US-Mexico Border, Climate Change, and Infectious Diseases

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Children and Infectious Disease: Canaries in a Coal Mine

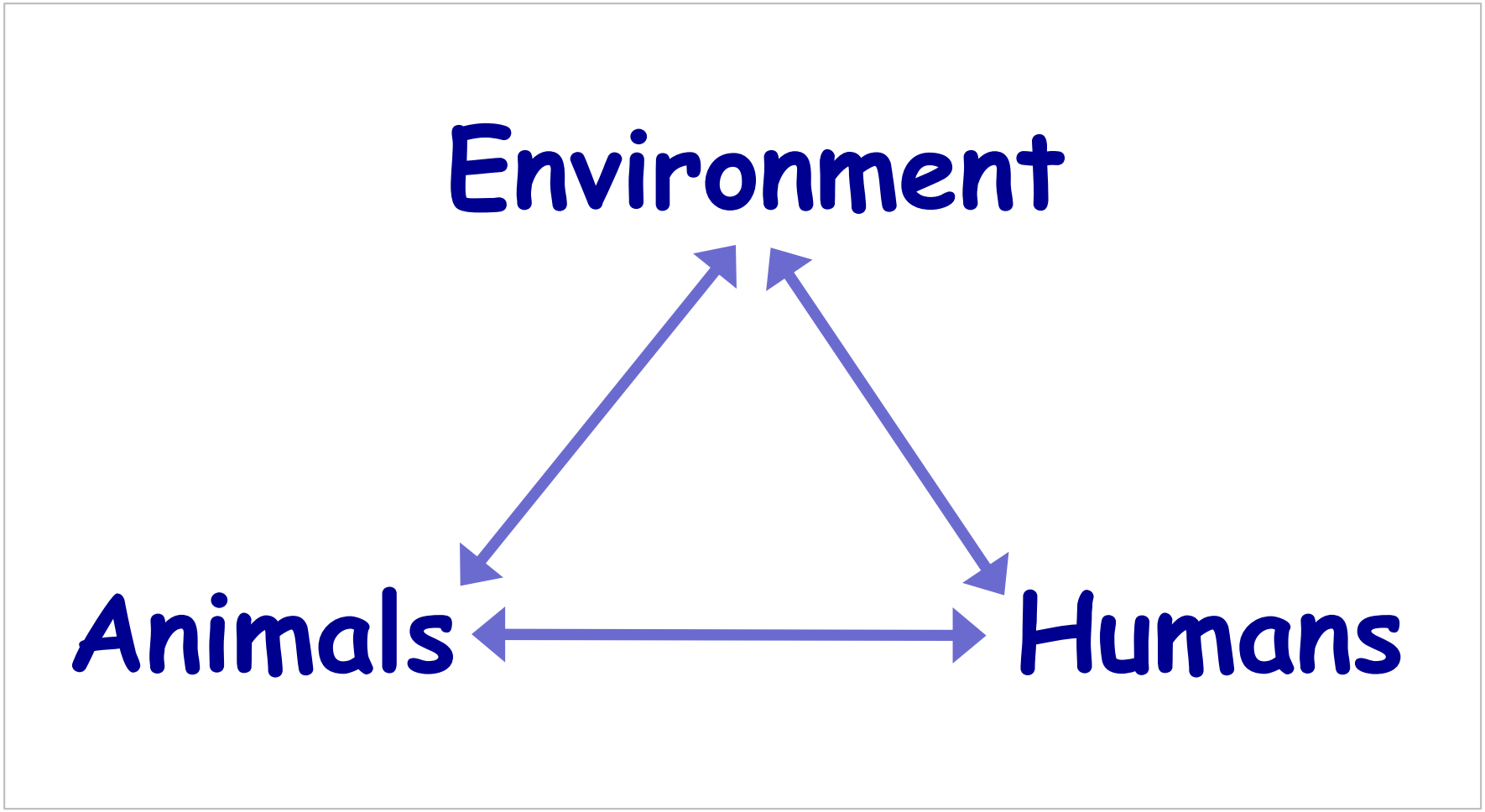
- Diarrhea
- Zoonotic disease

Infectious Disease Vulnerability of Border Region

- Arid ecosystem
- High biodiversity
- Pacific migratory bird pathway
- High human population mobility (busiest international border in the world)
- Urban development challenges

