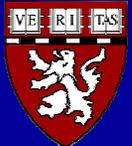


Climate Change and Human Health

MIT

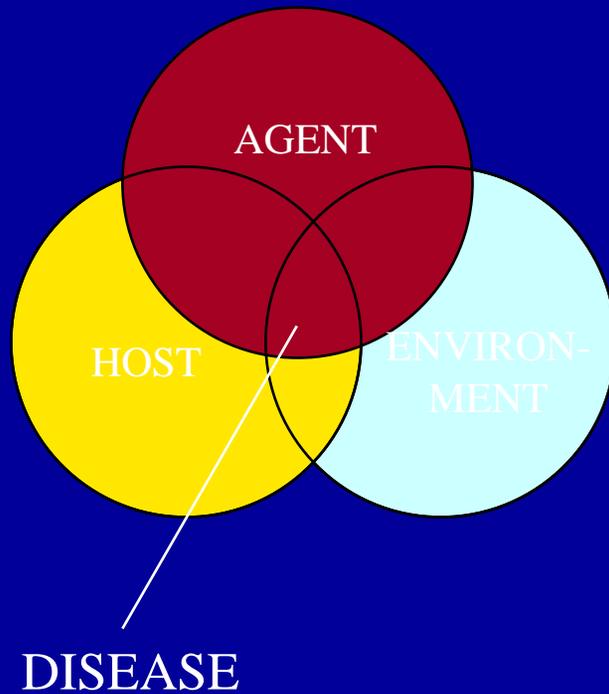
Paul R. Epstein, MD, MPH



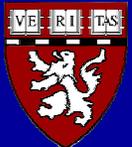
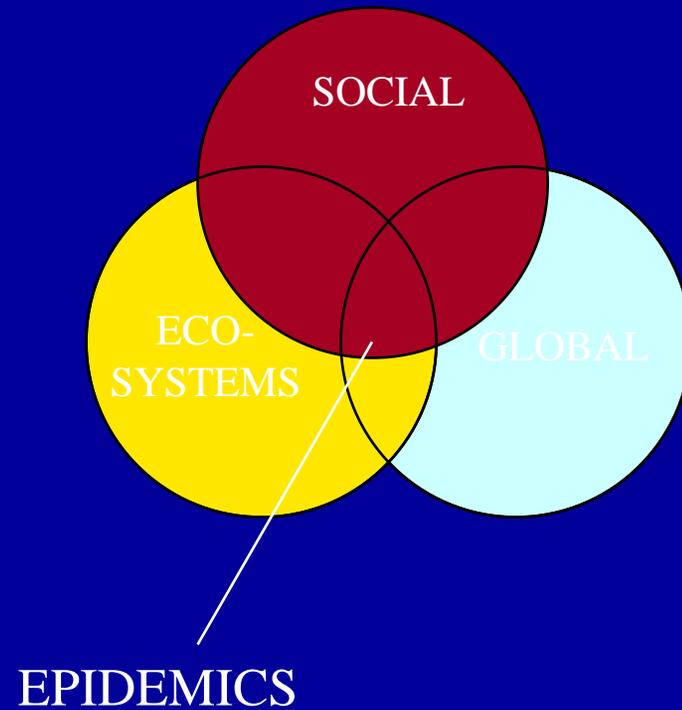
CENTER FOR HEALTH AND THE GLOBAL ENVIRONMENT

HARVARD MEDICAL SCHOOL

Epidemiological Framework

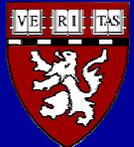


Ecological-Epidemiological Framework



United Nations Intergovernmental Panel on Climate Change Third Assessment Report 2001

1. Climate is changing
2. Human activities are contributing
3. Biological systems are being affected
on all continents
4. Weather is becoming more extreme

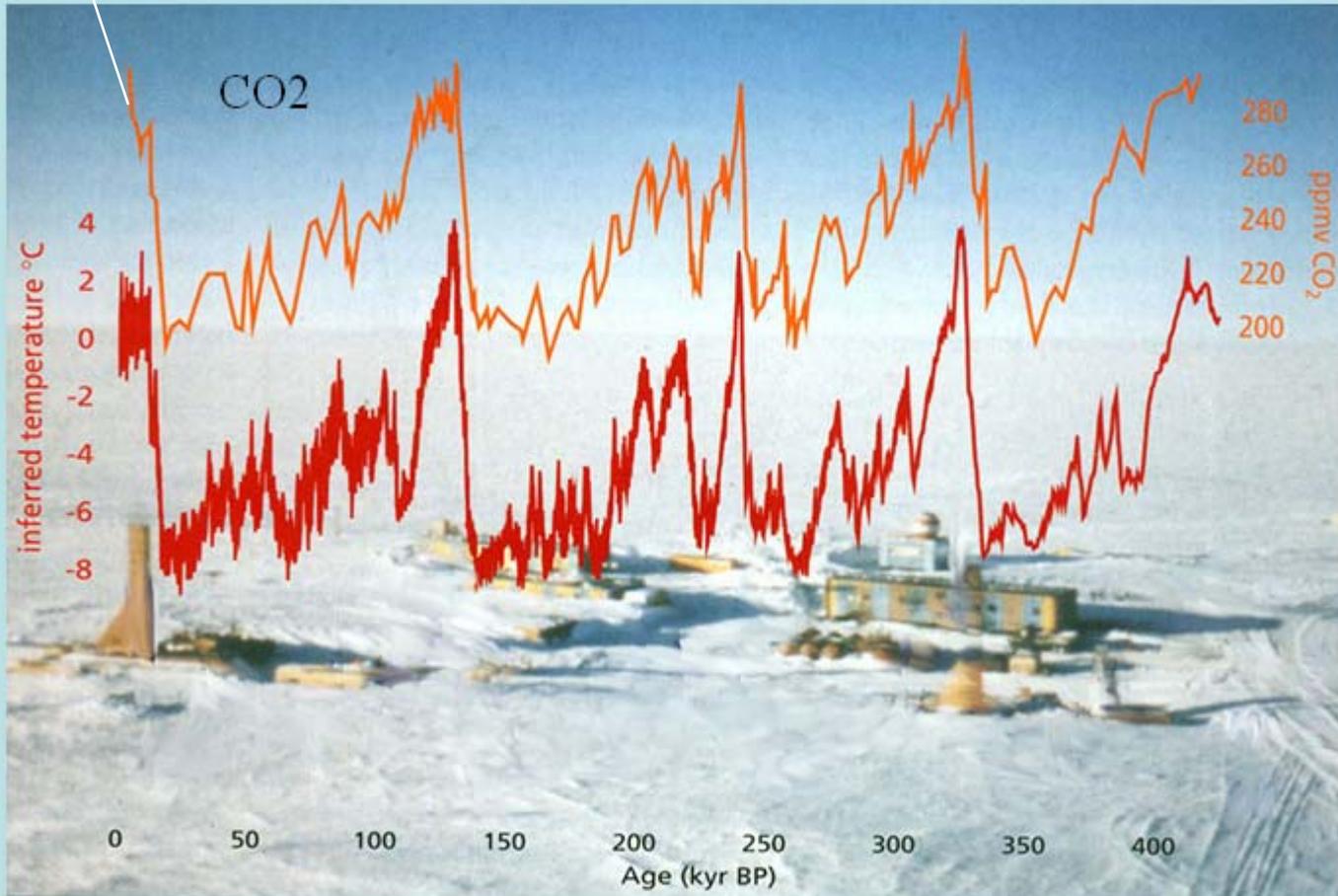


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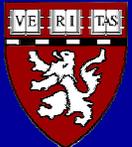
HARVARD MEDICAL SCHOOL

