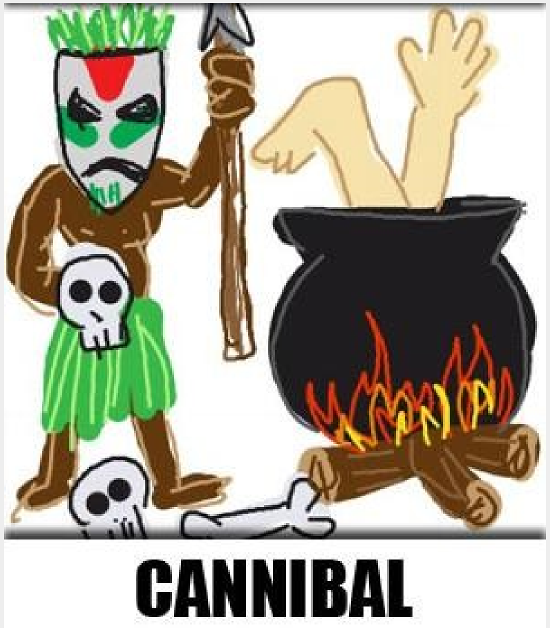
The amazing tale of the time travelling cannibals



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Outline

- Introduction
- Goals
- Assumptions
- Model
- Results
- Discussion

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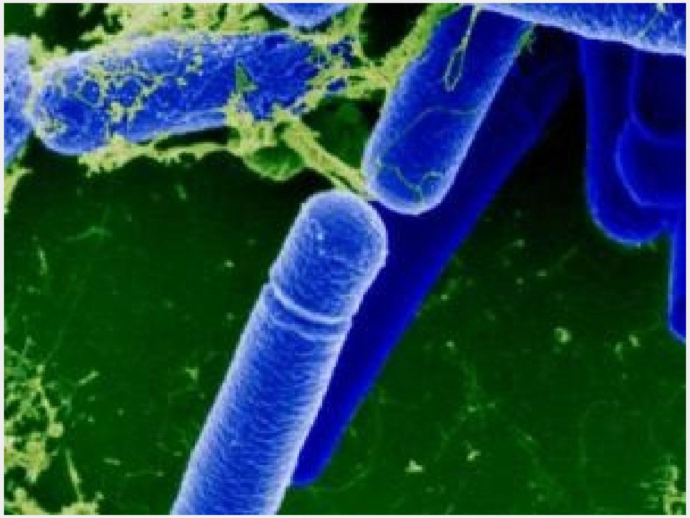
Introduction – *Bacillus subtilis*

Bacillus subtilis is the model organism selected to study the glories and miseries of **sporulation.**

This species derives its nourishment from decaying organic matter. **The resources will eventually be depleted** by the growing bacterial colony unless a new source of nutrients is found.

Because of enviromental conditions, they have to deal with different situations, like **irregular nutrient supplies or complete lack of nutrients.**



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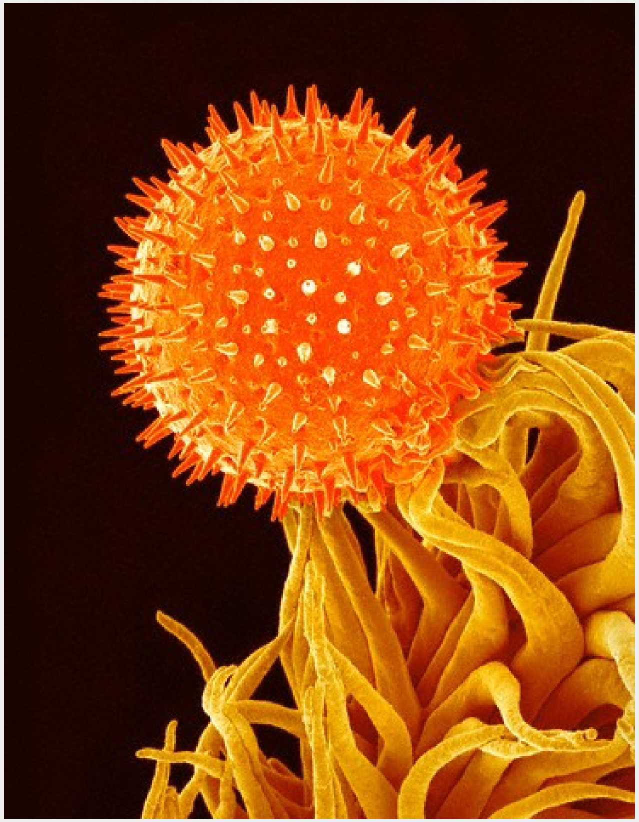
Introduction – Sporulation

“I can think. I can wait. I can fast.”
— Hermann Hesse, Siddhartha

Sporulation is the formation of metabolically inactive and extremely resistant cells called spores.



They are able to endure extreme conditions:

- Lack of nutrients
- Dryness
- High and low temperatures
- Sao Paulo's parties

Sporulation is used as the LAST RESORT !!

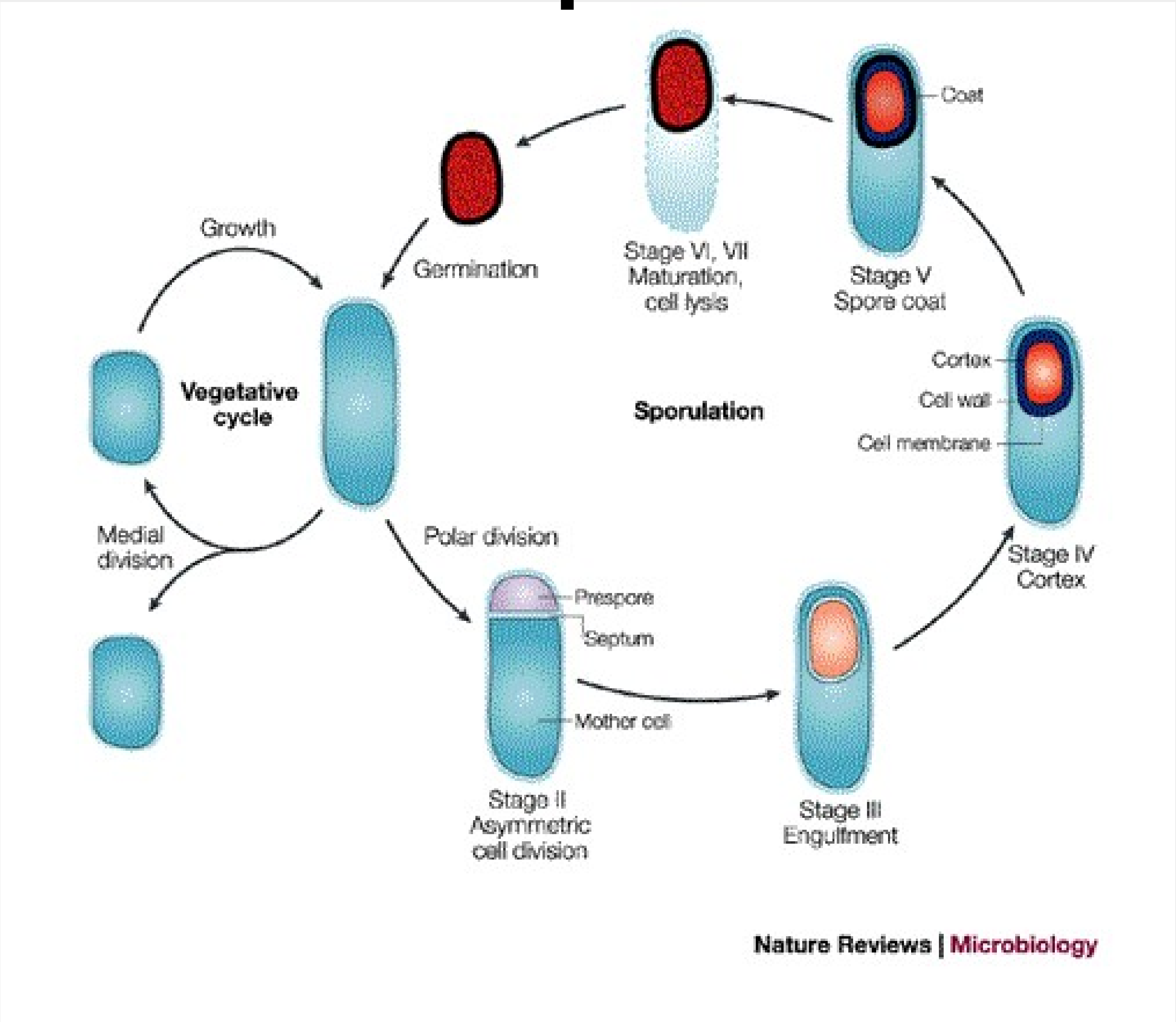
What triggers sporulation?

B. Subitilis has a unique class of enviromental-sensing mechanisms: **they can percieve the amount of nutrients**. If they sense a lack in resources, it will go into the sporulation phase.

B. Subitilis **is also able to sense the population density**. If it is high, the bacteria knows that resources will probably run out.

(Sé Station, Sao Paulo Metró, Brasil)

Introduction – Sporulation stages



Introduction – Polymorphs

There are polymorphisms in the peptides and proteins responsible for the density sensing mechanism.

Two morphotypes are considered

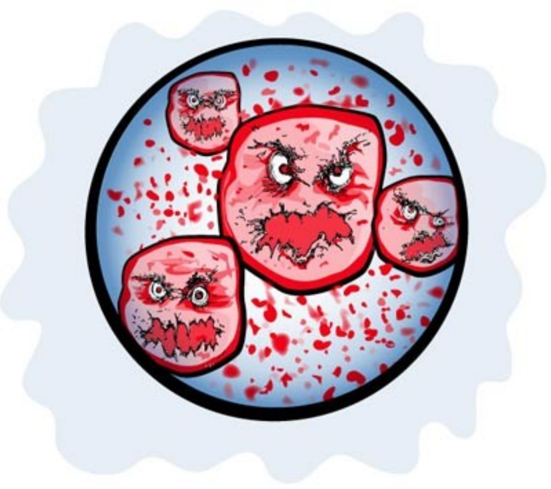
Normal: They are able to are feel the population density accurately.