Urban Development Challenges

- Breeding ground for rodents
- Close exposure of humans and animals
- Contamination of water



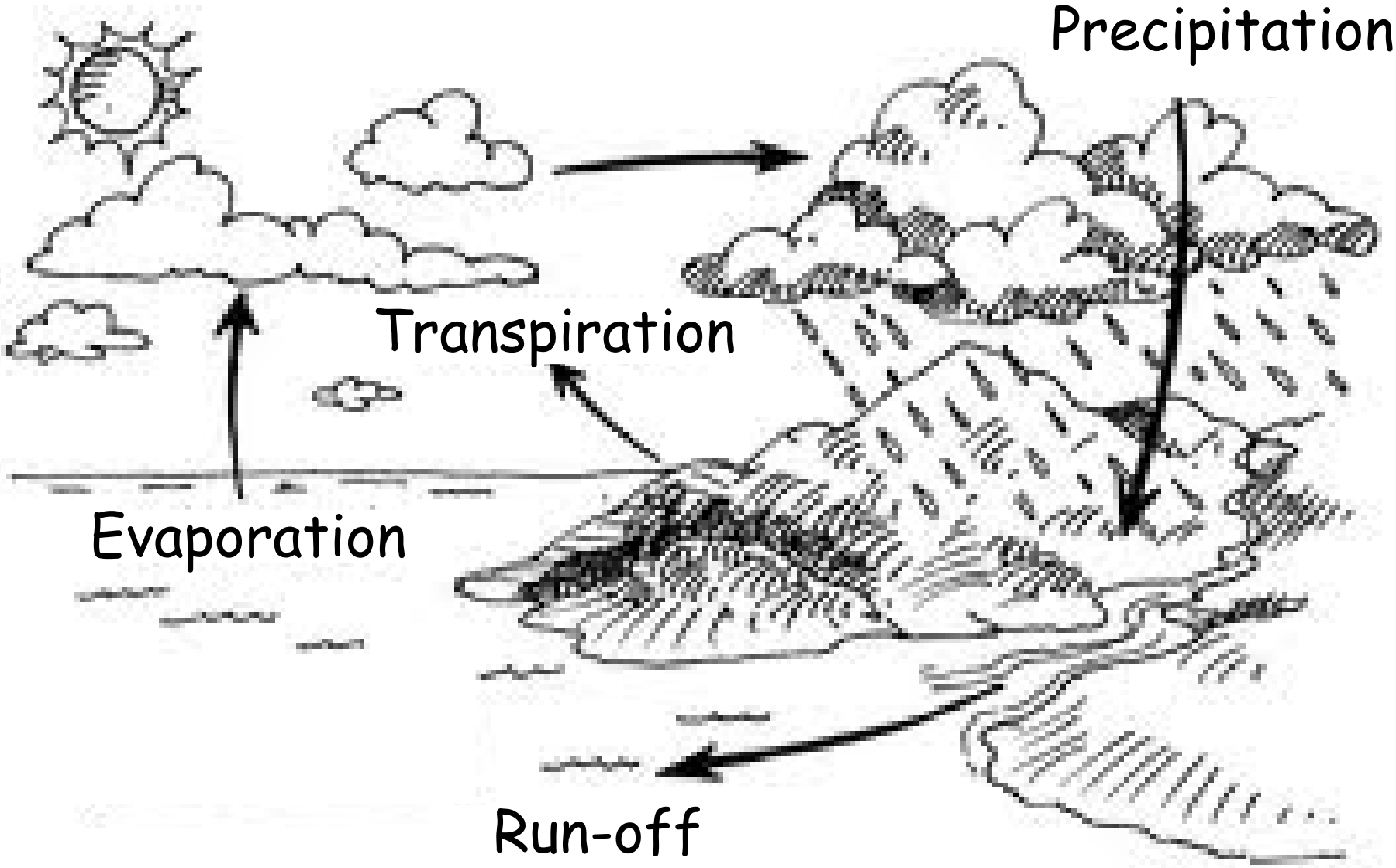
Atlas et al. 2010. Microbe
Casas et al. 2011. Intl. J. Microbiol. doi: 10:1155/2010/754368
Casas et al. 2011. Gut Pathogens 3:10 doi:10.1186/1757-4749-3-10

