Jet Stream or Jet Plane?
The Effects of Climate on Influenza in the United States

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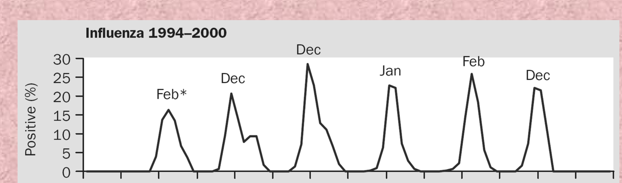
Overview

Influenza (commonly referred to as the flu) is one of the most deadly of all airborne and upper-respiratory infections. On average, over **36,000 deaths** and over **1.5 million hospitalizations** in the United States are attributed to influenza each year. Moreover, annual influenza epidemics can have **multi-billion dollar impacts** on the United States economy.

Influenza epidemics in the United States occur most frequently during the cold season (November-March) and typically peak in February. As such, viral transmission and susceptibility have long been linked to cold temperatures and indoor crowding, particularly in schools and the workplace. Other environmental factors (e.g., humidity, wind, exposure to sunlight) and human behaviors (e.g., travel, exposure, time spent indoors) have also been used to explain the seasonal variability in influenza outbreaks. **The degree to which these factors (environmental vs. behavioral) affect the incidence of influenza, however, remains largely unknown.**



Seasonal pattern of influenza incidence across the United States and month of peak incidence (from Dowell and Ho, 2004)

Our current understanding of the relationship between climate and influenza is based largely on research performed by members of the medical and epidemiological fields with **relatively few contributions from climate scientists**. The broad scope of research methodologies employed by members of both fields (laboratory-based studies vs. large-scale circulation-based studies) makes it challenging to establish a causal link between climate and the influenza virus.

Purpose

The purpose of this research is to illustrate the relationships between various climate variables (e.g., temperature, humidity) and influenza across a range of biological scales (e.g., pathogen microbiology) and atmospheric scales (e.g., large-scale air mass characteristics).

We have adopted Comrie's (2007) **Epidemiological Triangle of Disease (ETD)** to isolate the individual components of the climate-influenza relationship, synthesize the available information and data, and pose new research questions that invite multidisciplinary collaboration among experts in climate and disease.