All weather = $f(\text{CC} + \text{NV})$

379ppm



M



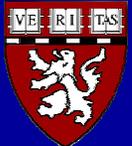
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HARVARD MEDICAL SCHOOL

Vostok Ice Core

Since 2001, studies show:

- CO₂ rise is accelerating, 3ppm/yr, up from 1.8
- Tropical oceans are warmer and saltier, surface waters near the poles are cooler and fresher
- Polar and mountain glacial ice is diminishing at surprising rates
- Winds around both poles are becoming more forceful.



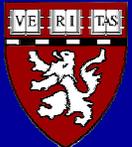
Deep Ocean Warming

Oceans: 14.2×10^{22} J

Atmosphere: 6.6×10^{21} J

Levitus et al. *Science* 2000; 287:2225

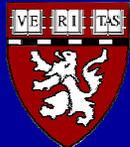
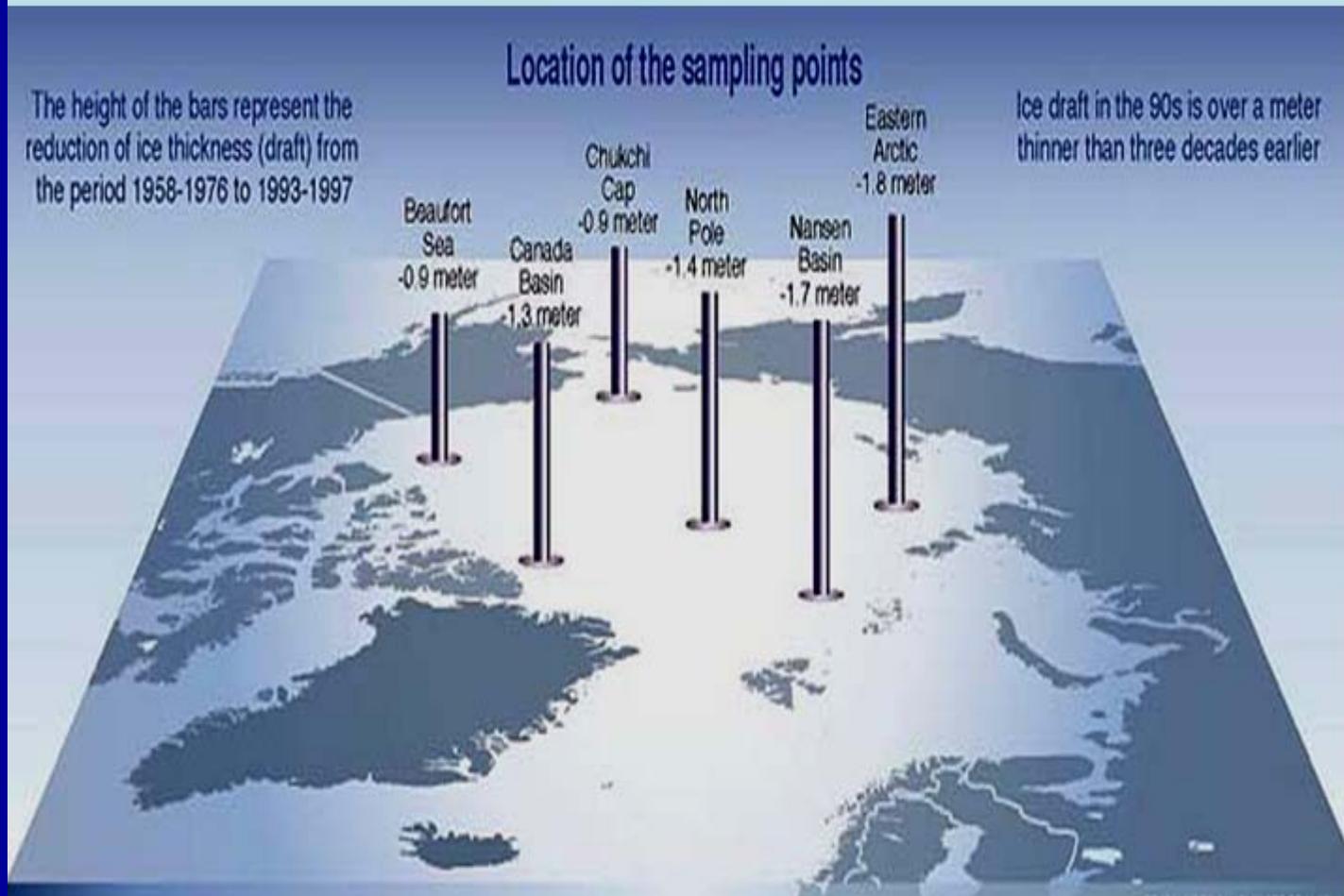
Parrilla et al. *Nature* 1994;369:48



