Weather/Climate Sensitive Infectious Diseases

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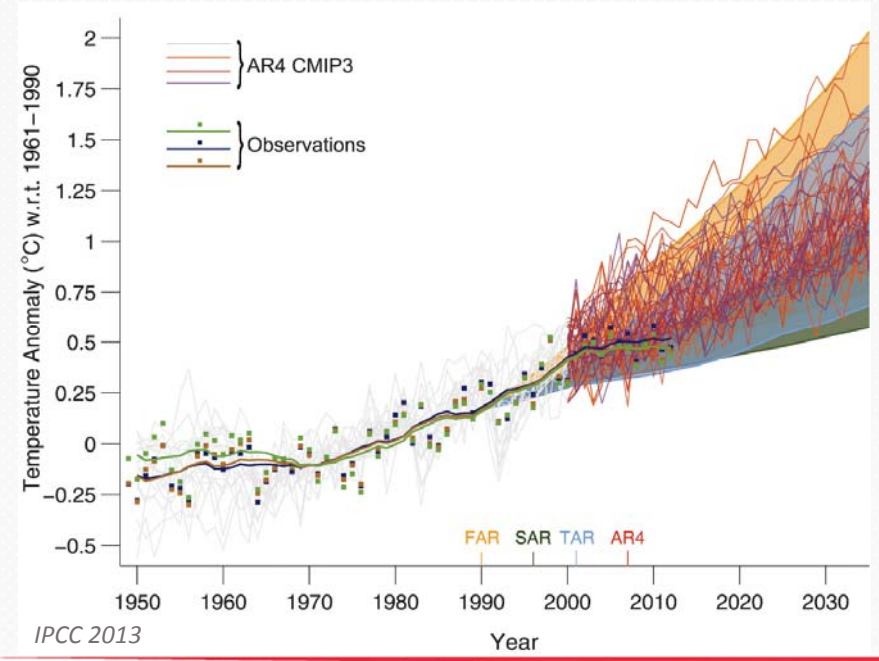
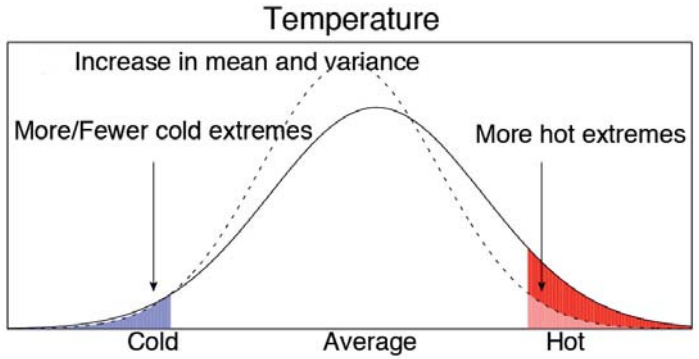
Aedes.Caltech.edu/cgi-bin/hgGateway

