Defensive symbiosis – tales from an uneasy alliance

CSEE 2024

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Defensive symbiosis

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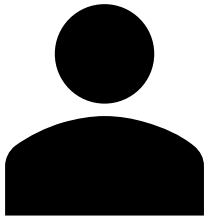
Defensive symbiosis



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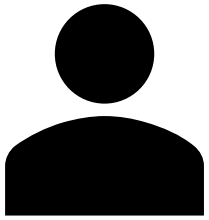

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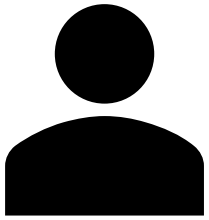

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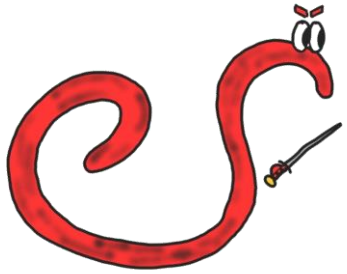

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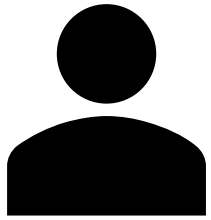

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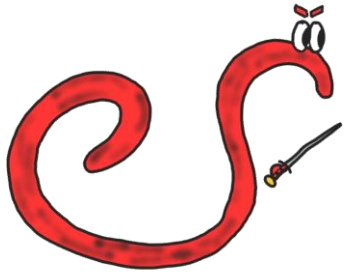

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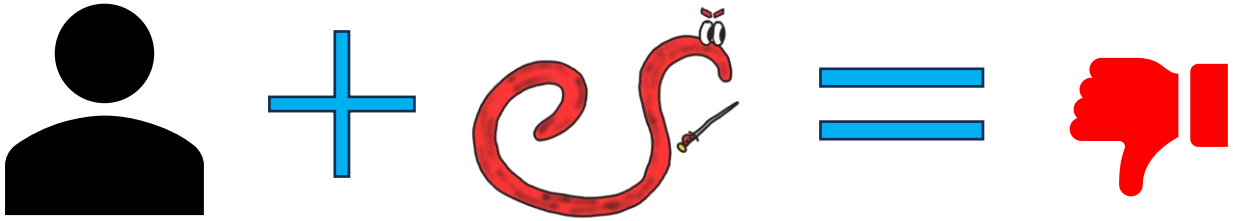

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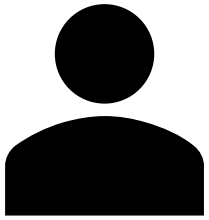

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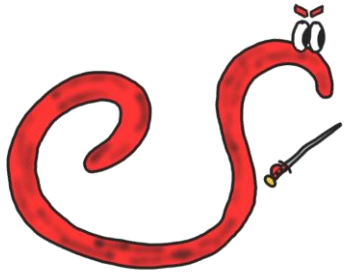

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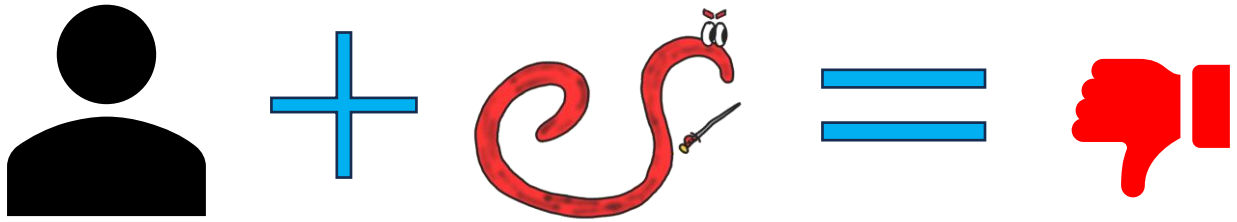

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Aims of the studies

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Biological "rules"

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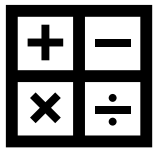

Mathematical framework

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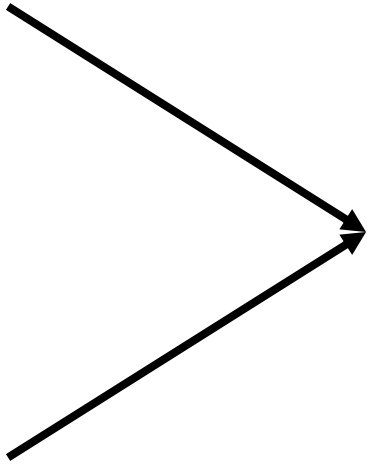

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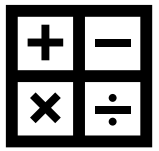

Mathematical model

$$\frac{\mathrm{d}\boldsymbol{X}}{\mathrm{d}t} = \boldsymbol{f}(\boldsymbol{X})$$

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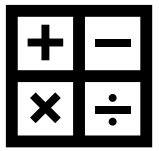

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Analysis/ inference

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Question: Can defensive symbionts be used as a biocontrol against parasitic infections?

Mathematical framework

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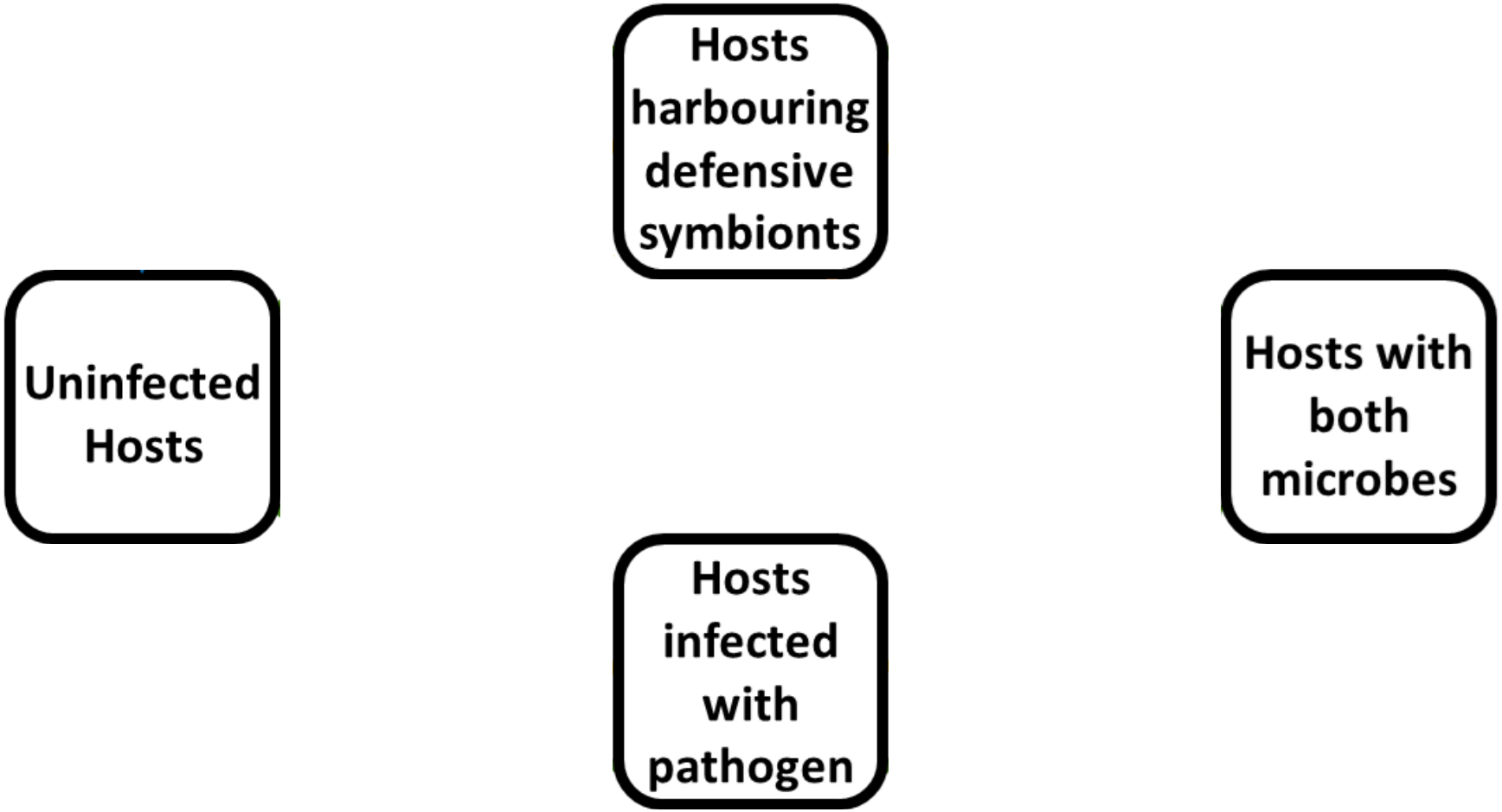

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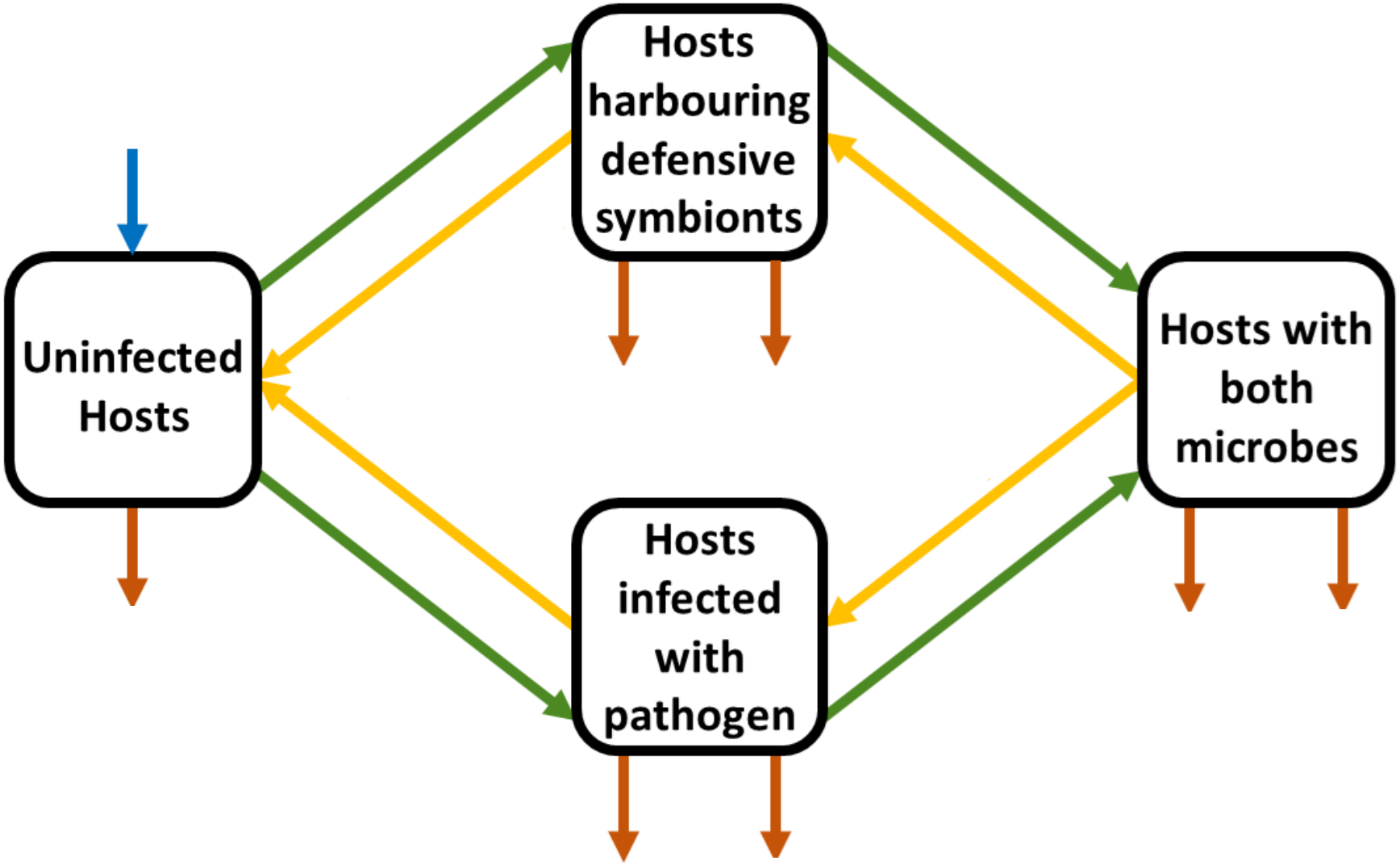

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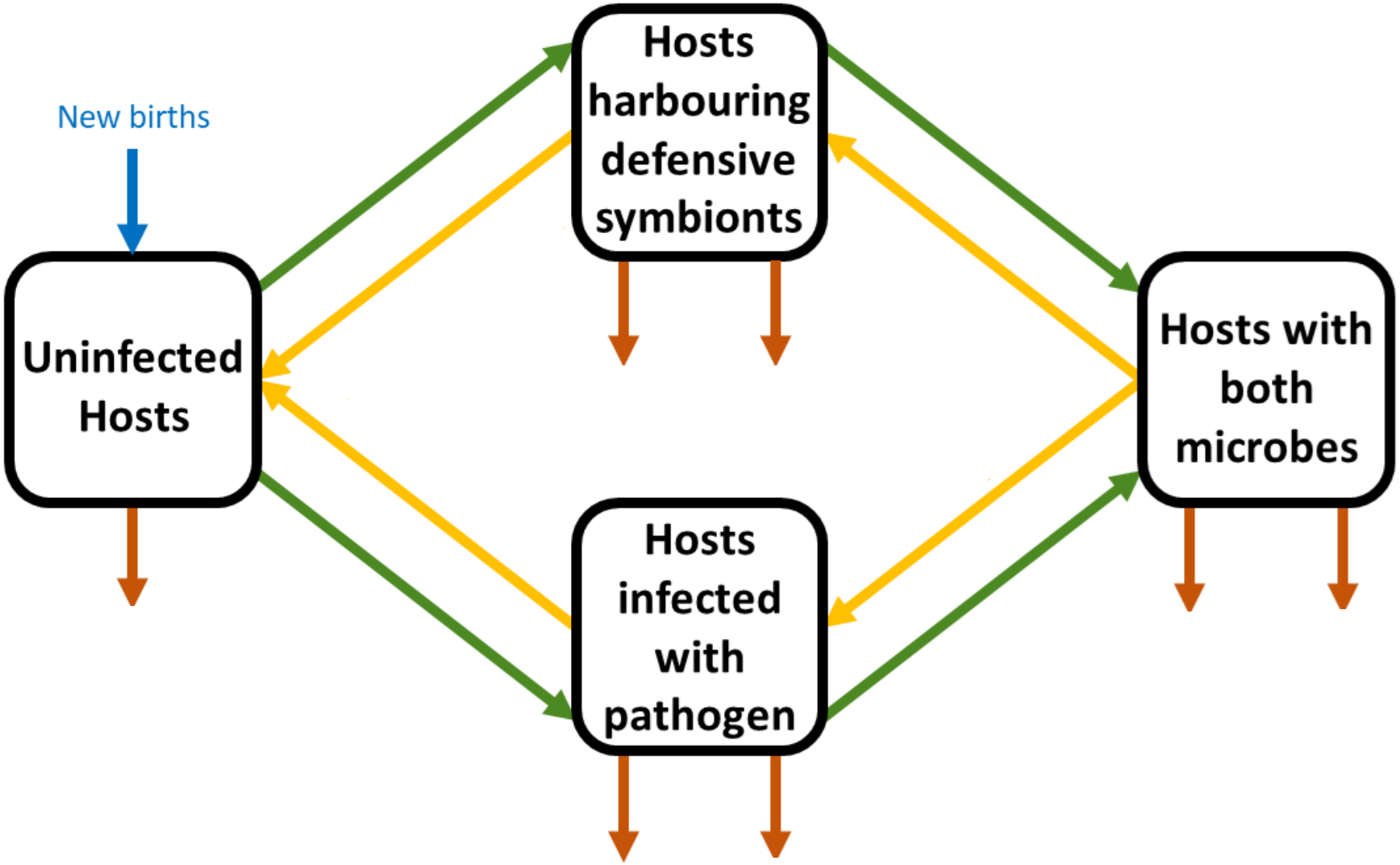

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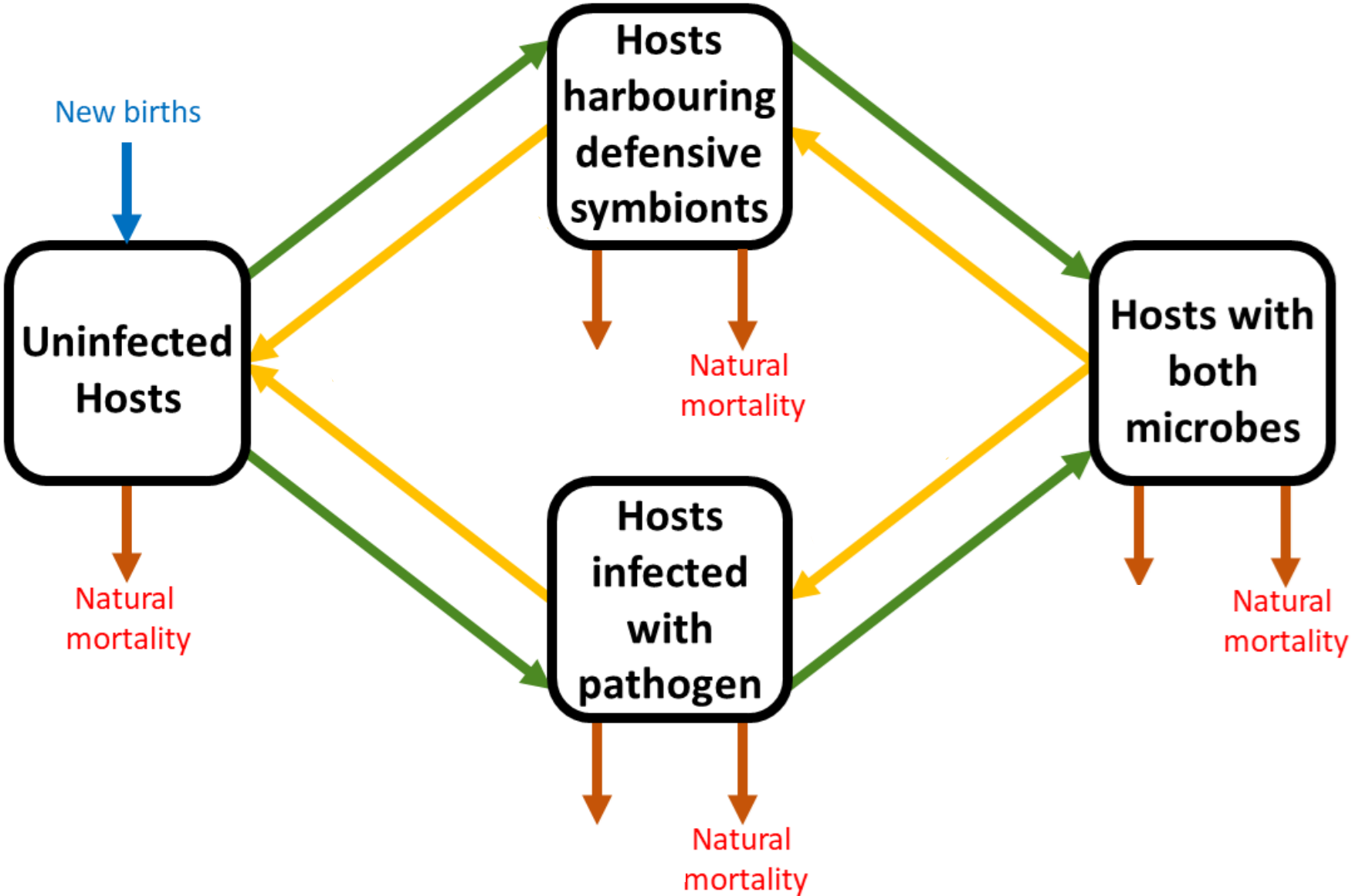

