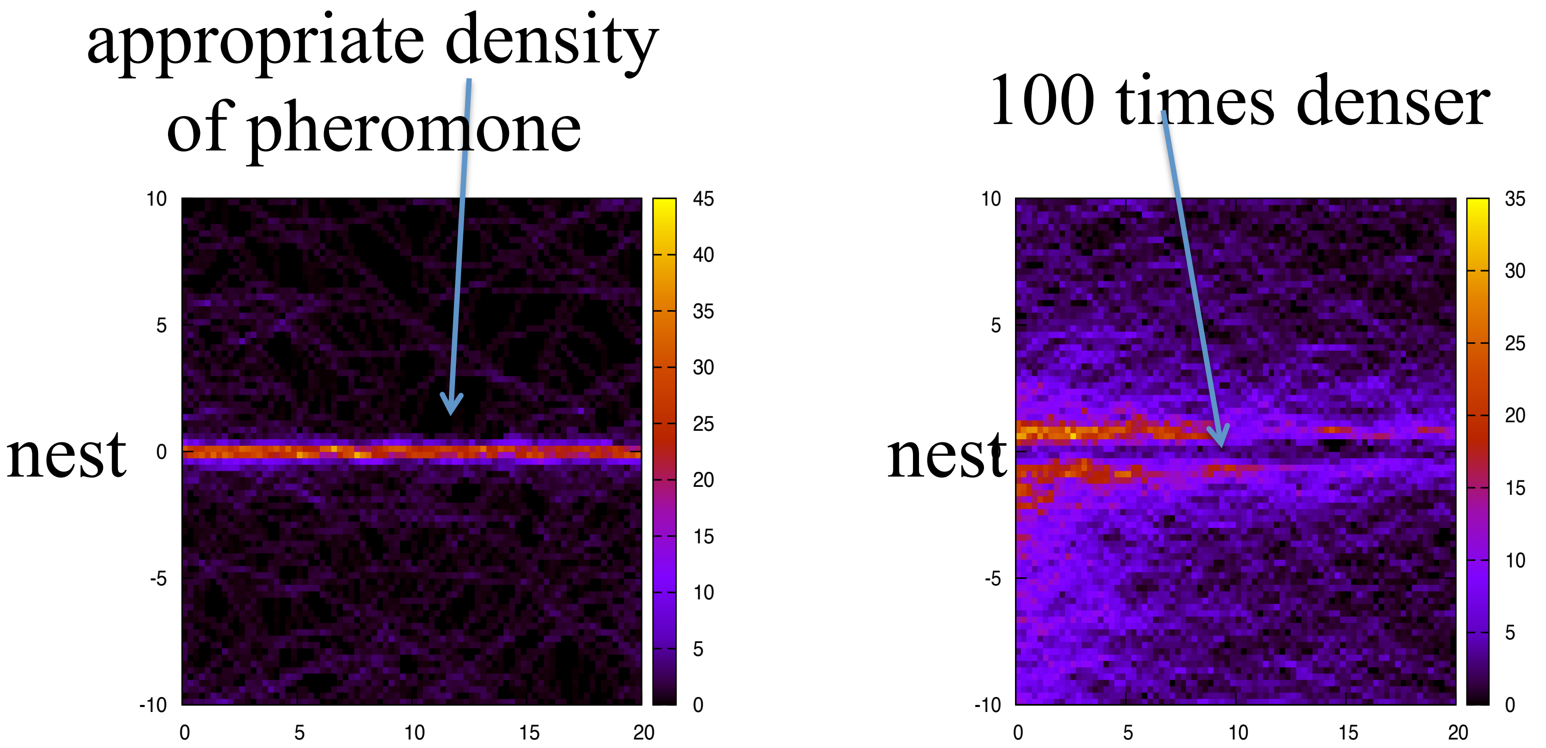
Introduction

Positive feedback



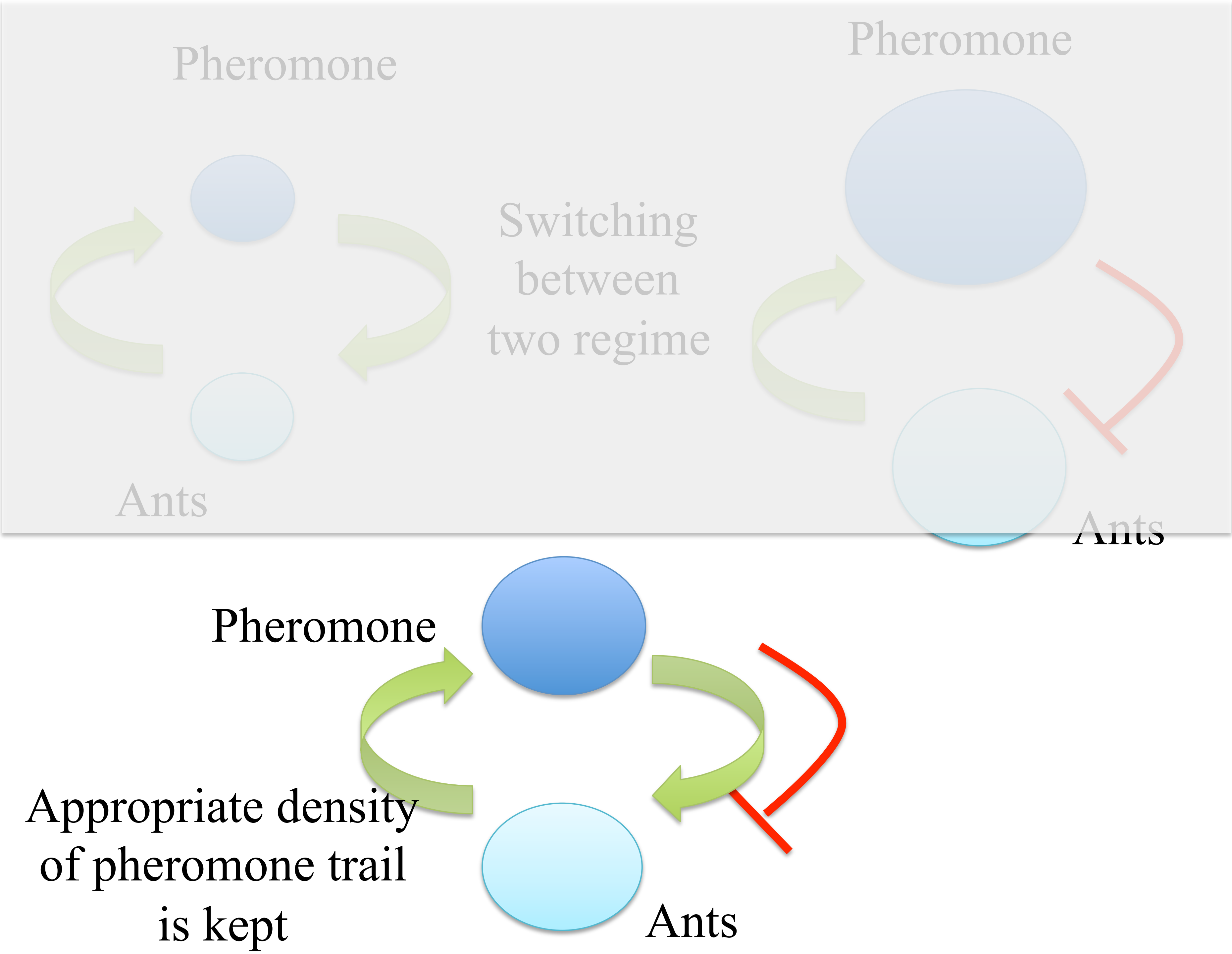
Over-Positive feedback



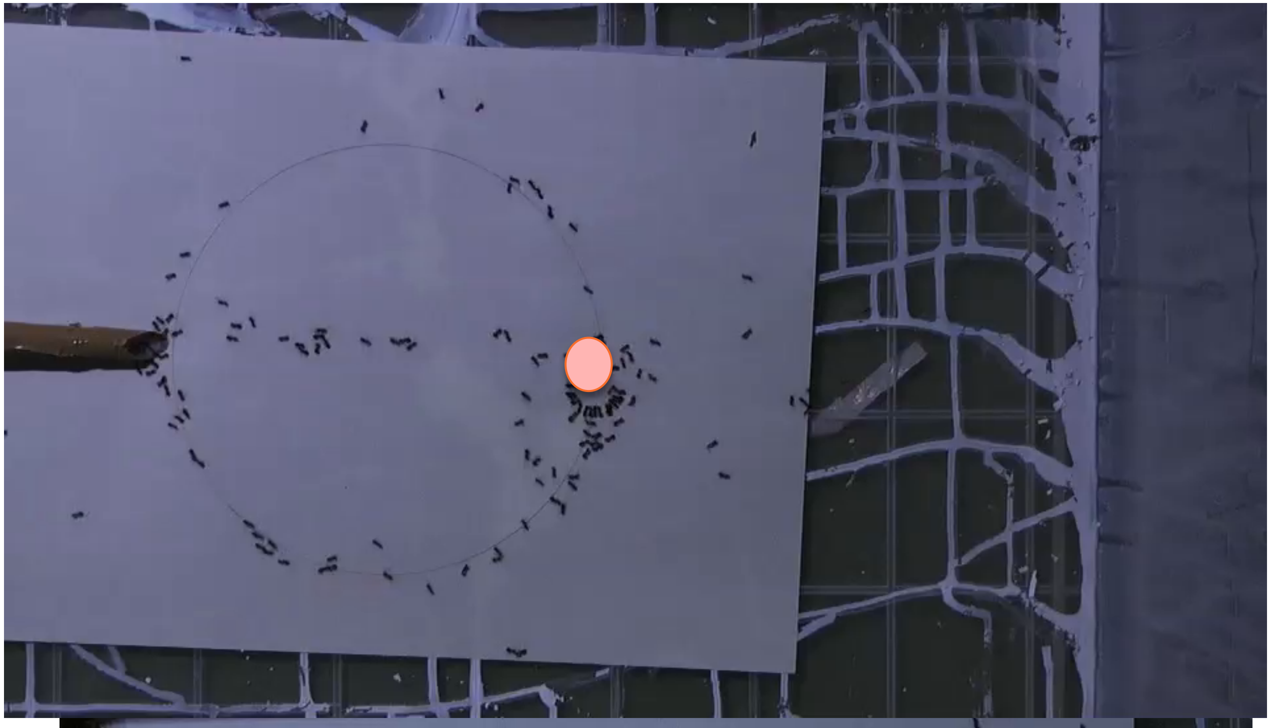


Time-averaged number density of ants

By Katsuhito Naka(Hiroshima)


Pheromone
Ants
Switching
between
two regime
Pheromone
Ants
Pheromone
Appropriate density
of pheromone trail
is kept
Ants