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HARVARD MEDICAL SCHOOL

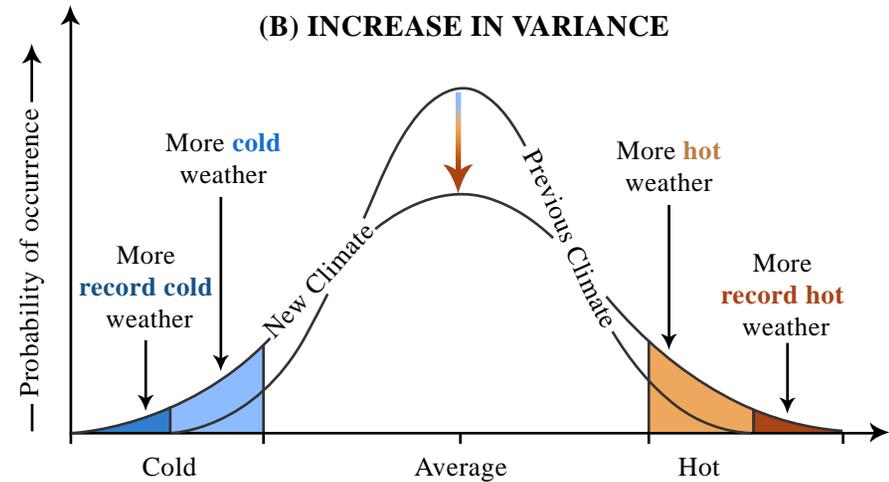
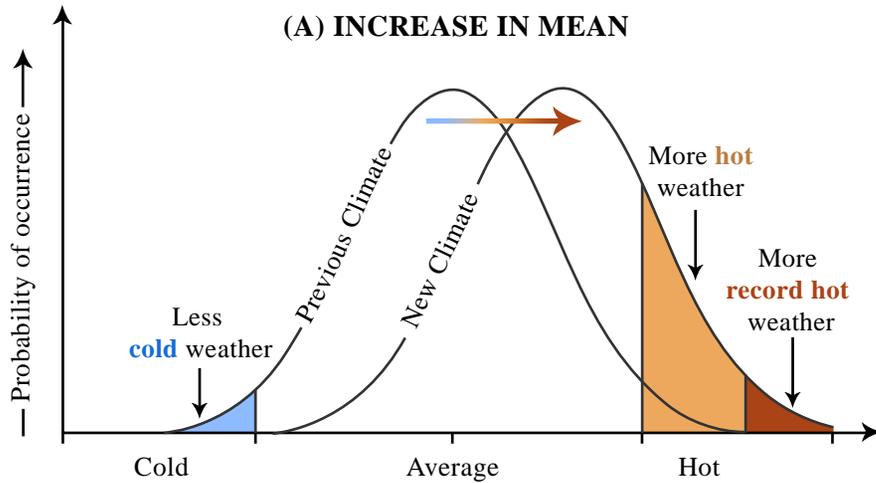
Observed Thinning of Arctic Sea-Ice 1960s - 1990s



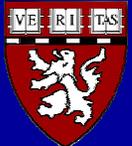
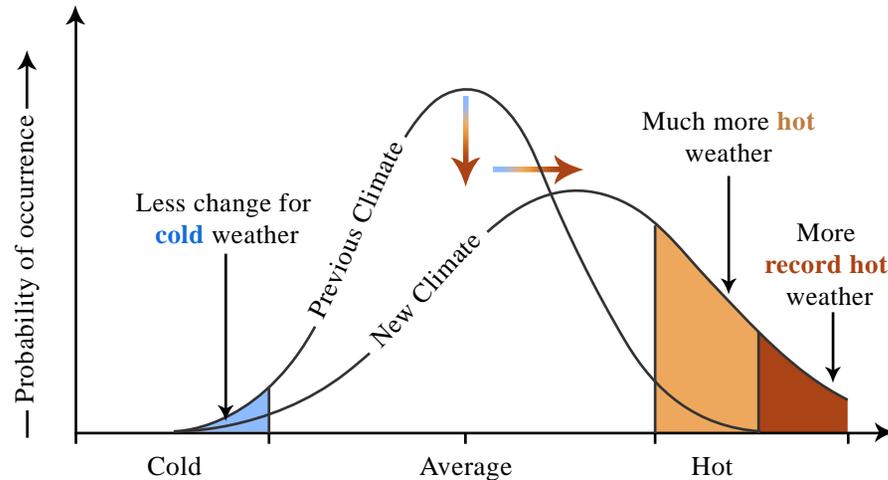
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The Changing Shape of the Curve

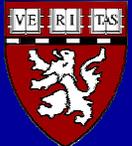
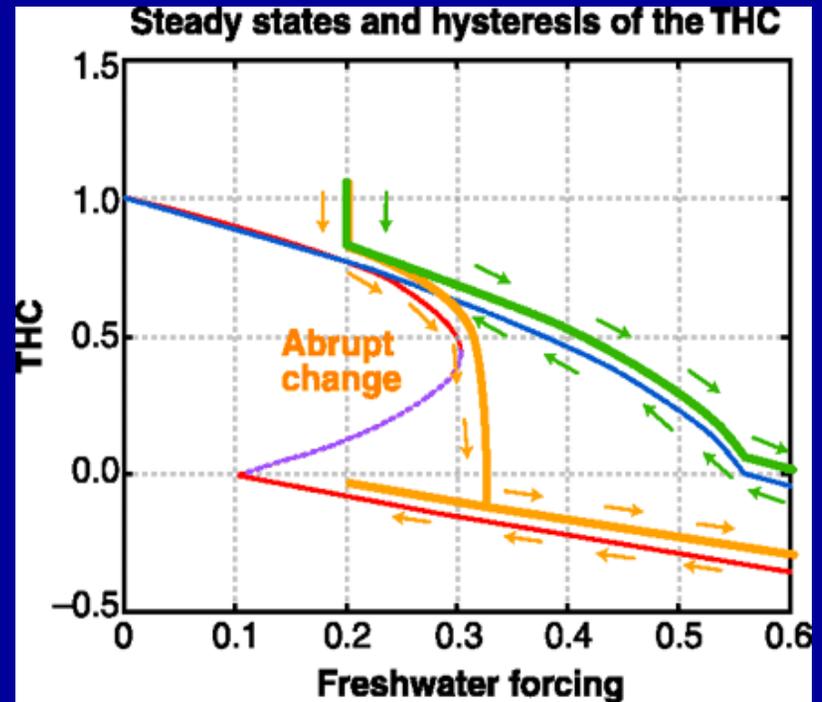


