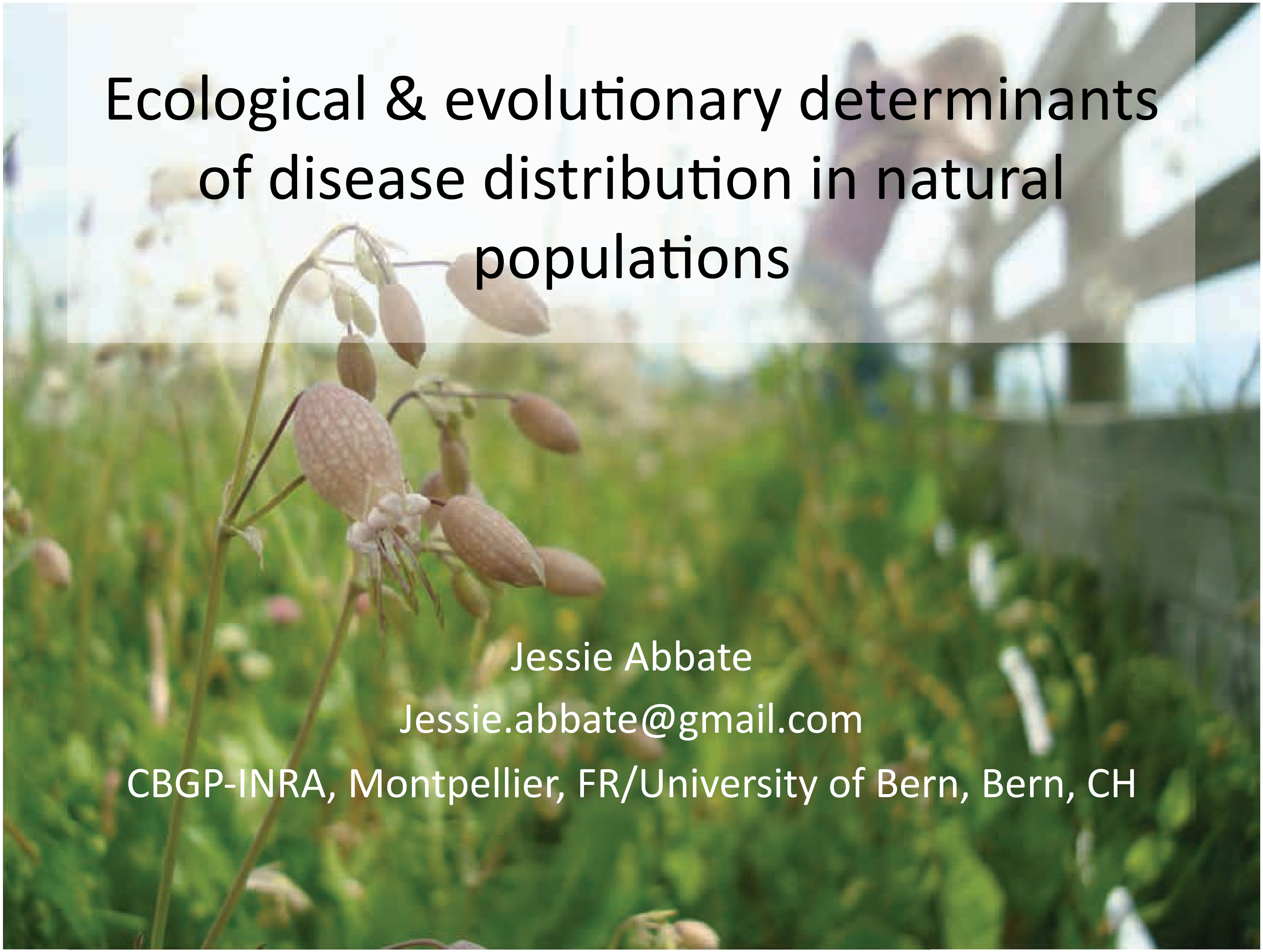


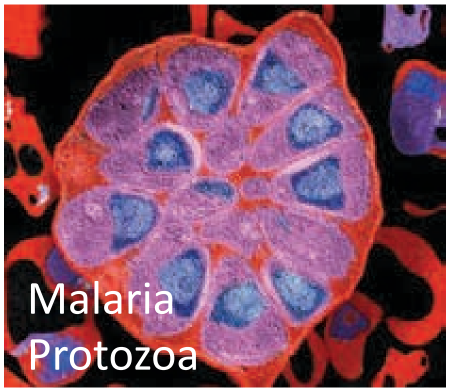
Ecological & evolutionary determinants of disease distribution in natural populations

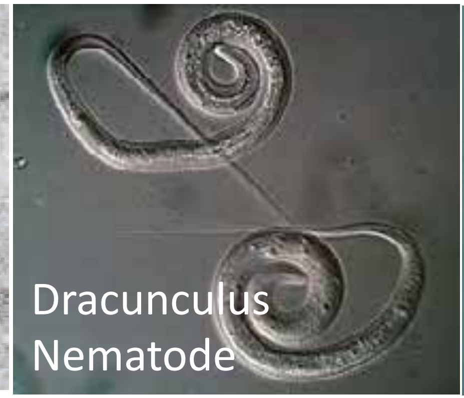
Jessie Abbate

Jessie.abbate@gmail.com

CBGP-INRA, Montpellier, FR/University of Bern, Bern, CH

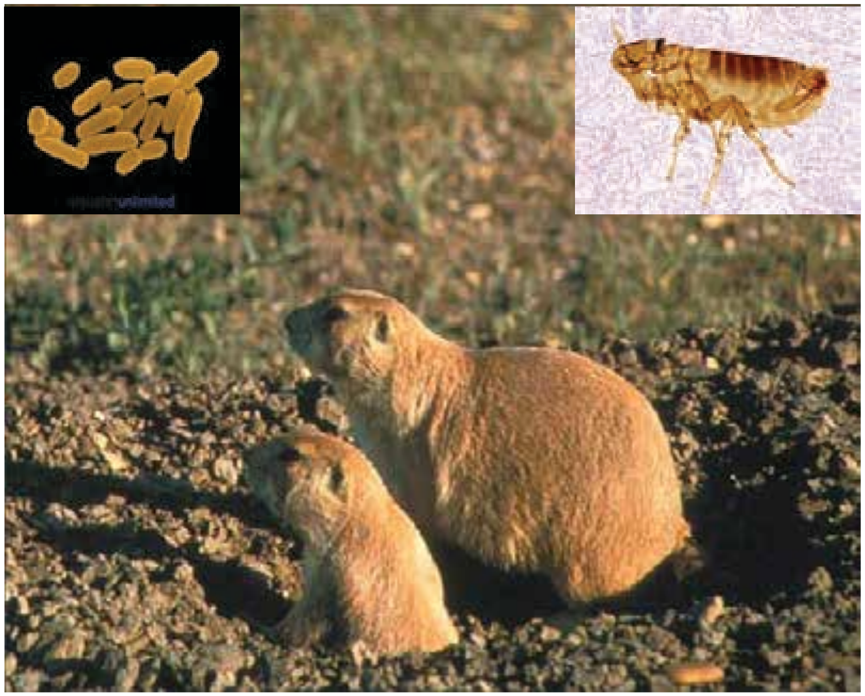
Infectious Disease

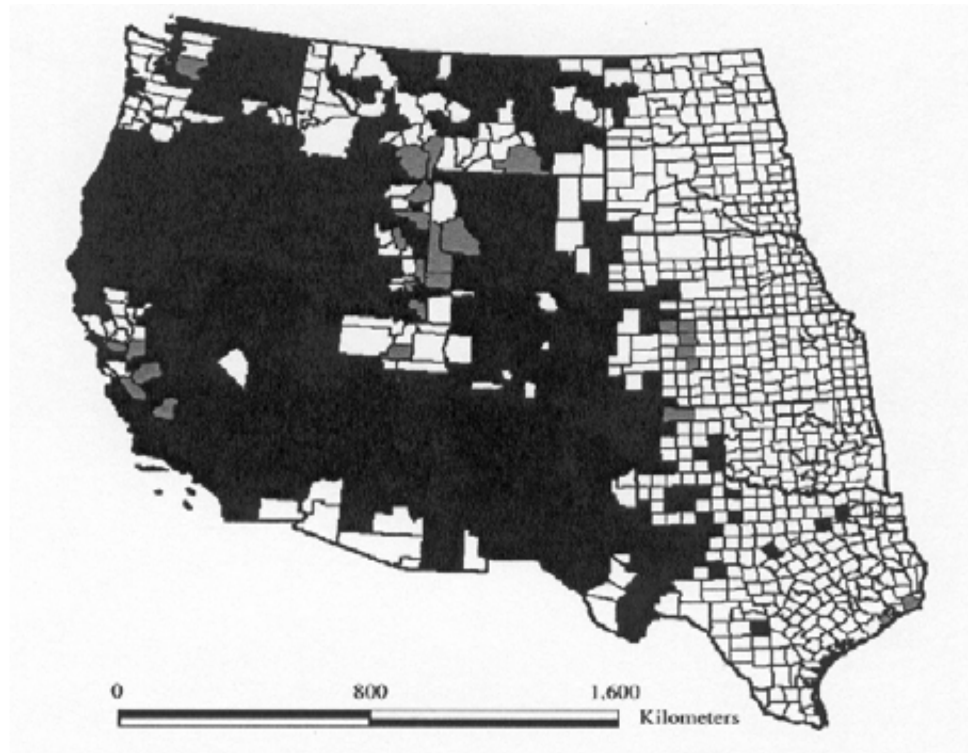




- Integral to natural evolutionary and ecological dynamics of populations
- Large impacts on human health, agriculture, wildlife management, and conservation
- Predicting emergence (presence and severity) is useful for anticipating and focusing control strategies

LIMITS to DISEASE DISTRIBUTION in NATURE





Example:

Sylvatic Plague in small mammals limited to west of the 100th Meridian

Antolin et al. 2002; Strapp et al. 2004

What factors affect the distribution of infectious disease?

- Natural History & Population Dynamics
- Geographic Distribution & Evolutionary History
- Host – Pathogen Genetics
- Phenotype & Life-History Traits
- Environmental Variables
- Ecological Interactions

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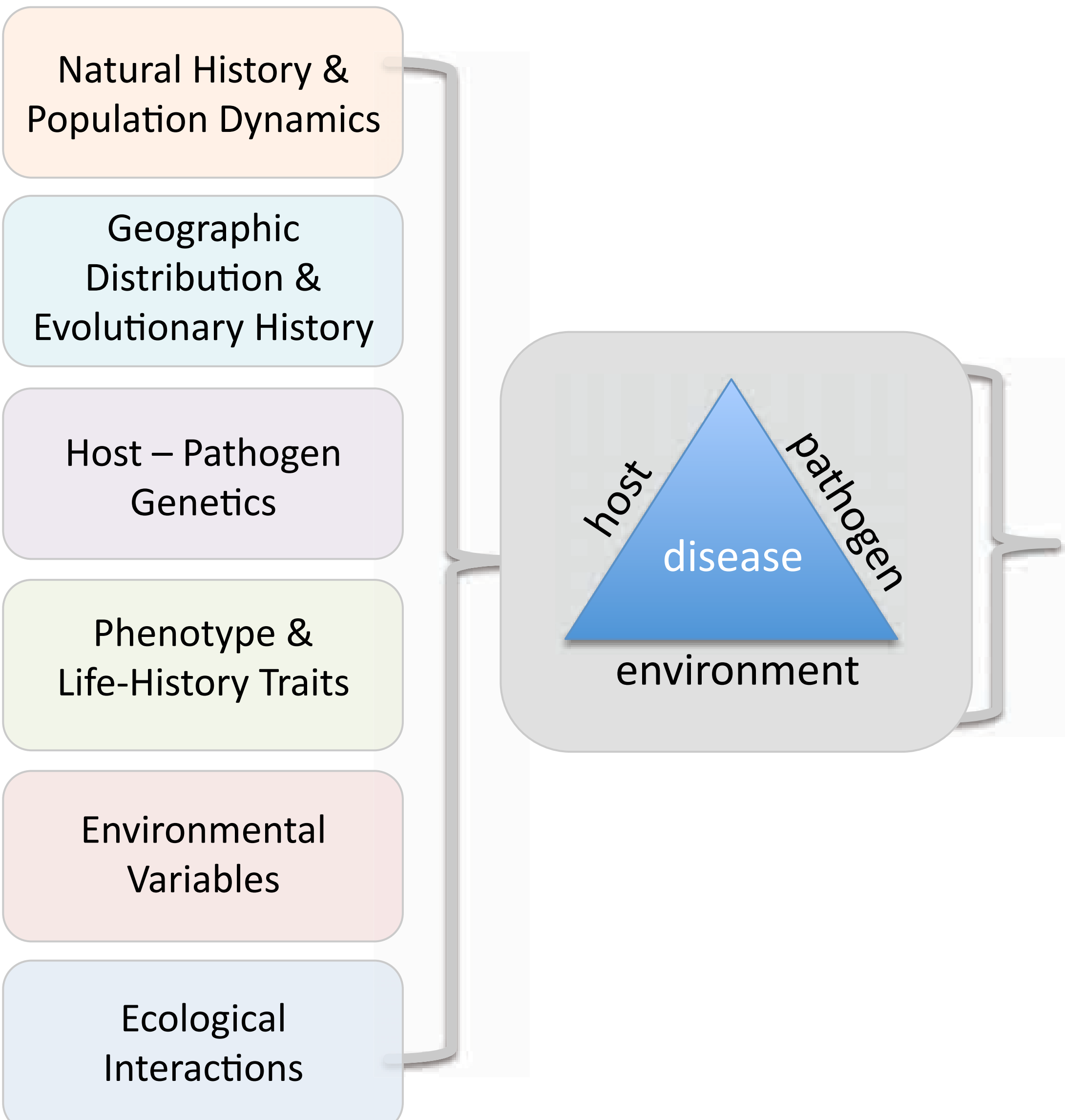

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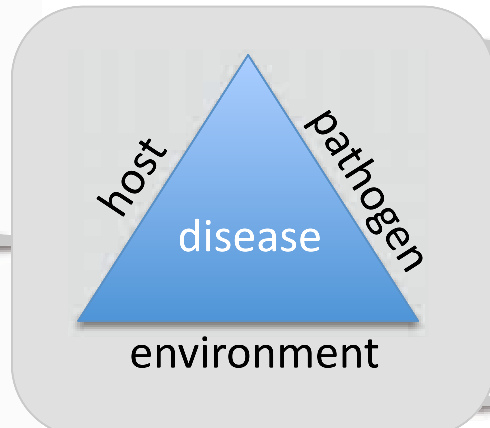
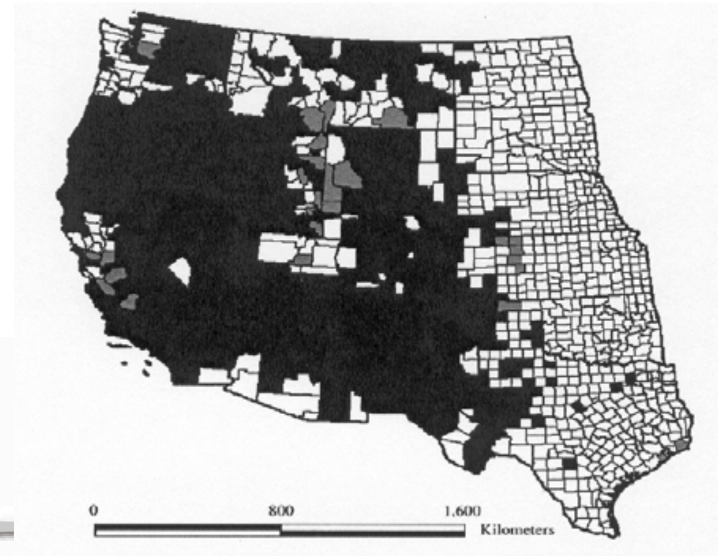
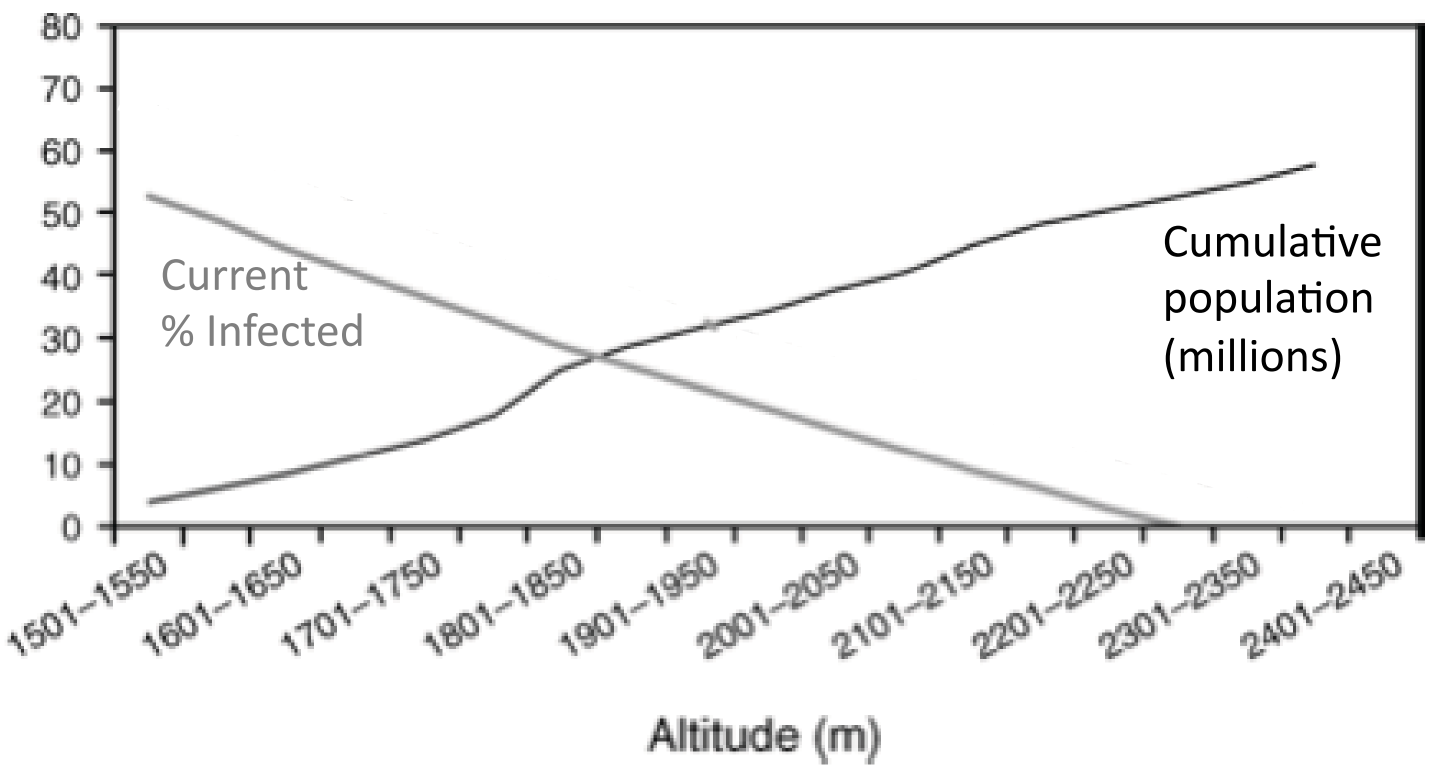
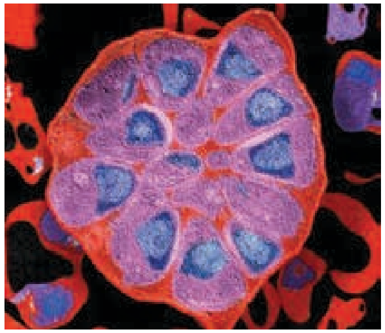