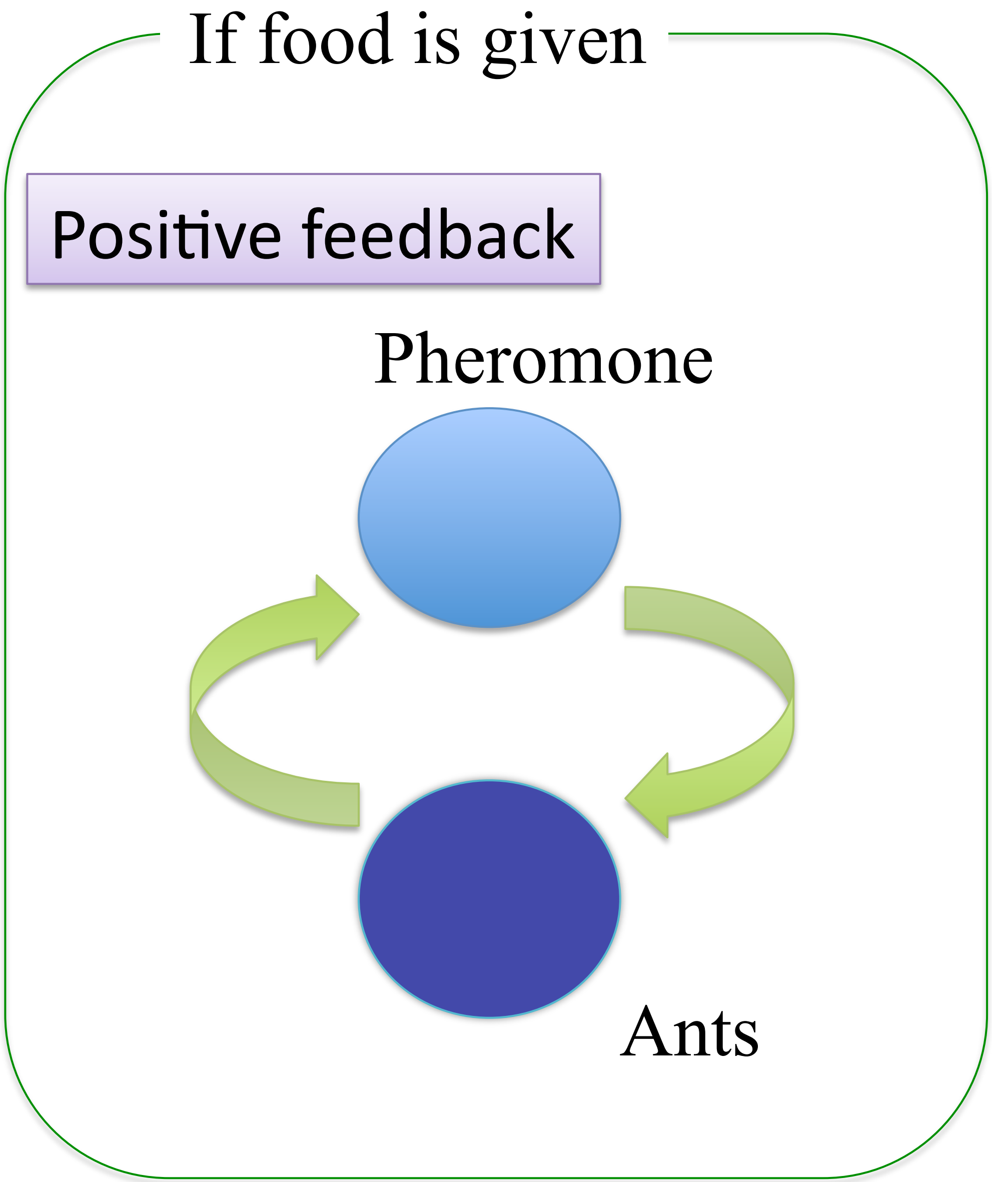
motivation2



えさ有り
With food

えさ無し
Without food

Initially pasted pheromone

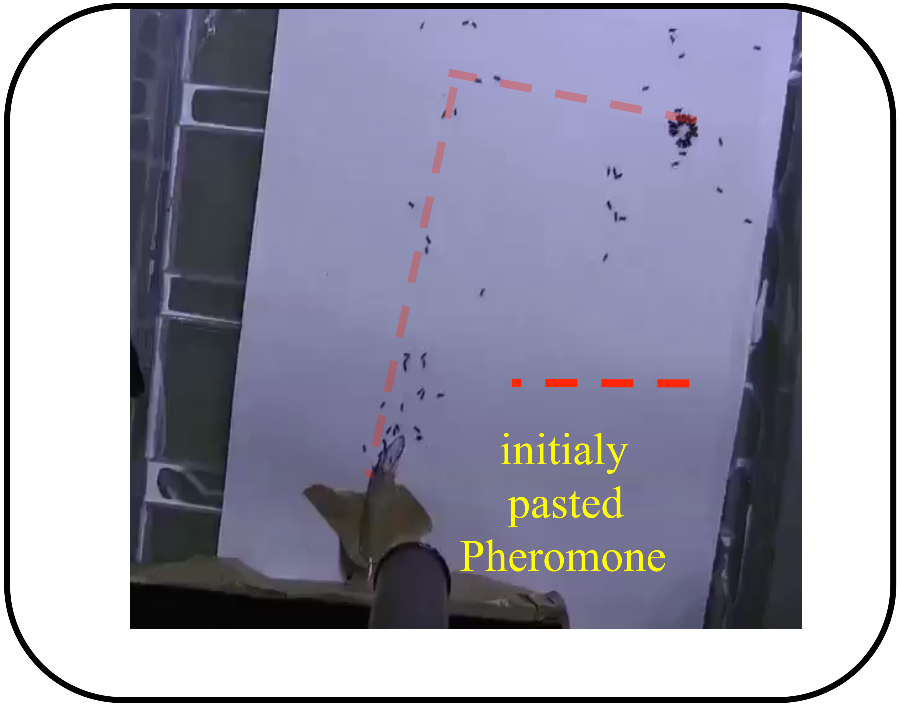


No trail is formed

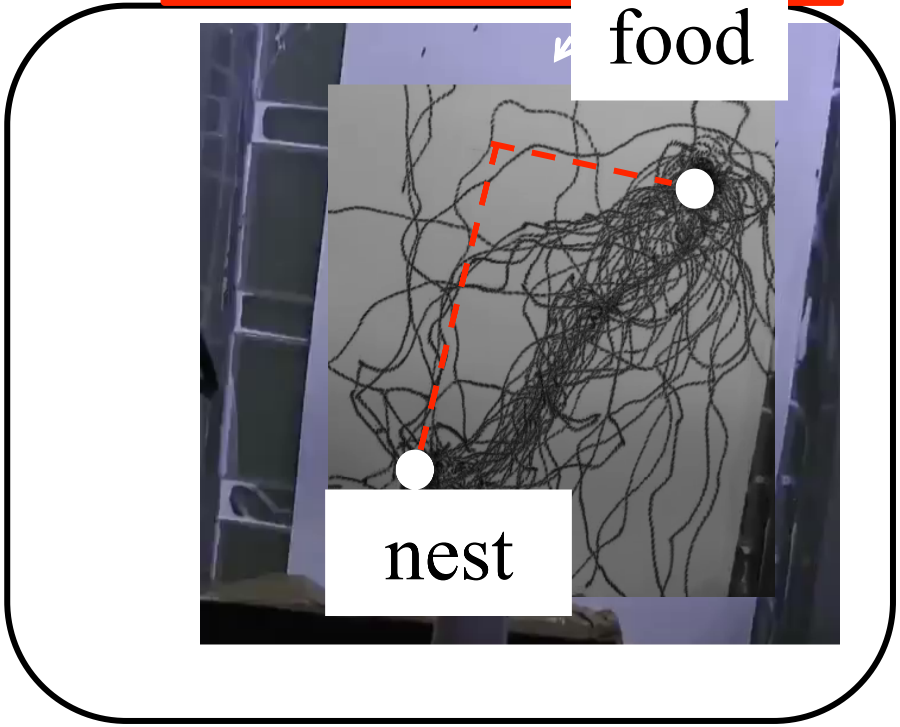
条件に依存して消滅する正のフィード・バック

Experiment

chemical information

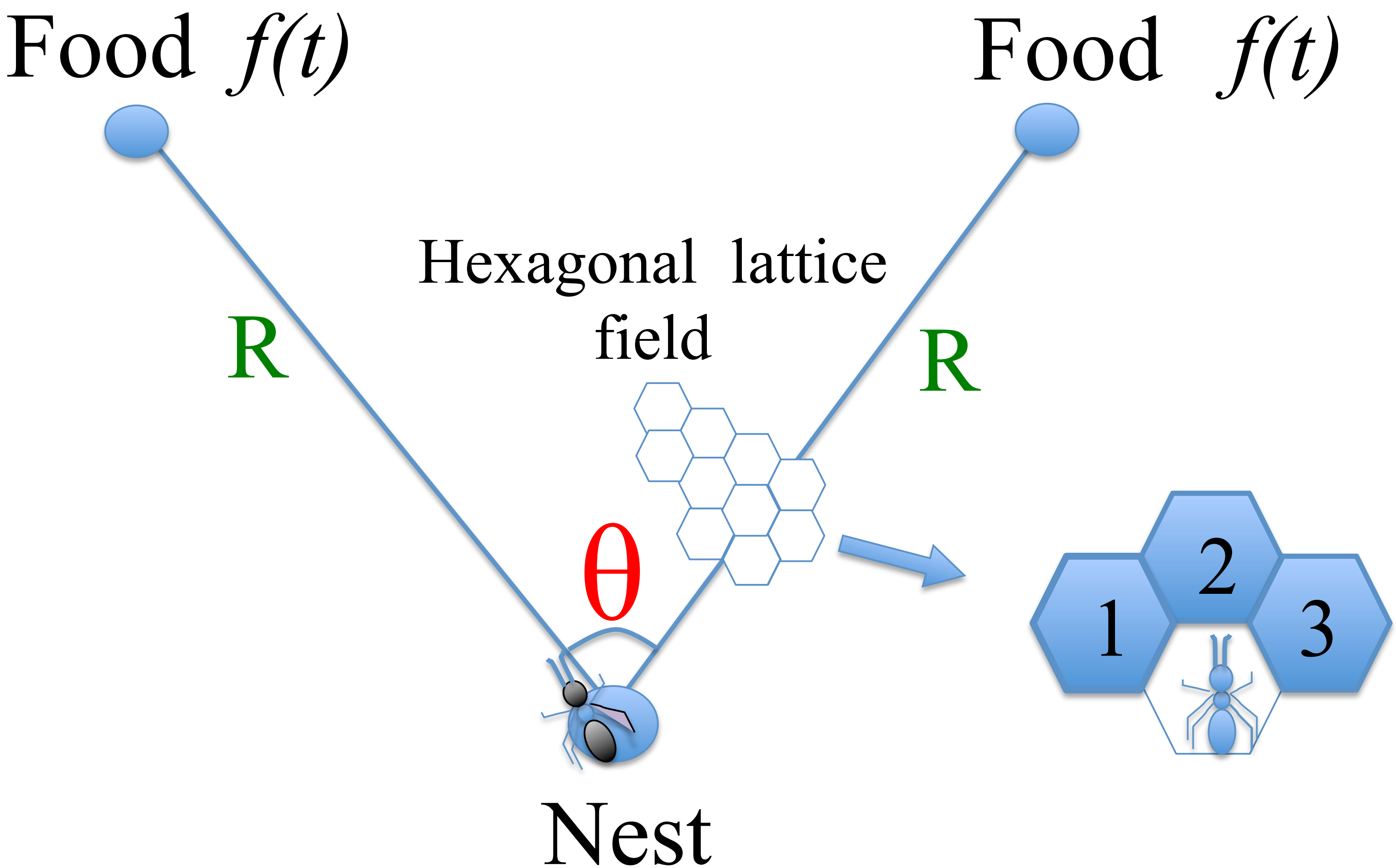


visual information



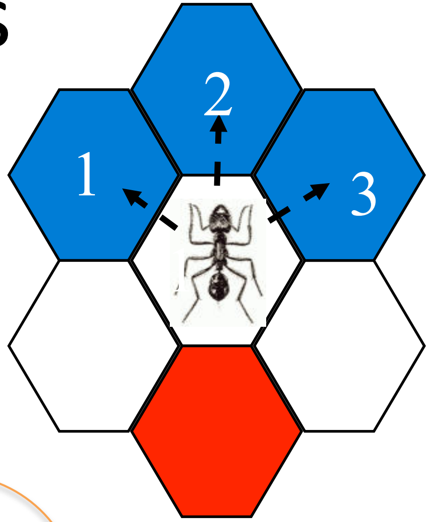
ants make a combined use of different information