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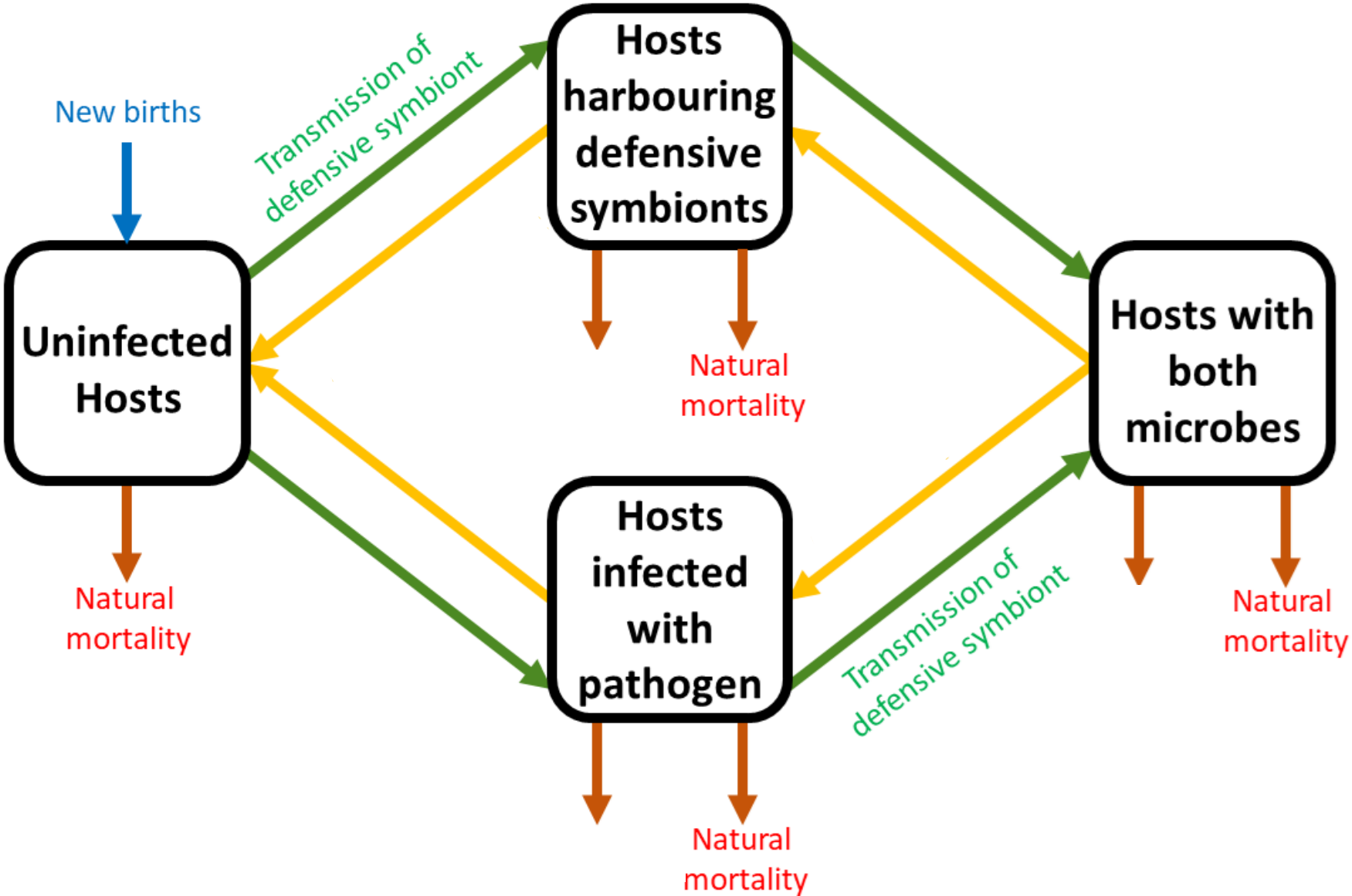

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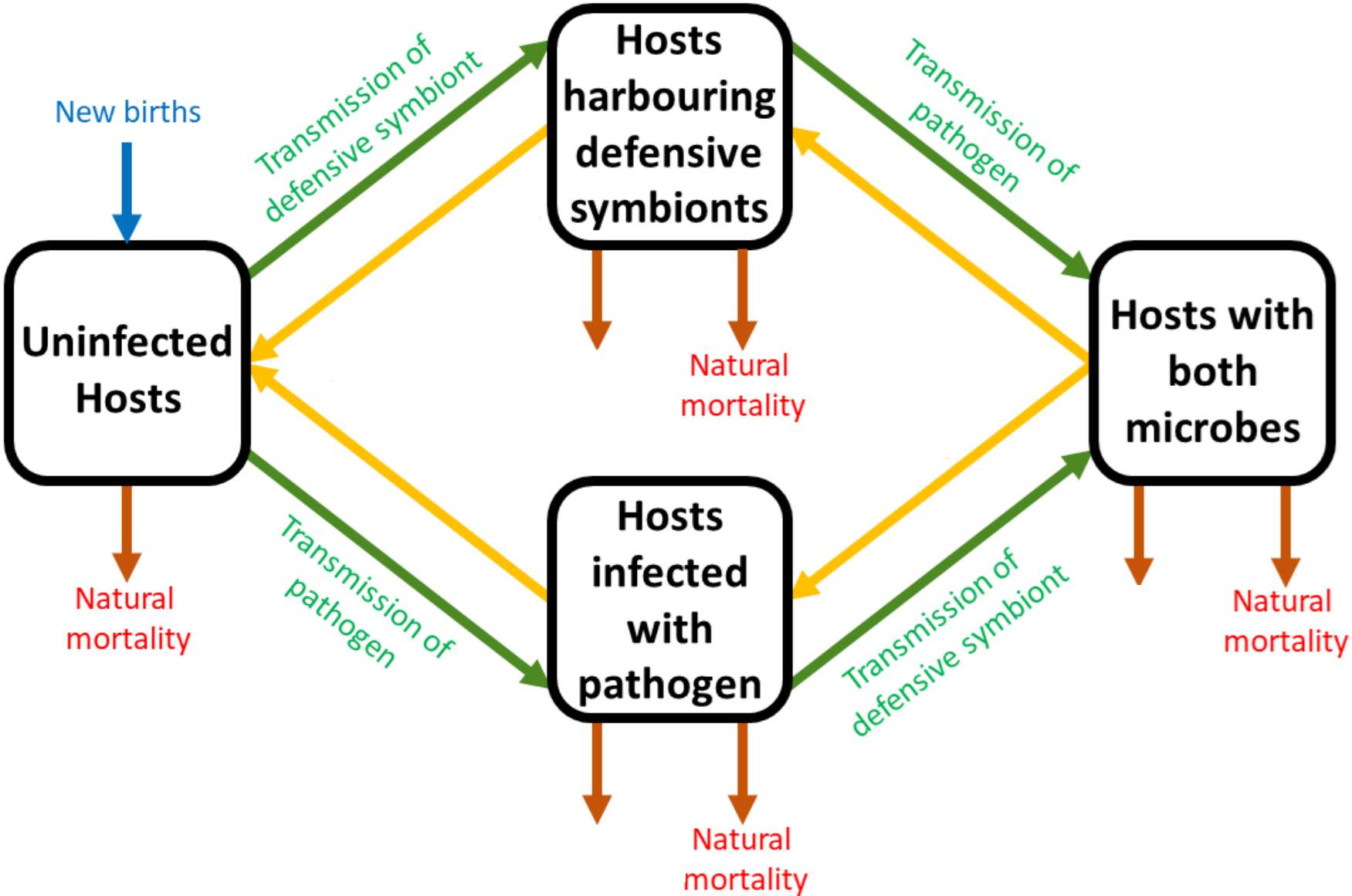

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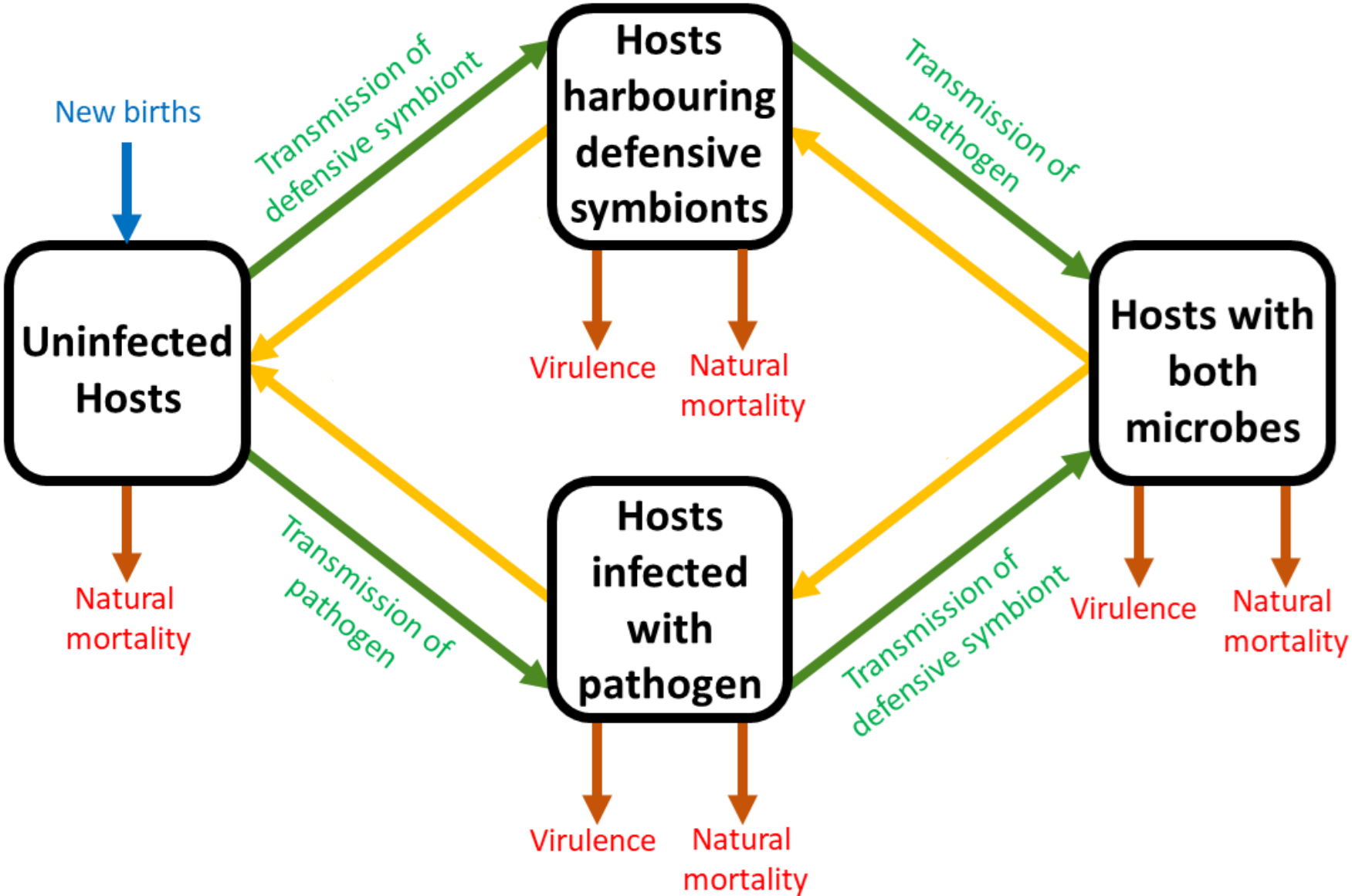

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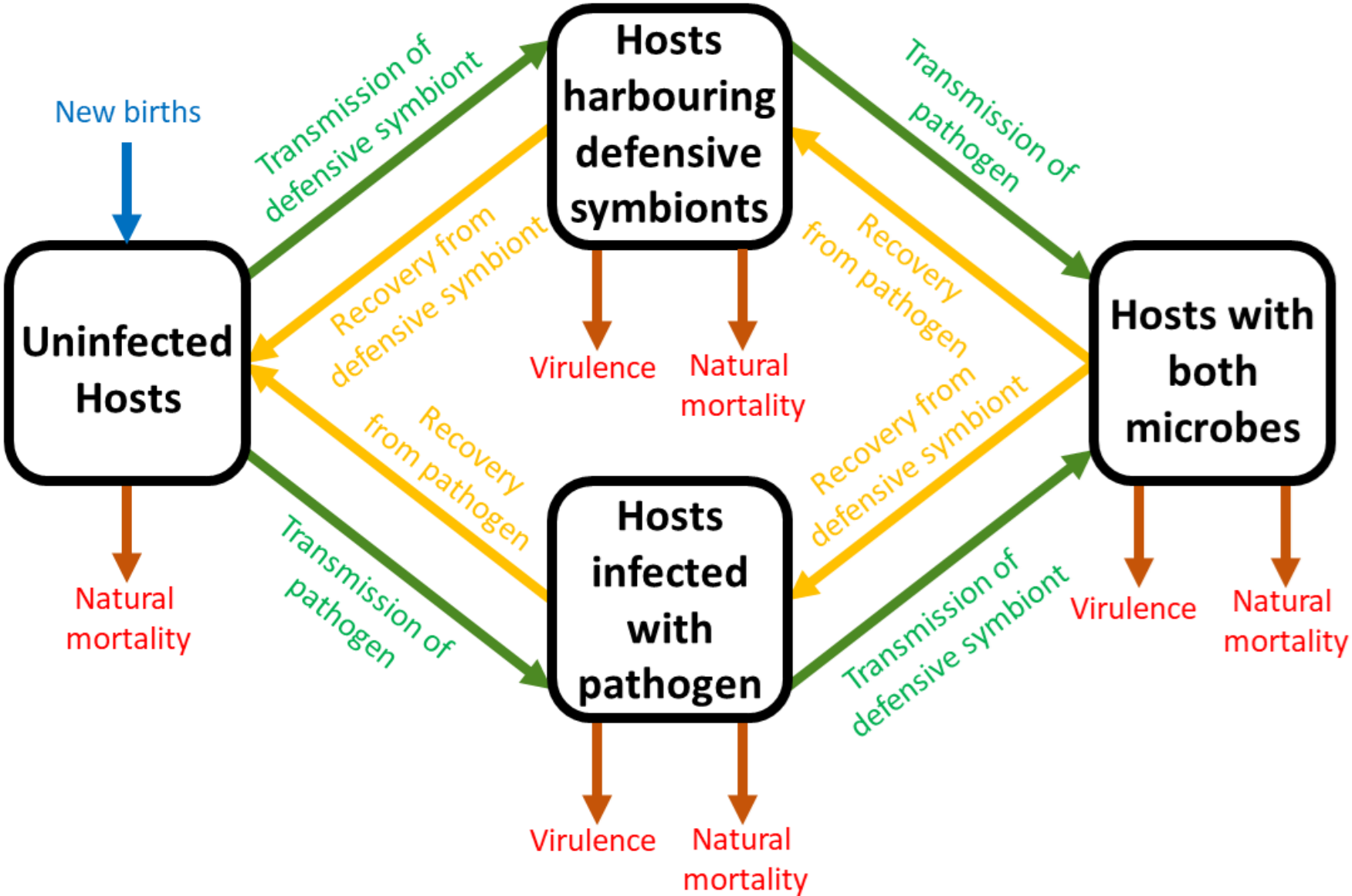

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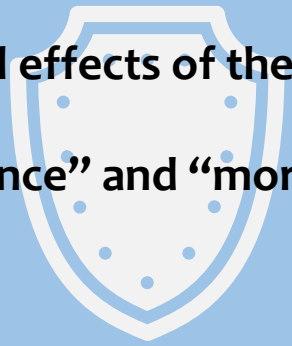

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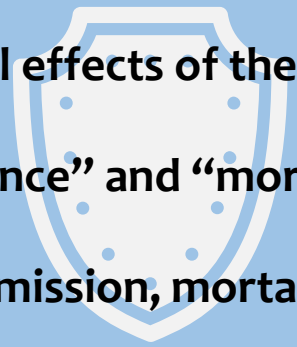

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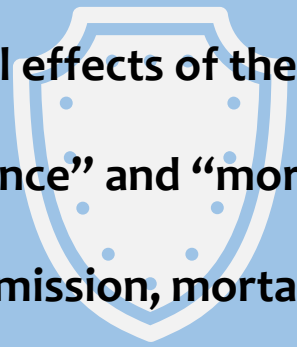

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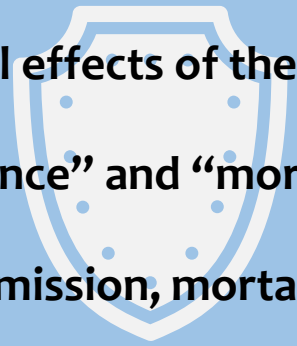

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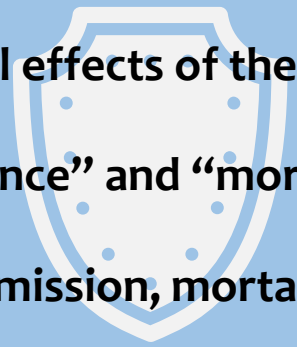

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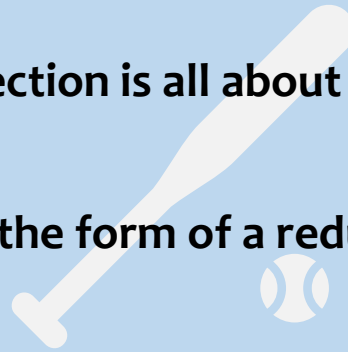

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For modelling purposes, takes the form of a reduction in transmission when harbouring the defensive symbiont compared to without

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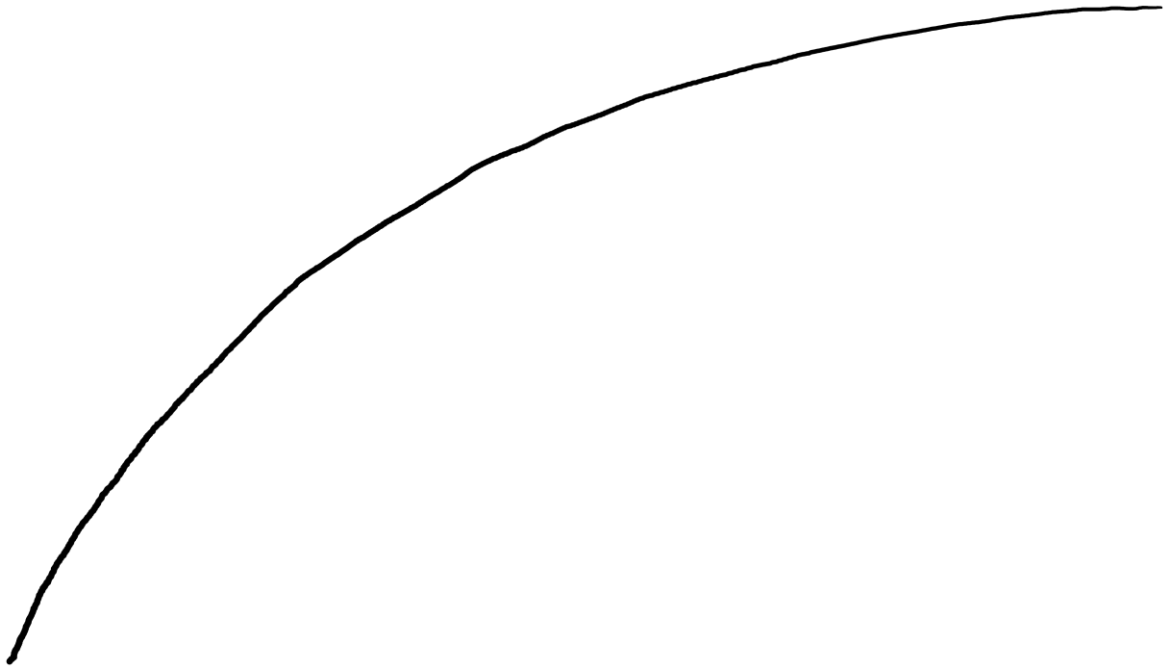