The Epidemiological Triangle of Disease

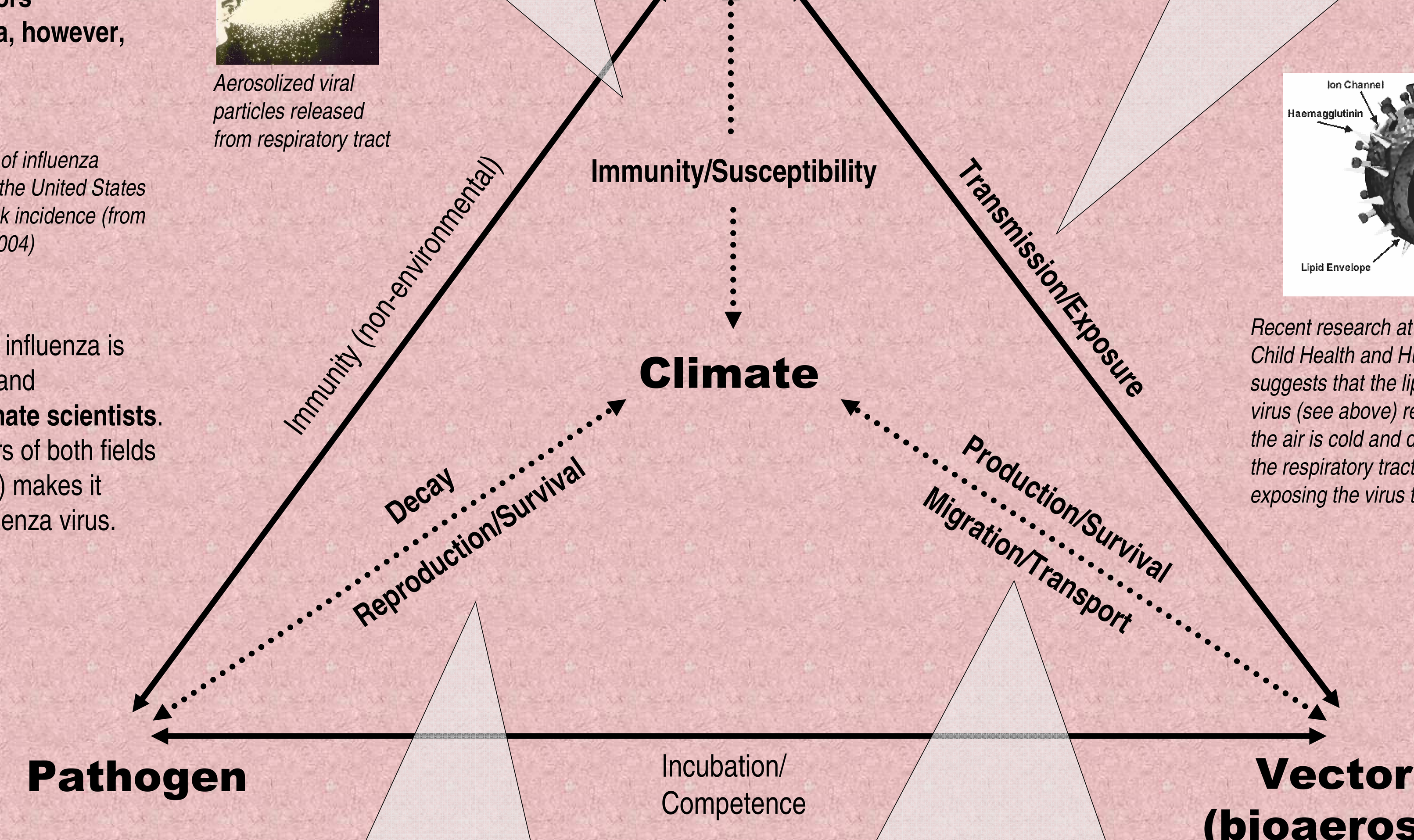
In a recently published review article on climate change and human health, Comrie (2007) uses a diagrammatical concept (ETD) to illustrate the "multifactorial" relationship between the **primary components of disease ecology (pathogens, hosts, vectors) and the environment, of which climate is a major determinant.** We have revised the original template of the ETD to emphasize the climate component, as well as increase its flexibility so that it may be applied to other classes of infectious diseases with hypothesized climate connections.

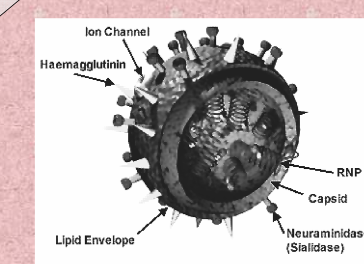
Synthesizing the Climate-Influenza Relationship

<u>Host Immunity/Susceptibility</u>: Recently, it has been suggested that the seasonality of influenza activity may be linked to patterns in host susceptibility. During the off-season the virus becomes latent as the host immune system develops **resistance through a stronger melatonin pulse**. Seasonal variations in the solar cycle, however, occur with much regularity from year to year and do not offer sufficient explanation for the inter- and intra-seasonal trends in influenza activity. On a physiological scale, the breathing of cold air can **slow mucociliary clearance of the nasal passage**, encouraging viral spread into the respiratory tract.

<u>Transmission/Exposure</u>: Studies investigating the transmission of the influenza virus have generally been conducted on non-human subjects in laboratory settings. For example, a study on viral transmission between guinea pigs found that low relative humidity (20-35%) and low temperatures (5-15 degrees C) were most favorable for transmission. Such conditions resemble those associated with dry indoor heating and cold outside temperatures. Transmission did not occur above 80% relative humidity and 30 degrees C. Respiratory droplets containing the influenza virus may remain active up to 24 hr when the air is exceptionally dry (less than 25% relative humidity). Strong winds may "kick-up" these active droplets, further increasing transmission.