Setup of Foraging Field



θ, R : Environmental Parameters

Choice of moving direction in each step by Chemo-taxis



- Choose one cell among three frontal cells

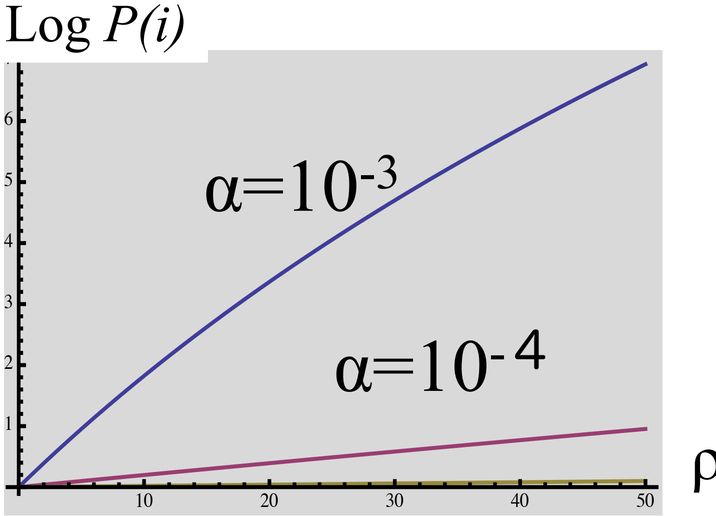
Prob. of choosing i-th cell (i={1,2,3})

$$P(i) \propto (\alpha_k \rho_i + z)^n \quad (n = 10)$$

ρ_i: pheromone density in i-th cell

α_k: sensitivity of k-th ant

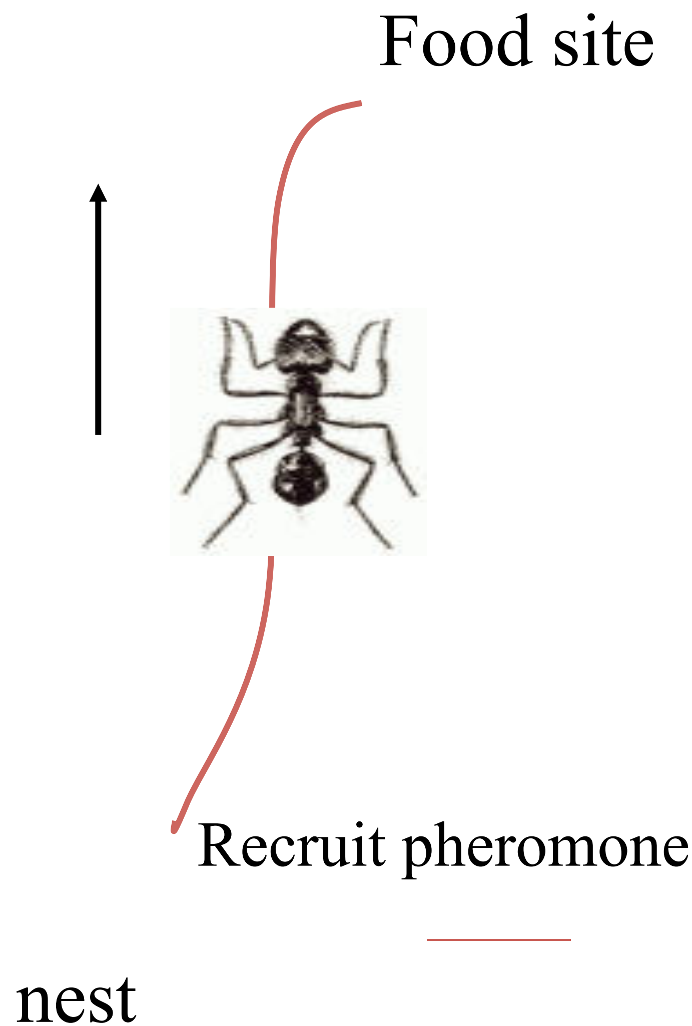
(**normalization** $P(1)+P(2)+P(3)=1$)



