Webinar: Costs and Benefits of Defending against Viral Infection: Lessons from Natural Ecosystems

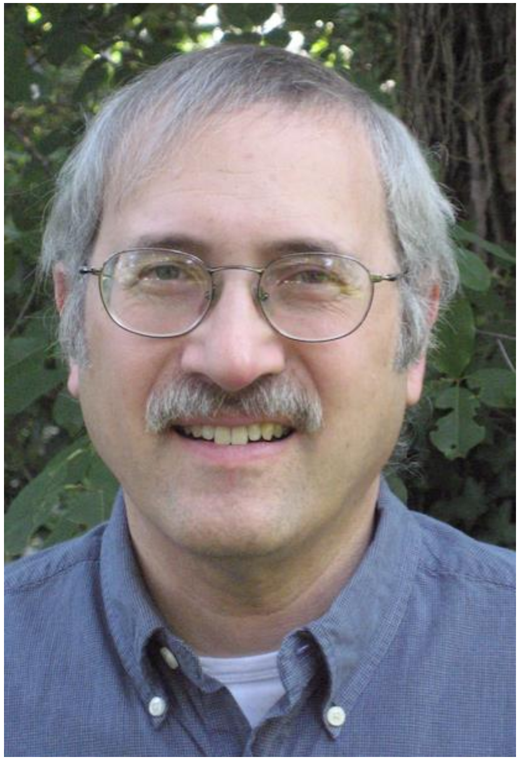
Presented by:

Professor David Talmy

National Institute for Mathematical and Biological Synthesis, University of Tennessee, Knoxville

With support from the National Science Foundation (DBI-1300426)

MEET YOUR MODERATOR



Louis J. Gross, PhD

Director, *National Institute for Mathematical and Biological Synthesis (NIMBioS)*

Director,*, The Institute for Environmental Modeling, University of Tennessee*

Chancellor's Professor *of Ecology and Evolutionary Biology and Mathematics, University of Tennessee*

NIMBioS
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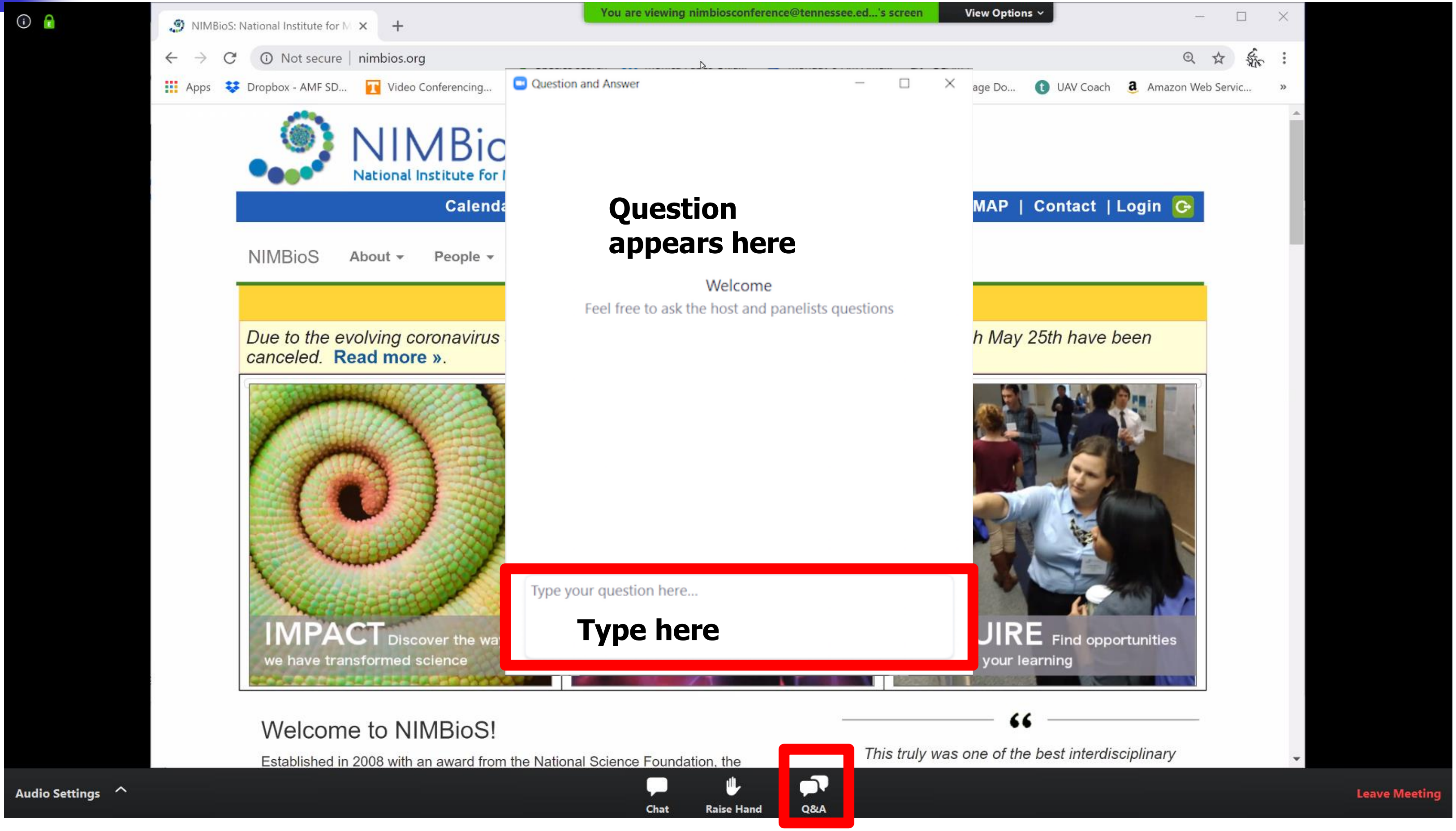
HOW TO INTERACT TODAY



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NIMBioS Webinar Series

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Upcoming Webinars

Modeling for a Globally Connected World: What Models are Good for and How they Work

Date: 3:30 EDT Tuesday, April 14, 2020

Speaker: Dr. Louis Gross, NIMBioS Director and Chancellor's Professor of Ecology and Evolutionary Biology and Mathematics at the University of Tennessee

Moderator: Dr. Suzanne Lenhart, NIMBioS Associate Director and Chancellor's Professor of Mathematics at the University of Tennessee

Abstract: Policies for the COVID-19 pandemic response have relied upon models of various types to project future trends and assess the potential impacts of alternative amelioration strategies. I invite you to join us for basic overviews of the process of modeling, the "art" of model construction, and the array of different kinds of approaches (mathematical, computational, and graphical) that are applied in the life sciences. The presentation is designed for a general audience without modeling background.

Dr. Lou ... areas of
ecolog ... change and the
develop ... ronmental
Modeli

Regist

NIMBioS.org/Webinars A recording of each webinar will be posted

MEET YOUR PRESENTER

David Talmy, PhD

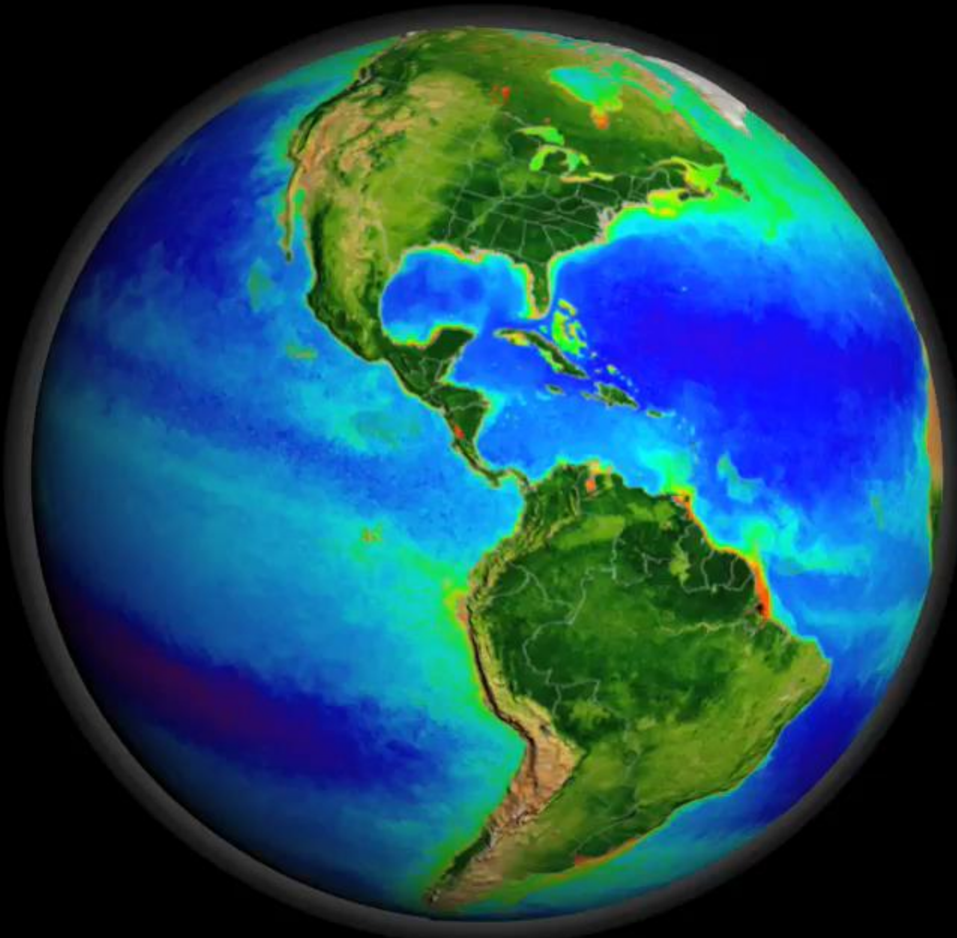
***Assistant Professor** of Microbiology, University of Tennessee*

***Adjunct Assistant Professor of** Ecology and Evolutionary Biology**,** University of Tennessee*

National Institute for Mathematical and Biological Synthesis

Costs and Benefits of defending against viral infection: Lessons from nature

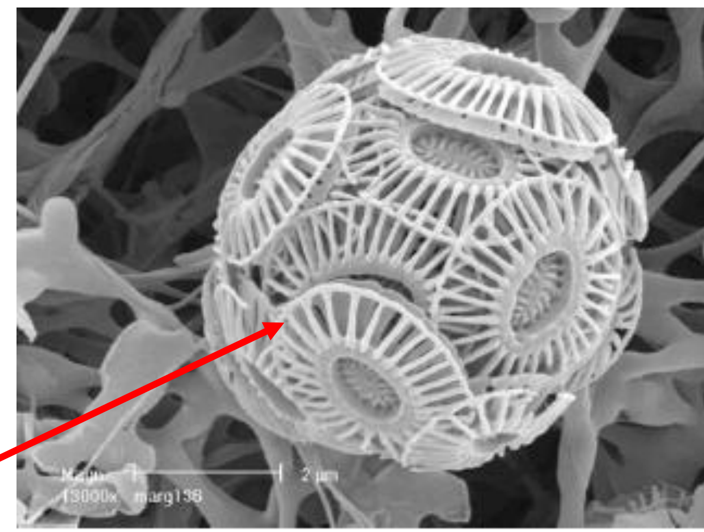
1) Viruses are extremely widespread in nature
2) All living organisms must balance the costs and benefits of defending against viral predation
3) Balancing costs and benefits of defending against viral infection has profoundly influenced natural ecosystems



False color chlorophyll from SeaWiFS satellite
(*https://svs.gsfc.nasa.gov/3450*)

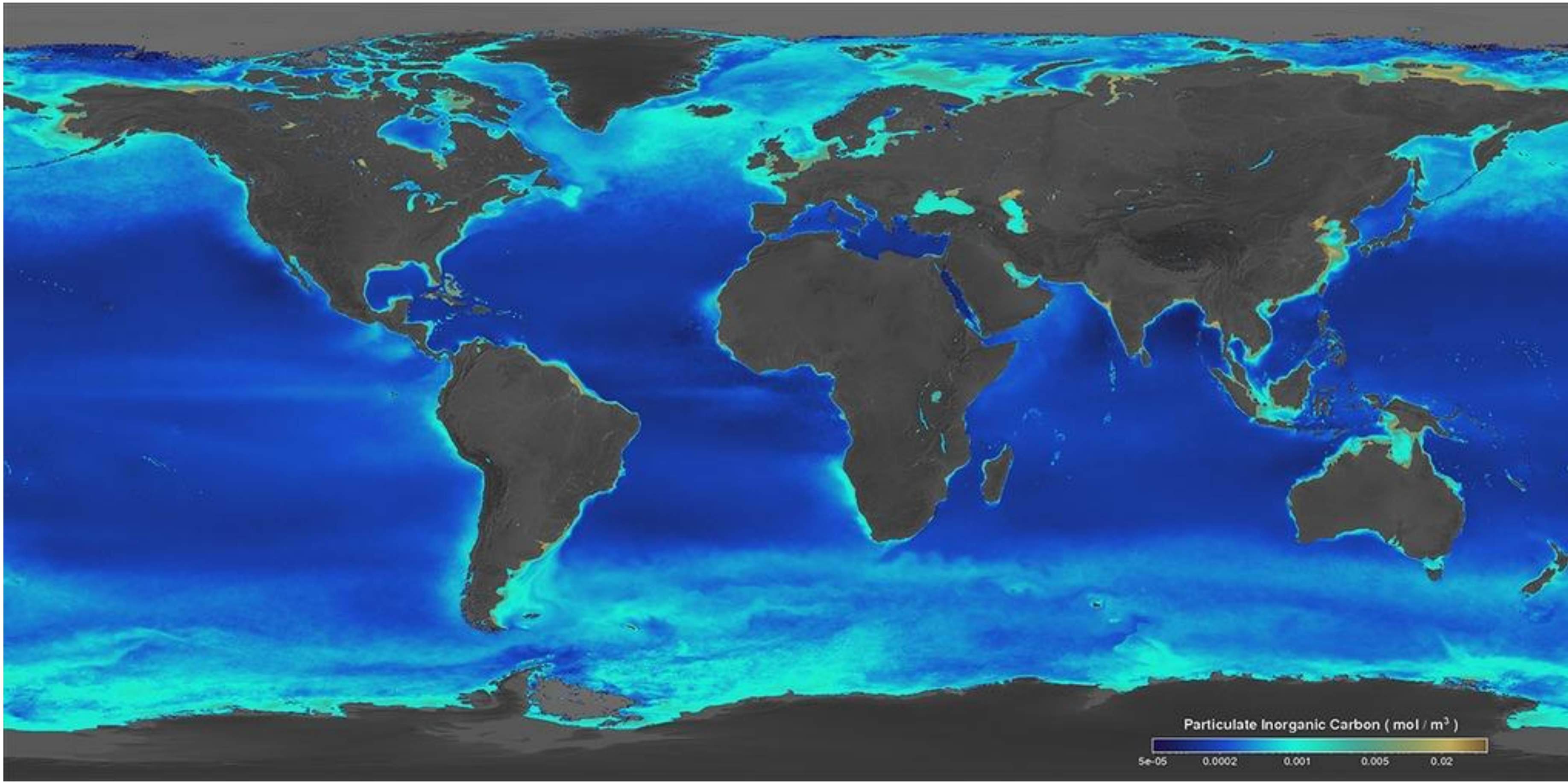
Plankton such as the coccolithophore *Emiliania huxleyi* have shaped Earth