Defficient: This ones are not able to sense the population density accurately.

Introduction – Antibiotic Attack

Because sporulation has a tradeoff (not all of the guys who sporulate will be able to germinate back), before sporulation, bacteria has one last card under her sleeve. It can secrete antibiotics which kills the oblivious surrounding bacteria that have not percieved lack of nutrients.

When this happens, the dead bacteria becomes an extra input of resources, which allows to delay sporulation .



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Goals/Questions

1. How does the expected period of nutrient arrival affects this system?
2. Which factors mostly affect the survive of D and N?
3. Is the coexistence between N and S possible?

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Assumptions

I. No environmental perturbations
II. Homogeneity in the distributions of resources
III. Homogeneity in the individuals distributions
IV. Morphotypes are 100% hereditary
V. The antibiotic attack kills only the Defficient morphotype
VI. Trade of between morphotypes:

$$\beta_D > \beta_N$$

$$\delta_N > \delta_D$$

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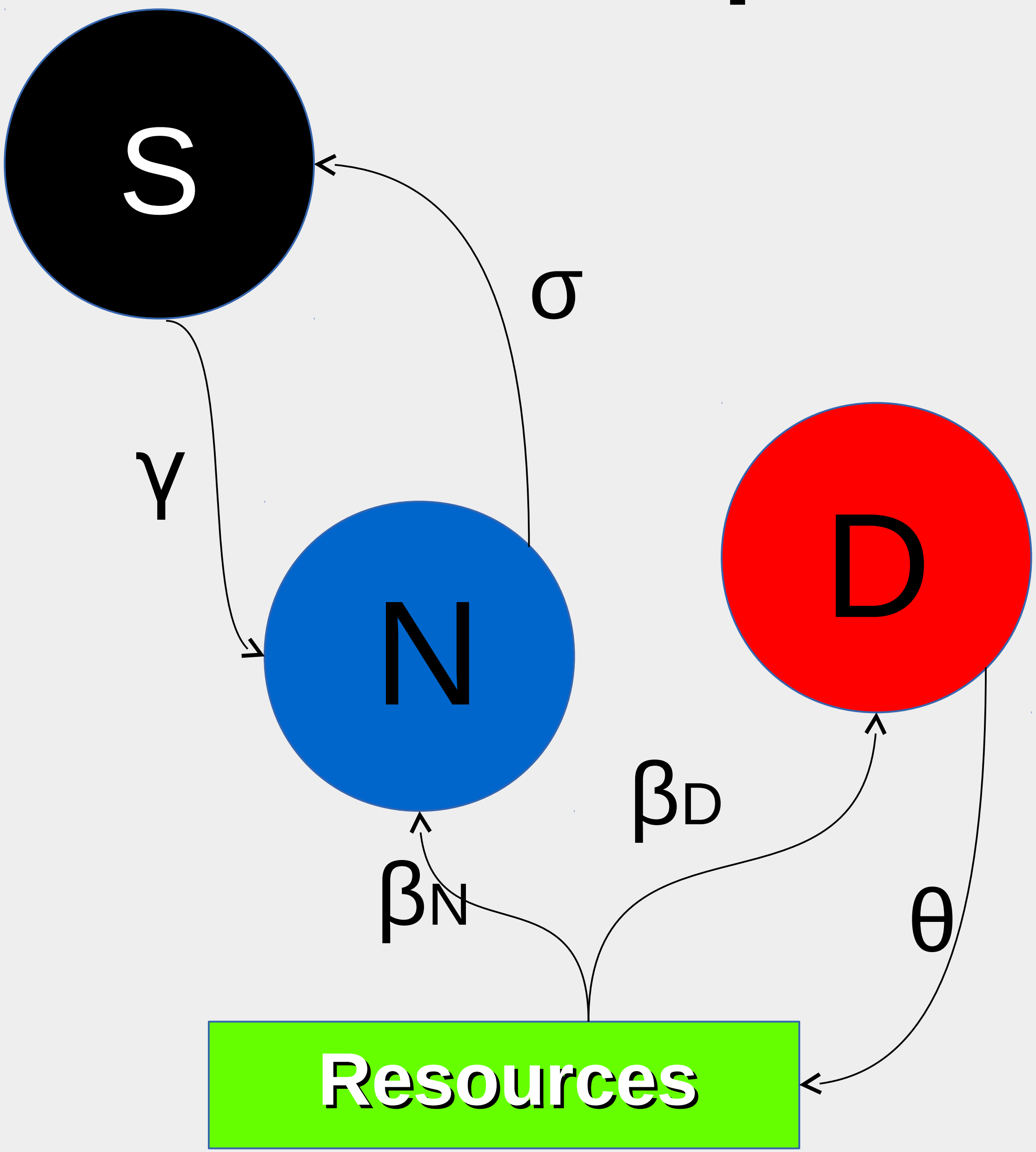
Conceptual model