Human alteration of the environment …

- Changes in agriculture (*Salmonella, E. coli*)
- Changing demographics (Nipah virus, Dengue)
- Environment disruption (Lyme disease, SARS)
- Disruption of public health (Rabies)
- Human technology (*Legionella*)
- **Climate change**

Examples

The Water Cycle

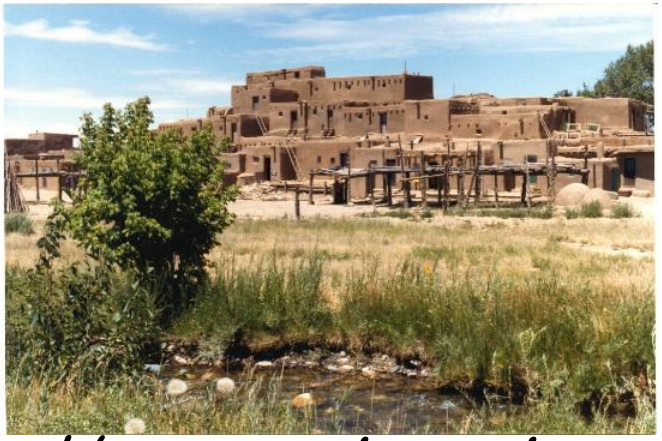


Impact of Altered Precipitation

- Both drought and flooding affect fresh water supplies, increasing transmission of pathogens like Salmonella and Rotovirus
- Increased rainfall provides more breeding grounds for mosquitos, promoting transmission of diseases
- Periodic drought followed by heavy rain often increases rodent populations

Four Corners Disease (1993)

Drought



Heavy spring rains

Mouse overpopulation

Hantavirus (Sin nombre)

http://www.cdc.gov/ncidod/diseases/hanta/hps/noframes/outbreak.htm

Sources of recent *Salmonella* outbreaks

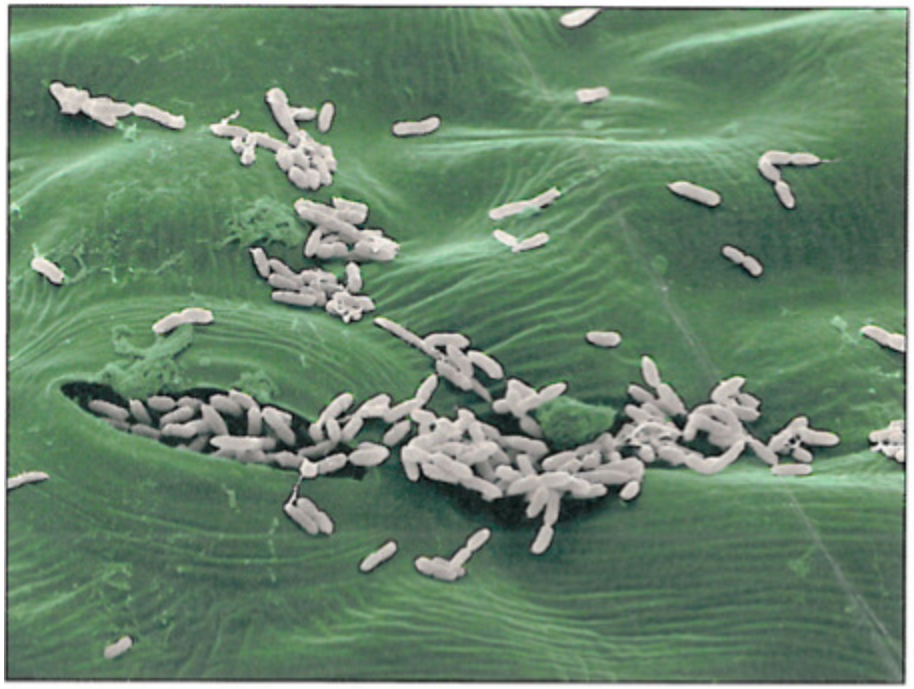
Animal products:
- Poultry
- Beef
- Pork
- Eggs
- Fish
- Milk
- Cheese
- Chocolate

