

# ***Evolution and Stability of Ring Species***

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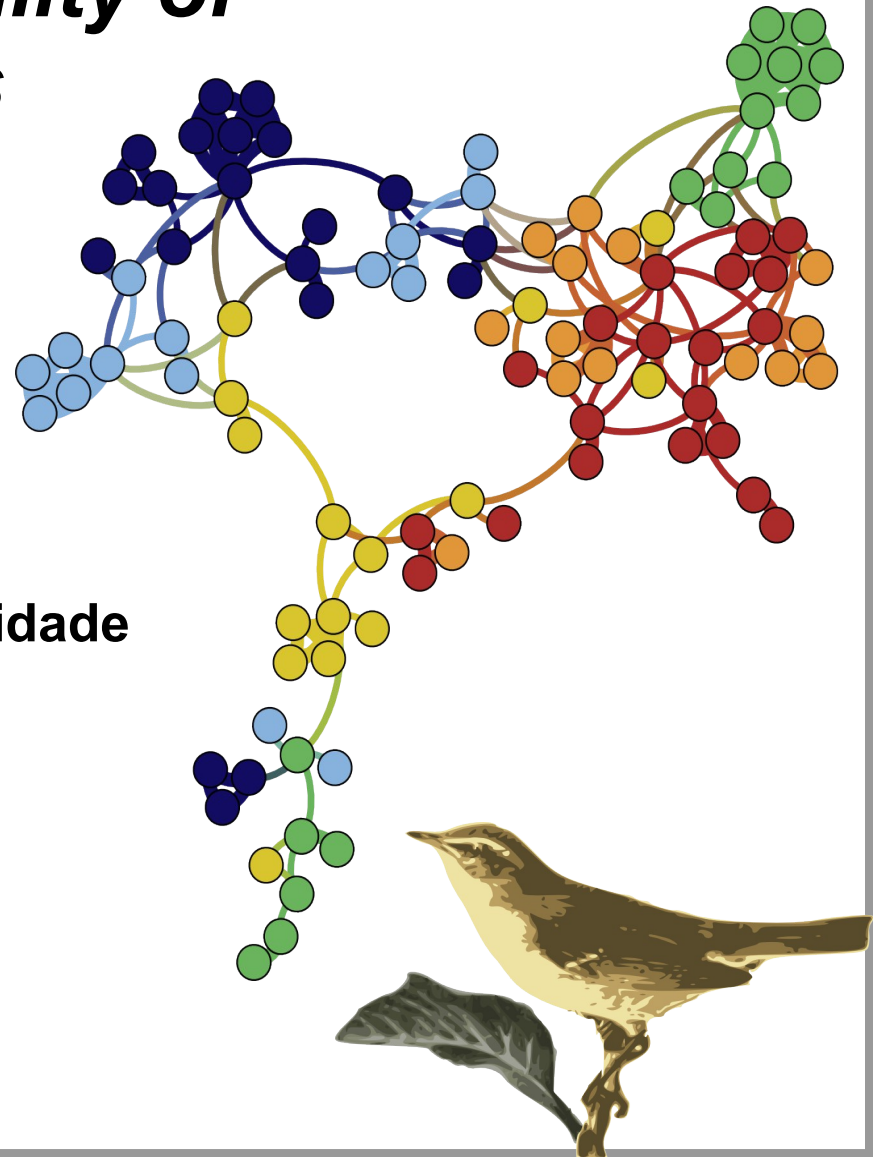
**Marcus A. M. de Aguiar<sup>2,3</sup>**

**Yaneer Bar-Yam<sup>3</sup>**

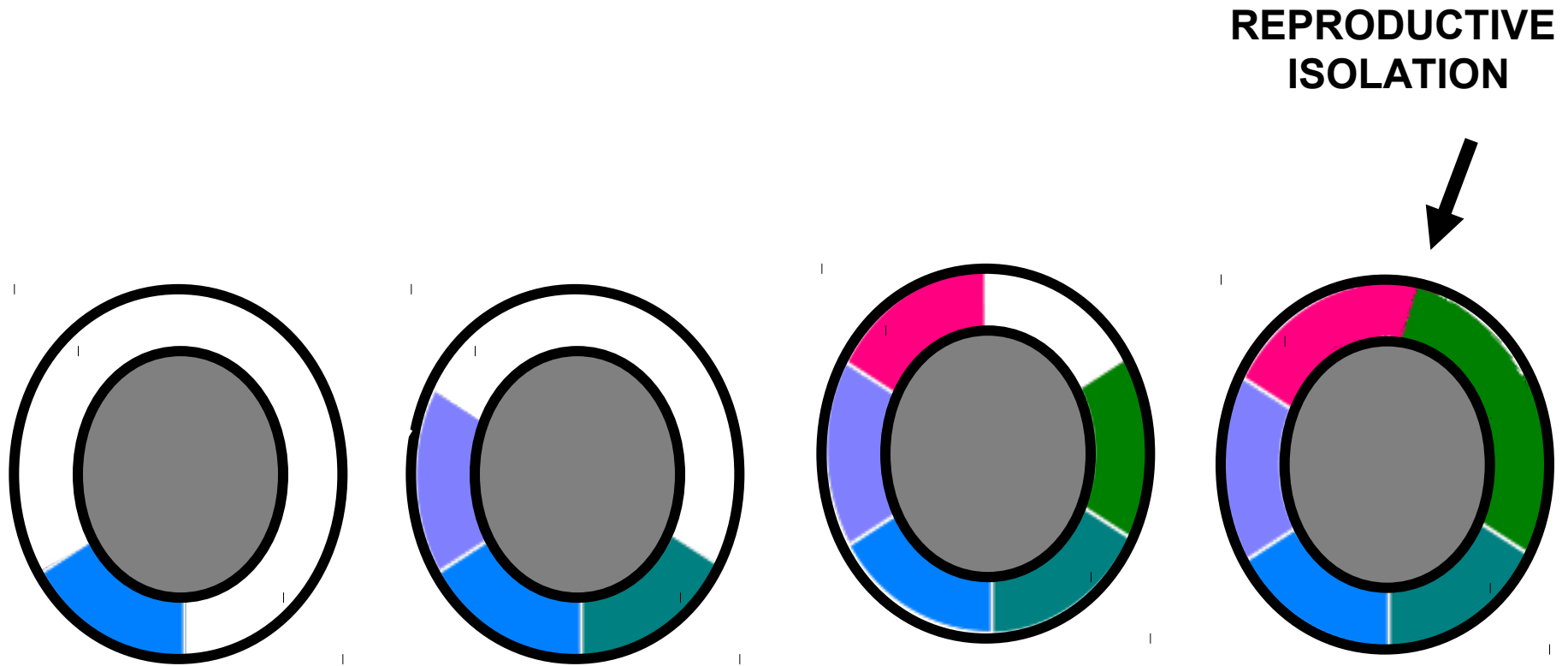
<sup>1</sup> Instituto de Biociências, Universidade  
de São Paulo