Predicting disease distribution is necessary for anticipating control strategies

Malaria in the Ethiopian highlands





Pascual & Bouma 2009 *Ecology*

Lafferty 2009 *Ecology*

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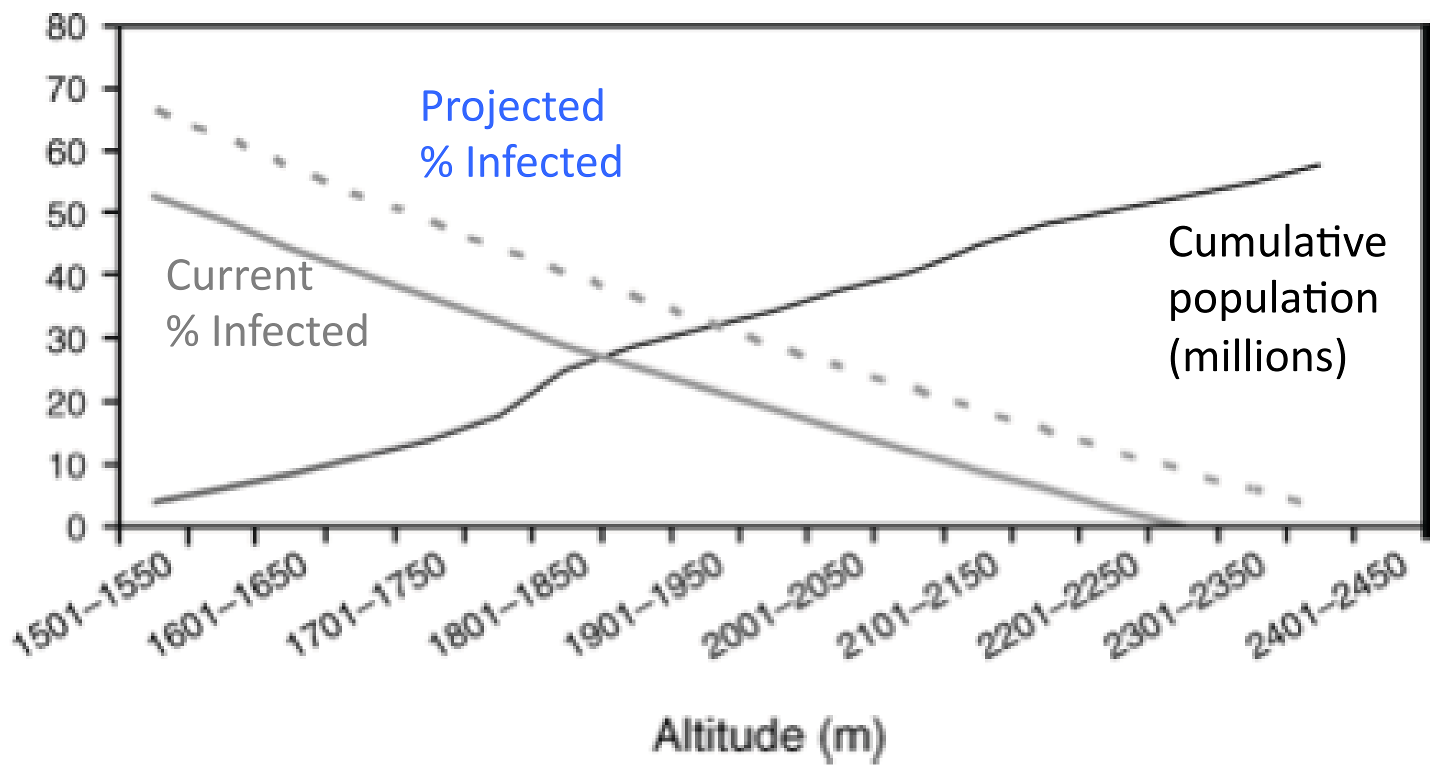

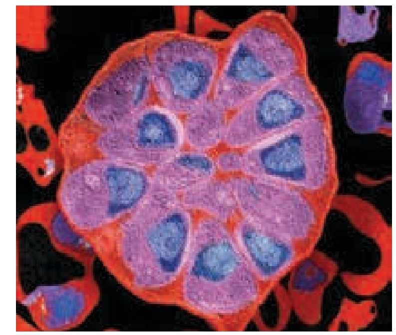

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1°C increase in temperature
= an extra 2.8 million children affected

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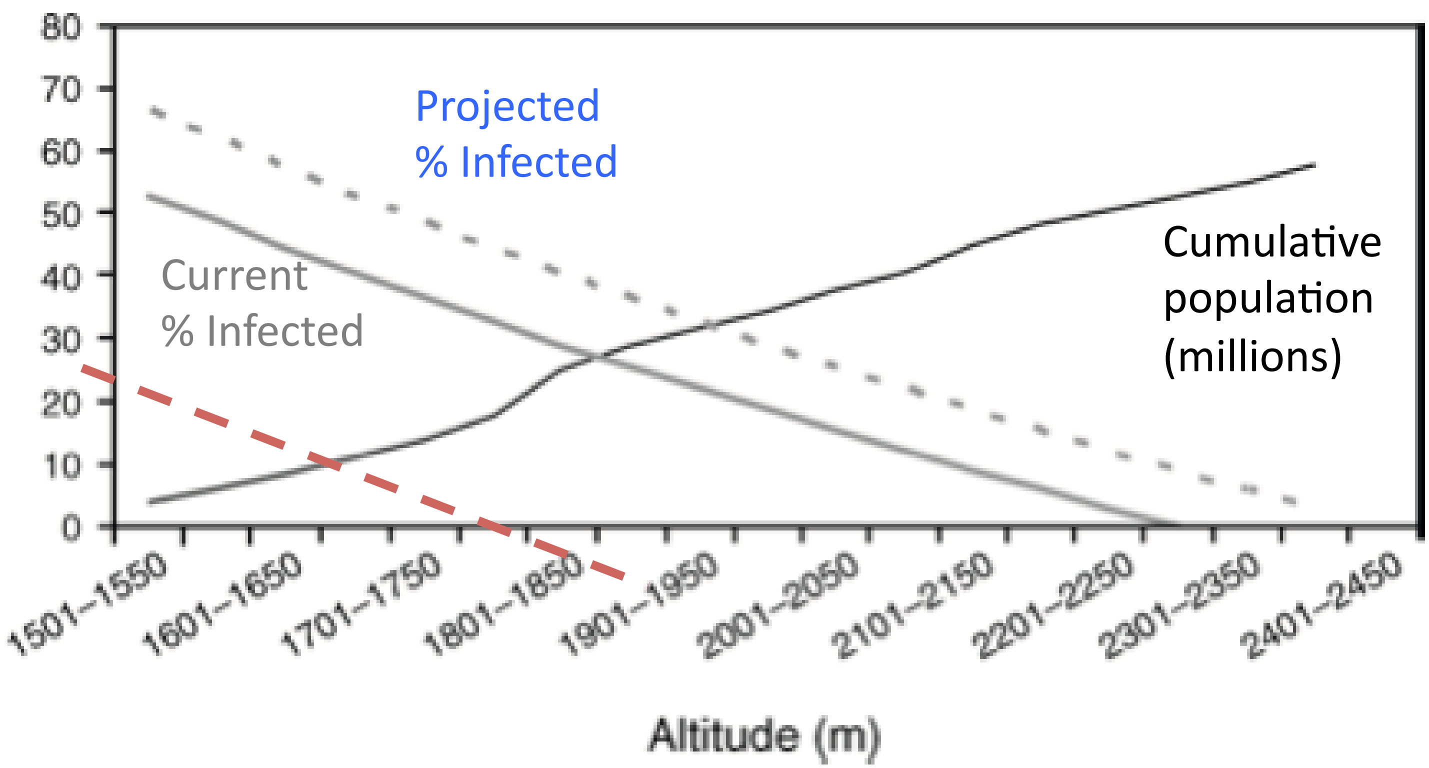

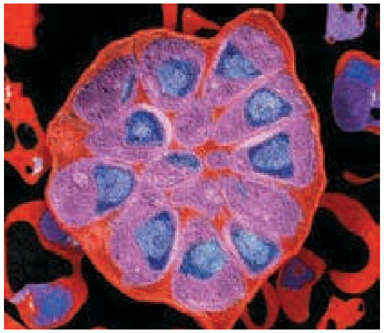

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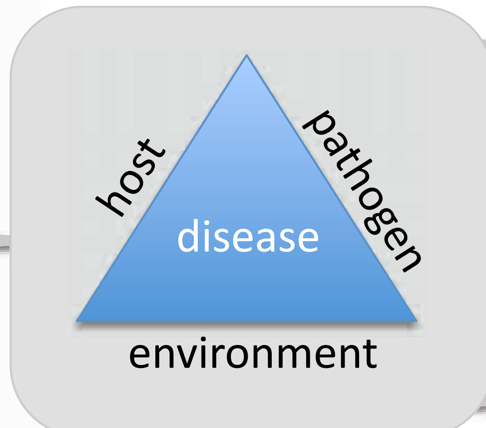

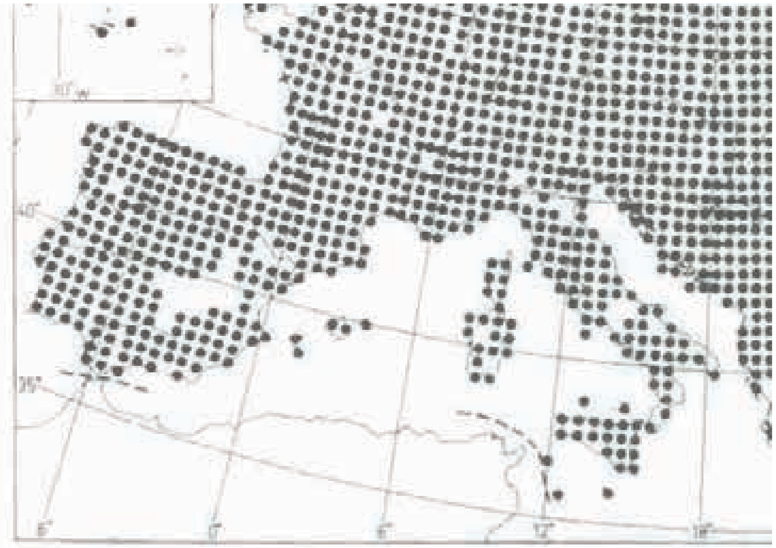

■ *Silene vulgaris*

Abbate & Antonovics 2014 *Oikos*

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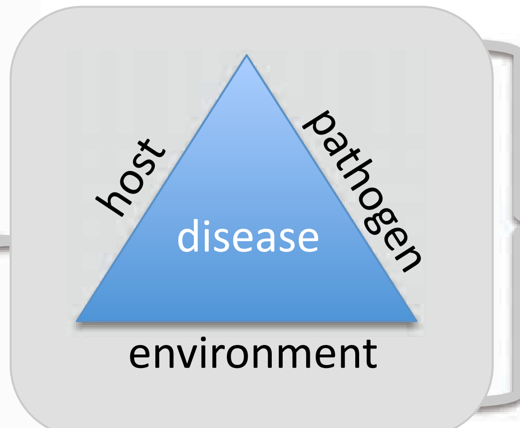

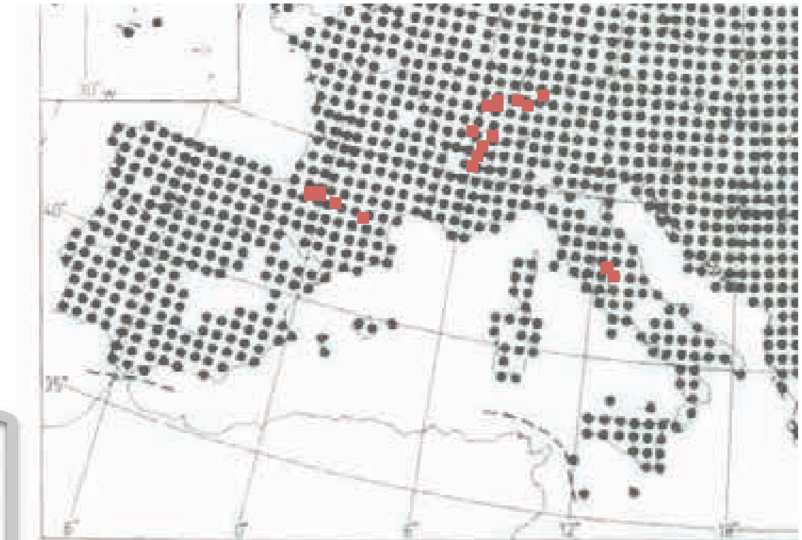

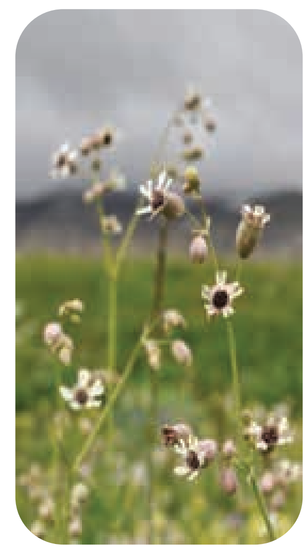

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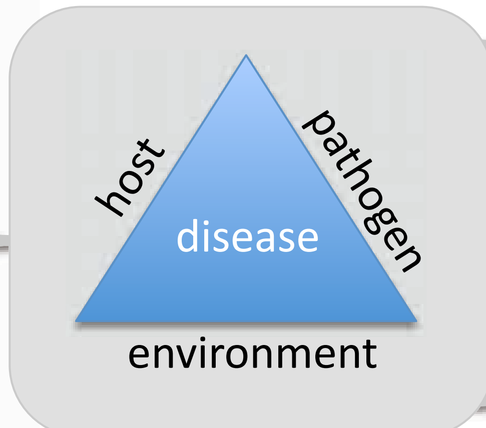
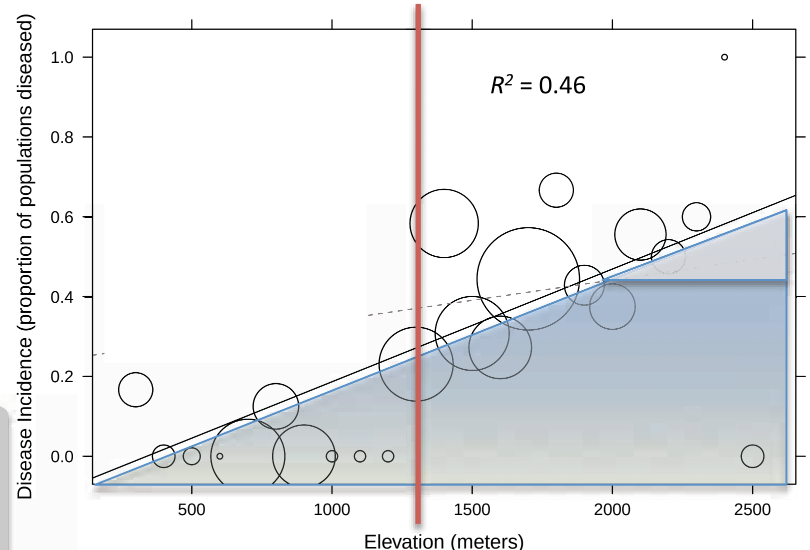
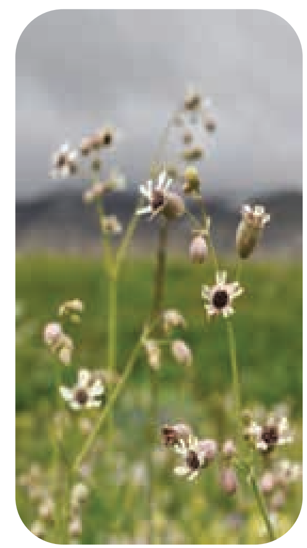