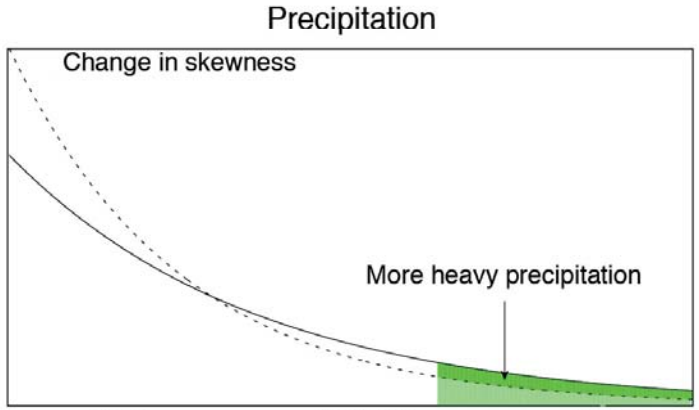
Climate Variability and Change

- Shift in mean and variance
- Increase in frequency of extreme conditions



IPCC 2013





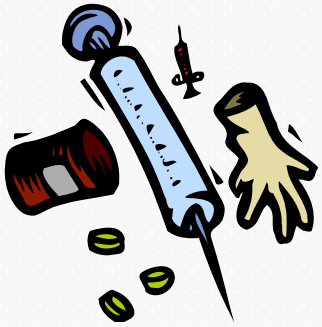
IPCC 2013

Climate Effects on Human Health

Extreme Temperatures

Extreme Weather

- Flooding
- Hurricanes
- Tornadoes



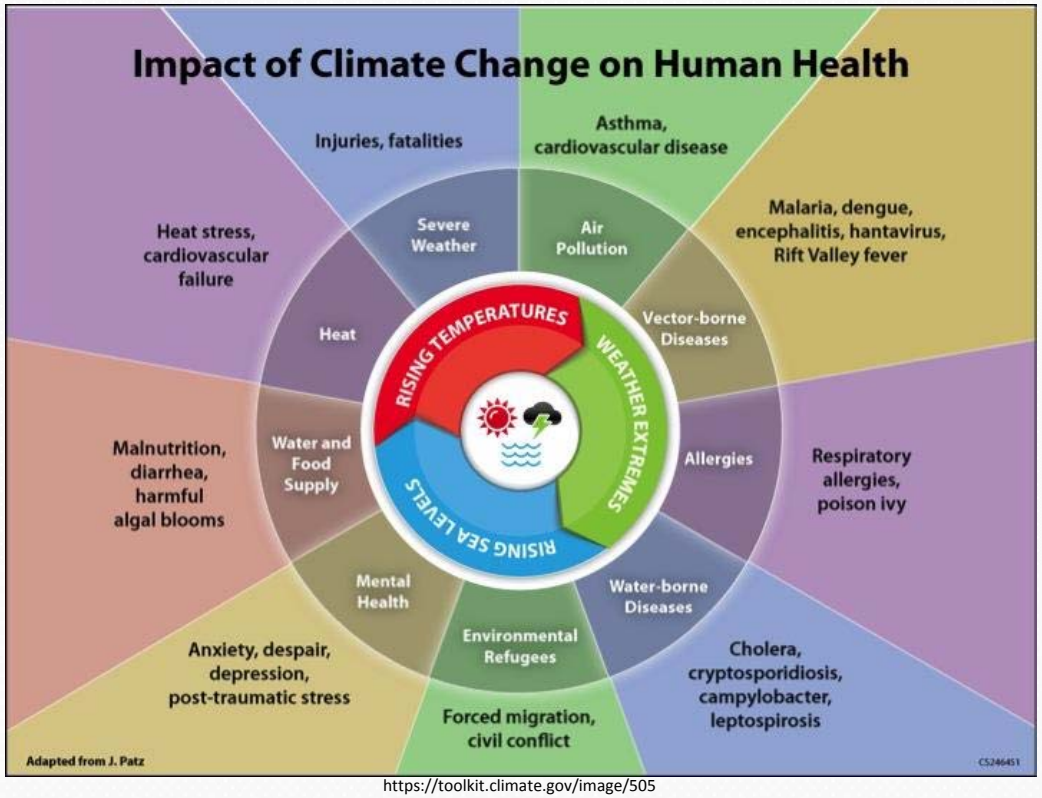
Pathogens

- Vector-borne
- Rodent-borne
- Water/food-borne
- Soil-borne
- Air-borne

Air Quality

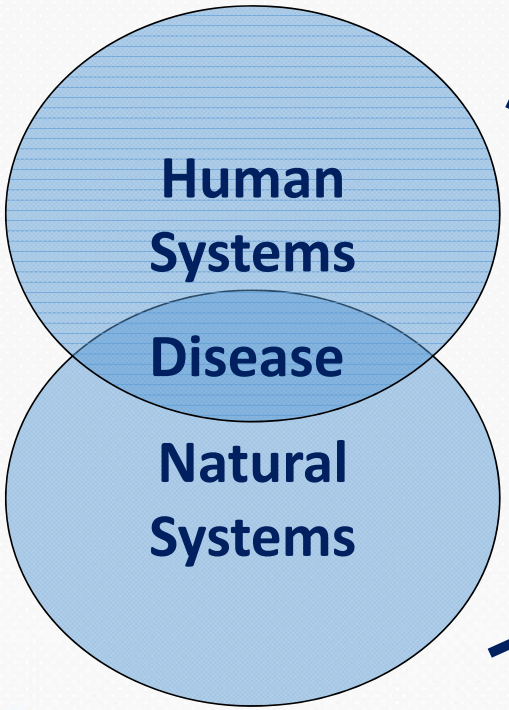
- Pollen
- Ozone
- Particulate Matter

Pathways from Climate Change to Health Outcomes



https://toolkit.climate.gov/image/505

Interdisciplinary Research

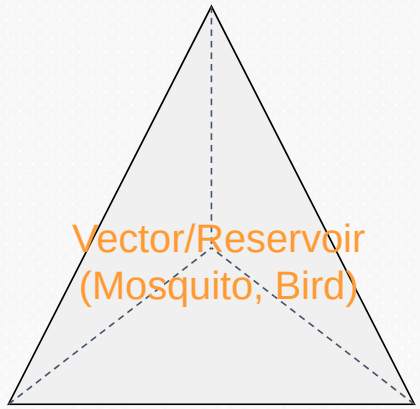


Interdisciplinary Research
Social Science
Epidemiology
Geography
Disease Ecology
Climate Science

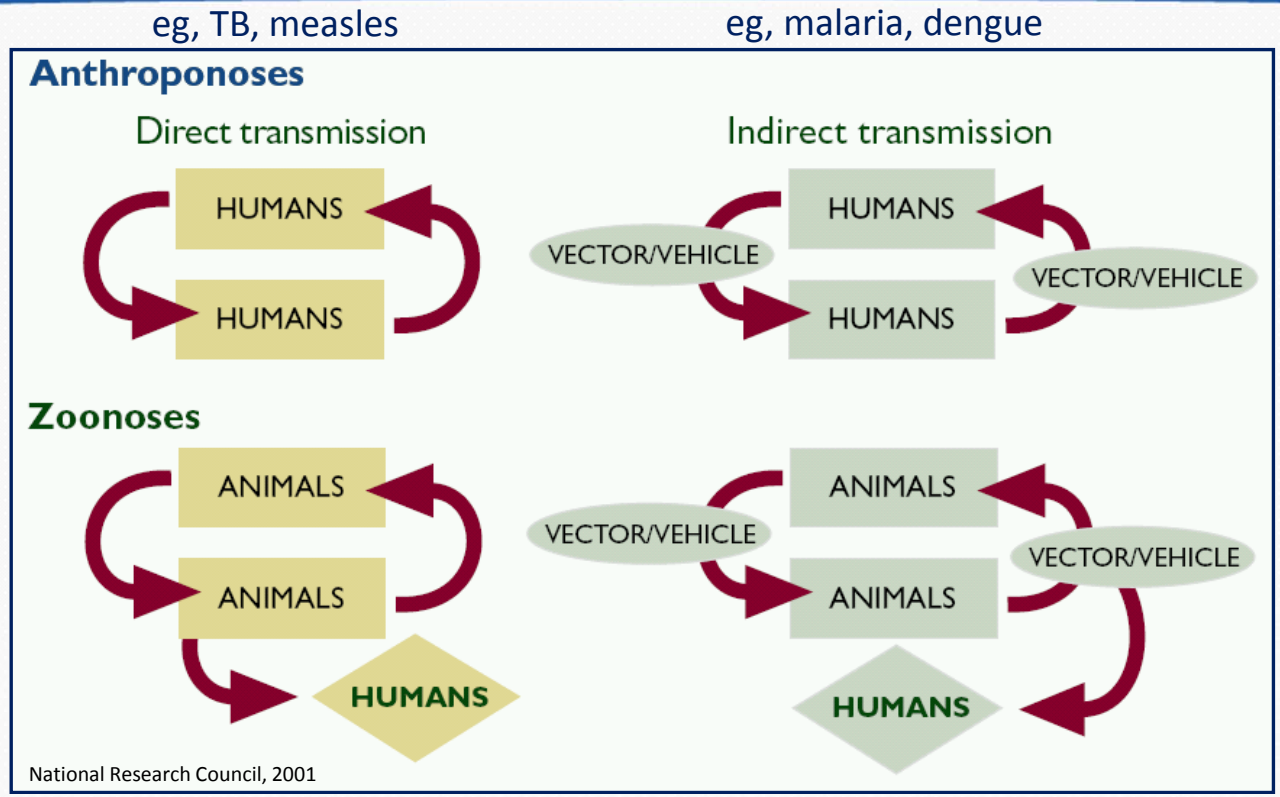
- Risk
- ***V***ulnerability
- $V = f(E, S, A)$
- ***E***xposure } Environmental Stimulus
- ***S***ensitivity
- ***A***daptive Capacity } Social Resilience

Infectious Disease Ecology

A *multi-factorial* relationship between hosts, agents, environment, and possibly a vector or reservoir



Infectious Disease Transmission Cycles

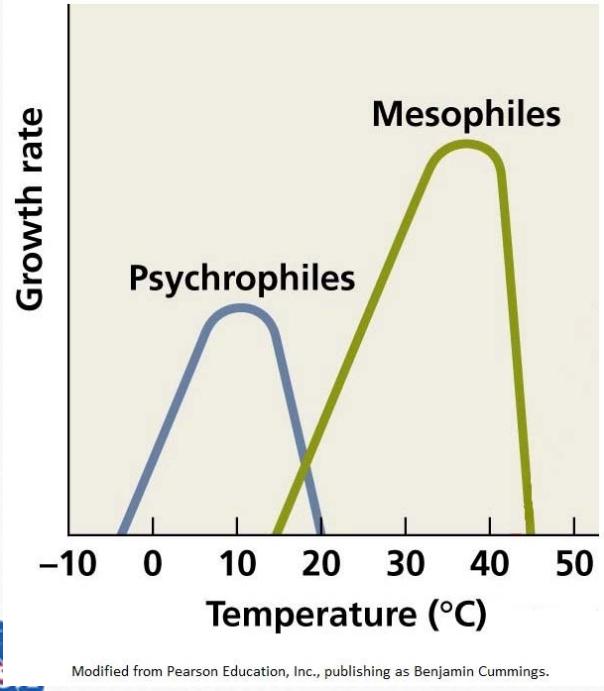


How Does Climate Affect Pathogen Ecology?

