

**Coping Effectively with  
EID:  
Why Paradigms are  
Important**

**Daniel R. Brooks  
Budapest  
16 February 2023**

Paradigms direct funding and  
human activities through  
theoretical expectations

A good paradigm keeps us from  
spending time and money and  
getting too little or nothing  
in return

**A bad paradigm wastes time and  
money**

# The Scope of the EID Crisis

Pathogens of all kinds affecting every species upon which humanity depends for survival and socio-economic development

Diseases we have never seen before; known diseases in hosts and places they had never been found before, or in places from which we thought they had been eradicated

# What is the source of these diseases?

Water, Food, Soil, Air, Casual contact, Sex, Wildlife, Pets, Anything that bites or feeds on us and species upon which we rely

**Rural, Urban, and Wildland settings**

Temperate and Tropical regions

**Developed and Developing countries**

# EID constitute a National Security Crisis for Every Country

Water Security

Food Security

Public Health Security

Socio-cultural Security

Economic Security

# Shortcomings of the Current Paradigm

**EID occur daily**

**This is happening much  
more often than predicted**

# **EID are *Expensive***

**\$1,300,000,000,000 per year**

***Before COVID Treatment Costs and  
Production Losses***

**More than the GDP of all but 15  
countries**

# *Unsustainably Expensive*

Trivellone, V., E.P. Hoberg, W.A. Boeger  
and D.R. Brooks. 2022. Food security and  
emerging infectious disease: Risk  
assessment and risk management. *Royal  
Society Open Science*

[dx.doi.org/10.1098/rsos.211687](https://dx.doi.org/10.1098/rsos.211687)

If we continue business as usual, EID  
costs in agriculture and livestock  
production in the US

**Will exceed the US GDP by 2080**

## Two Questions

With all of our  
scientific experience,  
knowledge, and expertise,  
why is there an EID  
crisis?

And why are we losing  
the battle?

**The Current Paradigm has  
Failed**

**We Need A New One**

# The Failure Has Been Noticed

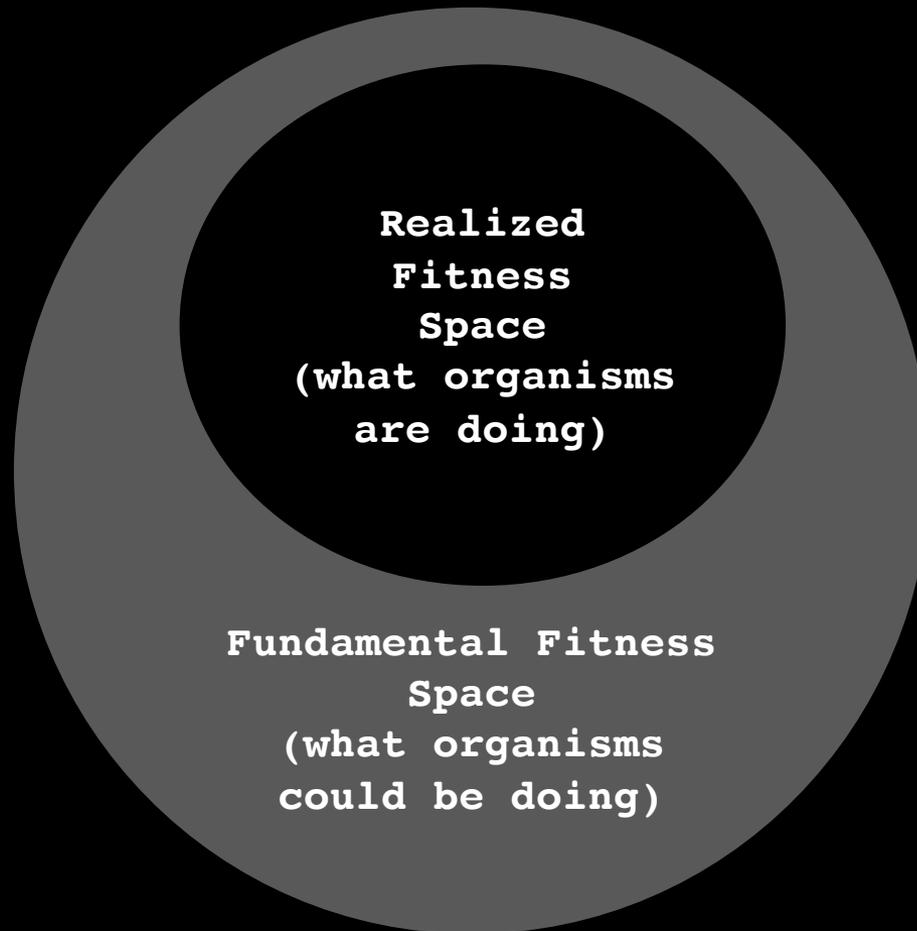
..you would think that the public health response would be a well-oiled machine by now. But yet again we have been blindsided.

— *New Scientist* 30 January  
2016

# How Does Nature Work?

...there are two factors [in evolution]; namely, the **nature of the organism** and the **nature of the conditions**. The former seems to be much more important; for nearly similar variations sometimes arise under, as far as we can judge, dissimilar conditions; and, on the other hand, dissimilar variations arise under conditions which appear to be nearly uniform – Charles Darwin (1872)