- Photosynthetic single-celled organism
- Abundant in the surface ocean
- Forms calcium carbonate 'coccoliths' (disks on surface)

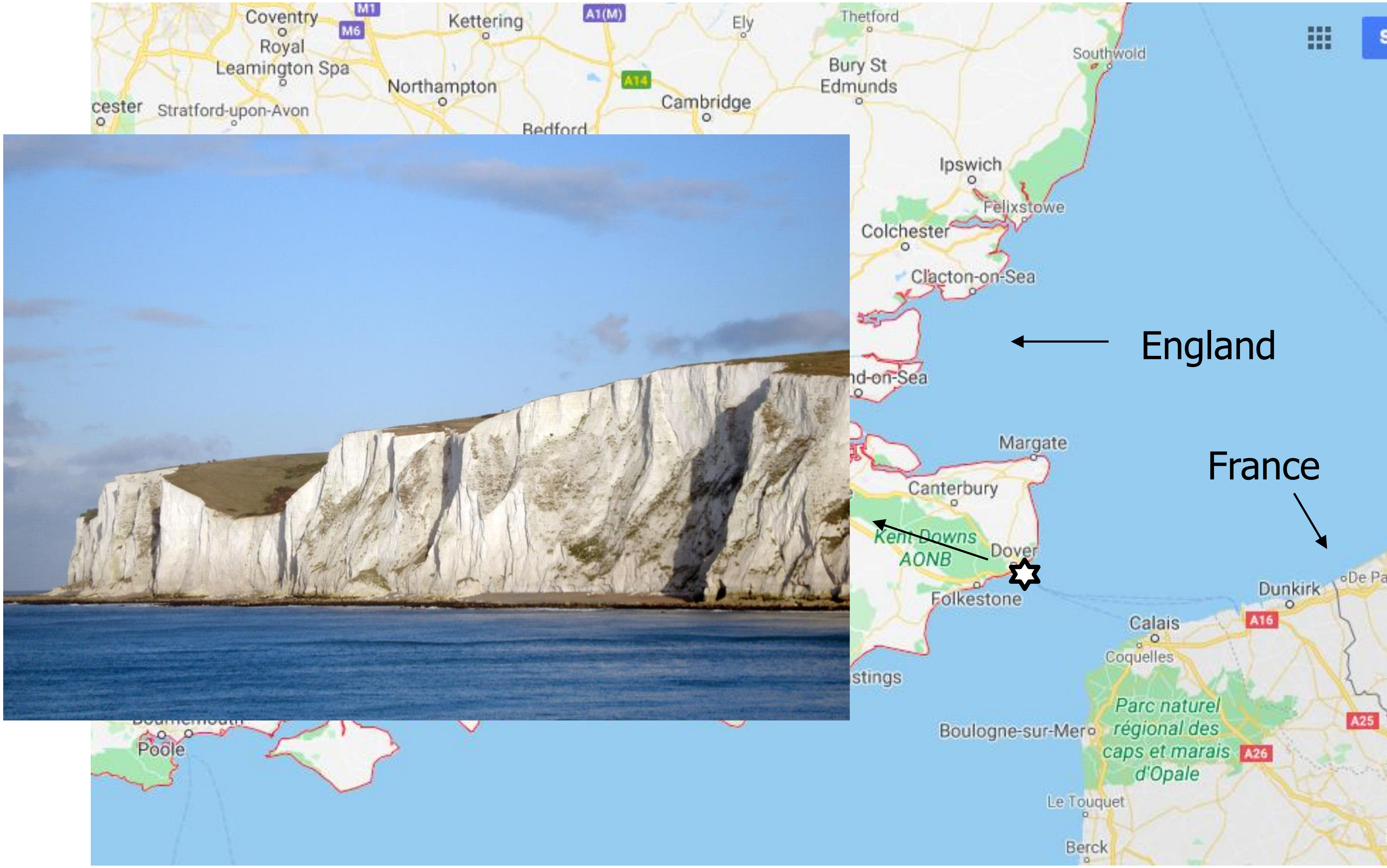


5 μm
(5 millionths of a meter)
(5 thousandths of a mm)

Calcium carbonate (often from coccoliths) is widespread in the modern ocean



Particulate inorganic carbon (PIC):
https://svs.gsfc.nasa.gov/30512

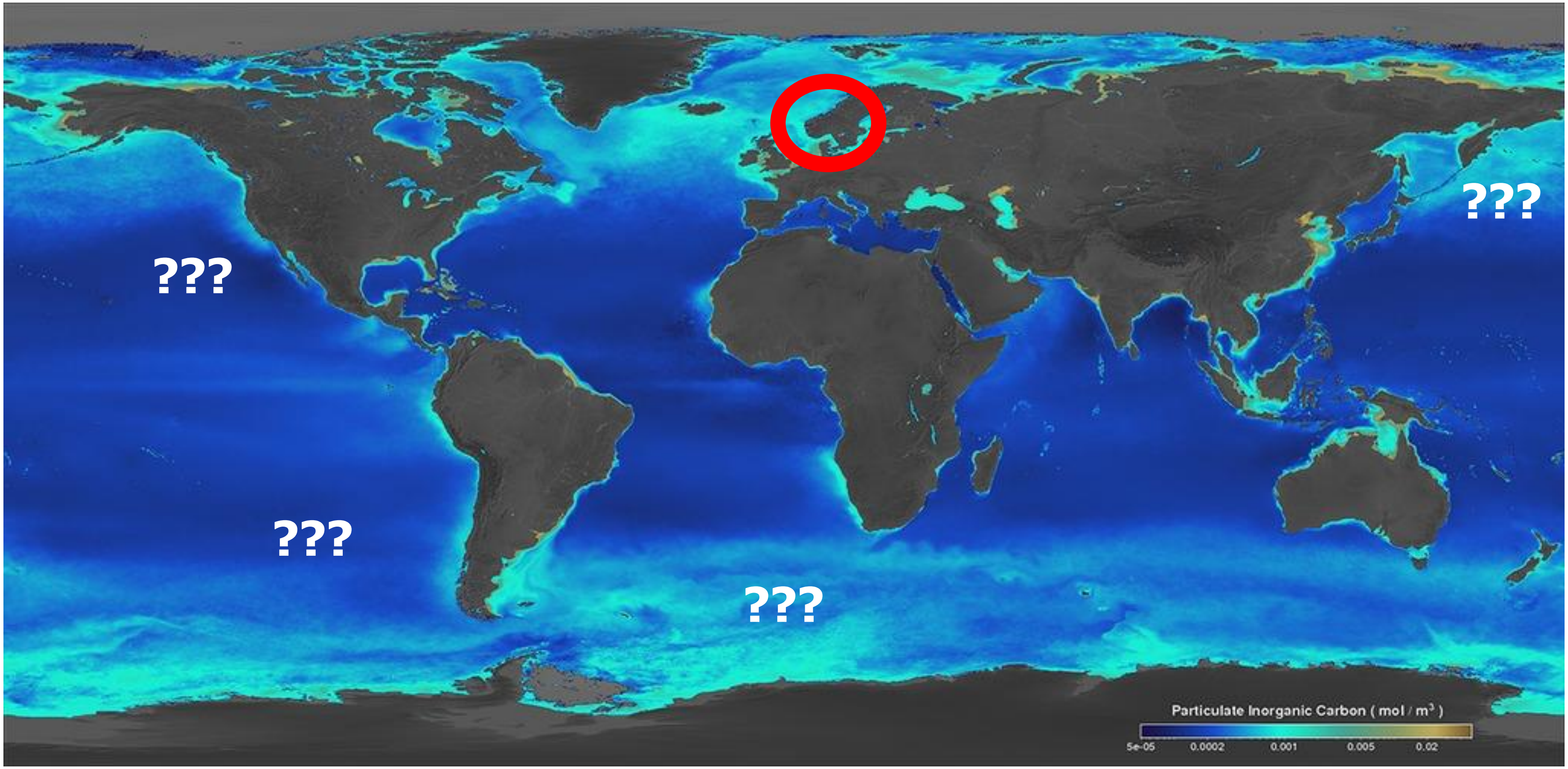

England
France
Coventry
Kettering
Ely
Thetford
Royal Leamington Spa
Northampton
Cambridge
Bury St Edmunds
Southwold
Stratford-upon-Avon
Bedford
Ipswich
Felixstowe
Colchester
Clacton-on-Sea
Margate
Canterbury
Kent Downs AONB
Dover
Folkestone
Dunkirk
Calais
Coquelles
Parc naturel régional des caps et marais d'Opale
Boulogne-sur-Mer
Le Touquet
Berck
Poole
A16
A25
A26
A14
M1
M6
A1(M)

EhV
(Emiliania huxleyi Virus)
and other predators

Infect and kill *E. huxleyi*

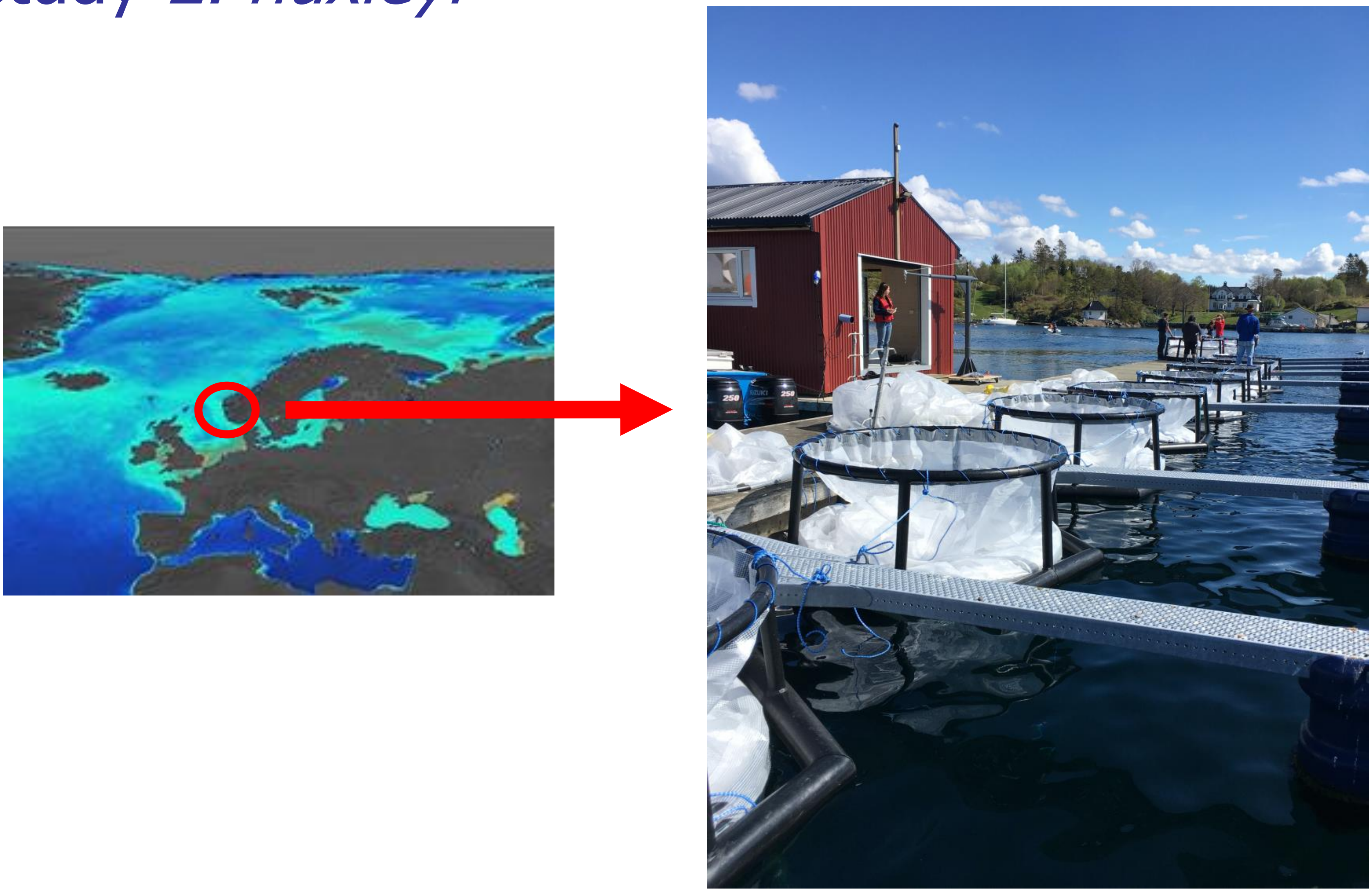
Heavy calcium carbonate in the outer shell sinks to the seafloor

Are there 'outbreaks' of viruses throughout the oceans?



https://svs.gsfc.nasa.gov/30512

Norwegian Fjord near Bergen is a great place to study *E. huxleyi*



Mesocosm ('middle-world')