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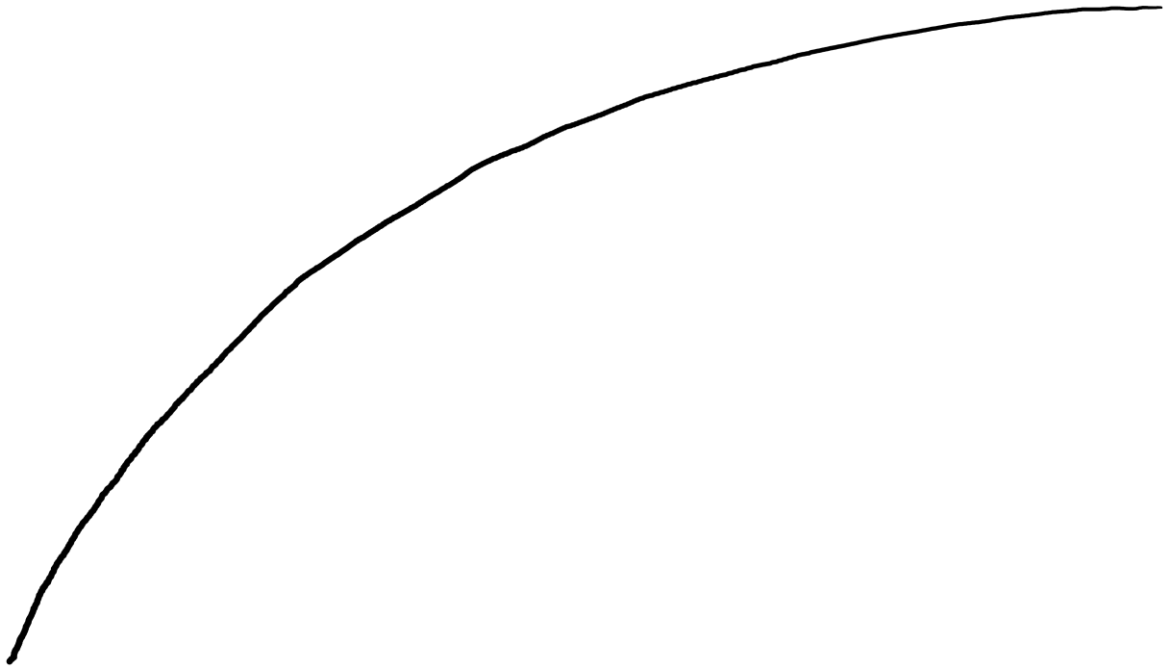

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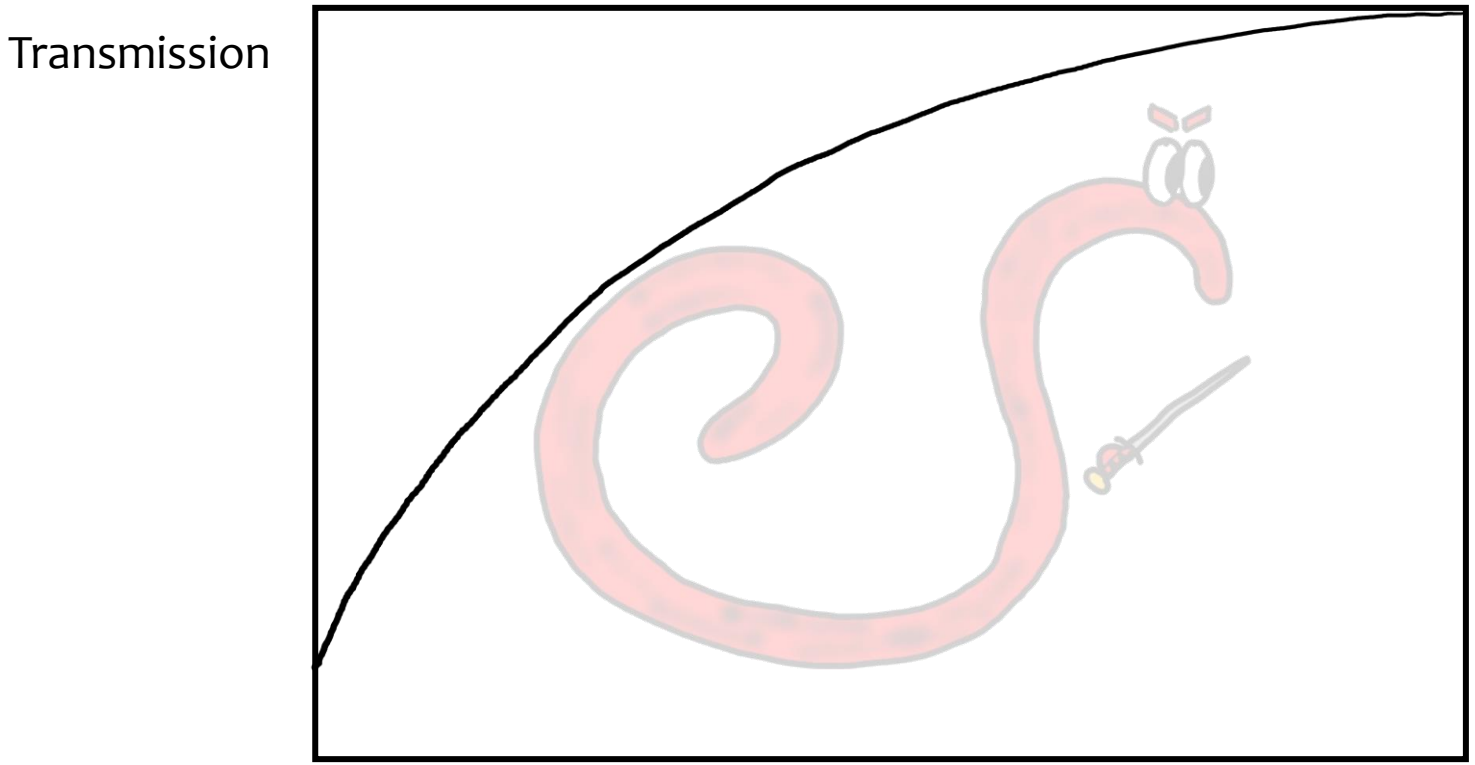

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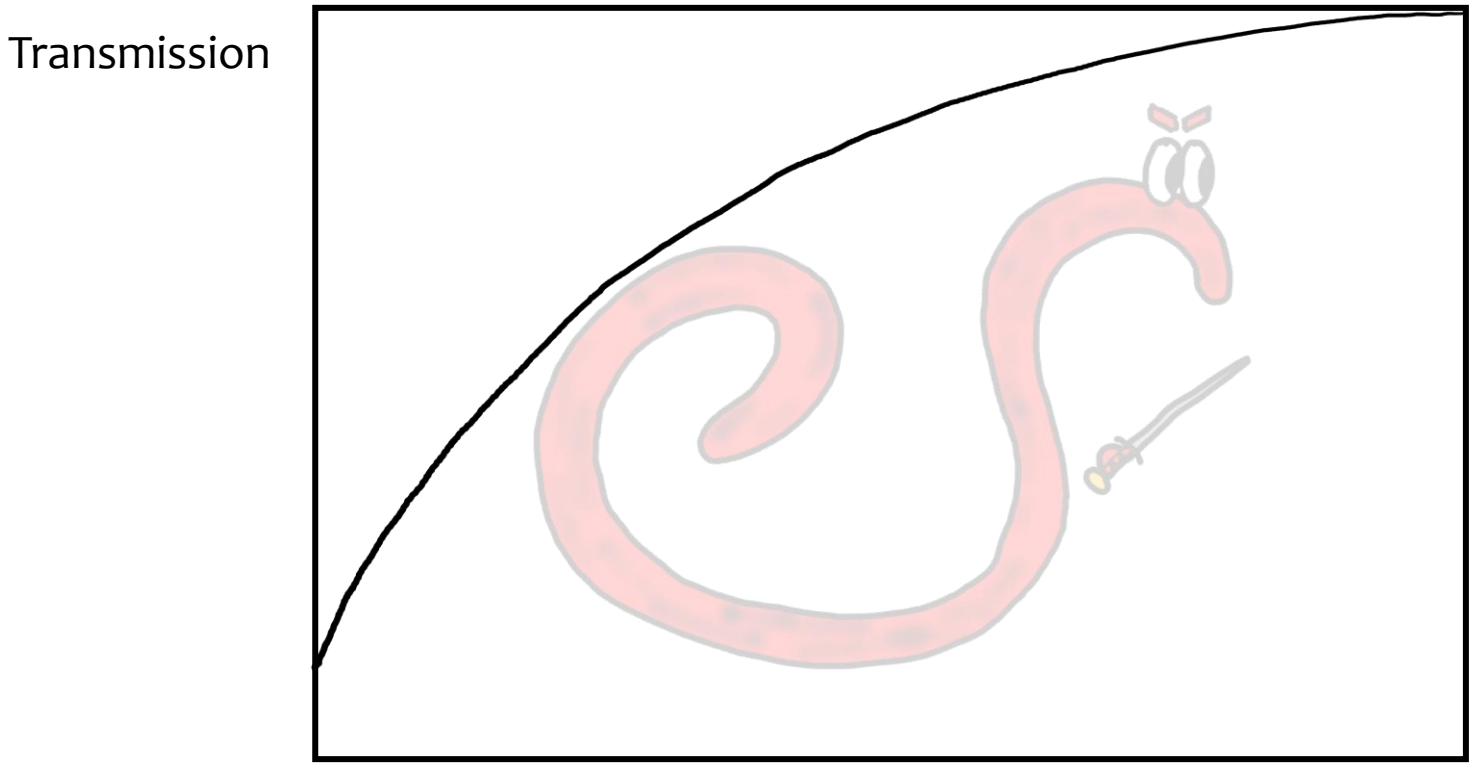

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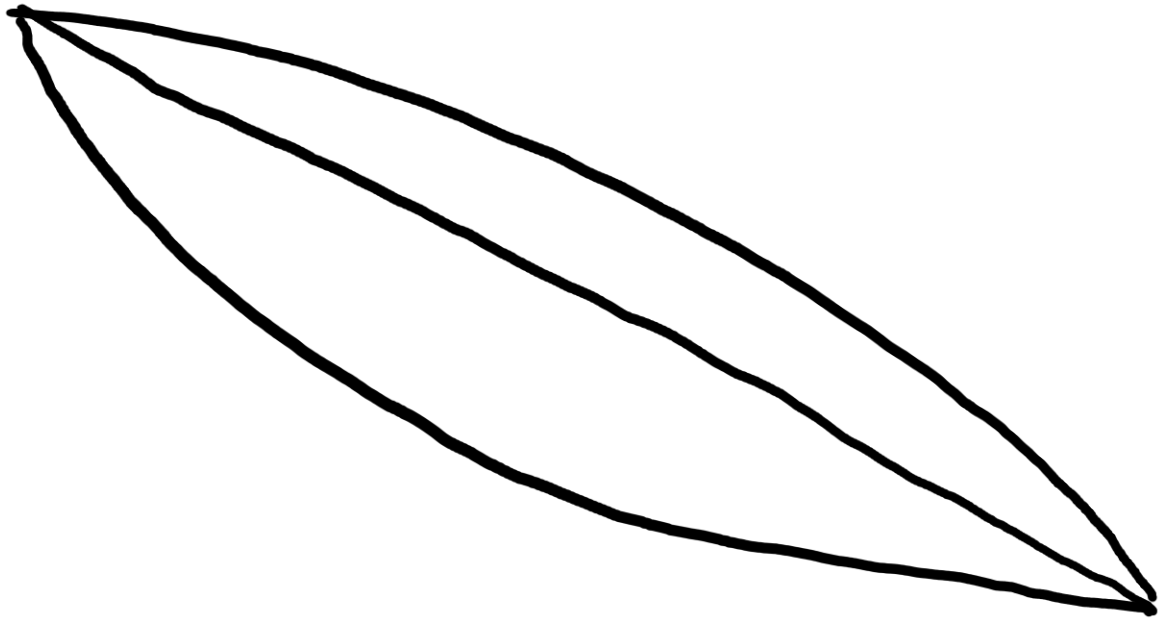

Protection

"% effort"

Ranges from 0 to 1

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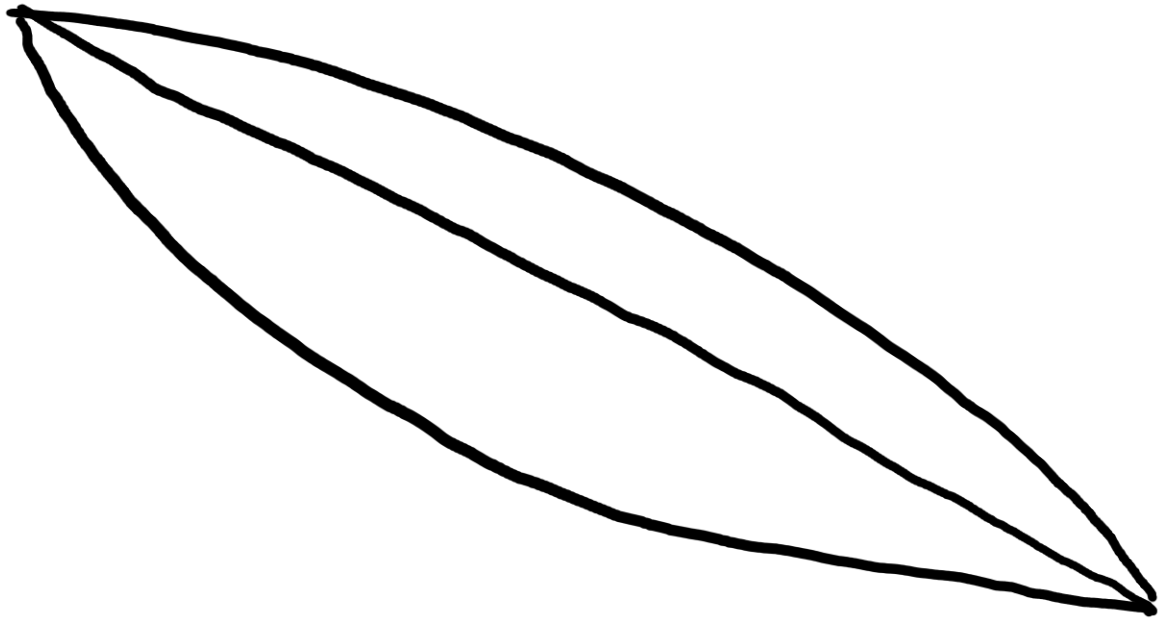

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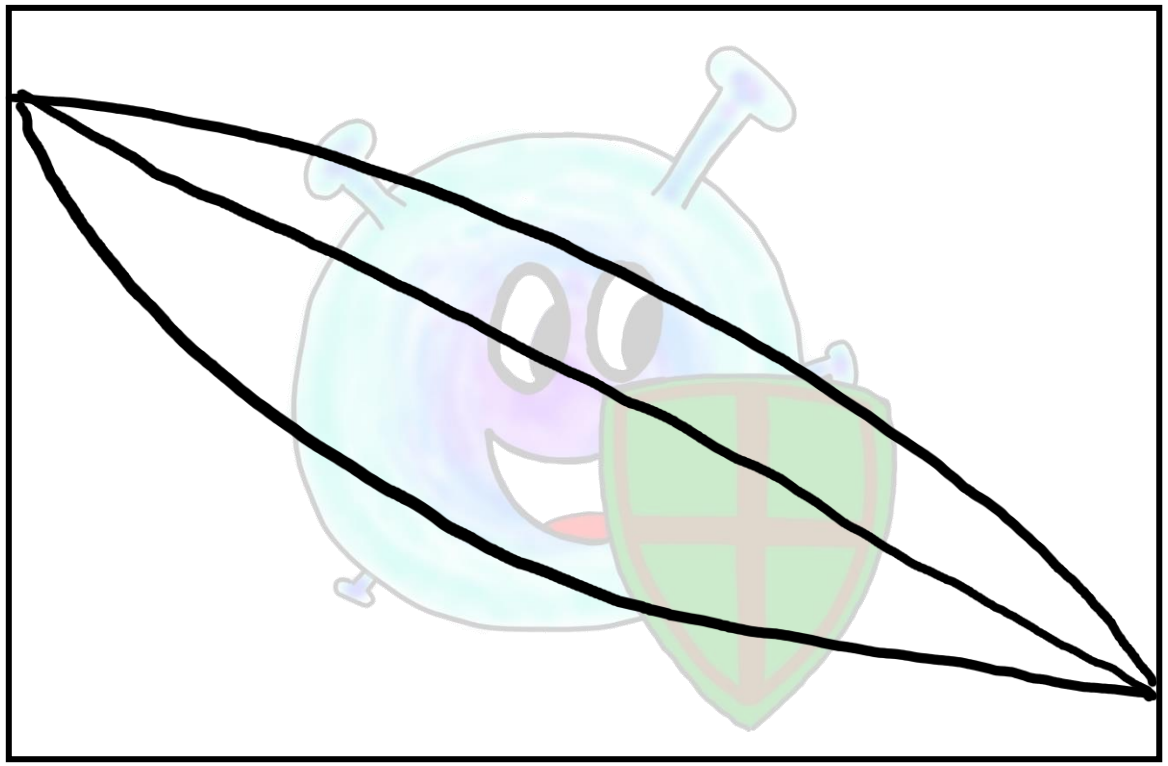

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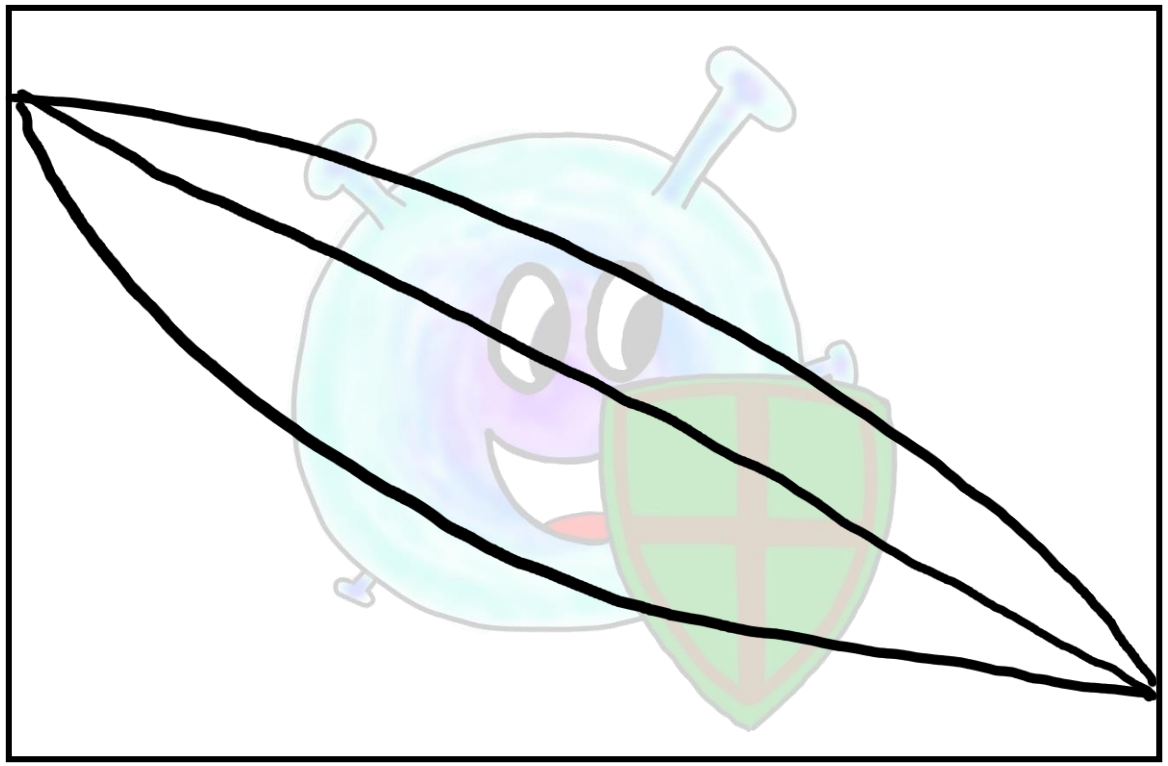