Modes in foraging trip 1

1. Exploration mode

   explore food following recruit pheromone



Mode2 in foraging trip 2

2.homing

・try to go back to the nest after taking food, during which way

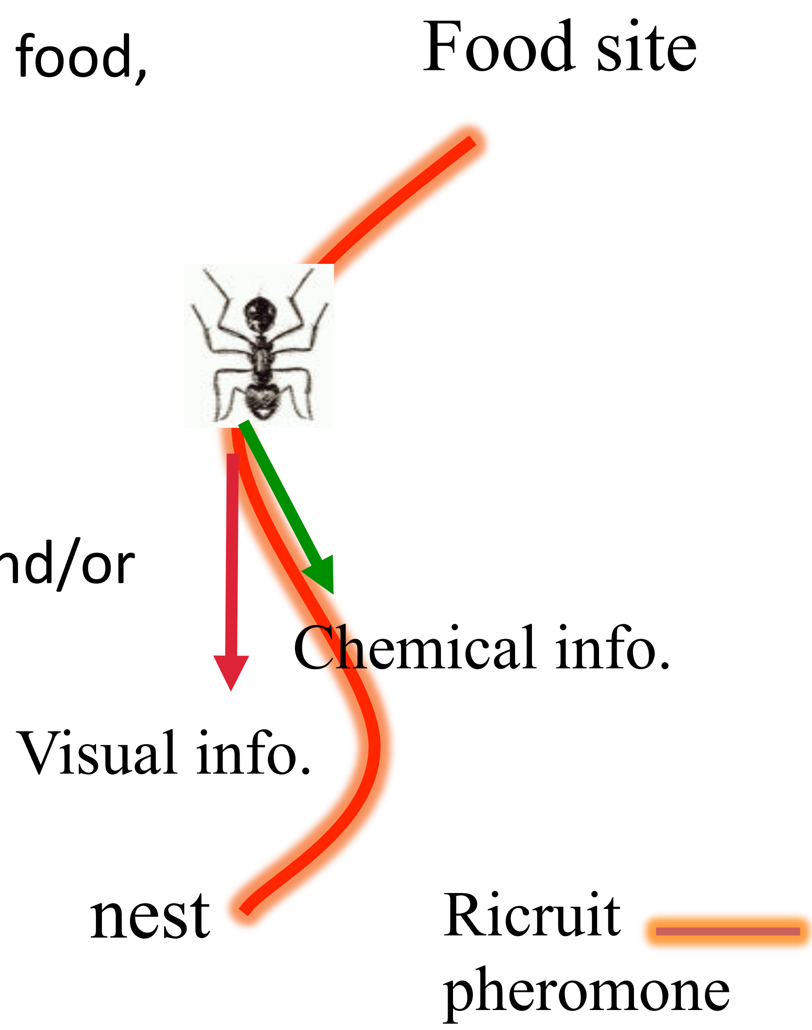
leave recruit pheromone

・the choice of homig dircetion; depends on the combination of

Chemical information (pheromoner) and/or

Visual information

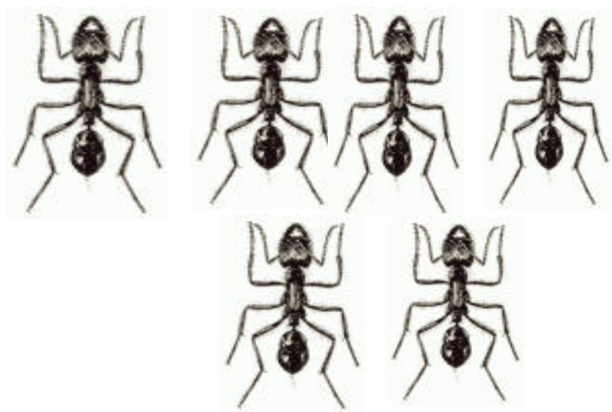
・On reaching nest, go back to the exploring mode



A set of Parameters characterizing foraging colonies:

{**Number of normal ants** & **Sensitivity of dull ants** }

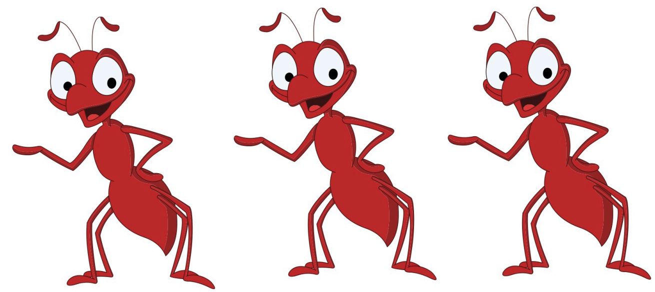
n (in totally 500ants) **α (< α_{normal}=50)**



Normal Ants

($\alpha=\alpha_{normal}=50$)

+



Dull Ants

($\alpha < \alpha_{normal} = 50\times10^{-1}, 50\times10^{-2}, 50\times10^{-3}, 50\times10^{-4}, \cdot\cdot, 50\times10^{-7}$)

number ratio n : 500－n

Foraging Efficiency E

E: Total amount of food which a colony of 500 ants carry to the nest per unit time