Study *E. huxleyi* and their viruses in nature

https://fjordphytoplankton.wordpress.com

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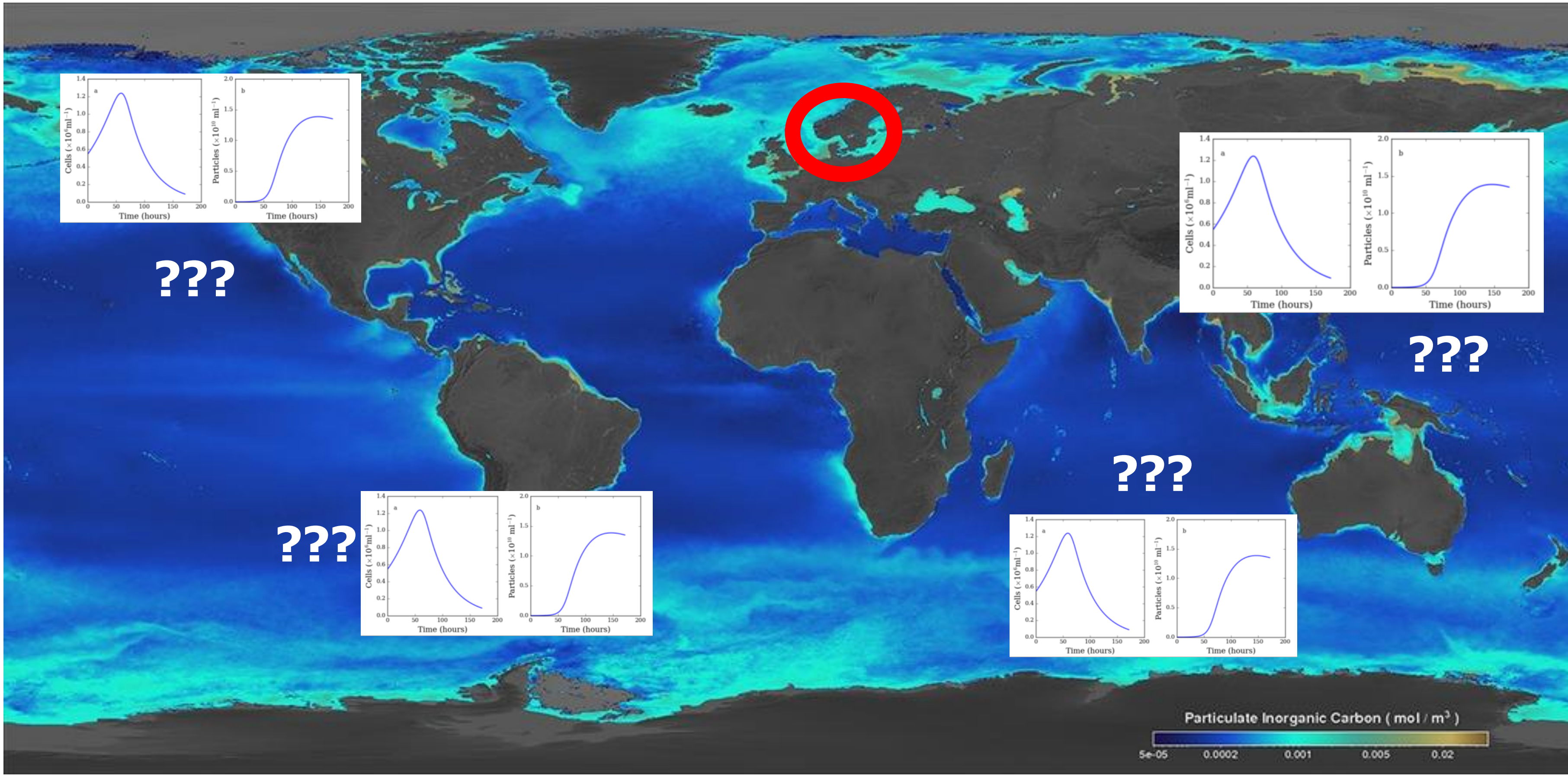

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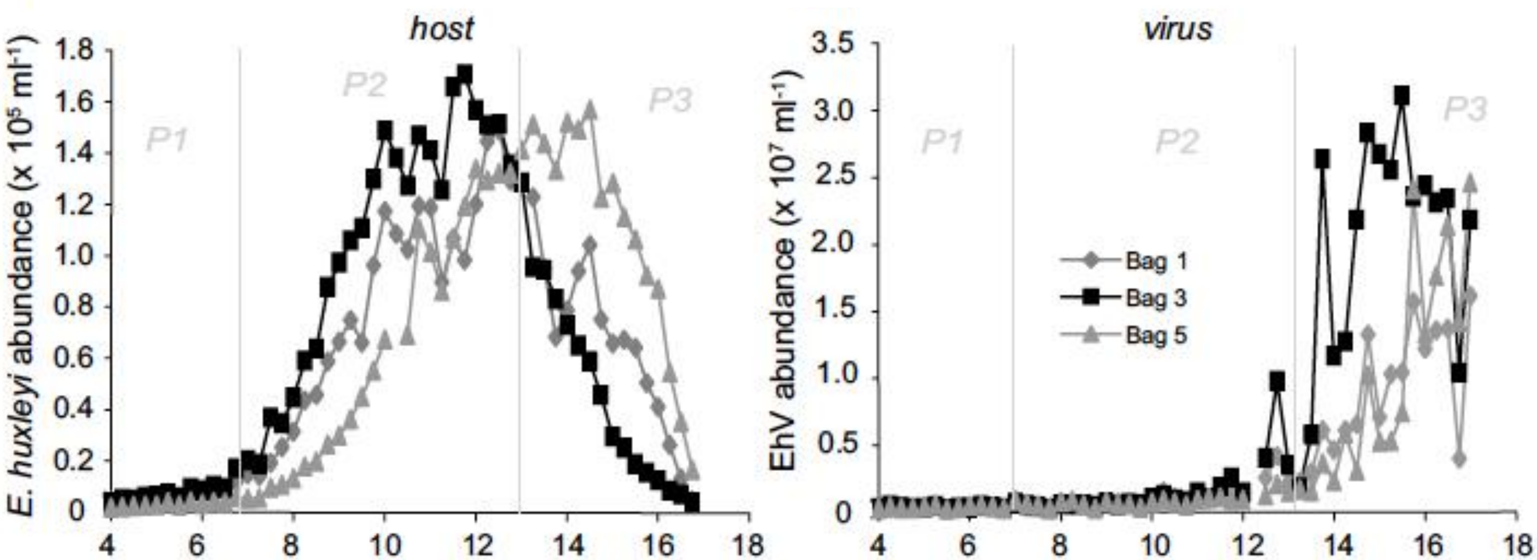
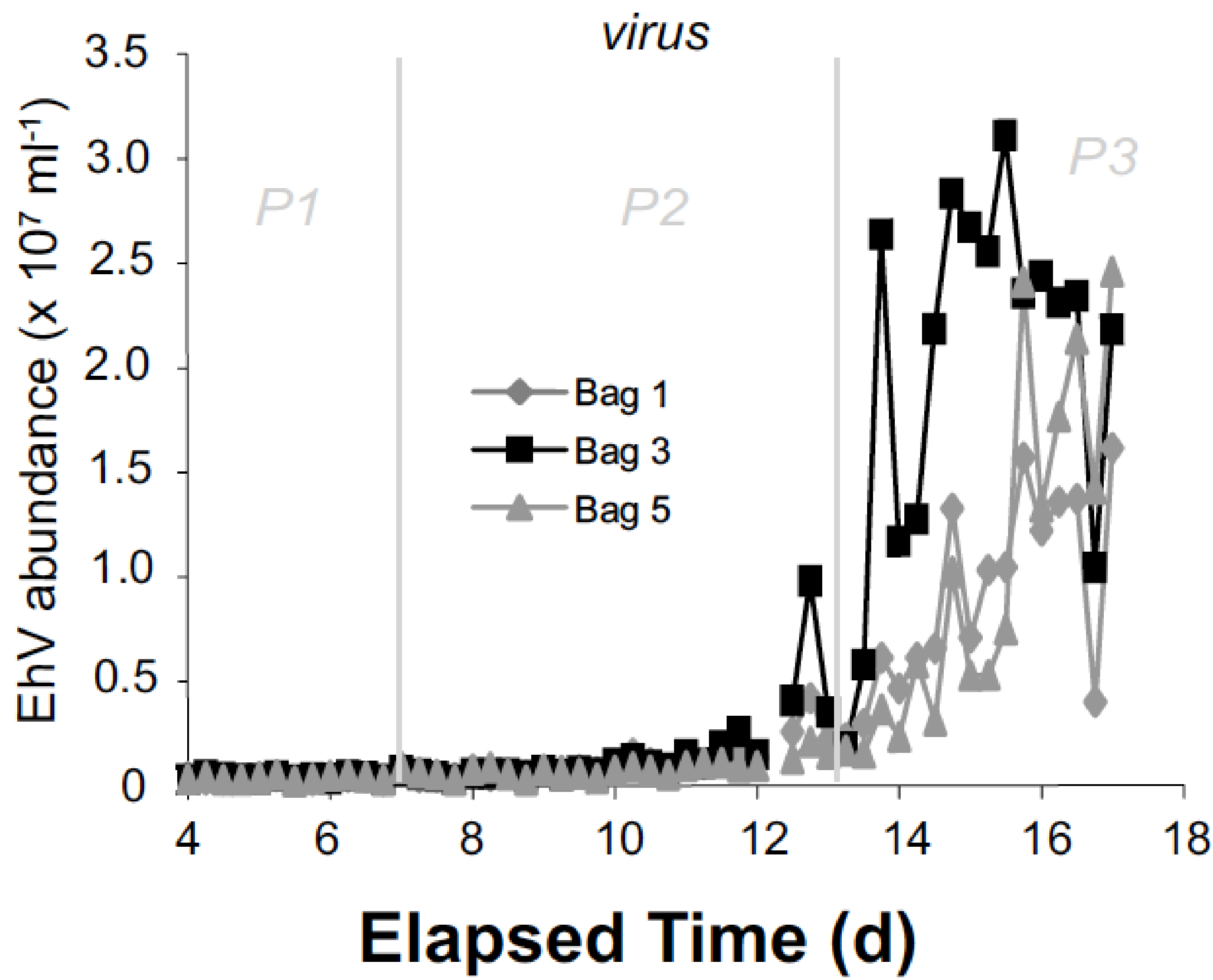


Elapsed Time (d)

Vardi et al., 2012

A virus ‘outbreak’ in a Norwegian Fjord…



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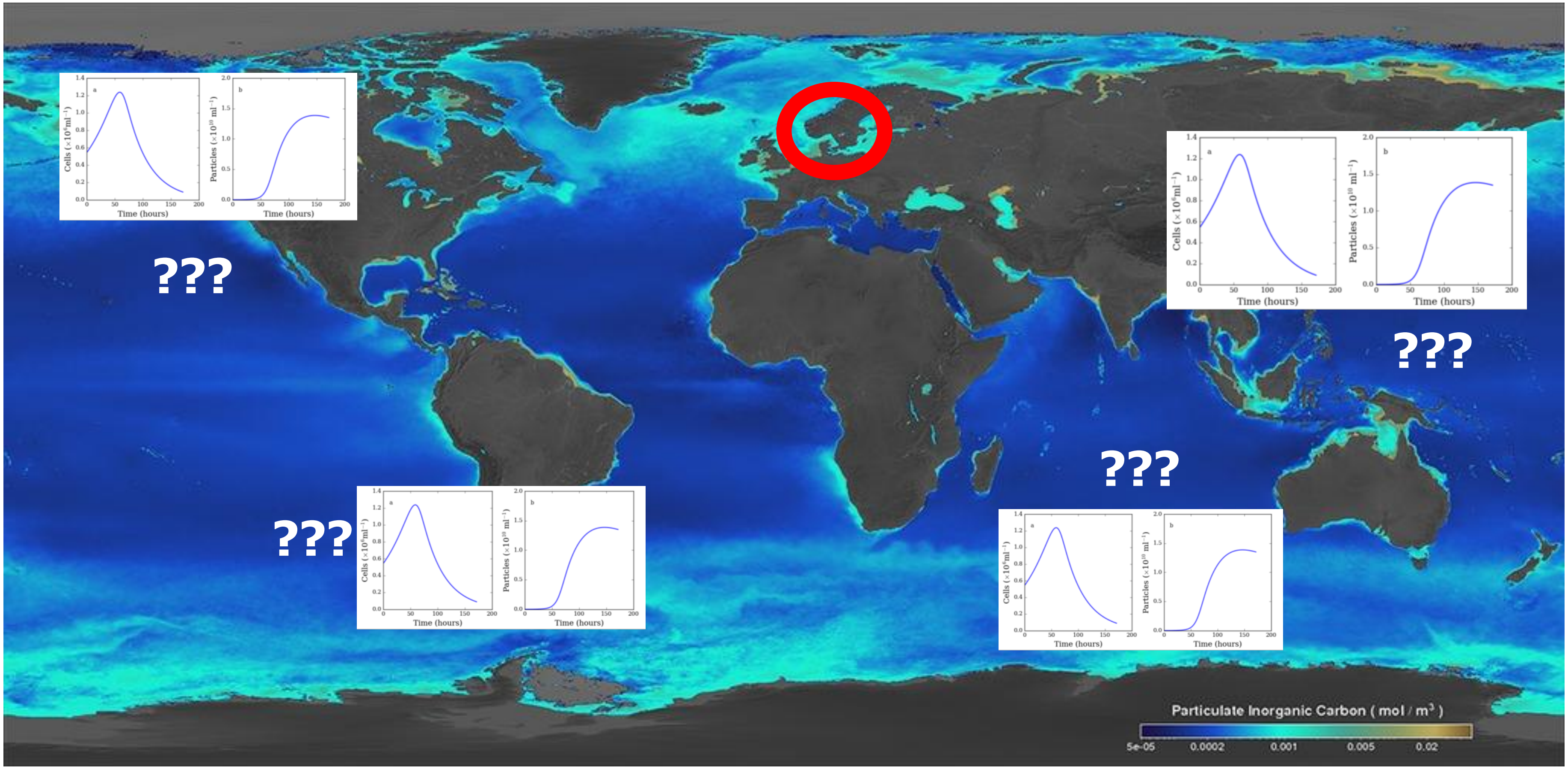
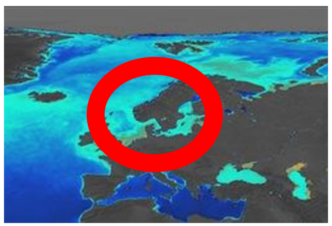


https://svs.gsfc.nasa.gov/30512

Models are tools that can be used to understand how widespread virus infection is in the ocean

"Real world"



Math

$$\frac{dR}{dt} = \underbrace{S_R}_{\text{resource inflow}} - \underbrace{\alpha RH}_{\text{resource utilization}}$$

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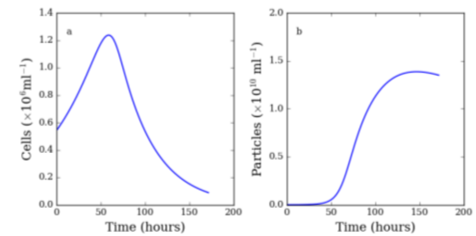
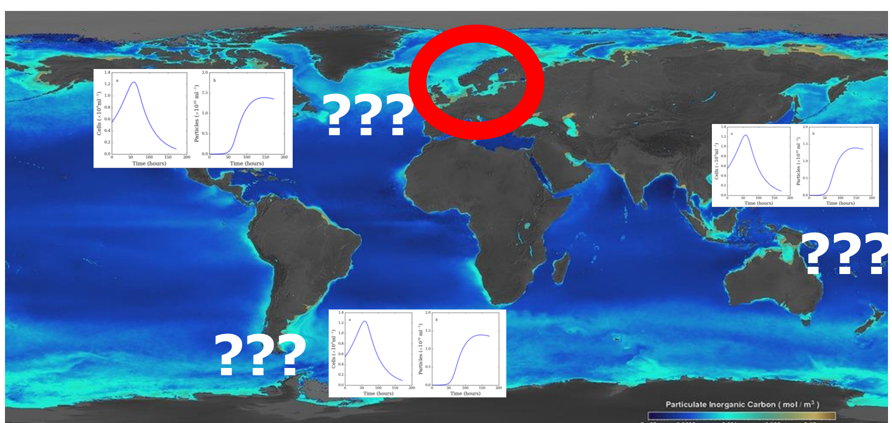
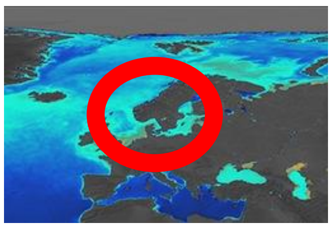