(C) INCREASE IN MEAN AND VARIANCE



Assessing Climate Stability

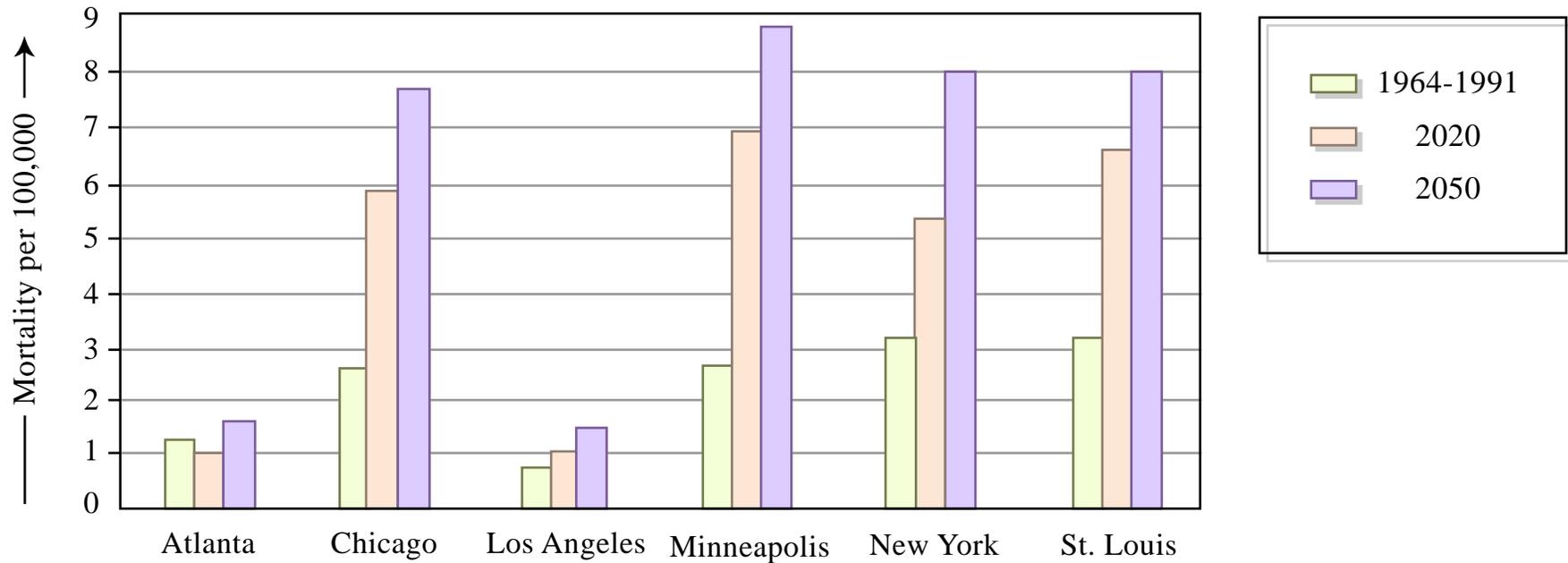
- Rates of Change
 - Variability
 - Gradients
 - Number of Components Changing



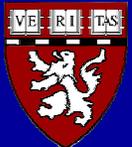
Model Projections: Heat Waves

AVERAGE SUMMER MORTALITY RATES

Attributed to hot weather episodes.



Estimates for 2020 and 2050 are based on the Max Planck GCM results (IPCC 1994)



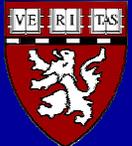
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Figure by MIT OCW.

Summer 2003 Heat Wave

France, Germany, Italy, Spain, Portugal 21-35, 000 Deaths



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Source: NASA

2003 Summer Temperatures
10°C (18°F) >30year average

INDIA

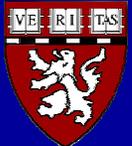
June 2003

T 122°F

>1400 deaths

July Floods

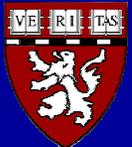
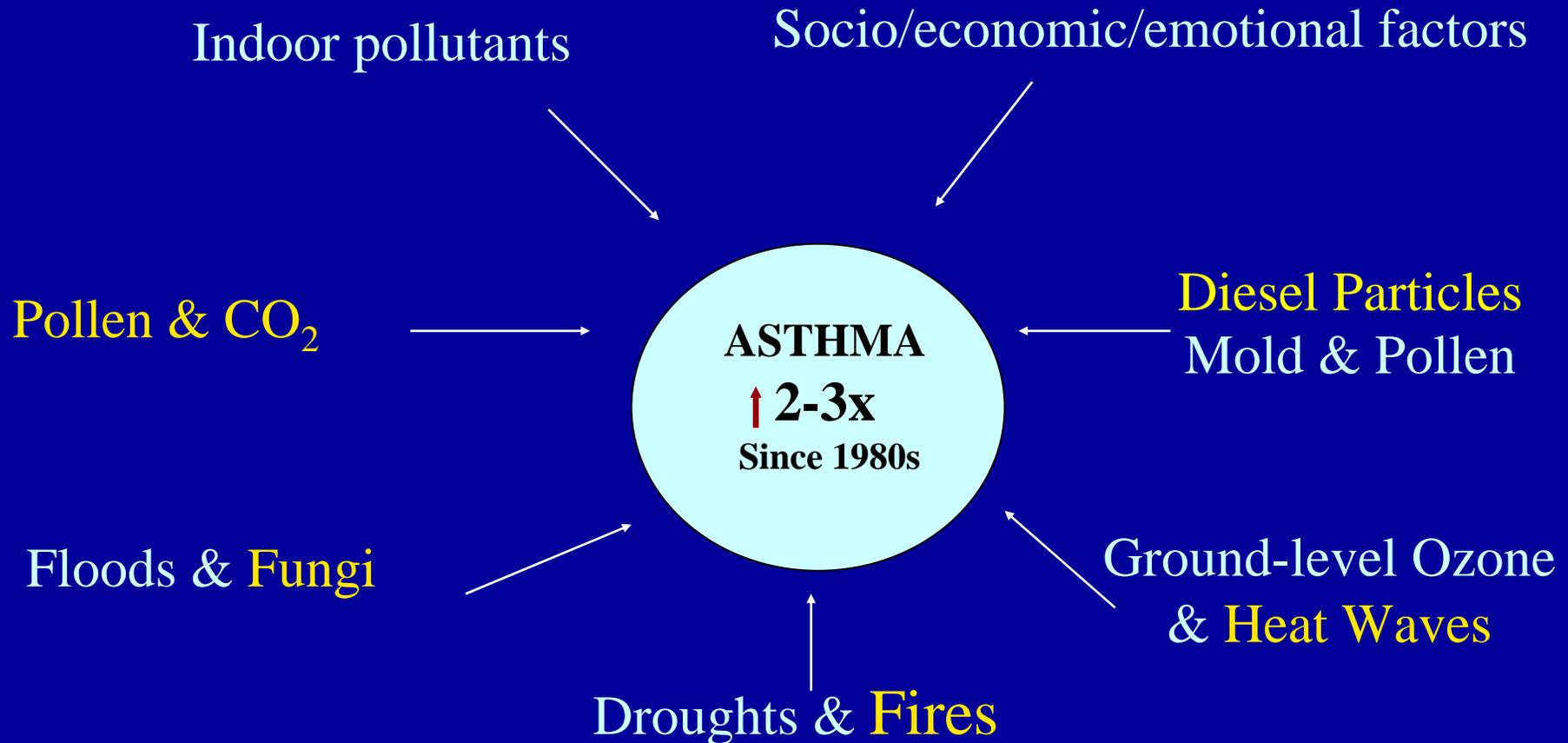
Japanese B encephalitis