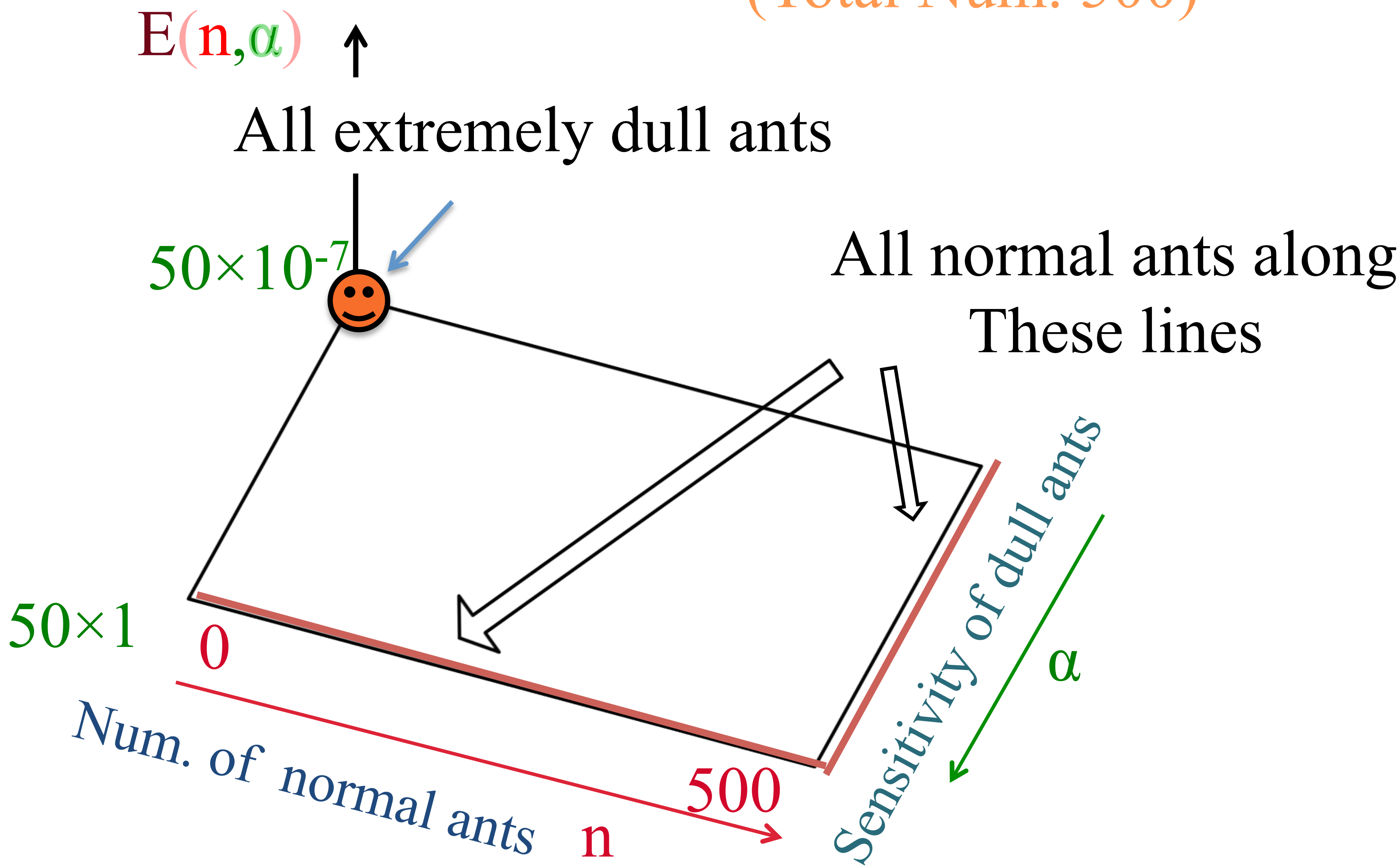
What we measure

$E(n, \alpha)$: Foraging Efficiency as the function of

# of normal ants & **Sensitivity of dull ants**

E: Foraging Efficiency in (n, α) space

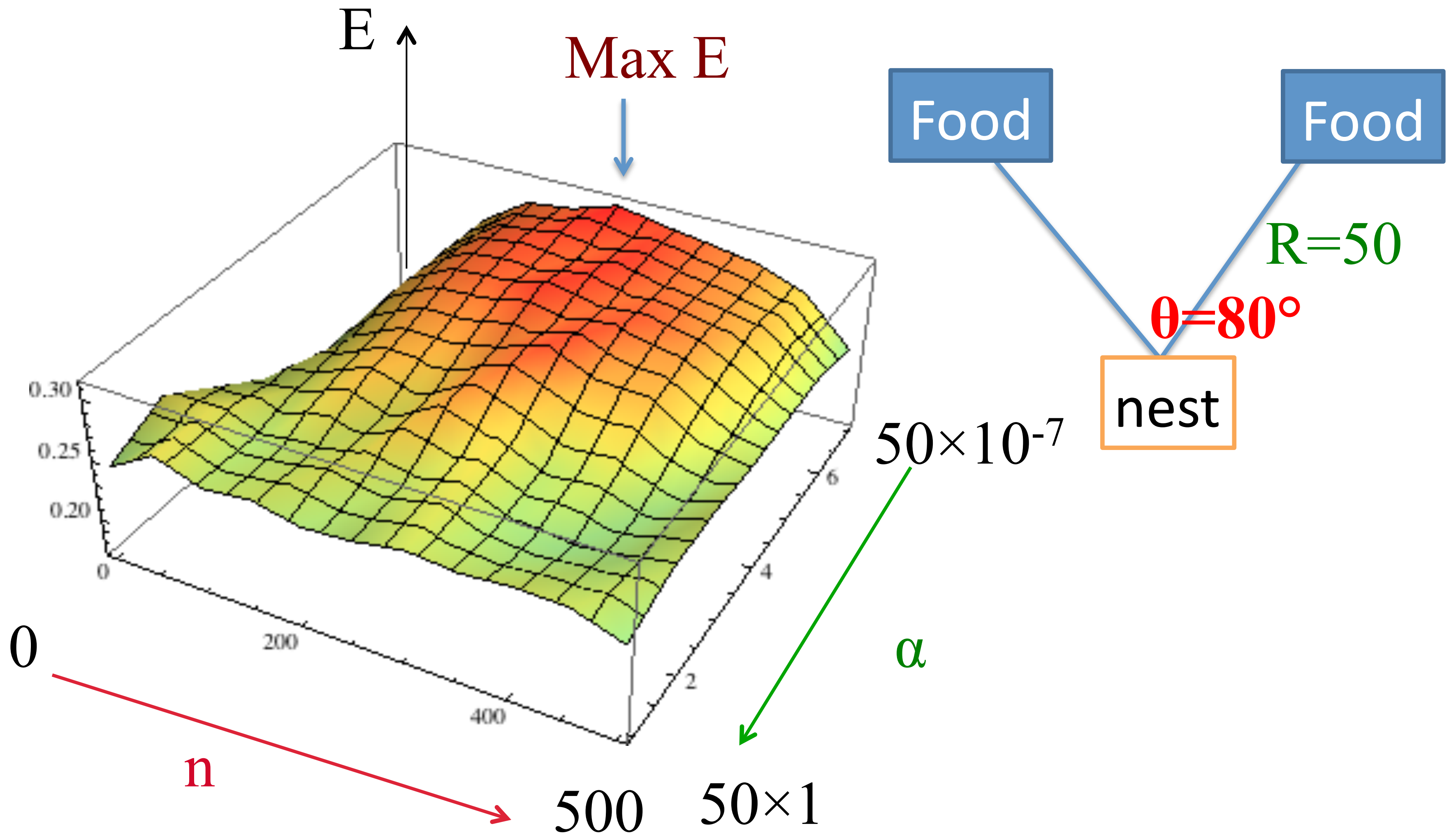
(Total Num. 500)



Result 1 E(n,α): Foraging Efficiency in the space of

n: num. of normal ants & α: Sensisitvity of dull ants

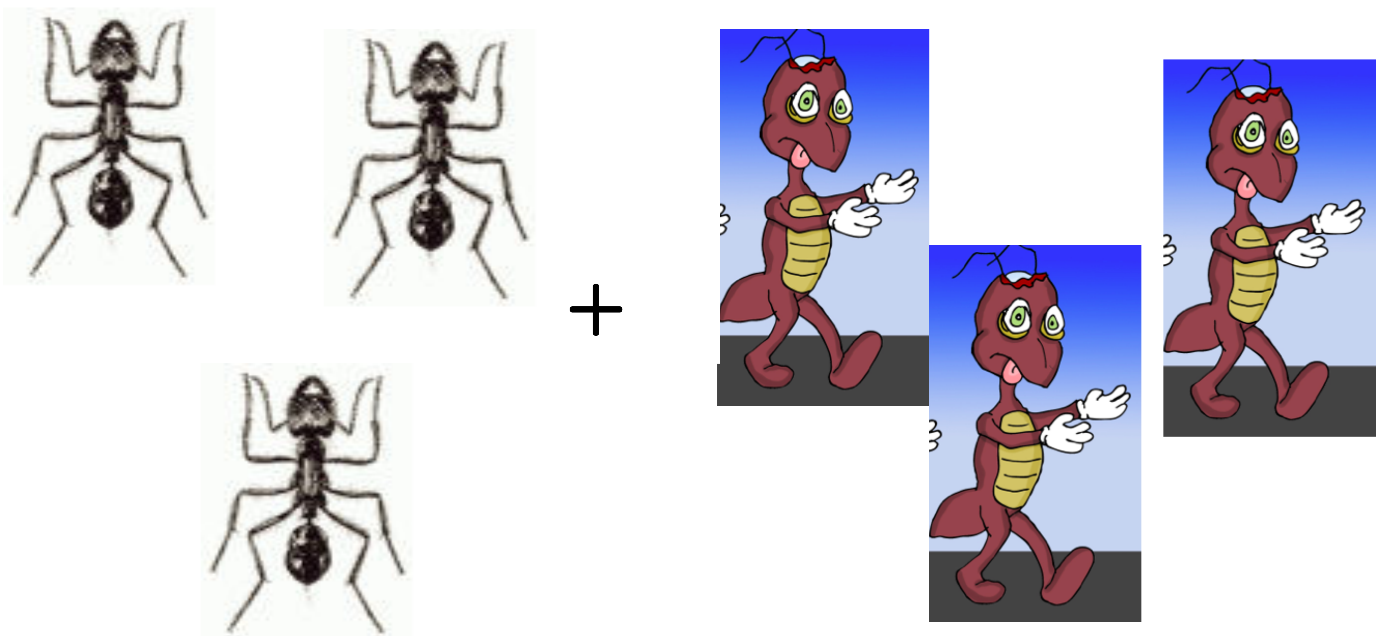
(total number of ants 500)



Optimal colony :