# The Nature of the Conditions: Sloppy Fitness Space



# **The Nature of the Organism: Ecological Fitting**

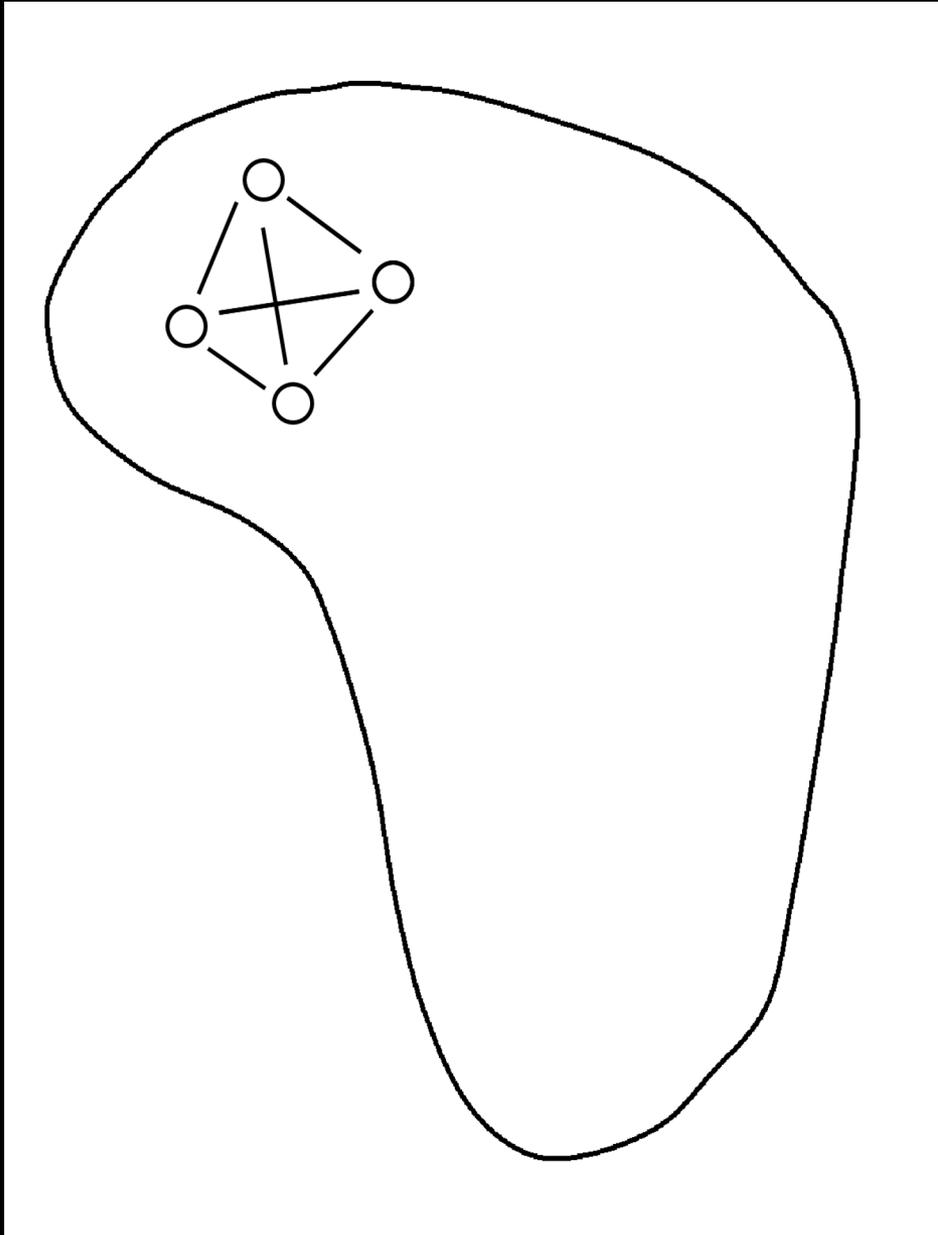
**This allows organisms and  
species to be exploiters and  
explorers**