Modeling
(math meets "real world")



Models can be thought of as scientific hypotheses

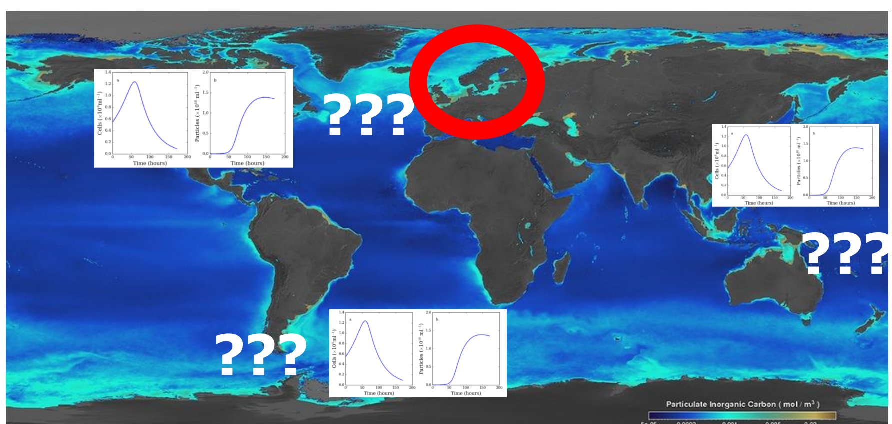
"Real world"



Math

Model A vs. model B

Modeling
(math meets "real world")

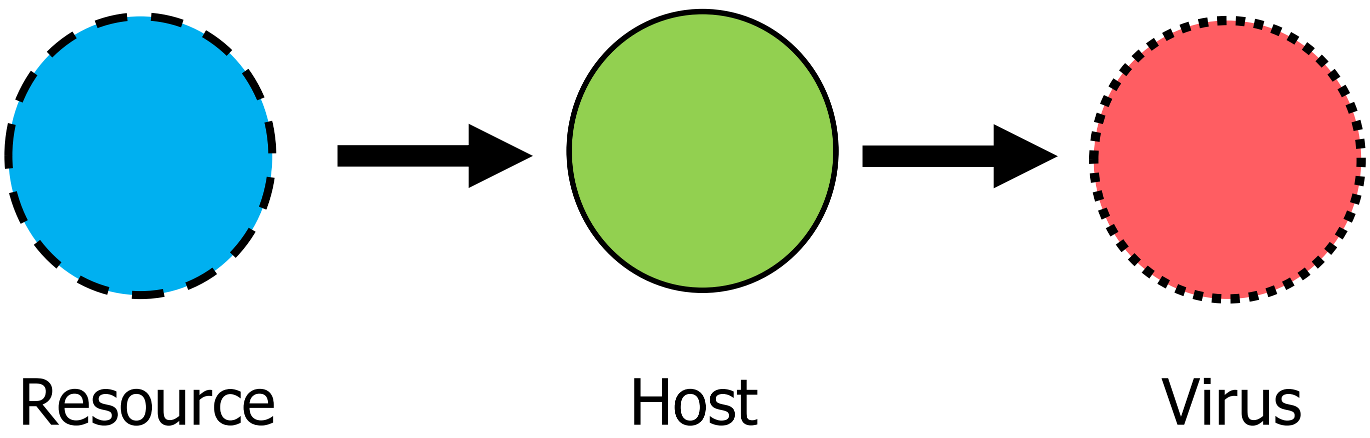


Two models of virus infection in the ocean

- Model A: “Epidemics are everywhere”
- Model B: Nature “flattens the curve”

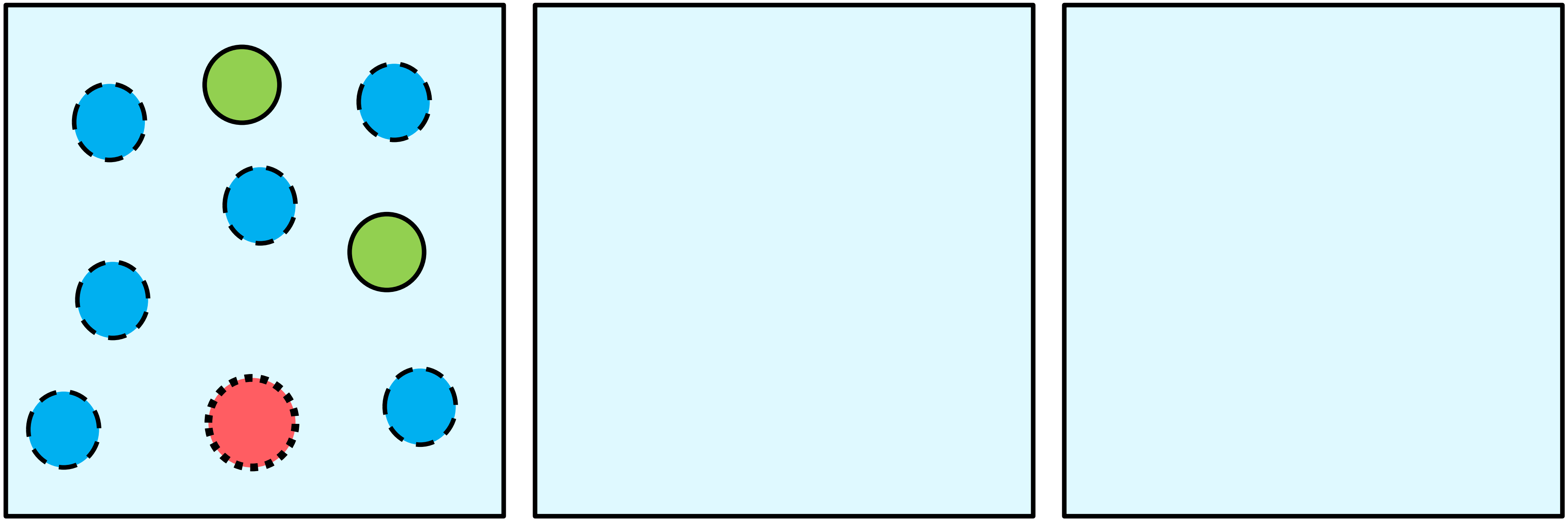
These models can be tested with data

Model A: “Epidemics are everywhere”



All **organisms** feed on **resources** and resist **predation**

Simplest model of resource-producer-consumer

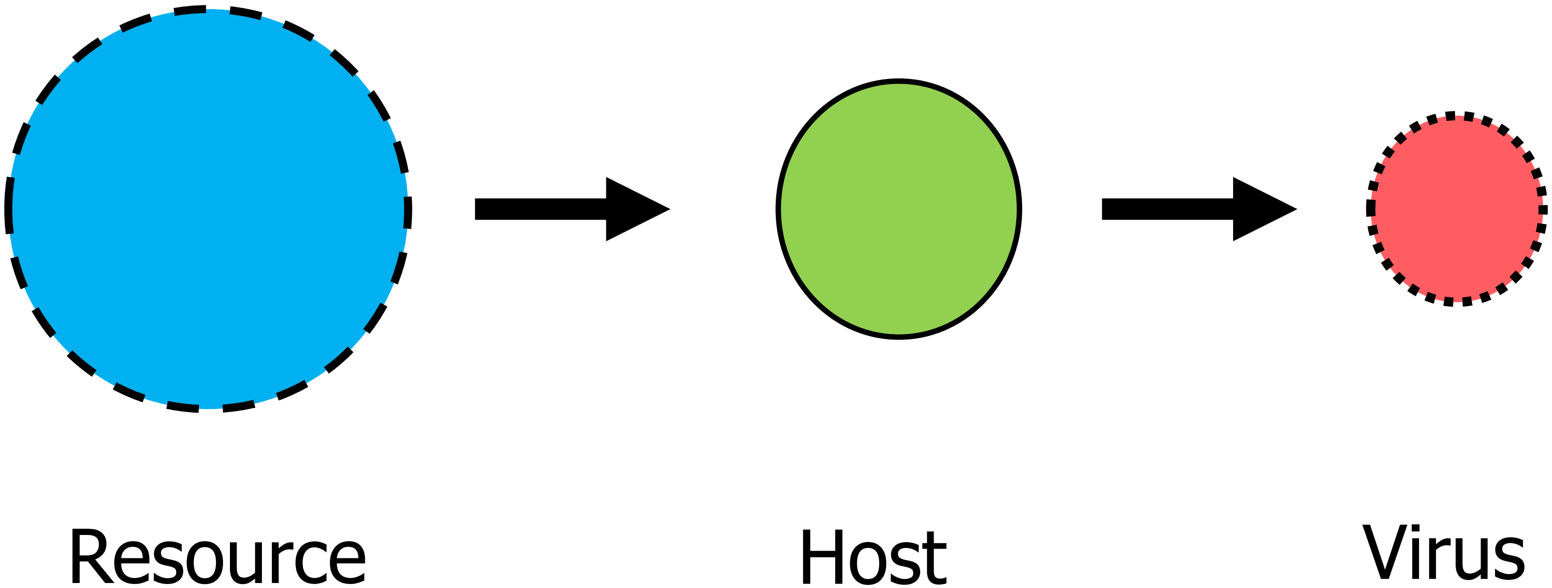


Beginning

Middle

End

Beginning



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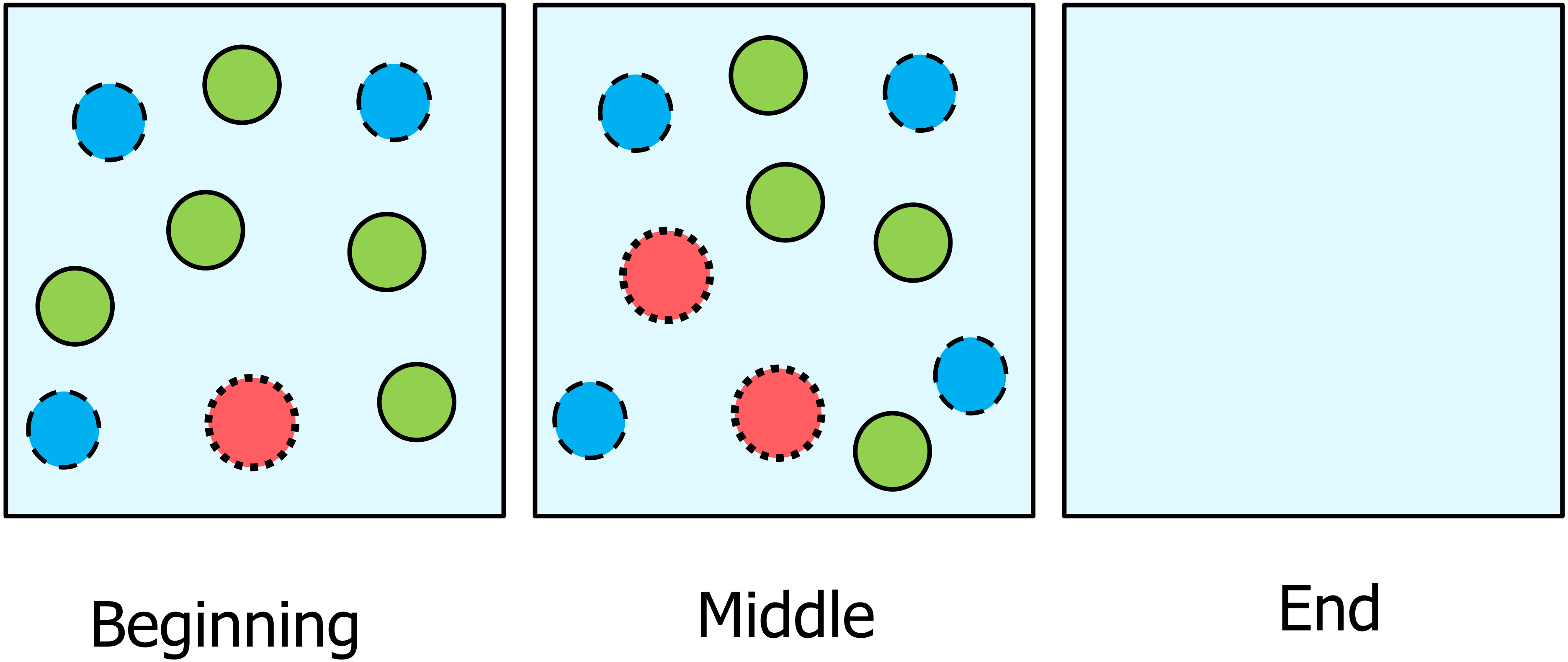
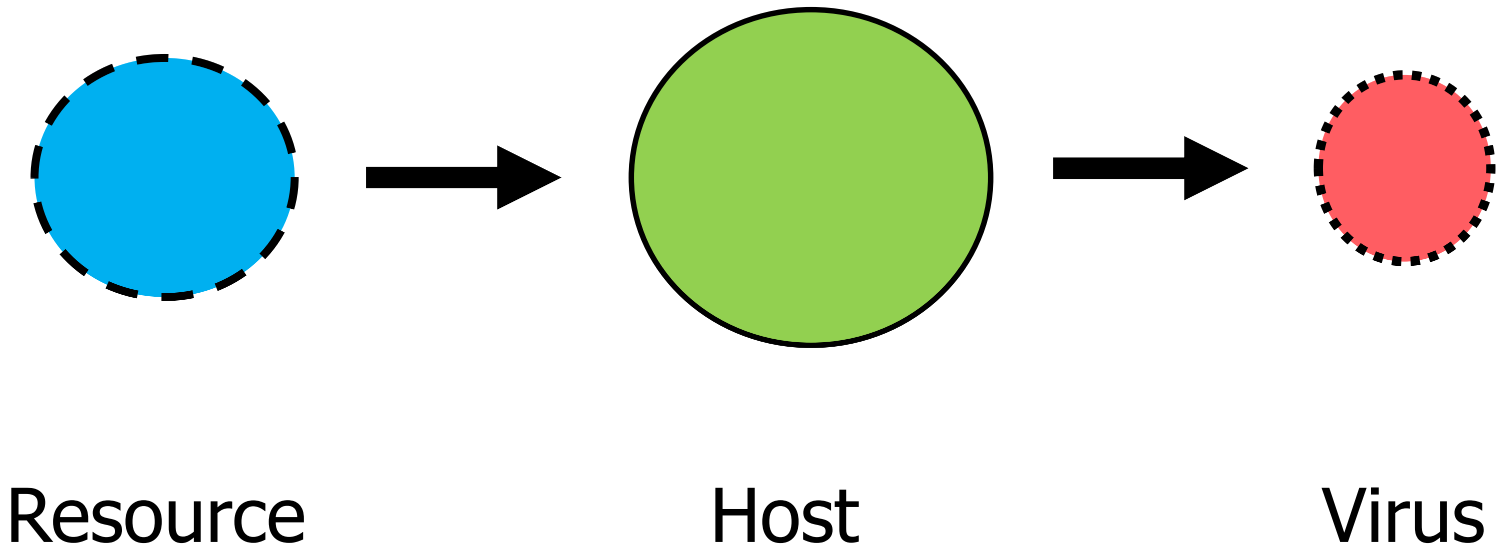