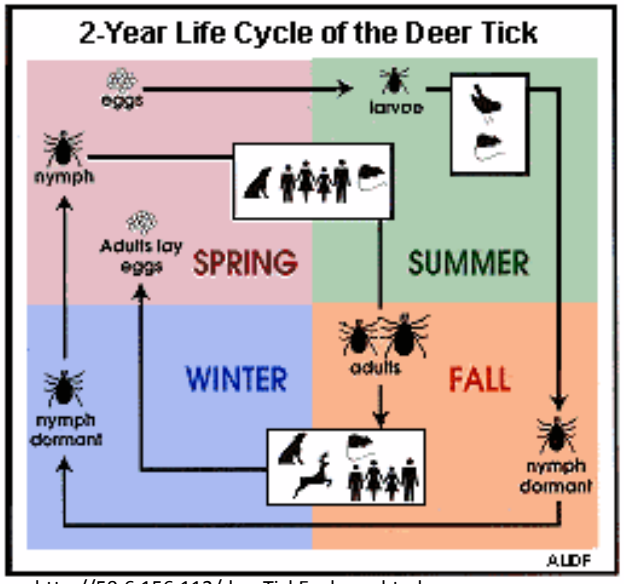
- Variables
  - Temperature: minimum, maximum, range
  - Precipitation: total, days with or without
  - Humidity: specific, relative
  - Wind: speed, direction
  - Other variables: surface pressure, ENSO
  - Climate Change
- Scale of Response
  - Temporal scale: daily, monthly, annual
    - Lags: delayed responses to weather/climate conditions
  - Spatial scale: point, local, regional

Temperature Effects on Pathogen Ecology

- Pathogen growth, survival, and incubation periods
- Vector/reservoir dynamics
- Human responses



Modified from Pearson Education, Inc., publishing as Benjamin Cummings.



http://50.6.156.112/deerTickEcology.shtml

Precipitation Effects on Pathogen Ecology

- Flooding causing contamination of drinking water

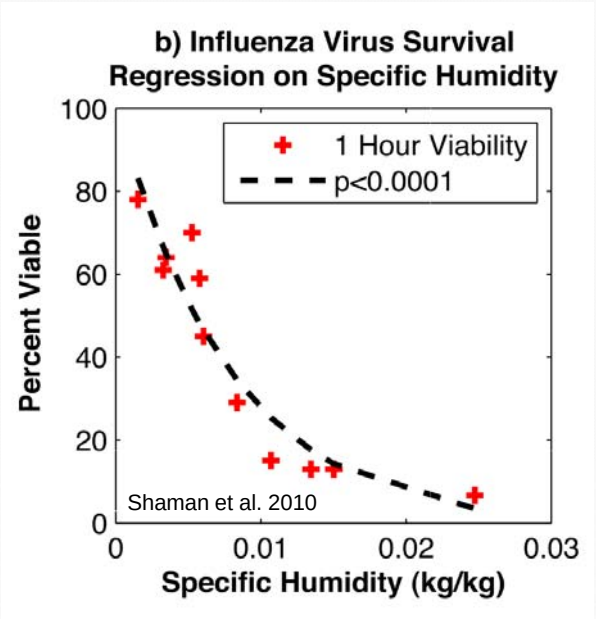
http://news.nationalgeographic.com/news/2010/03/100322/swimming-in-sewage-for-world-water-day/

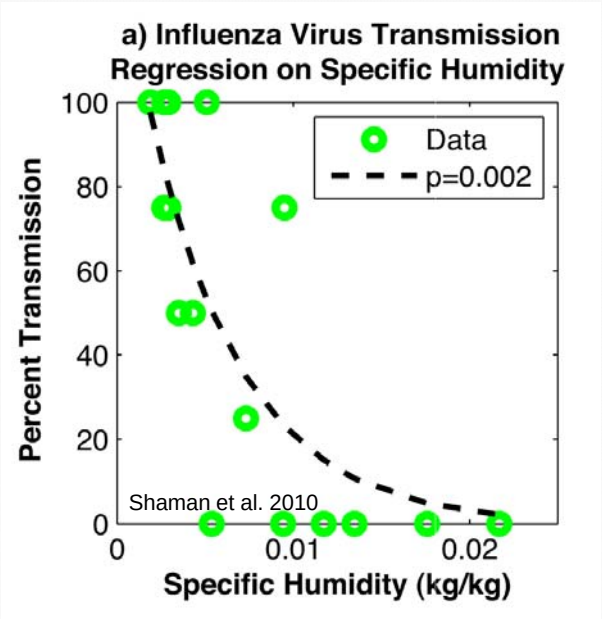
- Increasing in habitat for vectors such as mosquitoes

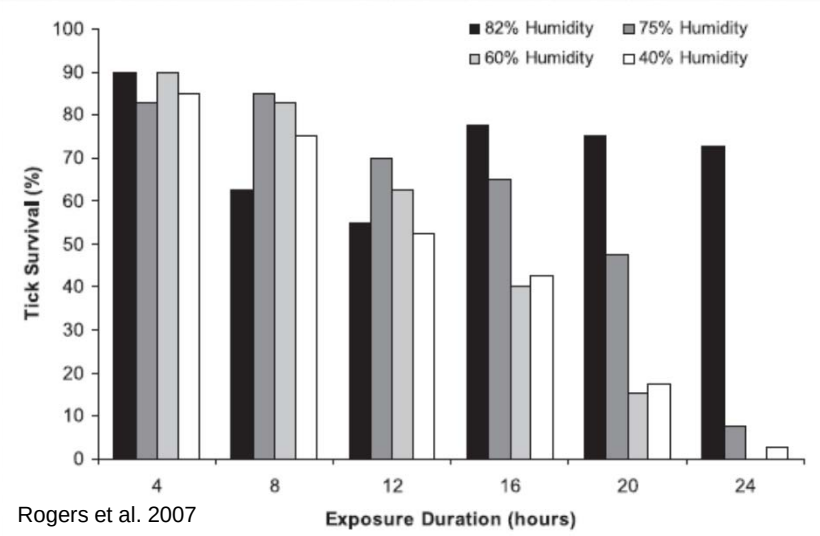
http://www.sgvmosquito.org/services_mosquitos.php

Humidity Effects on Pathogen Ecology

- Pathogen Survival
- Pathogen Transmission
- Vector Survival







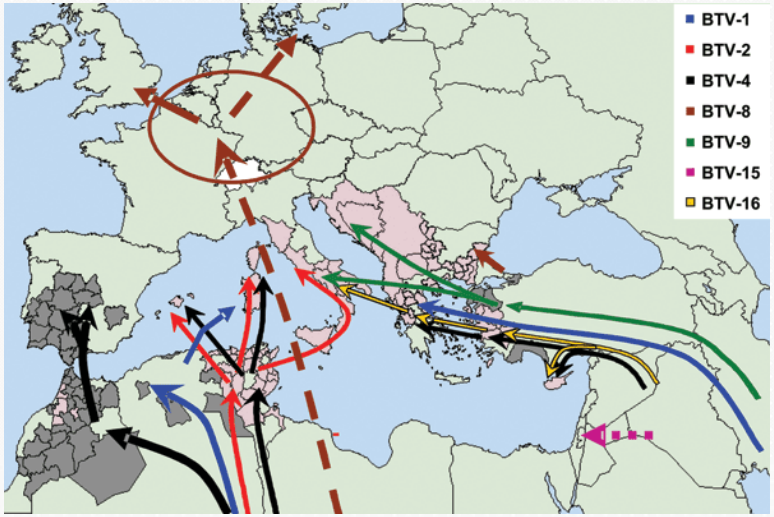
Rogers et al. 2007

Wind Effects on Pathogen Ecology

- Pathogen Dispersal

http://www.oasisanimalclinic.com/2013/02/28/valley-fever-and-the-haboob/

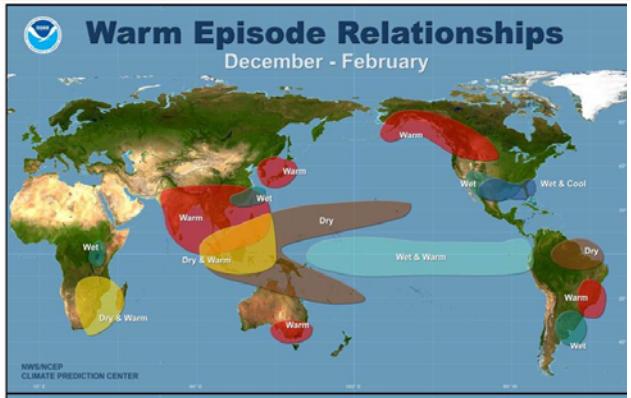
- Vector Dispersal



https://en.wikipedia.org/wiki/Bluetongue_disease

ENSO Effects on Pathogen Ecology

- The El Nino Southern Oscillation (ENSO) effects the previously discussed atmospheric variables
- Caution, effects are NOT always consistent