Pets:
- Turtles
- Reptiles
- Dogs
- Cats
- Birds
- Pet food
- Treats

Plant products:
- Alfalfa sprouts
- Bean sprouts
- Melons
- Marijuana
- Lettuce
- Onions
- Tomatoes
- Peppers
- Cilantro
- Cereal
- Rice
- Flour
- Nuts (peanut butter)

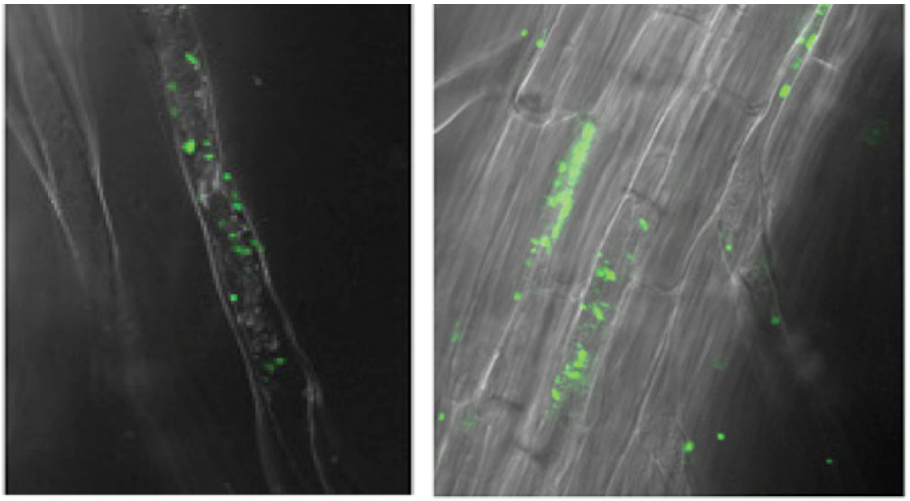
Why has transmission via plants increased recently?

Growth in plants



Chemotaxis toward photosynthetic cells;

Scanning EM of *Salmonella* on stomata of lettuce leaf (3250x)



3 hr 20 hr

GFP labeled *Salmonella* Typhimurium growing inside Arabidopsis tissue

Kroupitski et al. (2009) AEM 75: 6076; PLoS ONE (2008) 3: e2279

Why?