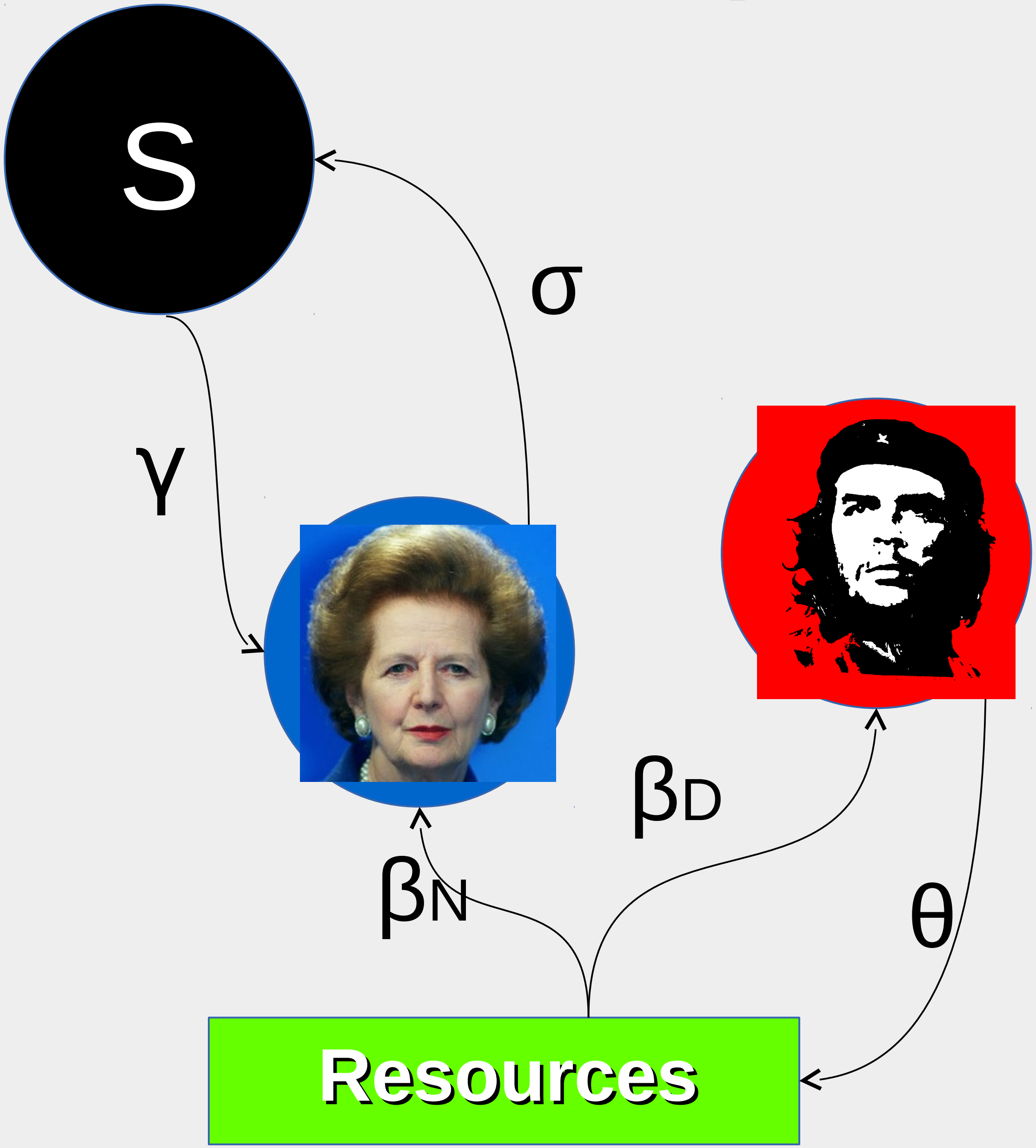
γ- Germination

σ- Sporulation

βN, βD- Consumption Efficiency

θ- Antibiotic attack

Conceptual model



γ- Germination

σ- Sporulation

βN, βD- Consumption Efficiency

θ- Antibiotic attack

Main features

a) Periodic fluctuation in resources

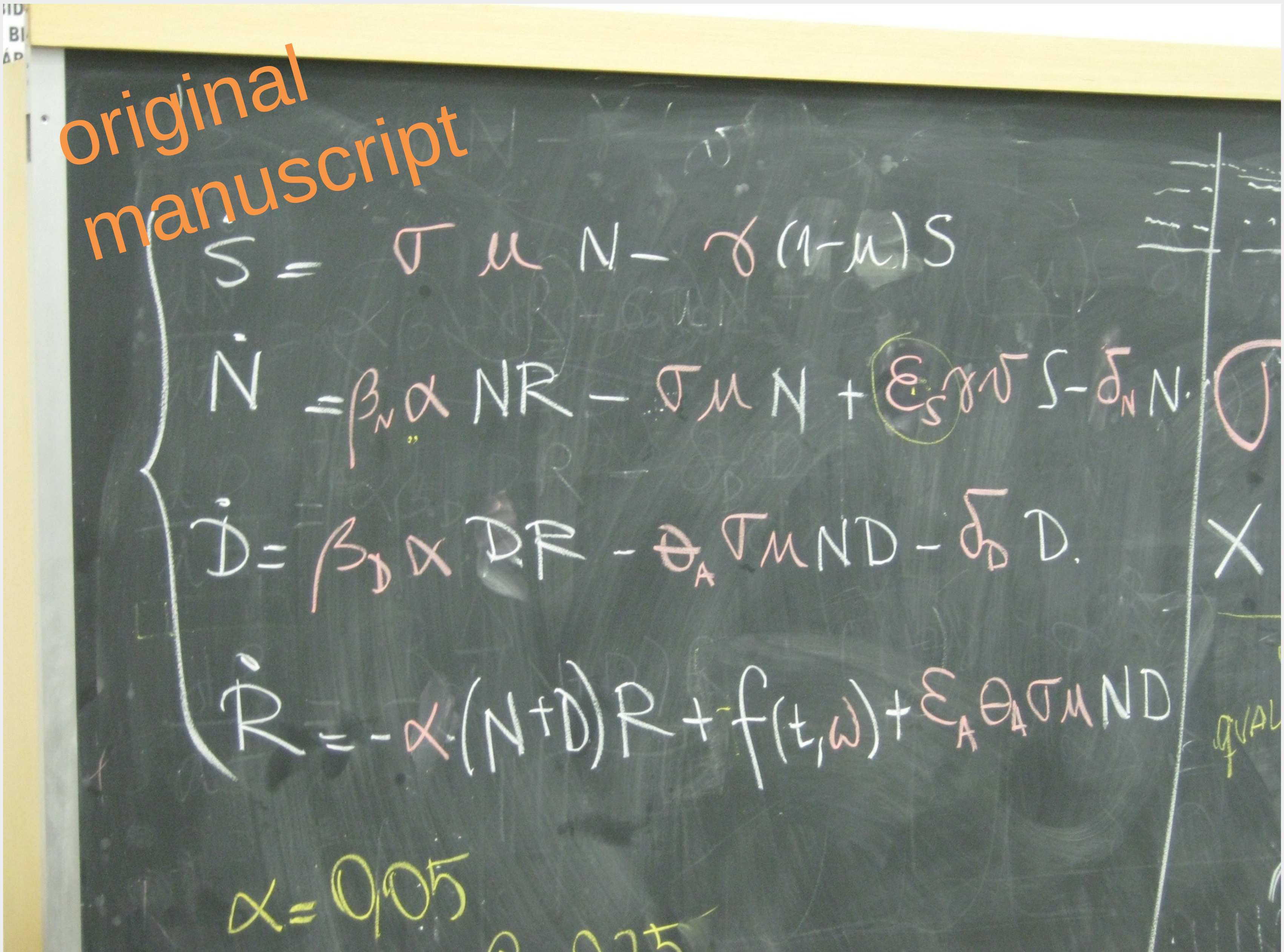
b) Sporulation and antibiotic attack mediated by resource availability

c) Resources modeled explicitly

d) Indirect competition of morphotypes through resource consumption

e) Trade-off between morphotypes

Model


original manuscript
S = σ μ N − γ (1−μ) S
Ṅ = β_N α NR − σ μ N + ε_S γ σ S − δ_N N.
Ḋ = β_D α DR − θ_A σ μ ND − δ_D D.
Ṙ = −α (N+D) R + f(t,ω) + ε_A θ_A σ μ ND
α = 0,05

Model

$$\frac{dS}{dt} = \text{sporulation} + \text{germination}$$

$$\frac{dN}{dt} = \text{reproduction} - \text{sporulation} + \varepsilon.\text{germination} - \text{death}$$

$$\frac{dD}{dt} = \text{reproduction} - \text{death} - \text{antibiotic}$$

$$\frac{dR}{dt} = -\text{consumption} + \text{resource input} + \text{antibiotic}$$

Model

$$\frac{dS}{dt} = \sigma u N - \gamma(1-u)S$$

$$\frac{dN}{dt} = \alpha\beta_N NR - \sigma u N + \varepsilon_S \gamma(1-u)S - \delta_N N$$

$$\frac{dD}{dt} = \alpha\beta_D DR - \delta_D N - \theta_A \sigma u N D$$

$$\frac{dR}{dt} = -\alpha(N+D)R + f(t) + \theta_A \sigma u N D$$

Model

$$\text{Decision Function} \longrightarrow u = \frac{N + D + 1}{N + D + K + 1}, 0 < u \leq 1$$

$$\text{Resources Function} \longrightarrow f(t,w) = [\cos(\frac{2\pi}{w} + 1]^4, 0 < w \leq \infty$$

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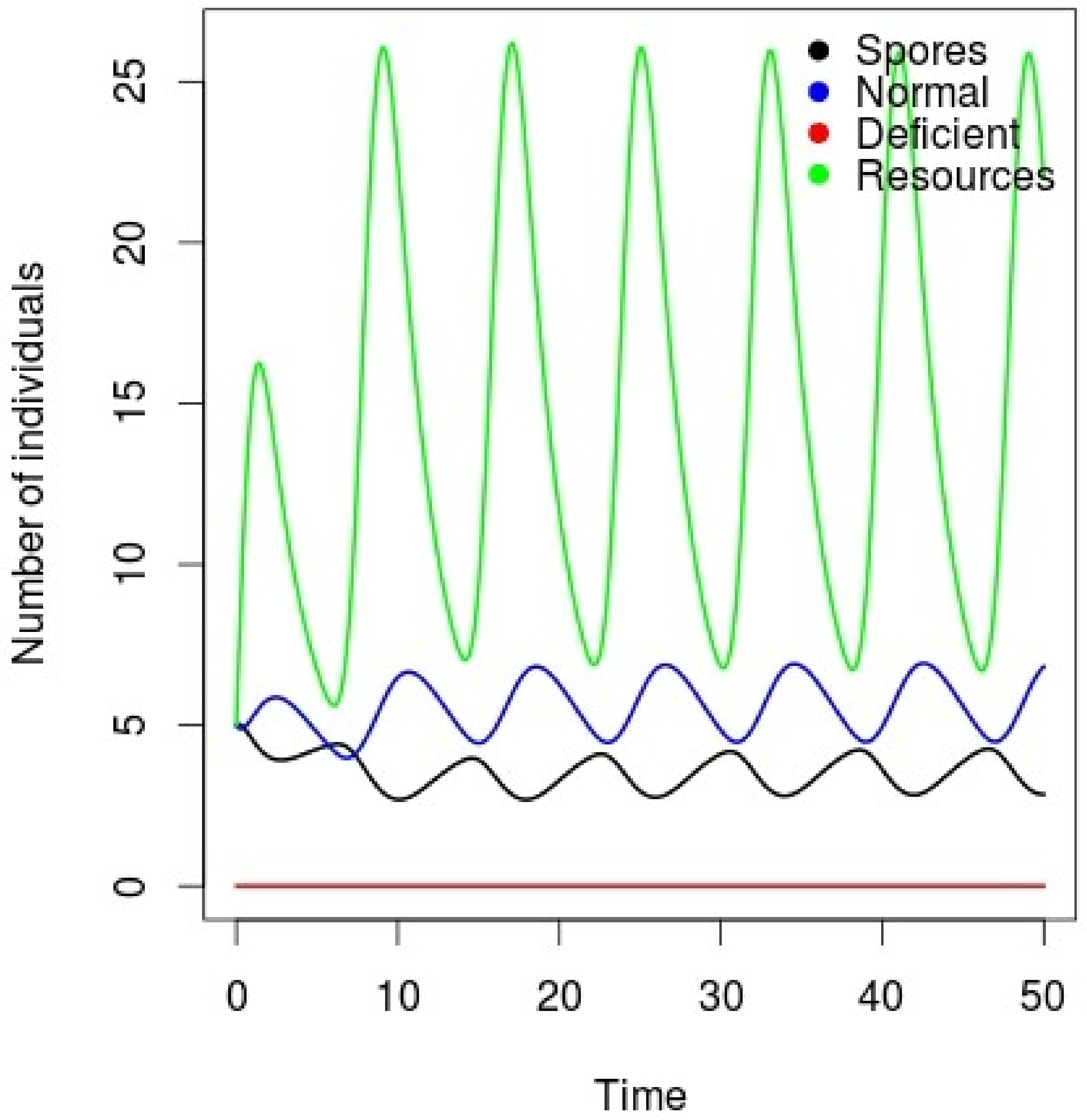
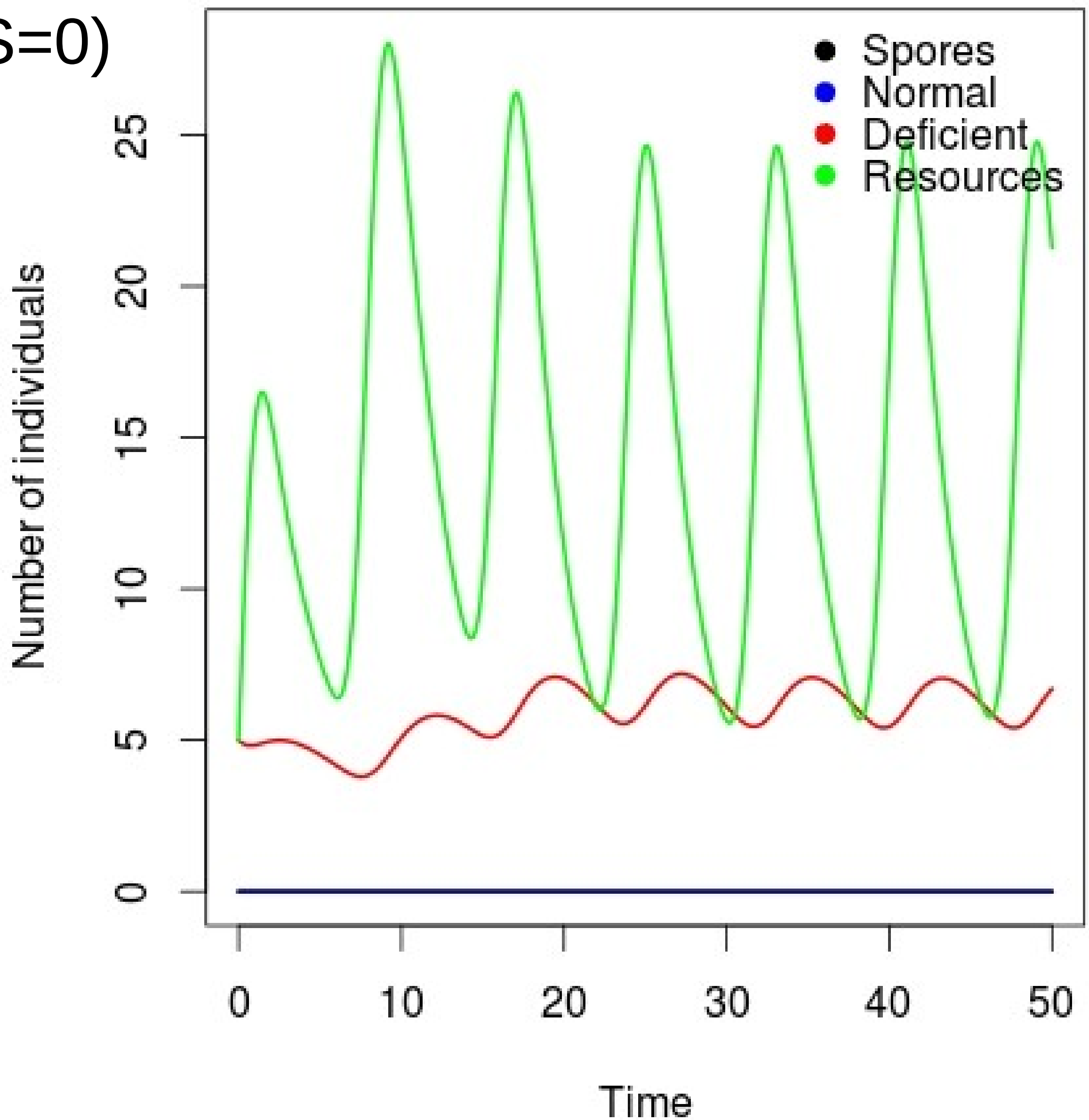
Results – Equilibrium states