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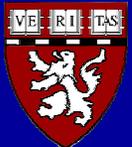
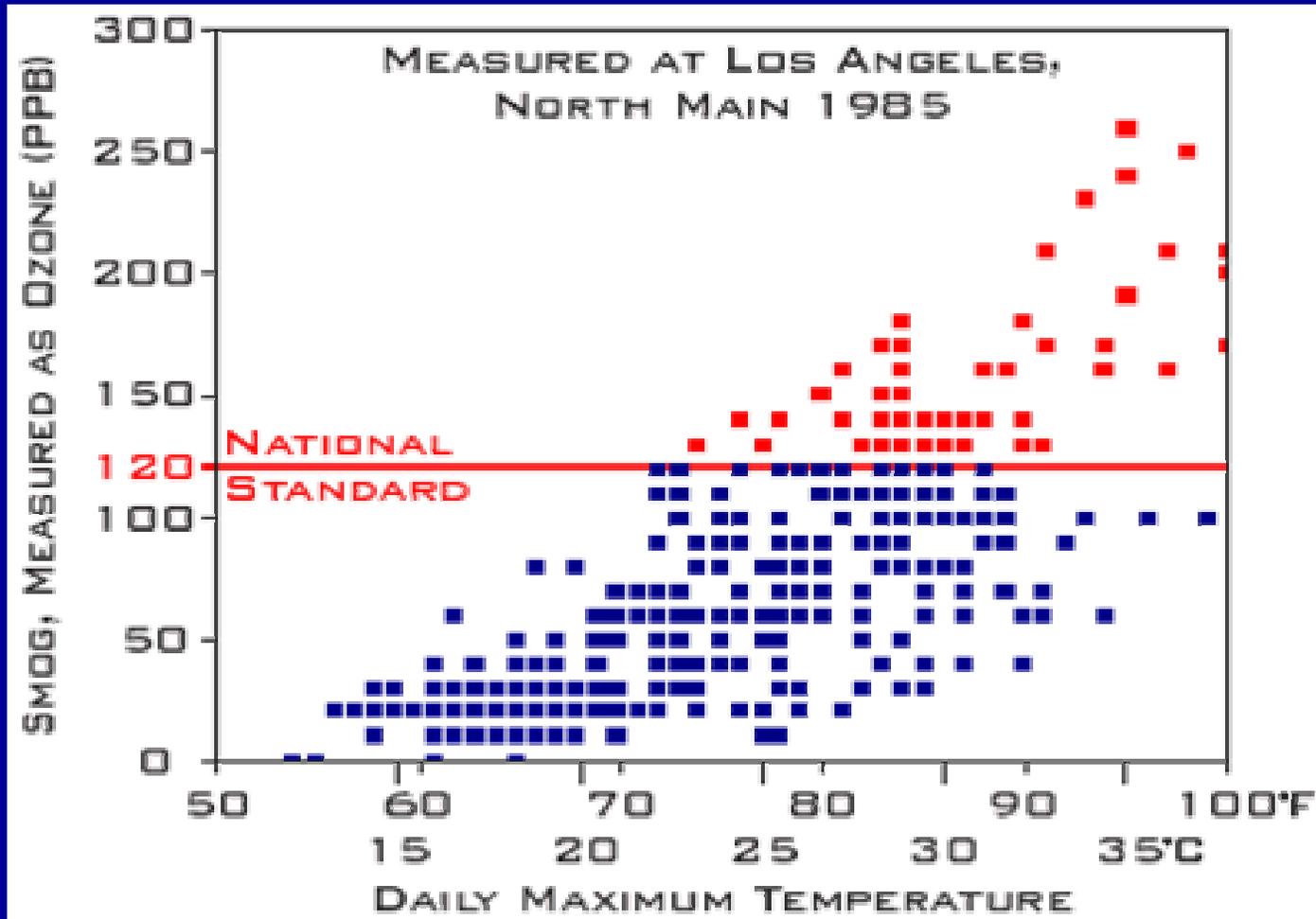
Air Pollution and Climate Change



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Ground-level Ozone And Temperature