Binary-Mixture of two types of extreme ants

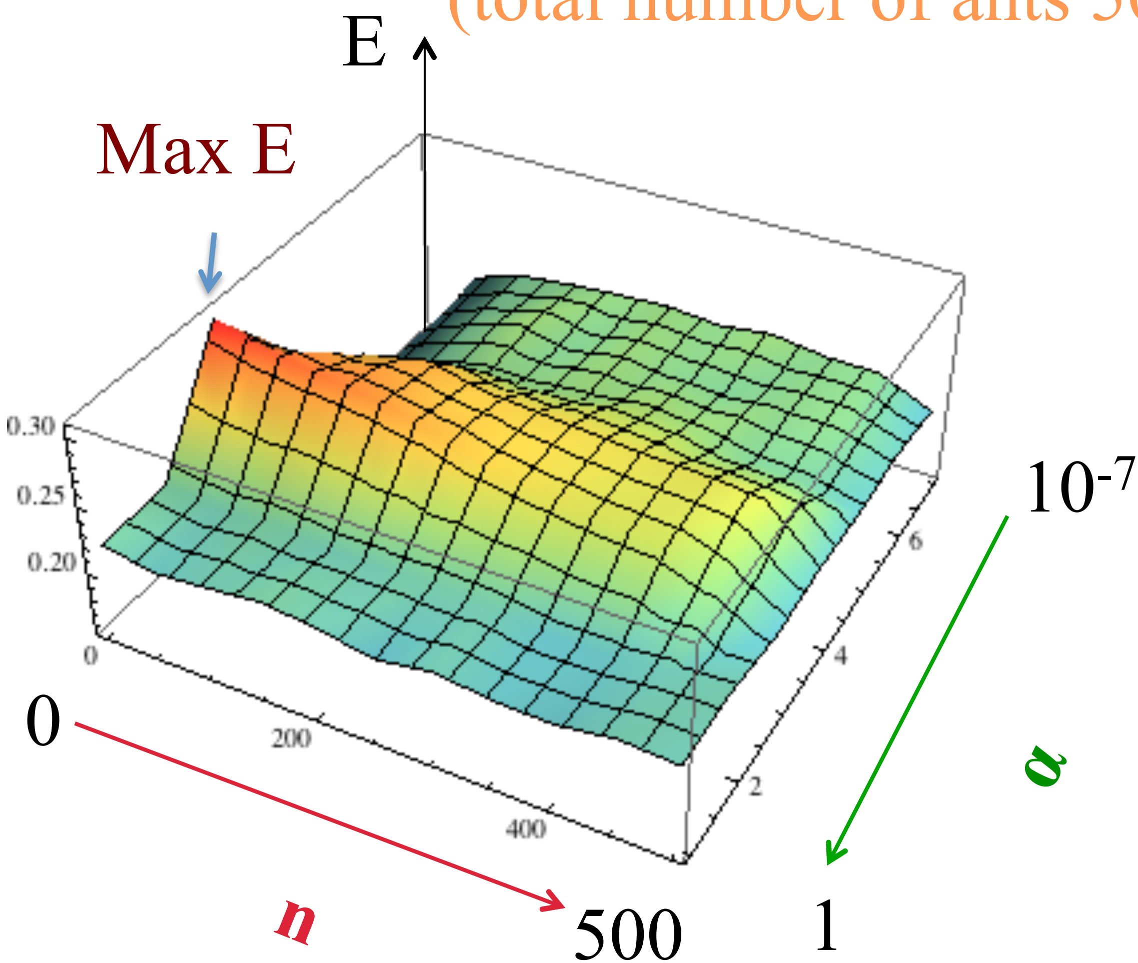
Normal ants & Extremely-dull ants

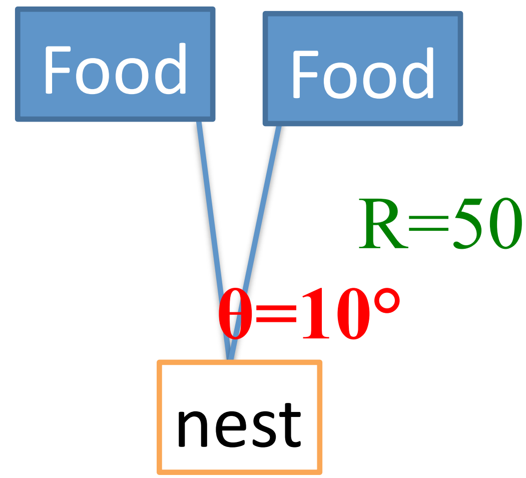


Result 2 E(n,α): Foraging Efficiency in the space of

n: # of normal ants & α: Sensisitvity of dull ants

(total number of ants 500)

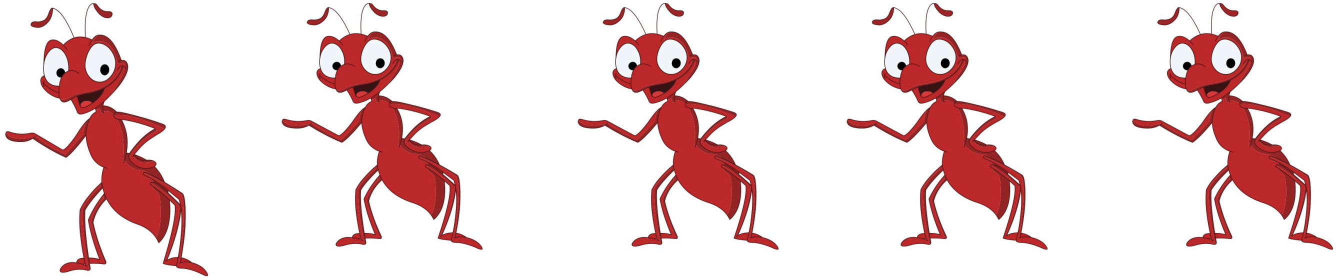




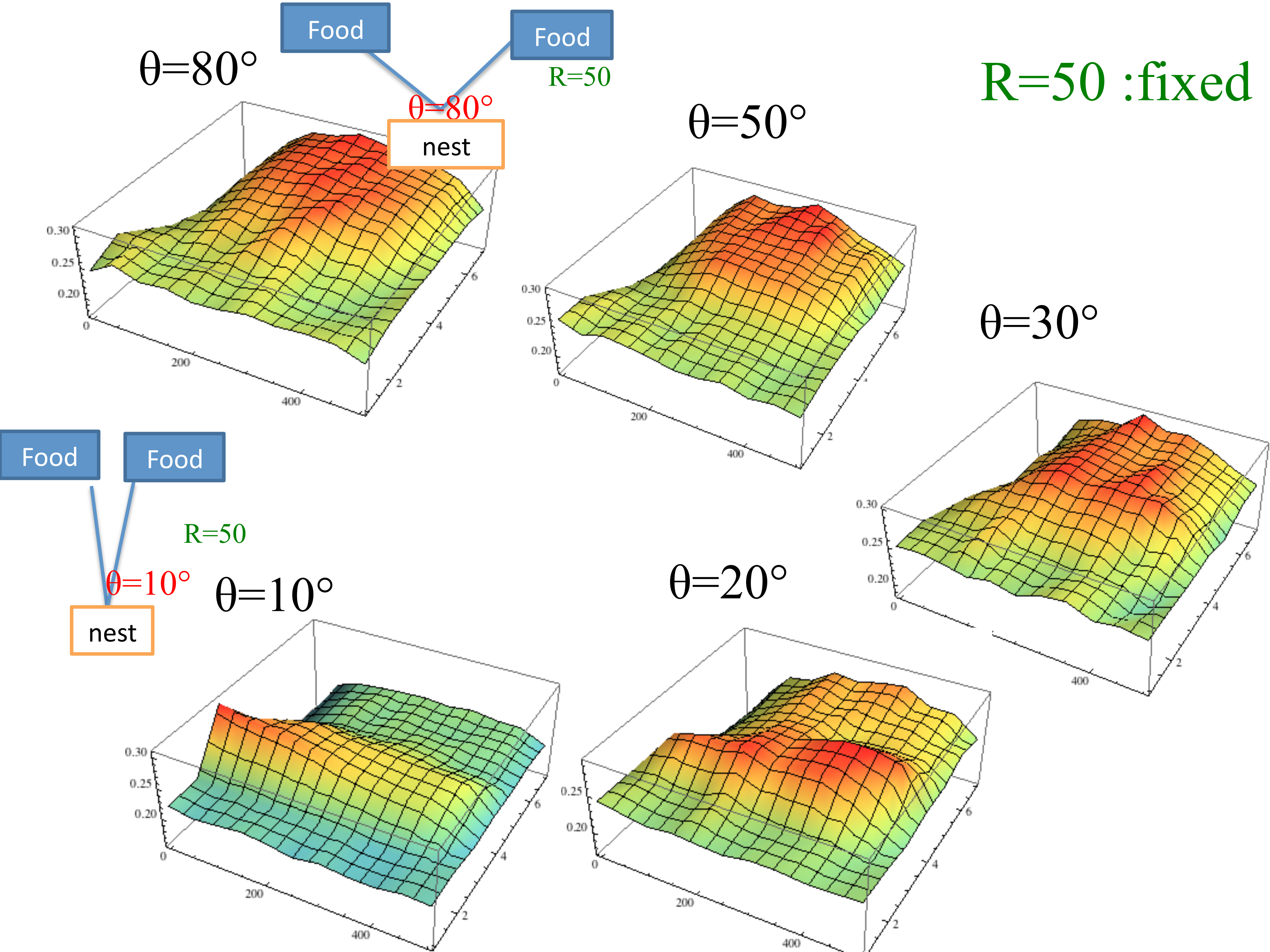
Optimal colony :