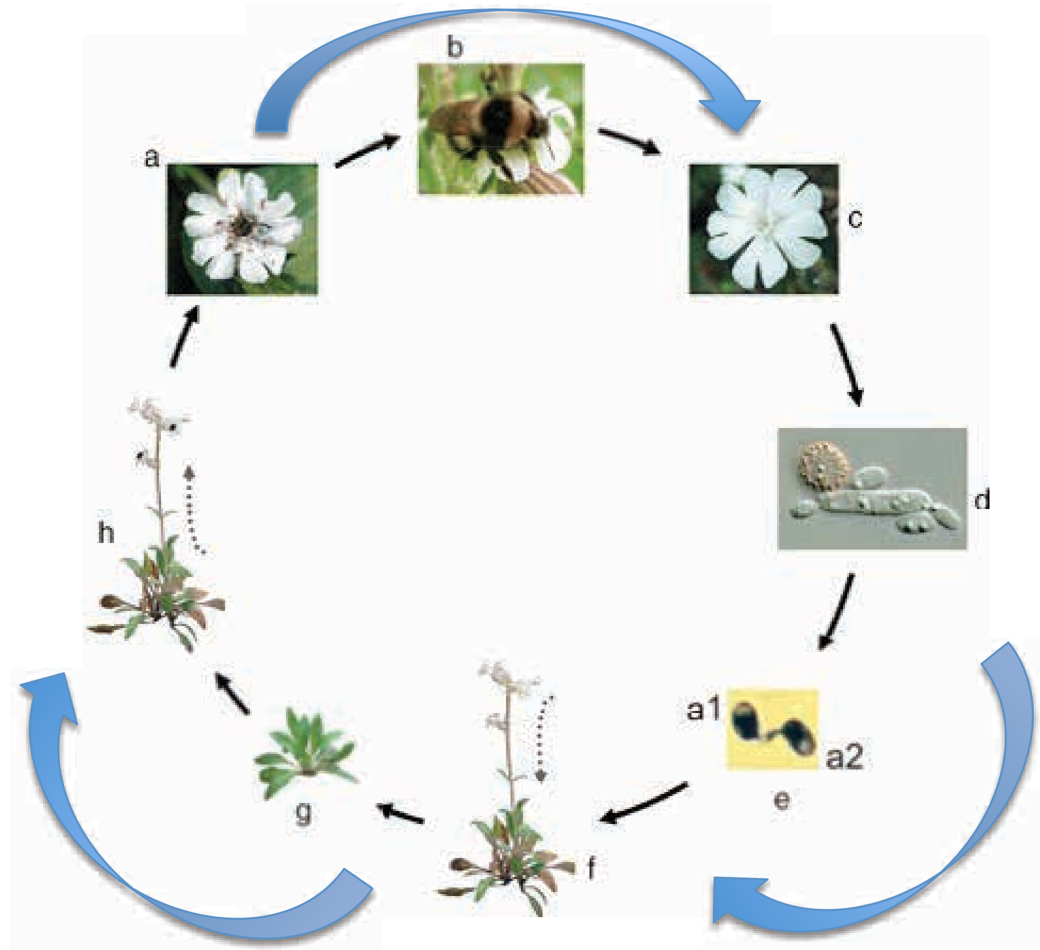
Abbate & Antonovics 2014 *Oikos*

The pathogen

Microbotryum spp. "Anther Smut"

- Obligate species-specific parasitic
- Bacidiomycete
- Pollinator-transmitted (mechanical)
- Sterilizes and alters host behavior
- Model for sexually-transmitted & sterilizing diseases

Disease Expression and Spore dispersal



Systemic Infection

Germination, Sex, Infection

Giraud et al. 2008 *Eukaryotic Cell*

The host

Silene vulgaris “Bladder Campion”

- Perennial Caryophyllaceae
- Gynodioecious
- No (current) agricultural value

The host

Silene vulgaris "Bladder Campion"

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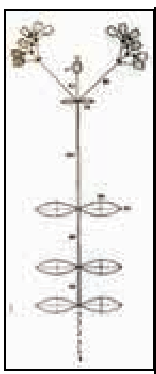
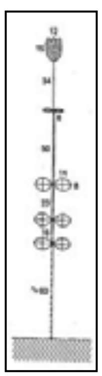




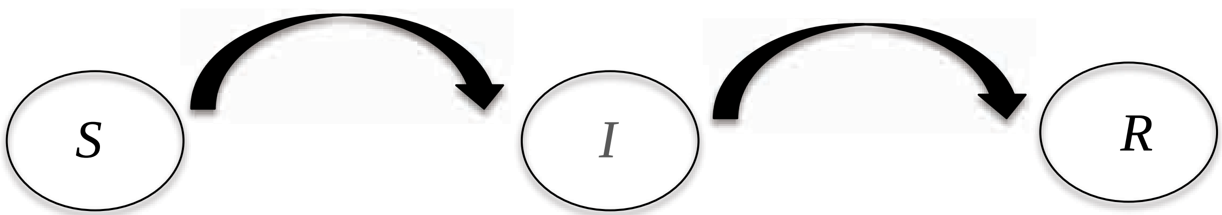
The host

Silene vulgaris "Bladder Campion"

- Perennial Caryophyllaceae
- Gynodioecious
- No (current) agricultural value
- Morphologically variable
- Generalist-pollinated

Kerri Coon (UGA)

Epidemiological Approach



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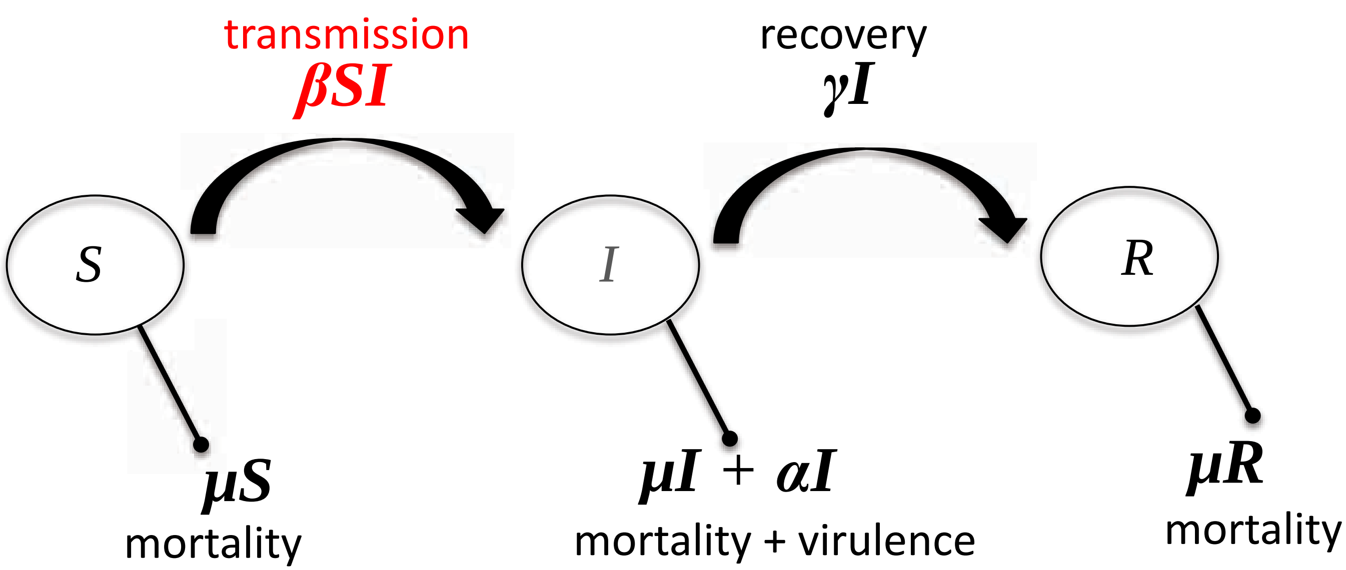

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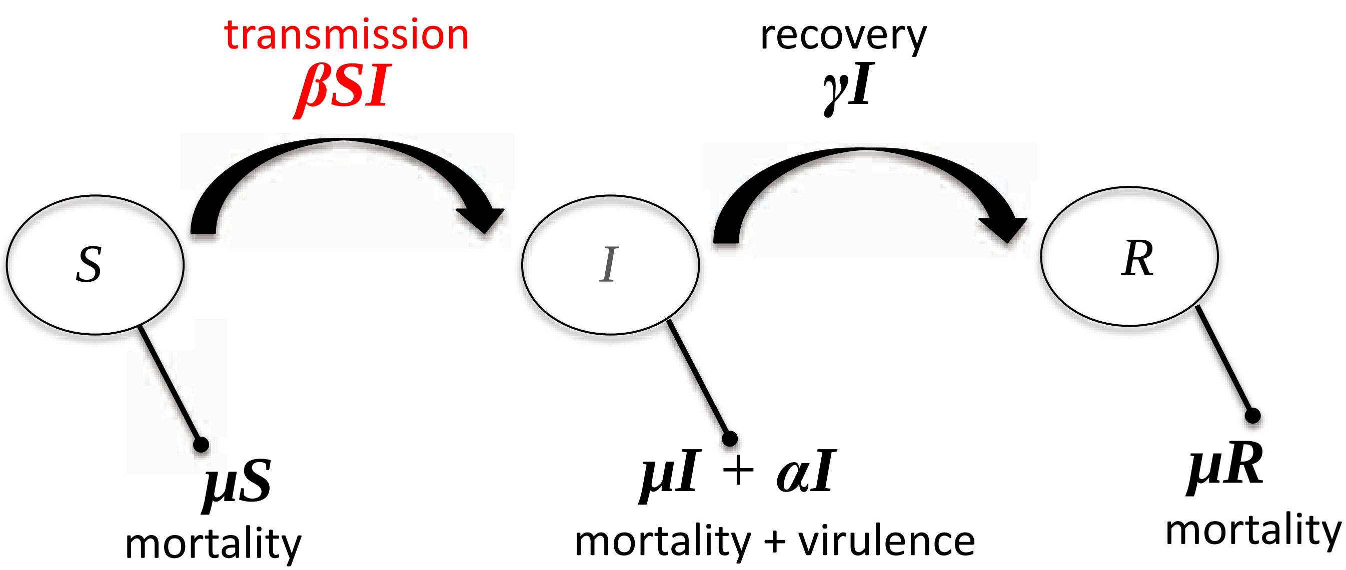
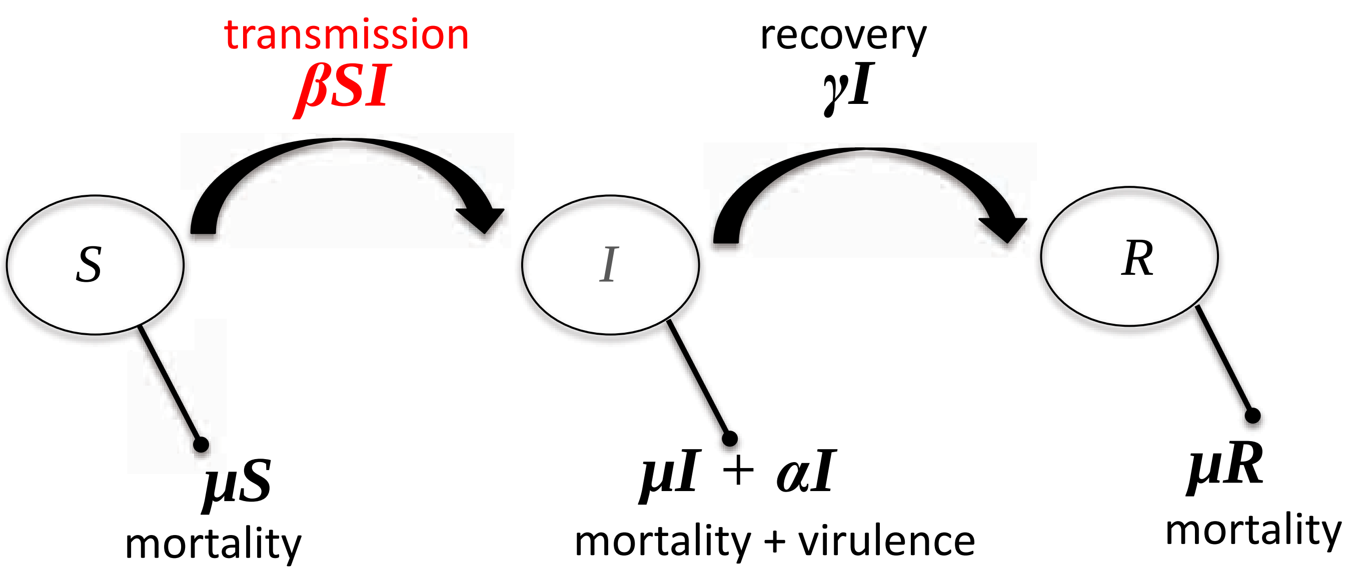


β= contact rate (c) x ***probability of infection (δ)***

Epidemiological Approach

$$I = \beta SI - (\mu + \alpha + \gamma)I$$



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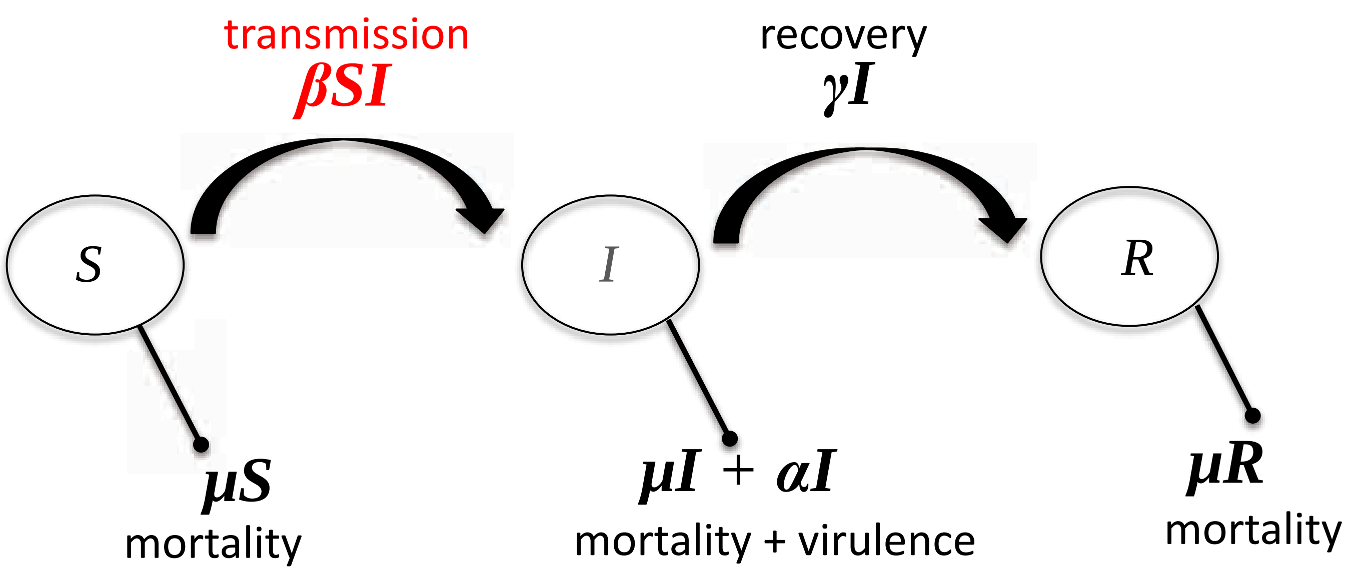

$$I = \beta SI - (\mu + \alpha + \gamma)I$$

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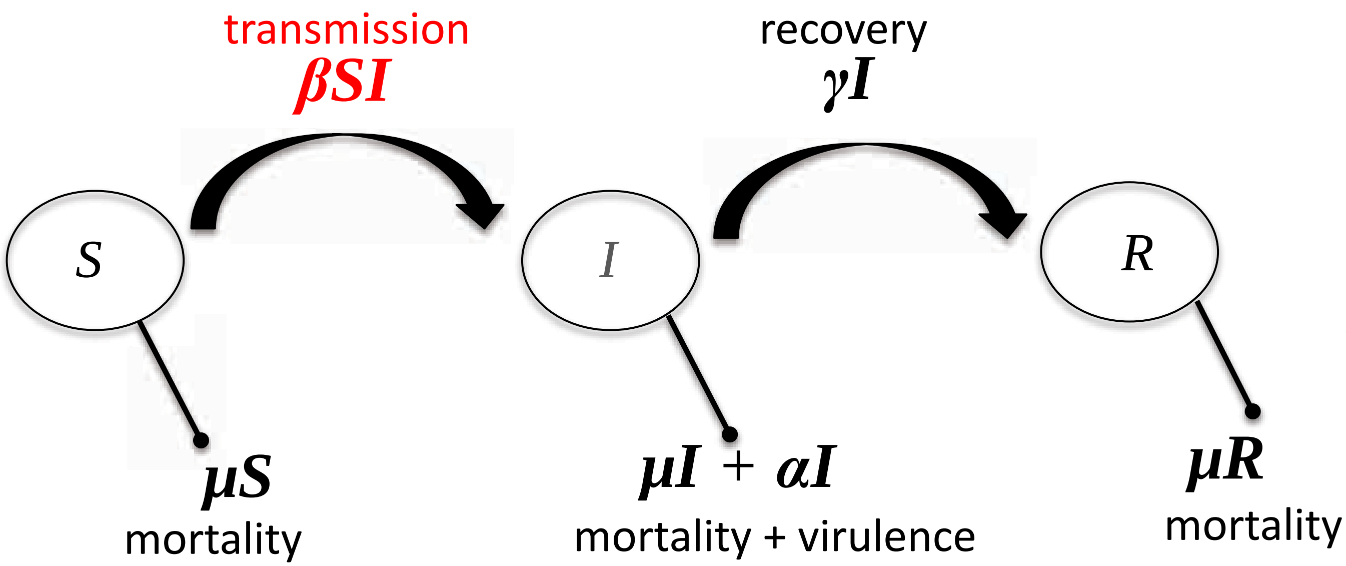

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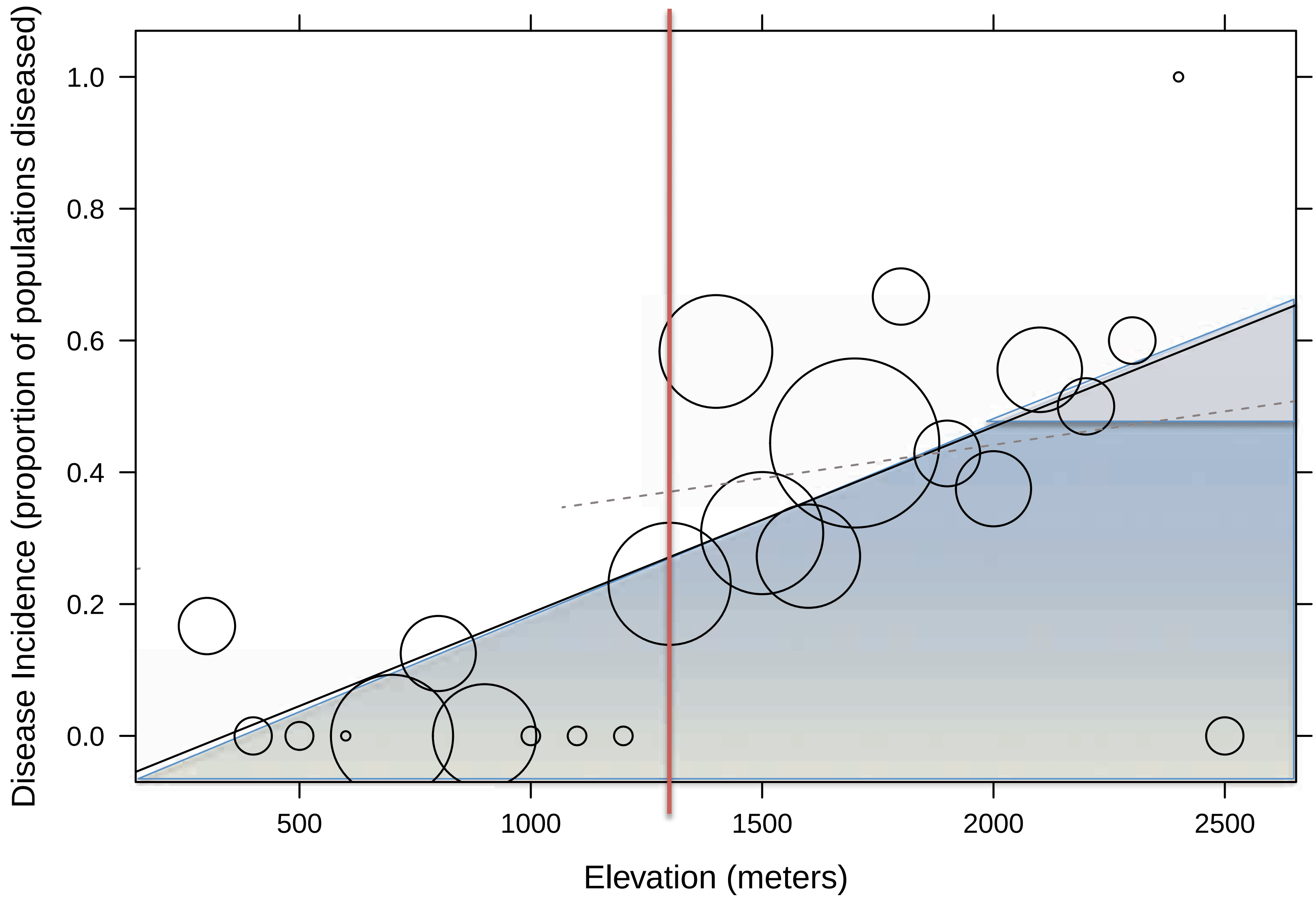
$$R_o = \frac{\beta SI}{(\mu + \alpha + \gamma)I}$$