First case. Initial population of Defficient is zero. (D= 0)



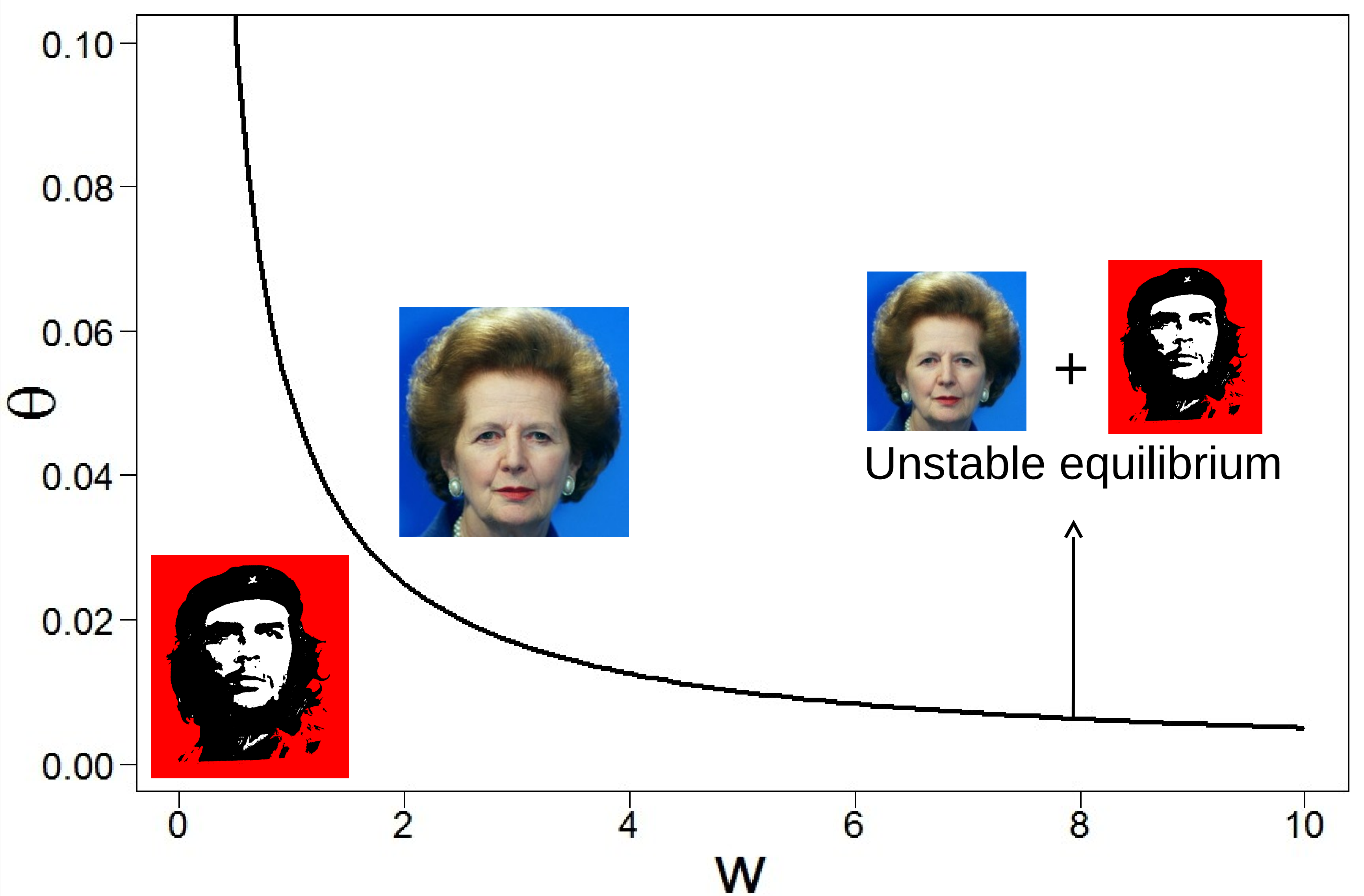
Results – Equilibrium states

Second case. Initial population of Normal and Spores is zero. (N=S=0)