Uniform colony of

All Weakly Dull Ants

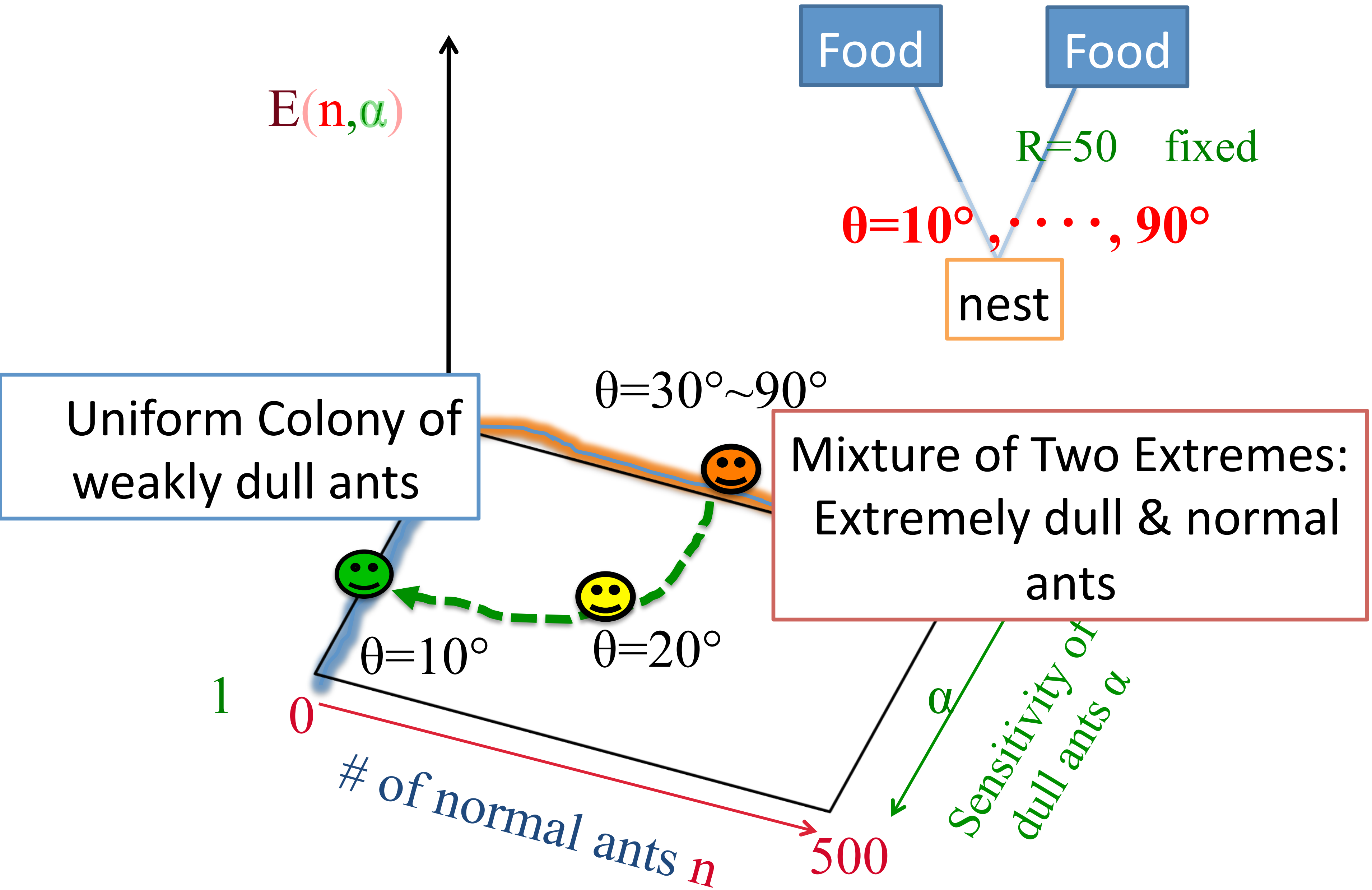


R=50 :fixed



Food
Food
R=50
θ=80°
nest
θ=80°
θ=50°
θ=30°
Food
Food
R=50
θ=10°
nest
θ=10°
θ=20°
0.30
0.25
0.20
0
200
400
2
4
6

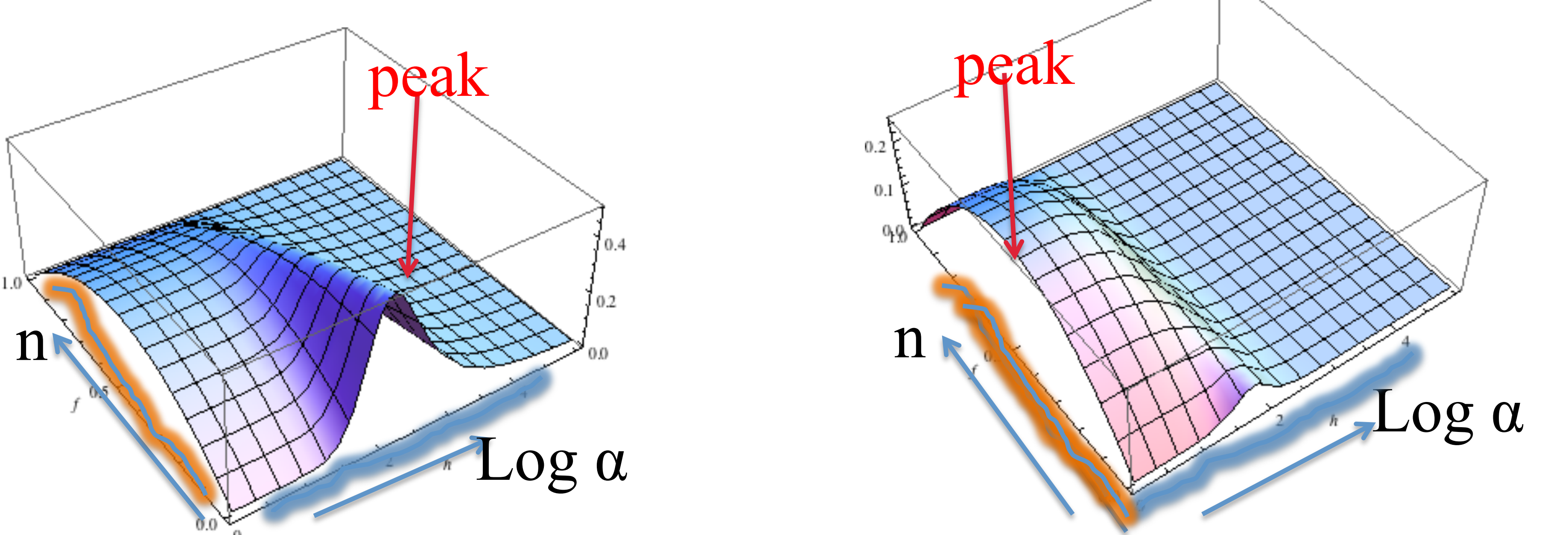
Shift of Optimal Colony According to the change of θ