Endemic Equilibrium = 1

Epidemic* > 1 > *Fade-out

β= contact rate (c)* x *probability of infection (δ)

Epidemiological Approach



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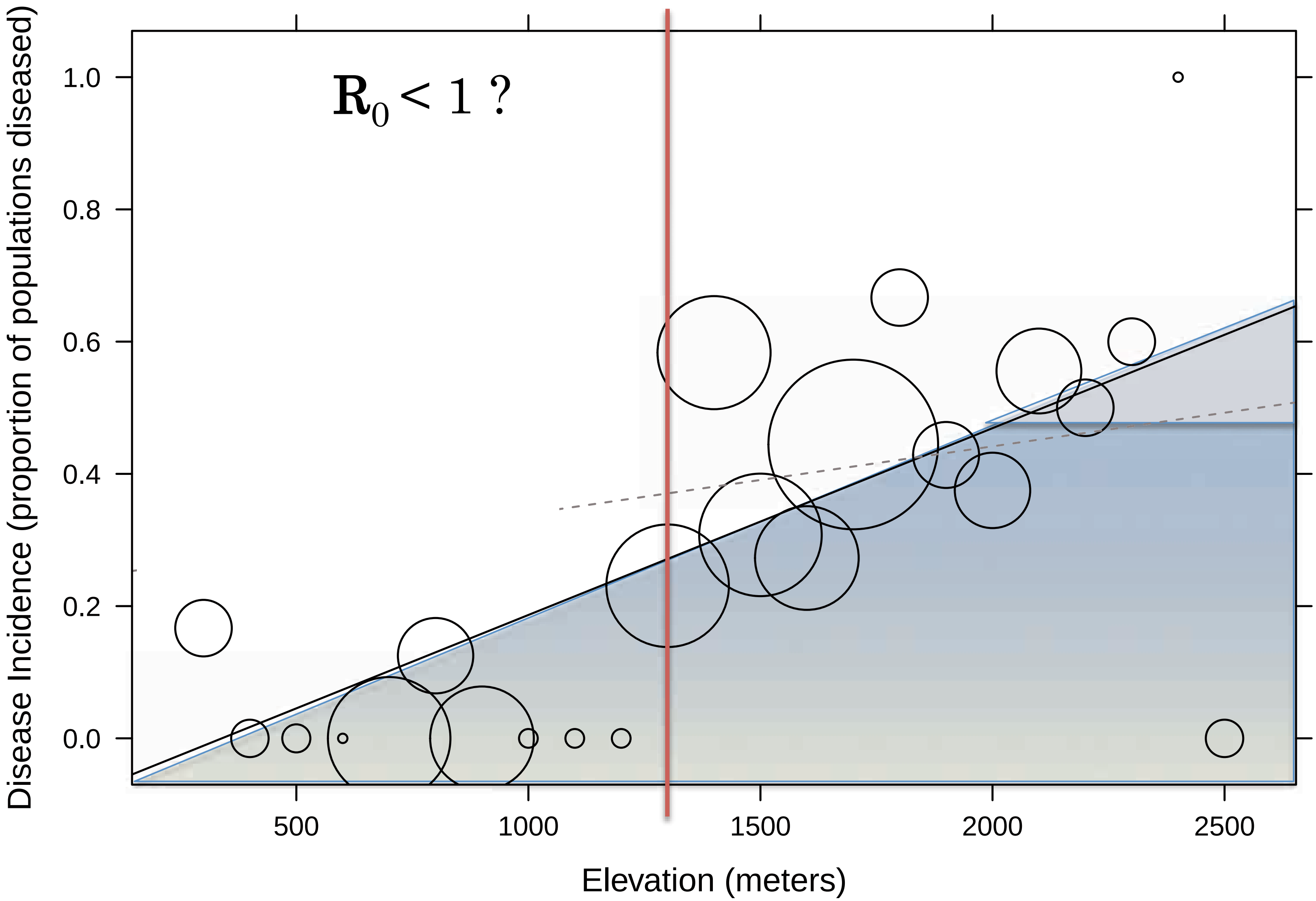

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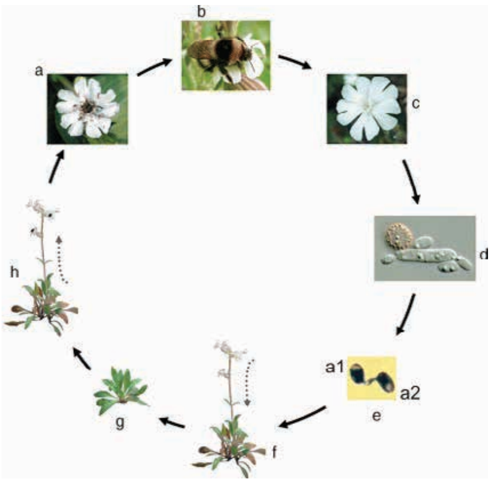
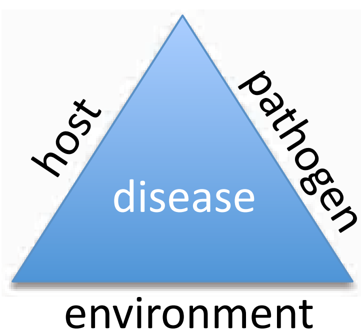
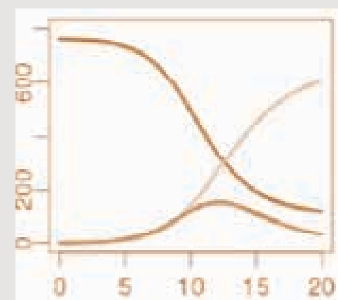




- Host availability (S)
- Pathogen availability (I)
- Transmission (β)
  - Contact
  - Probability of Infection
- Recovery (γ)
- Virulence ?



Experiments

- Host population differences across elevation :
  - ecotypic adaptations
  - resistance to disease

- Environmental effects on infection success :
  - disease expression
  - infectivity

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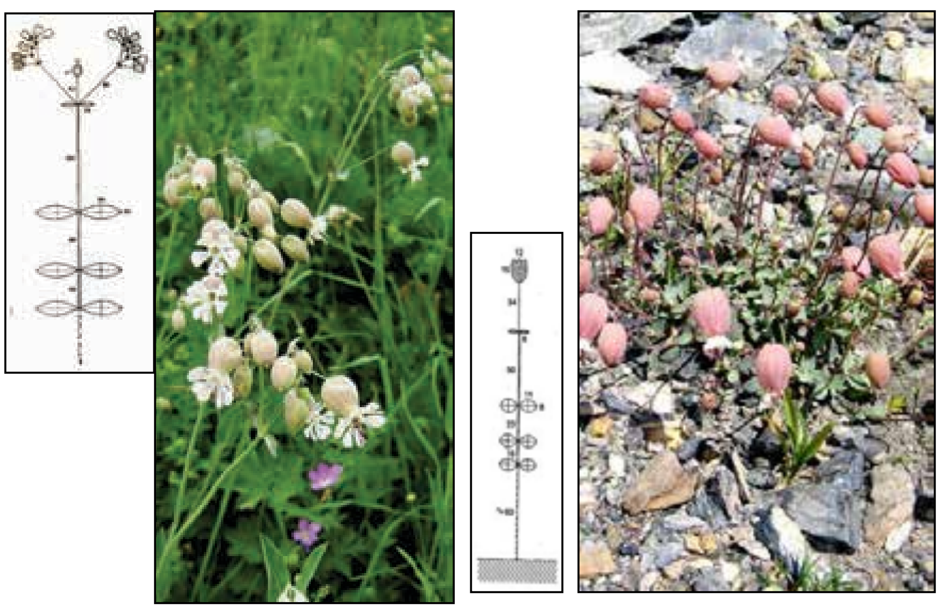
The host

Silene vulgaris “Bladder Campion”

- Ecological and phenotypic variability



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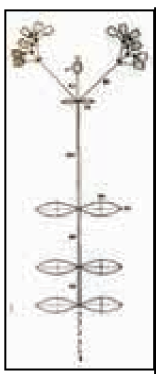
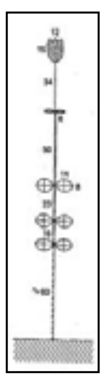
Are low-elevation hosts more resistant to the disease?





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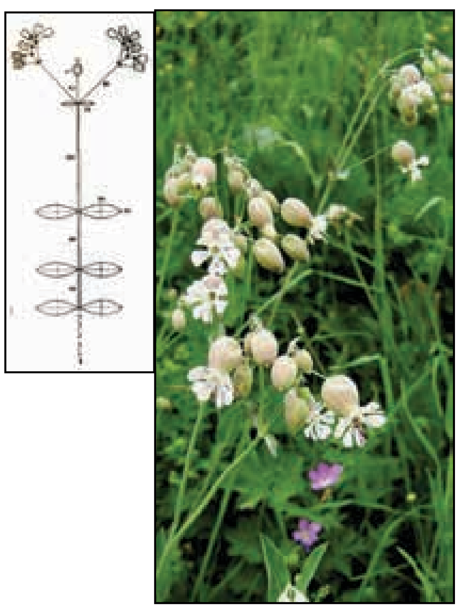
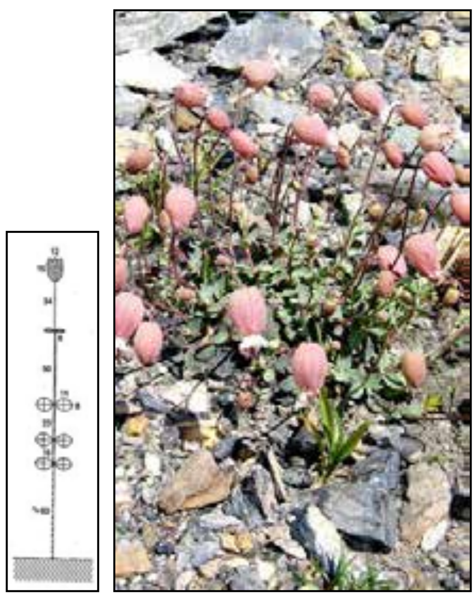
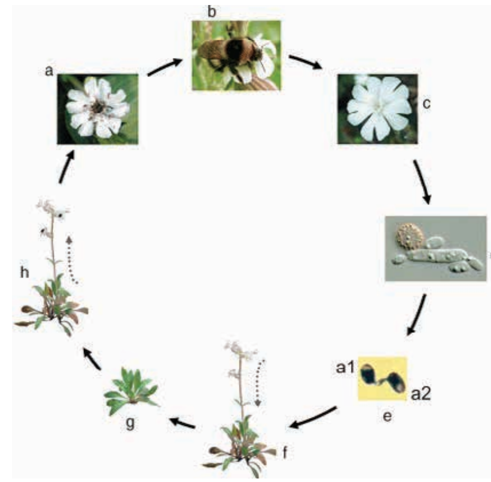
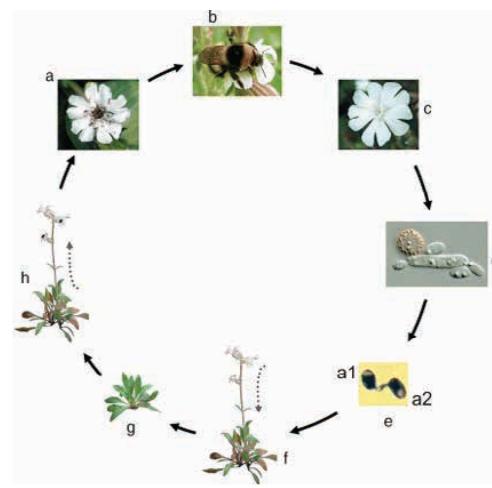




- Classical AVOIDANCE resistance



- RECOVERY resistance



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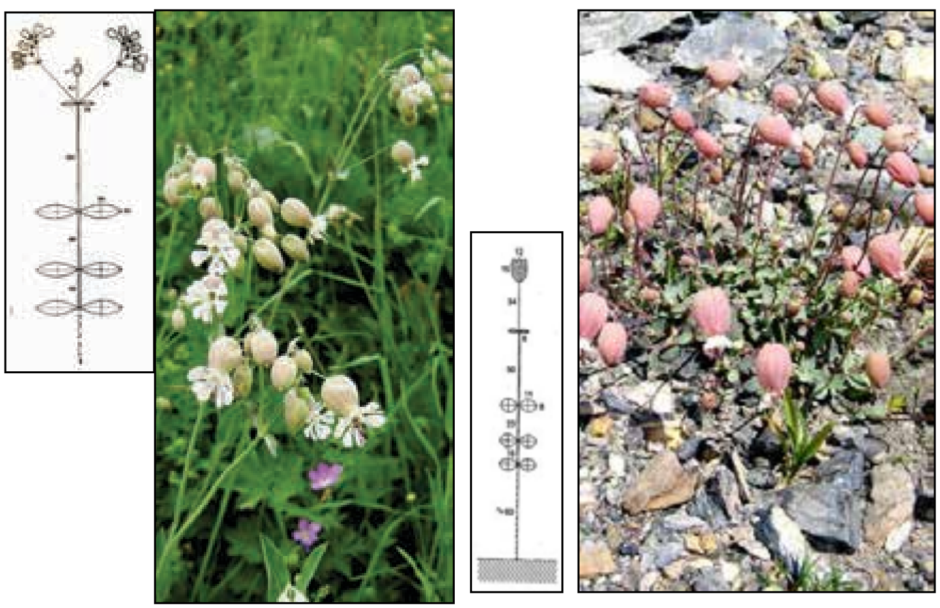

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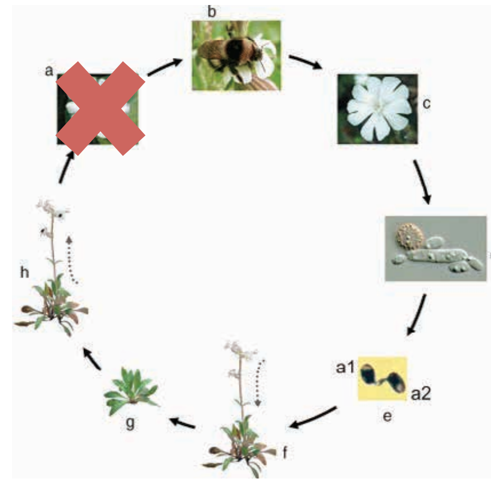

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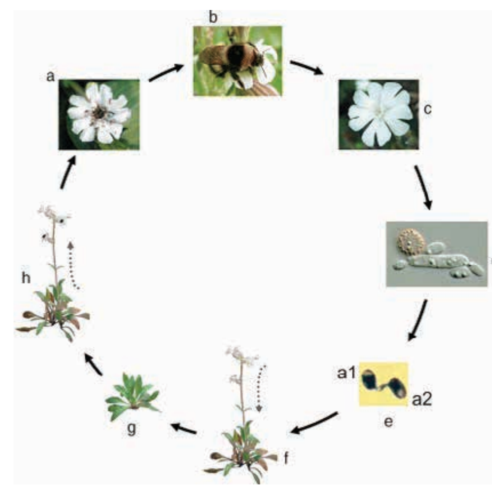

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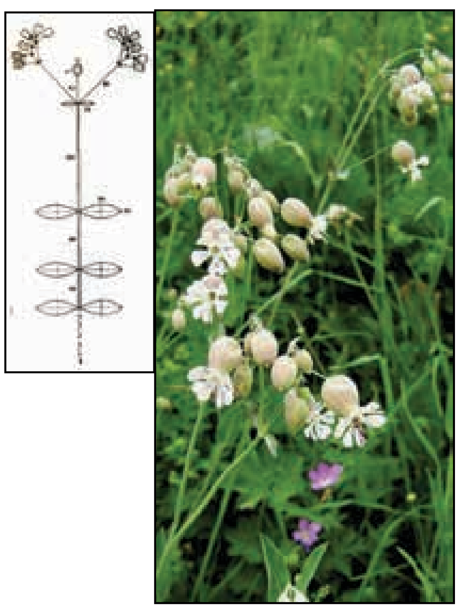