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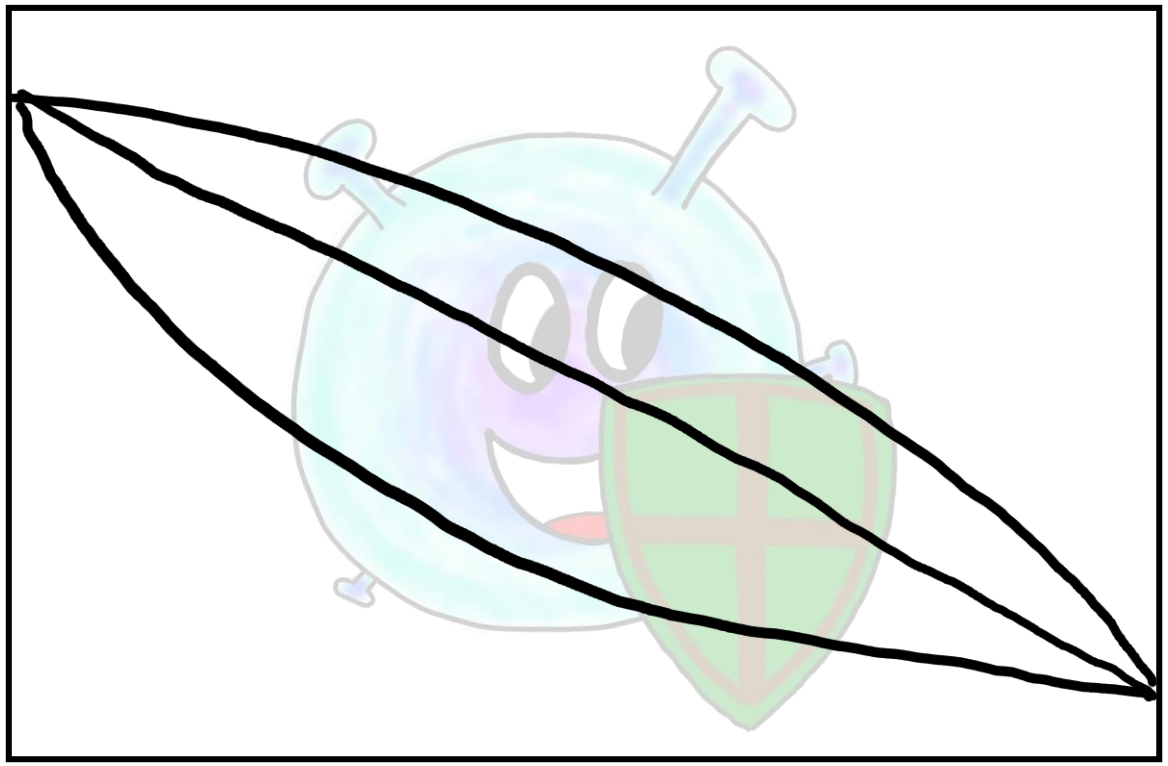

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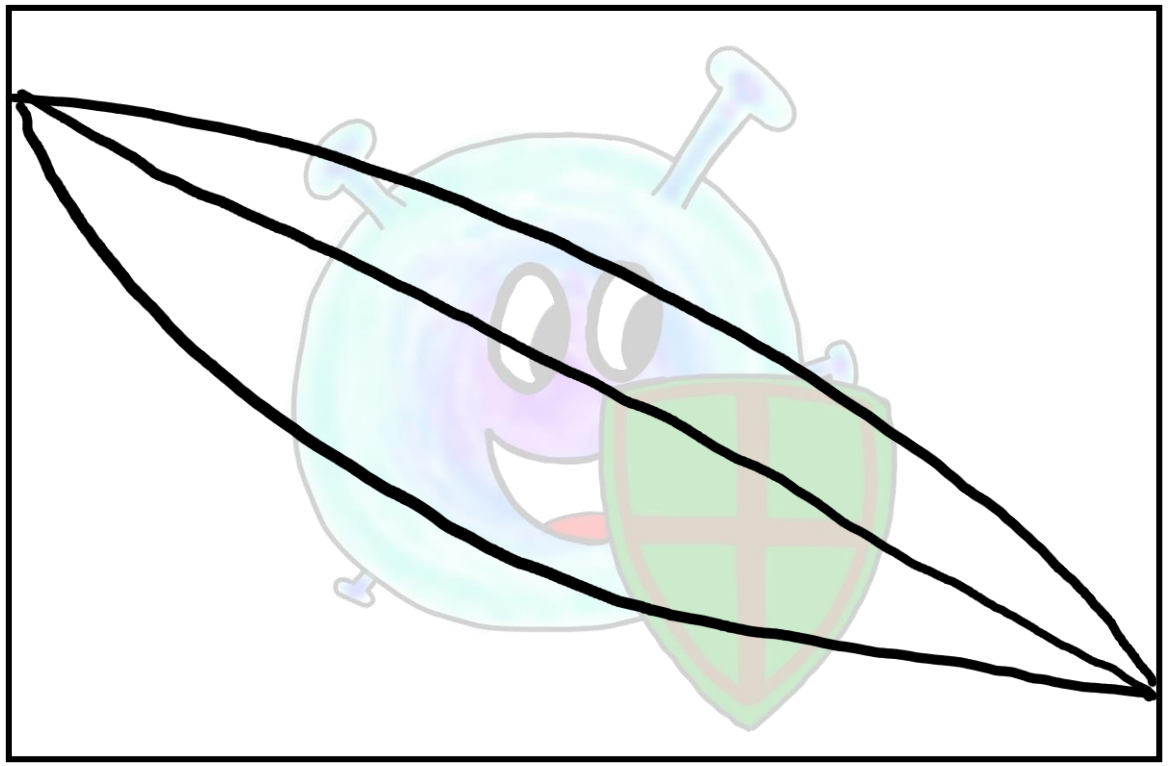

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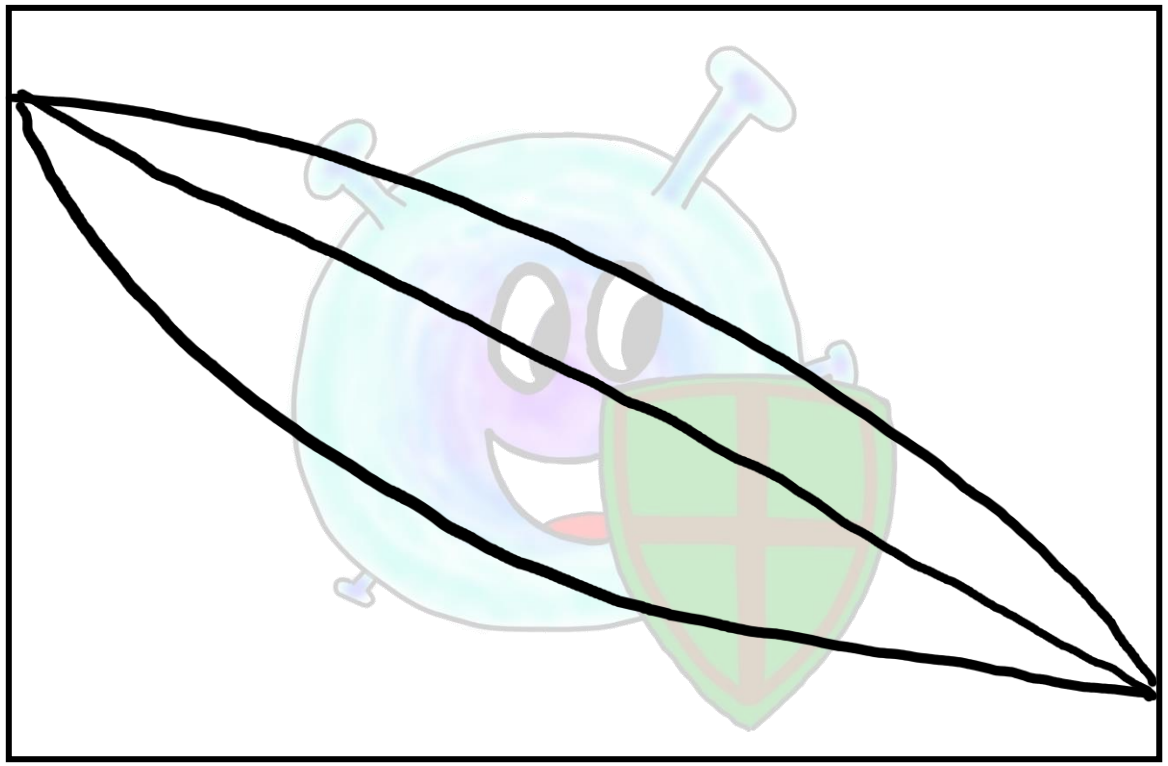
Transmission



Protection

Trade-off

Divert resources for reproduction to protect host

Protection

"% effort"

Ranges from 0 to 1

Defensive symbiosis

Assumptions and questions to answer:

- How does defence occur? ✓
- How does the pathogen evolve? ✓
- What are the costs of protection? ←

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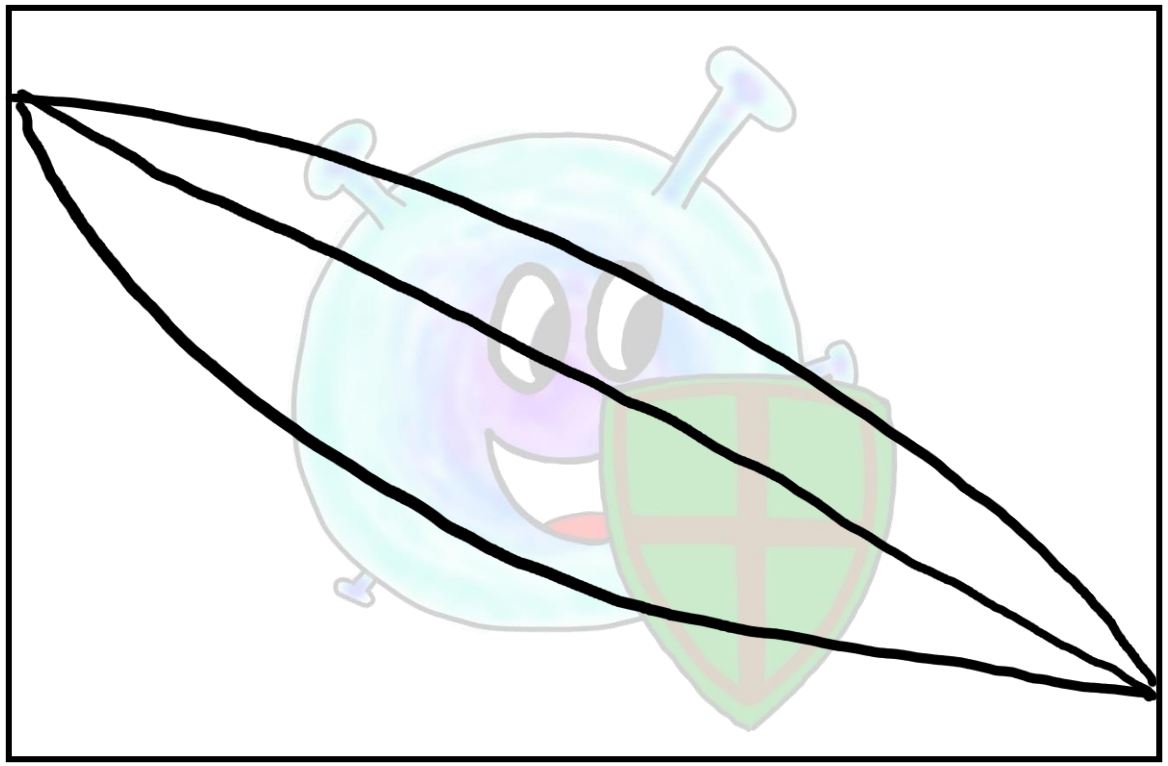

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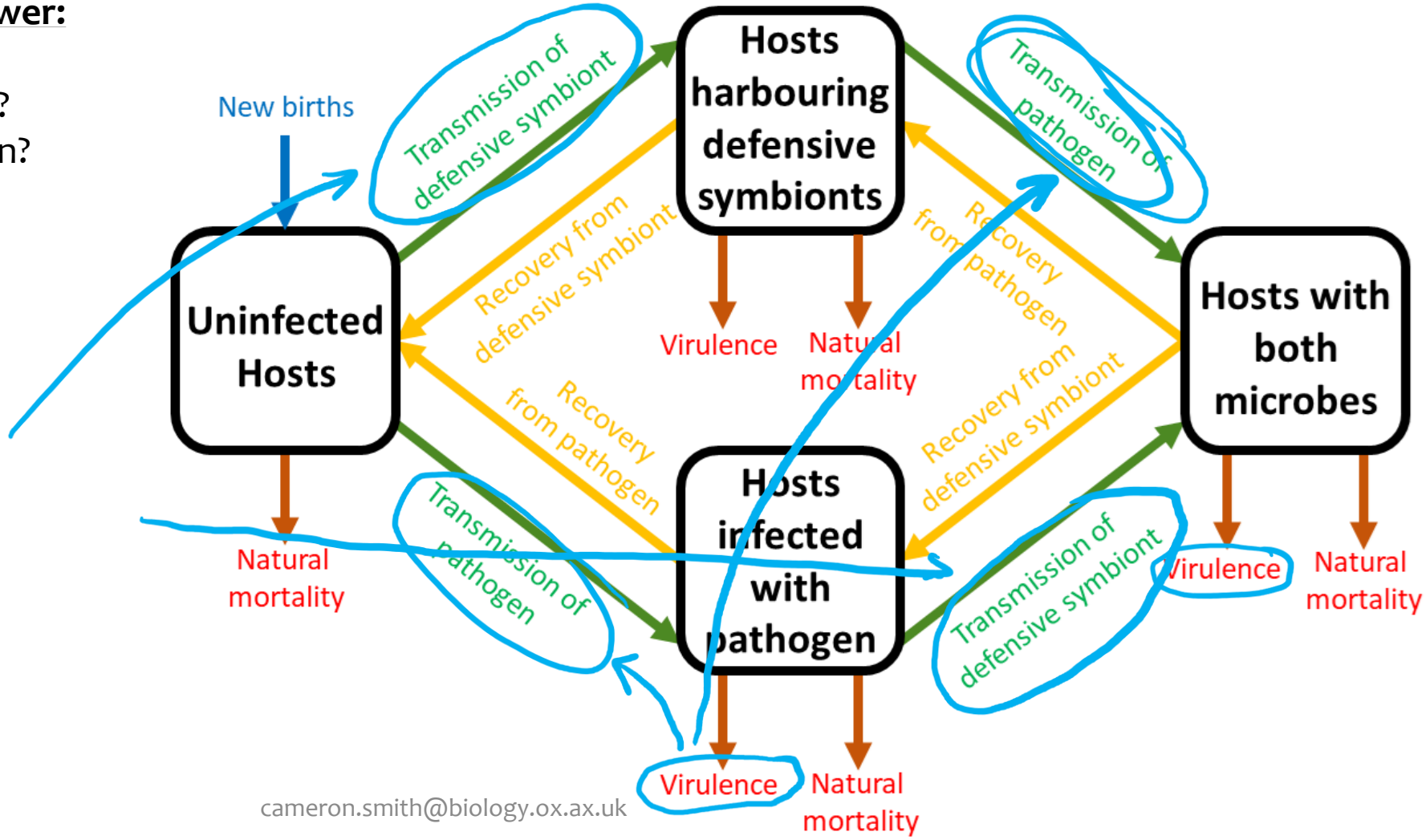

cameron.smith@biology.ox.ax.uk

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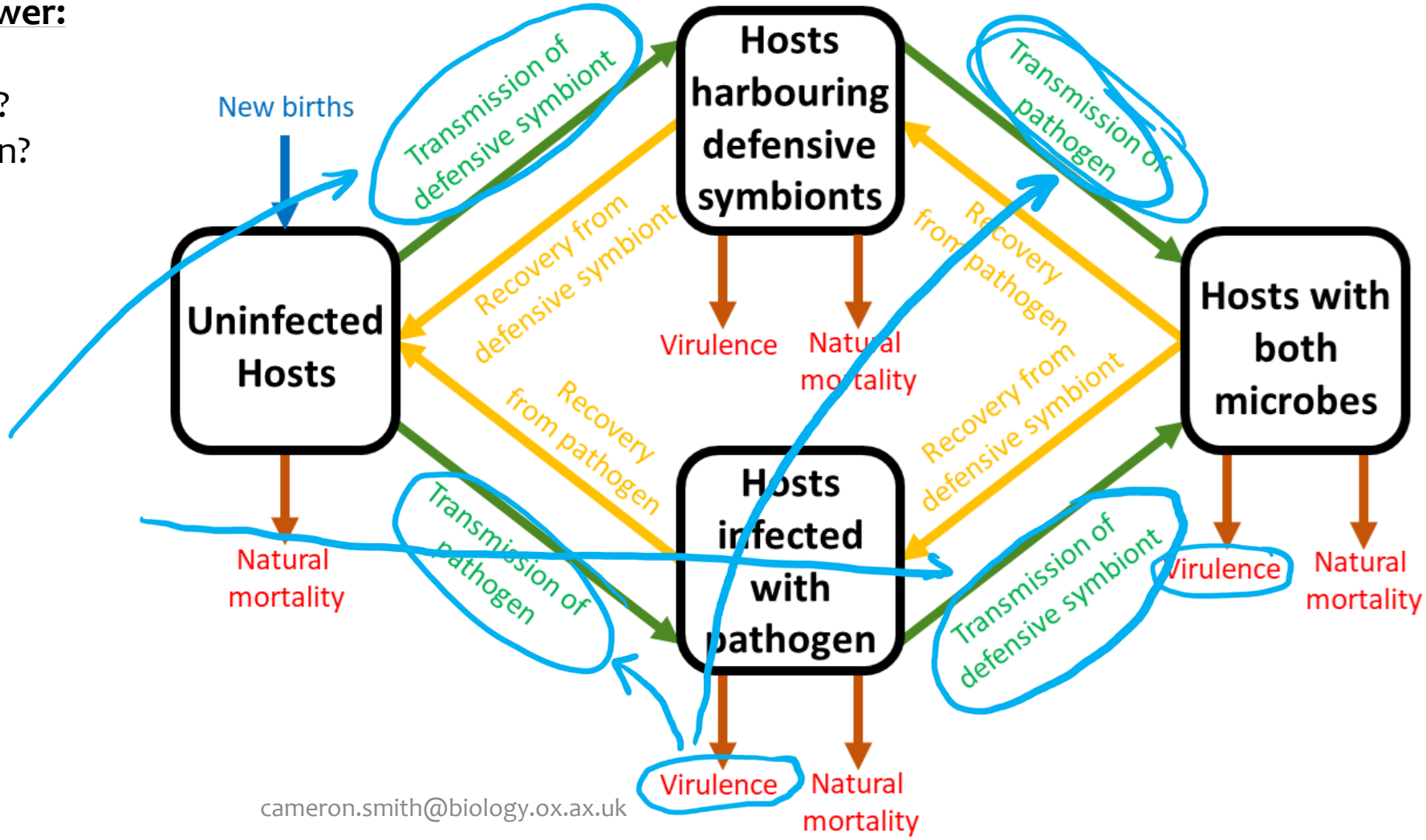