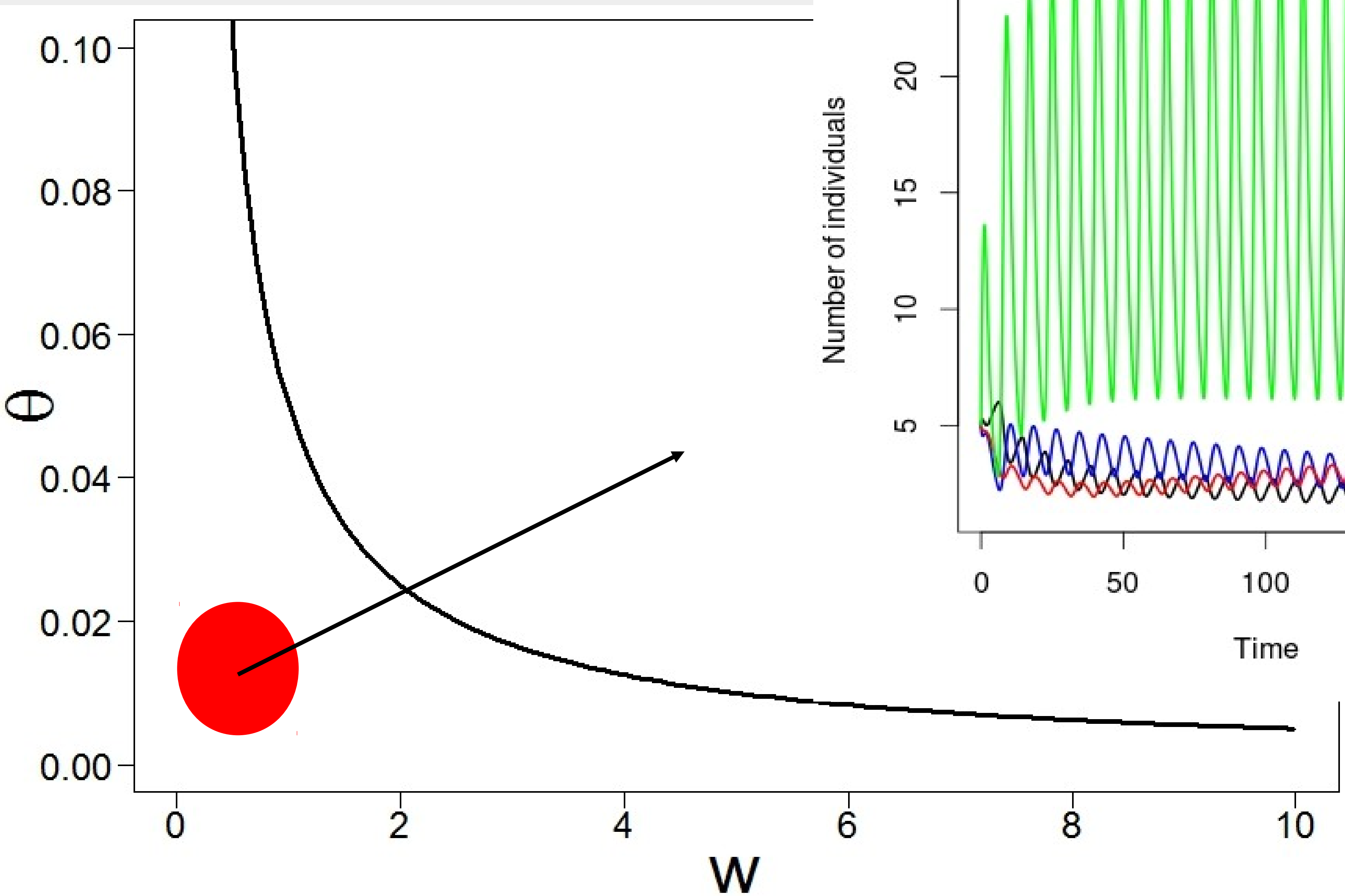


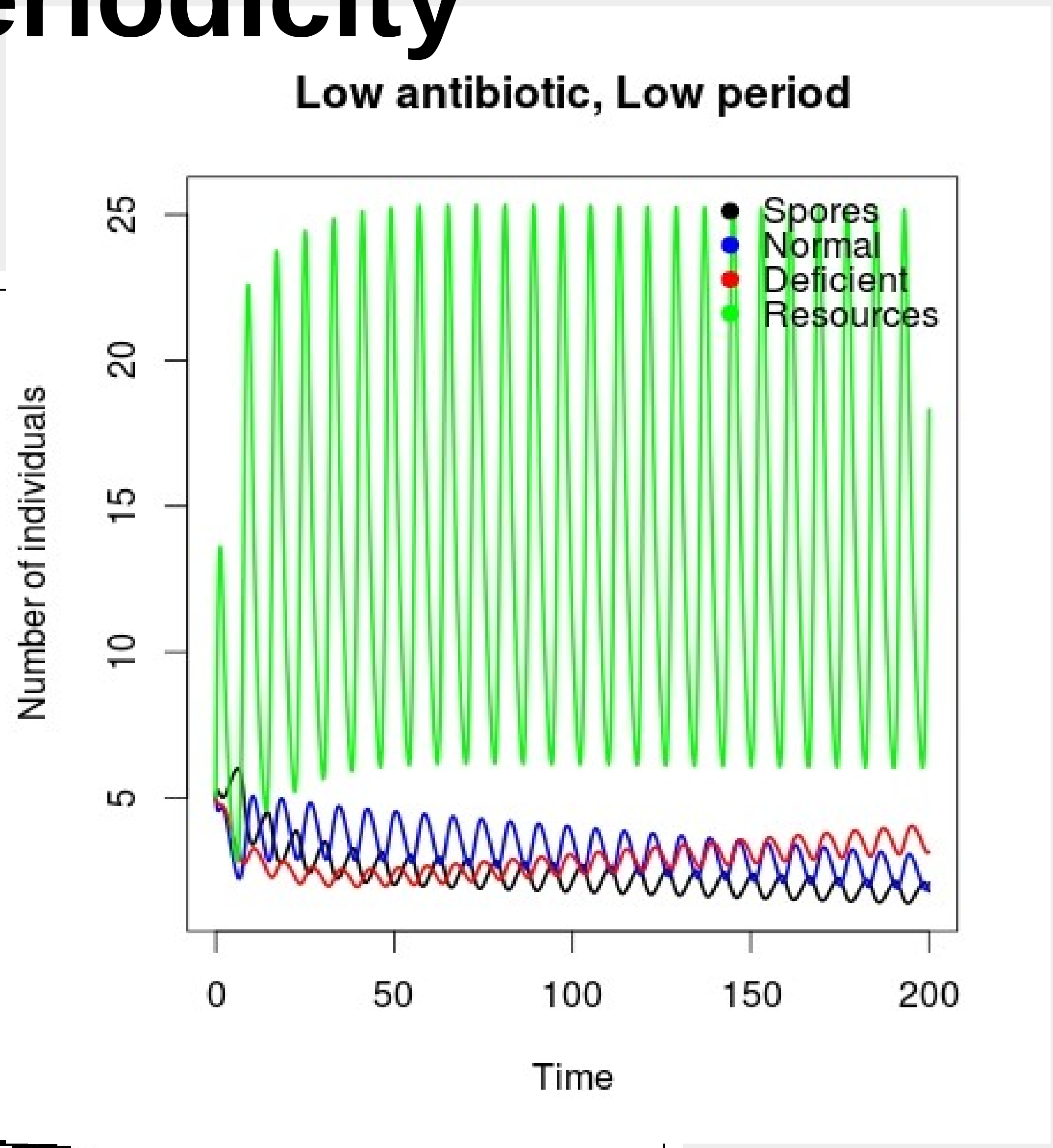
Results – Equilibrium states

Third case. It depends

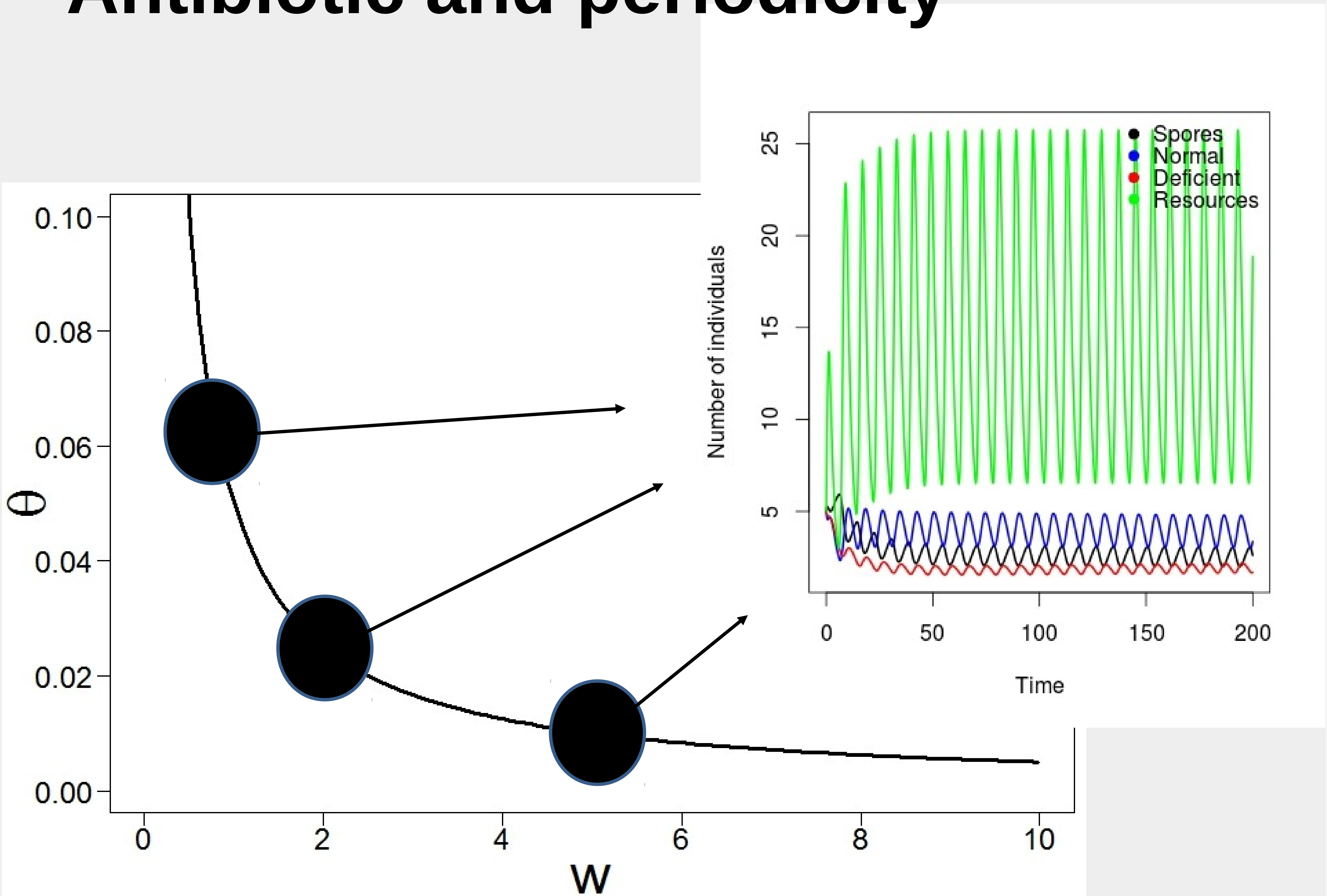


Antibiotic and periodicity

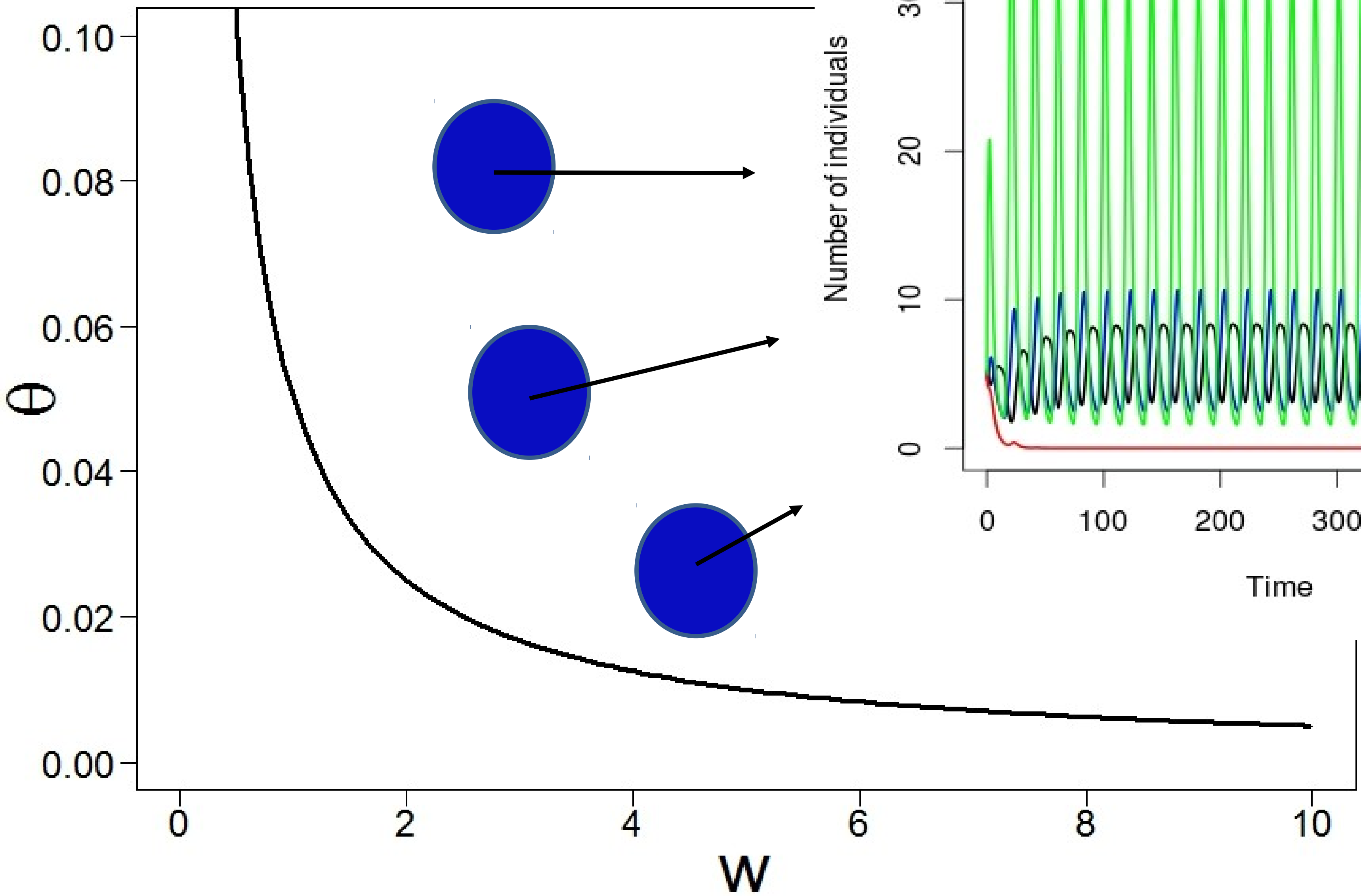


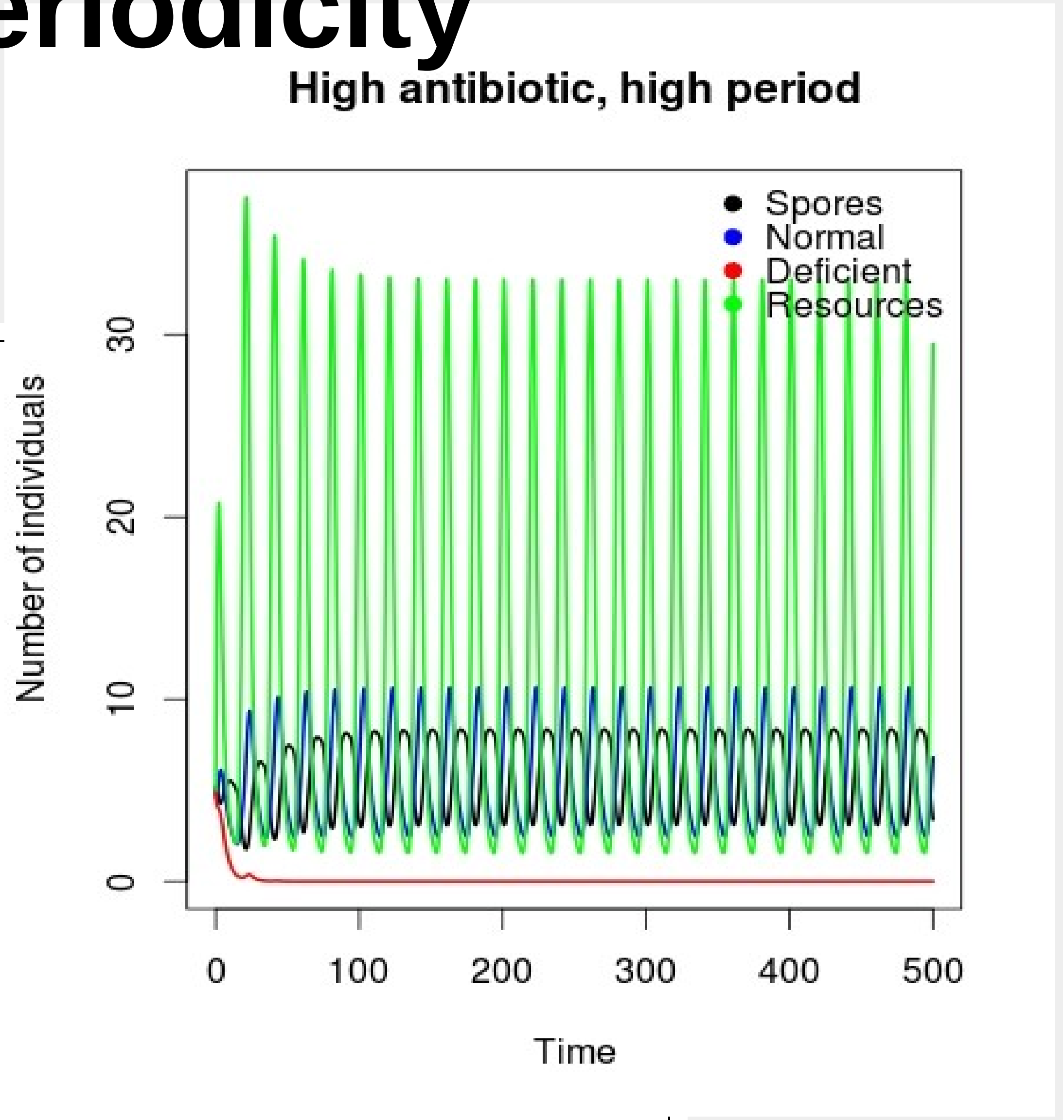