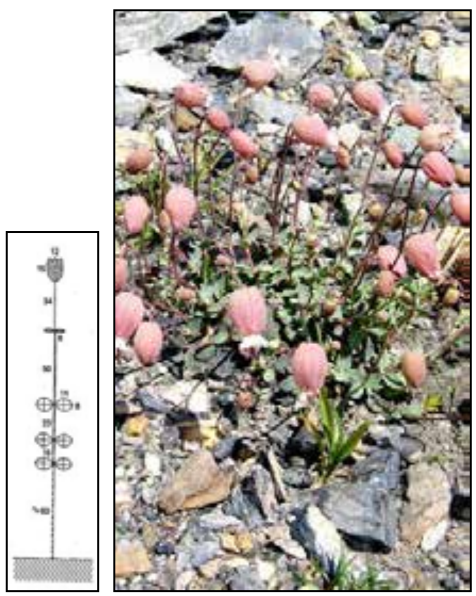

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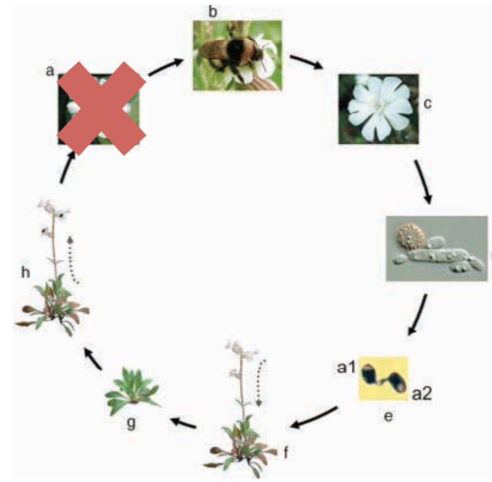

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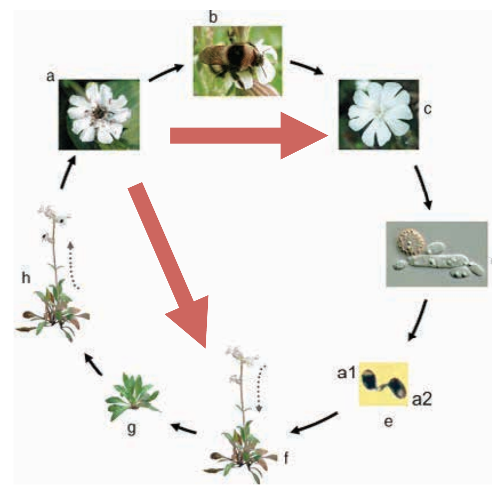
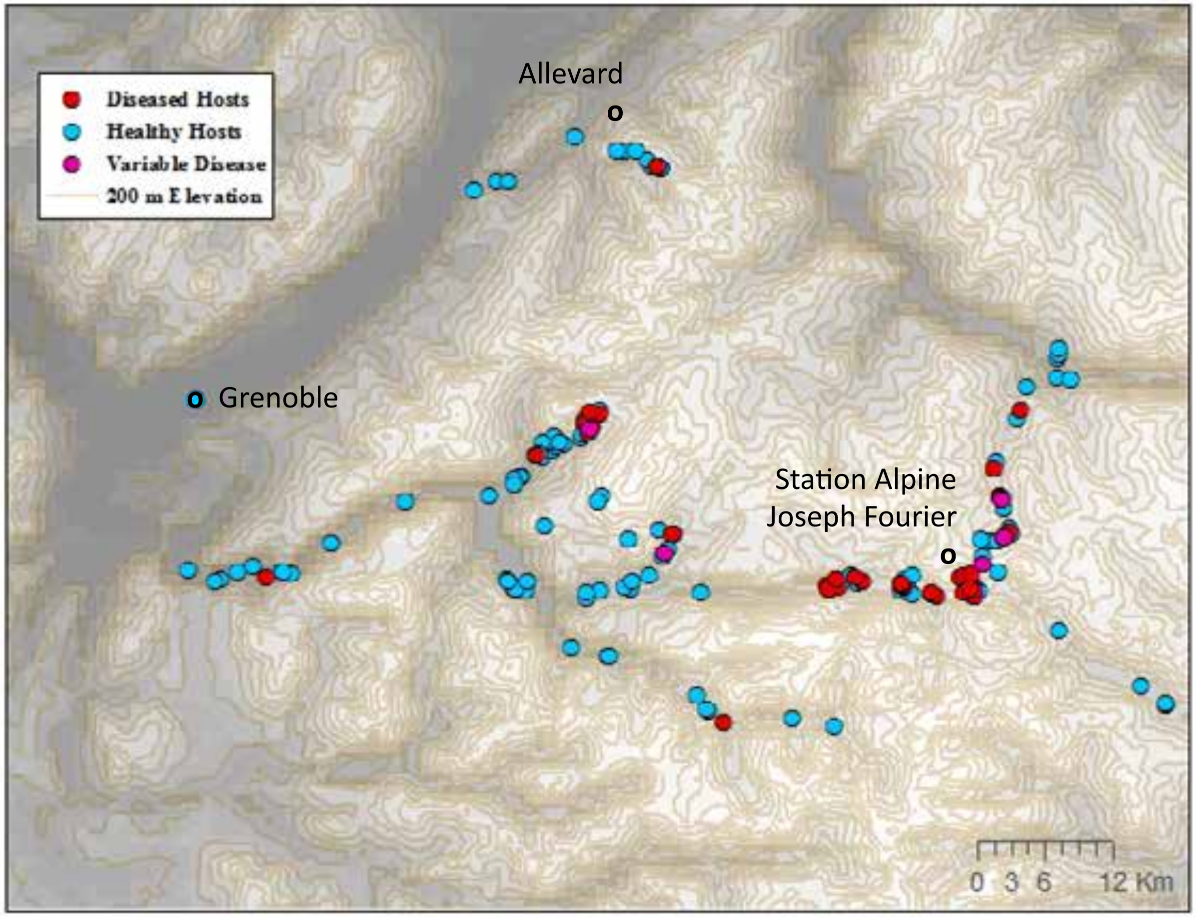
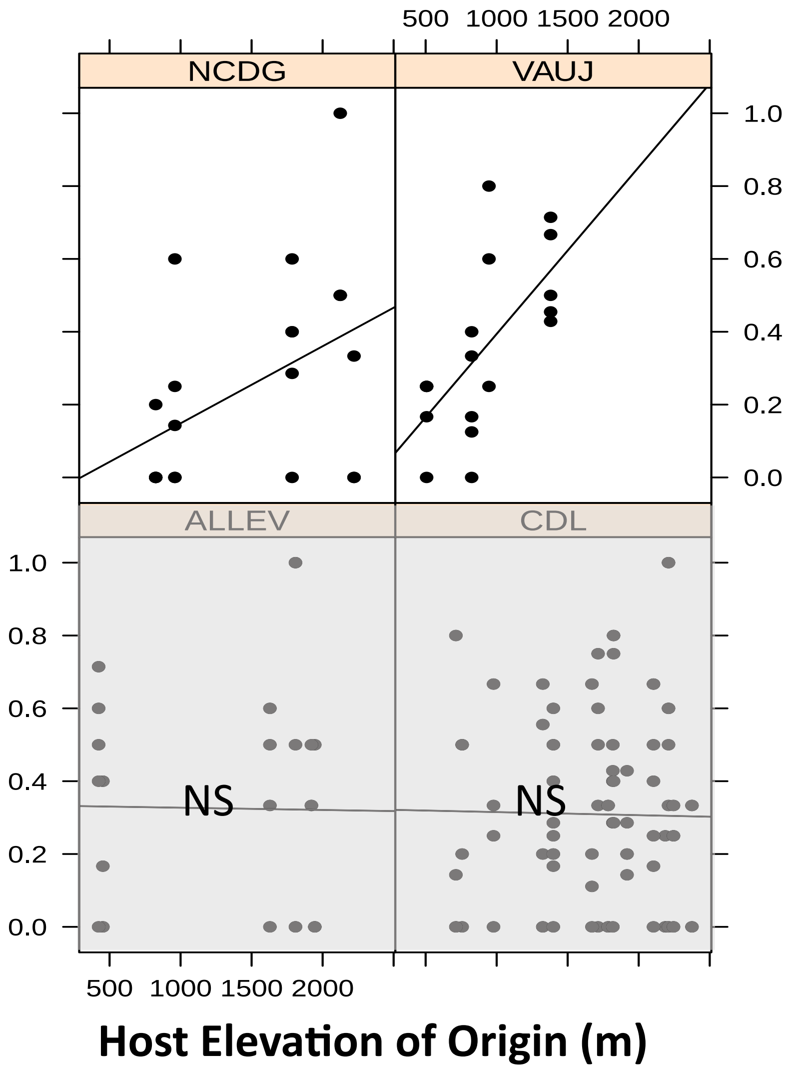


Lab-Inoculations

Genetic
Effects on Host Resistance?



Genetic
Effects on Avoidance Resistance?



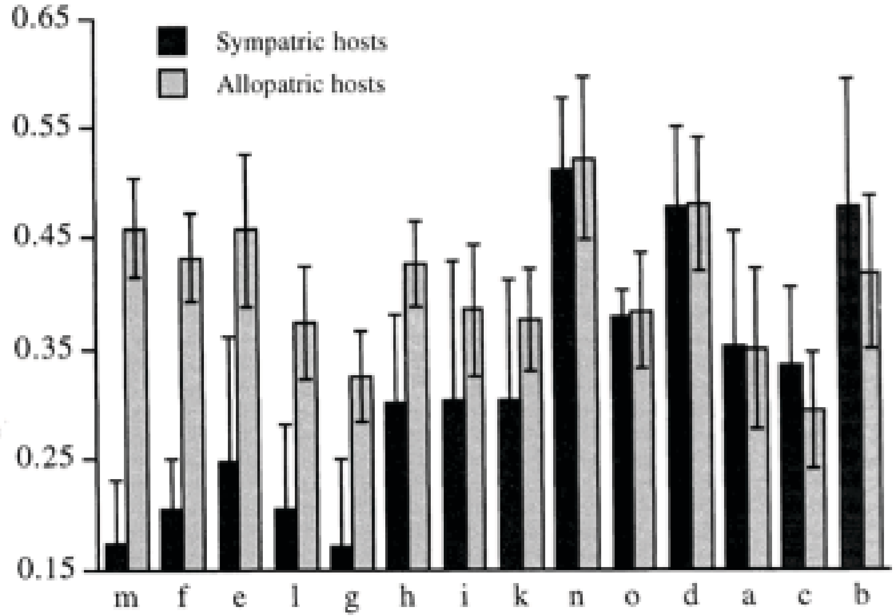
- High-elevation host populations have higher rates of avoidance ($p<0.05$)

- High-elevation hosts appear to carry more resistance

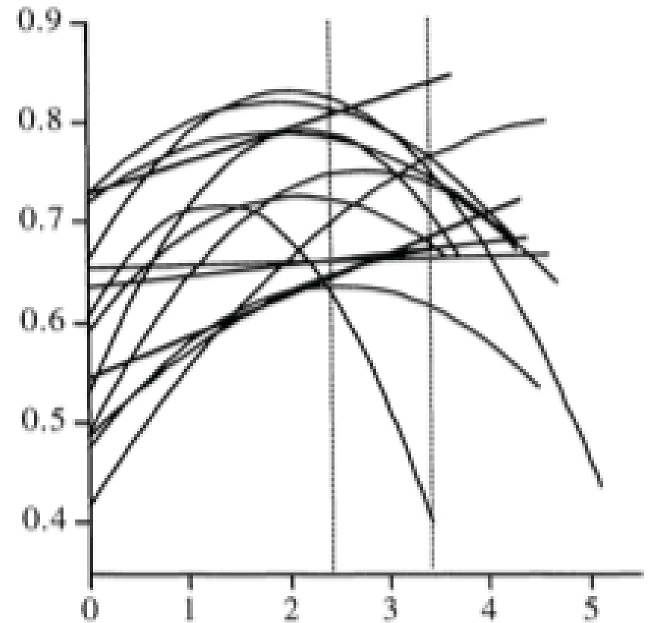
- Not surprising, given anther-smut is known to show patterns of maladaptation to its local host populations (Kaltz et al. 1999)

<u>Local mal-adaptation of *M. violaceum* to *S. latifolia*</u>

proportion successful infections



pathogen population



ln distance (km +1)

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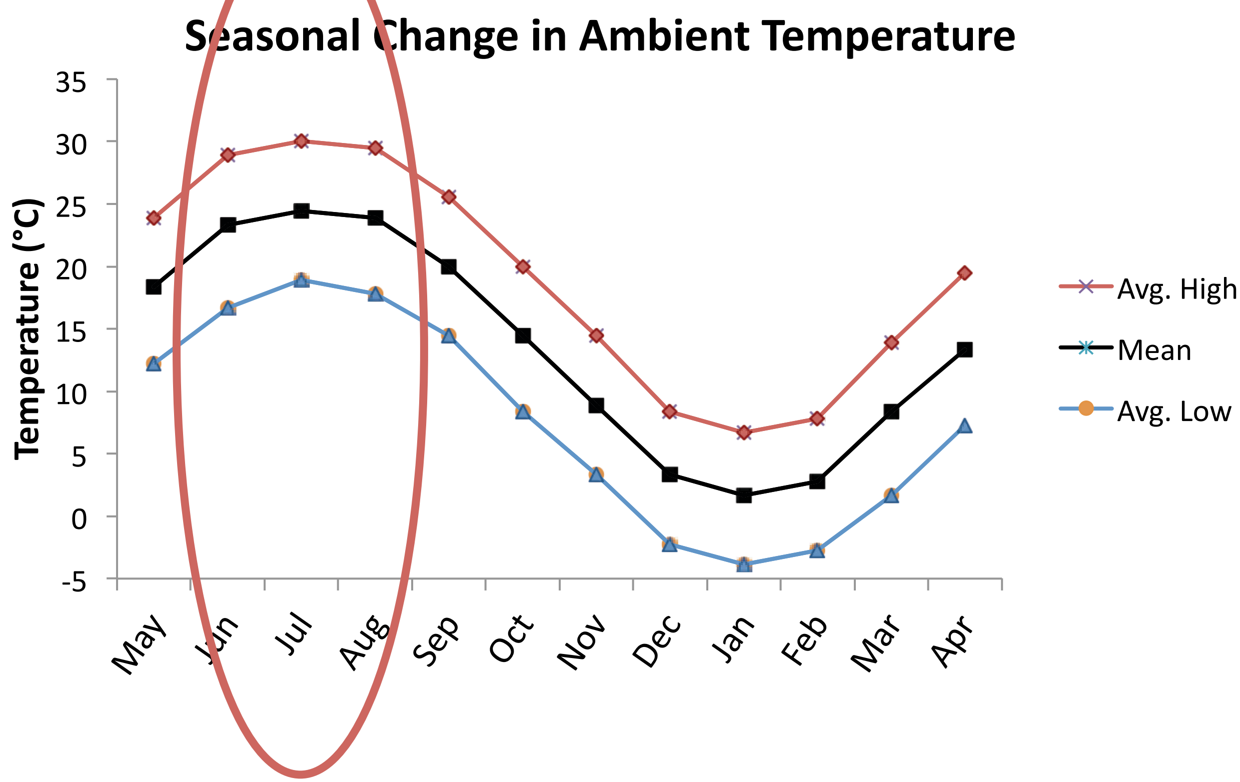
Temperature
Effects on Host Recovery?



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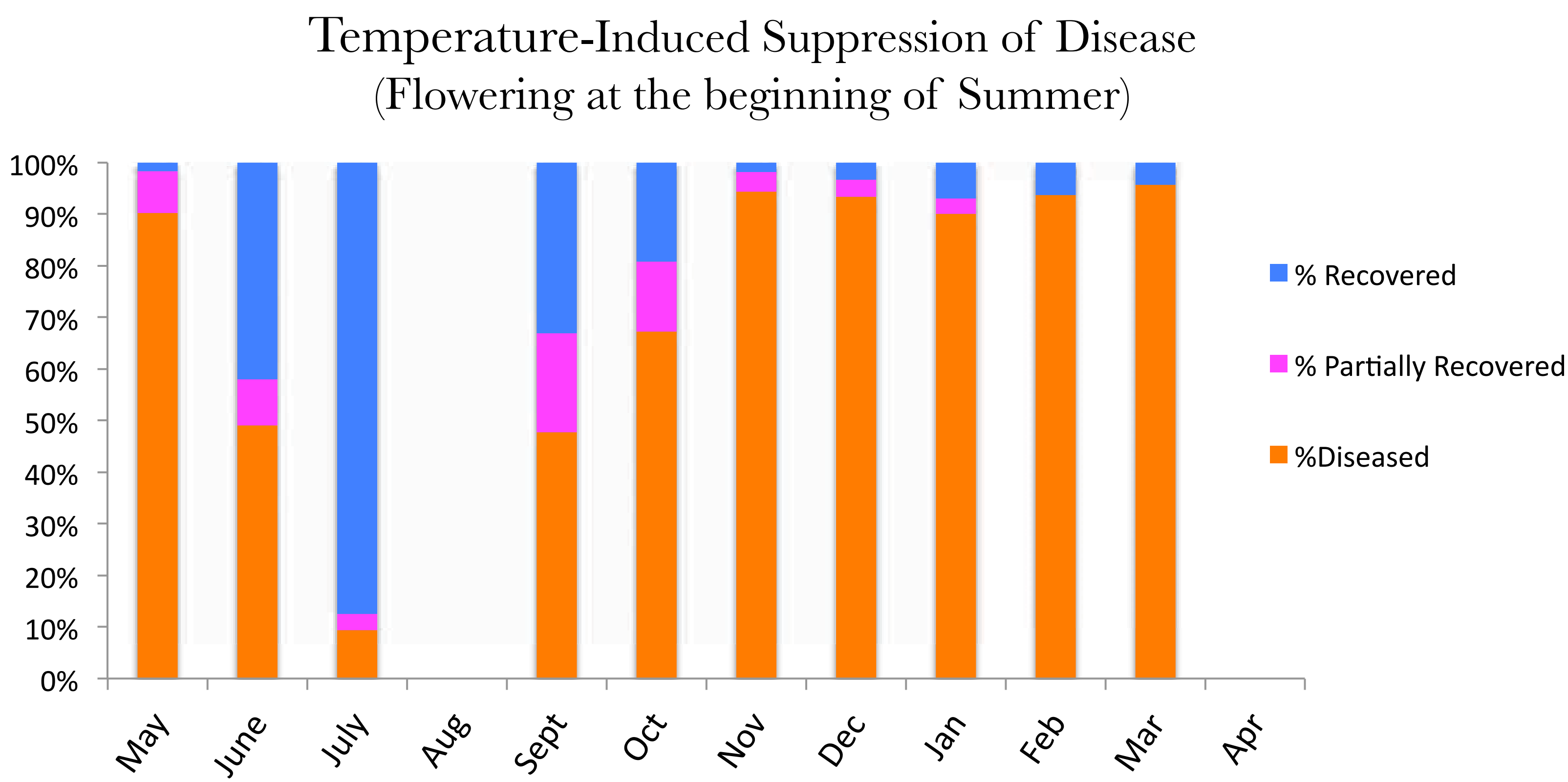