<sup>2</sup> Instituto de Física, Universidade  
Estadual de Campinas

<sup>3</sup> New England Complex Systems  
Institute

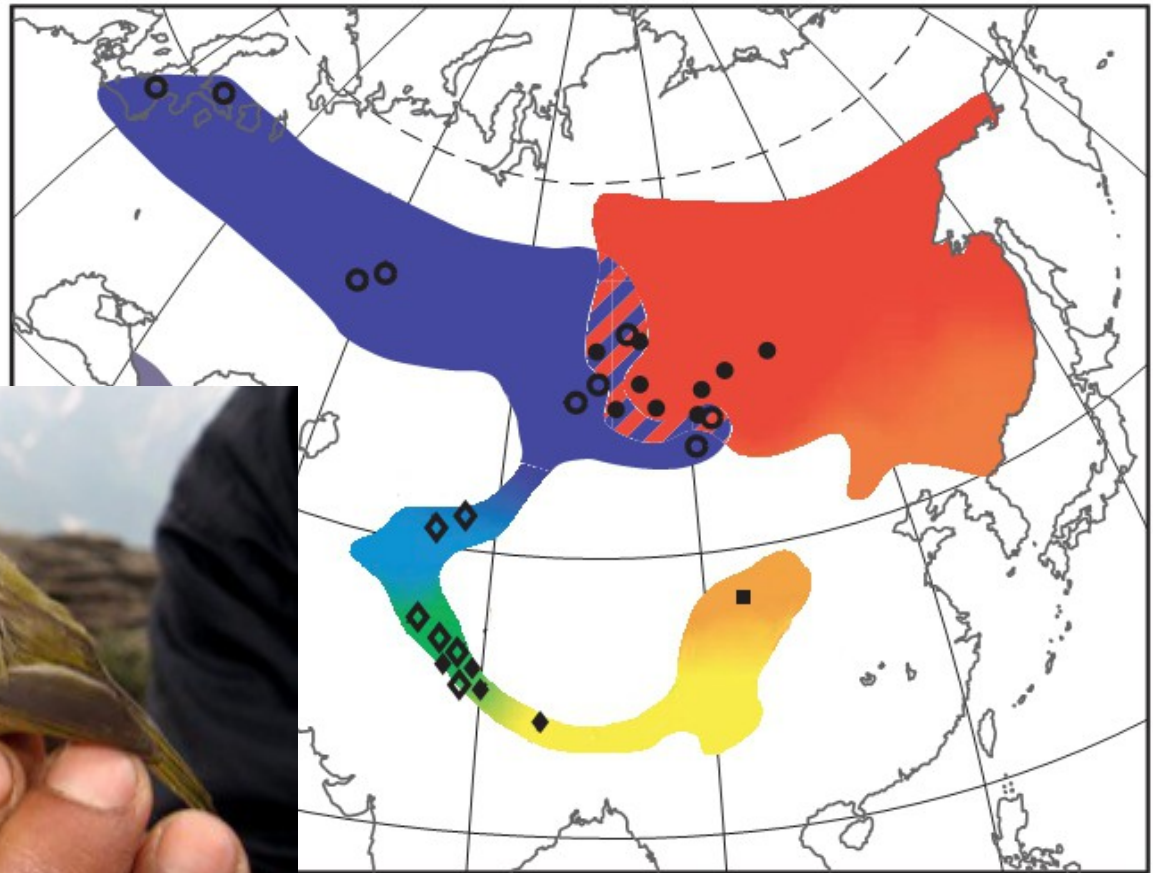


# Ring Species



# Ring species in nature

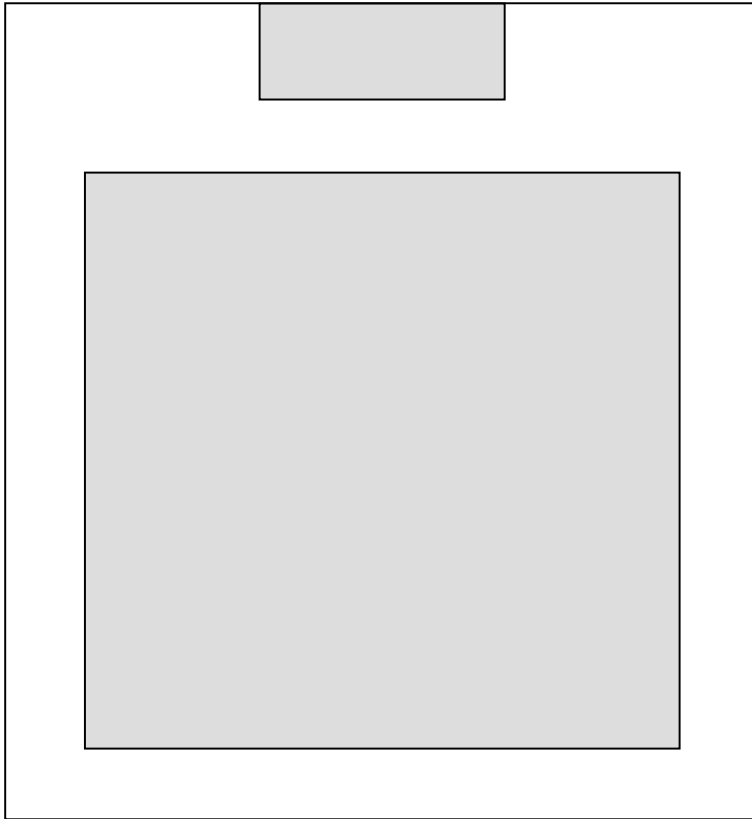
## *Phylloscopus*



Irwin *et al.* 2005

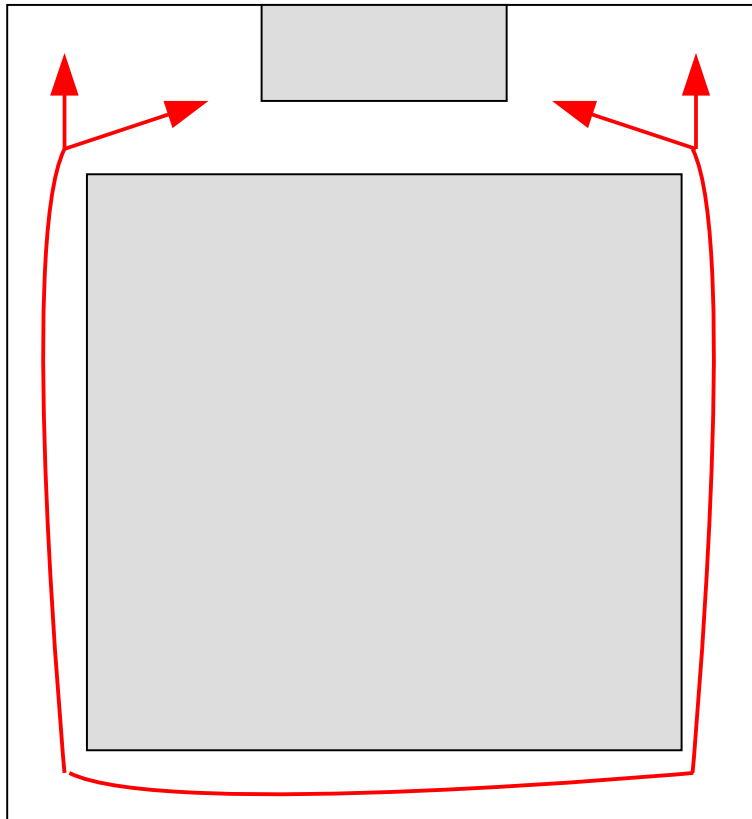
# Geographical barriers

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# Geographical barriers

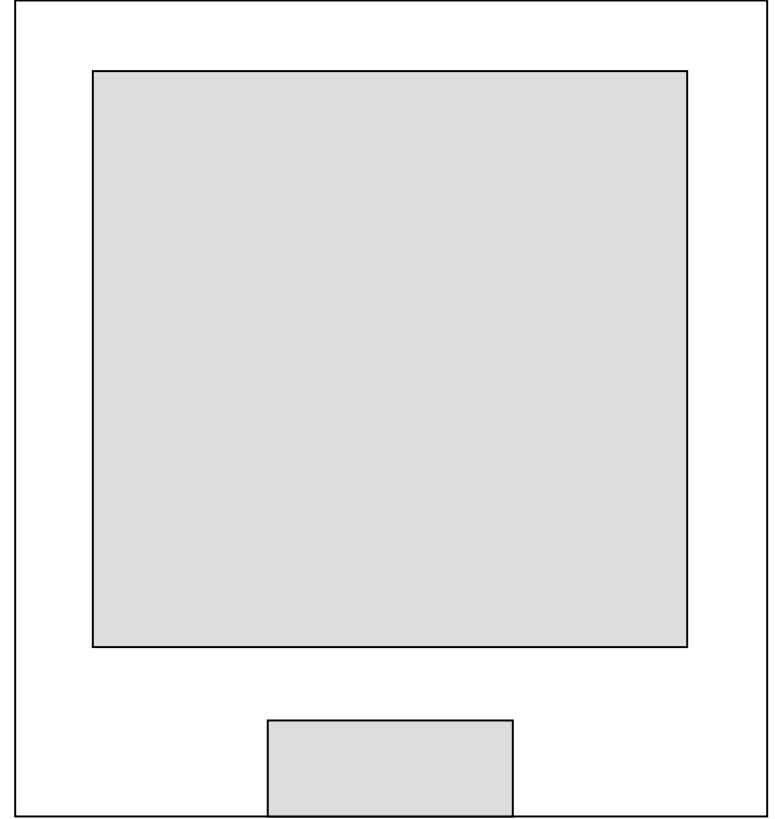
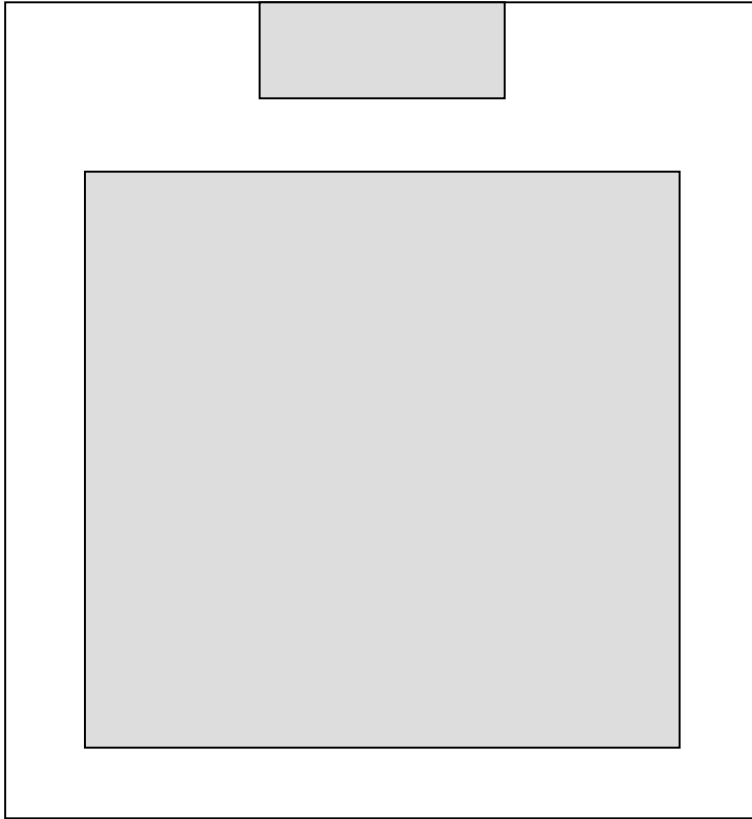
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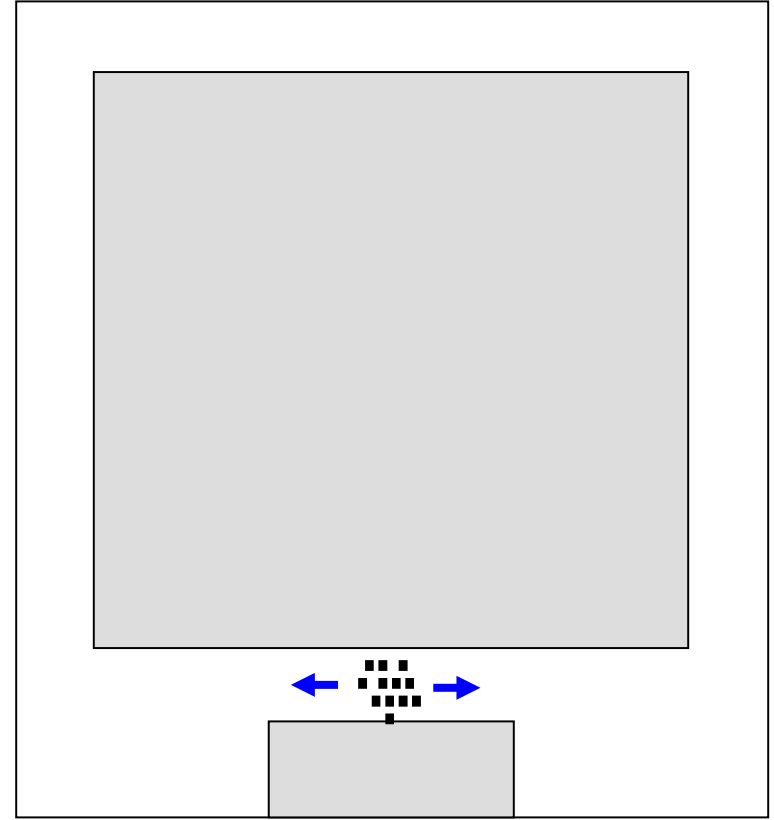
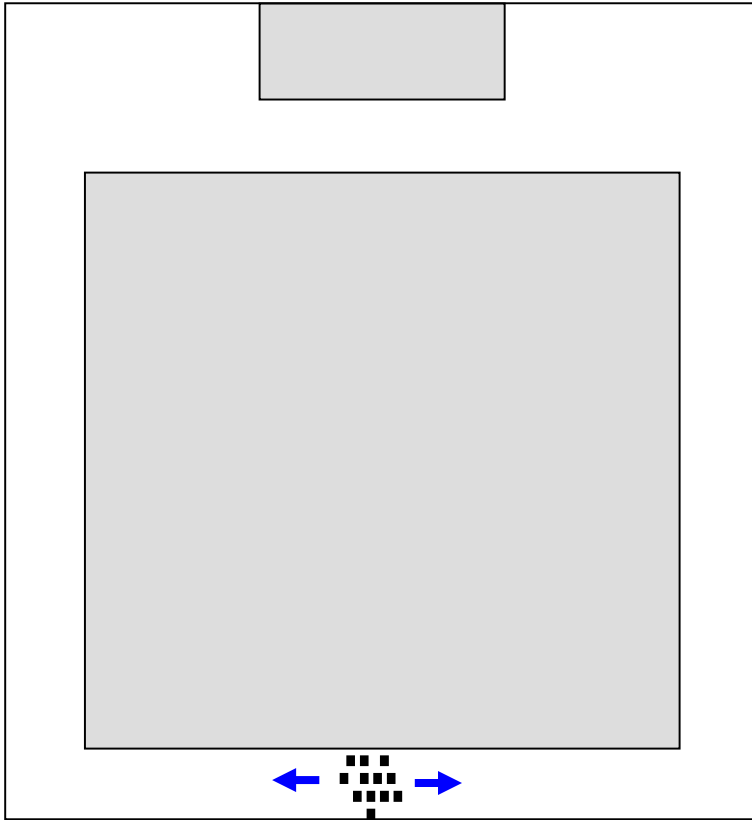
**POPULATION**

# Geographical barriers

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# Geographical barriers



# The model

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**AGENT**



**GENES**

0 0 0 0 0 0 0 0 0 0 ... 0 0 0 0 0 0 0 0 0 0

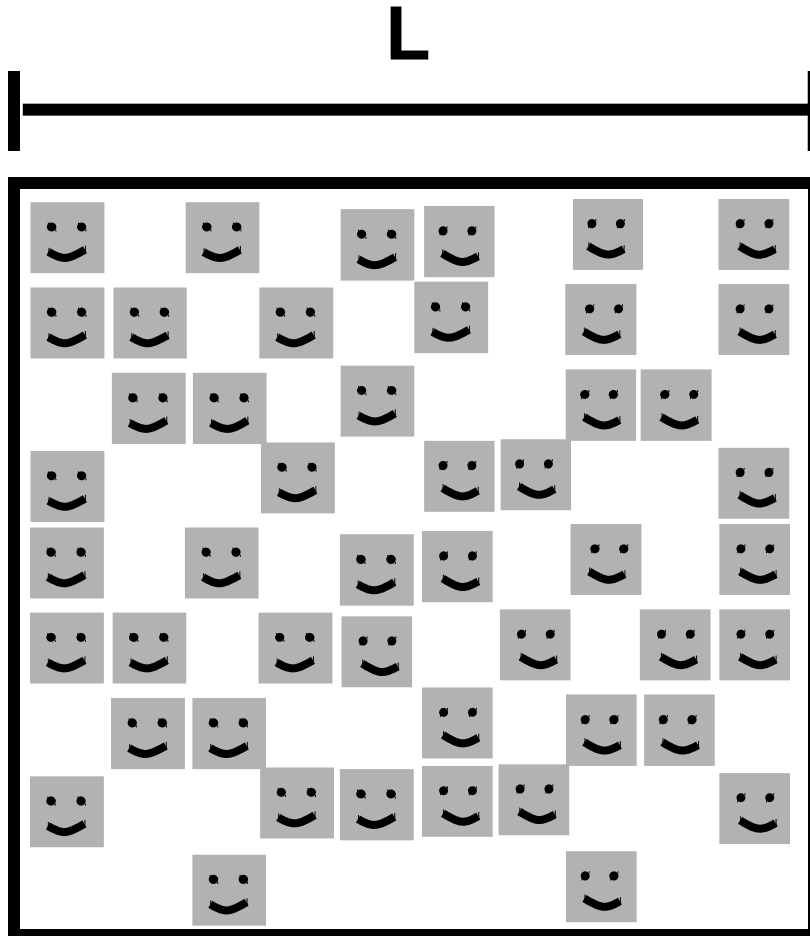
**POSITION IN SPACE**

**$X_{(AGENT)}$ ,  $Y_{(AGENT)}$**



# The model

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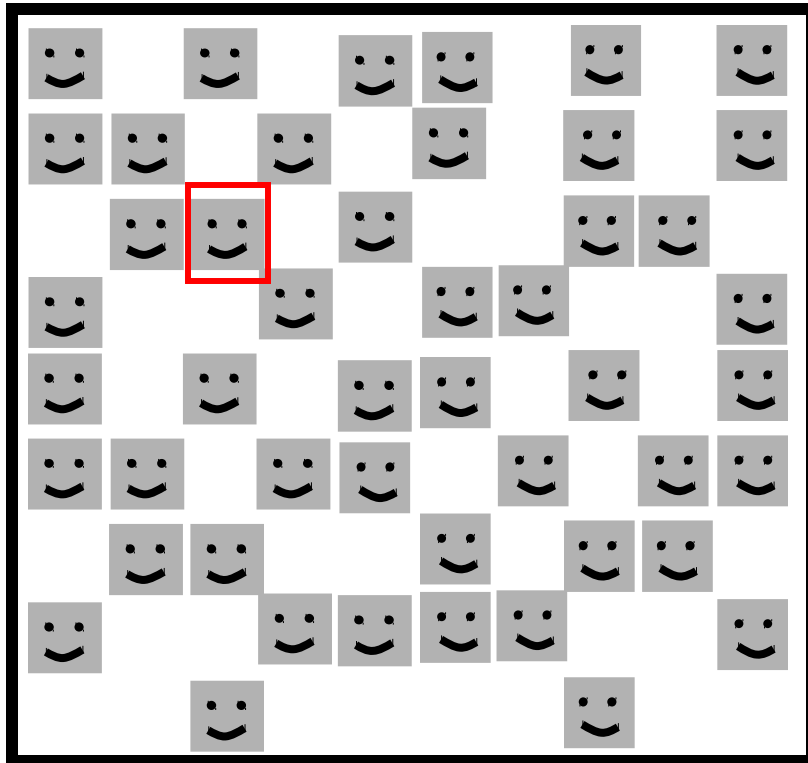