High Resolution Images can be found at:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ENSO/ENSO-Global-Impacts/

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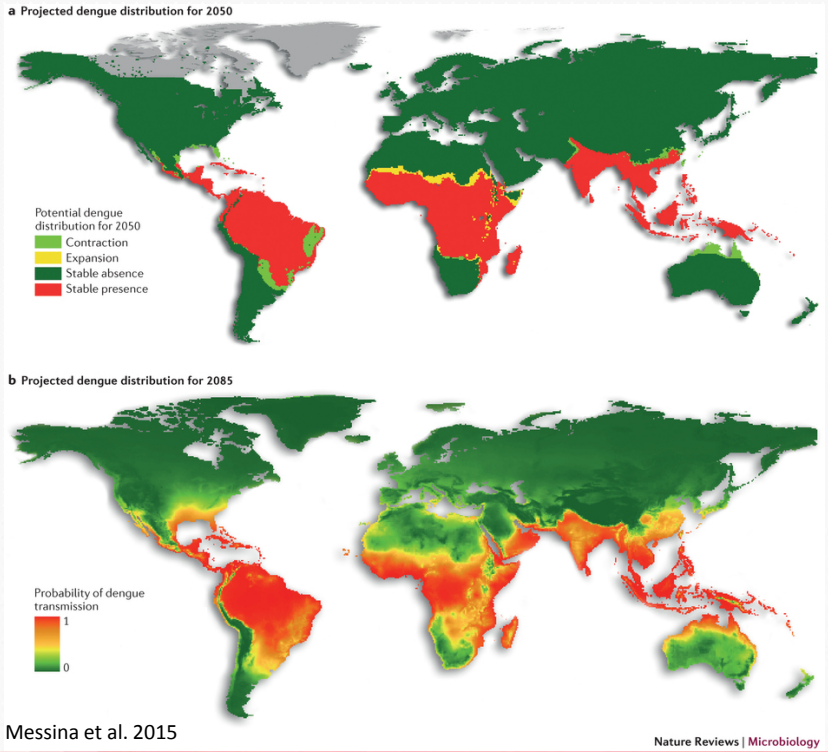
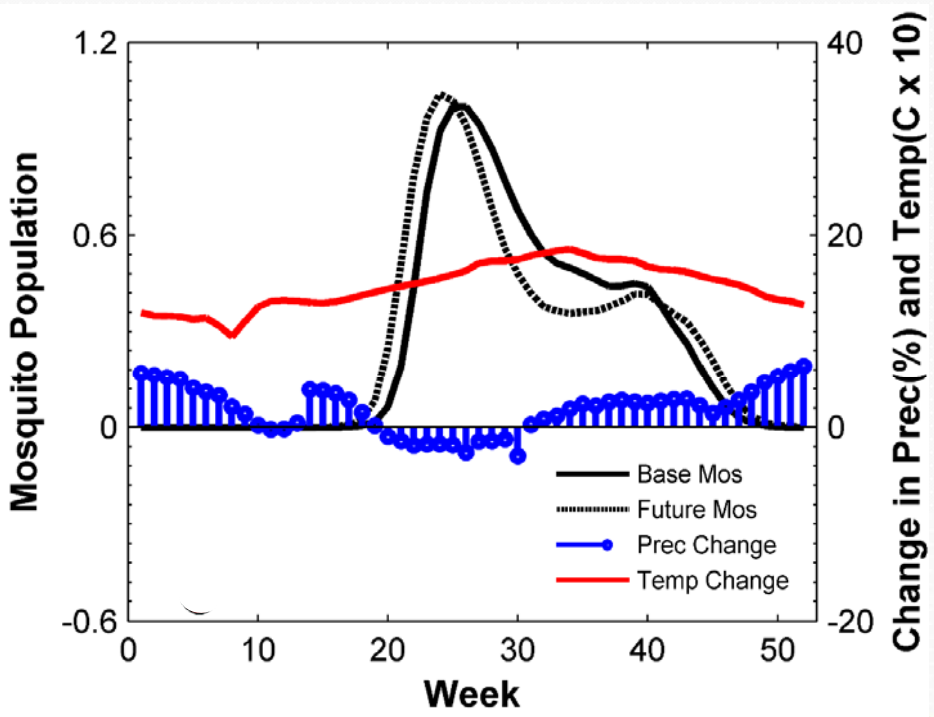
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ENSO/ENSO-Global-Impacts/

Climate Change Effects on Pathogen Ecology

- Increase in pathogen/vector range, seasonality, and magnitude



Messina et al. 2015



Morin et al. 2013

Temporal Scale and Pathogen Ecology

Daily

- Weather events
  - Storm
  - Frost
- Role
  - Habitat destruction or creation
  - Die offs

Weekly

- Weather systems
  - Frontal system
  - Heatwave
- Role
  - Water contamination
  - Life cycle acceleration
  - Vulnerability

Monthly

- Seasonal cycles
  - Precipitation patterns
- Role
  - Cycles of transmission
  - Potential introductions

Annual

- Climate regimes
  - Climate change
  - Ecological shifts
- Role
  - Species range expansion
  - Novel ecologies

Decadal

Time Lags in Pathogen Ecology

Daily	Weekly	Monthly	Annual	Decadal
• Noise	• Pathogen development • Vector proliferation • Incubation periods		• Host/reservoir behavior • Other biotic responses	• Pathogen / reservoir / host colonization • Adaption / evolution

Spatial Scale and Pathogen Ecology

Site/Point

- Microclimate
  - Pool of standing water
  - Protected area like sewer
- Role
  - Vector/pathogen growth
  - Transmission source

Local

- Ecosystem
  - Wetlands area
  - Forrest
- Role
  - Host, pathogen, vector, habitat
  - Facilitation of pathogen transmission cycle

Regional

- Climate zone
  - Tropical, Arid, temperate
- Role
  - Creation of meta-populations
  - Pathogen range expansion

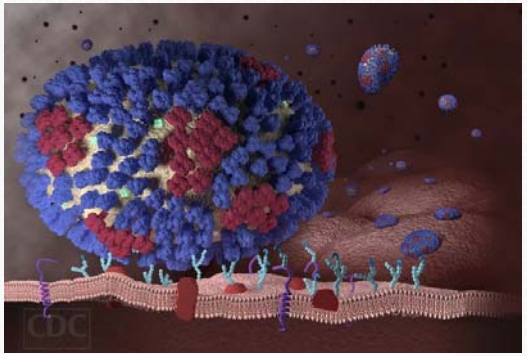
Continental

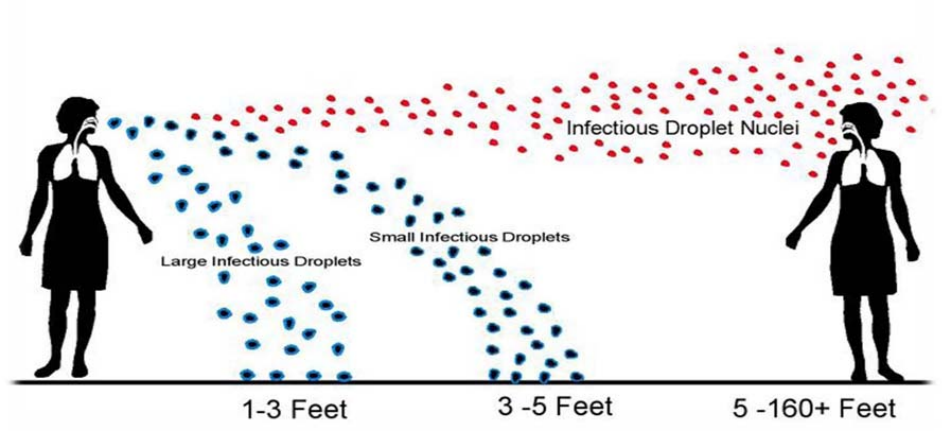
Survey of Some Important Climate Regulated Infectious Diseases