Middle



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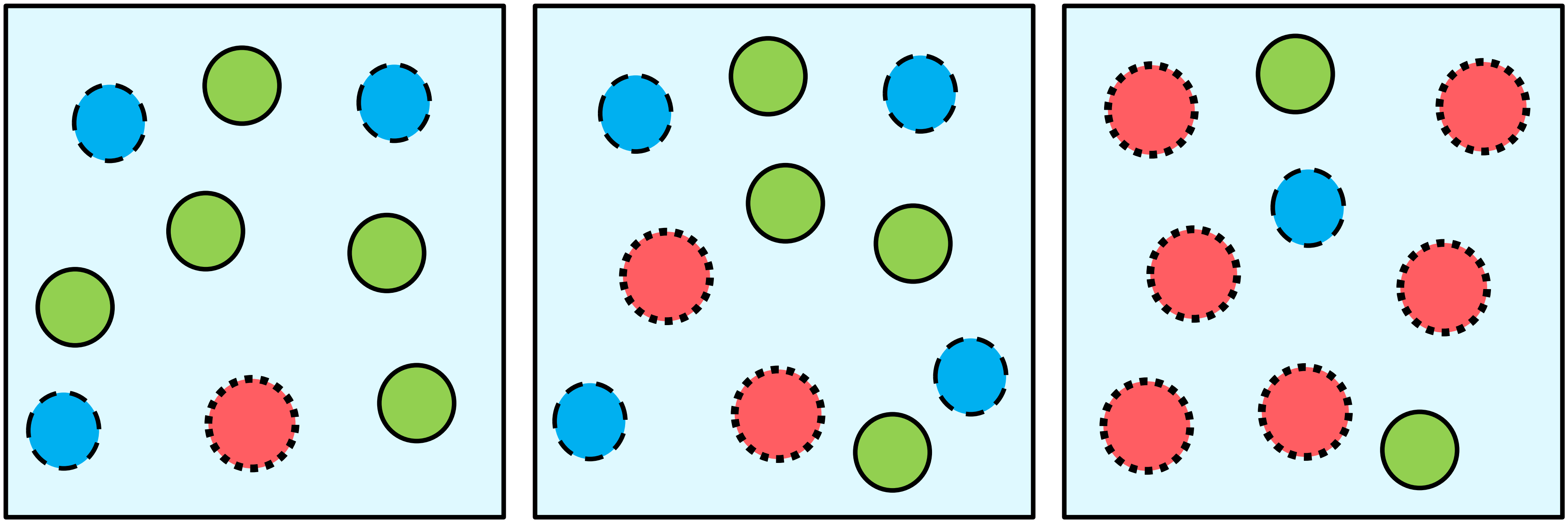
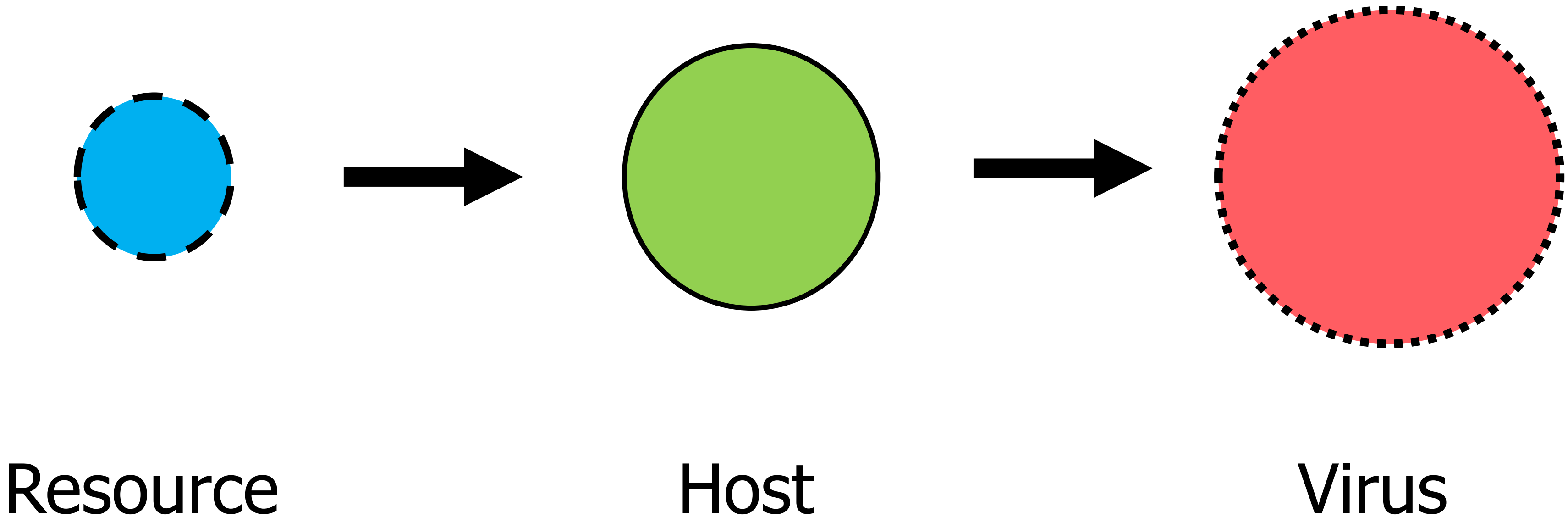


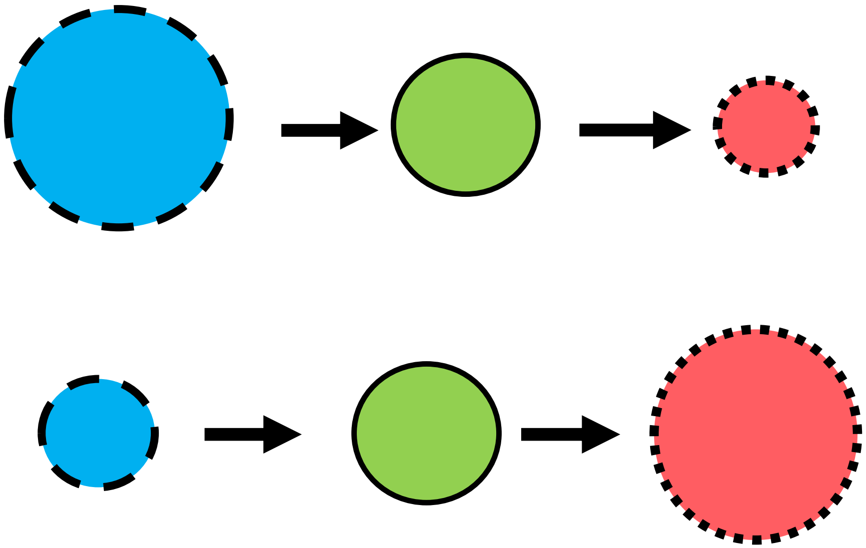
Beginning Middle End

End

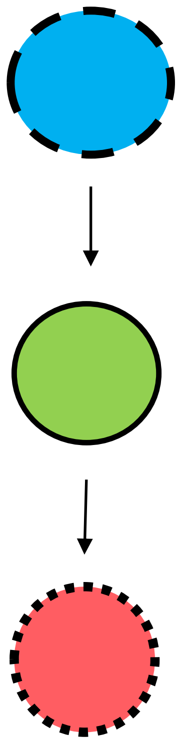


Models can be thought of as scientific hypotheses

Model A:
“epidemics are everywhere”



Model A Equations



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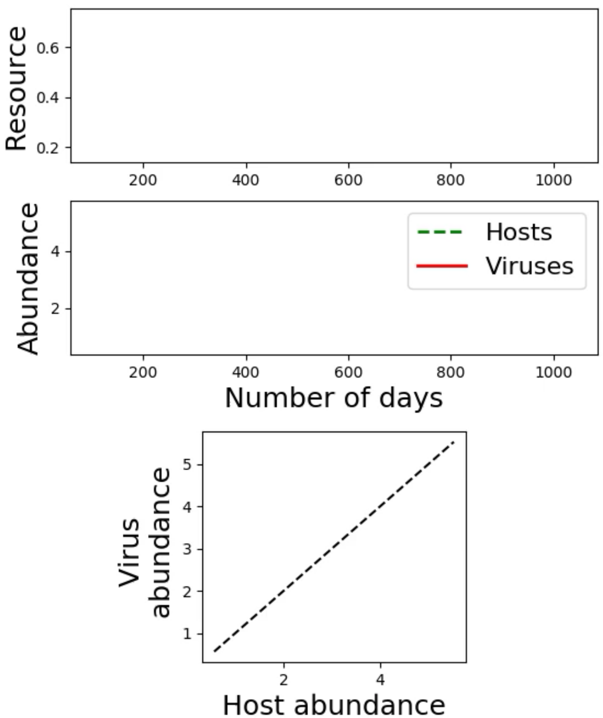
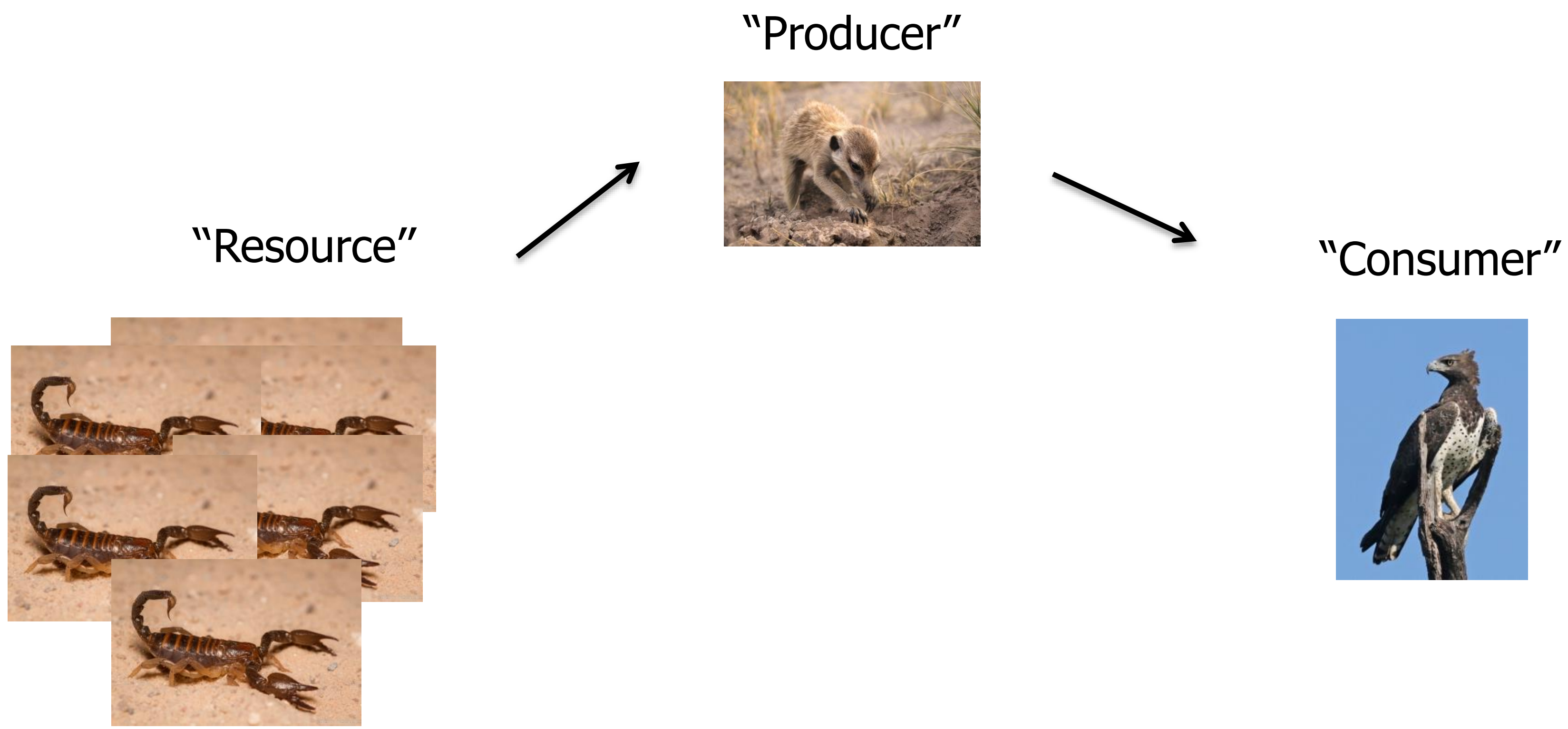


Model B:
Nature "flattens the curve"

Model A: With meerkats, scorpions, and eagles

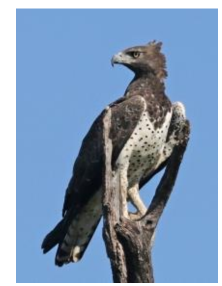


Model A: With meerkats, scorpions, and eagles

"Resource"

"Producer"

"Consumer"



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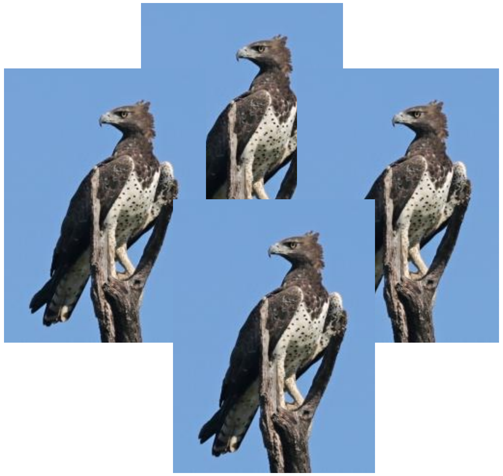
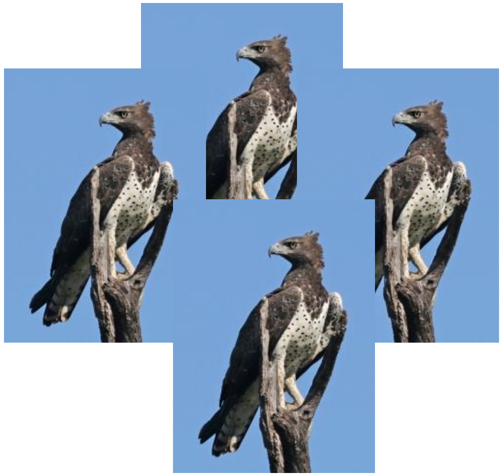


Model B: Nature "flattens the curve"

"Producer"

"Resource"

"Consumer"