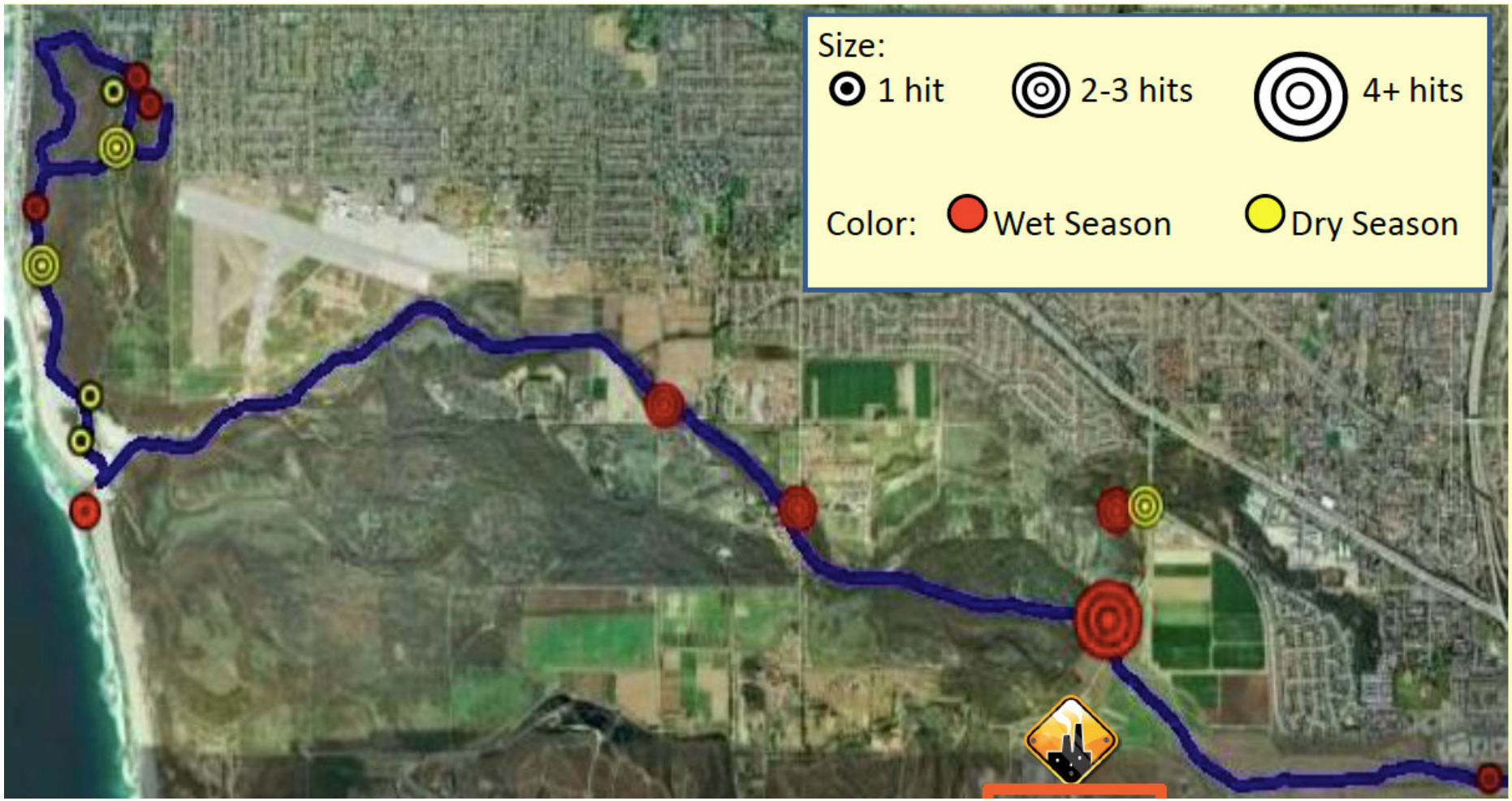
- Arid farm land / dependent on irrigation
- Highly variable annual rainfall / Frequent droughts
- Mixing of human, animal, and plant pathogens
- Selection for survival of bacteria inside plants

Tijuana River Estuary

Sewage Run-off into Ocean

Increase in human infections on both sides of border

Tijuana River Estuary



Environmental Reservoir of Virulence and Antibiotic Resistance Genes

Many Other Examples

Diseases transmitted by

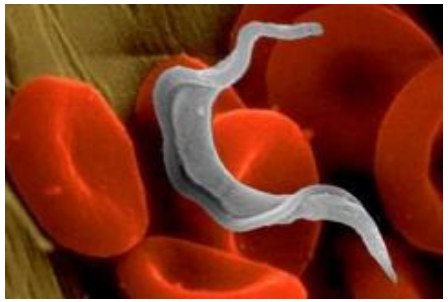
- ticks (Rickettsia, Mexicali 7/15)

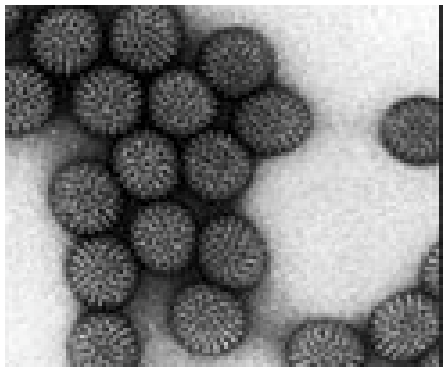
- aerosols (tuberculosis and influenza)