**Evolutionary lagload  
(phylogenetic conservatism)**

**Phenotypic plasticity**

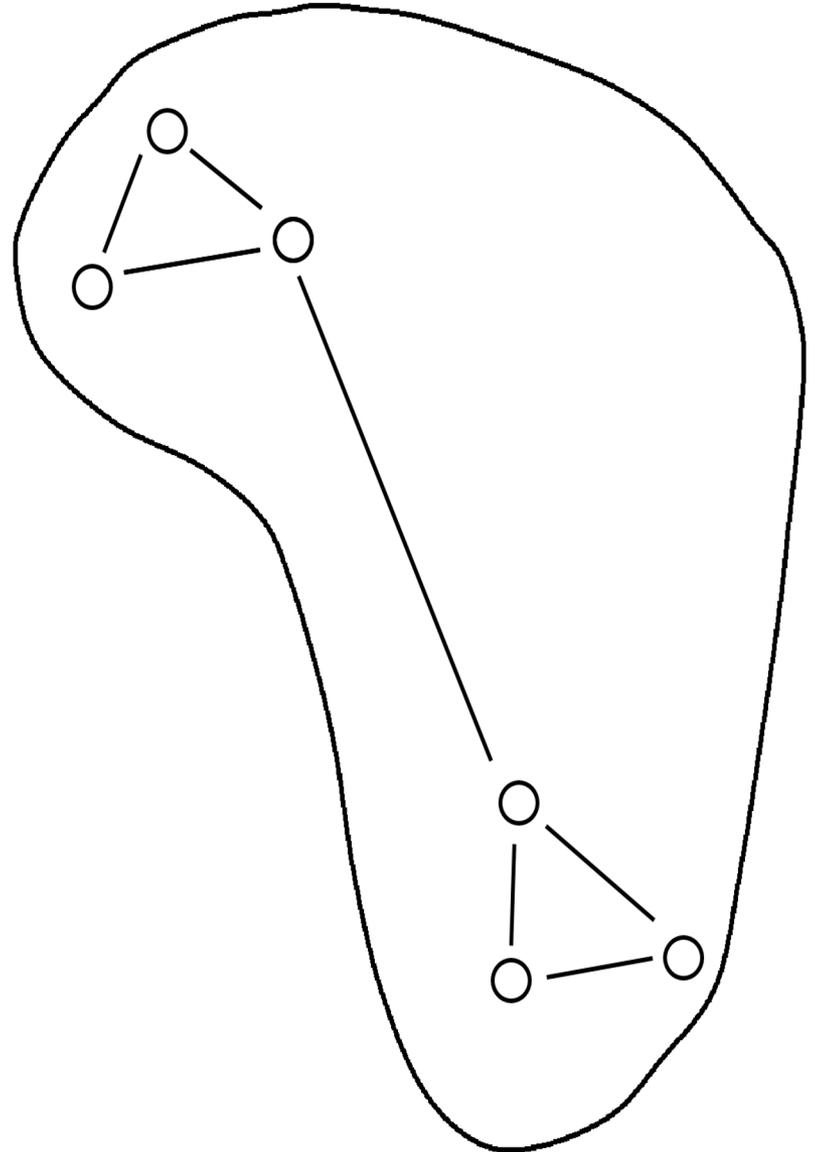
**Co-option**

**Exploitation:**  
specializing,  
maximum  
fitness,  
maximum  
conflict,  
fitness space  
maximally  
sloppy

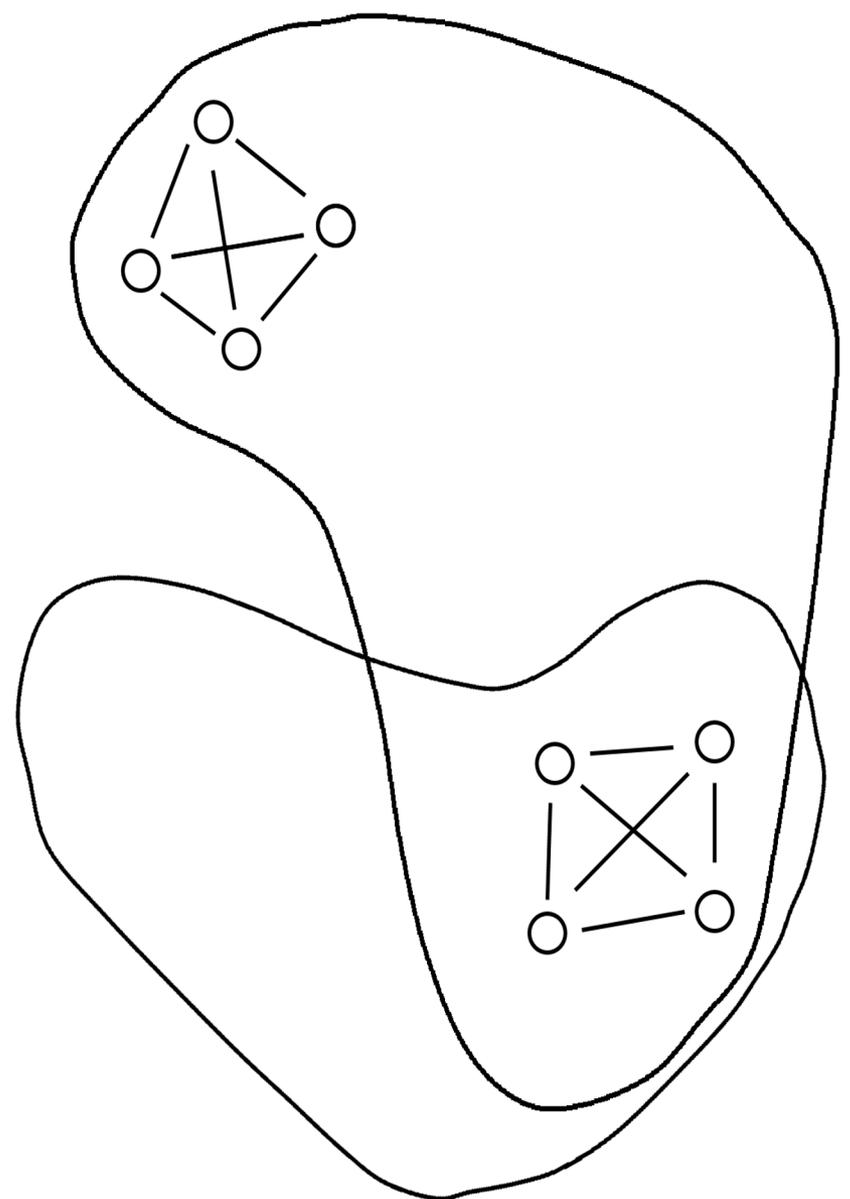


# Exploration:

generalizing,  
reduced  
fitness;  
reduced  
conflict;  
fitness space  
sloppiness  
reduced



**Conflict  
Resolution:  
Co-  
accommodation**



# Darwinian Evolution

*Conflict resolution by  
ecological fitting in  
sloppy fitness space,  
with co-accommodation,  
all reinforced by natural  
selection*

# The Geography of Darwinian Evolution: The Taxon Pulse

Stable conditions: biotic isolation

Perturbed conditions: biotic expansion

Alternating episodes of isolation and  
expansion produce complex mosaics of  
interspecific associations

# Diversity Begets Diversity

**Stable conditions: exploit and specialize (the fittest), accumulate potential (novel variants), fitness space becomes sloppier**

**Perturbed conditions: explore and generalize (the fit), spend potential (pre-existing variants; EF in SFS), fitness space becomes less sloppy**

# What is the Stockholm Paradigm?

It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us..There is grandeur in this view of life..from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved.

— Darwin 1872

**A Perfect  
Storm**

**Climate Change**

**Emerging  
Disease**

**Us**

The background of the right side of the image is a microscopic view of cells in a petri dish. The cells are visible as small, circular structures with internal details, set against a background of larger, more diffuse circular shapes. The color gradient transitions from green at the top to yellow in the middle, and then to orange and red at the bottom.