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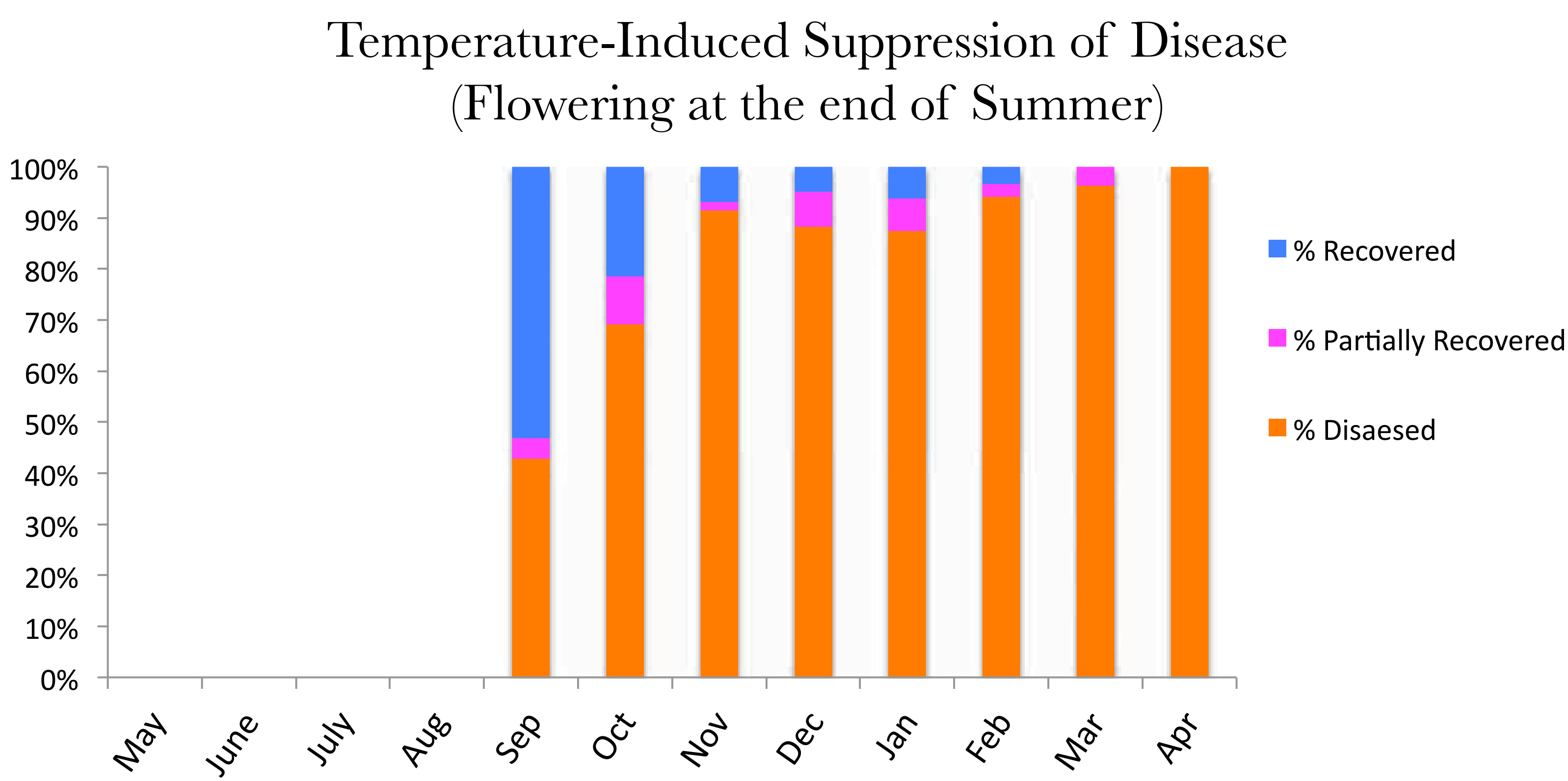
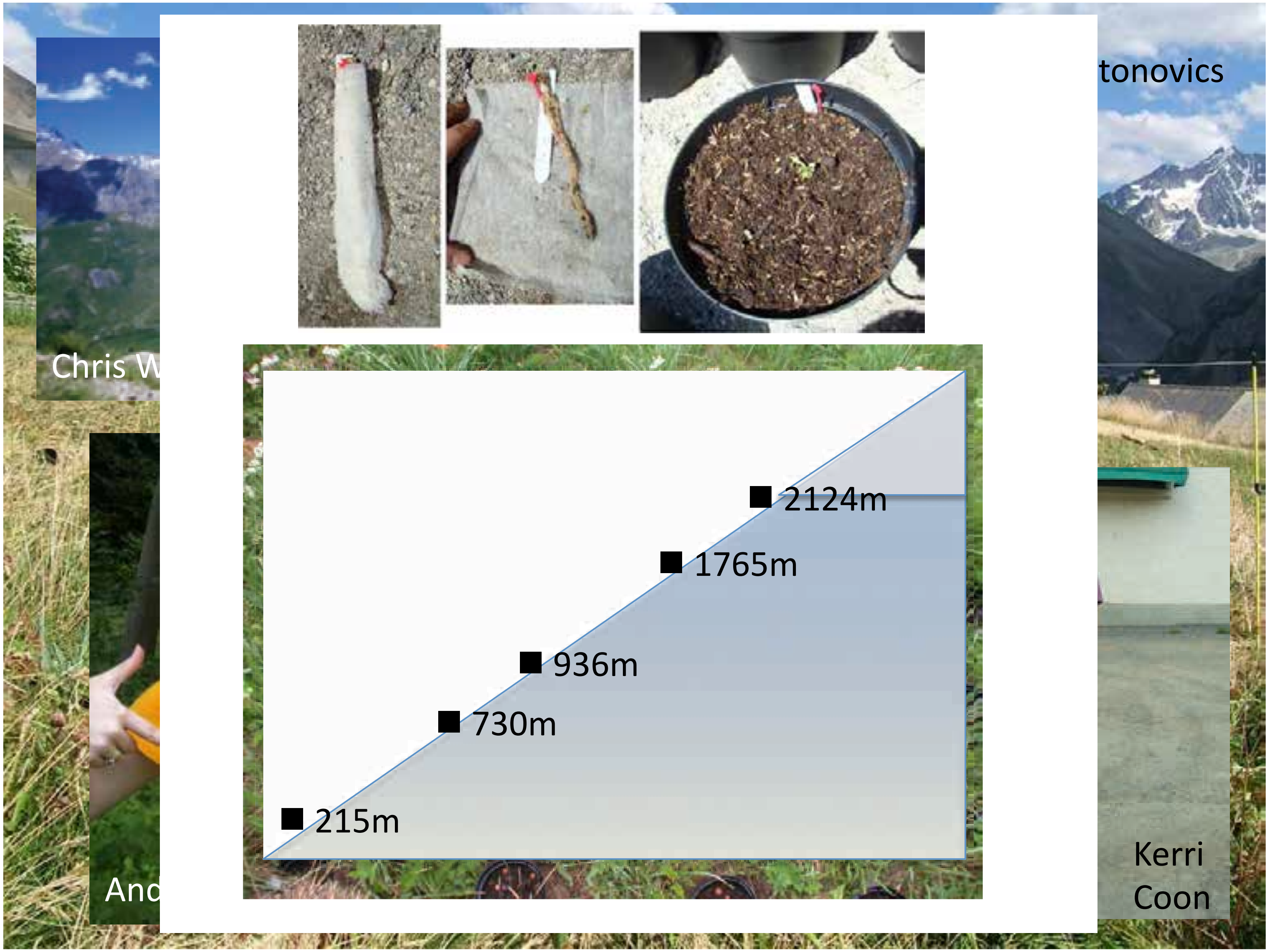
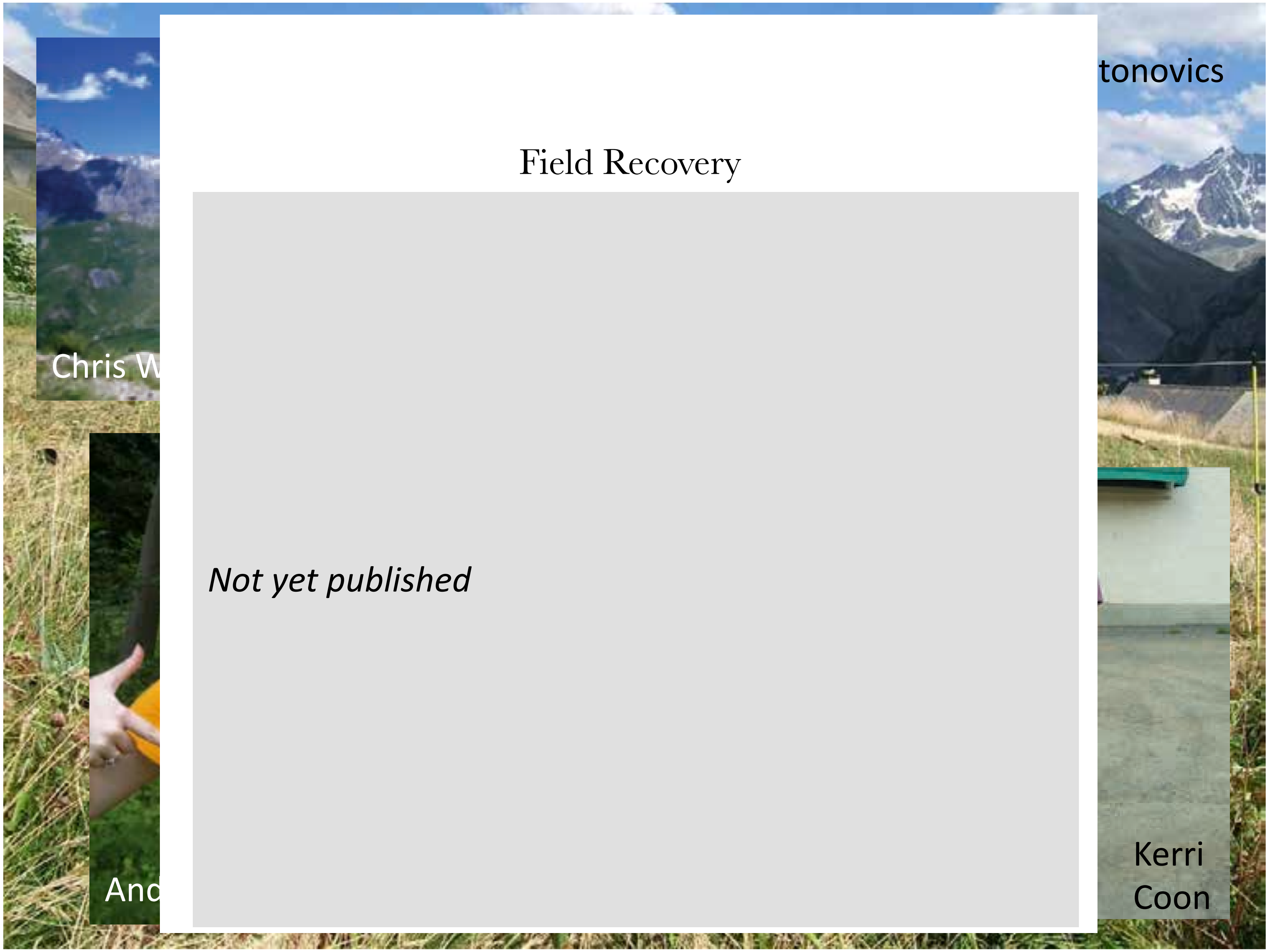



Janis Antonovics
Chris Winstead-Derlega
Andrea Berardi
Kerri
Coon


2124m
1765m
936m
730m
215m
Kerri
Coon



Field Recovery

Not yet published

Genetic
Effects on Temperature-induced Recovery?

Not yet published

Genetic
Effects on Temperature-induced Recovery?

recovery

avoidance

Not yet published

Cost of Host Recovery?

Not yet published

Inducible Defense and Environmental Stress: Costs or Synergy?

Andrea Berardi
(UVA; UC Boulder)

Flavonoids, Local Adaptation,
and Inducible Defense

Inducible Defense and Environmental Stress: Costs or Synergy?

Andrea Berardi
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Flavonoids, Local Adaptation,
and Inducible Defense

Plant secondary metabolic products:

-Pollinator attraction
-UV sunscreen
-Stress response
-Herbivore and fungal defense

Inducible Defense and Environmental Stress: Costs or Synergy?

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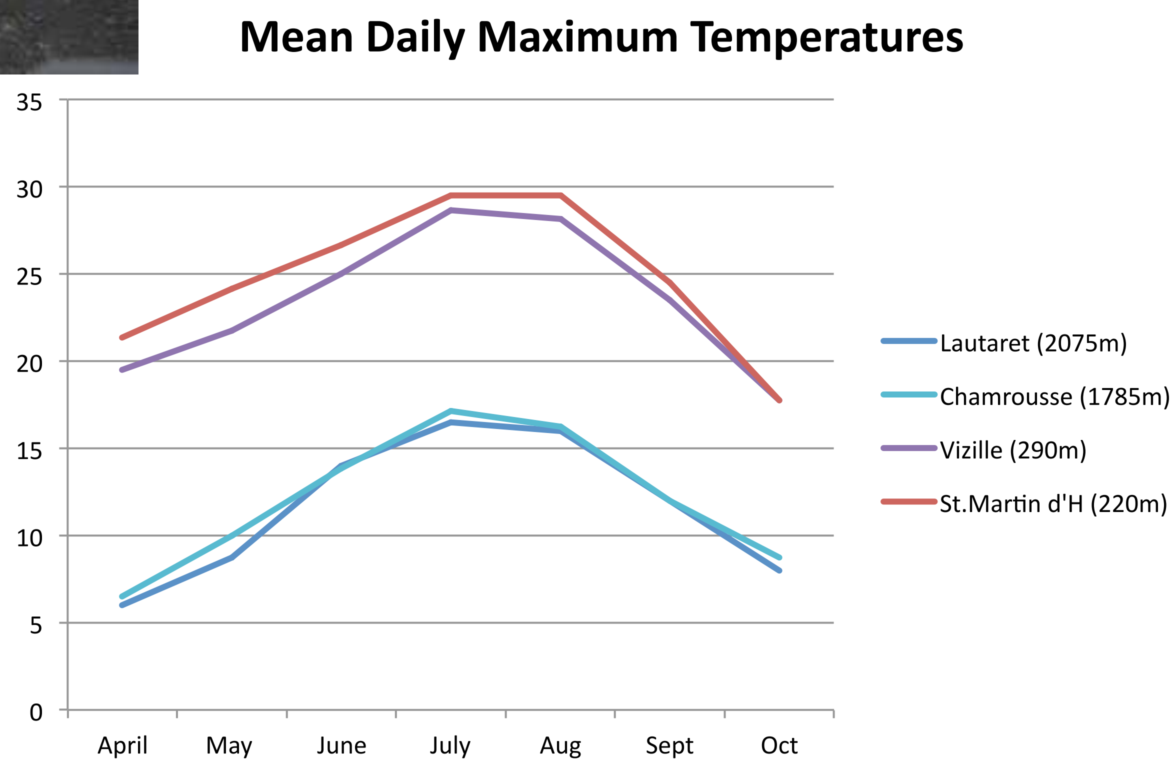
Not yet published

Do high temperatures inhibit infection success?



Lab-Inoculations

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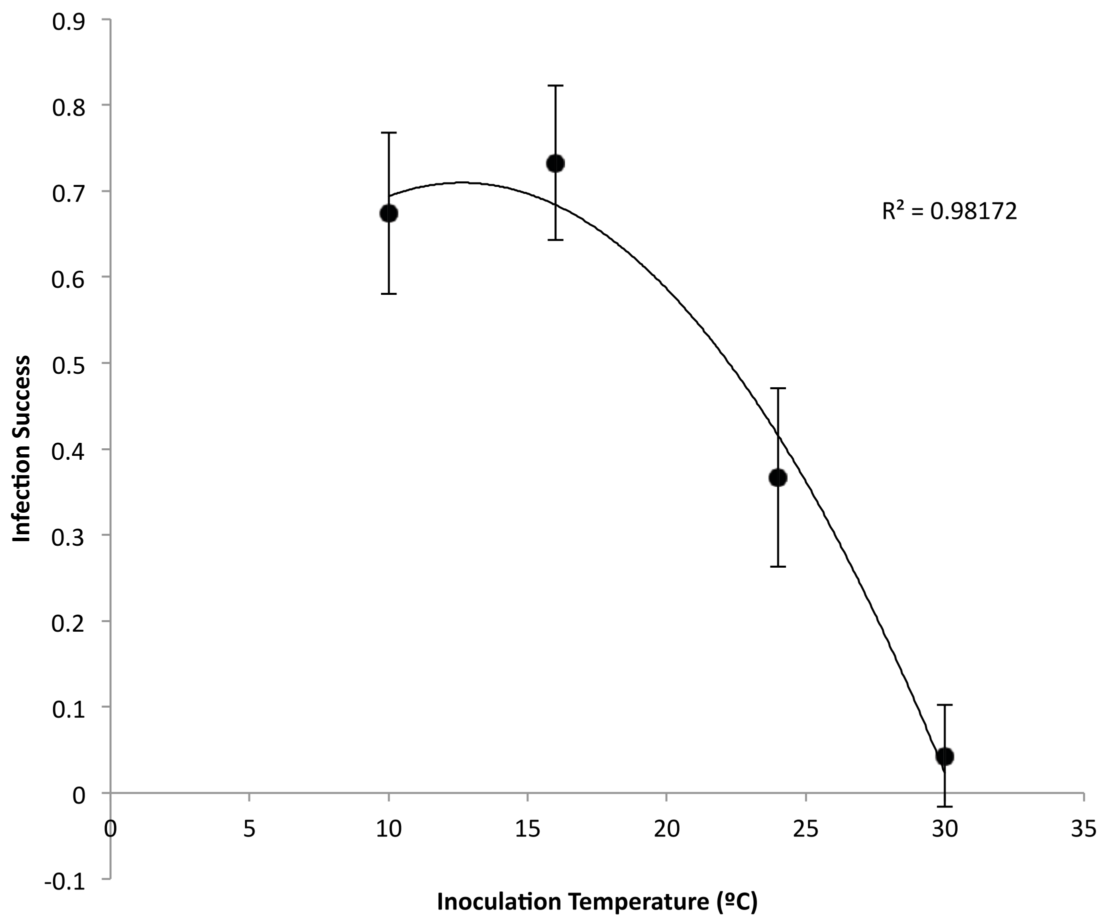