Aerosolized viral particles released from respiratory tract





Recent research at the National Institute of Child Health and Human Development suggests that the lipid envelope encasing the virus (see above) remains intact longer when the air is cold and dry. As the aerosol enters the respiratory tract the envelope "melts", exposing the virus to healthy host cells.

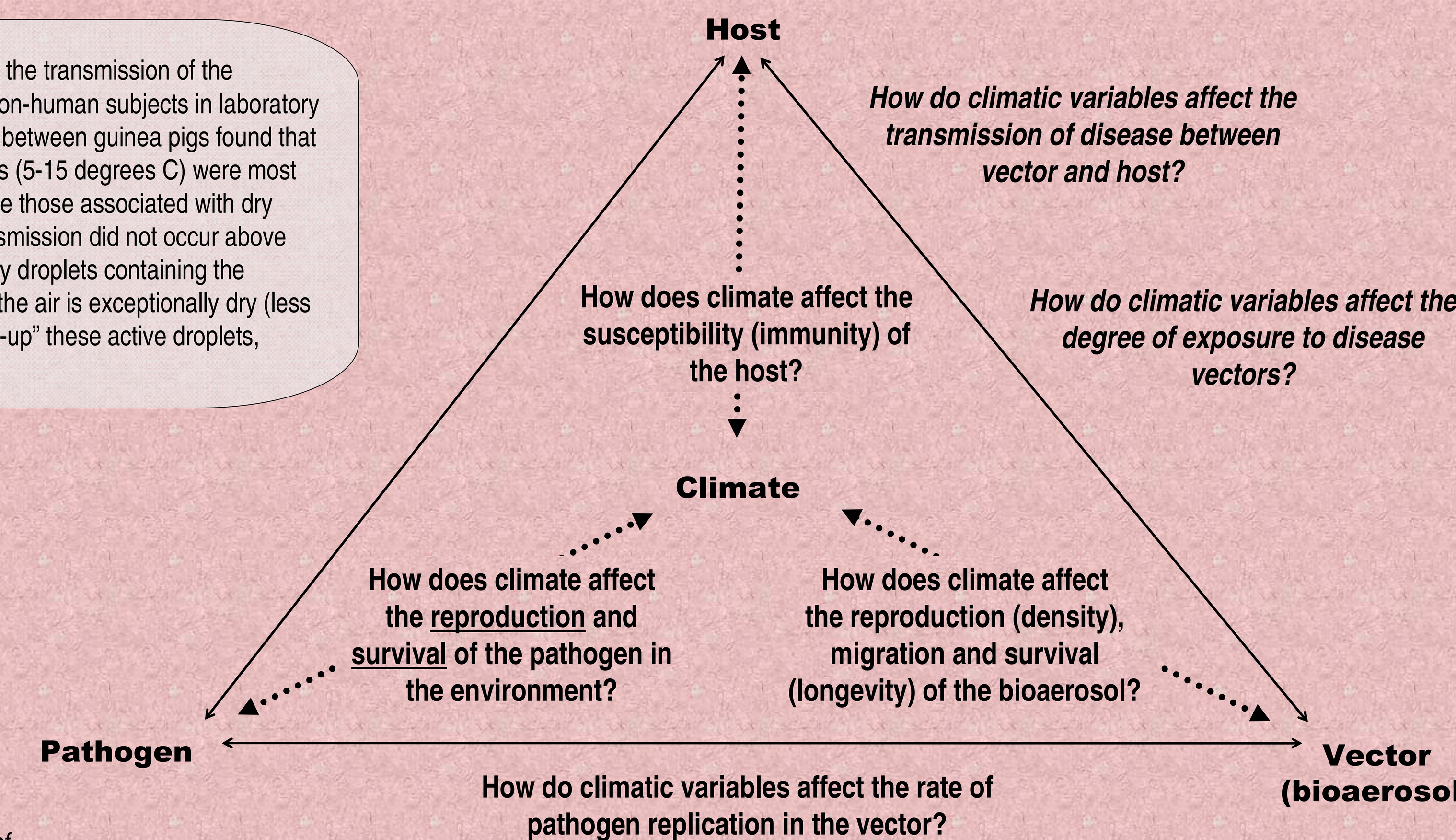
<u>Virus Reproduction/Survival/Decay</u>: This issue addresses one of the initial criterion for infection – a strain of the virus must be available in the environment. Interestingly, there is still **much debate as to how the influenza virus exists in its ambient state** and what happens to it during the "off-season". Some studies suggest a cross-equatorial migration during the off-season while other studies suggest that the virus enters a dormant state or exists at very low levels (sub-epidemic). Biological studies also show that viral strains will decay at faster rates with high humidity and more ultra-violet radiation (sunlight).