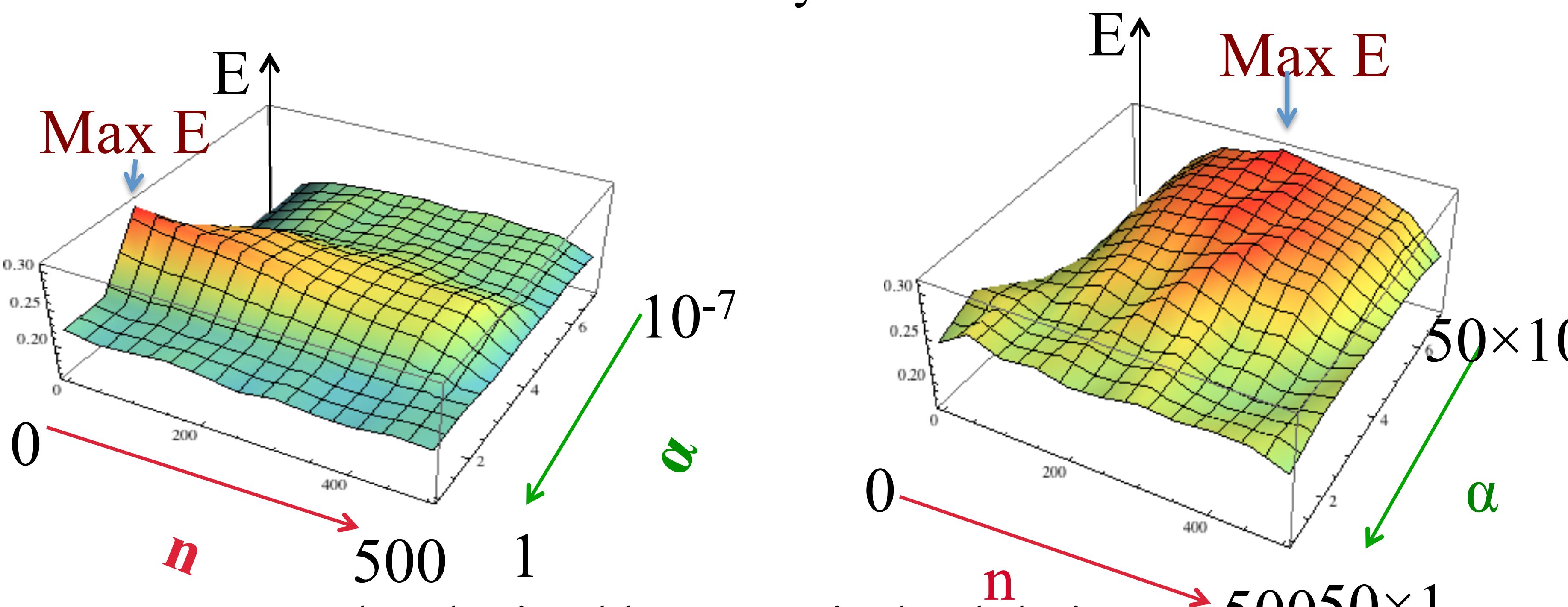
We tried to formalize the phenomena and proposed one of possible scenarios in the workshop

However, in this note, we are sorry to omit the part of formalism

It is because, details of theoretical discussions are still in the level of private communication among authors.



Results obtained by formalism



Results obtained by numerical calulation

Conclusion

○Including inefficient (=dull) ants within a colony increase the foraging efficiency of colony

○The optimal way of including inefficient (=dull) ants sharply change depending on foraging environment

From a binary mixture of extremely-dull and sensitive normal ants to the uniform colony of all-weakly dull ants

○A mathematical formulation for the above phenomena is made.

But on the half-way

Perspective

Is the generalization of this story possible?

↓

Transition of noise–induced efficient behavior in many-body systems:

From homogeneous noise to heterogeneous noise

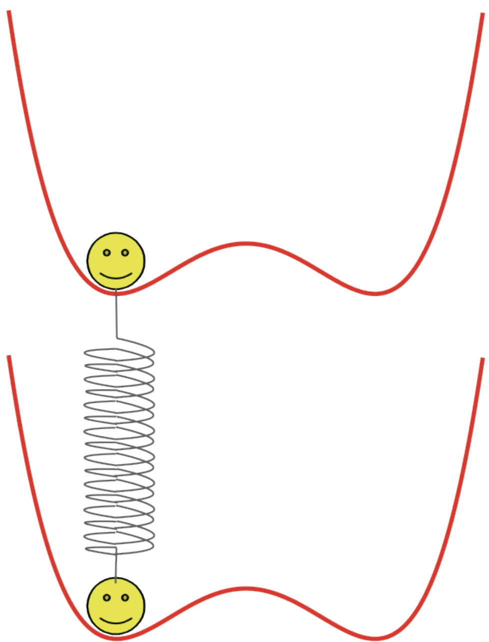
Example

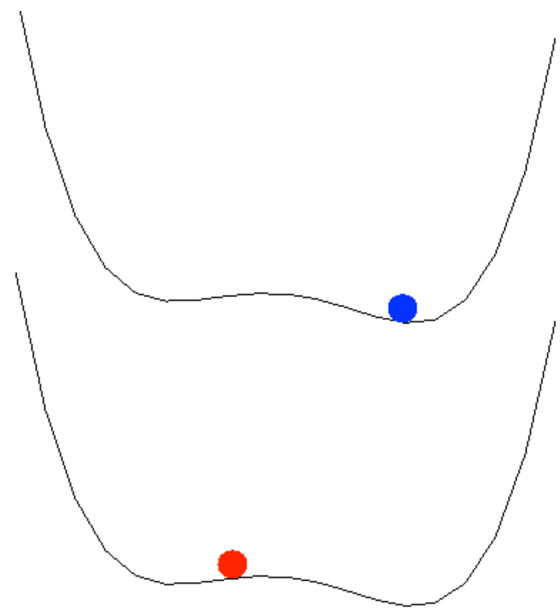
Stochastic resonance under inhomogeneous noise

$$
\begin{cases}
\dfrac{dx_1}{dt} = -\dfrac{dV(x_1)}{dx_1} + A\cos(\Omega t) + \xi_{x_1}(t) + k(x_2 - x_1) \\
\dfrac{dx_2}{dt} = -\dfrac{dV(x_2)}{dx_2} + A\cos(\Omega t) + \xi_{x_2}(t) + k(x_1 - x_2) \\
V(x) = -x^2 + x^4 \\
\langle \xi_{x_i}(t) \rangle = 0 \\
\langle \xi_{x_i}(t+s)\xi_{x_i}(t) \rangle = 2D_{x_i}\delta(s)
\end{cases}
$$

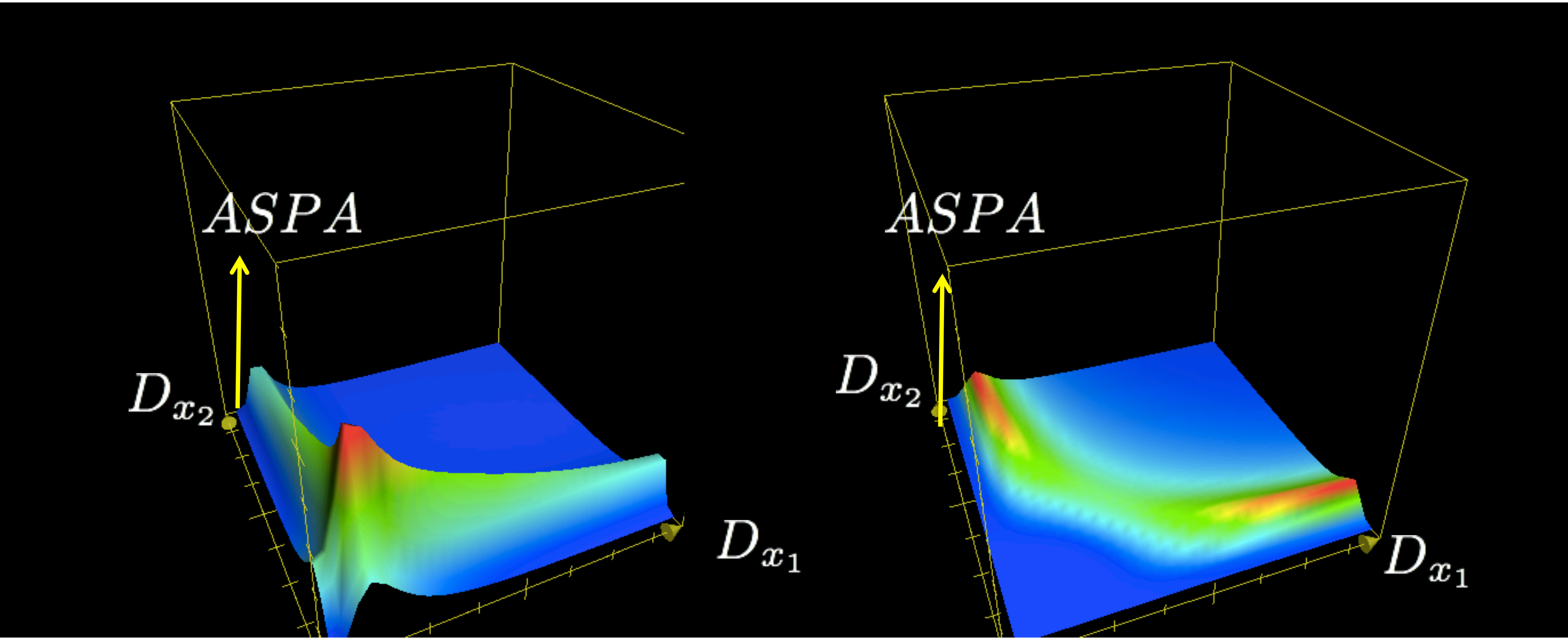
鳥越章吾修士論文

$D_{x_1} \neq D_{x_2}$ inhomogeneous noise





Weak coupling　　Strong coupling



ASPA: degree of stochastic resonance averaged over elements 1 and 2.

D1,D2: amp. of noise induced to 1 and 2,respectively

1.R. Kawai, A. Awazu , and H. Nishimori, PRE. Vol.84,021135-1-5 (2011)
2. R. Kawai, S. Torigoe, K. Yoshida , A. Awazu , and H. Nishimori, PRE. Vol.82, 051122-1-7 (2010)