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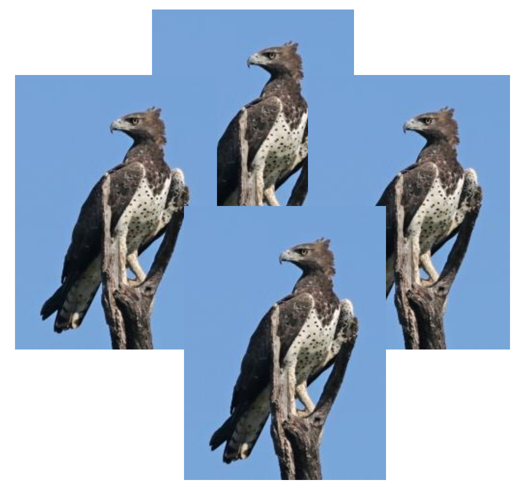
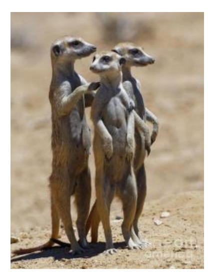
"Resource"

"Consumer"





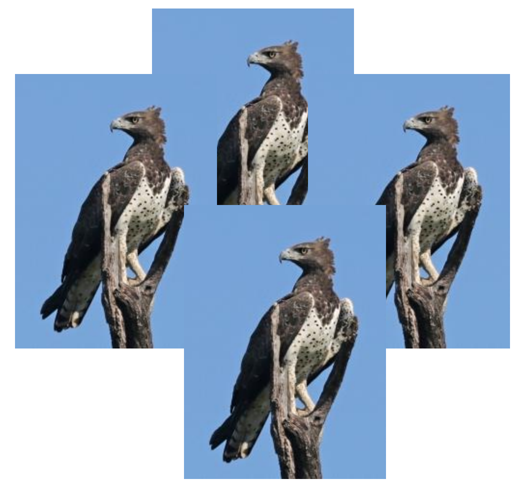
"Defensive producer"

Model B: Nature “flattens the curve”

“Producer”

“Resource”

“Consumer”



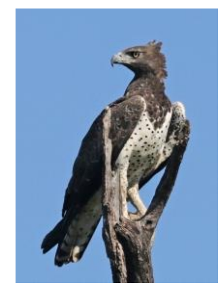
“Defensive producer”

Model B: Nature "flattens the curve"

"Producer"

"Resource"

"Consumer"



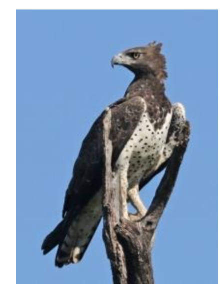
"Defensive producer"

Model B: Nature “flattens the curve”

“Producer”

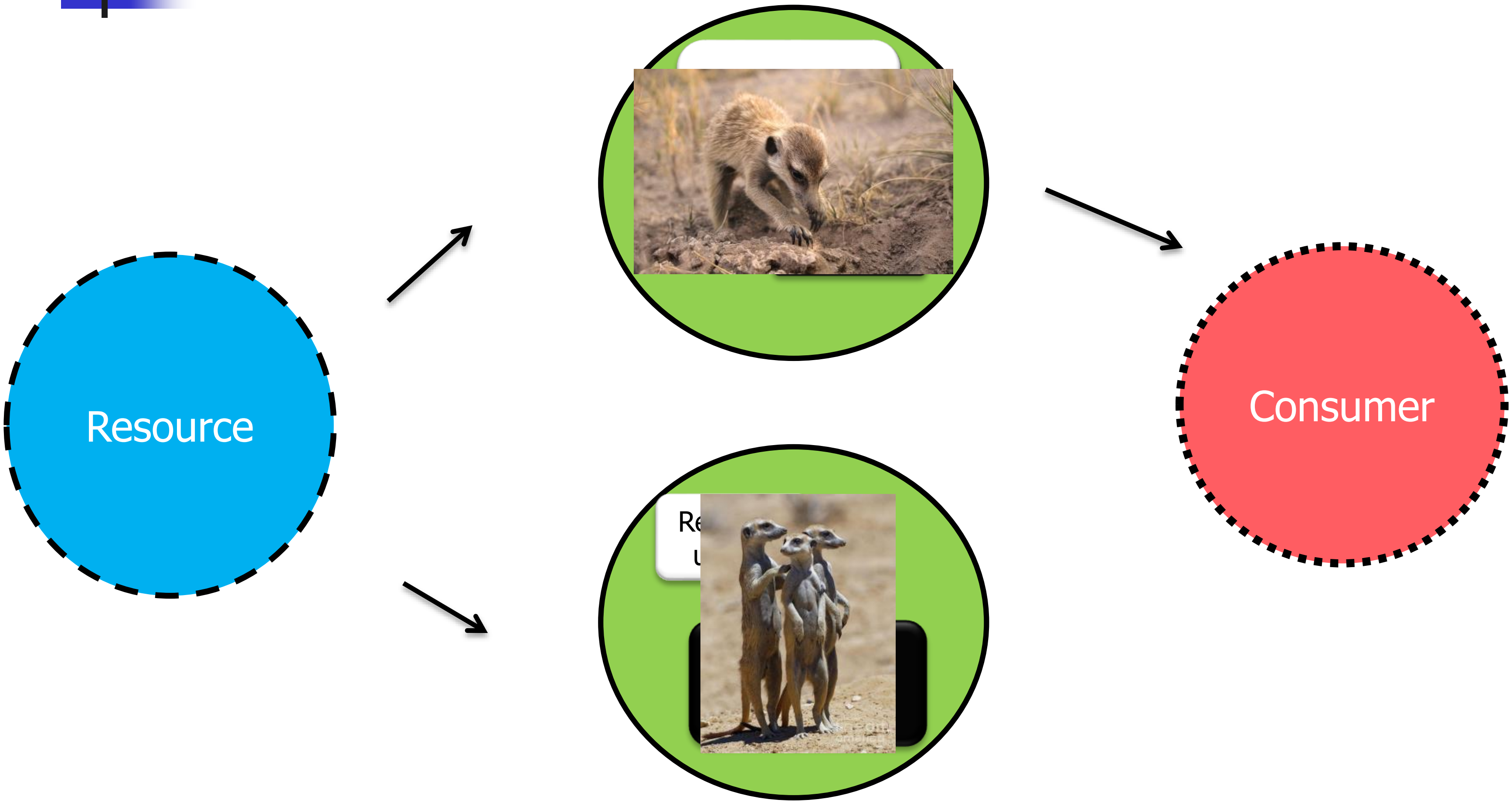
“Resource”

“Consumer”



“Defensive producer”

Alternative hypothesis: defensive behaviors inhibit many “outbreaks” from happening



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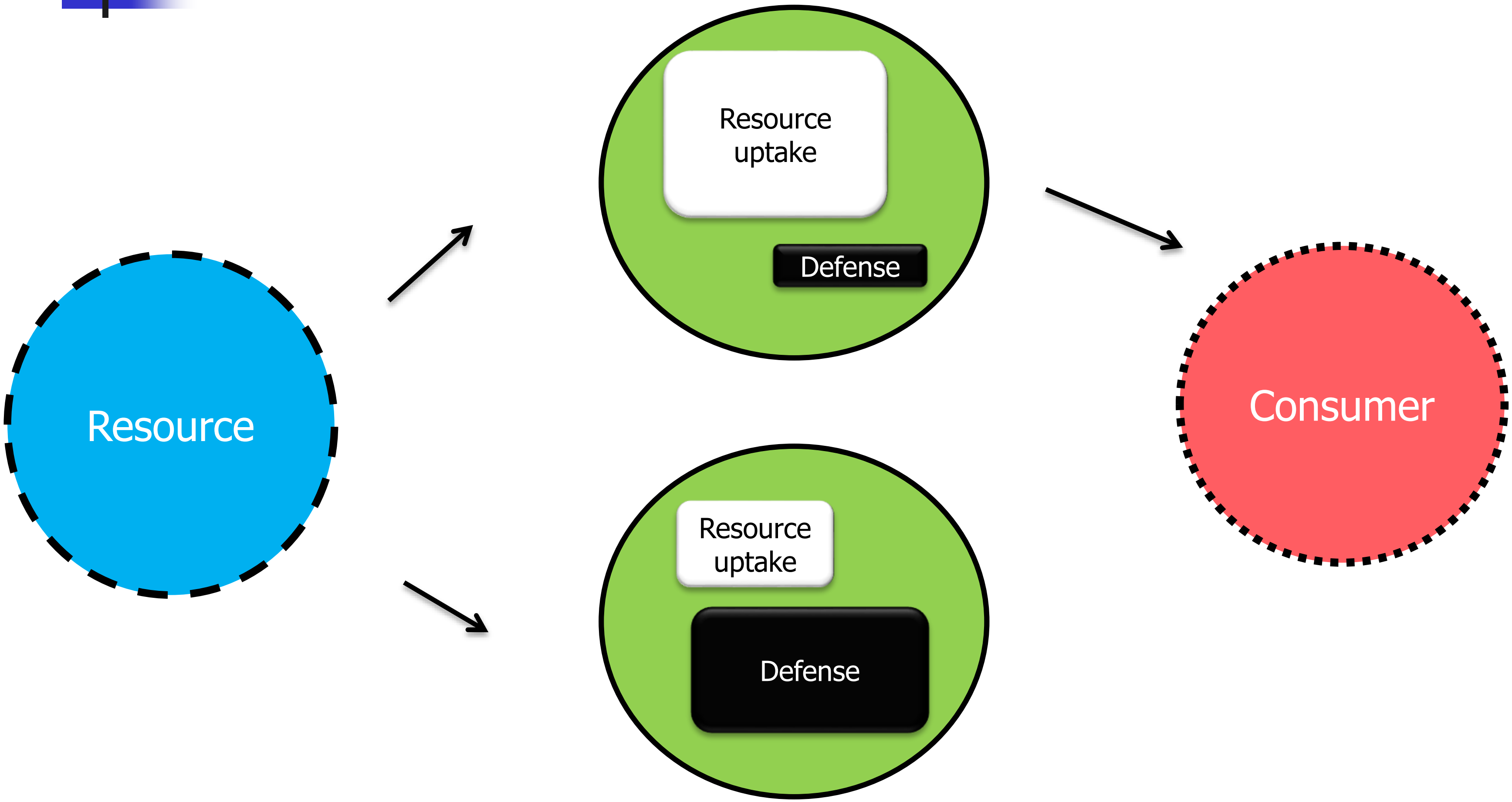
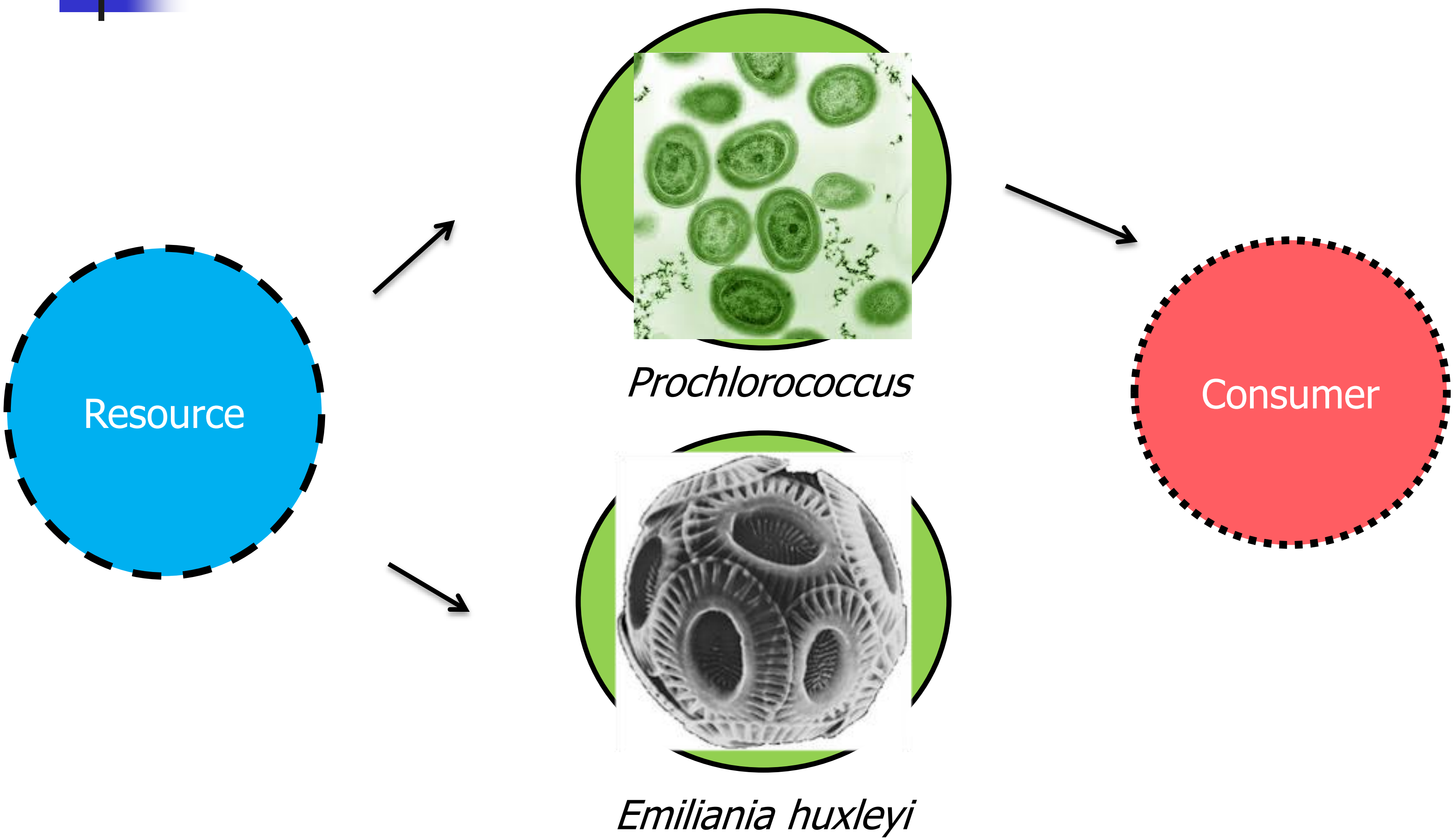
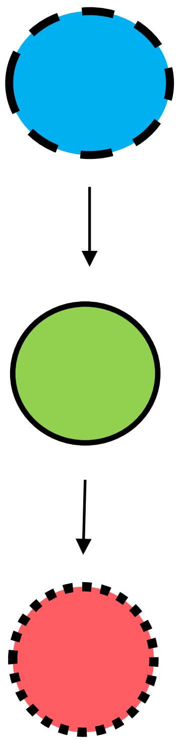


Balancing costs and benefits of defending against predation has shaped ecosystems