**CARRYING CAPACITY**

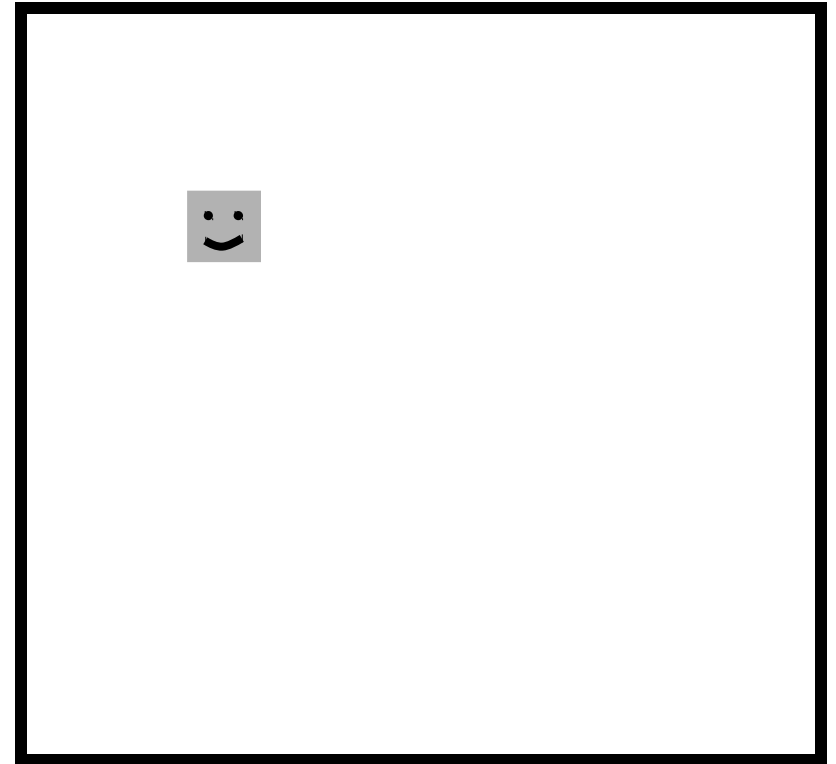
**MUTATION RATE**

# The model: Time evolution

$T_n$



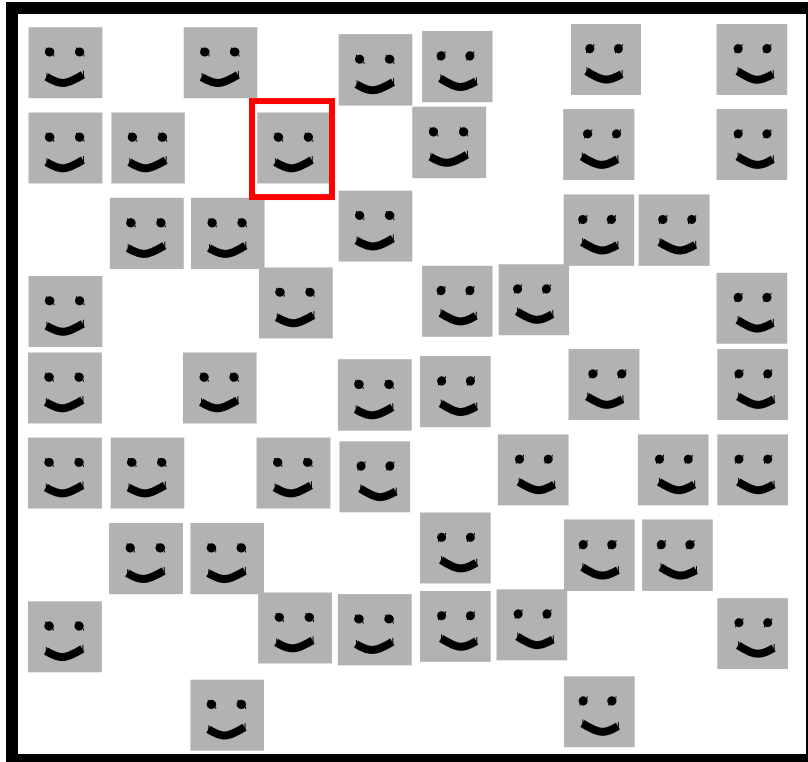
$T_{n+1}$



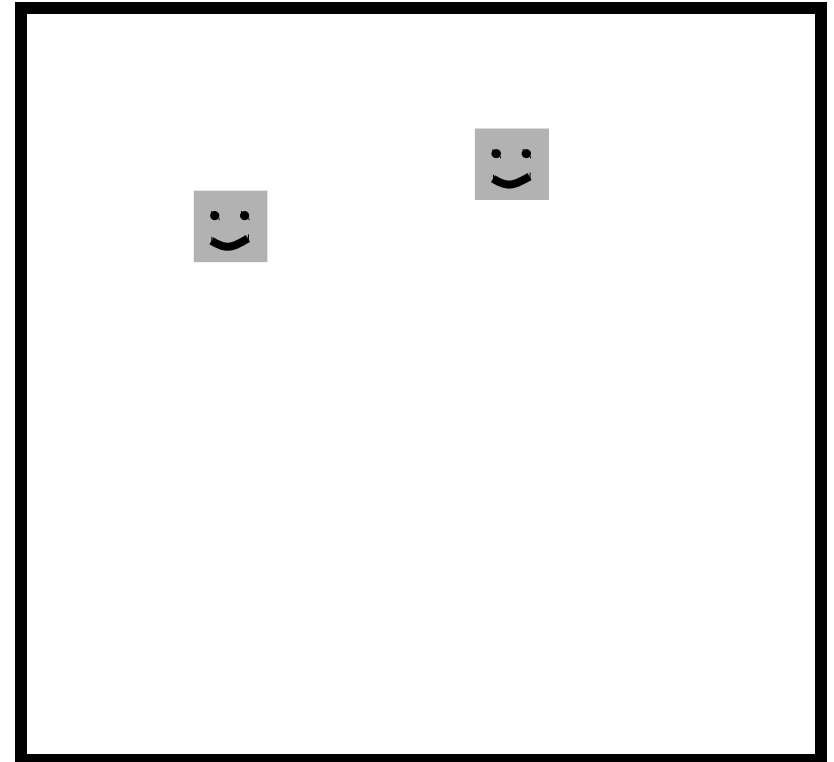
DISCRETE GENERATIONS

# The model: Time evolution

$T_n$



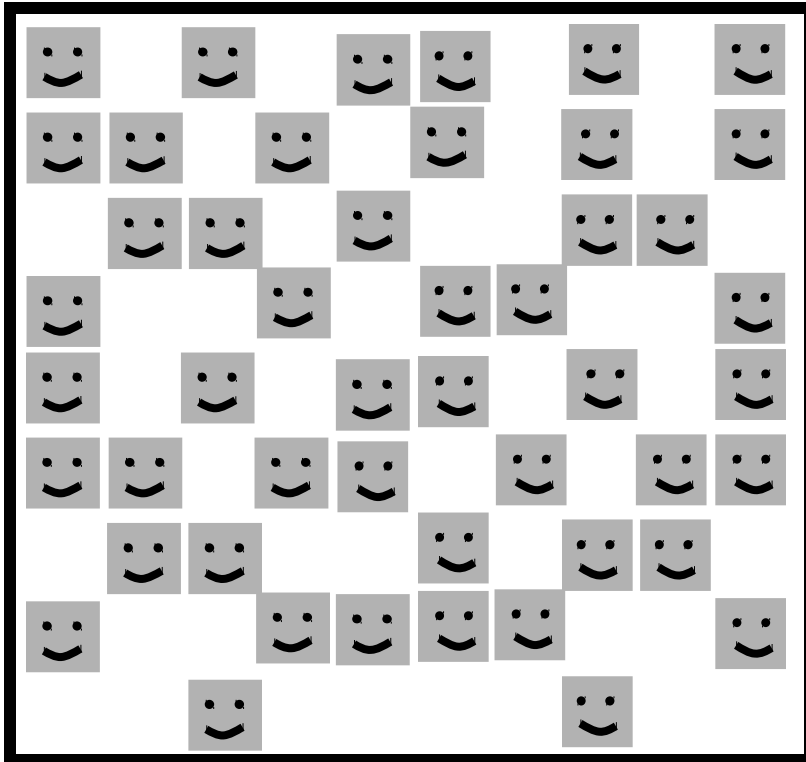
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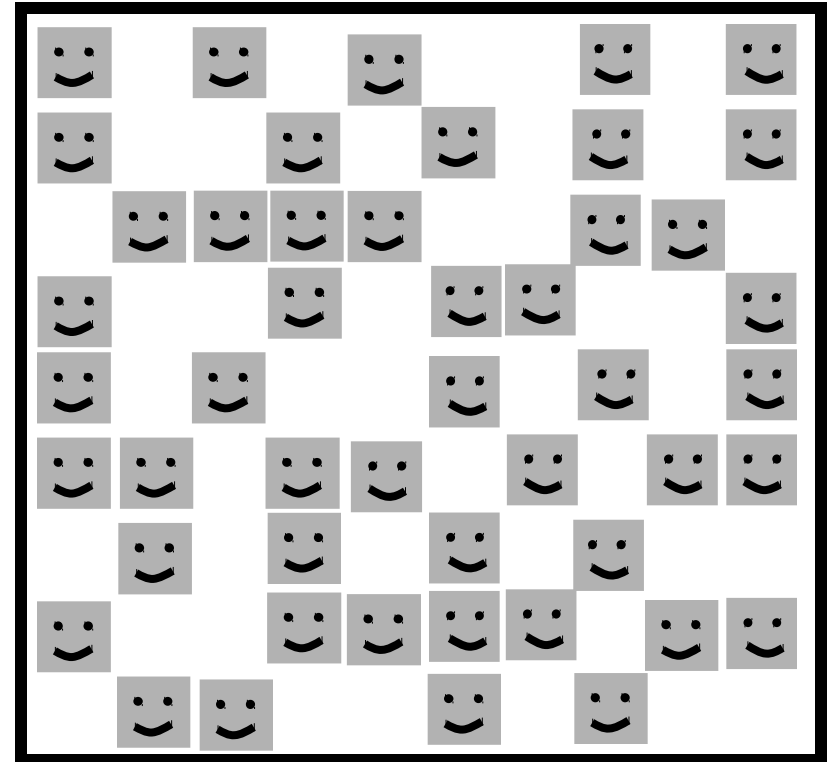
DISCRETE GENERATION