- marine animals (Leptospirosis in Sea Lions, Ensenada, La Paz)

- toxins (red tide/phytoplankton and aflaxotoxin/fungi)

Real-time Impact of Climate Change





- Increased terrestrial temperature
  - Insect vectors: Dengue, Chagas, Reduced biodiversity
- Increased ocean temperature
  - Growth of pathogens: Vibrio parahaemolyticus
- Changes in the water cycle
  - Flooding and drought: Salmonella, EHEC, Rotovirus, etc
  - Rodent vectors: Hanta virus

- Increased average terrestrial and ocean surface temperature
  - Changes in precipitation
  - Storms, floods, drought

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- Contamination of water by pathogens
- Increase in number / activity of vectors
- Changes in populations of animal carriers

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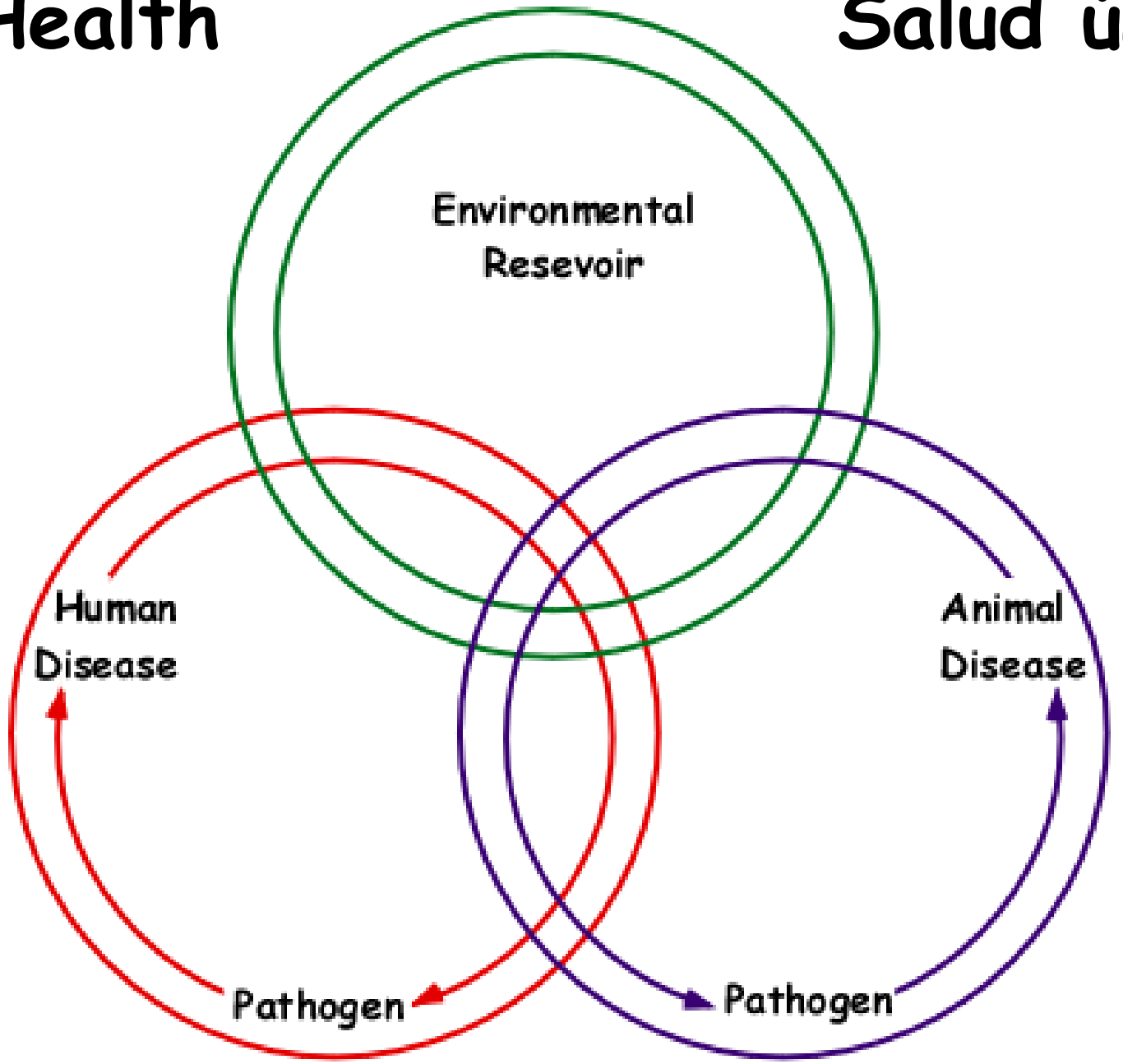
- Diarrheal diseases
- Diseases transmitted by ticks, mosquitos, and other insects
- Diseases transmitted from animals