Model B Equations



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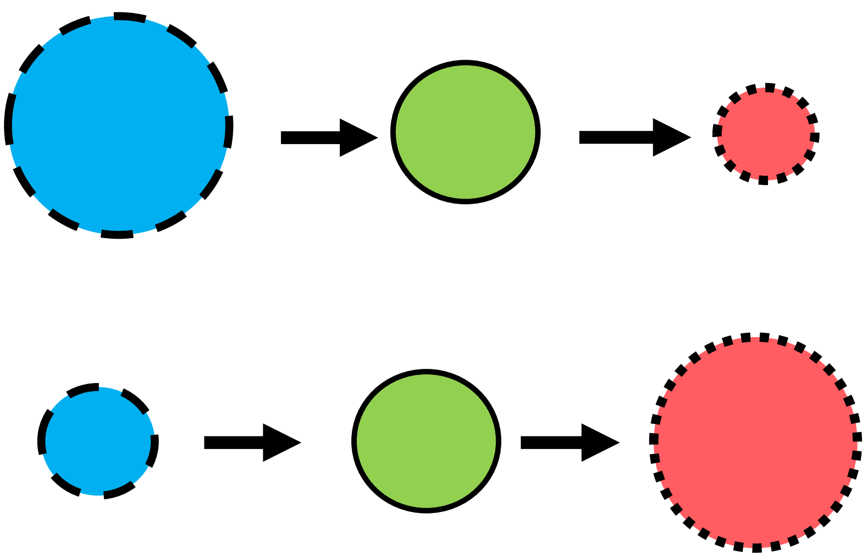
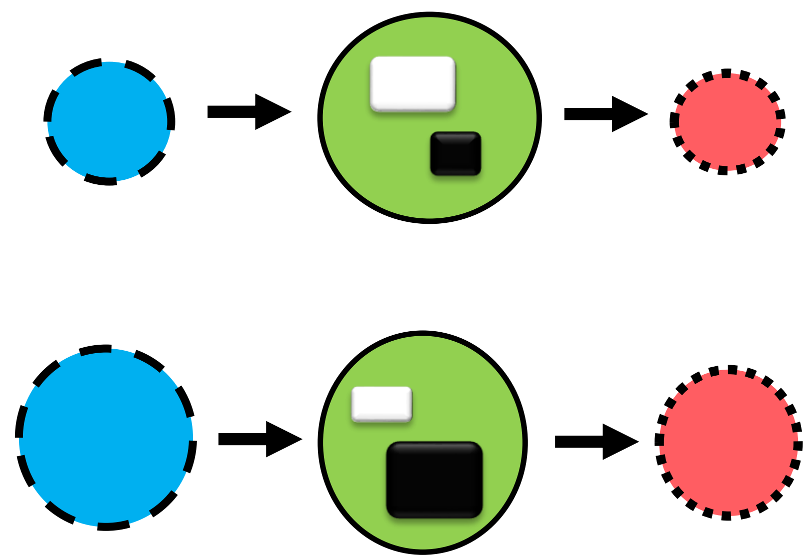
$$\boxed{log(\alpha) + log\left(\frac{1}{\phi}\right) = \text{Constant}}$$

Models can be thought of as scientific hypotheses

Model A: “epidemics are everywhere”



Model B: shifting resource allocation ”flattens the curve”



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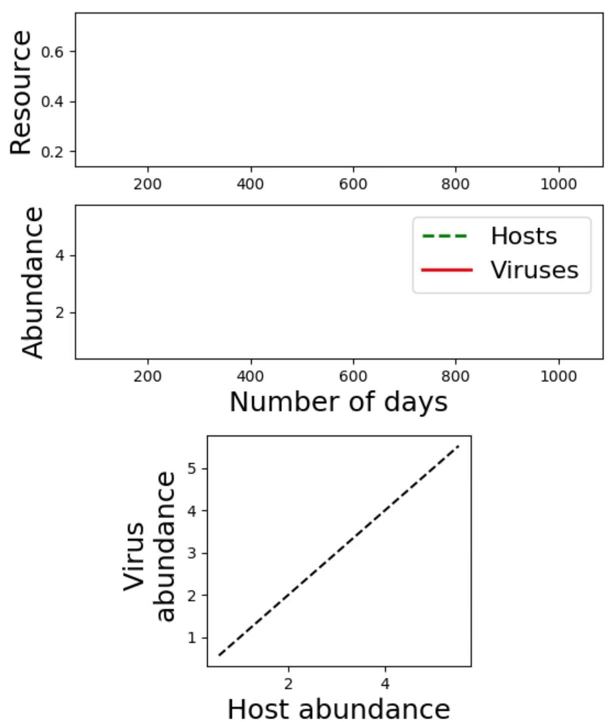
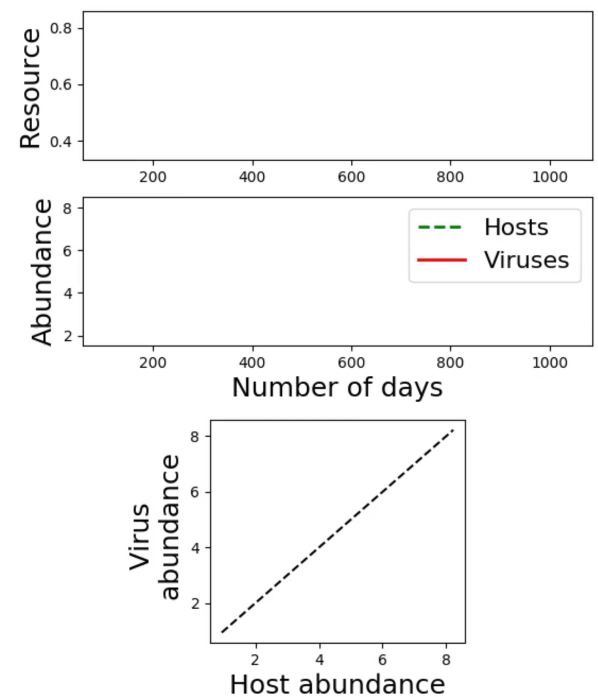


Model B:
Nature "flattens the curve"



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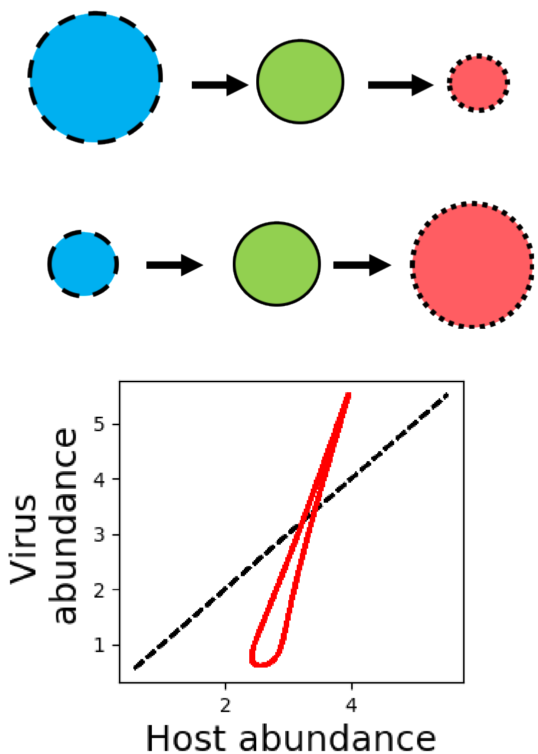

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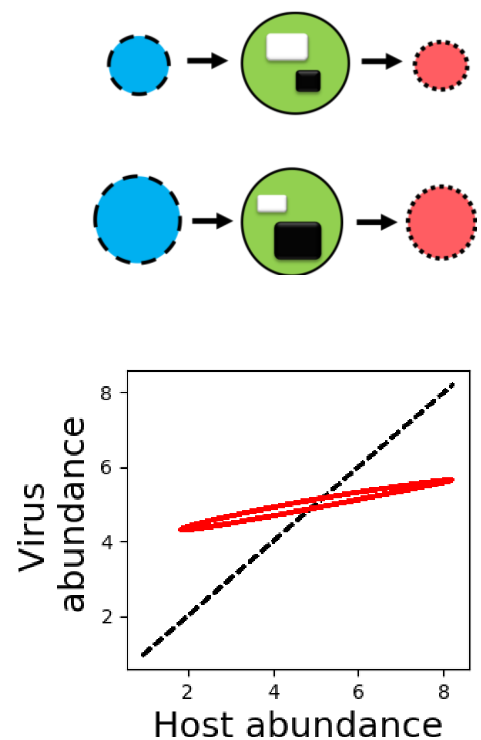
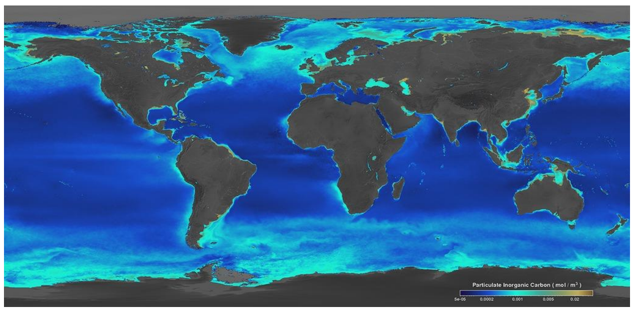
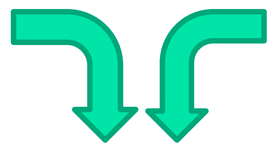


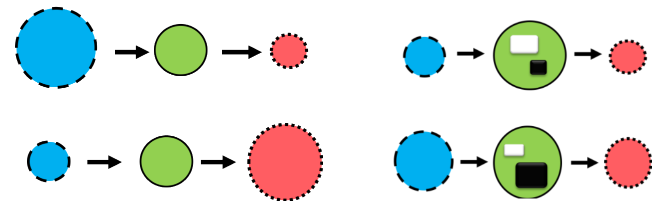
Models can be thought of as scientific hypotheses

"Real world"





Math

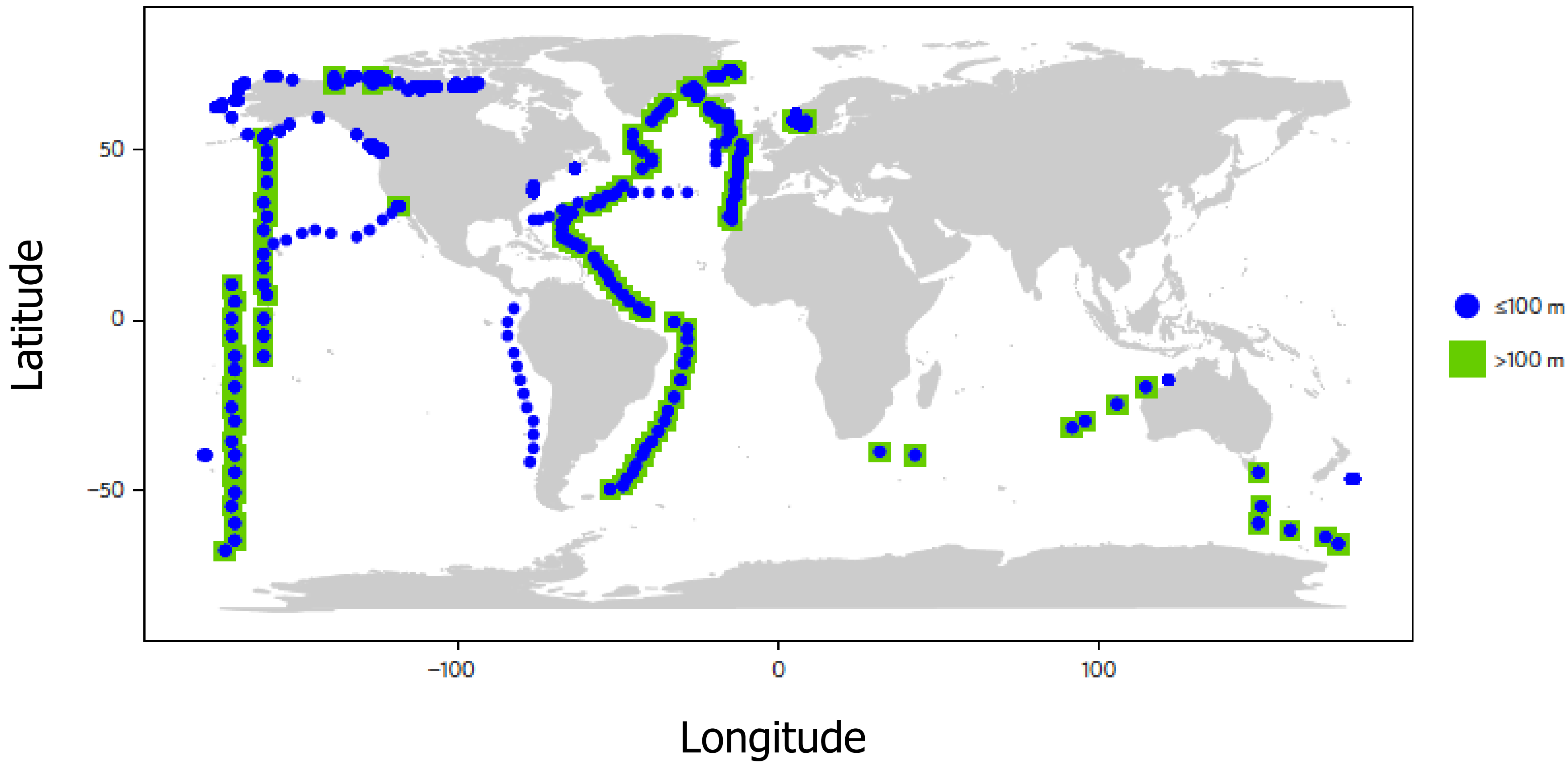


Model A

model B

???