- Airborne: Influenza
- Soil-borne: Valley fever
- Food-borne: Salmonella, E. coli
- Water-borne: Cholera
- Rodent-borne: Hanta vius pulmonary syndrome, plague
- Vector-borne: Dengue fever, Lyme disease

Airborne: Influenza

- Viral infection transmitted via airborne and contact routes
  - Associated with ~250,000 - 5000,000 deaths annually
- Specific humidity is the best predictor of transmission

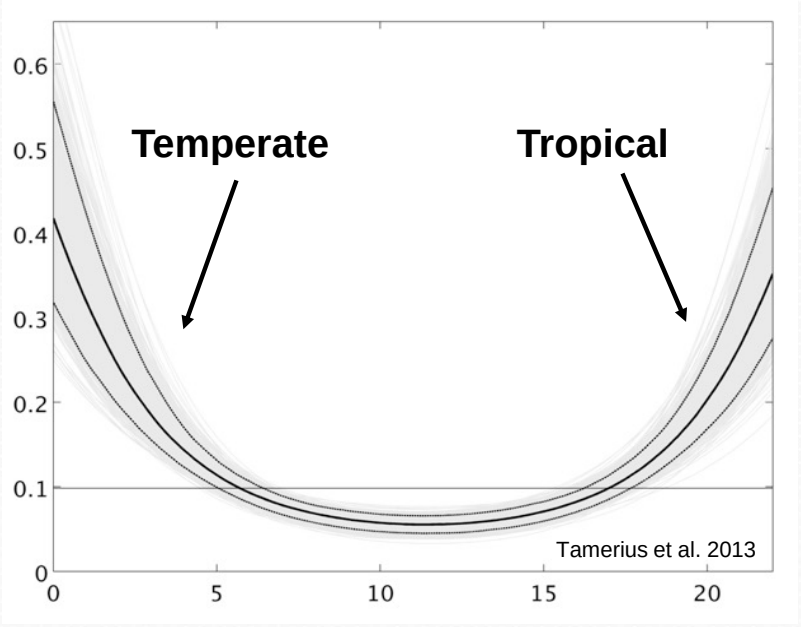


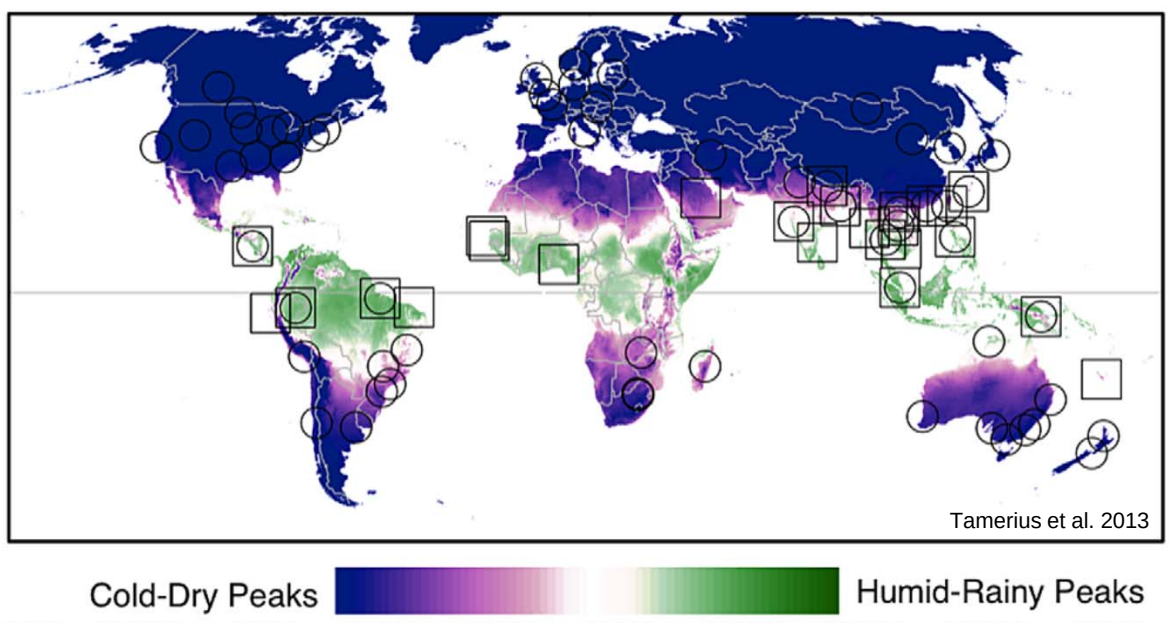


Alfa-img.com

Airborne: Influenza

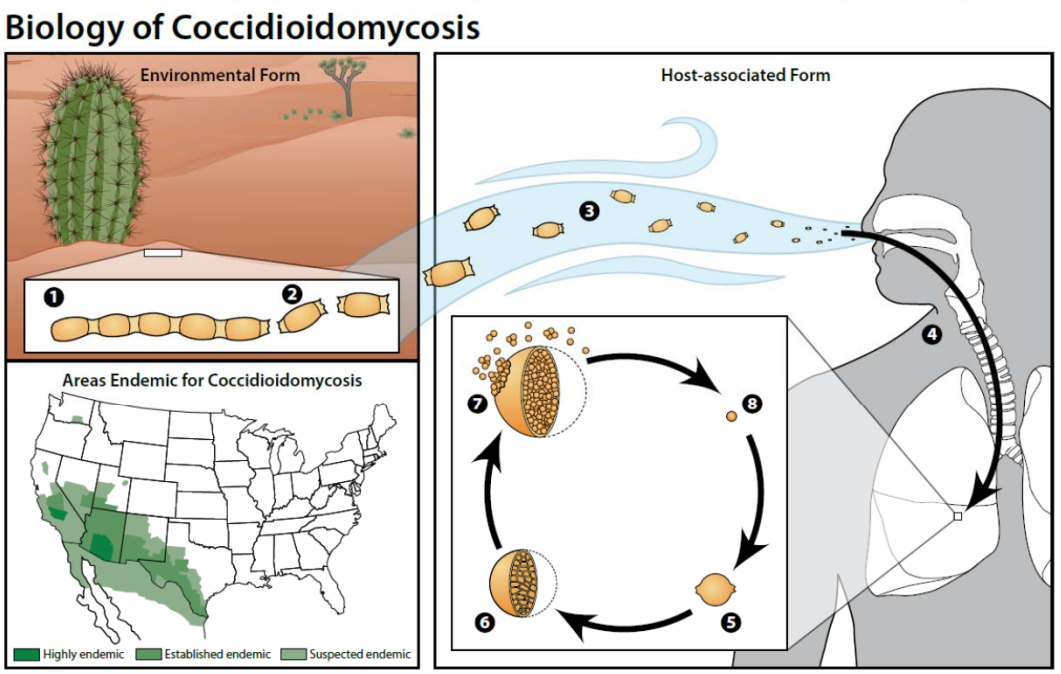
- Epidemics occur at low and high levels of specific humidity