THE  
**STOCKHOLM  
PARADIGM**

CLIMATE CHANGE  
AND EMERGING  
DISEASE

DANIEL R. BROOKS, ERIC P. HOBERG,  
AND WALTER A. BOEGER

# Darwinian Evolution and Pathogens

**Stable conditions: exploit, specialize,  
isolate, restricted host range,  
accumulate potential (emergence of novel  
variants), host fitness space becomes  
sloppier (more potential hosts)**

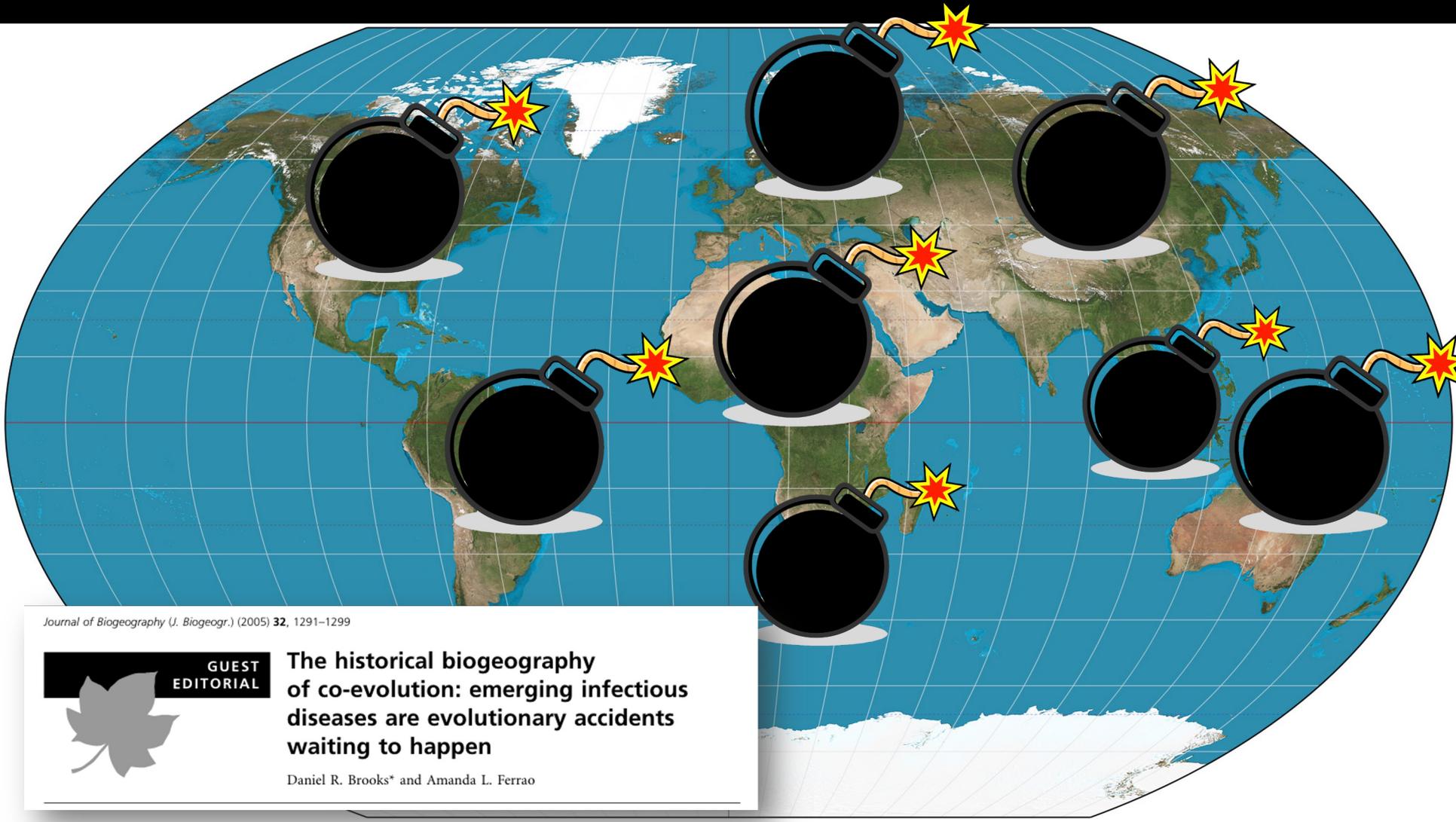
**Perturbed conditions: explore,  
generalize, expand, increased host  
range, spend potential (EF in SFS),  
fitness space becomes less sloppy (fewer  
potential hosts)**

# Darwinian Evolution and Host Range: The Oscillation Hypothesis

**Stable conditions: restricted host range**  
**Perturbed conditions: expanded host  
range**

**Repeated episodes of climate change  
produce complex mosaics of specialized  
host-pathogen systems with vast  
potential for rapid emergence and  
indefinite diversification**

# We live in a Minefield of Evolutionary Accidents Waiting to Happen



*Journal of Biogeography* (*J. Biogeogr.*) (2005) **32**, 1291–1299

GUEST  
EDITORIAL



**The historical biogeography  
of co-evolution: emerging infectious  
diseases are evolutionary accidents  
waiting to happen**