# The model: Time evolution

$T_n$



$T_{n+1}$



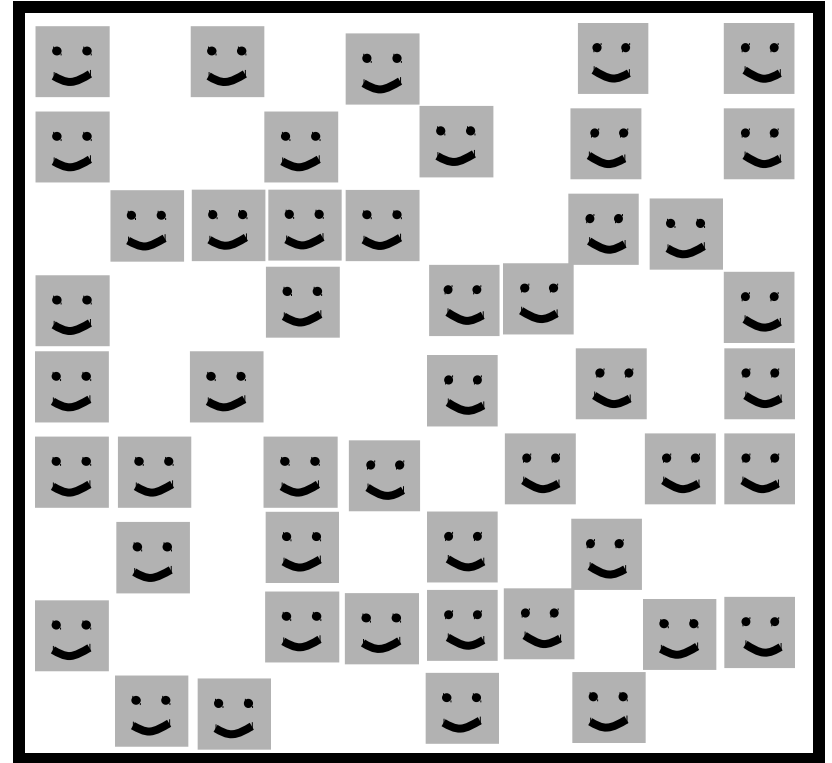
DISCRETE GENERATIONS

# The model: Time evolution

$T_n$

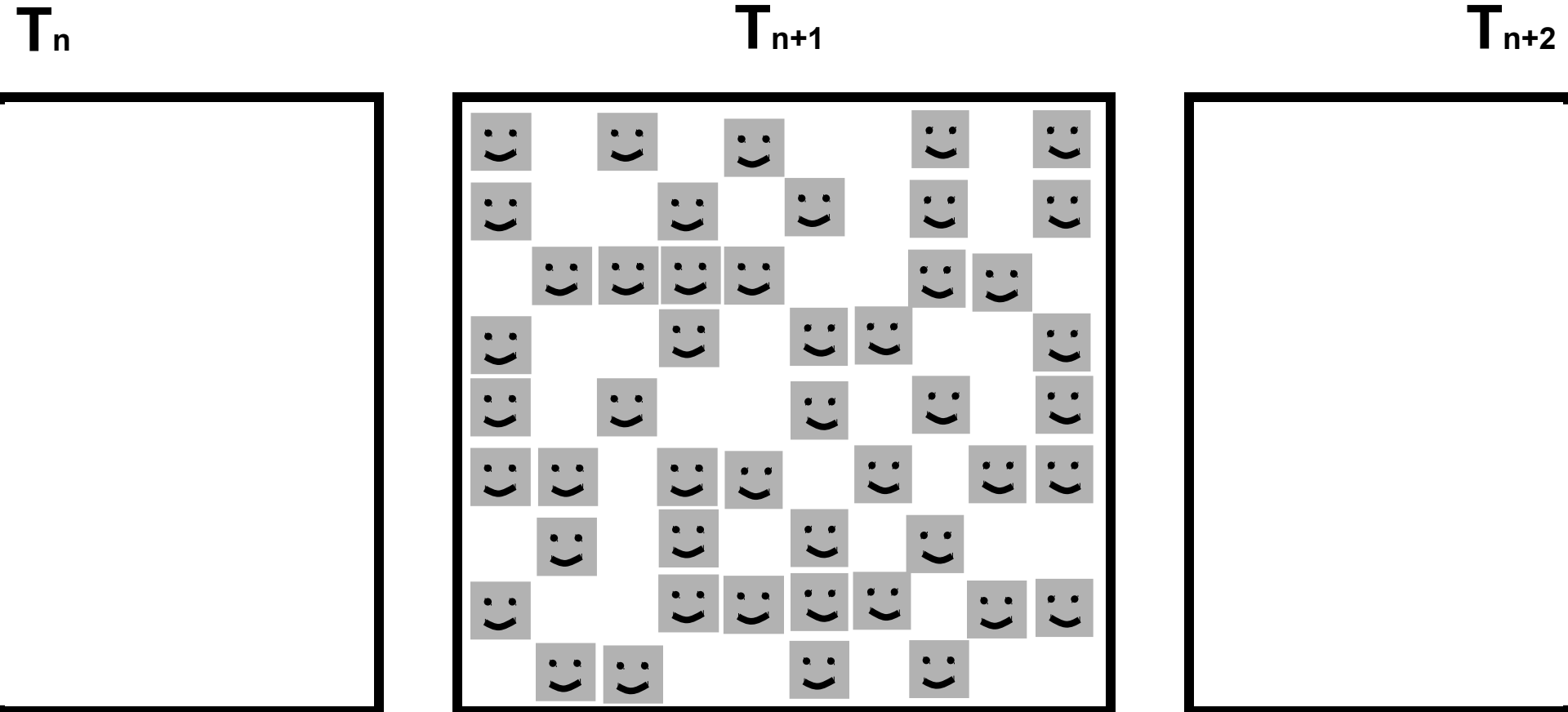


$T_{n+1}$



DISCRETE GENERATIONS

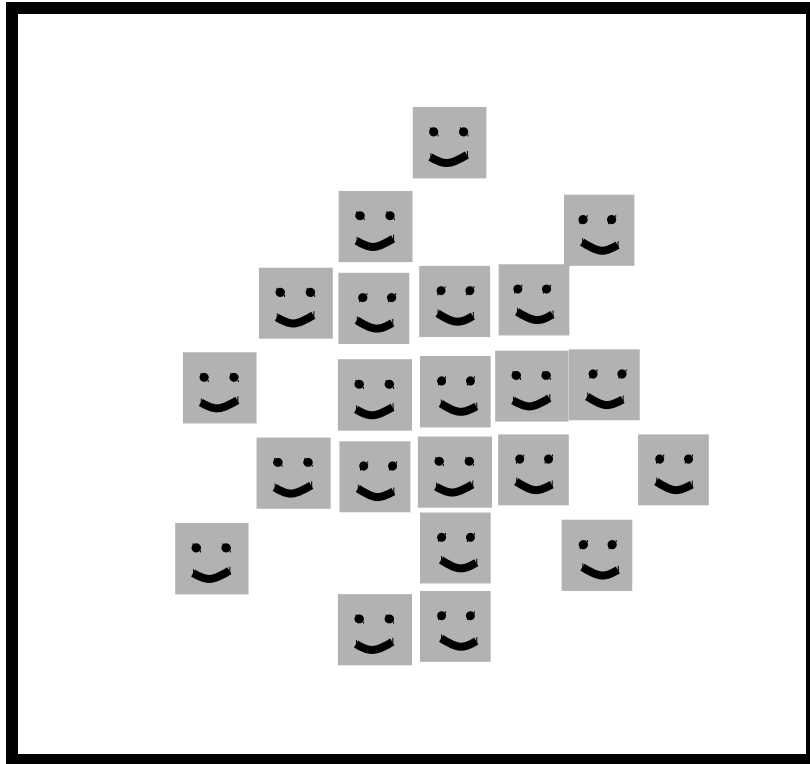
# The model: Time evolution



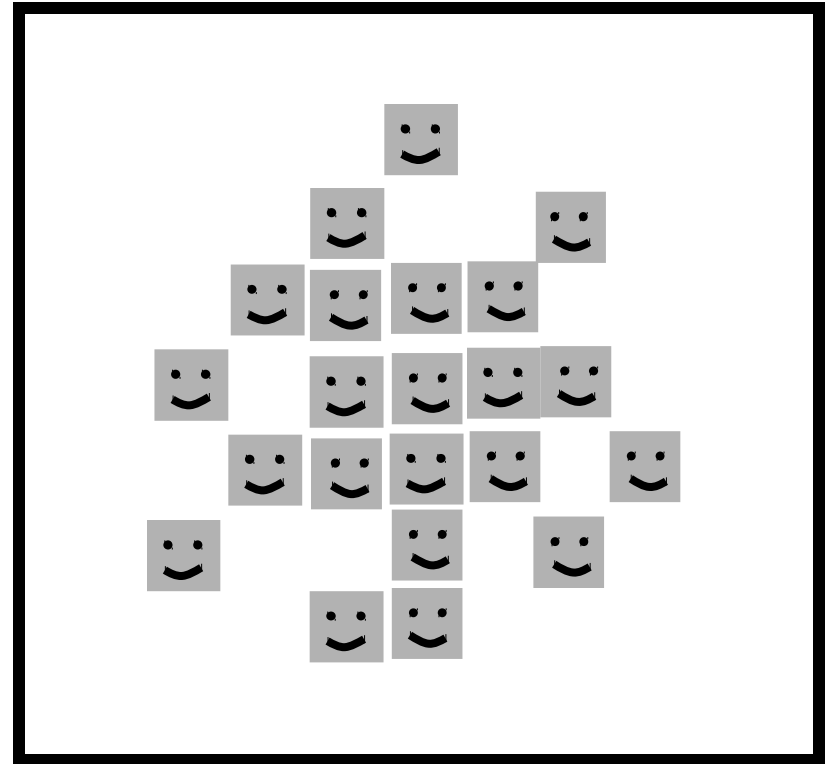
DISCRETE GENERATIONS

# The model: population growth

$T_n$

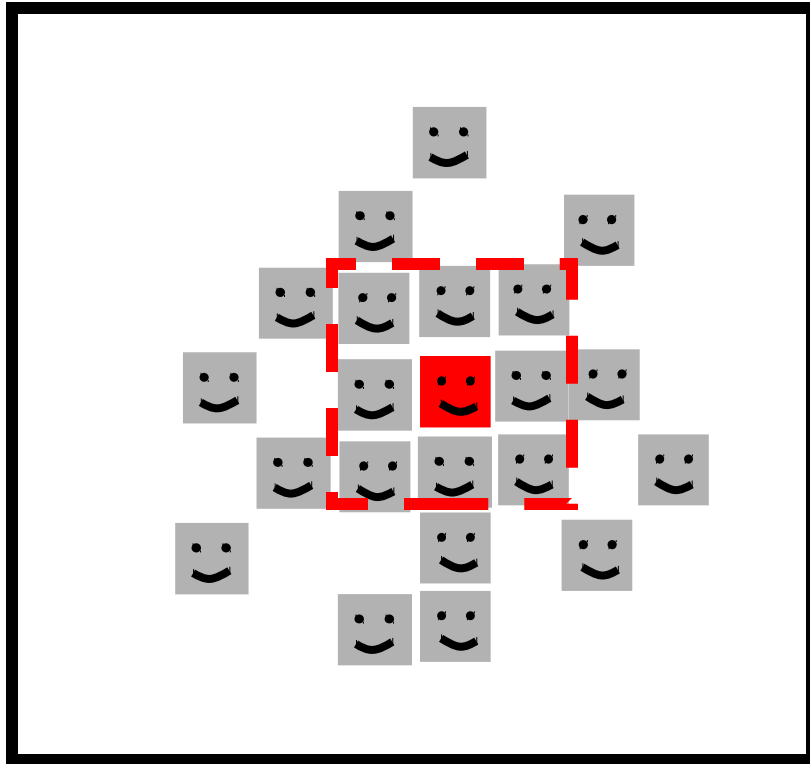


$T_{n+1}$

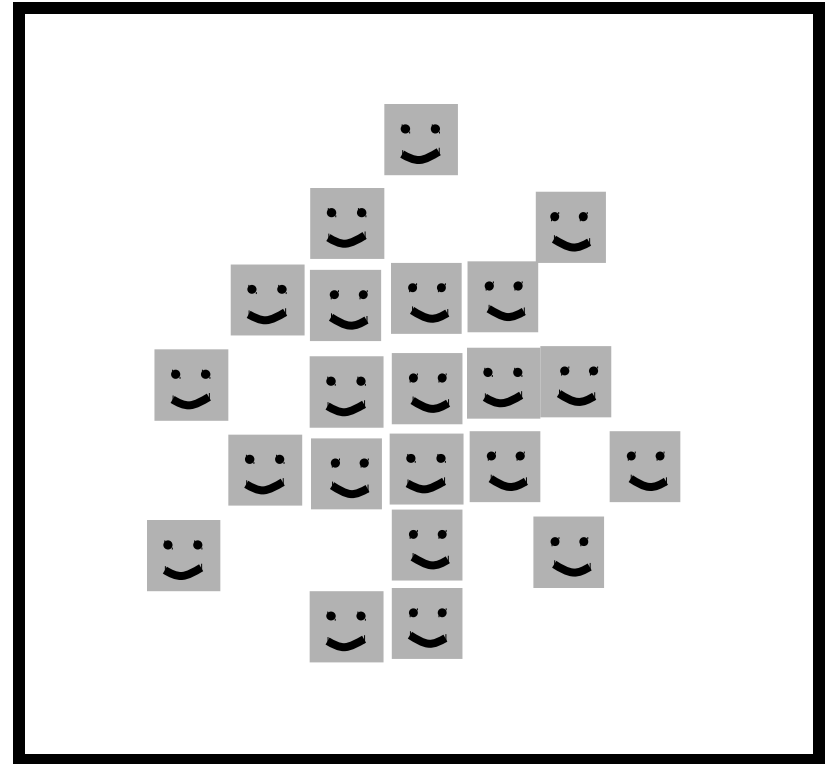


# The model: population growth

$T_n$



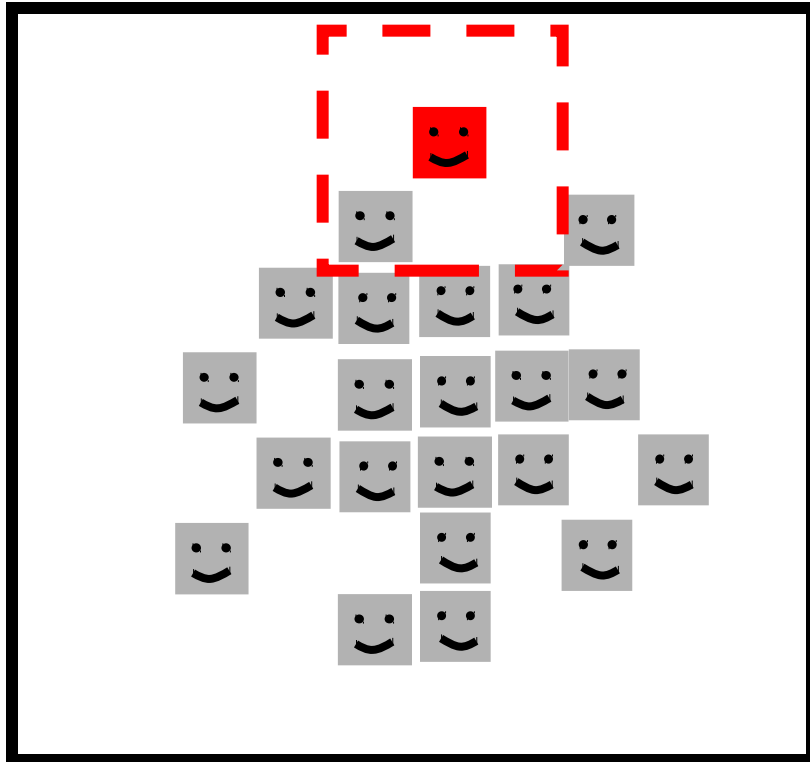
$T_{n+1}$



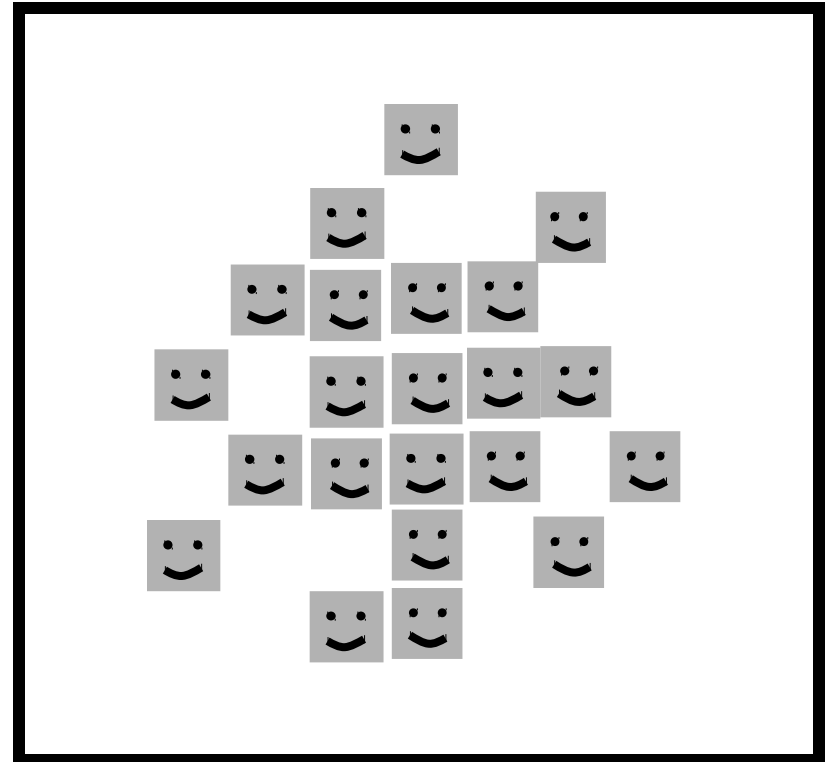