<u>Vector (bioaerosol) Reproduction/Survival/Decay</u>: Infection with influenza, as with most upper-respiratory illnesses, occurs when the pathogen enters the nose and mouth via small respiratory droplets (i.e., bioaerosols) suspended in the air. Coughing and sneezing produce significant quantities of aerosolized viral particles that can disperse over broad areas. Previous research has shown that that exhaled bioaerosols (within which the pathogen becomes embedded) are **more stable and do not settle rapidly when the air is dry**, thus increasing their "residence time" in the air and the likelihood of transmission. Bioaerosols containing the influenza virus are generally between 5-10 micrometers in size when dispelled from the respiratory tract, but **shrink to less than half their original size in dry ambient air** (generally less than 40% relative humidity).

Selected References

• Dowell, S.F., and M.S. Ho, 2004: Seasonality of infectious diseases and severe acute respiratory syndrome – what we don't know can hurt us. *Infectious Diseases*, 4, 704-708.
• Comrie, A., 2007: Climate change and human health. *Geography Compass*, 1/3, 325-339.
• Dowell, S.F., 2001: Seasonal variation in host susceptibility and cycles of certain infectious diseases. *Emerging Infectious Diseases*, 7, 369-374.
• Lowen, et al., 2007: Influenza virus transmission is dependent on relative humidity and temperature. *Pathogens*, 3, 1470-1476.
• Tellier, R., 2006: Review of aerosol transmission of Influenza A virus. *Emerging Infectious Diseases*, 12, 1657-1662.
• Polozov, I.V., et al., 2008: Progressive ordering with decreasing temperature of the phospholipids of influenza virus. *Nature Chemical Biology*, 4, 248-255.

Asking the Right Questions: How Can Climatologists Contribute?



Proposed Research Initiatives and Recommendations

Based on the information obtained through construction of the revised ETD, we propose a number of research initiatives aimed primarily at promoting <u>multidisciplinary collaboration</u> but with an emphasis on identifying the specific areas of inquiry where climatologists can best contribute to a more complete understanding of the climate-influenza relationship:

- *Identify the empirical relationships between large scale atmospheric attributes and influenza. Relate the frequency and phasing of air mass types (i.e., an air mass-based climatology) to the incidence and level of activity of influenza cases.*
- *Look for within-type variability of various meteorological parameters (e.g., temperature, humidity, radiation, wind) that might help explain short-term (intra-seasonal) trends in influenza activity.*
- *Asses the likelihood of changes in influenza incidence under various climate change scenarios. Develop more robust models and predictions by incorporating epidemiological research (e.g., trends and patterns in vaccinations). Are there climate events that can help "trigger" viral spread?*
- *Propose an influenza "forecast" that is based at least initially on air mass type and trajectory. Collaborate with members of the public health field so that relevant medical data can be ingested into predictive models.*

In addition, we recommend the following as preliminary conceptual guidelines and methodological frameworks for future research in climate and public health:

- *Before empirical relationships between climate and public health can be used for predictive purposes, a physical basis for these relationships needs to be established and confirmed.*
- *From a climatological perspective, we need to focus on those variables that influence human health at scales that currently reflect the most significant environmental change.*
- *Ultimately, in the case of public health and environmental change, the goal of the climatologist is to develop a reproducible methodology linking climate and health that can be applied to a series of health concerns that interest a large portion of the population. The development and preliminary implementation of the ETD in this study represents a first step in this direction.*