Soil-borne: Valley Fever

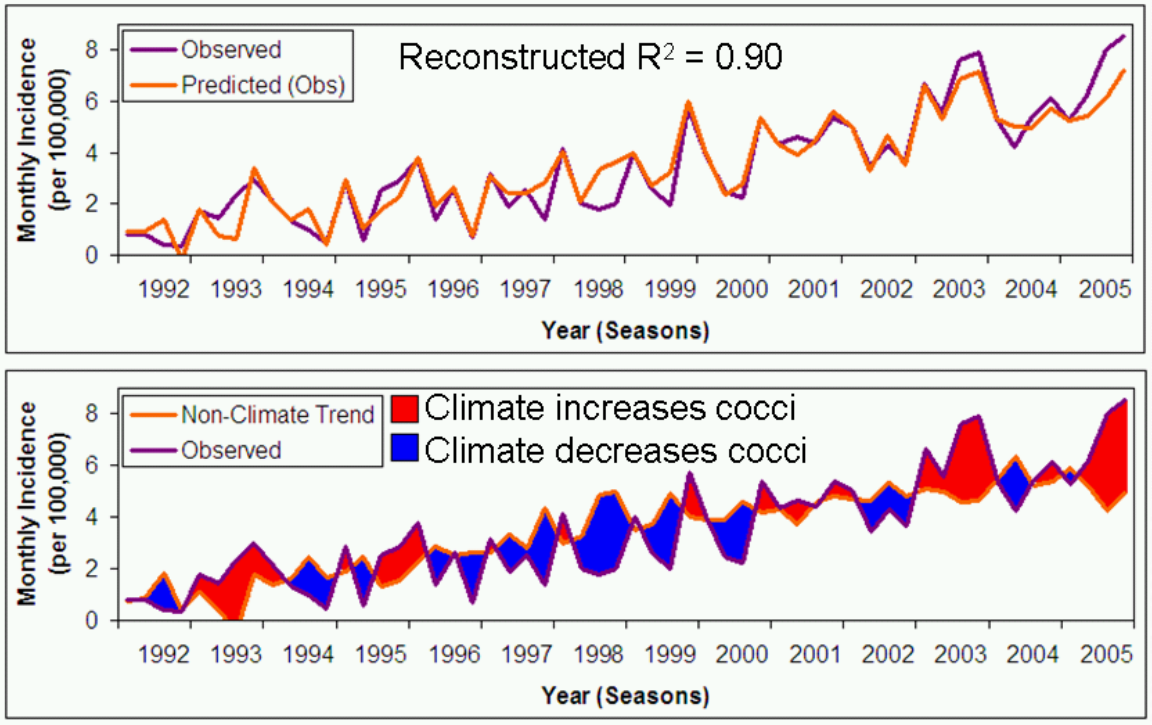
- Valley fever is caused by the soil fungus Coccidiodes
- Symptoms: fatigue, cough, fever, shortness of breath, headache, night sweats, muscle/joint pain, rash
  - Most people do not show symptoms
  - Severe symptoms are rare
- Infection occurs by breathing in the spores



In the environment, *Coccioides spp.* exists as a mold (1) with septate hyphae. The hyphae fragment into arthroconidia (2), which measure only 2-4 µm in diameter and are easily aerosolized when disturbed (3). Arthroconidia are inhaled by a susceptible host (4) and settle into the lungs. The new environment signals a morphologic change, and the arthroconidia become spherules (5). Spherules divide internally until they are filled with endospores (6). When a spherule ruptures (7) the endospores are released and disseminate within surrounding tissue. Endospores are then able to develop into new spherules (6) and repeat the cycle.

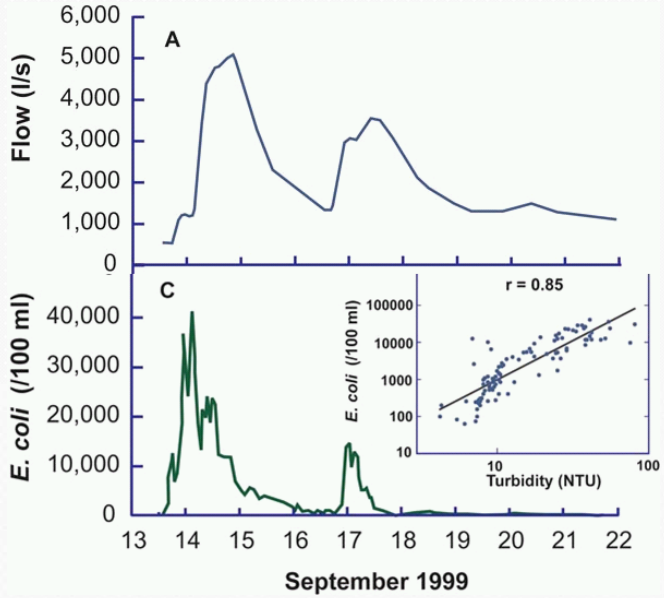
Soil-borne: Valley Fever

- Grow and blow hypothesis: moist conditions to grow, dry conditions to blow



Waterborne/Foodborne: E. coli, Salmonella

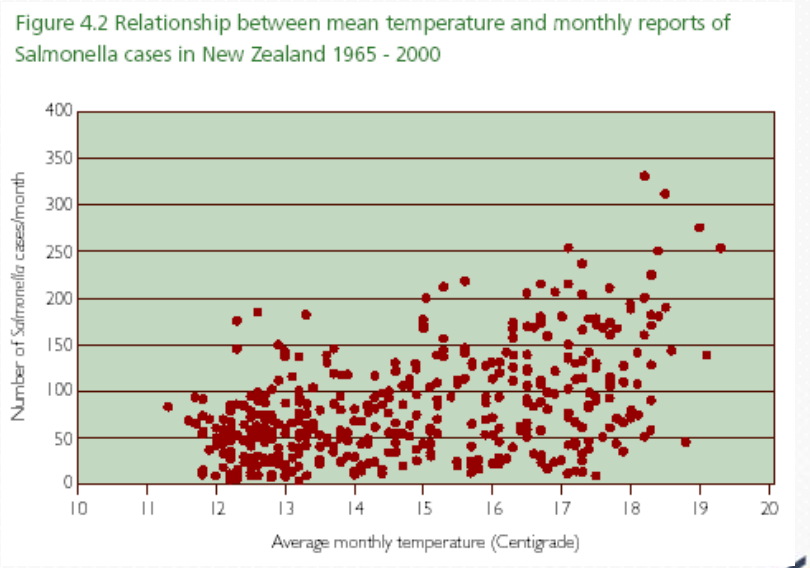
- Escherichia coli and Salmonella are intestinal bacteria found in humans and animals
- Symptoms: Diarrhea, stomach cramps, fever



http://www.niwascience.co.nz/pubs/wa/12-2/images/flood2_large.jpg

Temperature Relationship

Precipitation Relationship



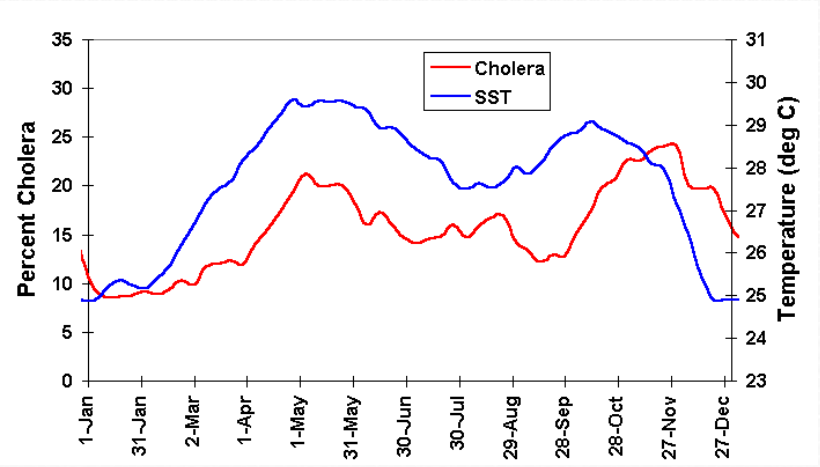
http://www.who.int/globalchange/climate/en/fig4.2.gif