# The model: population growth

$T_n$

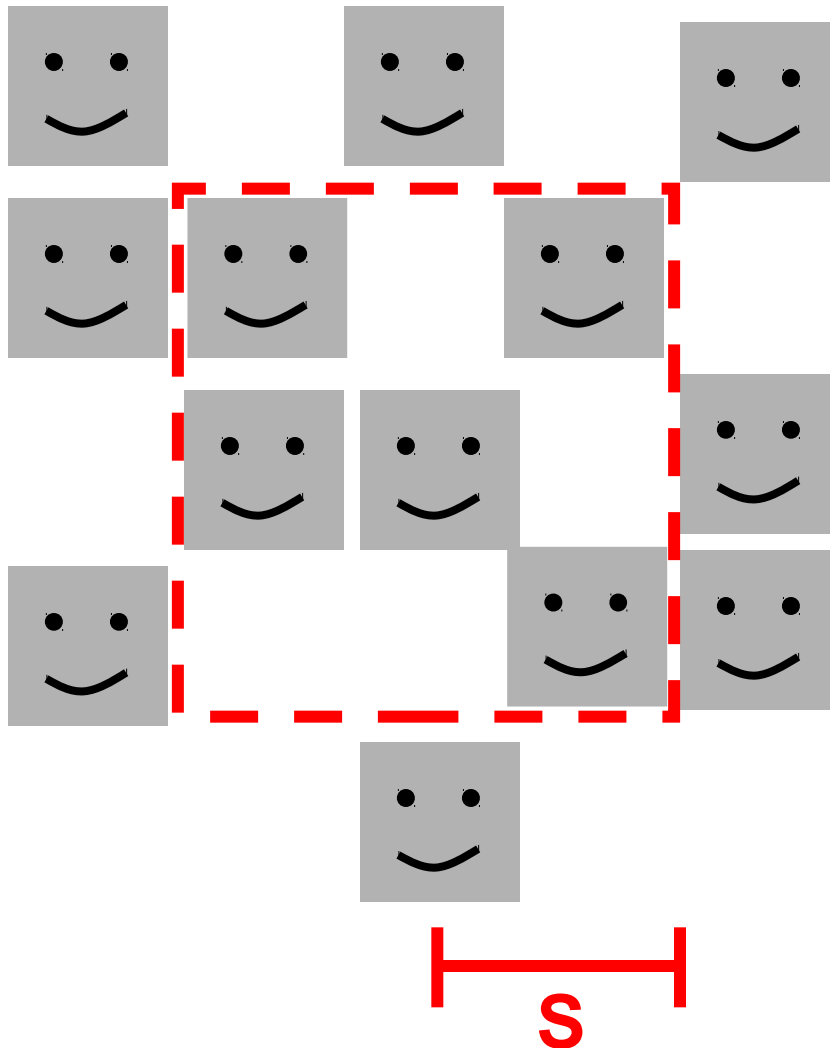


$T_{n+1}$



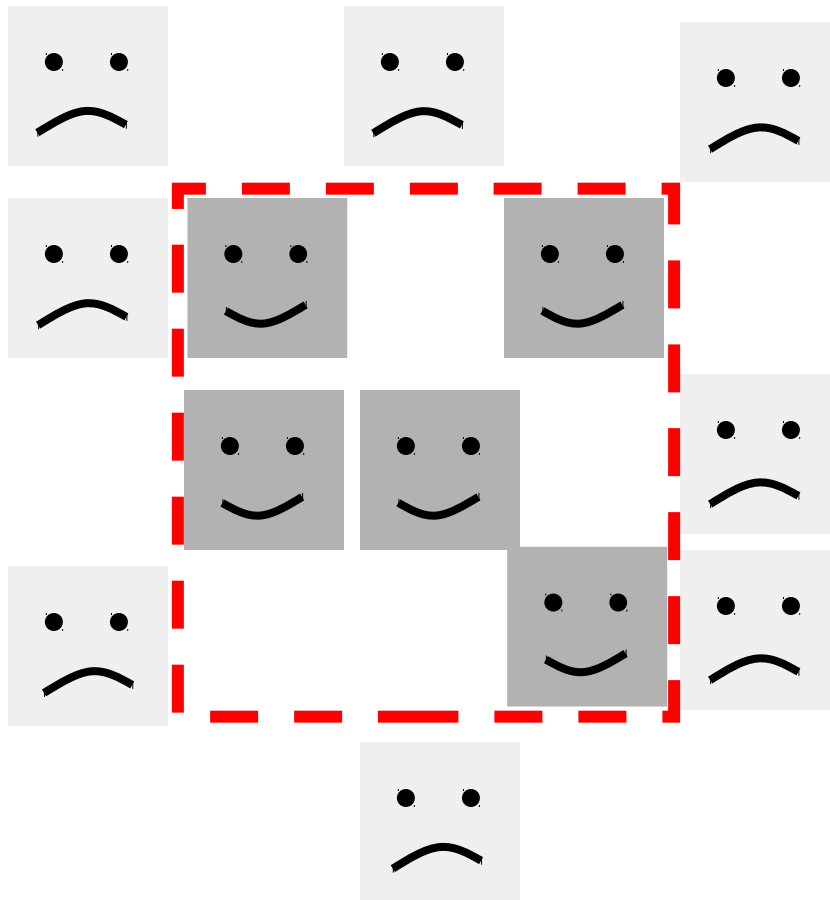
# The model: Reproduction

## BREEDING NEIGHBORHOOD



# The model: Reproduction

BREEDING NEIGHBORHOOD

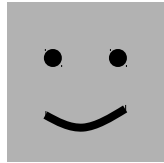


$s$

# The model: Reproduction

THERE IS A CRITICAL GENETIC DISTANCE ABOVE WHICH INDIVIDUALS  
DO NOT REPRODUCE

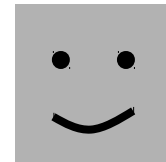
INDIVIDUAL



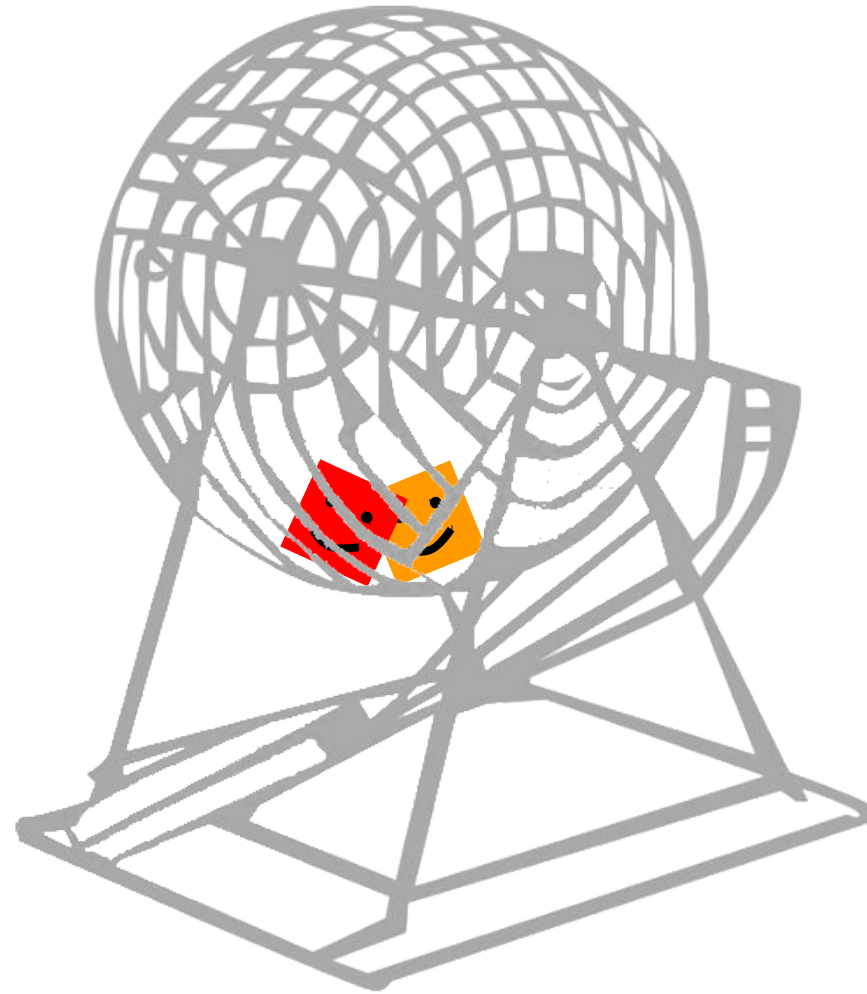
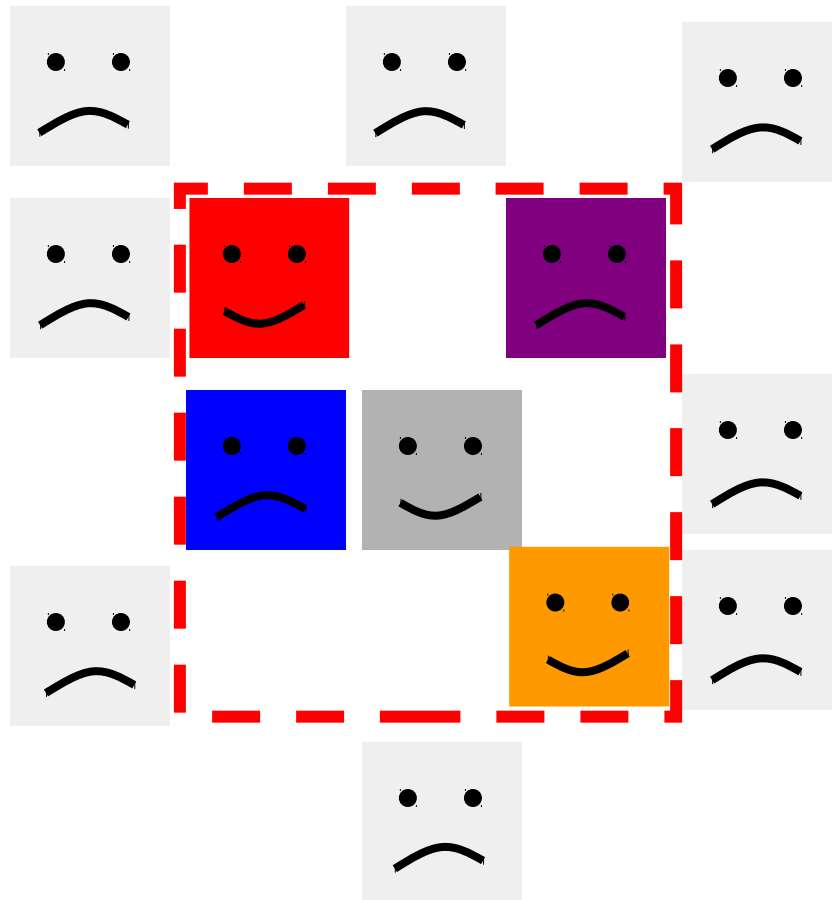
0	0	1	1	0	0	0	0	0	...	0	0	0	1	0	0	0	1	0	0	
≠						≠							≠				≠	≠		
1	0	1	1	0	0	1	0	0	1	...	0	0	1	1	0	0	0	0	1	0