RAGWEED POLLEN PRODUCTION and CO₂

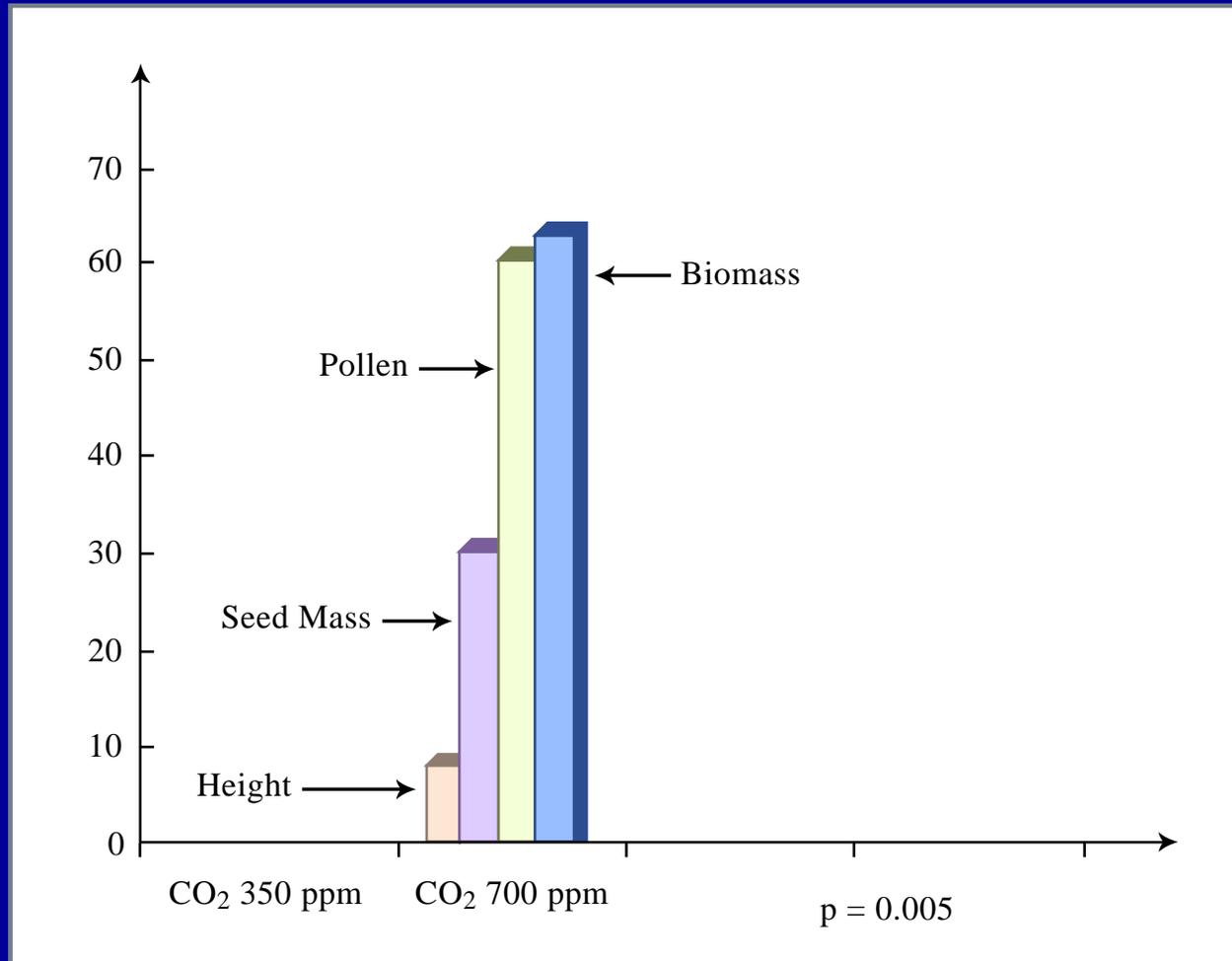
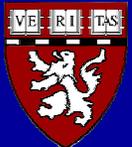
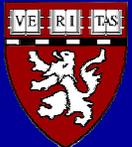
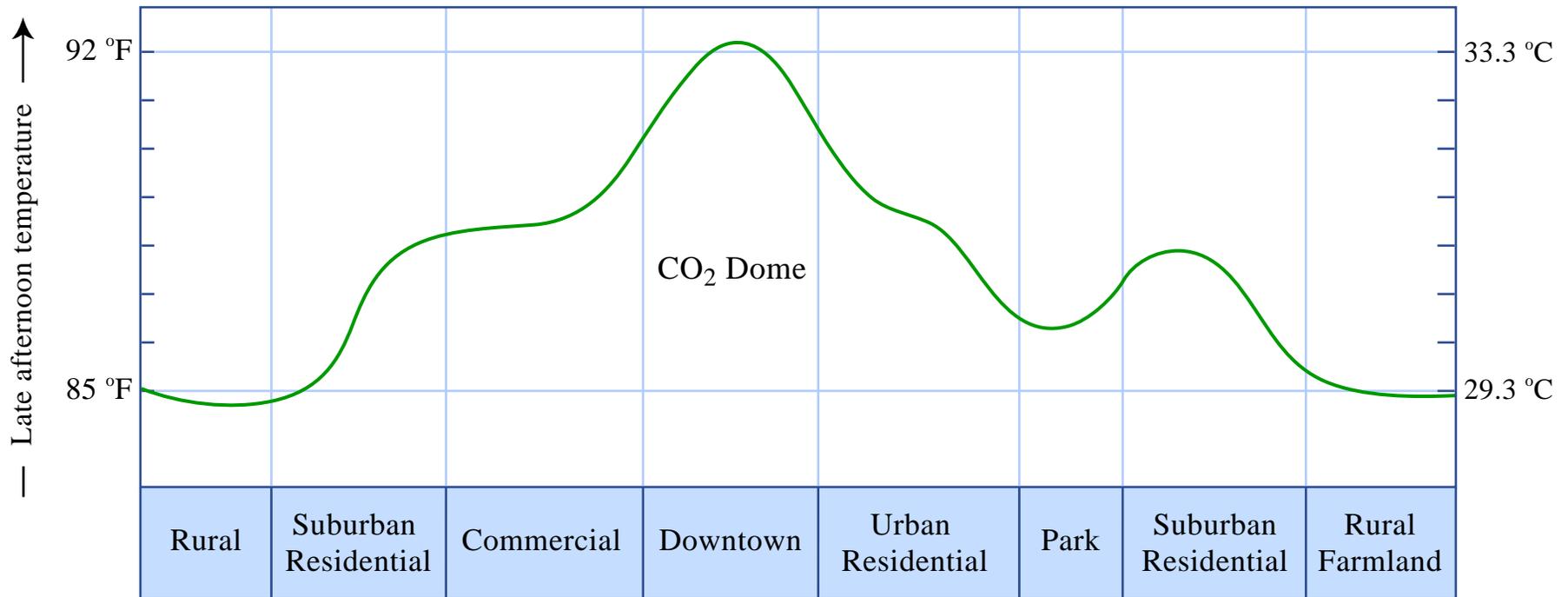


Figure by MIT OCW.



SKETCH OF AN URBAN HEAT-ISLAND PROFILE



Emerging Infectious Diseases

30 “NEW” TO MEDICINE SINCE 1976

HIV/AIDS

Legionnaires’

E. coli O157:H7

MDRTB & others

SARS

nvCJD



HPS

Vibrio cholerae O139

Nipah virus

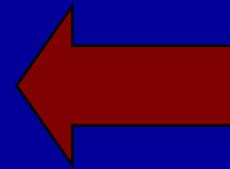
Ebola

Arenaviruses Lyme disease

RESURGENT & REDISTRIBUTING

Malaria, DF, WNV, Leptospirosis,

Cholera, Avian Flu



VECTORS

Mosquitoes

Ticks

Rodents

Bats

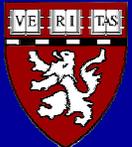
Tsetse Flies

Fleas

Lice

Snails

Algae



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Infectious Disease: A Driving Force In History

The Bad News:

PLAGUE

541 AD

1346 AD

The “Good” News

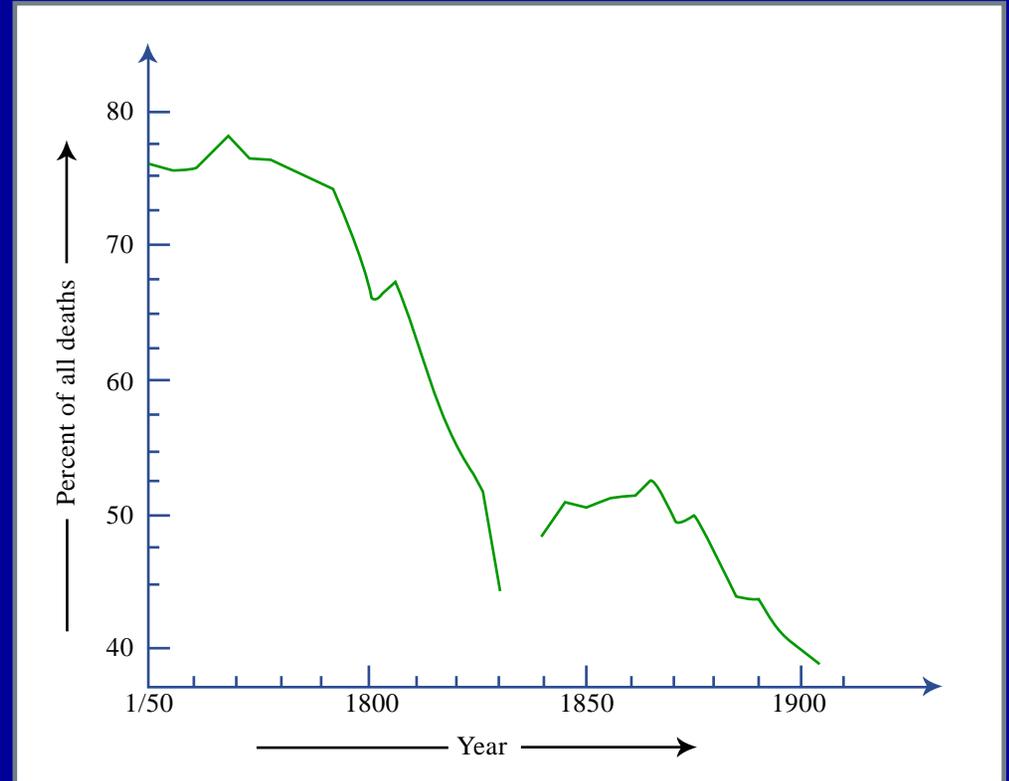
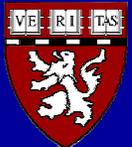


Figure by MIT OCW.

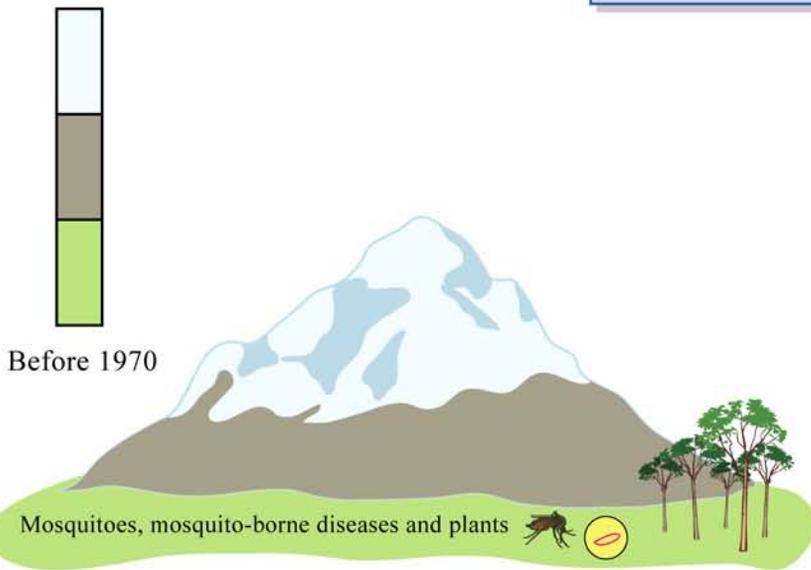
Deaths from IDs in London
Cholera, TB, Smallpox



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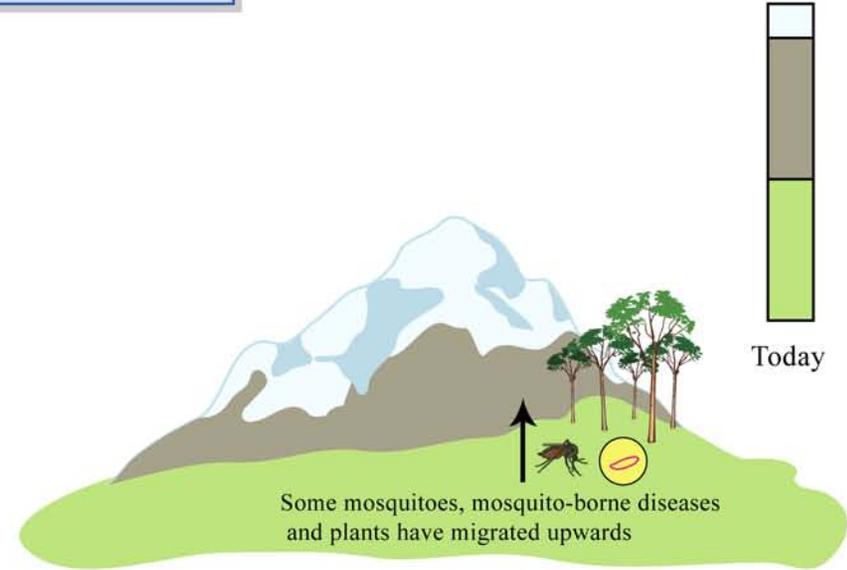
HARVARD MEDICAL SCHOOL

MONTANE REGIONS



Before 1970 ----- Cold temperatures caused freezing at high elevations.

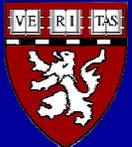
Result - Limited mosquitoes, mosquito-borne diseases (dengue fever or malaria) and many plants to low altitudes.



Today ----- Increased warmth has caused mountain glaciers to shrink in the tropics and temperate zones.

Result - Some mosquitoes, mosquito-borne diseases (dengue fever or malaria) and plants have migrated upward.