Abbate 2015 *Revised, Resubmitted*

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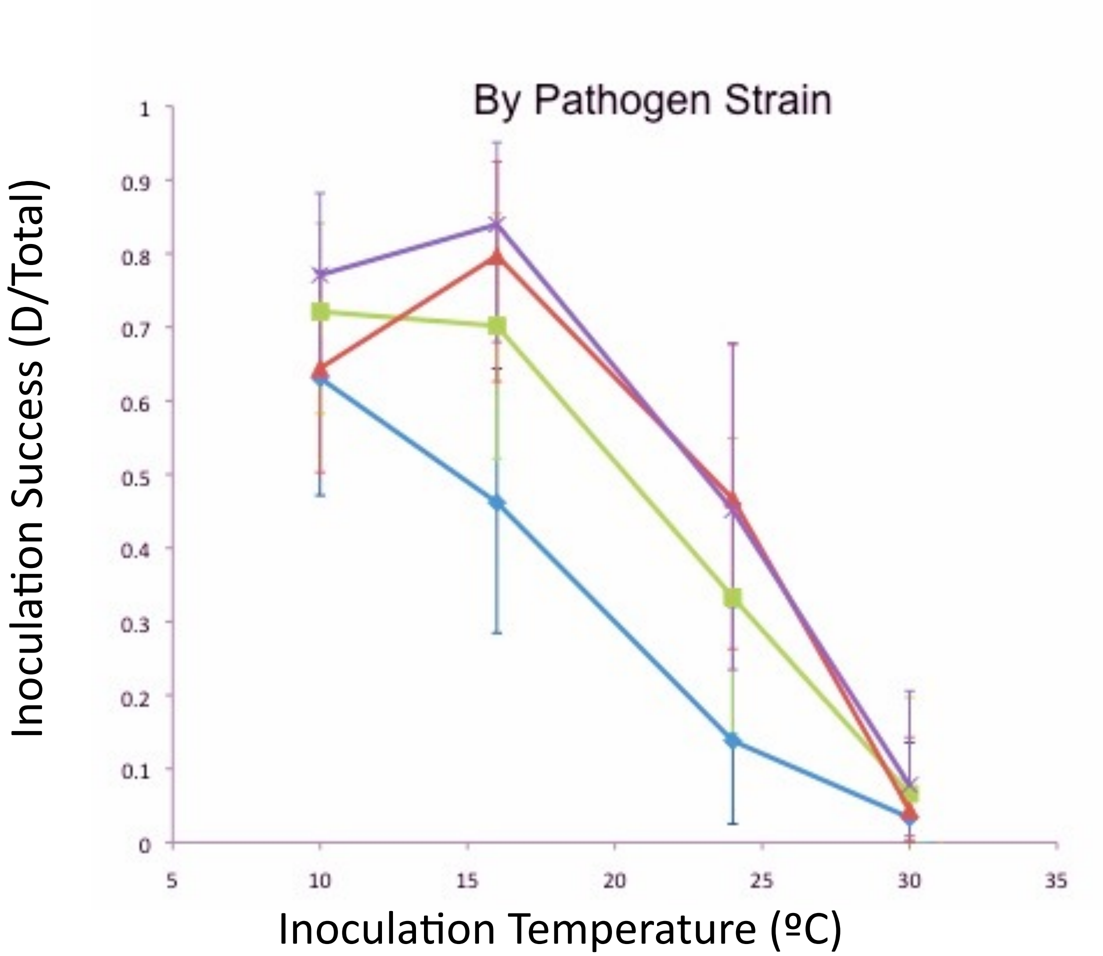

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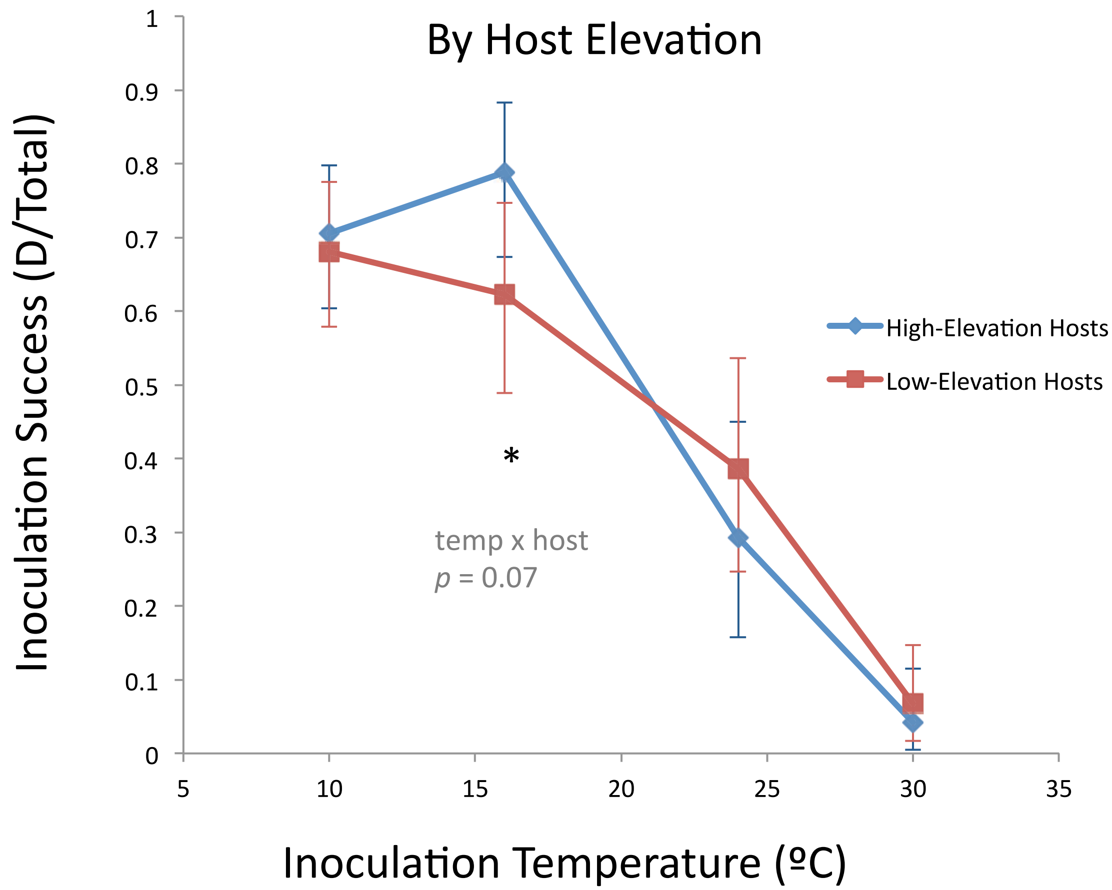

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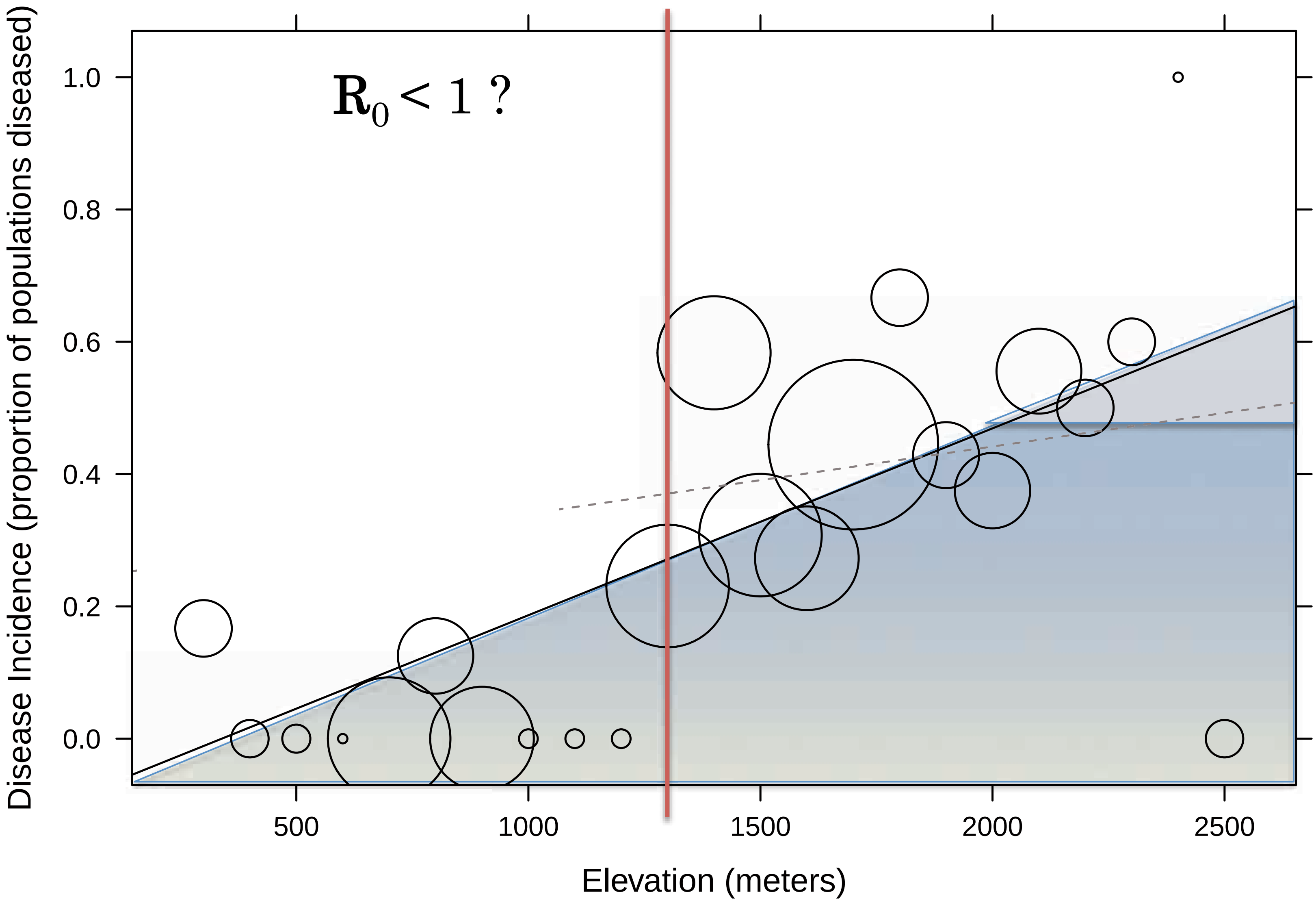
Fit it all together: Epidemiological Modeling



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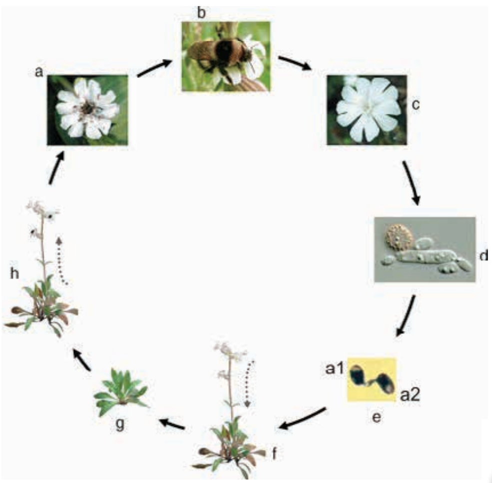

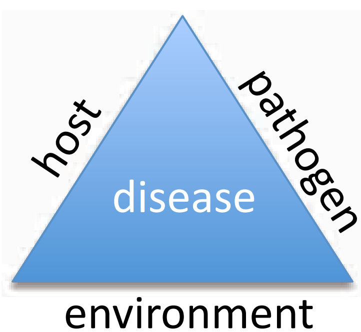

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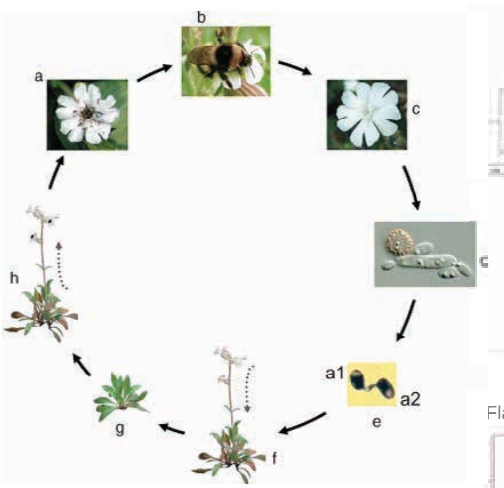
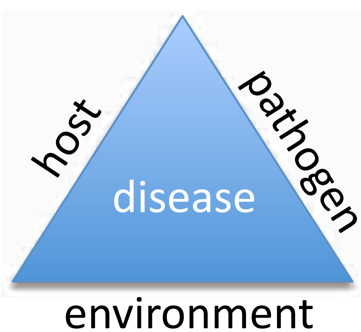
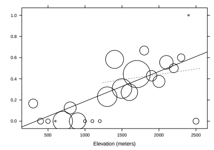


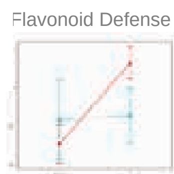




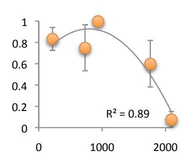
Natural History & Population Dynamics

Geographic Distribution & Evolutionary History

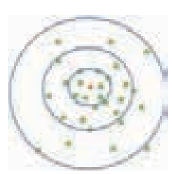
Host – Pathogen Genetics



Phenotype & Life-History Traits

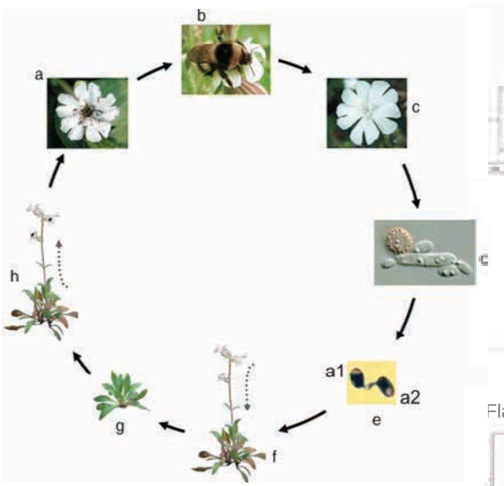


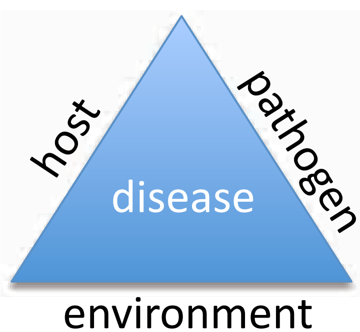
Environmental Variables

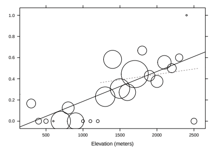


Ecological Interactions

Fit it all together: Epidemiological Modeling







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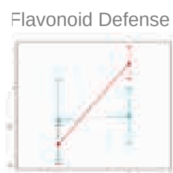

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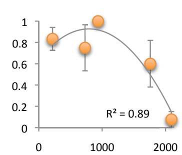

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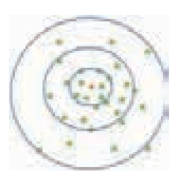

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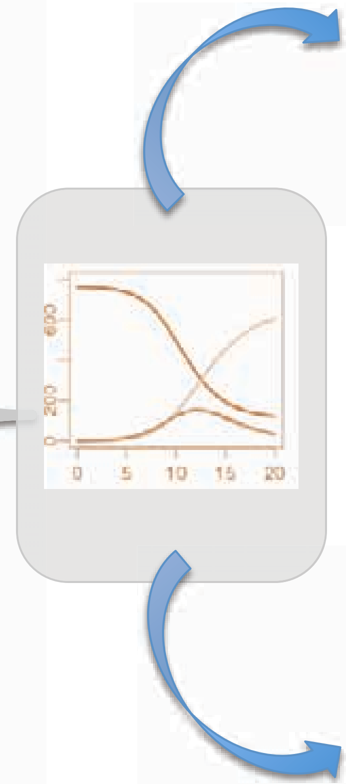

Under what conditions is a pathogen likely to invade?

Which parameters play a major role?