Waterborne/Foodborne: Cholera

- Caused by bacteria *Vibrio cholerae*
- Symptoms: Diarrhea, vomiting, cramps
  - Severe symptoms are rare
- Cause by water or food contamination
- Climate relationship: ocean temps, pH, and salinity affect zooplankton blooms

http://www.cdc.gov/cholera/general/

http://healthline.com



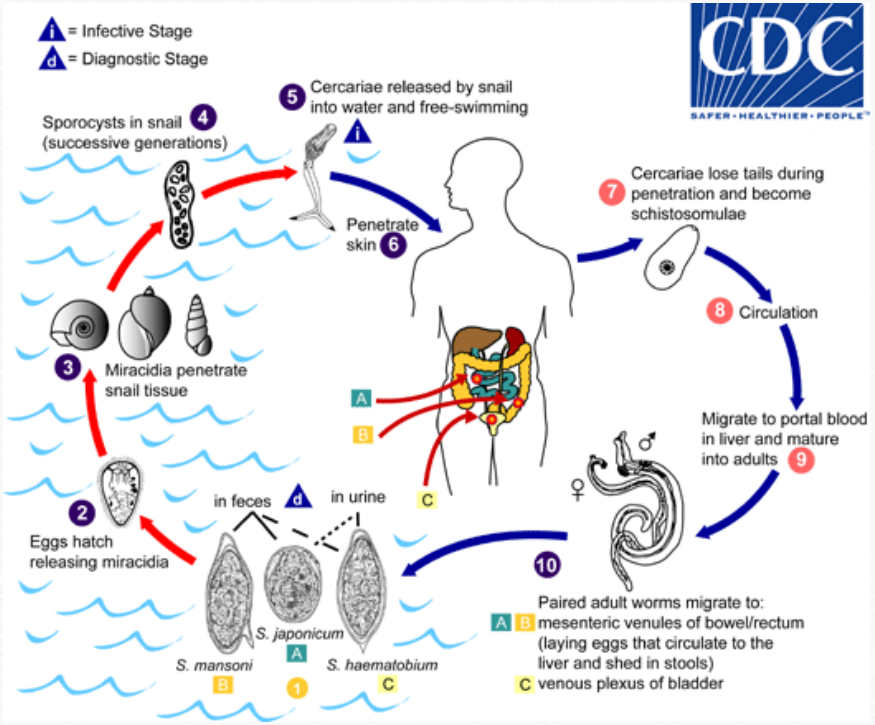
http://ecohealth.wisc.edu/index.php/submenu-temp-cholera.html

Waterborne: Schistosomiasis

- Caused by *Schistosoma* nematodes
- Symptoms: rash (initial), fever couch, much ache (later), abdominal pains, enlarged liver, blood in stool and urine (chronic)
- Snail is vector for nematode and are sensitive to water temperature

https://en.wikipedia.org/wiki/Schistosoma

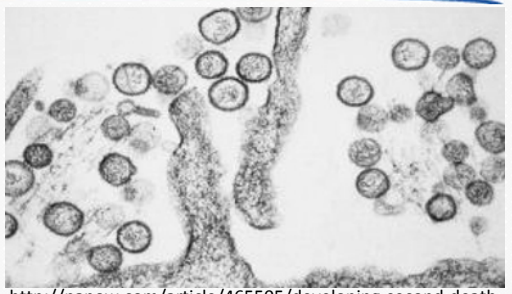
http://arstechnica.com/science/2015/07/shrimpocalypse-how-reintroducing-prawns-could-save-humans-from-deadly-disease/



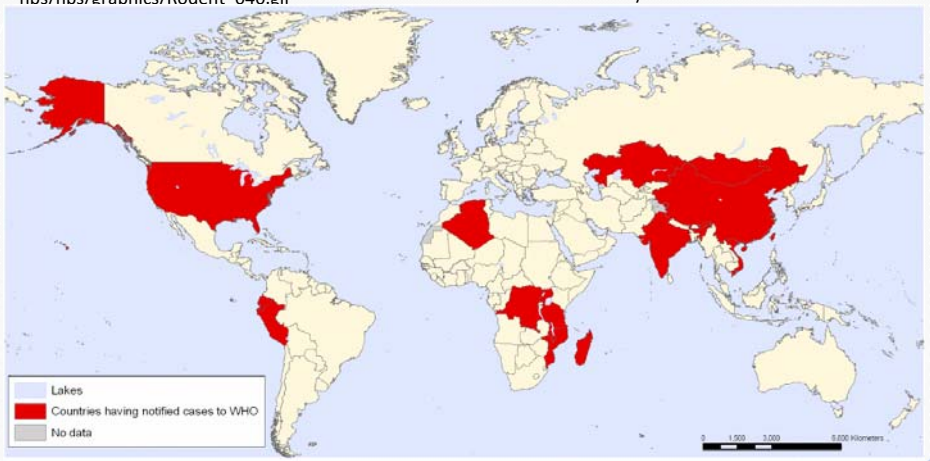
Rodentborne: Hantavirus, Plague

- Hantavirus pulmonary syndrome (HPS)
  - Virus transmitted though mouse urine, feces, and saliva
  - Early stage symptoms: fatigue, fever, and muscle aches
  - Late stage symptoms: coughing, shortness of breath, chest tightness
- Plague
  - Caused by bacteria *Yersinia pestis* carried by fleas on rodents
  - Symptoms: sudden onset of fever, headache, chills, and weakness

http://www.cdc.gov/ncidod/diseases/hanta/hps/hps/graphics/Rodent_040.gif

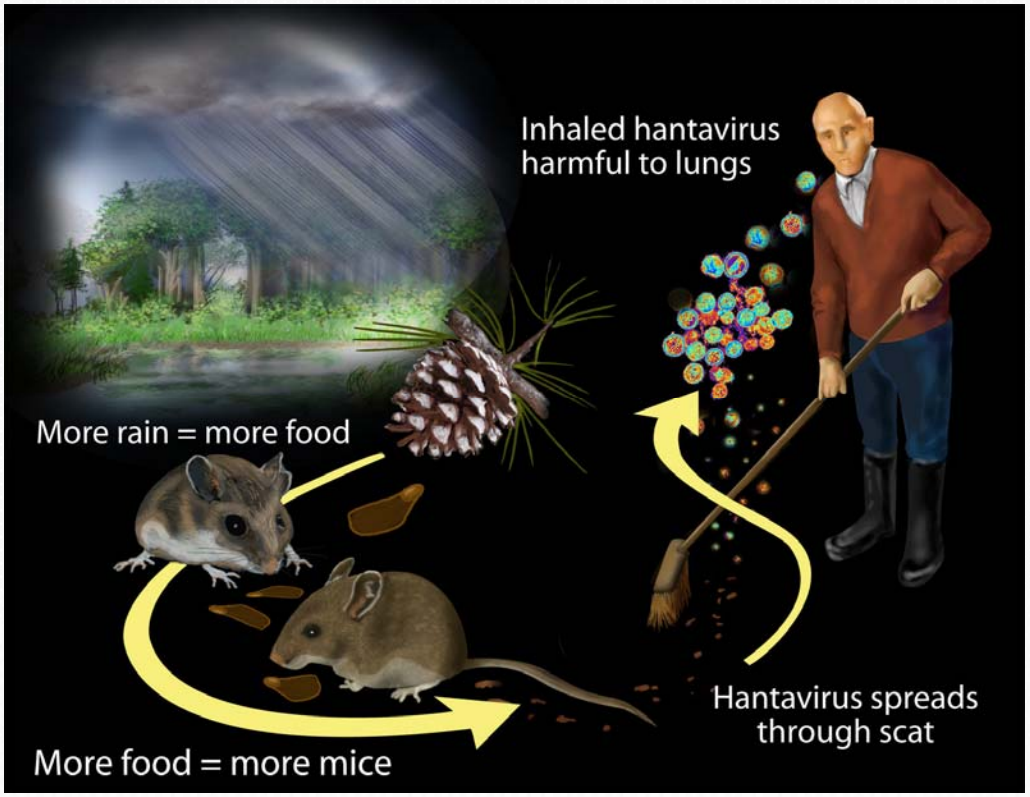


http://panow.com/article/465505/developing-second-death-caused-hantavirus-sask-year