Daniel R. Brooks\* and Amanda L. Ferrao

**What is Needed to Link the  
Conceptual Framework to  
the real world?**

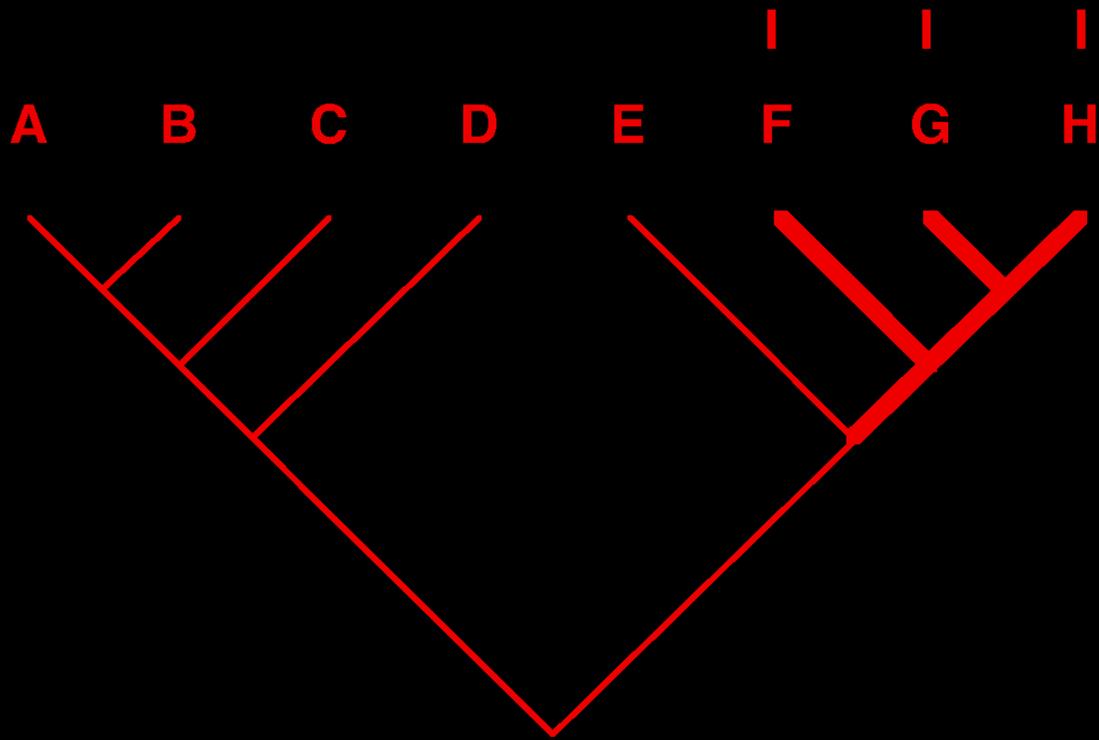
**Empirical Support**

**A Robust Modeling Platform**

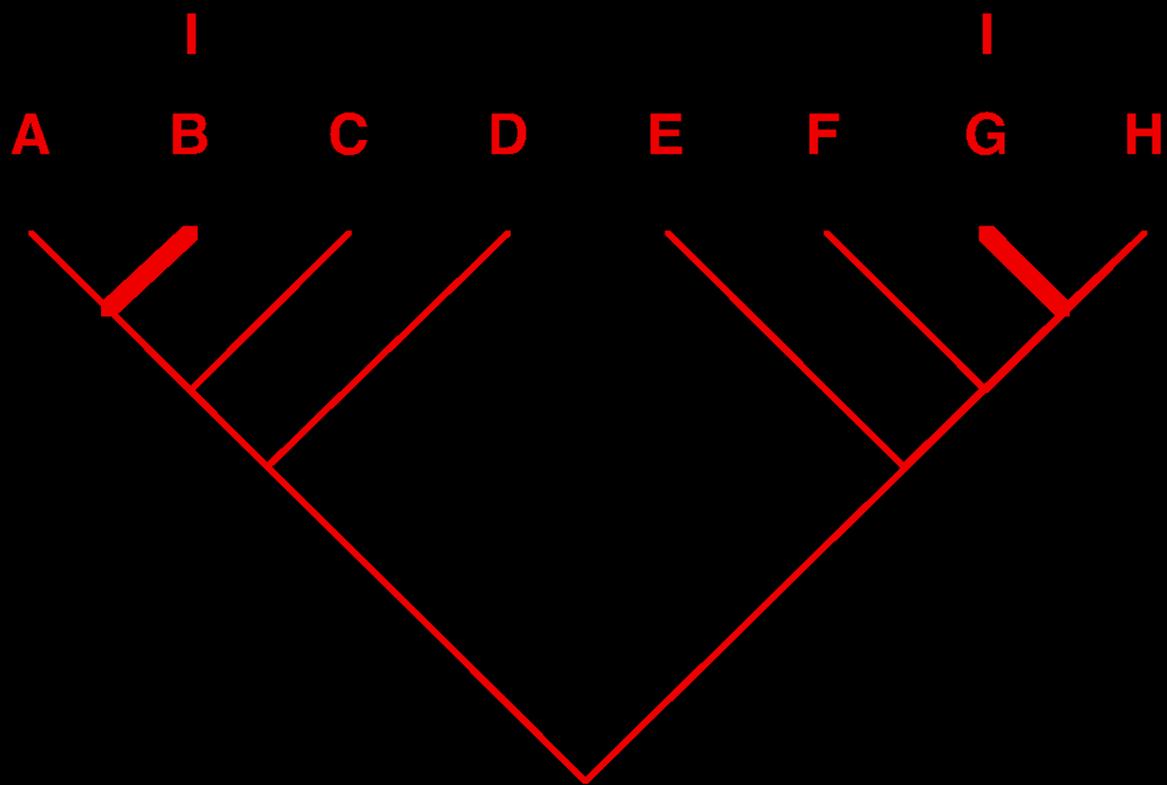
# The Stockholm Paradigm and Pathogens

Many host range changes but  