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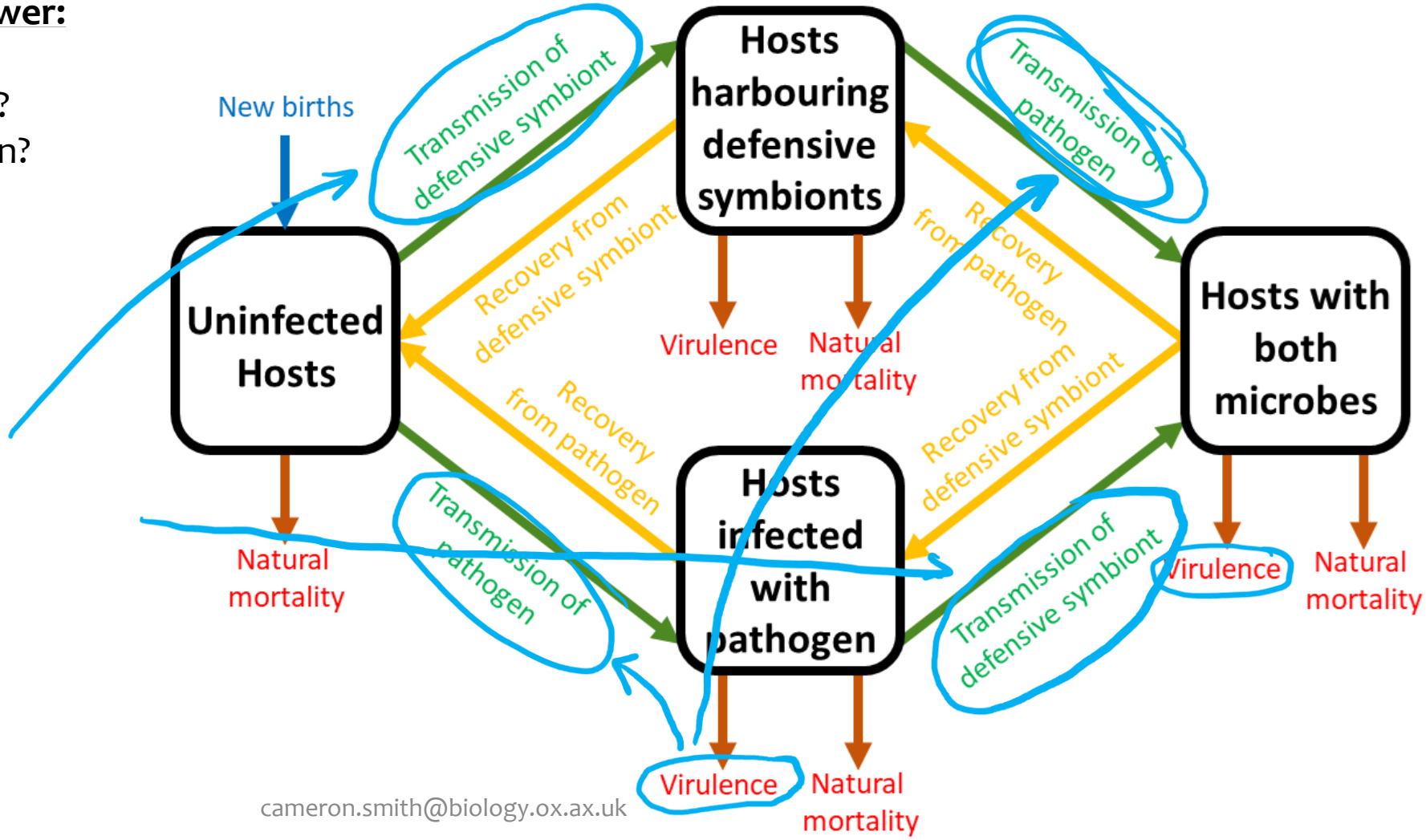

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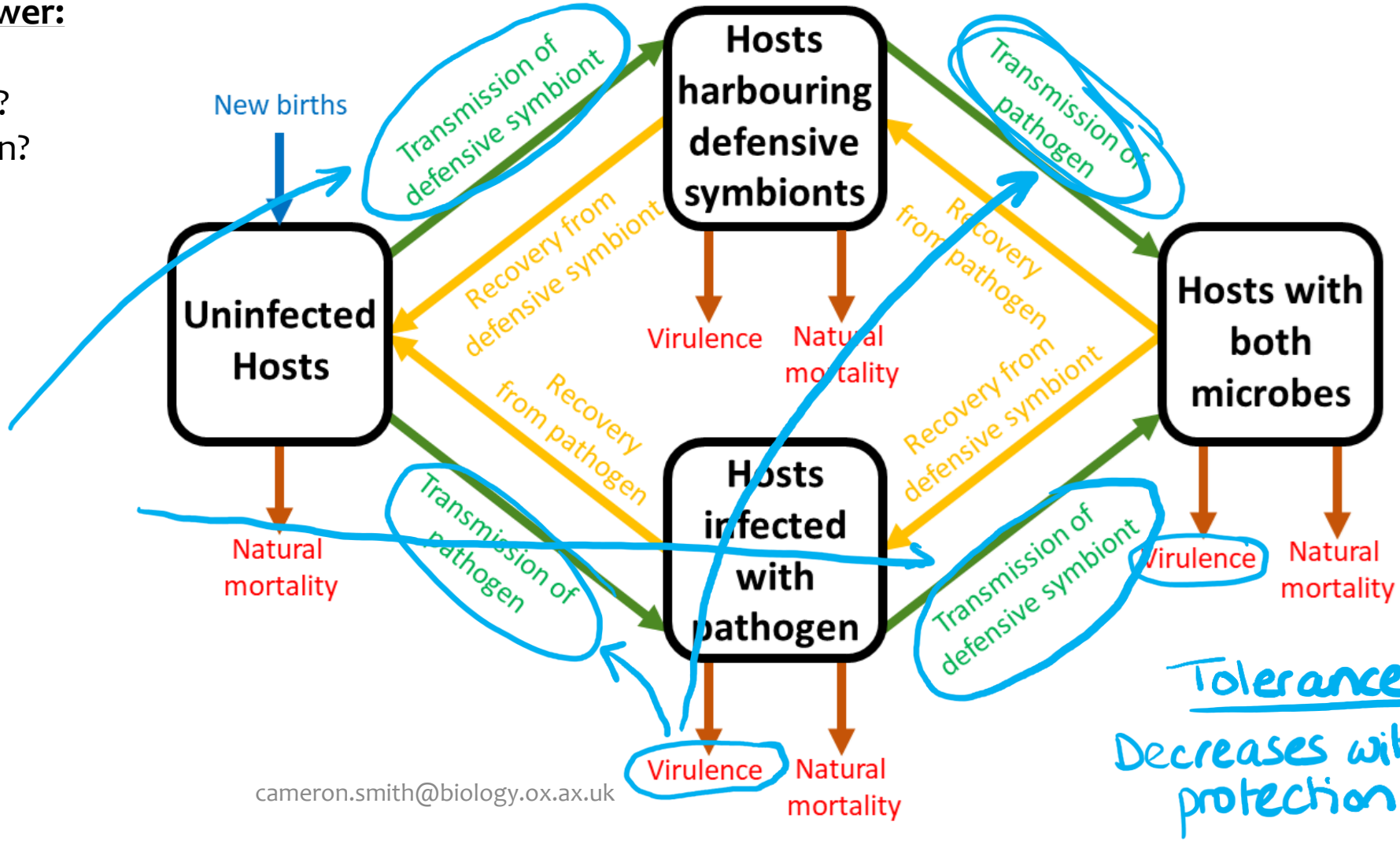

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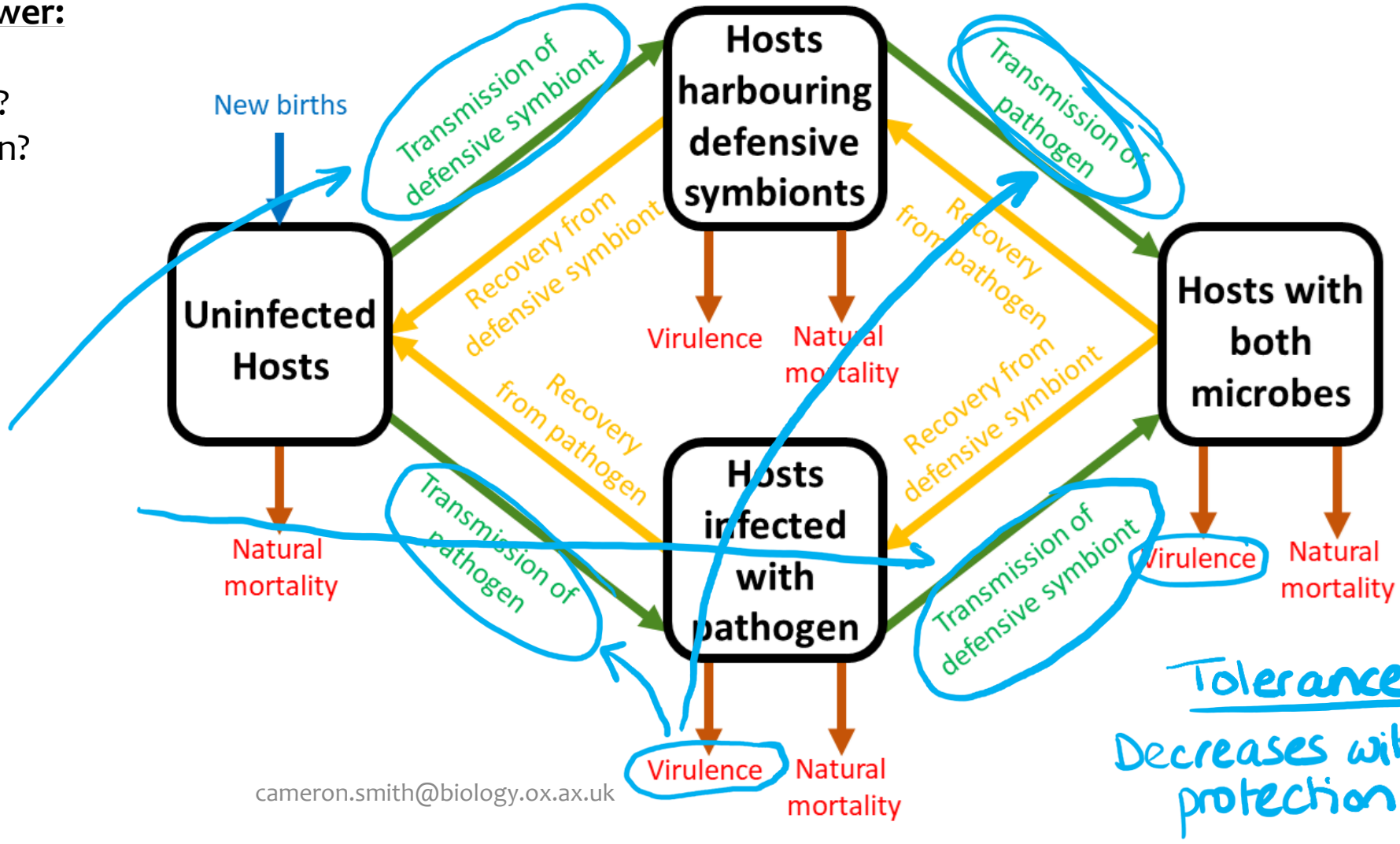

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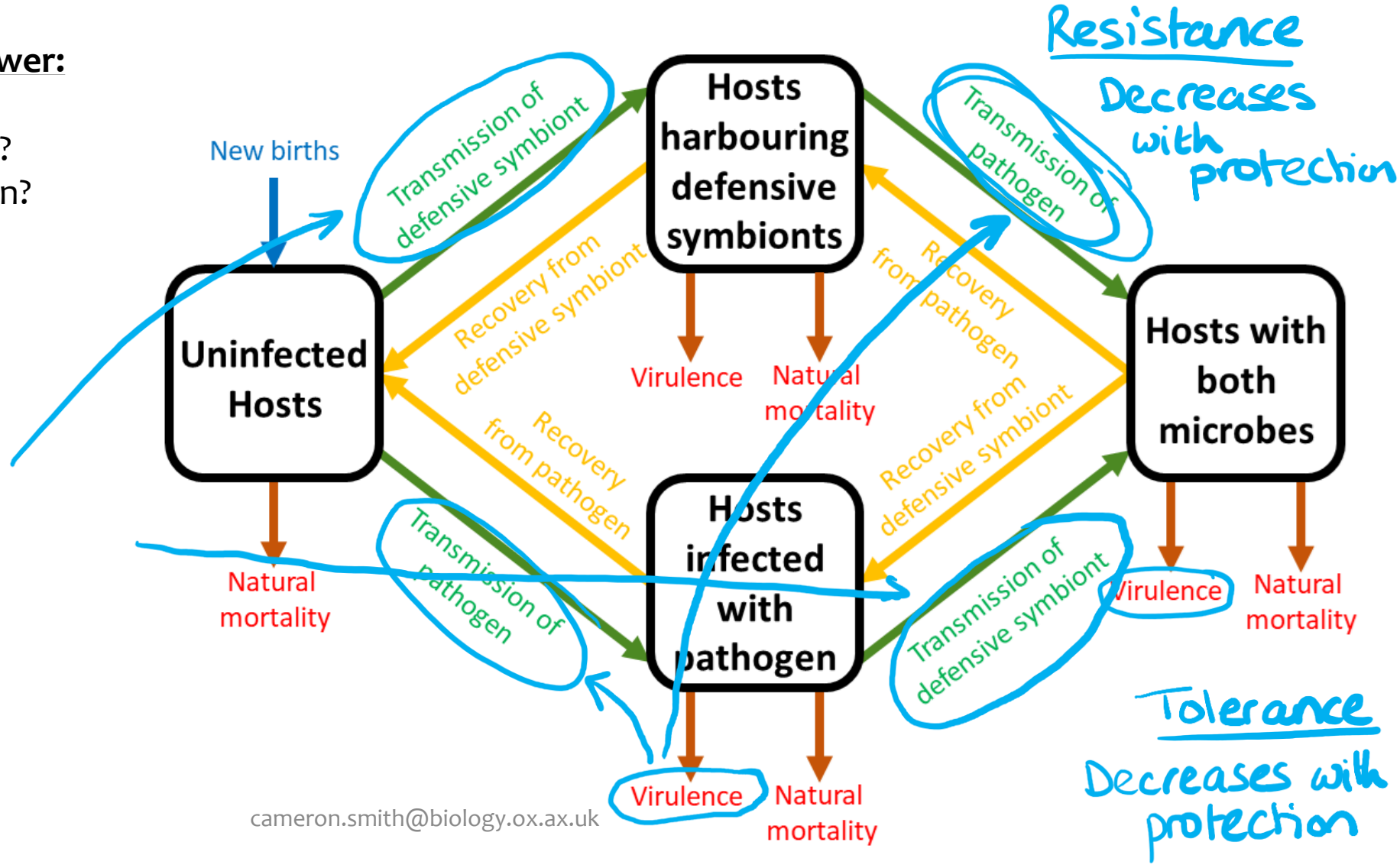

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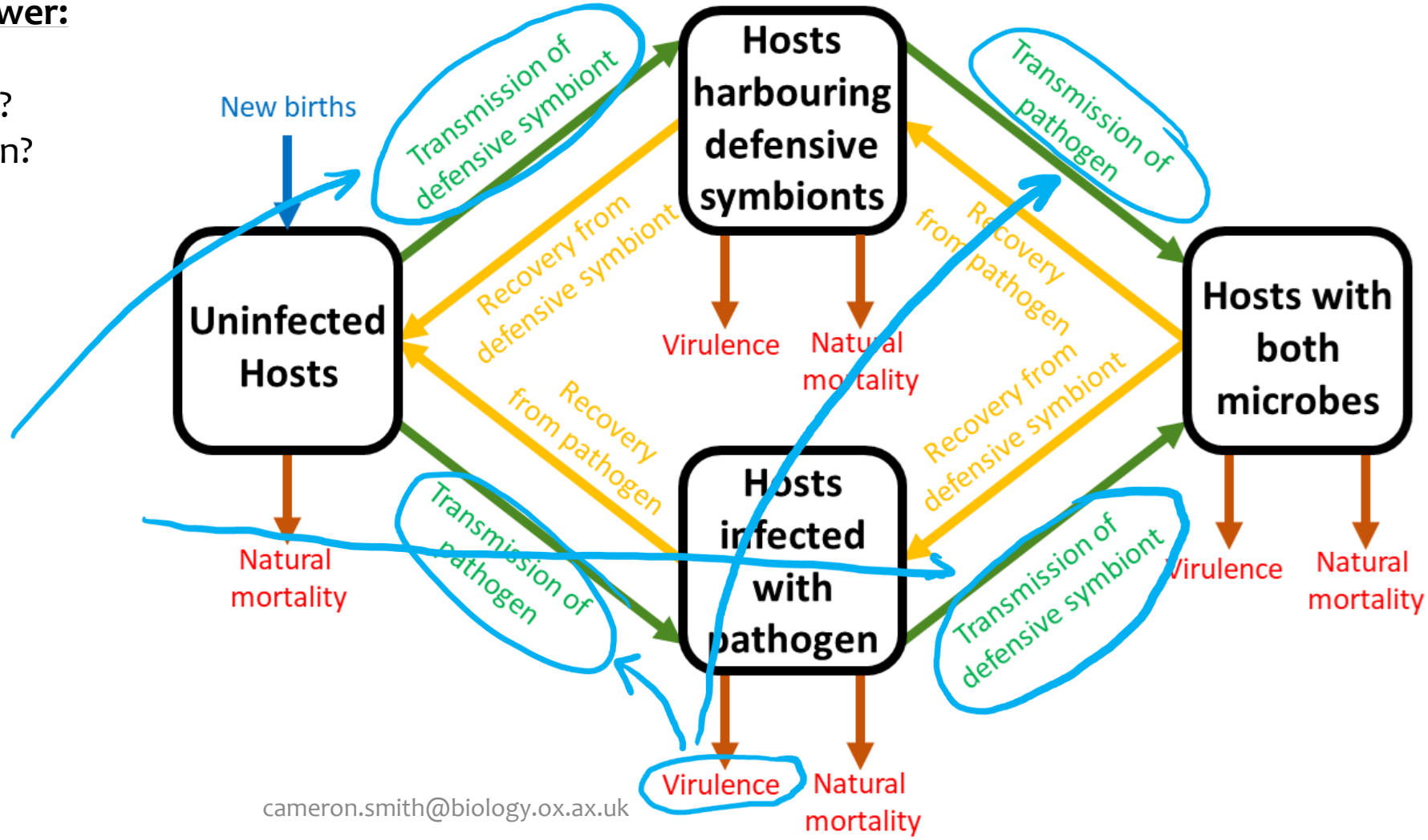

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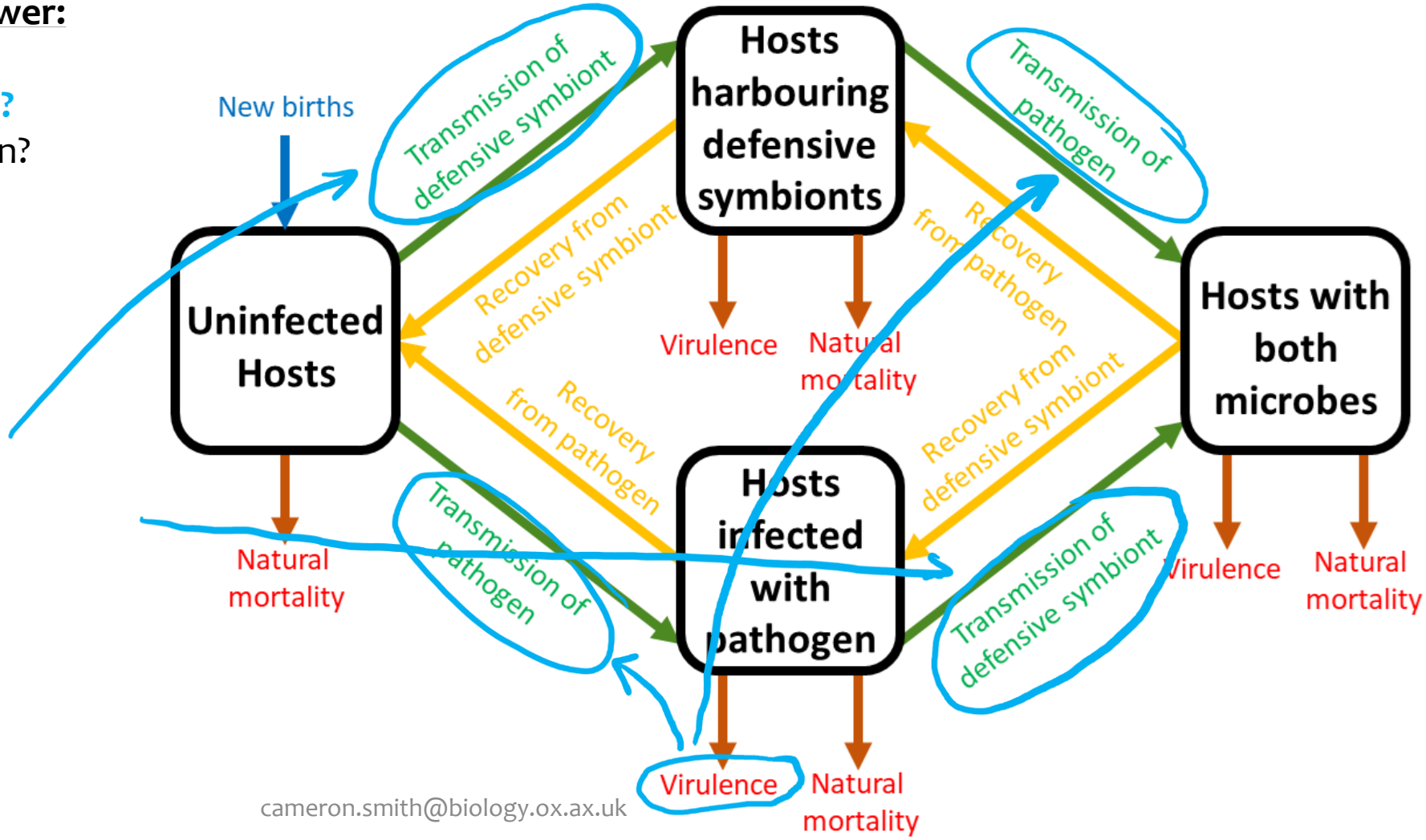