ADDITIVE EFFECT

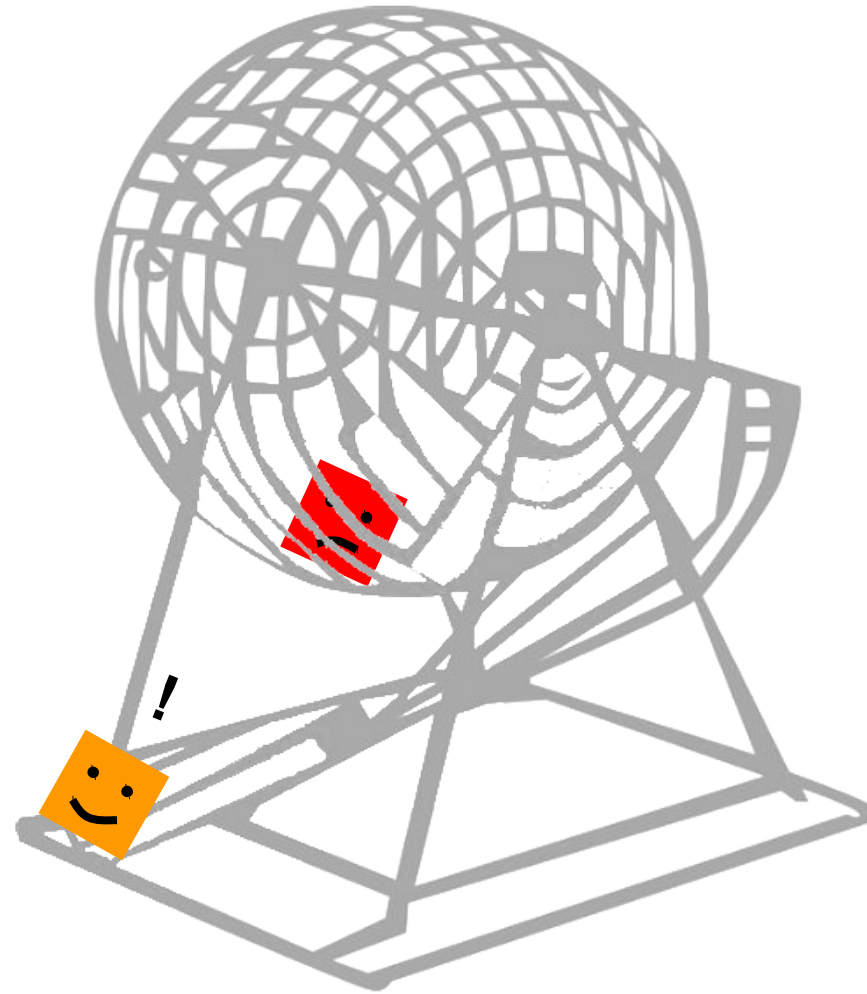
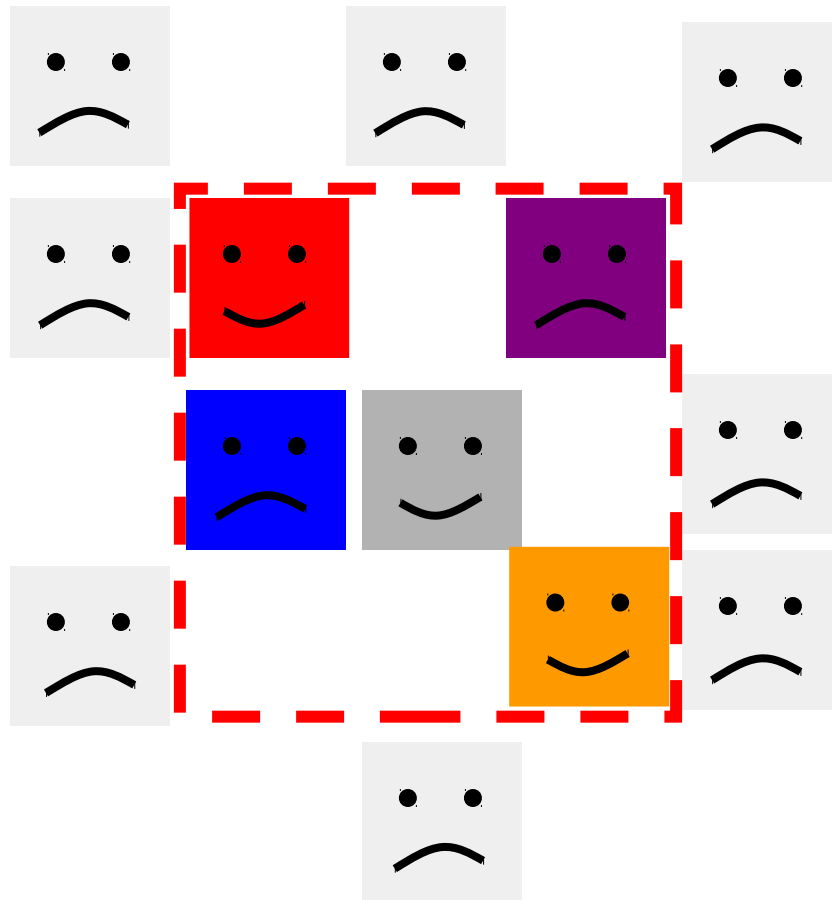
NEIGHBOR 1



# The model: Reproduction

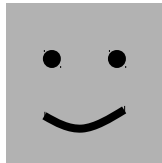


# The model: Reproduction

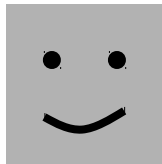


# The model: Reproduction

## RECOMBINATION



1 0 0 0 1 0 0 0 0 0 0 ... 1 0 0 0 1 1 0 0 0 0



0 1 0 0 1 0 0 0 0 0 0 ... 0 0 1 0 0 0 1 0 0 1

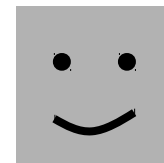
CROSS-OVER POINT

## RECOMBINANT A

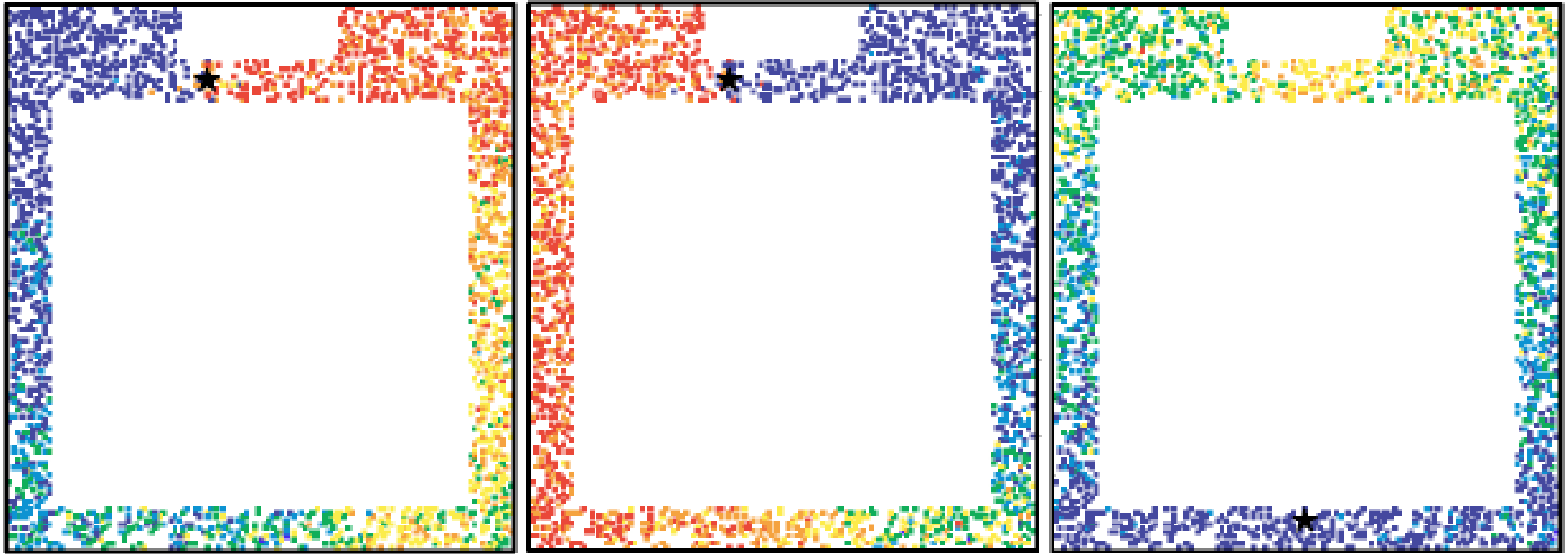
1 0 0 0 1 0 0 0 0 0 0 ... 0 0 1 0 0 0 1 0 0 1