not random

Cophylogeny is not cryptic  
cospeciation







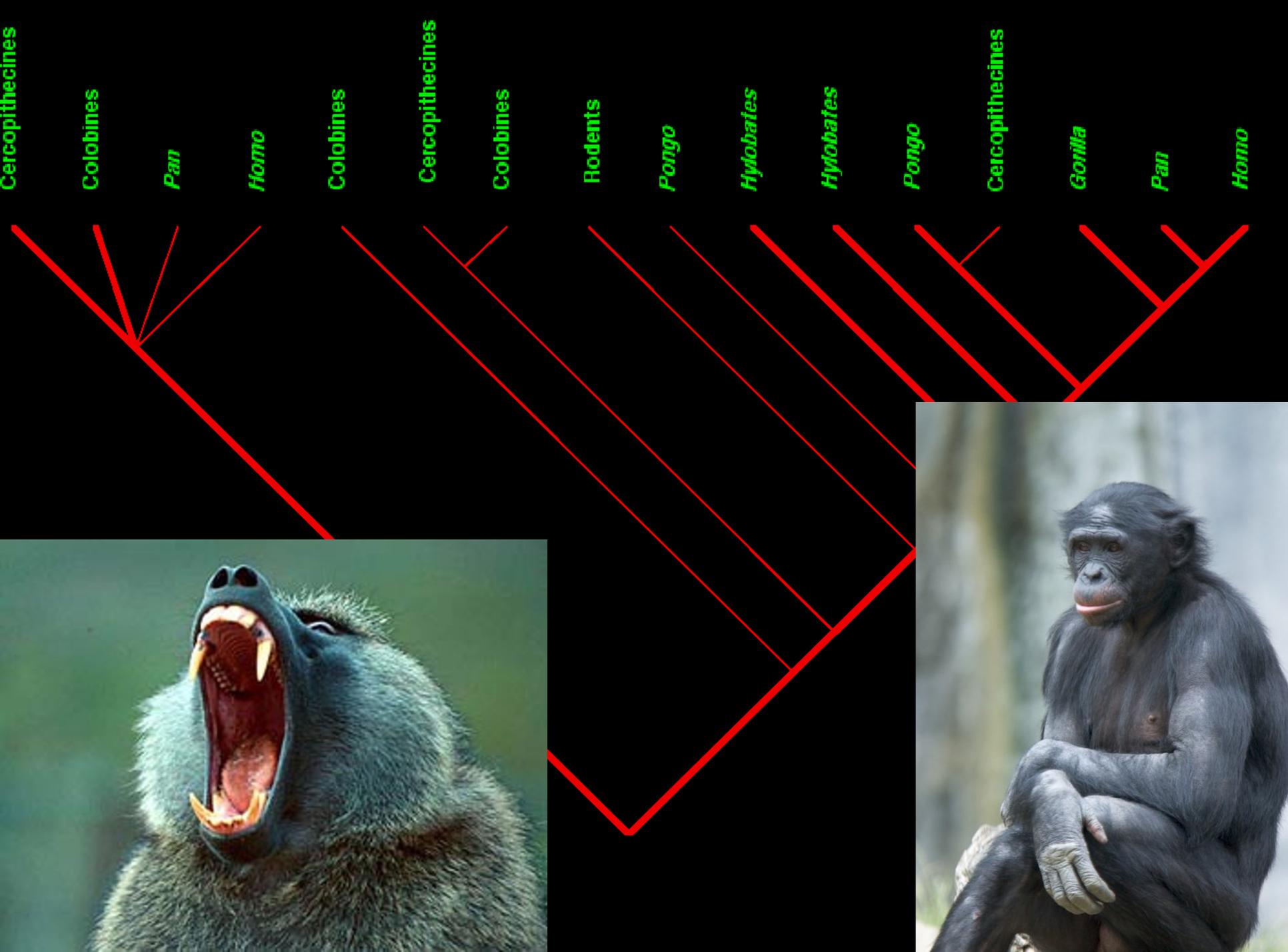
# The Stockholm Paradigm and Pathogens

The evolutionary history  
of pathogens will reflect  
host range oscillations  
and taxon pulses

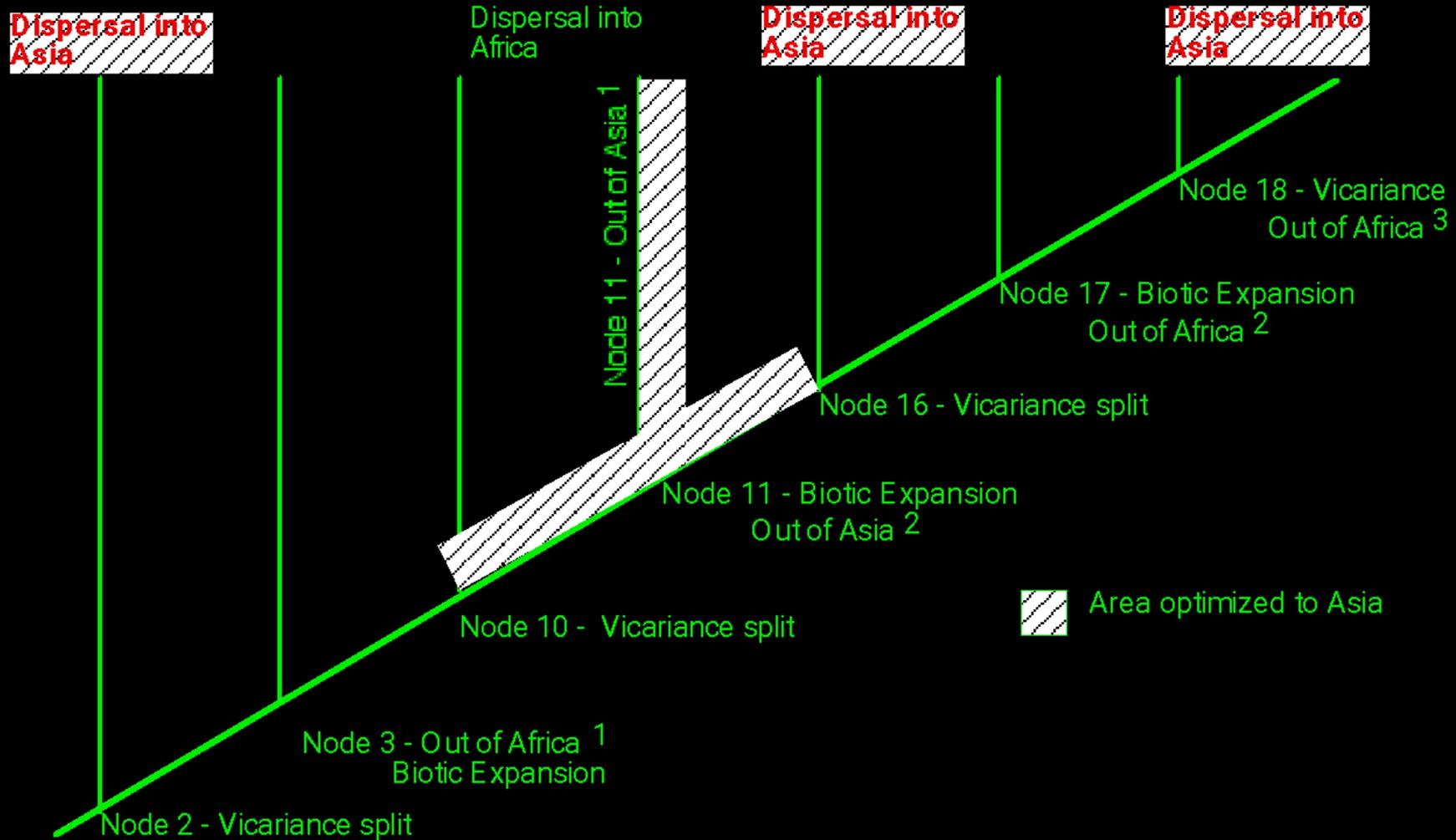
# The Stockholm Paradigm: Hosts and Geography