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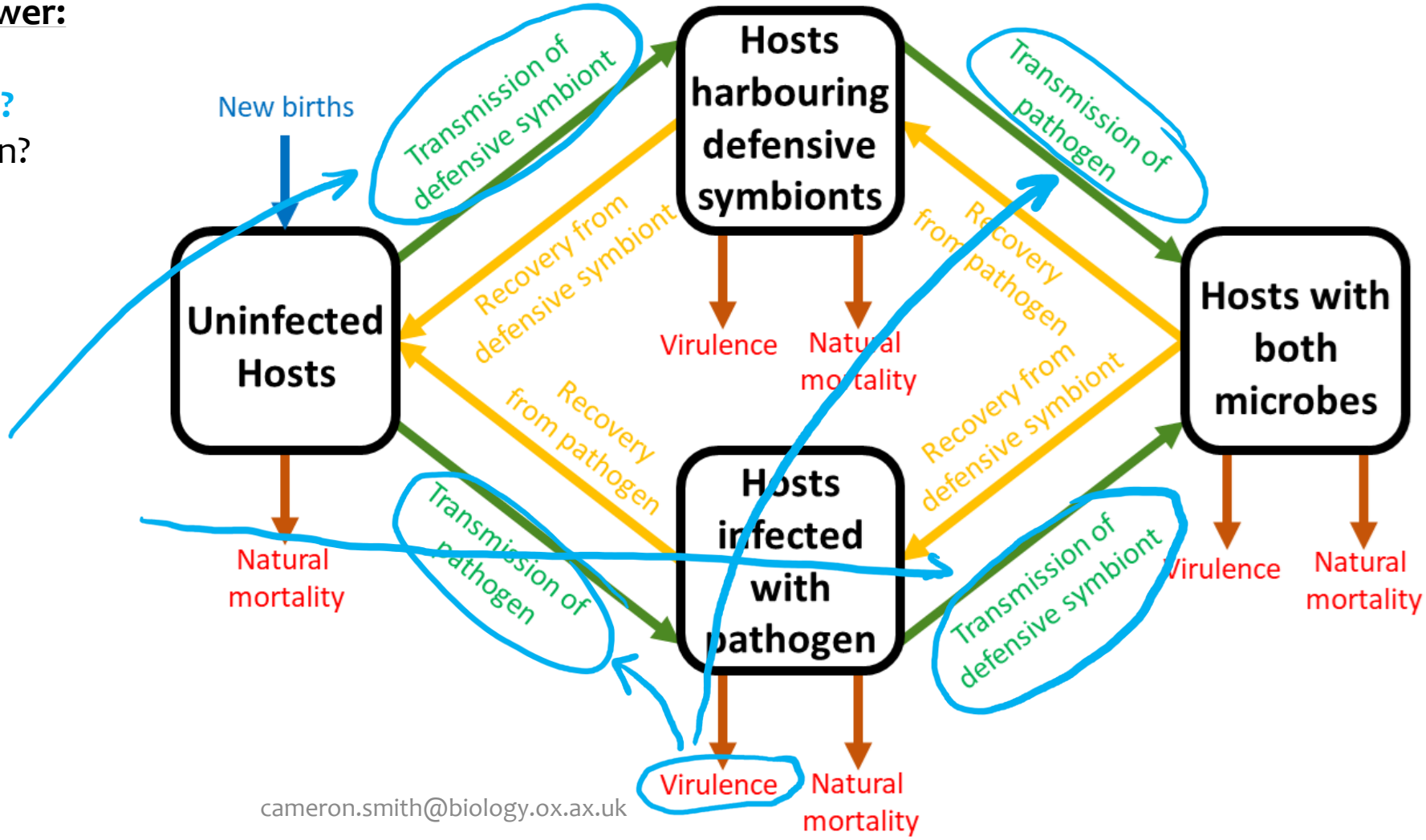

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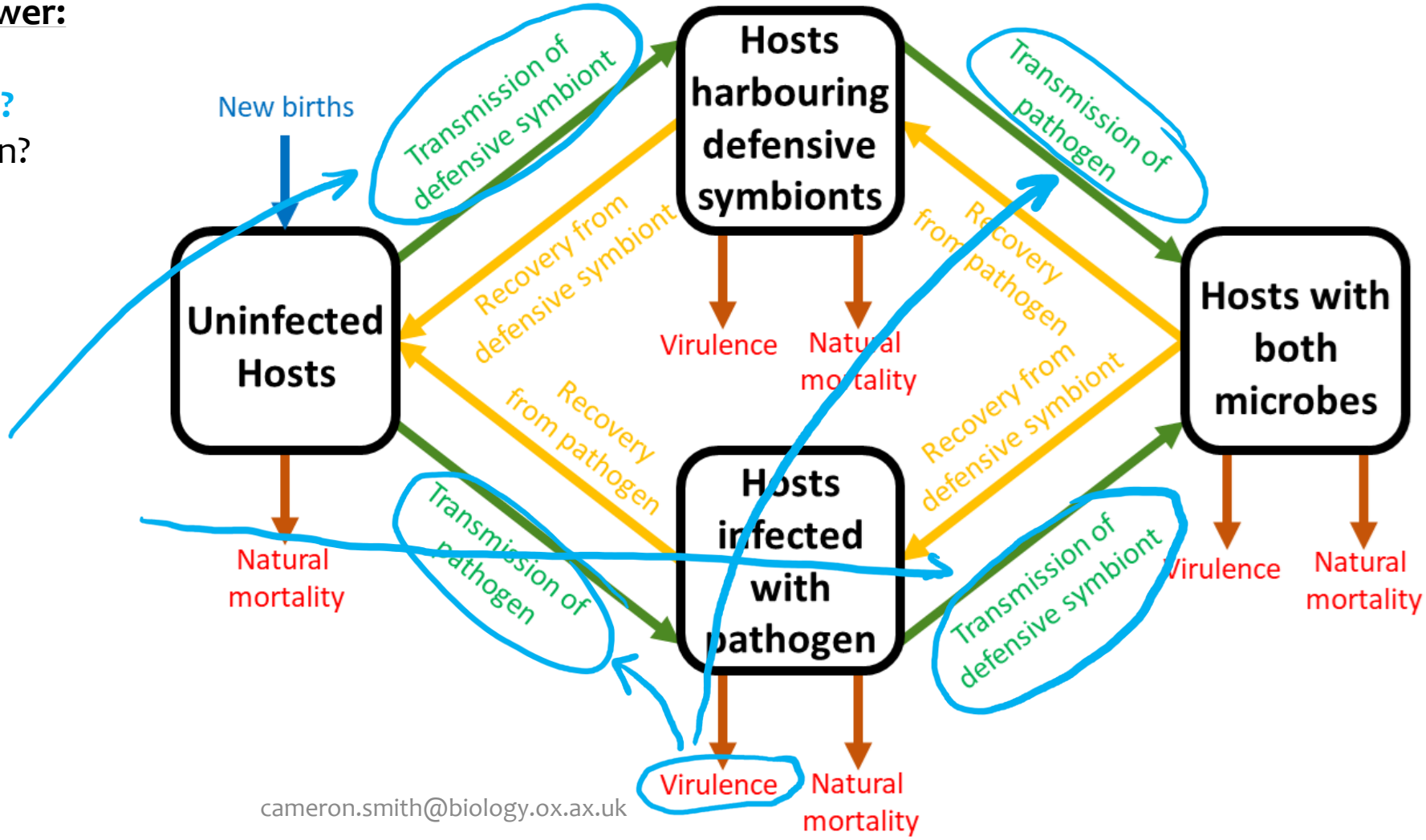

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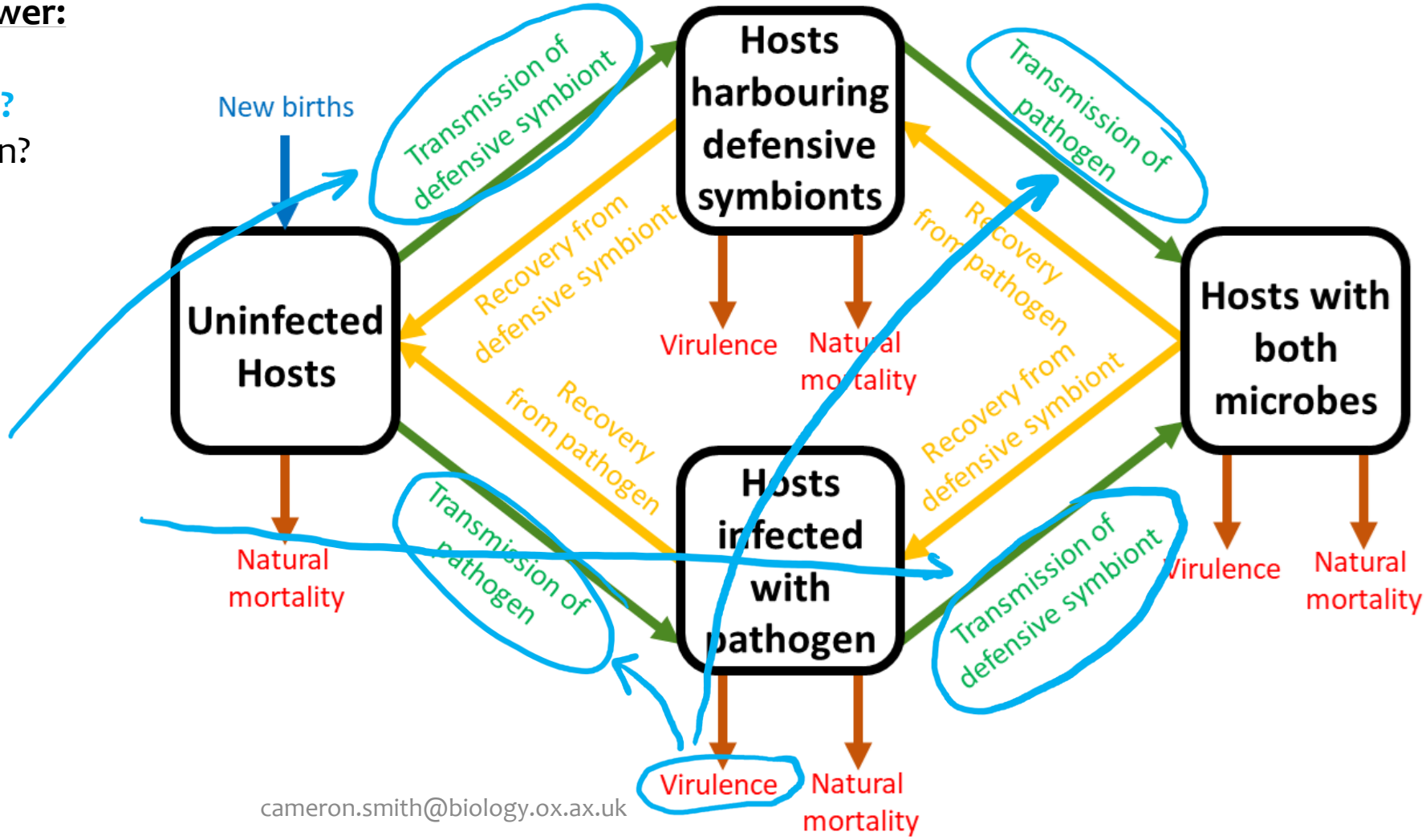

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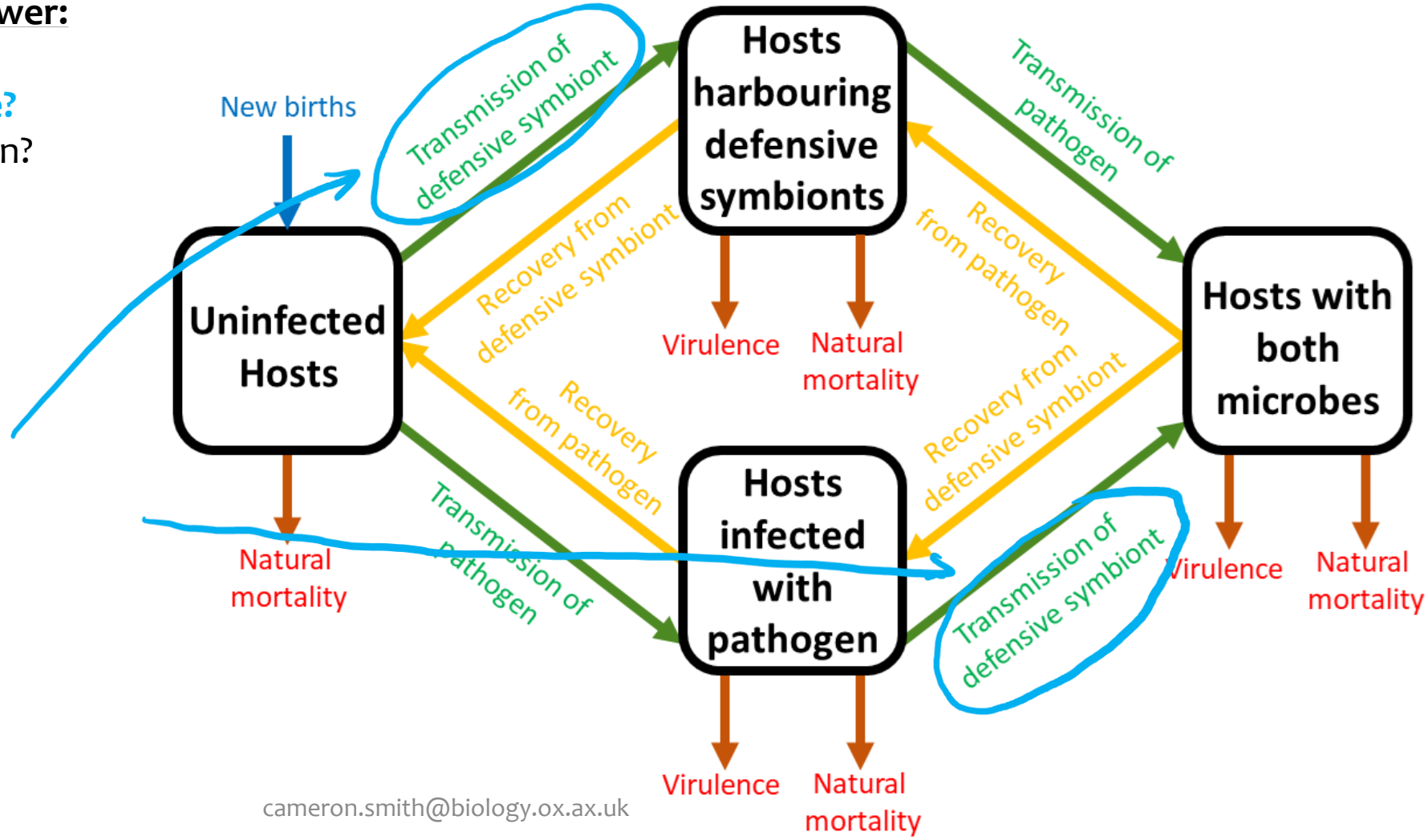

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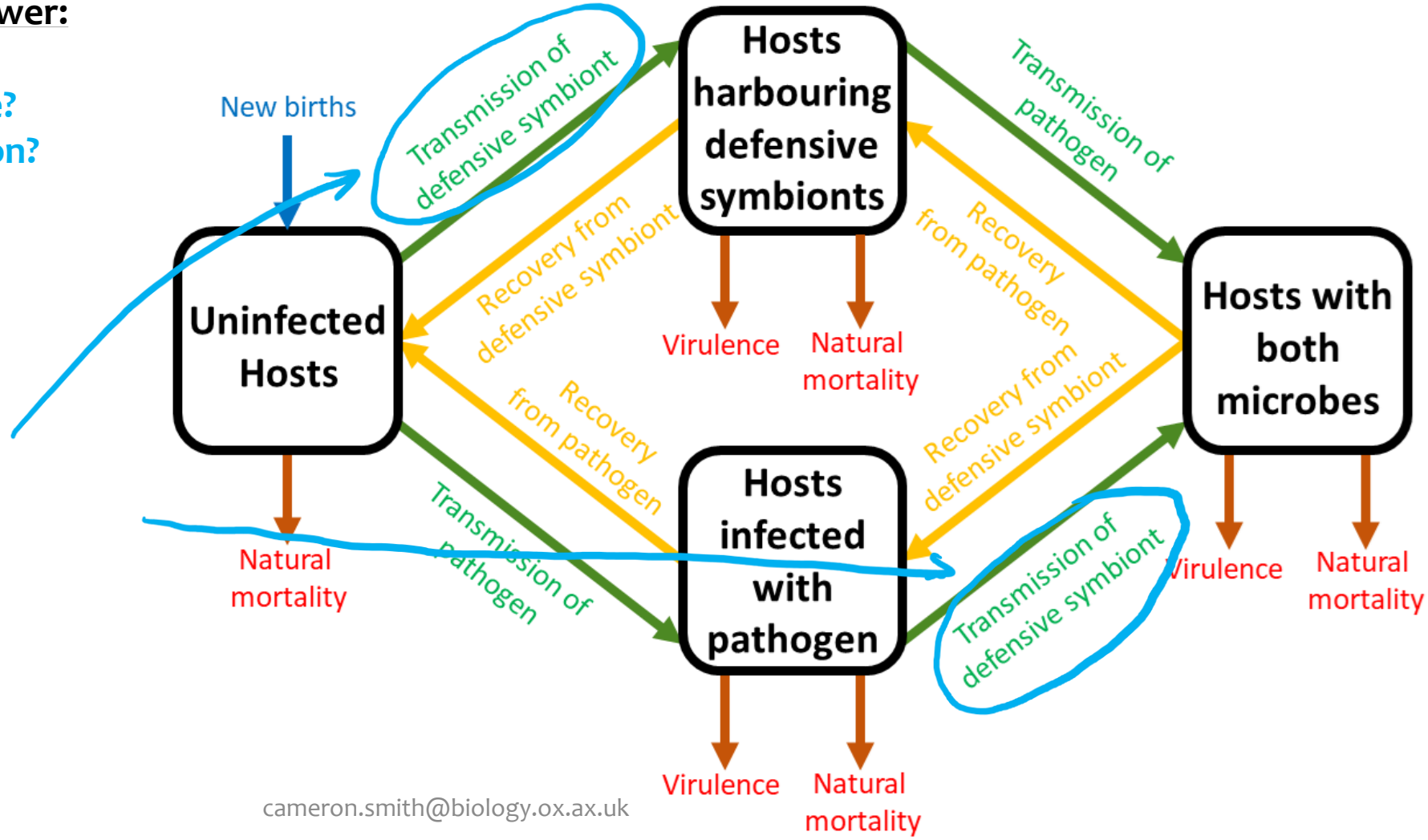