## RECOMBINANT B

0 1 0 0 1 0 0 0 0 0 0 ... 1 0 0 0 1 1 0 0 0 0

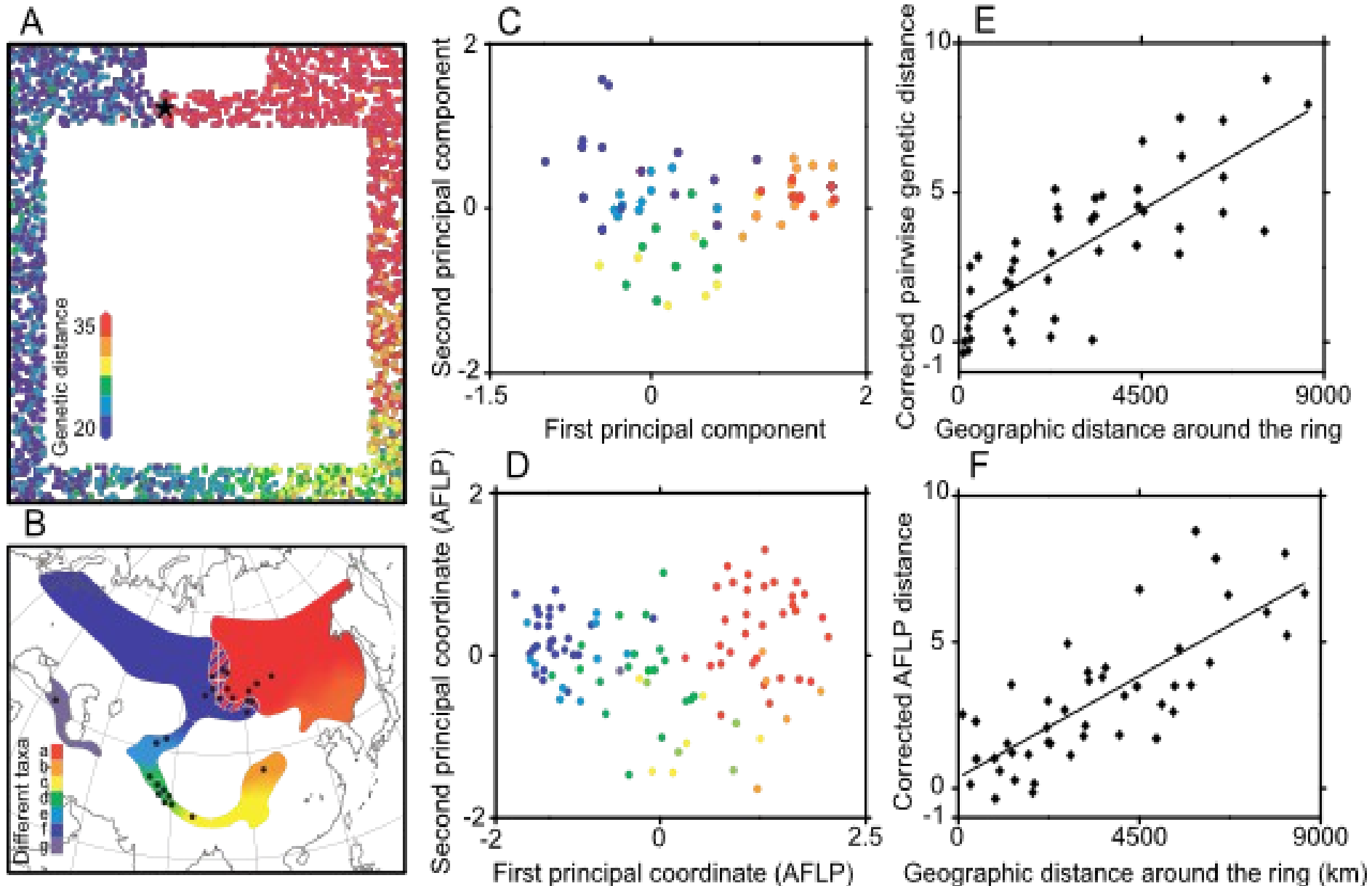


# Ring species?

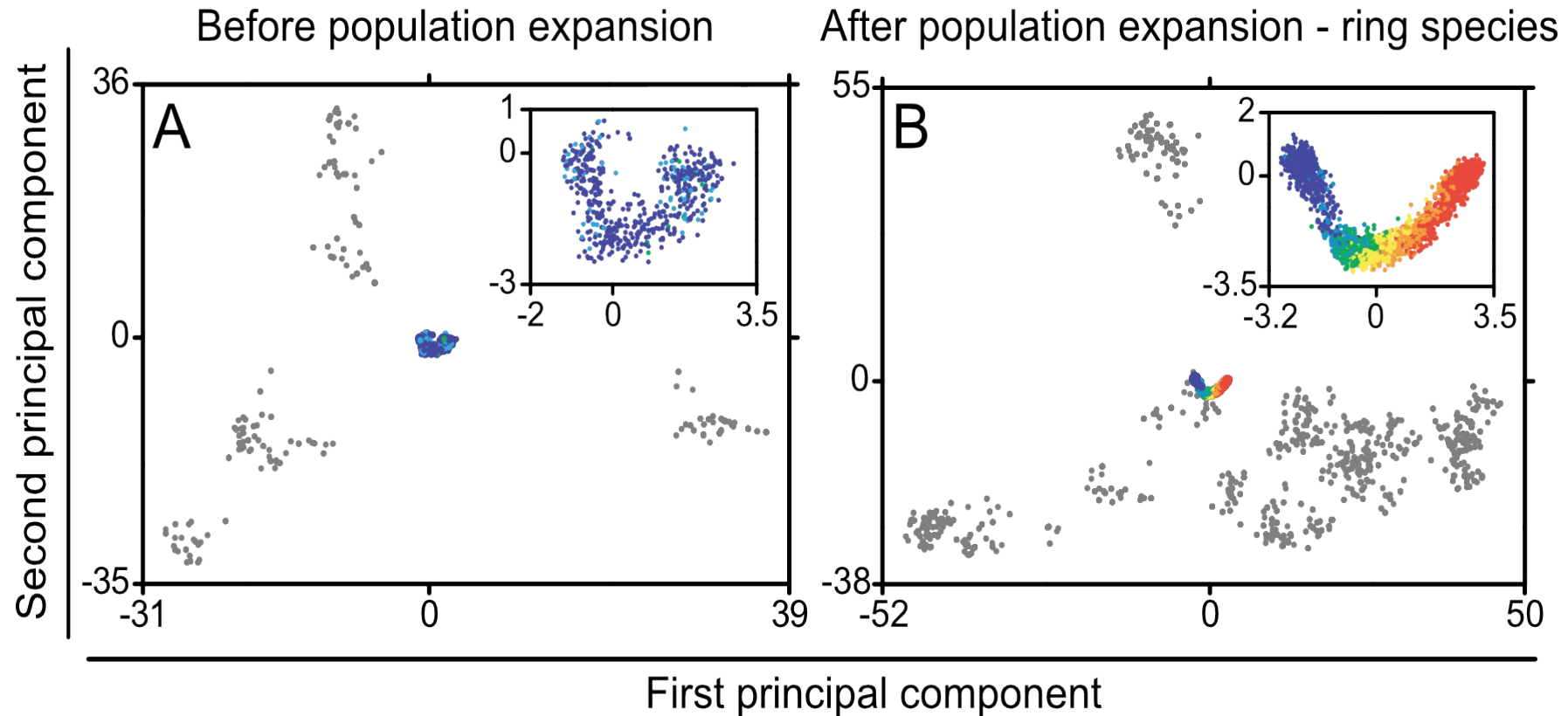




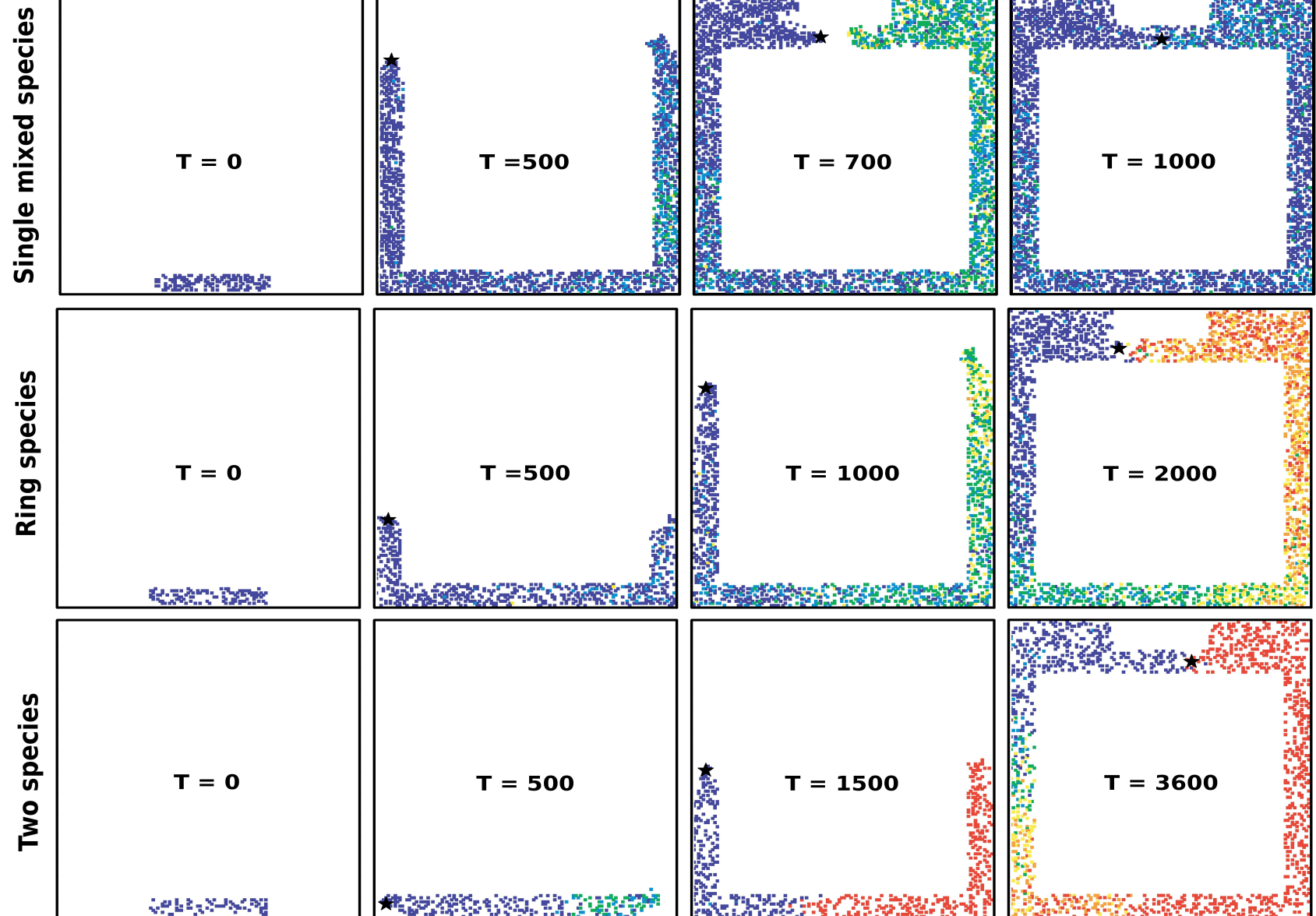
# Validation – multiple patterns



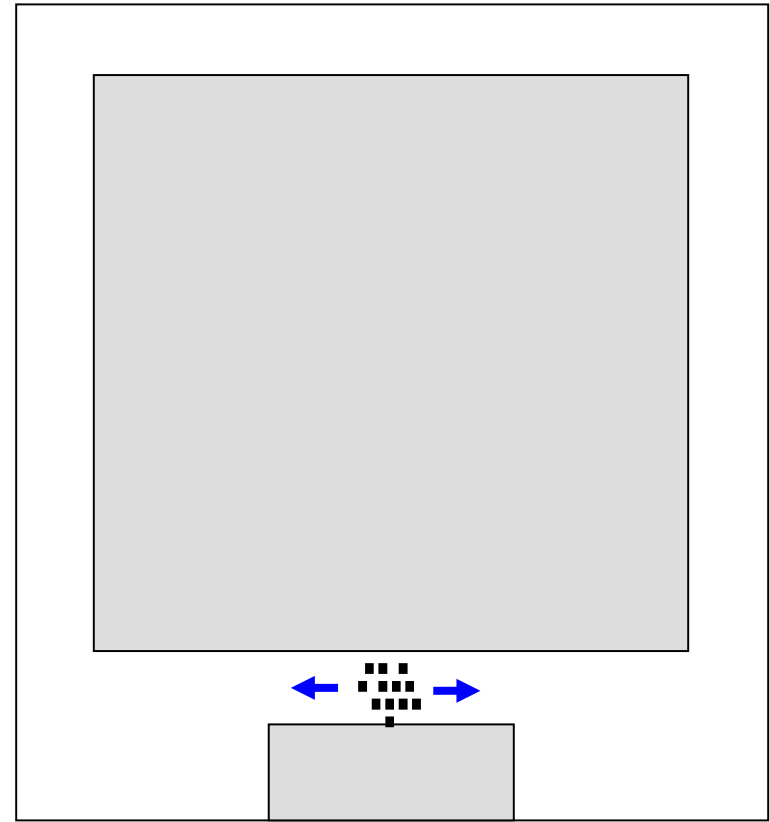
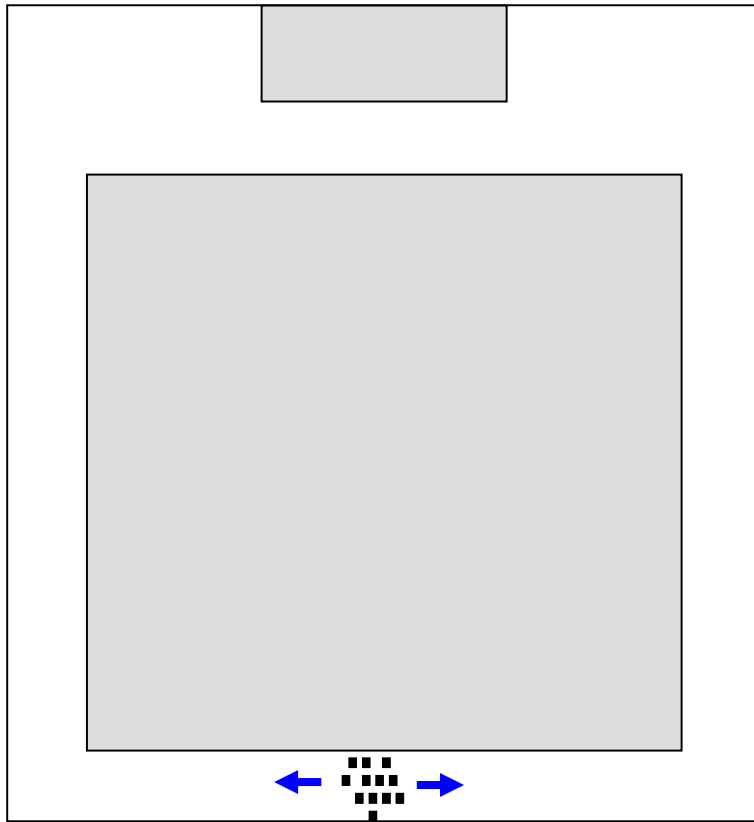
# Validation – multiple patterns



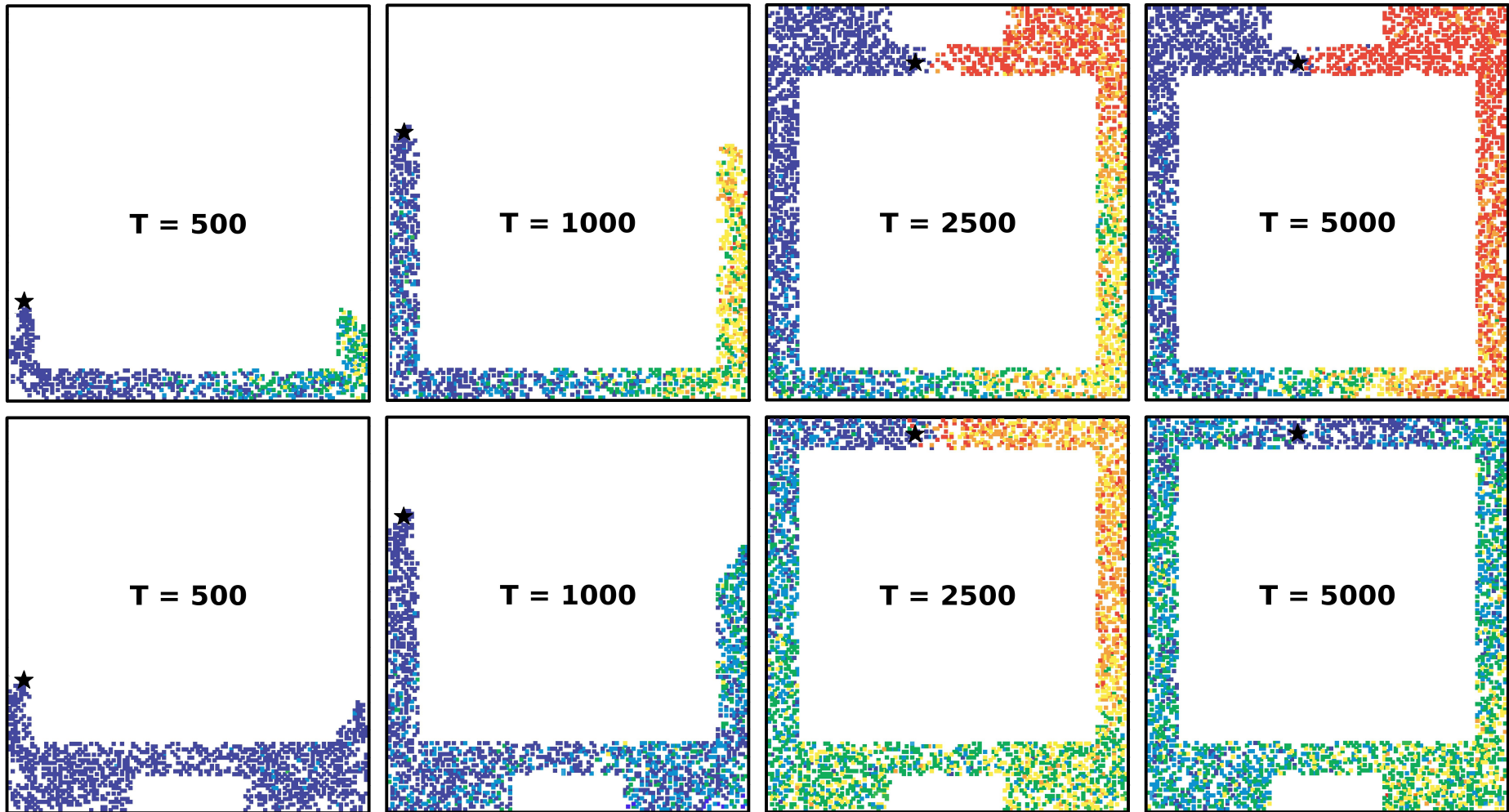
# Possible outcomes of population expansion