Geographic expansion will be  
associated with host range  
expansion

Geographic isolation will be  
associated with host range  
reduction



# The Taxon Pulse



# Co-accommodation and Pathogens

Traits associated with  
transmission dynamics and  
microhabitat preference will  
be phylogenetically  
conservative and widespread

# The Stockholm Paradigm and Pathogen Diversification

Host range expansion and  
geographic expansion are  
correlated with pre-existing  
capacities

Host range reduction and  
geographic isolation are  
correlated with the emergence  
of new capacities

**J. Ralph Audy (1958)**

**The geographic range of a  
pathogen exceeds the  
geographic range of disease  
caused by it**

**Silent spread – asymptomatic  
carriers and misdiagnoses**

# The Stockholm Paradigm and *Audy Space*

Host range and geographic  
distribution will be  
proportional to the number of  
published reports of the  
pathogen

# The Stockholm Paradigm: The Modeling Platform

Walter will discuss the  
structure and amazing current  
results of the SP Modeling  
Platform in the next  
presentation

# The Stockholm Paradigm: Putting Evolution to Work

#1

Pathogens are not enemies  
or threats or agents of  
illness and death

**Pathogens are natural  
components of the  
biosphere and their  
associations with, and  
effects on, various hosts  
need to be understood from  
that perspective**

#2

**Infectious Disease**

**Emergence does not Require**

**New Genetic Capacities**

**Allowing a Pathogen to**

**Colonize a New Host**

# The Stockholm Paradigm

Emerging infectious diseases  
are expressions of *pre-*  
*existing capacities* given *new*  
*opportunities* – this allows  
disease to emerge rapidly

New genetic capacities arise  
*after* emergence

**#3**

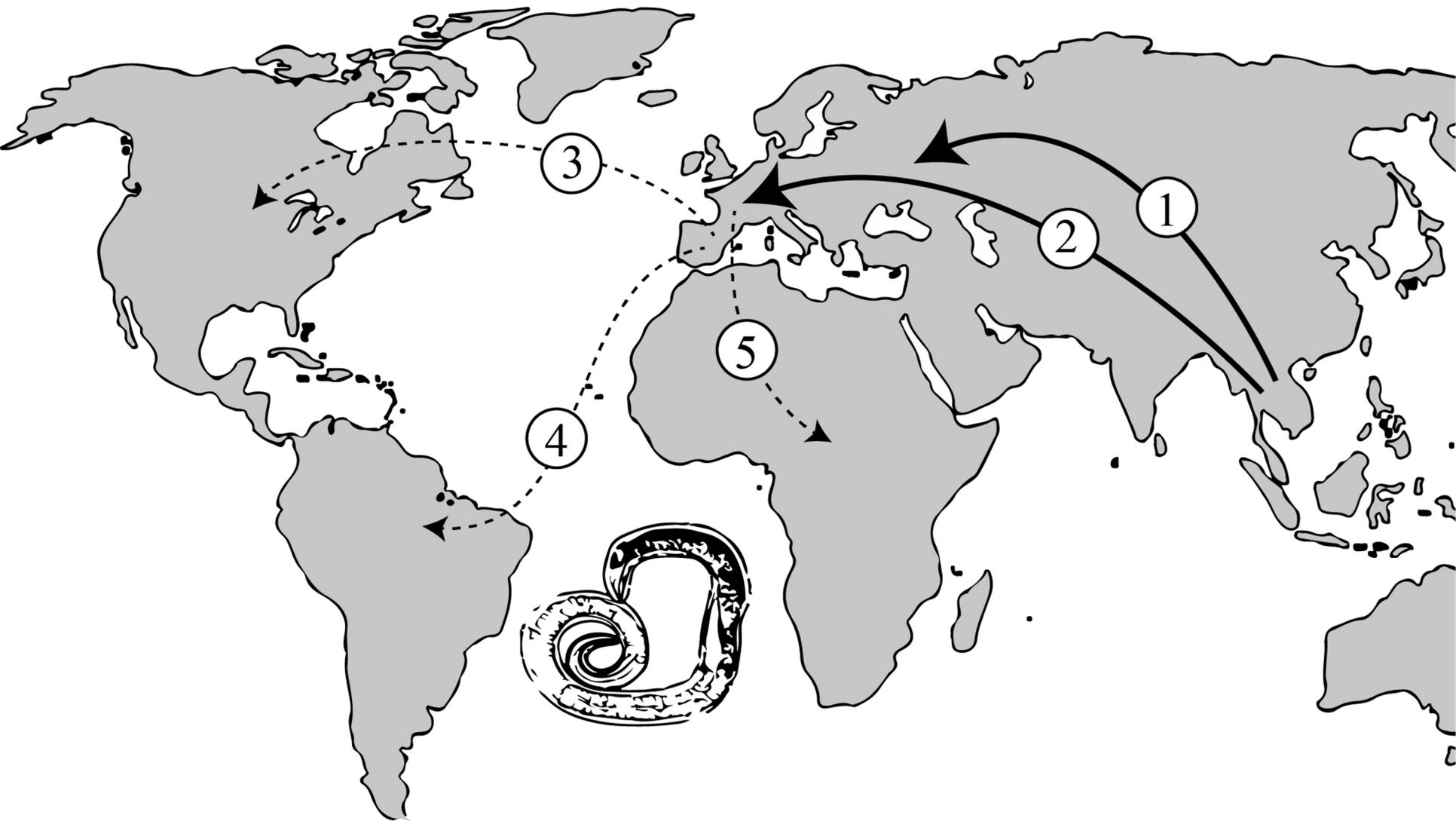
**There is a Direct  
Connection Between Climate  
Change and Emerging  
Infectious Disease**