One Health

Salud única



Human Health paradigm:

Disease Surveillance → Investigation → Treatment

- Human disease

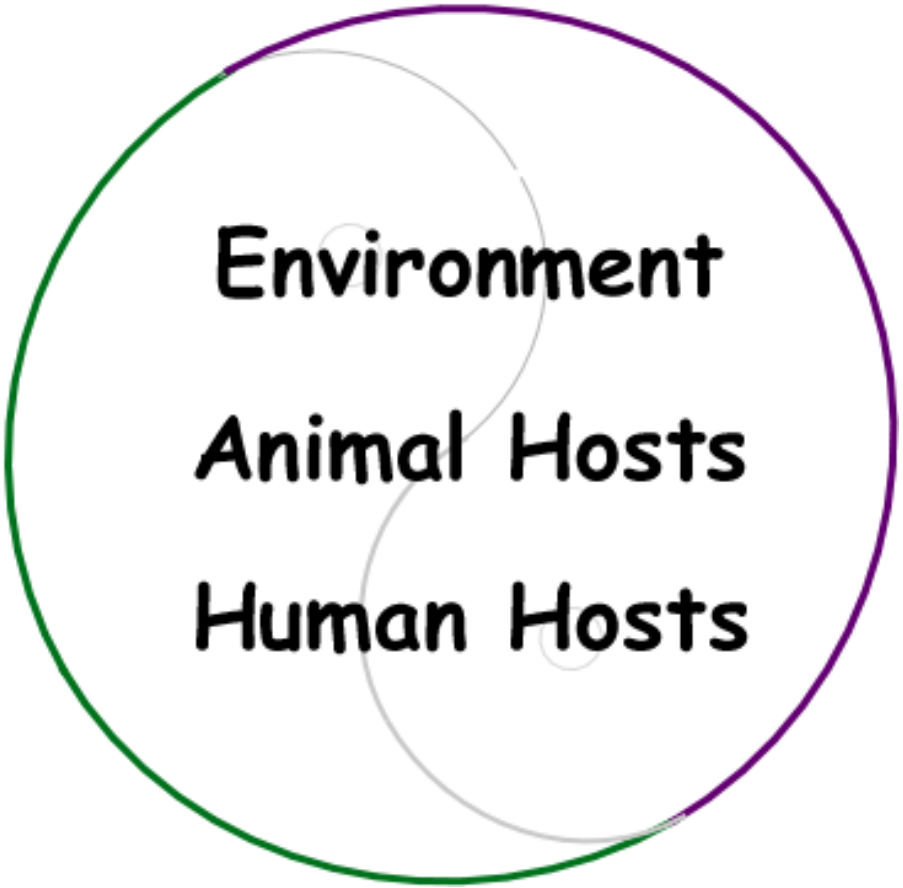
One Health paradigm:

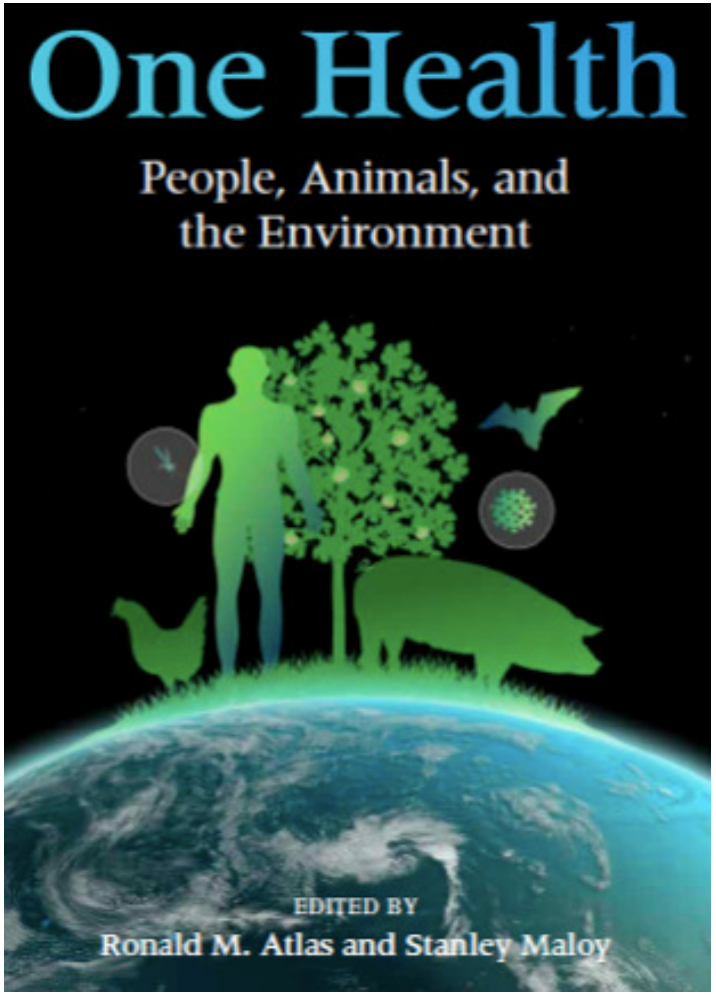
Environment Surveillance → Prediction → Prevention

- Environment
- Animals
- Human disease

Atlas & Maloy. 2014. One Health: People, Animals, and the Environment. ASM Press, Washington D.C.

One Health

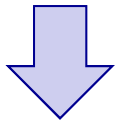

Environment
Animal Hosts
Human Hosts


One Health
People, Animals, and the Environment
EDITED BY
Ronald M. Atlas and Stanley Maloy

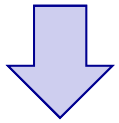
Tijuana River Watershed

How does this lead to new disease?

Reservoirs of potential pathogens in environment

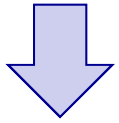


Disrupt environment



Natural selection for microbes with new properties

Exposure of animals to new microbes



Transmission to Humans

Emerging Infectious Diseases

1993	Hanta virus (mice)
1994	Plague (rats)
1995	Ebola (apes)
1996	CJD ("mad cow")
1997	H5N1 influenza (fowl)
1998	Nipah (bats)
1999	West Nile Virus (birds)
2000	Rift Valley Fever (goats)
2001	[Anthrax]
2002	Norovirus
2003	SARS (bats, game)
2004	Marburg Virus (monkeys)
2005	H5N1 influenza (fowl)
2006	E. coli 0157:H7 (cattle)
2007	Food-borne / MMP
2008	Salmonella (peppers)
2009	H1N1 influenza (pigs)
2010	Salmonella (eggs)
2011	E. coli 0104:H4 (sprouts)
2012	MERS Coronavirus (camels, bats)
2013	Neisseria meningitis
2014	Ebola (bats)

Climate Variation and Infectious Disease

- Wildlife die-offs (threaten biodiversity)
- Sewage runoff (rain / beach closures)
- Zoonotic infectious disease (close contact of humans and animals)
- Vector borne diseases (mosquitos, ticks)
- Emerging infectious disease and antibiotic resistance