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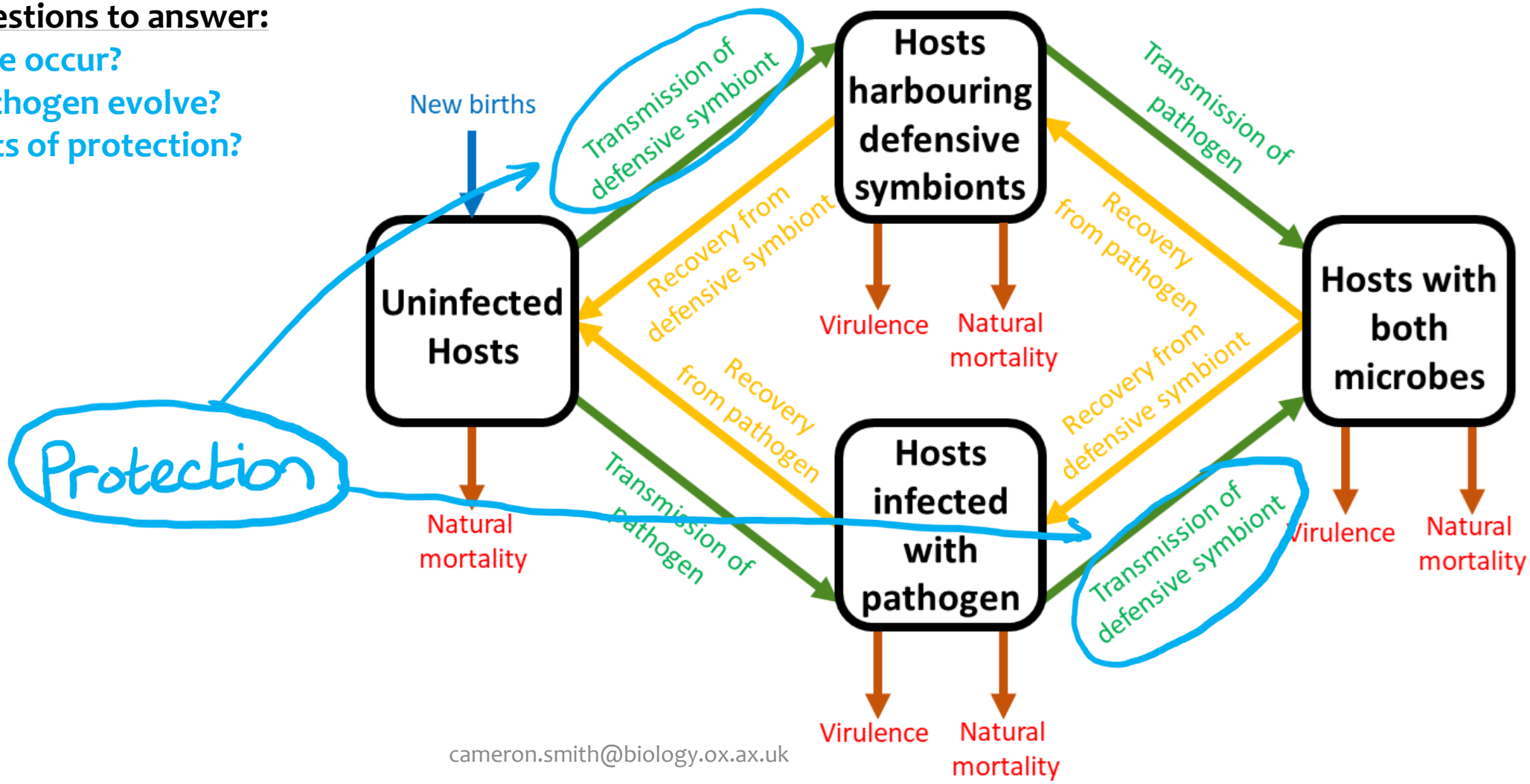

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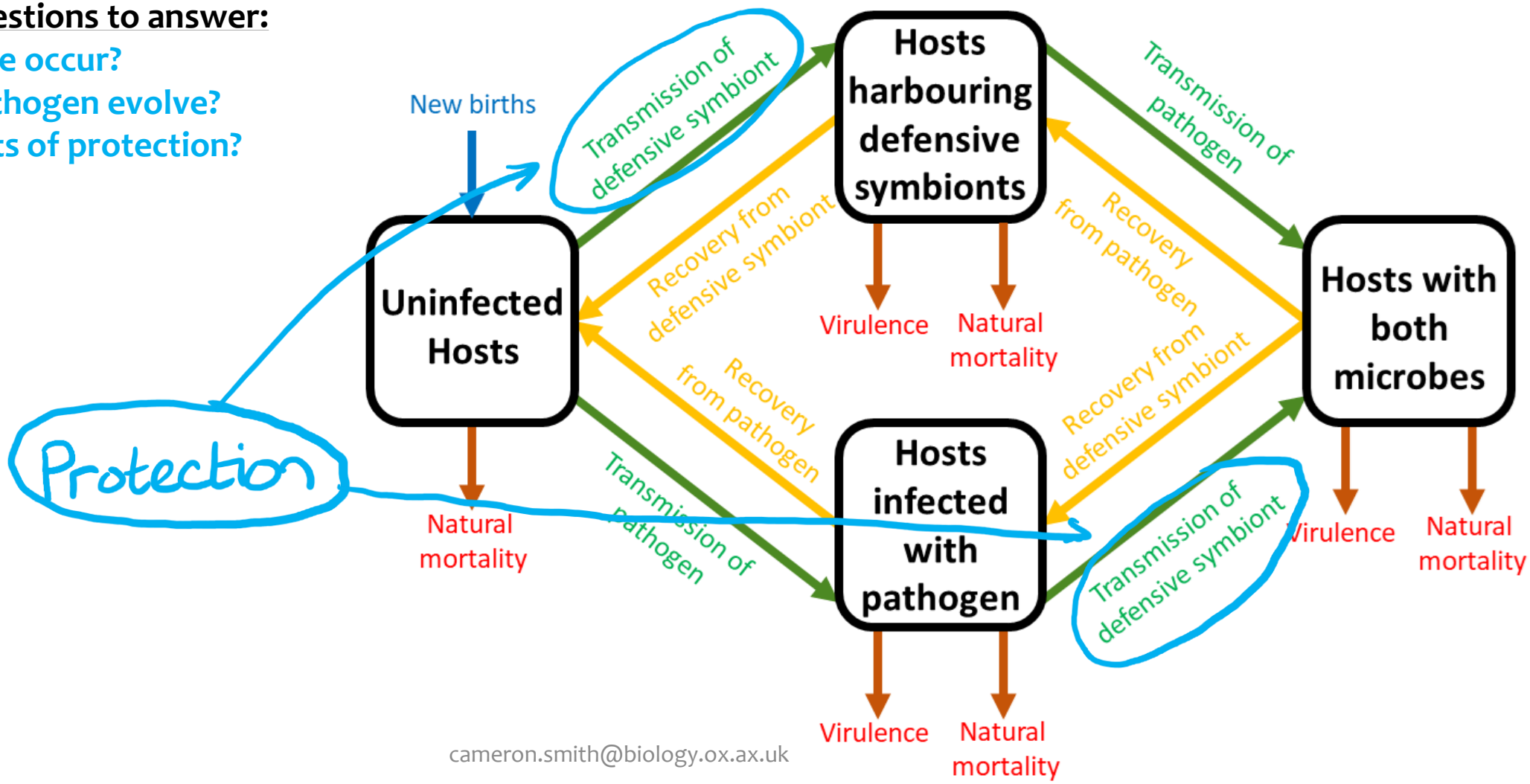

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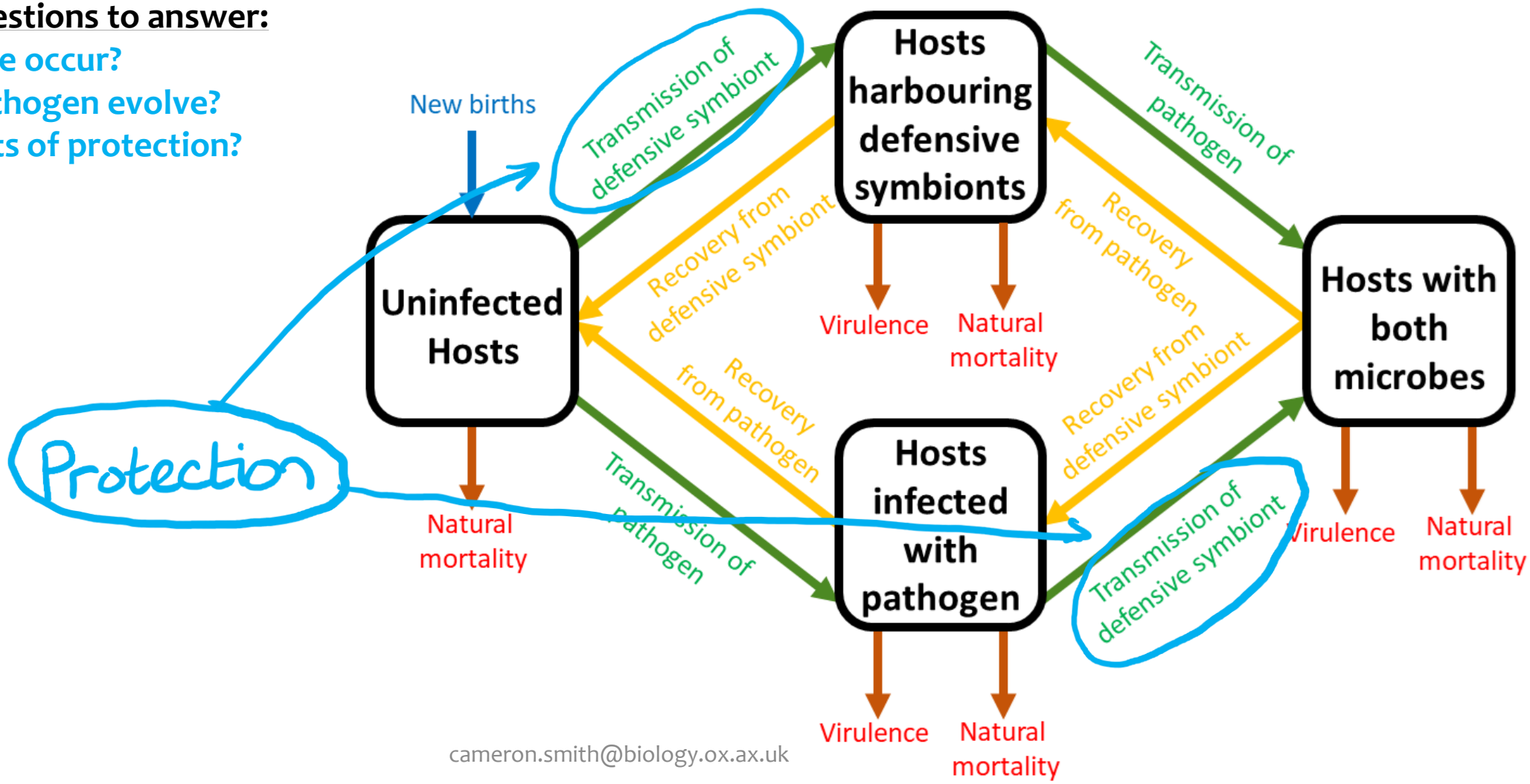

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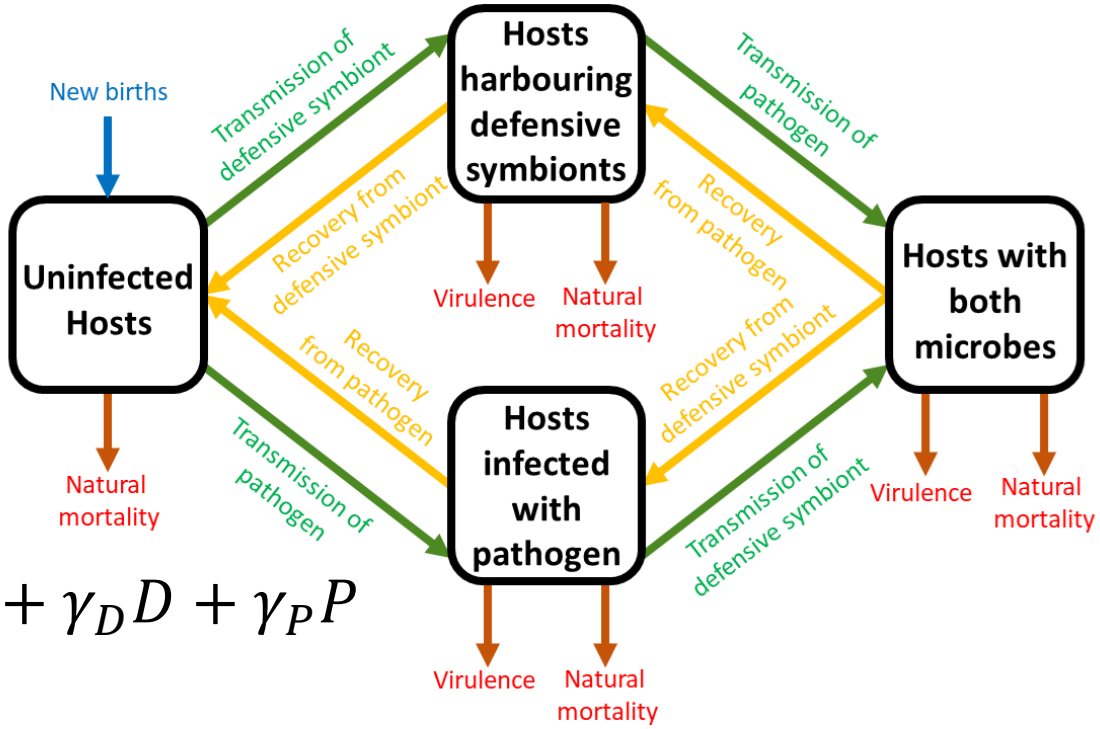

$$\frac{dH}{dt} = \nu(N) - [b + \beta_D(y)(D+B) + \beta_P(P+B)]H + \gamma_D D + \gamma_P P$$

$$\frac{dD}{dt} = \beta_D(y)H(D+B) - [b + \alpha_D + \gamma_D + \beta_P(P+B)]D + \gamma_P B$$

$$\frac{dP}{dt} = \beta_P H(P+B) - [b + \alpha_P(\beta_P) + \gamma_P + \beta_D(y)(D+B)]P + \gamma_D B$$

$$\frac{dB}{dt} = \beta_D(y)P(D+P) + \beta_P D(P+B) - [b + \alpha_D + (1-y)\alpha_P(\beta_P) + \gamma_D + \gamma_P]B$$

Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution		
Effect on host population Coevolution of parasite and symbiont		

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Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution	Evolved virulence increases as protection increases	
Effect on host population Coevolution of parasite and symbiont		

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Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution	Evolved virulence increases as protection increases	Evolved virulence increases as protection increases*
Effect on host population Coevolution of parasite and symbiont		

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Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution	Evolved virulence increases as protection increases	Evolved virulence increases as protection increases*
Effect on host population Coevolution of parasite and symbiont	Always detrimental to the host	

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Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution	Evolved virulence increases as protection increases	Evolved virulence increases as protection increases*
Effect on host population Coevolution of parasite and symbiont	Always detrimental to the host	Can be beneficial to the host

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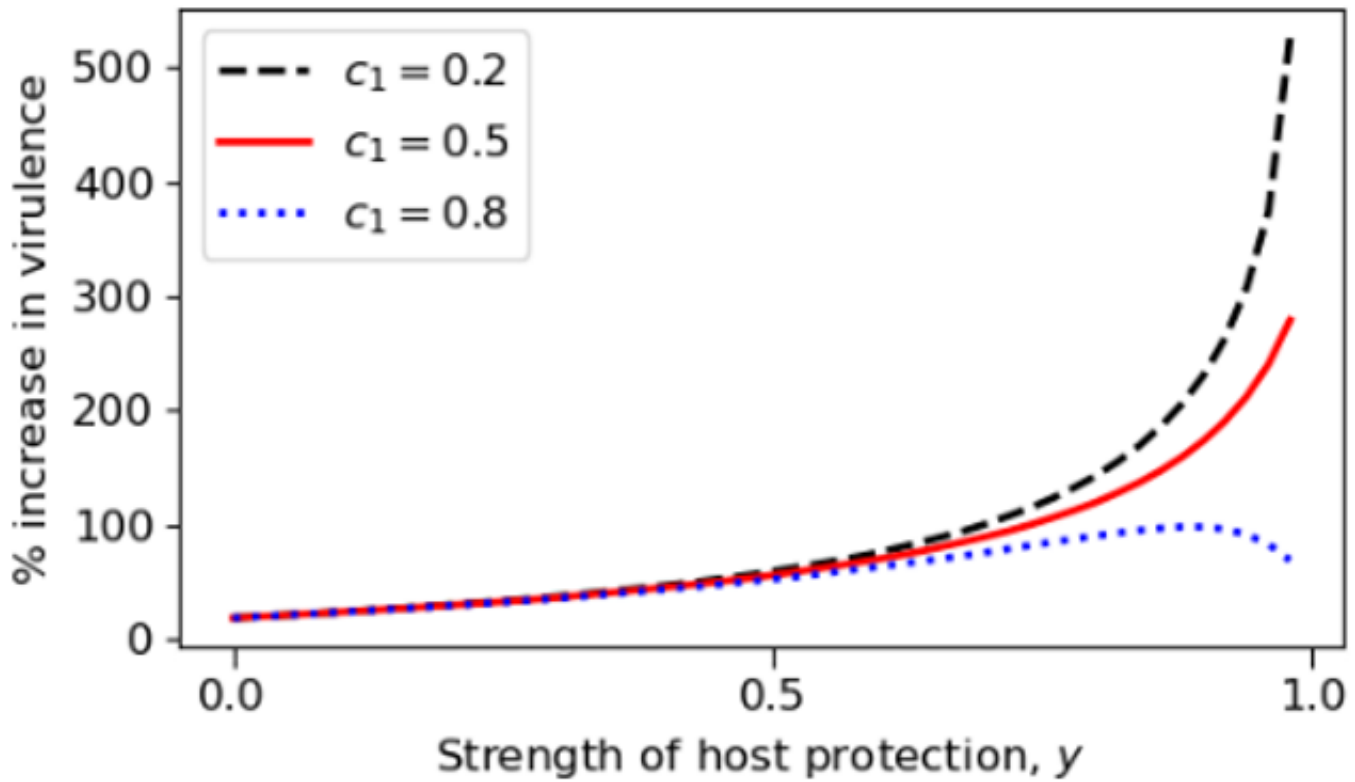
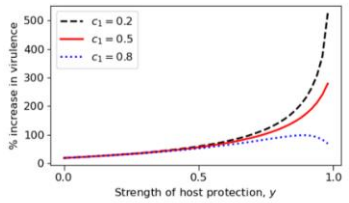

$c_1 = 0.2$
$c_1 = 0.5$
$c_1 = 0.8$
% increase in virulence
500
400
300
200
100
0
0.0
0.5
1.0
Strength of host protection, y

Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution		Evolved virulence increases as protection increases*
Effect on host population Coevolution of parasite and symbiont	Always detrimental to the host	Can be beneficial to the host

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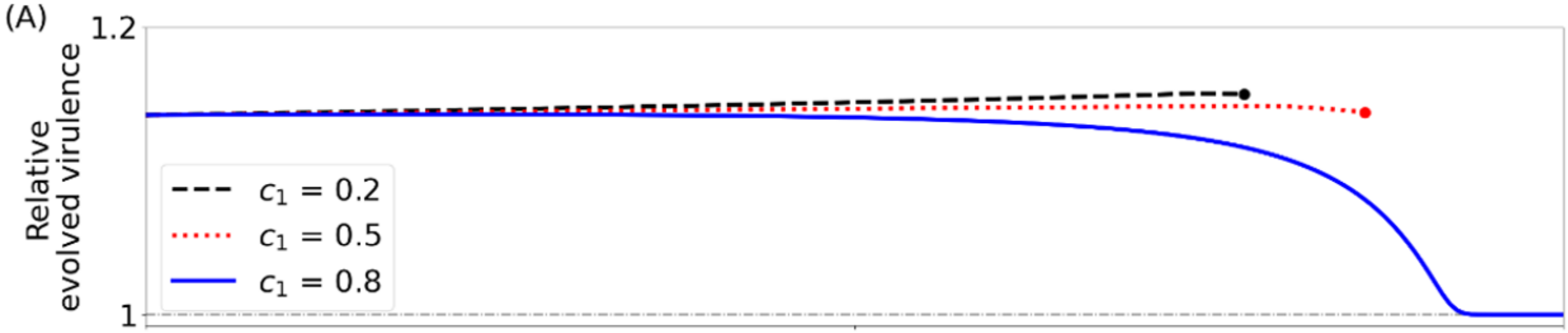
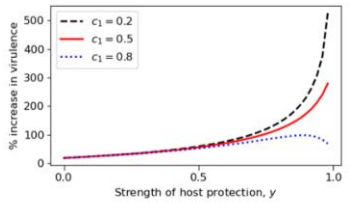