Antibiotic and periodicity



Antibiotic and periodicity





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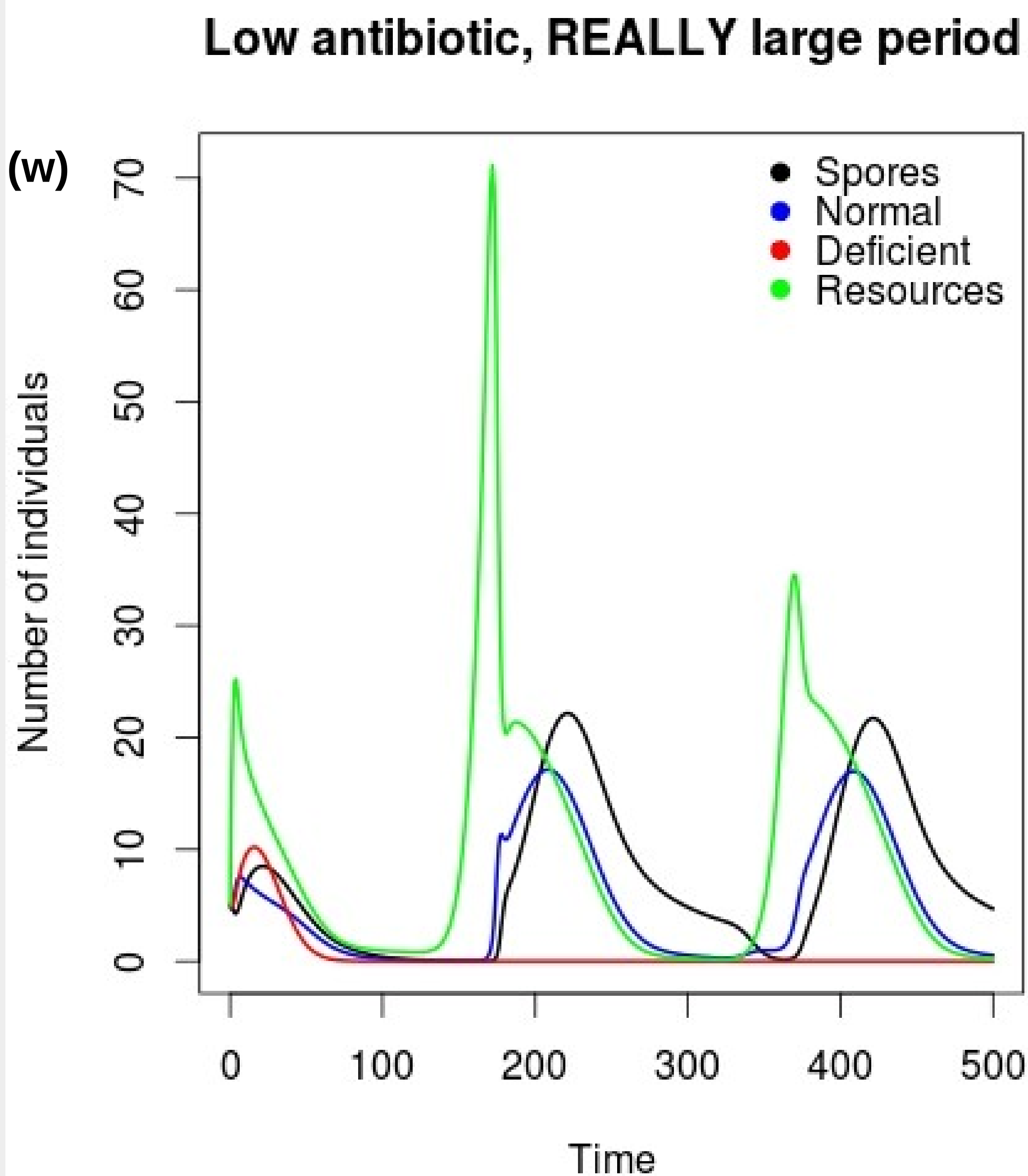
Discussion

1. **How does the expected period (w) of nutrient arrival affect this system?**

If w → ∞, N →wins.