# Geographicla barriers



# The effect of different geographical barriers

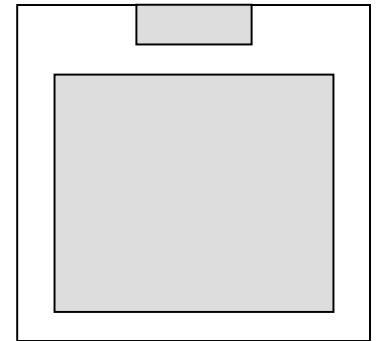
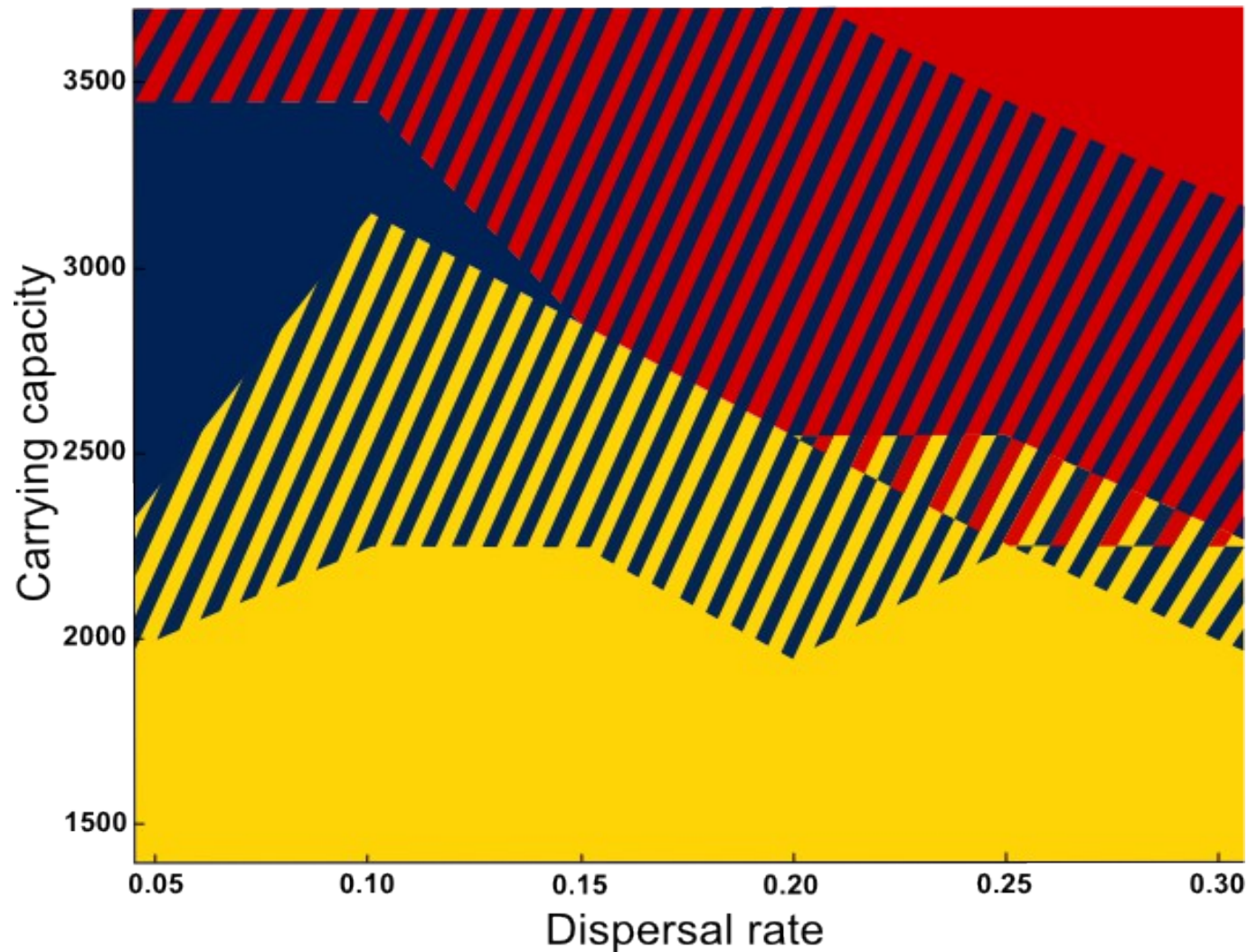


# The effect of different geographical barriers

MORE THAN 1 SPECIES

RING SPECIES

ONE SPECIES



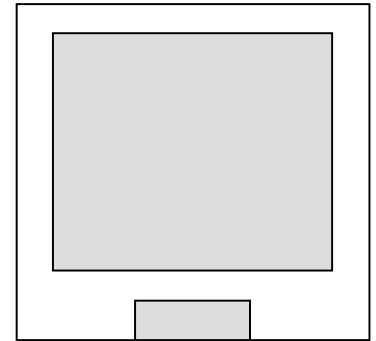
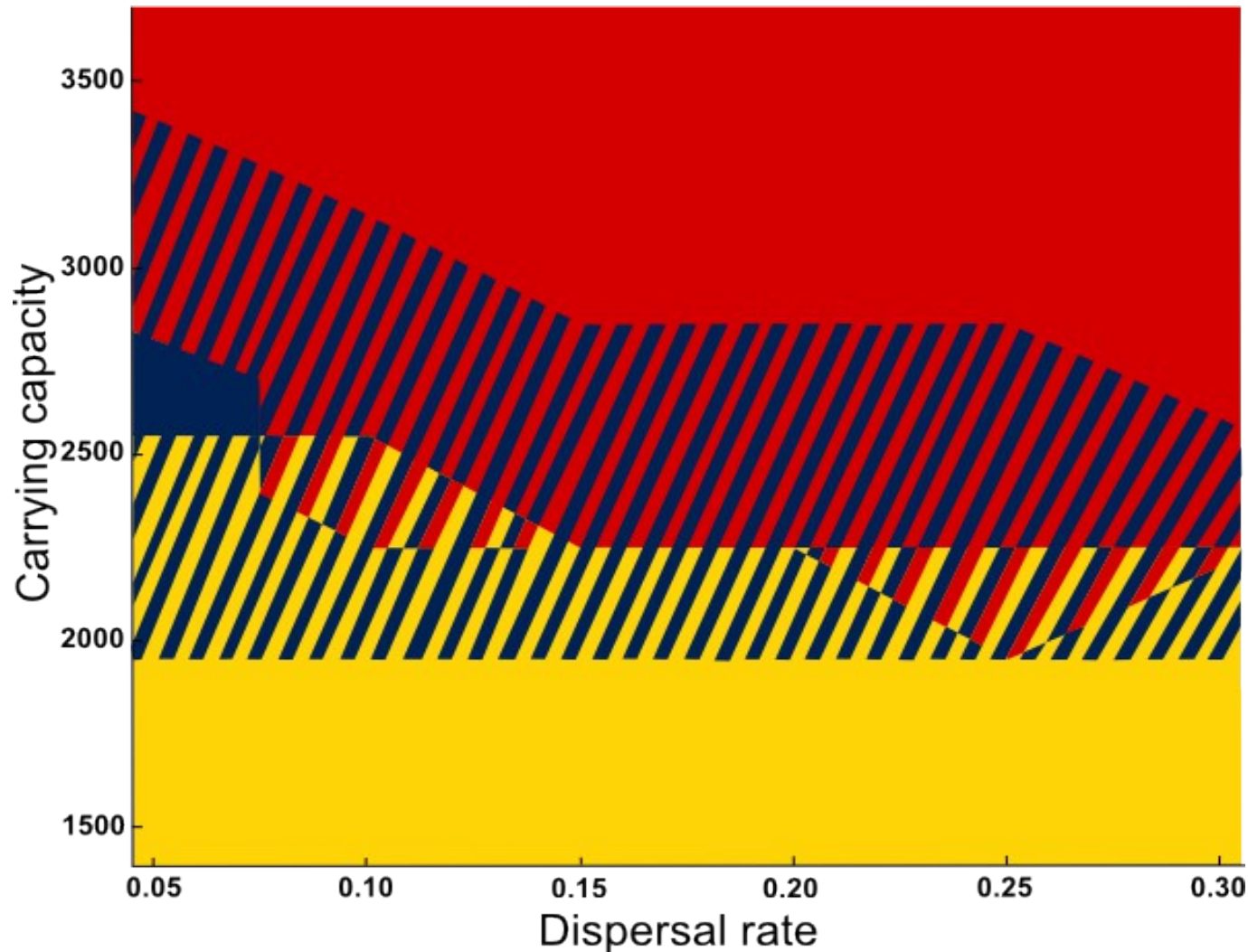


# The effect of different geographical barriers

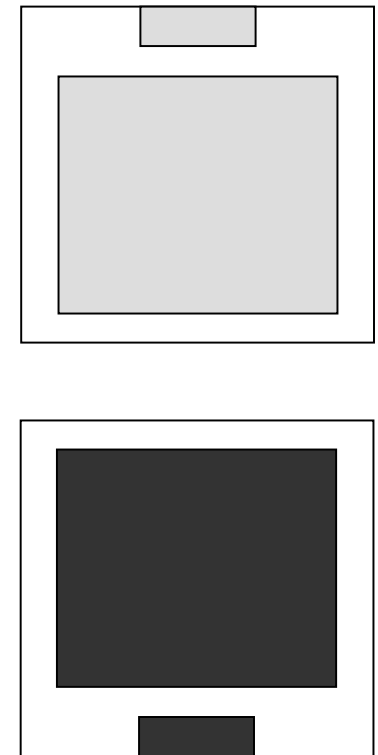
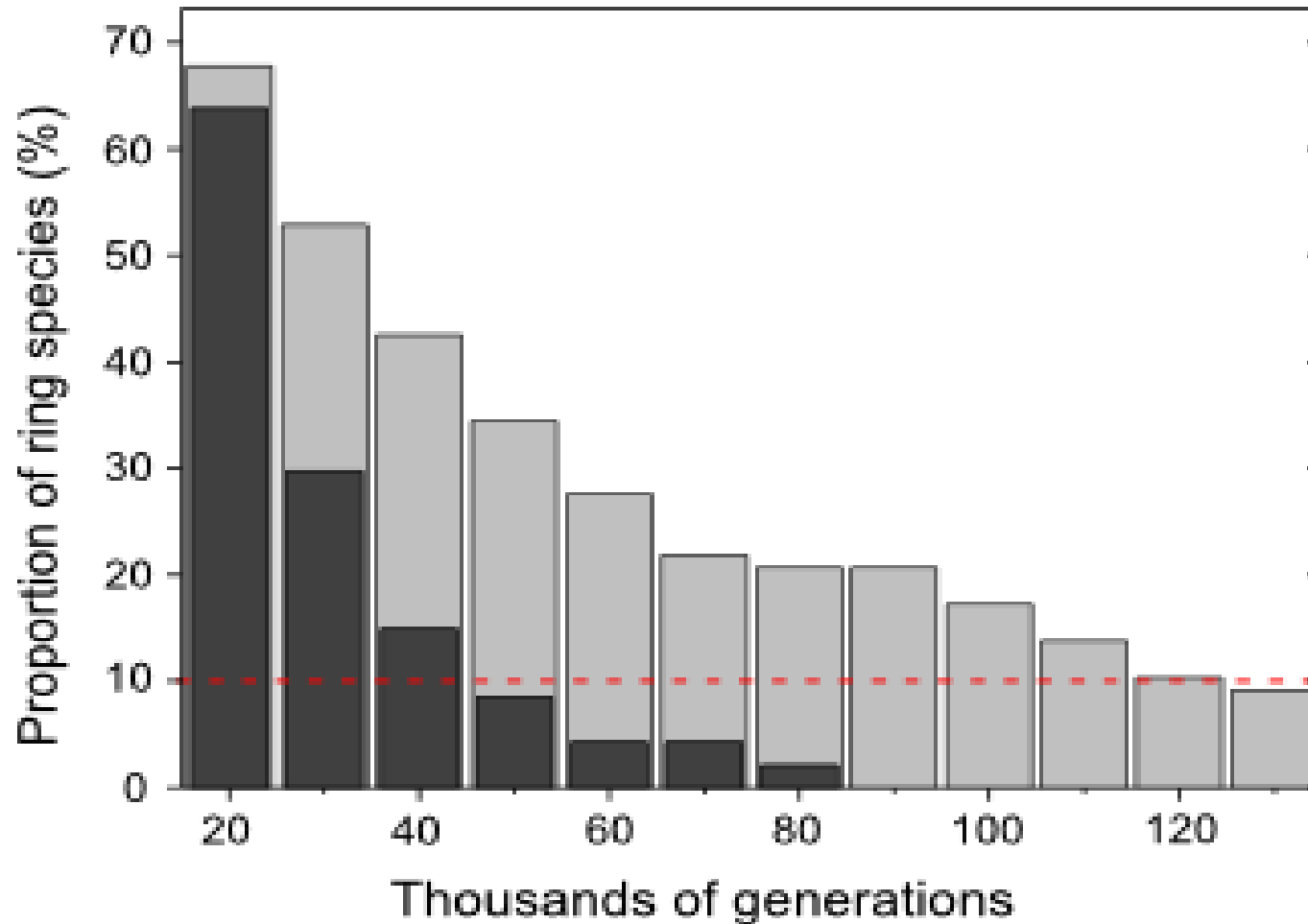
MORE THAN 1 SPECIES

RING SPECIES

ONE SPECIES



# The effect of different geographical barriers





# Summary

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**Ring species can be formed even without local adaptation by the balance between isolation by distance and gene flow**

**They are however expected to be rare, since they require fine-tuning of population, individual and landscape parameters**

**The topology of geographical barriers may effect ring species formation and stability**

**Even though neutral genetic gradients are not strictly estable, they can be maintained for relatively long times**