(A)
1.2
1
Relative evolved virulence
$c_1 = 0.2$
$c_1 = 0.5$
$c_1 = 0.8$

Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution		
Effect on host population Coevolution of parasite and symbiont	Always detrimental to the host	Can be beneficial to the host

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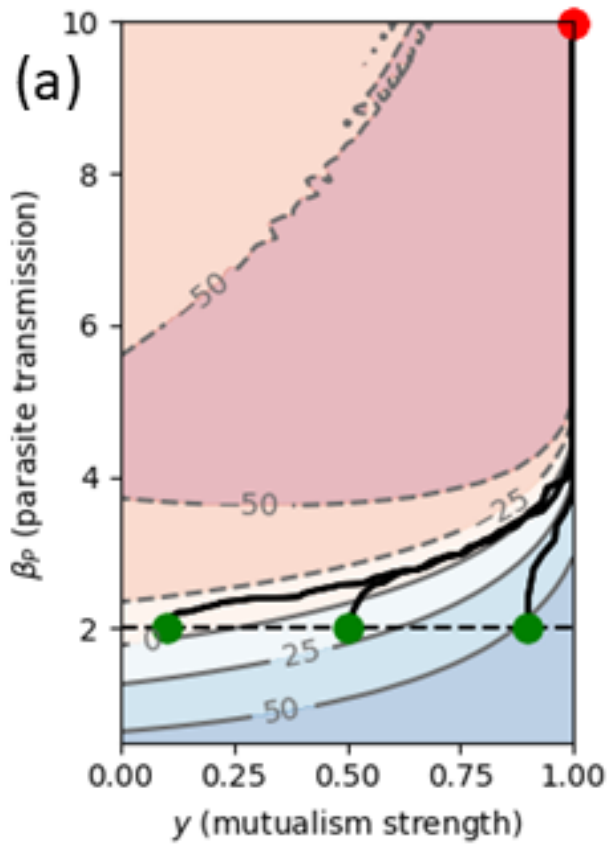
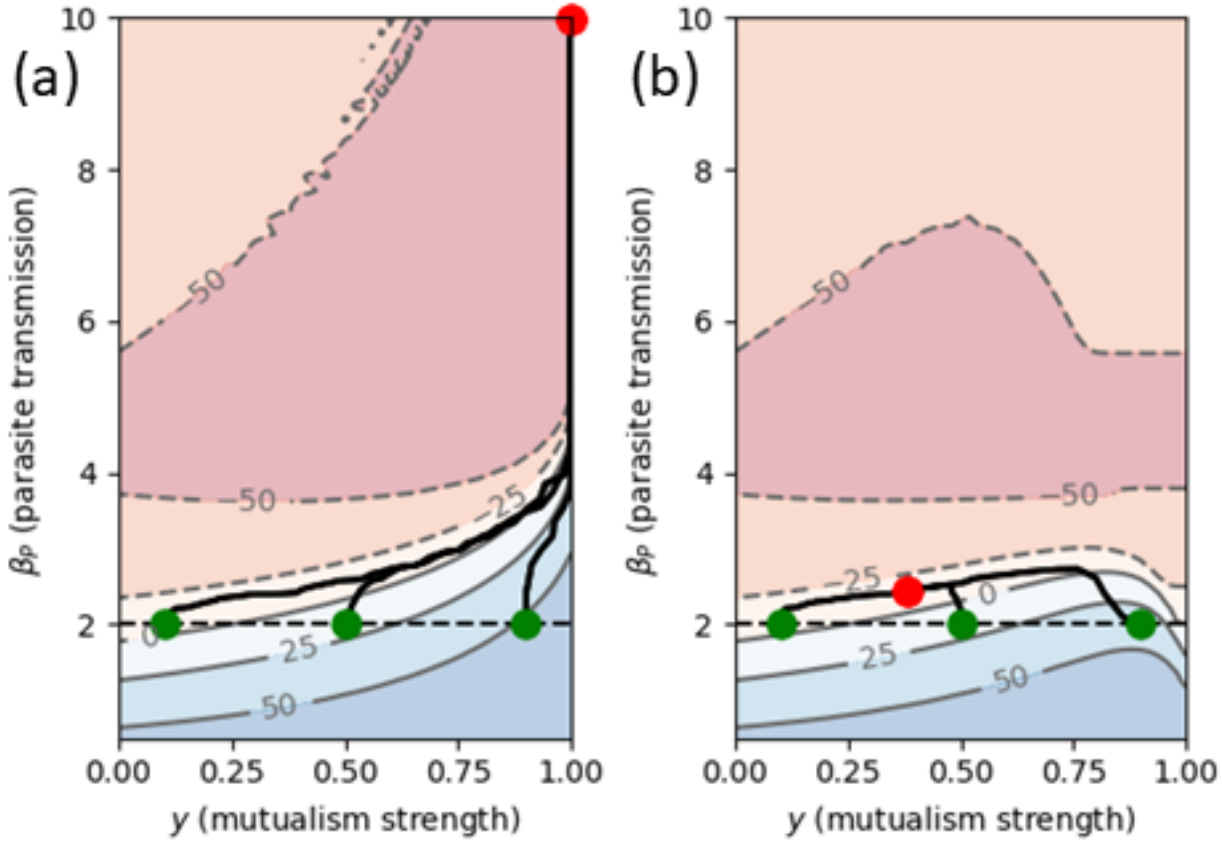
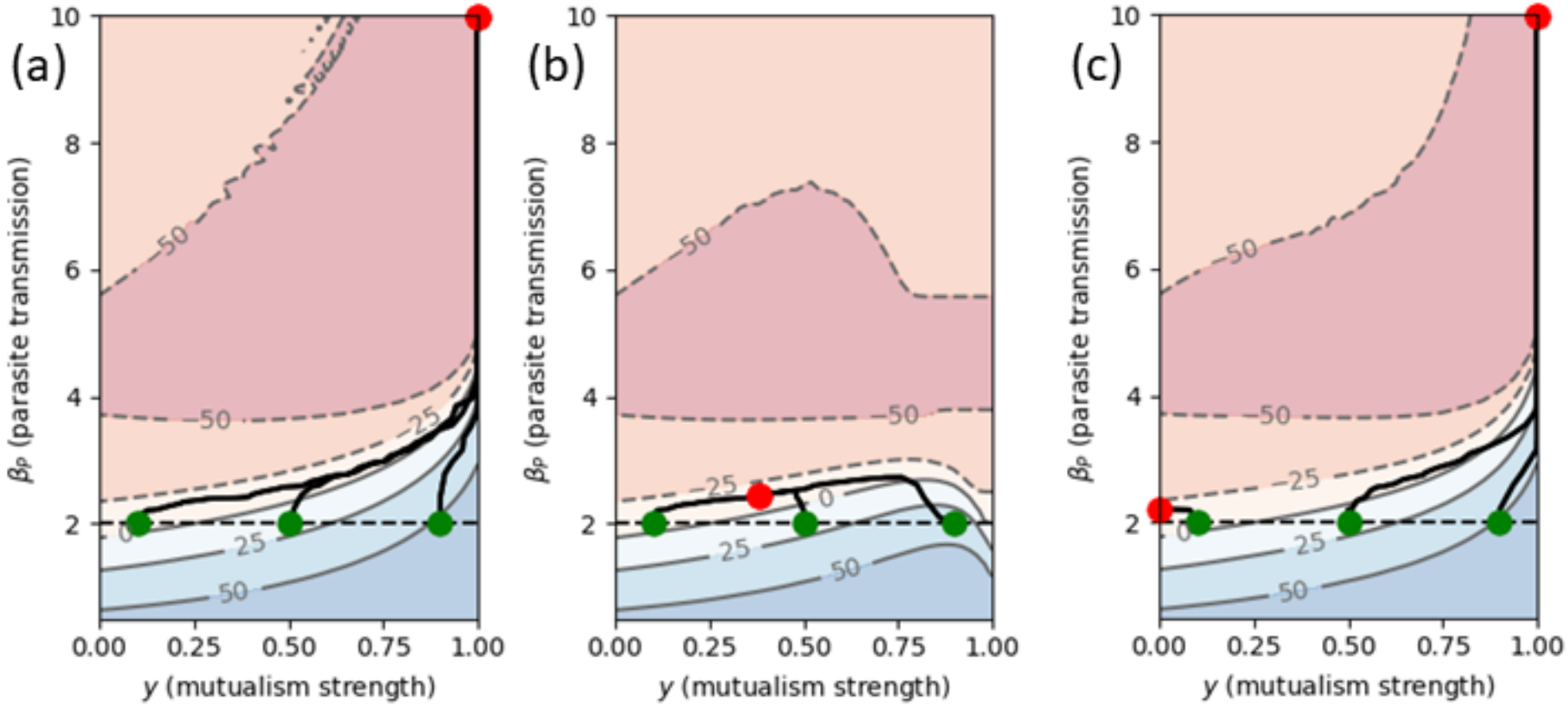
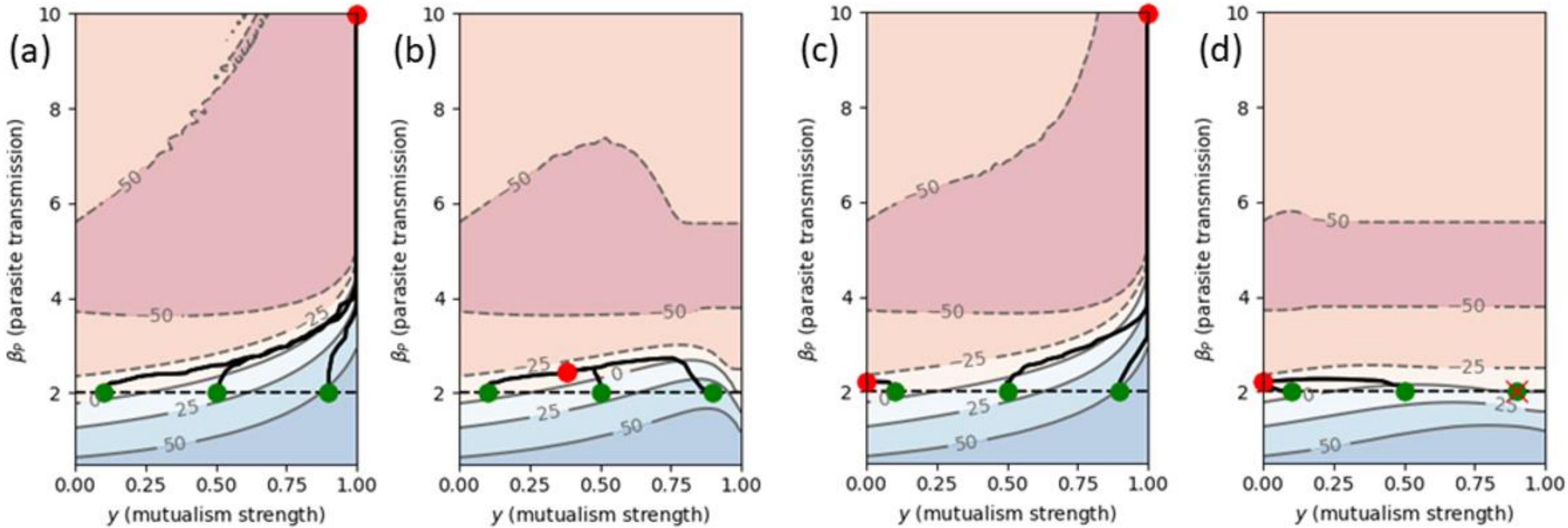
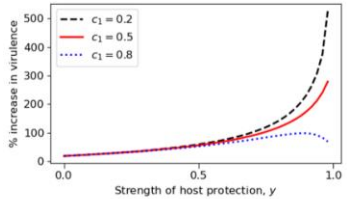
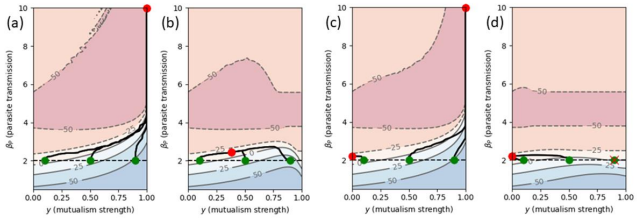

(a)
10
8
6
4
2
β_P (parasite transmission)
50
50
25
0
25
50
0.00
0.25
0.50
0.75
1.00
y (mutualism strength)


(a)
(b)
10
8
6
4
2
β_P (parasite transmission)
0.00
0.25
0.50
0.75
1.00
y (mutualism strength)
50
50
25
0
25
50
50
25
0
25
50


(a)
(b)
(c)
10
8
6
4
2
β_P (parasite transmission)
0.00
0.25
0.50
0.75
1.00
y (mutualism strength)
50
25
0


(a)
(b)
(c)
(d)
β_P (parasite transmission)
y (mutualism strength)
10
8
6
4
2
0.00
0.25
0.50
0.75
1.00
50
25
0

Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution		
Effect on host population Coevolution of parasite and symbiont		Can be beneficial to the host

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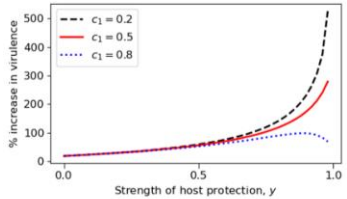
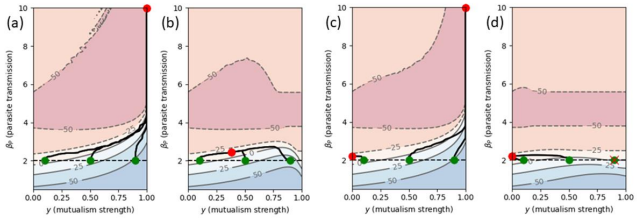
	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution		
Effect on host population Coevolution of parasite and symbiont		Can be beneficial to the host

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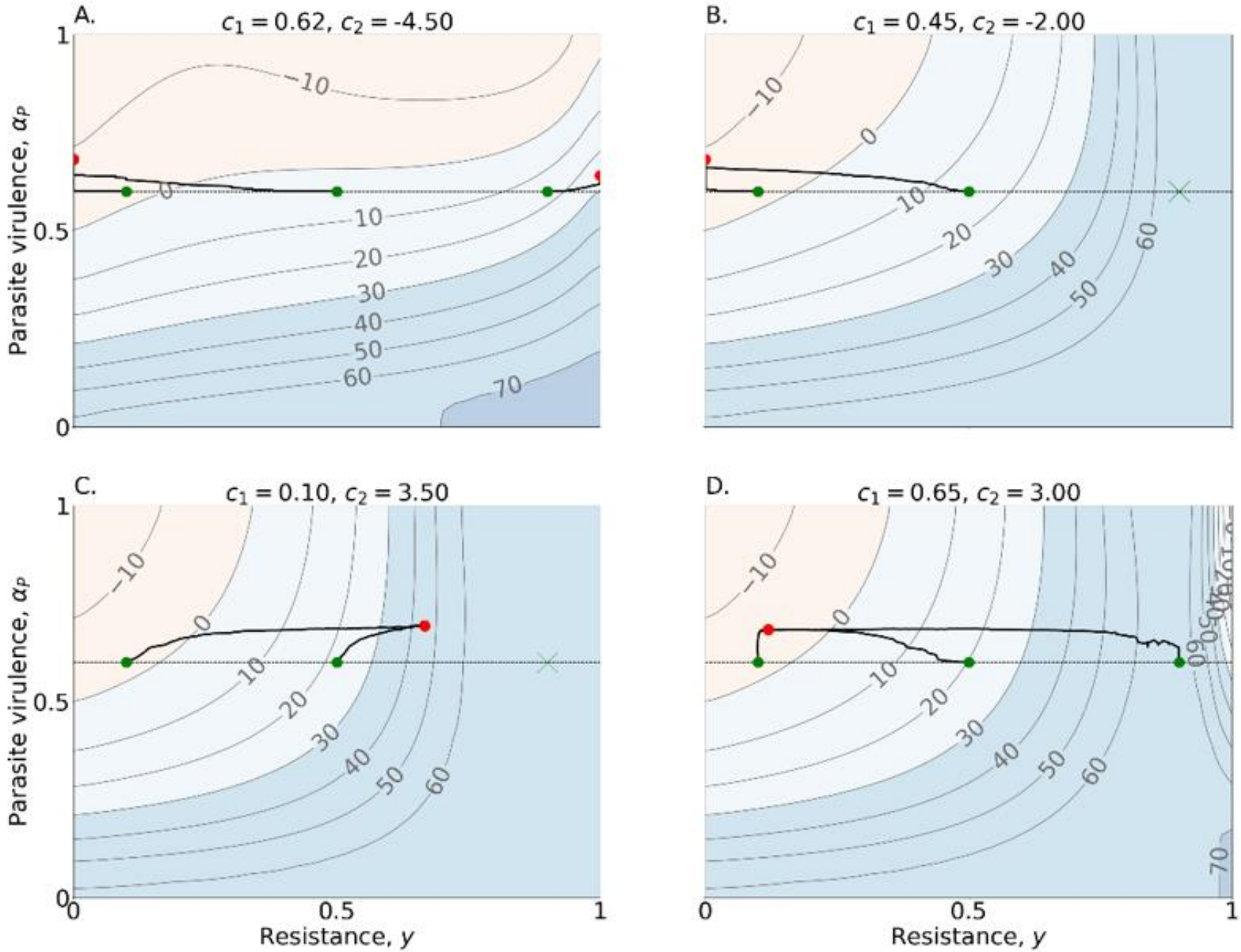
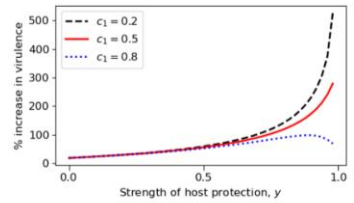
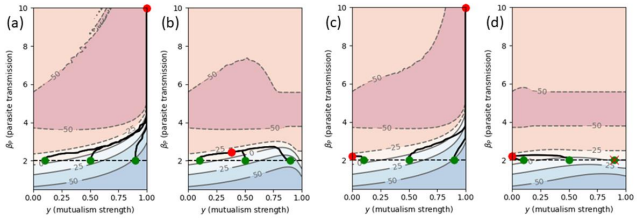
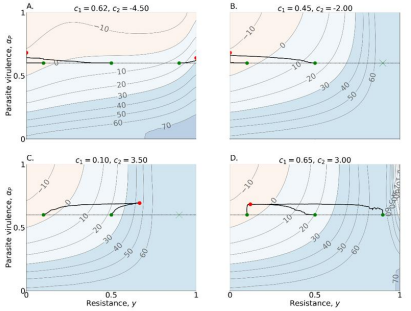

A.
$c_1 = 0.62$, $c_2 = -4.50$
B.
$c_1 = 0.45$, $c_2 = -2.00$
C.
$c_1 = 0.10$, $c_2 = 3.50$
D.
$c_1 = 0.65$, $c_2 = 3.00$
Parasite virulence, α_P
Resistance, y
0
0.5
1
−10
0
10
20
30
40
50
60
70

Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Effect on parasite virulence Only parasite evolution		
Effect on host population Coevolution of parasite and symbiont		

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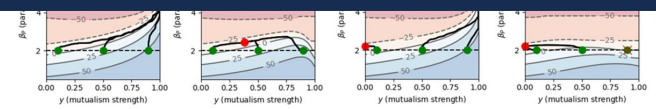
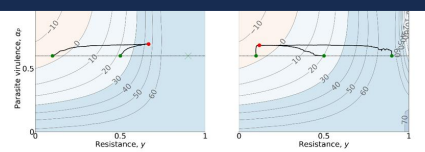
Results

	Tolerance Reduction of harmful effects	**Resistance** Reduction in transmissibility
Coevolution of parasite and symbiont		

Question: Can defensive symbionts be used as a biocontrol against parasitic infections?

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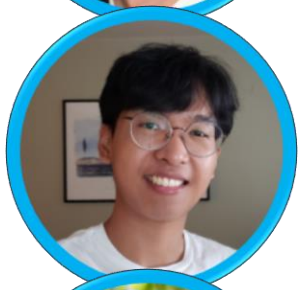
Thank you!

Tolerance-conferring defensive symbionts and the evolution of parasite virulence
C.A. Smith and B. Ashby
Evolution Letters, 2023

Ben Ashby

Simon Fraser University

eco-evo theory



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