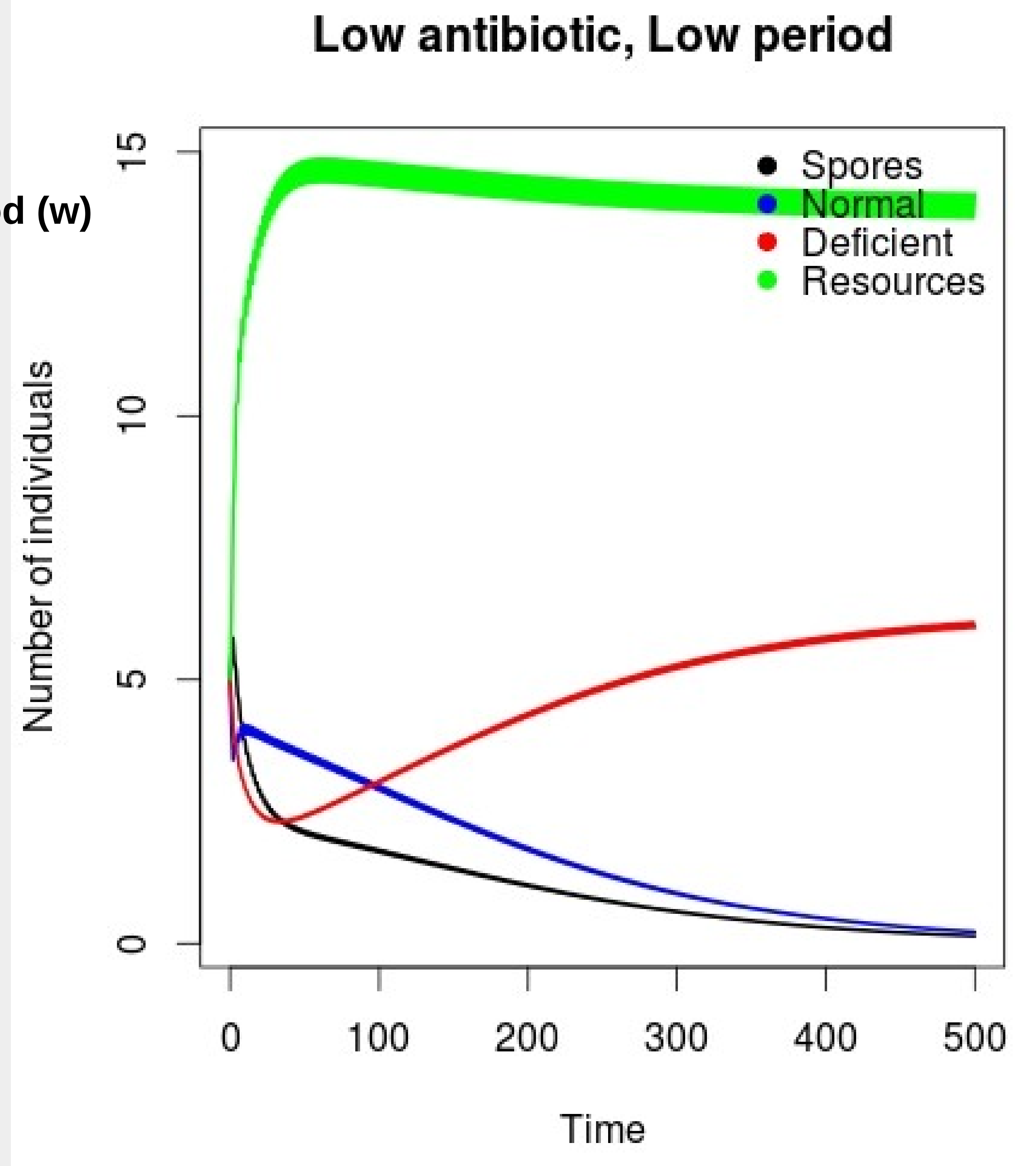


Discussion

1. **How does the expected period (w) of nutrient arrival affect this system?**

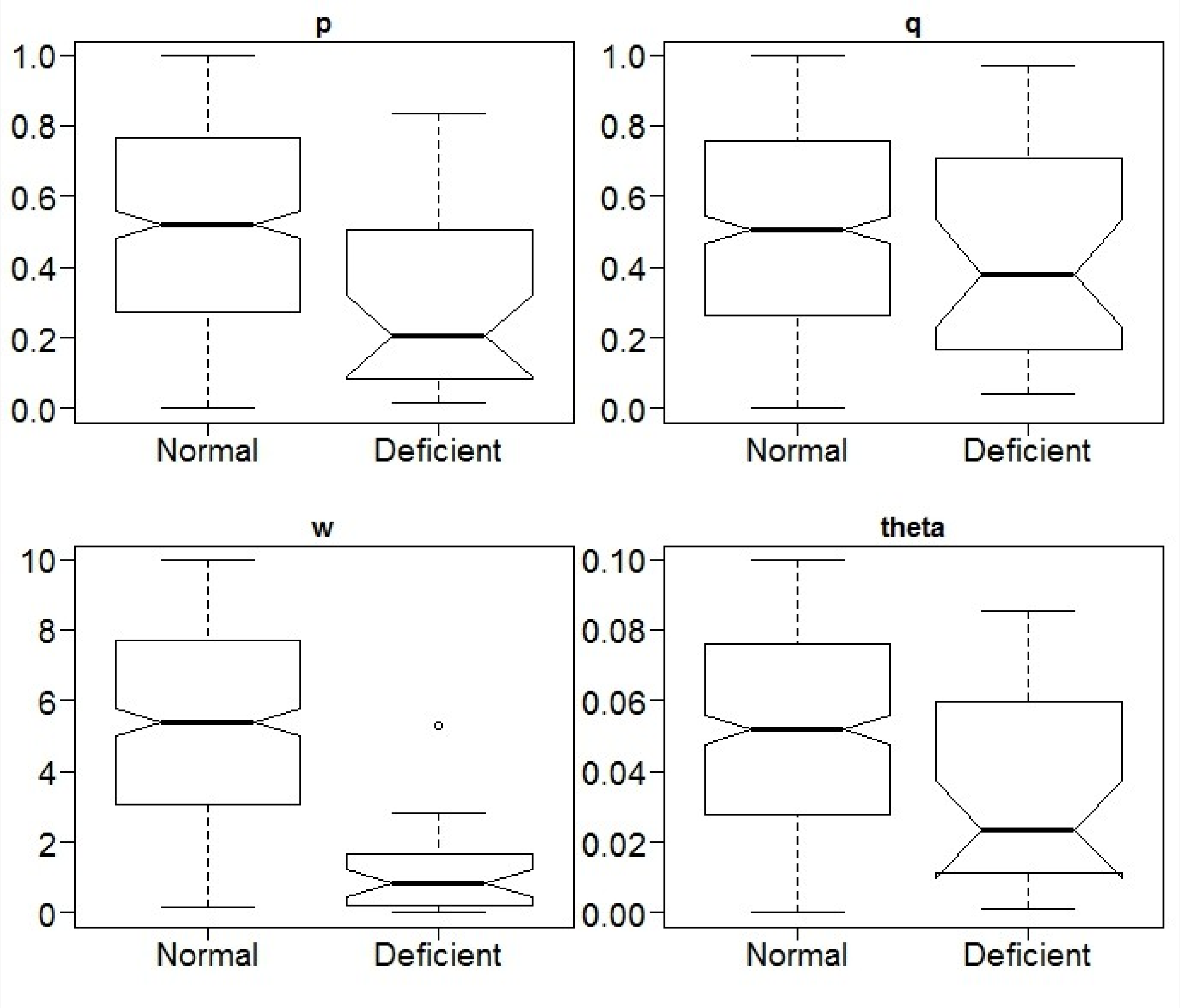
If w → ∞, N → win.

If w → 0, D → win.



Discussion – Parameter analysis

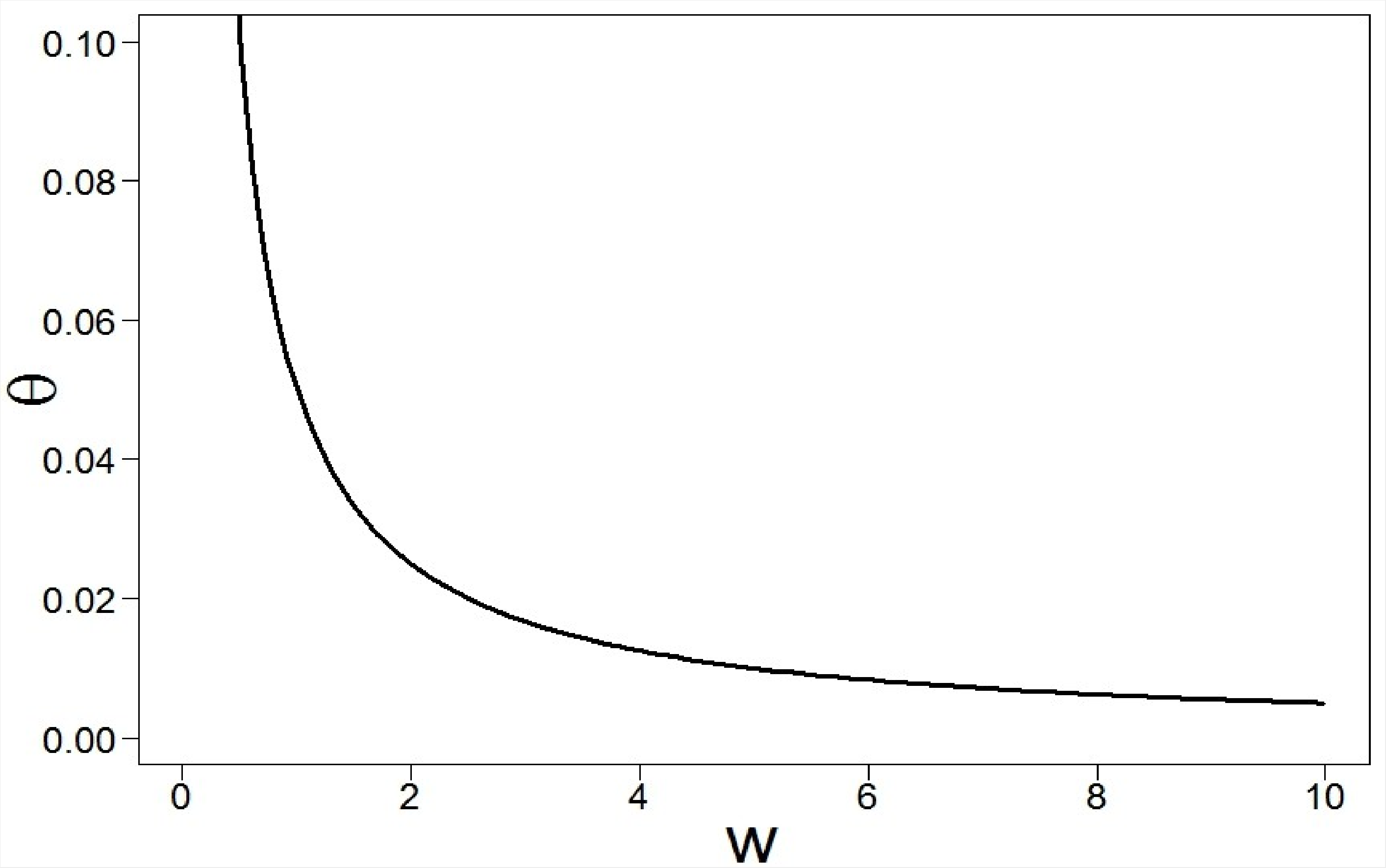
Which factors mostly affect the survival or extintion of D and N?