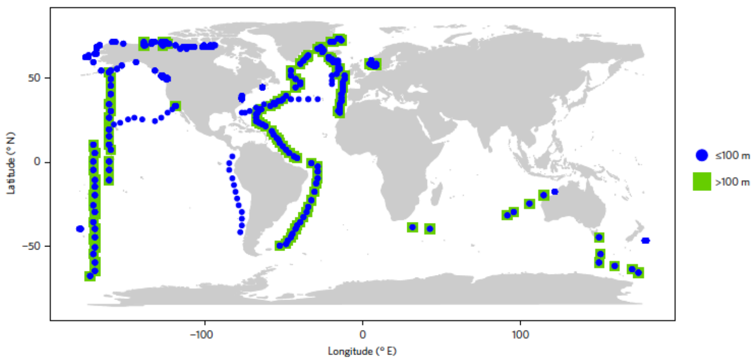
Sampling locations of microbes and viruses all over the world



Wigington et al., 2016

Models can be thought of as scientific hypotheses

"Real world"



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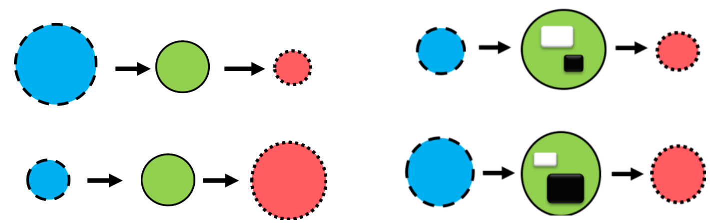


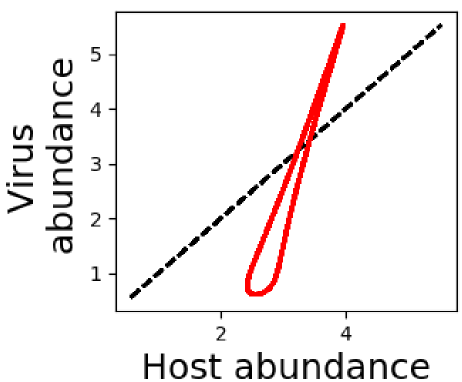
Model A

Model B

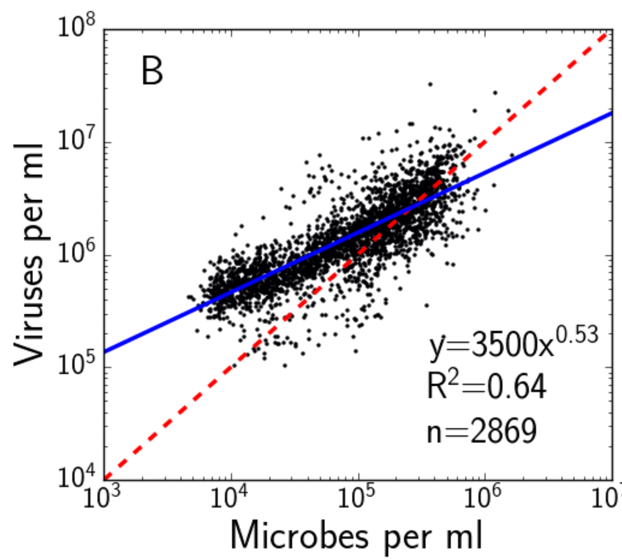
???

Model A vs. model B

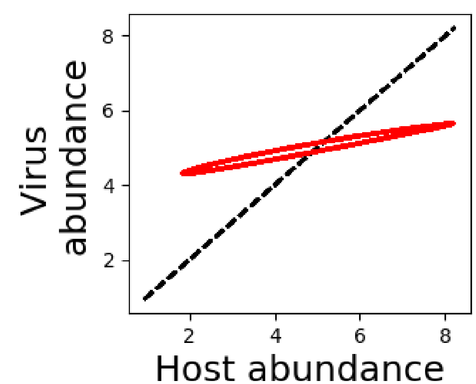
Model A



Data

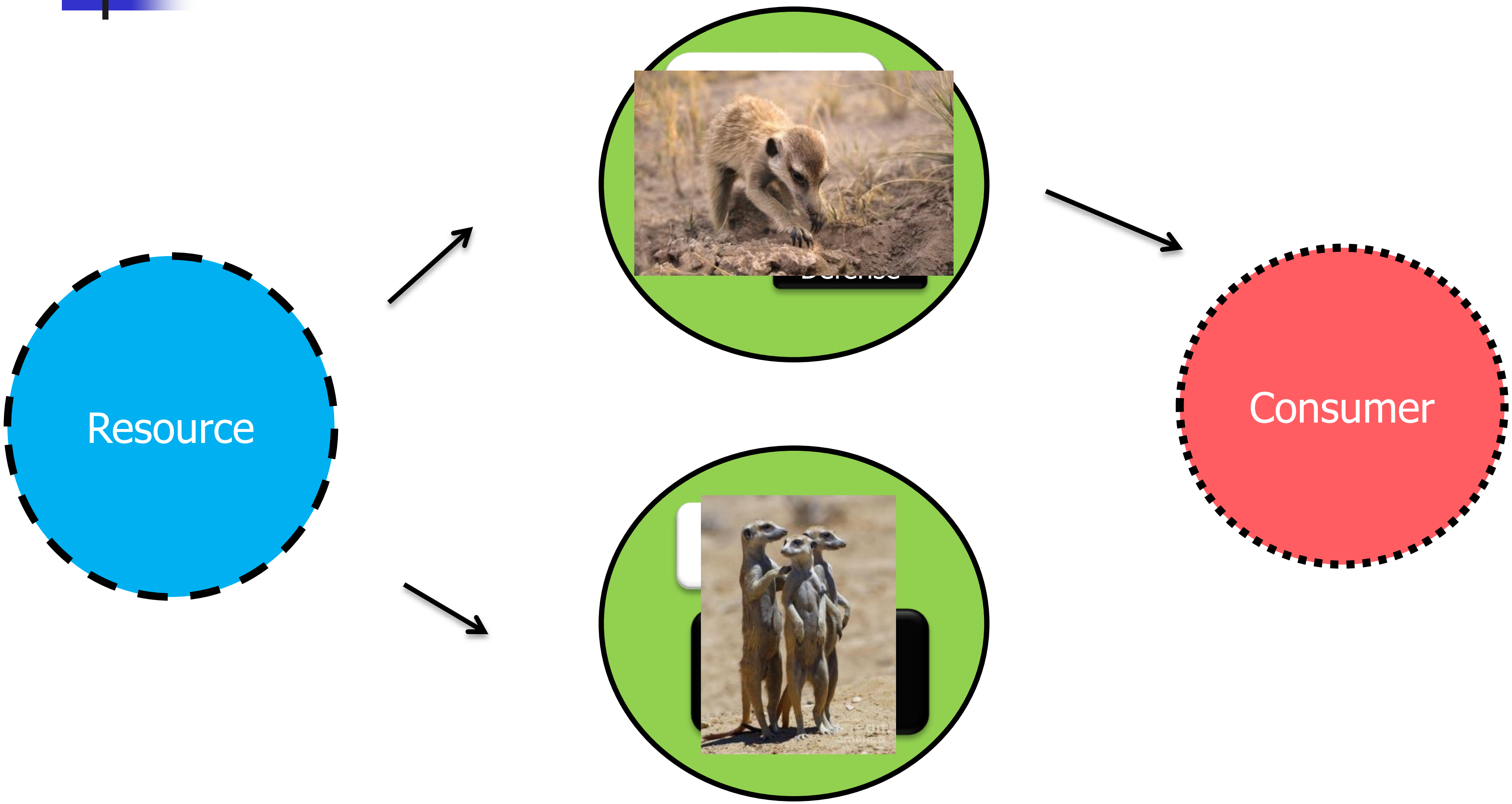


Model B

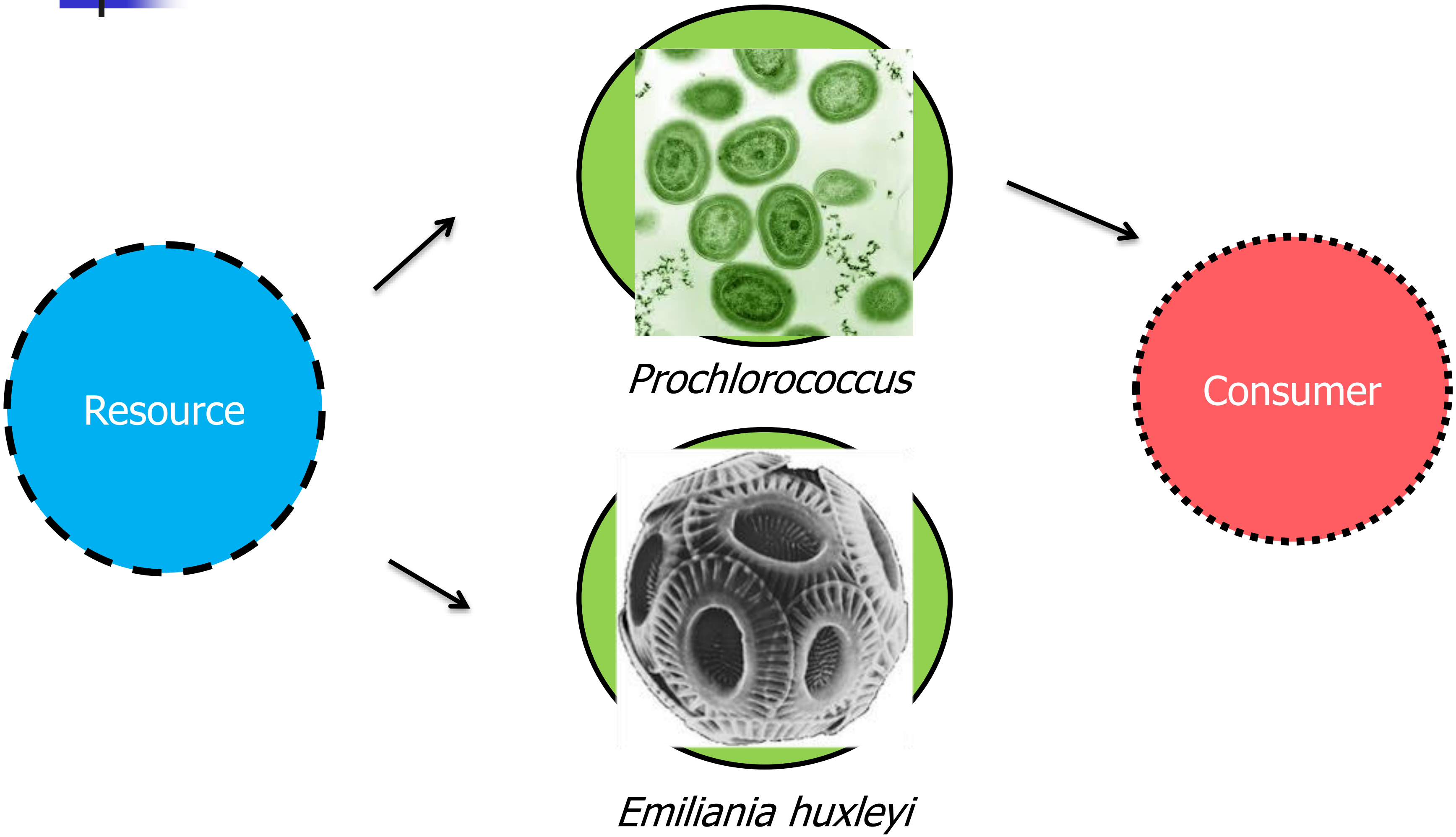


Wigington et al., Nature Microbiology, (2016) Marine Bacteria-virus

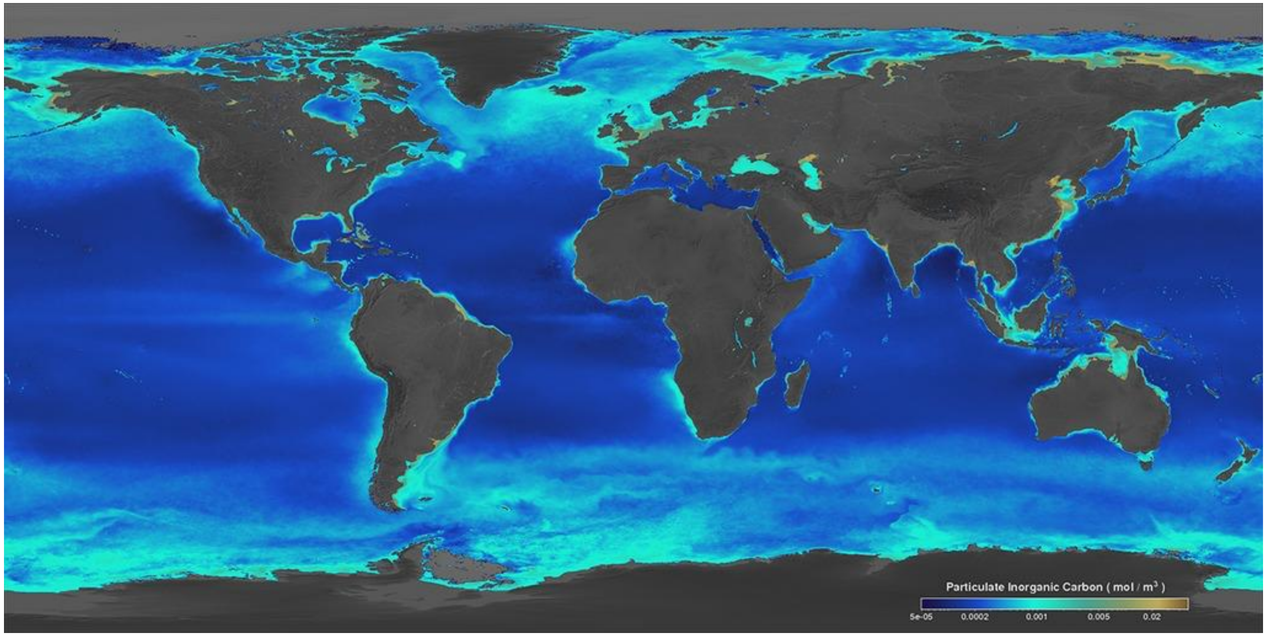
Balancing costs and benefits of defending against predation has shaped ecosystems



Balancing costs and benefits of defending against predation has shaped ecosystems



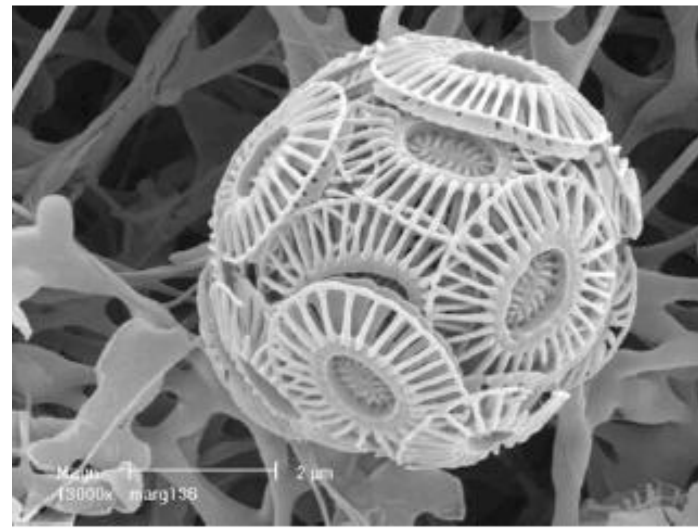
Adaptations to defend against ‘outbreaks’ may have had a lasting influence on Earth



Particulate Inorganic Carbon (PIC) https://svs.gsfc.nasa.gov/30512

Links between viruses, *E. huxleyi*, and the White Cliffs of Dover can be understood with models

White Cliffs of Dover



Emiliania huxleyi

Summary

- Mathematical models are a useful way to understand the 'rules' that control when virus 'outbreaks' happen in nature
- Nature may have 'flattened the curve' in diverse ways
- Defending against viruses and other predators has shaped ecosystems and Earth

- **Thank you for your participation!**

Questions? Please use the Question button on Zoom to post these

National Institute for Mathematical and Biological Synthesis