Rodentborne: Hantavirus, Plague

- Climate relationship
  - Warm wet springs increase vegetation availability
  - Rodent population explodes increasing rodent-human contact
  - In the case of HPS, dry summer increases aerosolization of virus
- Relationship not as strong as with many other diseases

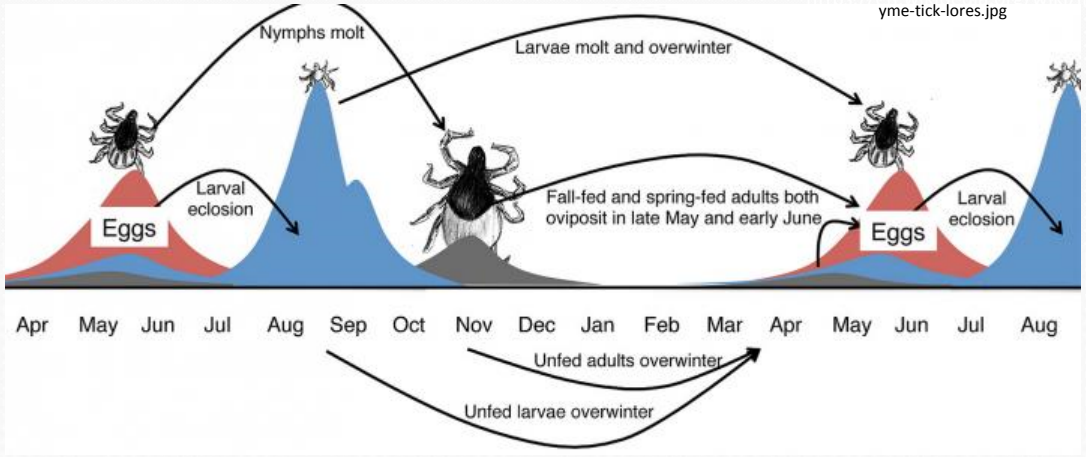


http://www.infectionlandscapes.org/2012/09/hantaviruses.html

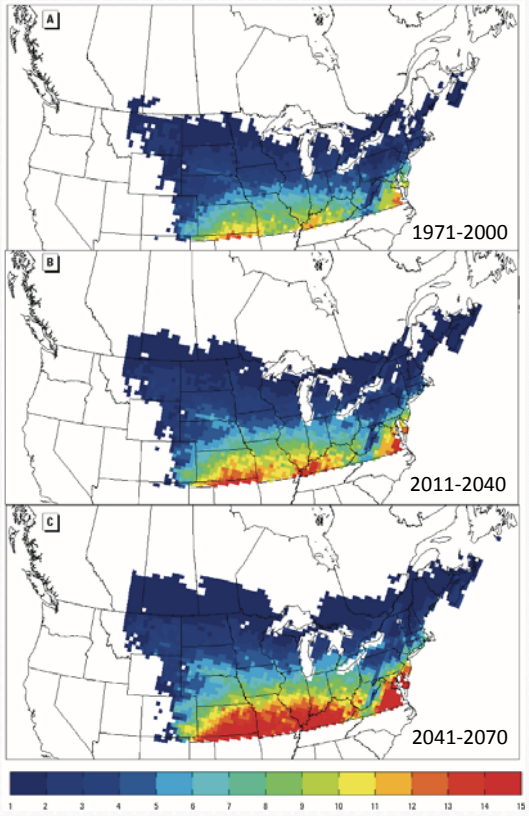
Vectorborne: Tick

- Ticks spread pathogens through blood meals
  - Life cycle tied to seasonal temperatures
  - Examples: Lyme diseases, Rocky Mountain spotted fever, Babesiosis, Powassan disease

http://www.cbc.ca/gfx/pix/lyme-tick-lores.jpg



http://oregonstate.edu/ua/ncs/archives/2015/feb/climate-change-may-affect-tick-life-cycles-lyme-disease



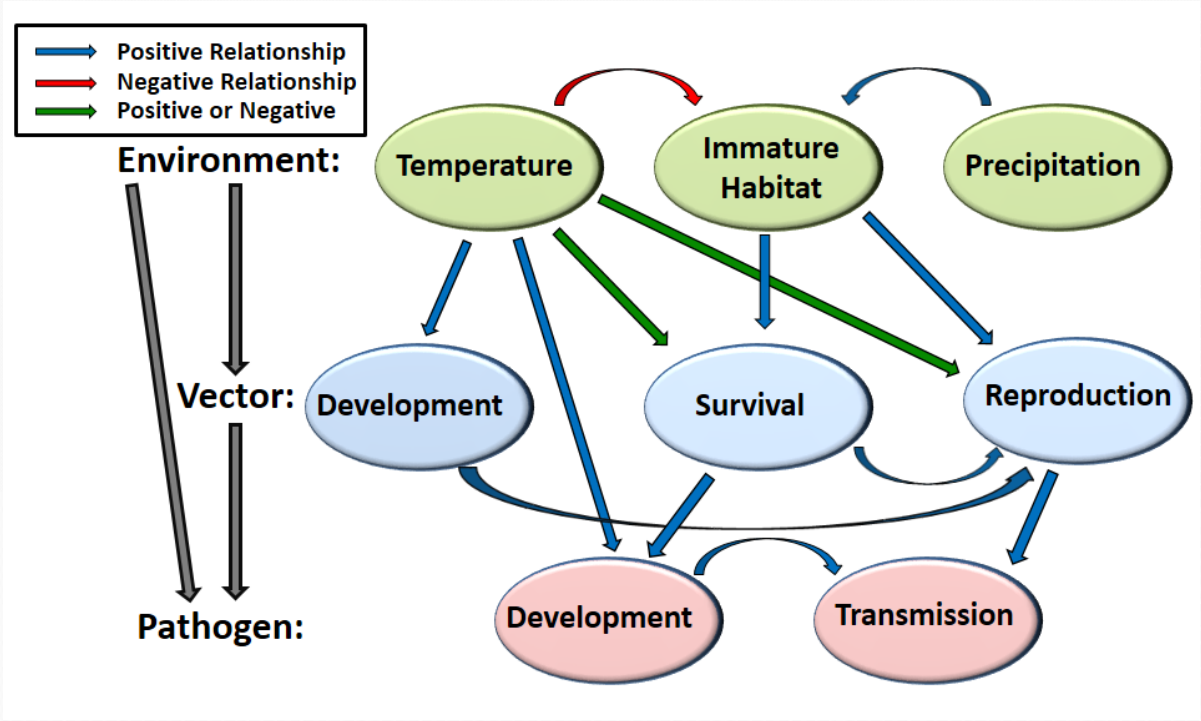
R_o for Lyme disease under various climate change scenarios (Ogden et al. 2014)

Vectorborne: Mosquitoes, Flies, ect.

- Many insect species transmit pathogens
  - Mosquitoes: malaria (anopheles), dengue fever (aedes), West Nile virus (Culex), ect.
  - Flies: onchocerciasis (blackfly), trypansomiasis (tsetse fly), leishmaniasis (sandfly), ect.
- Unique ecologies but usually influenced by climate

Vectorborne: Mosquitoes, Flies, ect.

- Weather/climate can influence pathogen ecology through multiple routes



Overall Conclusions

- Understanding climate and environmental effects on infectious disease ecology provides opportunities to simulate, investigate, and predict transmission dynamics
- However, natural and human systems are complex and coupled requiring interdisciplinary efforts to truly understand
- Future research must identify methods to transition research to better public health practice
  - Incorporate socio-economic and demographic variables into models
  - Creation of seasonal forecasts to help preparedness
- Without surveillance, treatment, and assessment of intervention strategies models will not be effective in reducing the burden of diseases!