Fit it all together: Estimating Ro

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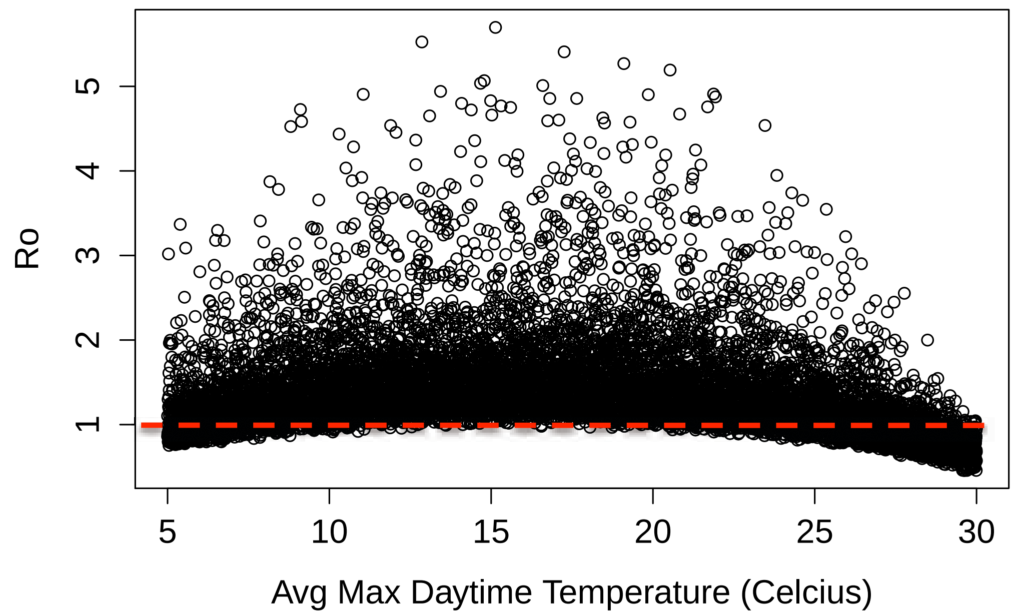

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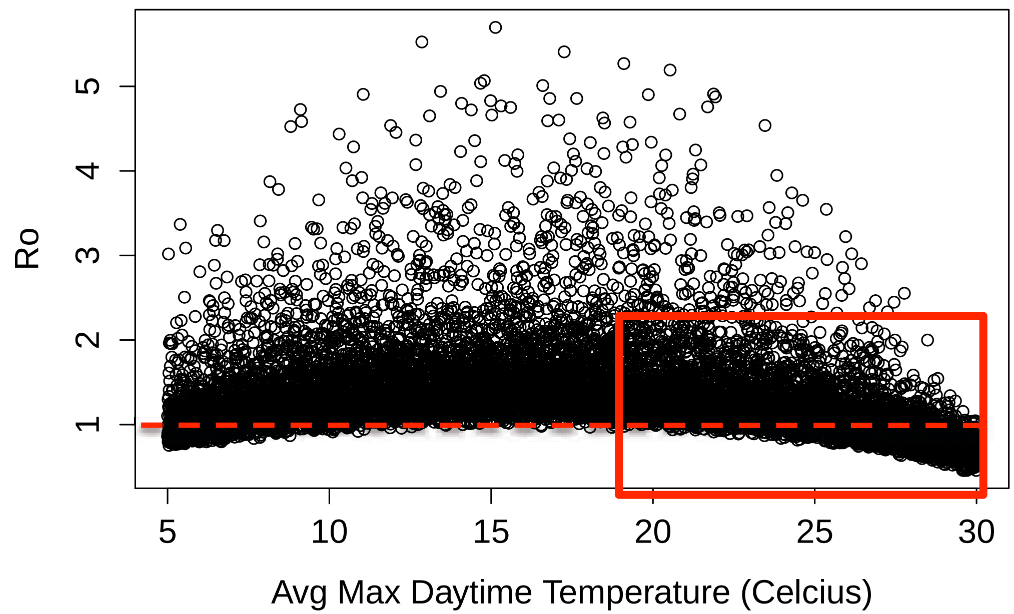

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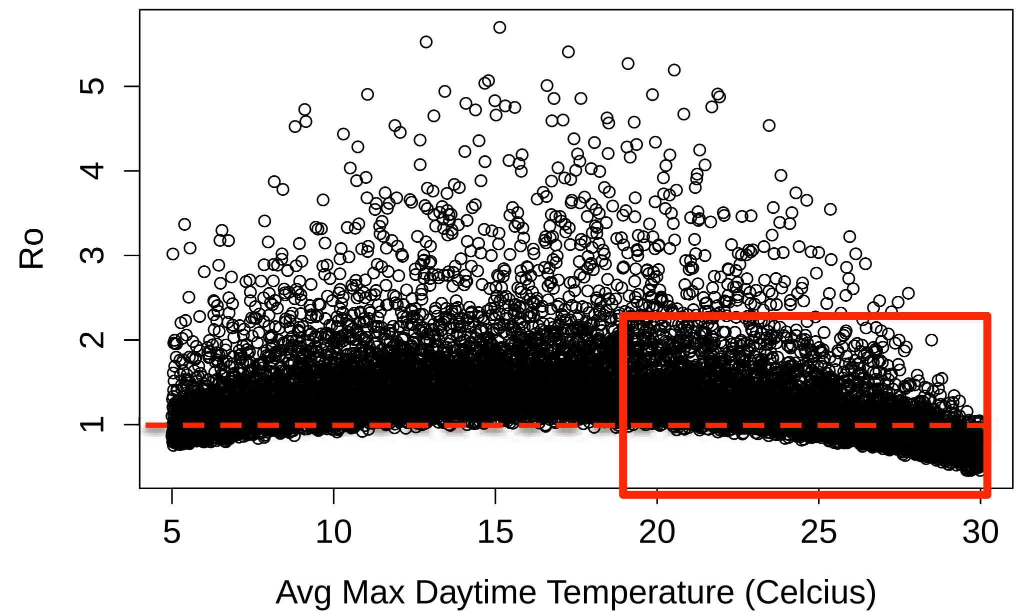
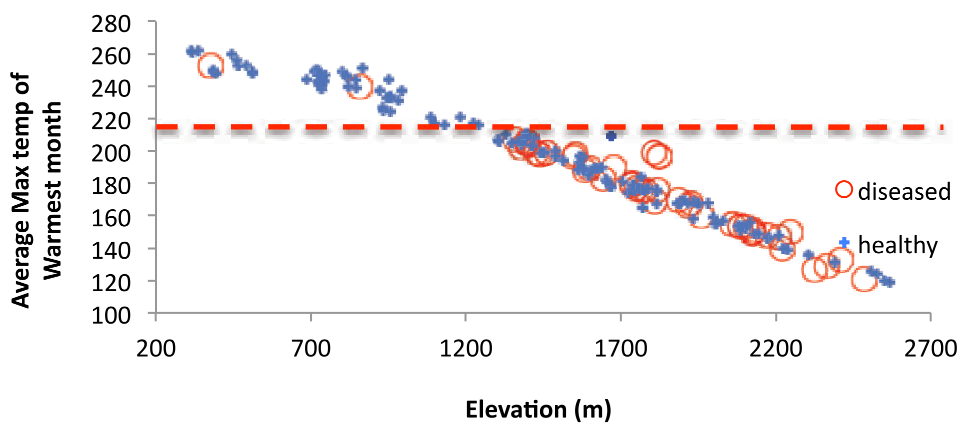




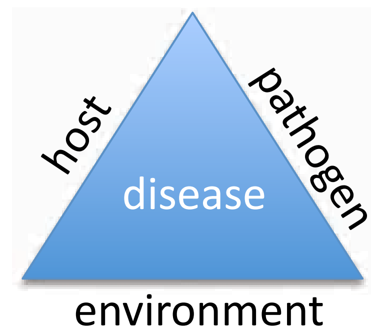
Fit it all together: Estimating Ro

Which parameters play a major role?
Elasticity Anlaysis

Not yet published

CONCLUSION & PERSPECTIVE

❖ Remember the disease triangle.



❖ An epidemiological approach can help synthesize co-occurrence of important factors.

❖ Temperature seems to be a pretty important factor for anther-smut disease in *S. vulgaris*, but it is not independent of other important factors that change across the climatic gradient (e.g., host recovery).

❖ Might the distribution of *S.vulgaris*-specific anther smut contract as global temperatures rise?

Lab-Inoculations

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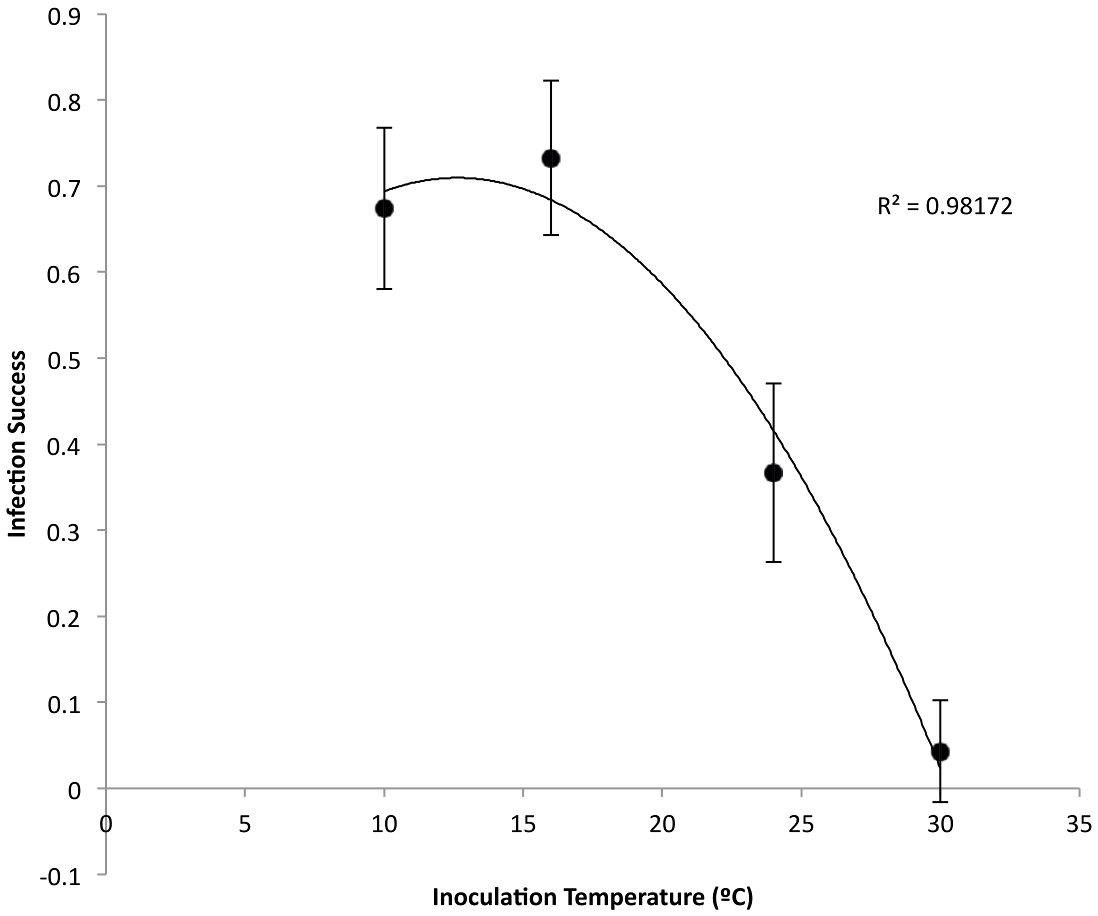


Can diurnal temperature variations "rescue" pathogen development?

Not yet published

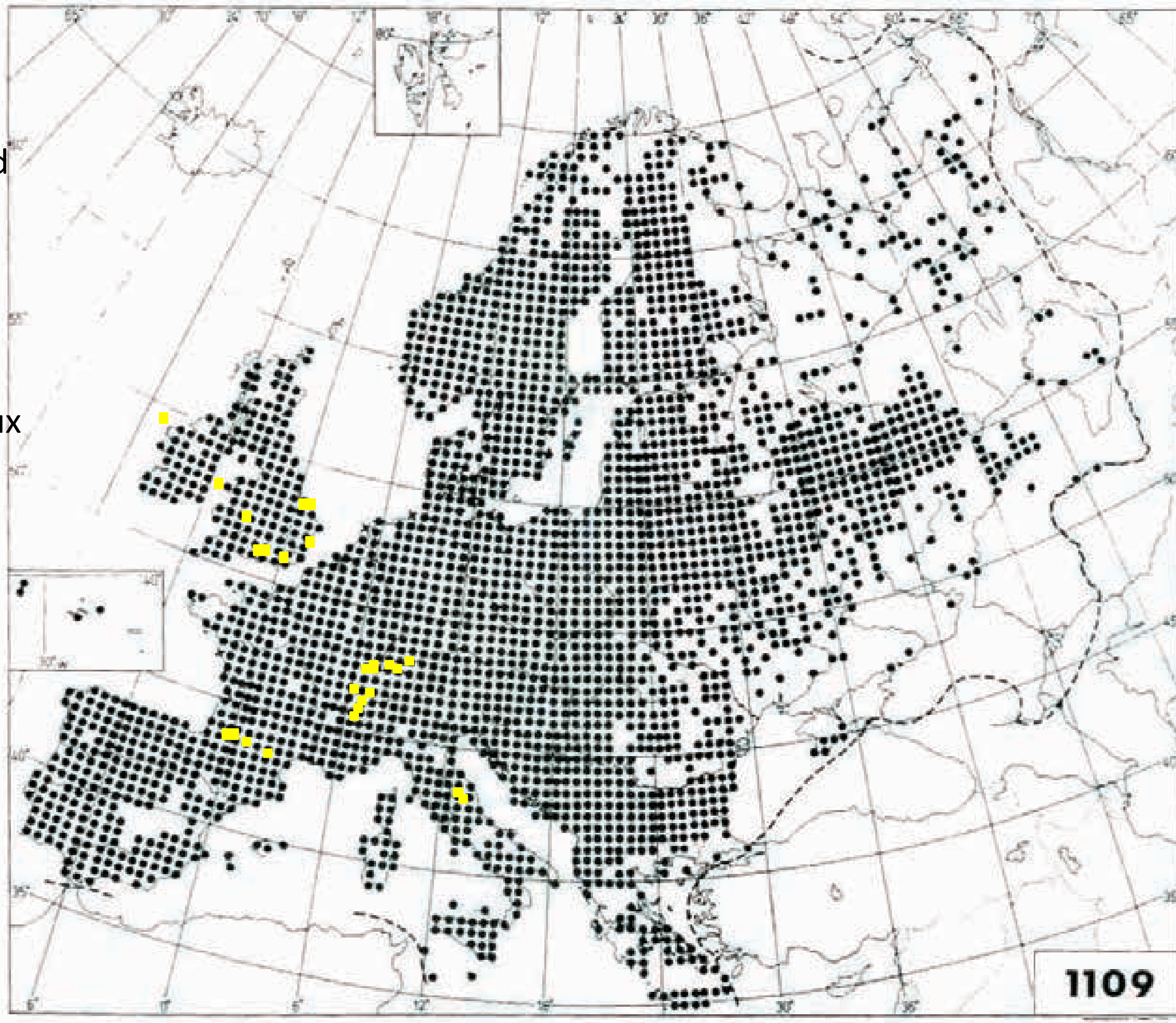
MvSv-MvSm Distribution

Tatiana Giraud

Pierre Gladieux

Alodie Snirc

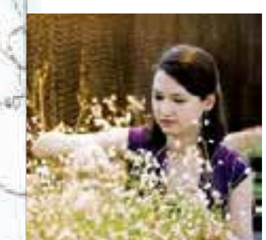
Michael Hood



Silene vulgaris

Steve Keller

Peter Fields

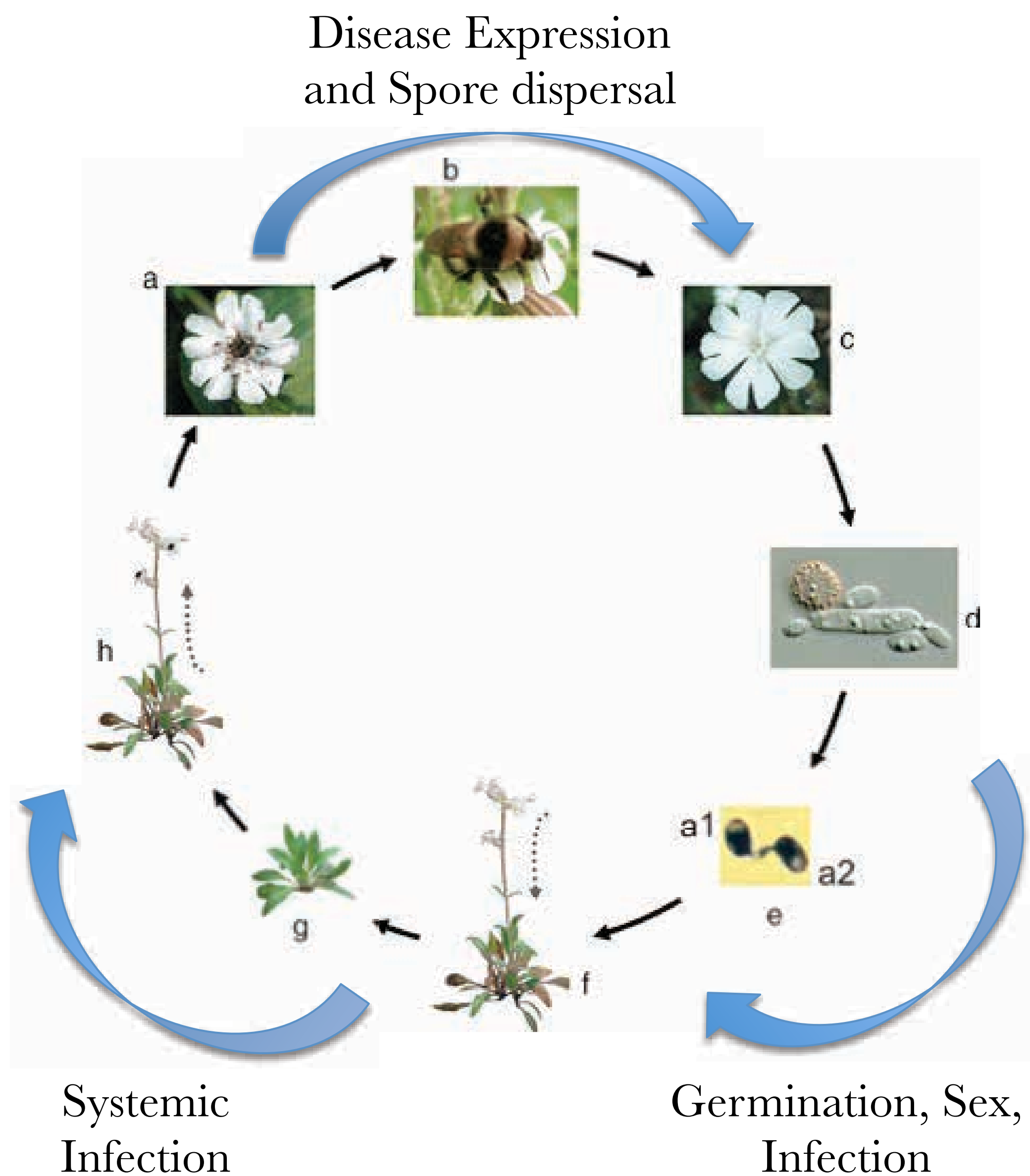


Andrea Berardi

The pathogen

Microbotryum spp. "Anther Smut"

- Obligate species-specific parasitic
- Bacidiomycete
- Pollinator-transmitted (mechanical)
- Sterilizes and alters host behavior
- Model for sexually-transmitted & sterilizing diseases



Giraud et al. 2008 *Eukaryotic Cell*

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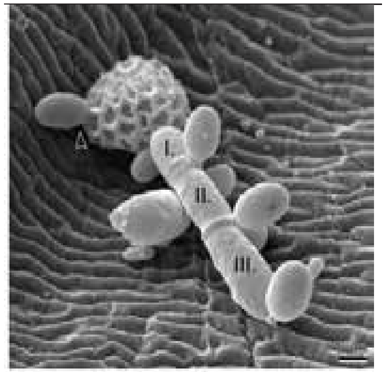
Schafer et al. 2010, Botany

In-vitro development



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“tenacitas in adversitas .... ad punctum!”

Serge Aubert, Rolland Douzet, LECA

Janis Antonovics, Michael Hood, Tatiana Giraud, Samuel Alizon

Seb Lion, Sylvain Gandon, Simon Fellous, Nathalie Charbonnel

Andrea Berardi, Peter Fields, Stephen Keller, Pierre Gladieux

Kerri Coon, Christopher Winstead-Derlega

UVA Biology Department

The Harrison Institute