# **Climate Change Leads to Movement**

**Climate change allows species  
to move, exposing them to  
pathogens to which they are  
susceptible but have never  
seen before**

**#4**

**Agriculture and  
Domestication, Trade and  
Travel, Urbanization, and  
War Create Massive New  
Opportunities for Emerging  
Infectious Diseases**



#5

**Cities are a Problem  
Not a Solution**

# Density and Connectivity Traps

**2-3°C above surroundings**

Require constant flow of water and  
material goods

**High population density with low  
kinship**

Extreme division of labor and  
extreme inter-dependency

**Safe environments for zoonoses**

Lifestyle supported by people too  
poor to miss work when they are sick

#6

**Pathogens do not magically  
appear and disappear**

**Pathogens are present even  
when they are not causing  
disease or making  
headlines  
(Audy Space)**

#7

We can be proactive about  
coping with EID

**From Aspiration to  
Operation: *One Health* from  
the Perspective of the  
*Stockholm Paradigm***

**If colonizing new hosts requires  
only new opportunities given  
specific pre-existing capacities**

**Those pre-existing capacities  
are predictable, allowing us to  
anticipate disease emergence**

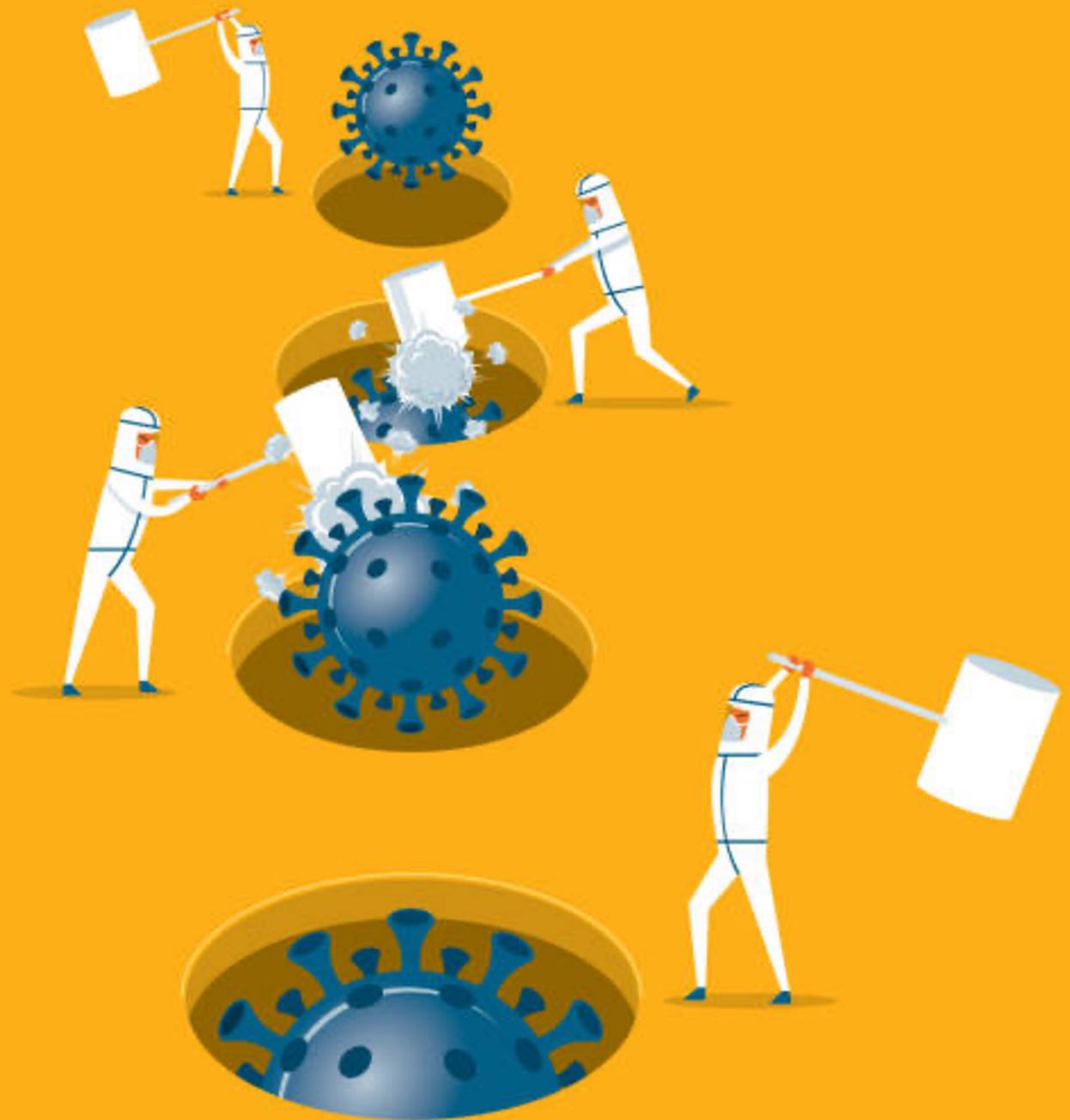
# **The Strategic Metaphor: *Anticipate to Mitigate***

**If we know what is  
coming, we can prevent  
some outbreaks and  
mitigate the impact of  
some outbreaks that occur  
(preventing pandemics)**

Once a pathogen becomes  
established in a new host as a  
result of *predictable pre-  
existing capacities*

*Unpredictable new capacities  
will emerge*

Unsustainably expensive crisis-  
response becomes our only option



**WAR ON COVID**



**YOU  
ARE  
HERE**



**Making it Happen:  
The Afternoon Presentations**

**Science and Public  
Service:**

**The DAMA Protocol**

**Science and Public Policy:  
The 3P's Perspective**