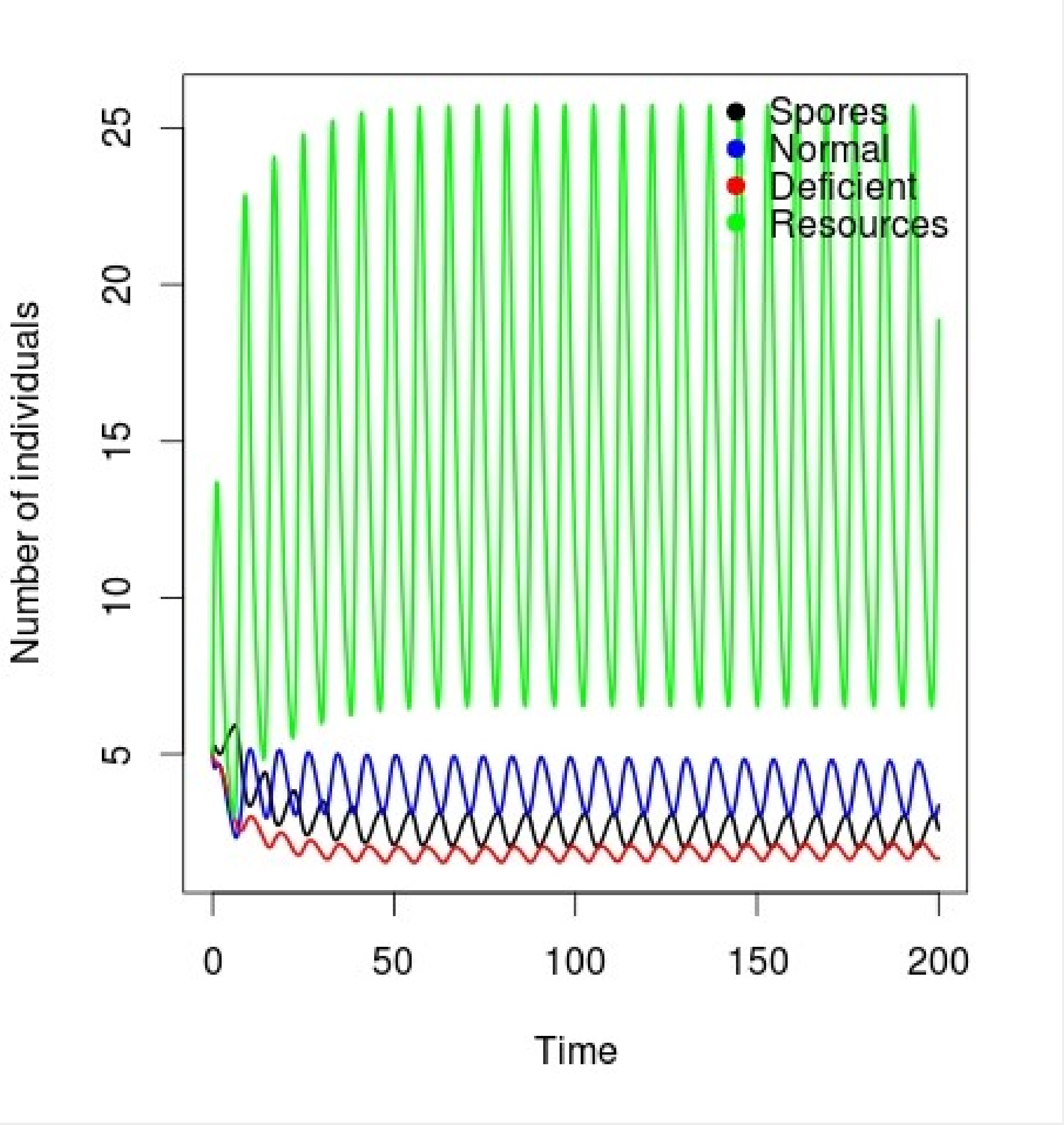
Discussion – Coexistence I

Is the coexistence between N and S possible?

Whenever antibiotic attack is present its really difficult to find parameters to achieve coexistence => Unstable equilibrium

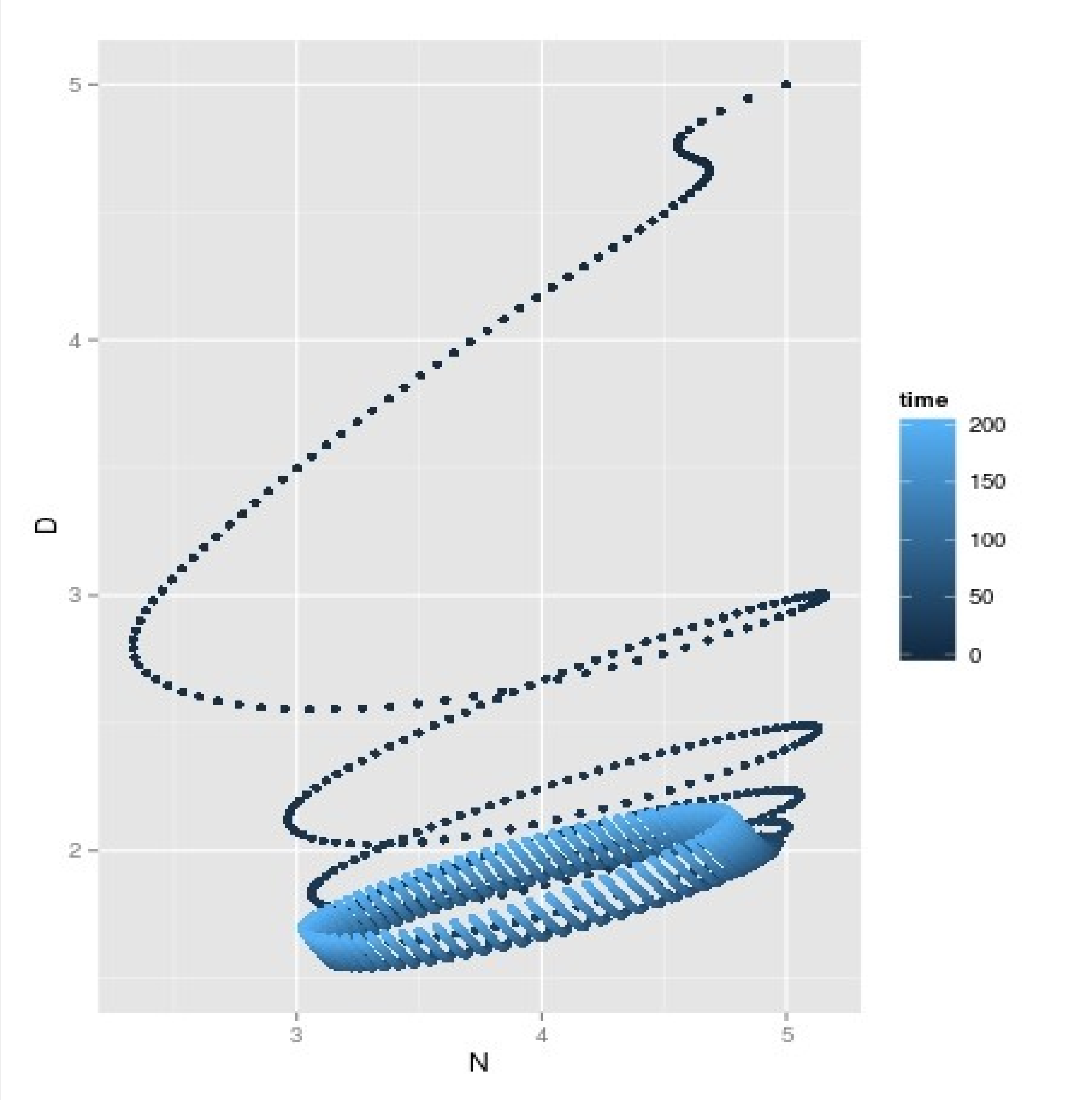


Discussion – Coexistence II



Discussion – Coexistence III

Phase space plot of the previous situations. (Notice that it almost reaches a stable orbit.)



###THE CANNIBALS####

THE MATECITO

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Thank you for the attention