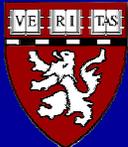
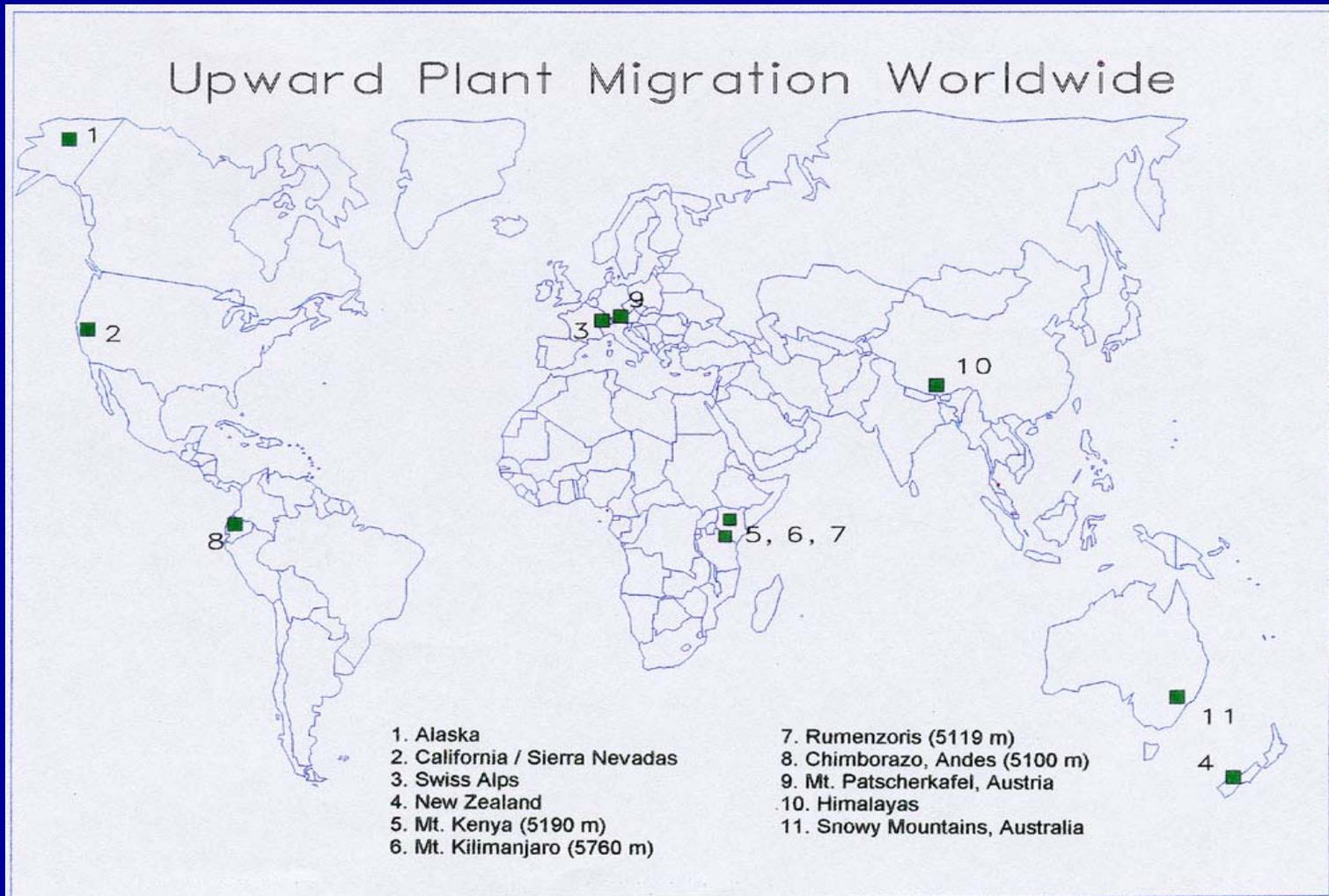
Figure by MIT OCW.



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HARVARD MEDICAL SCHOOL

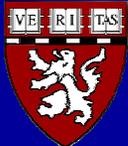
Upward Plant Migration



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HARVARD MEDICAL SCHOOL

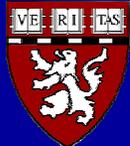
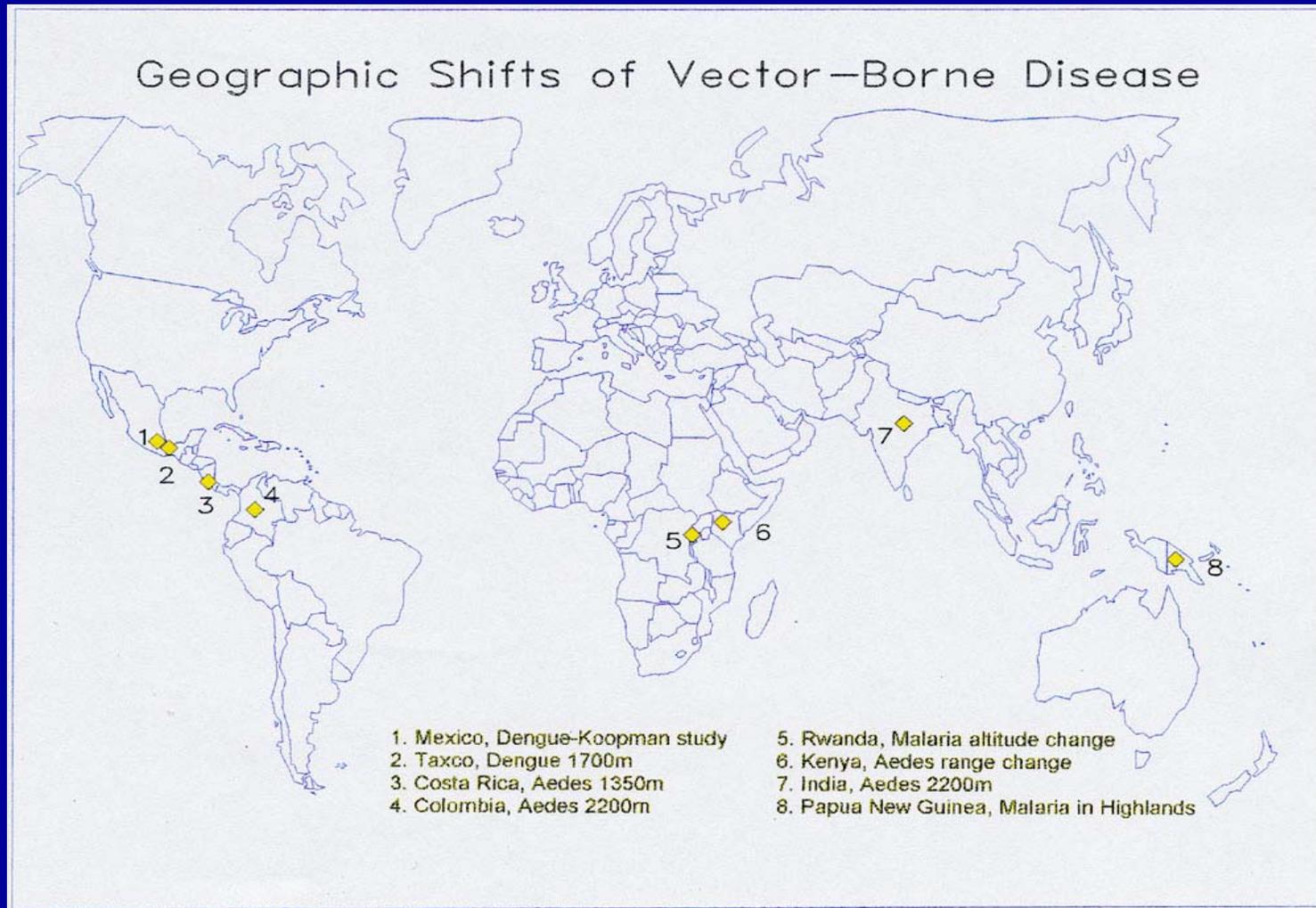
Changes in the Cryosphere



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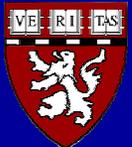
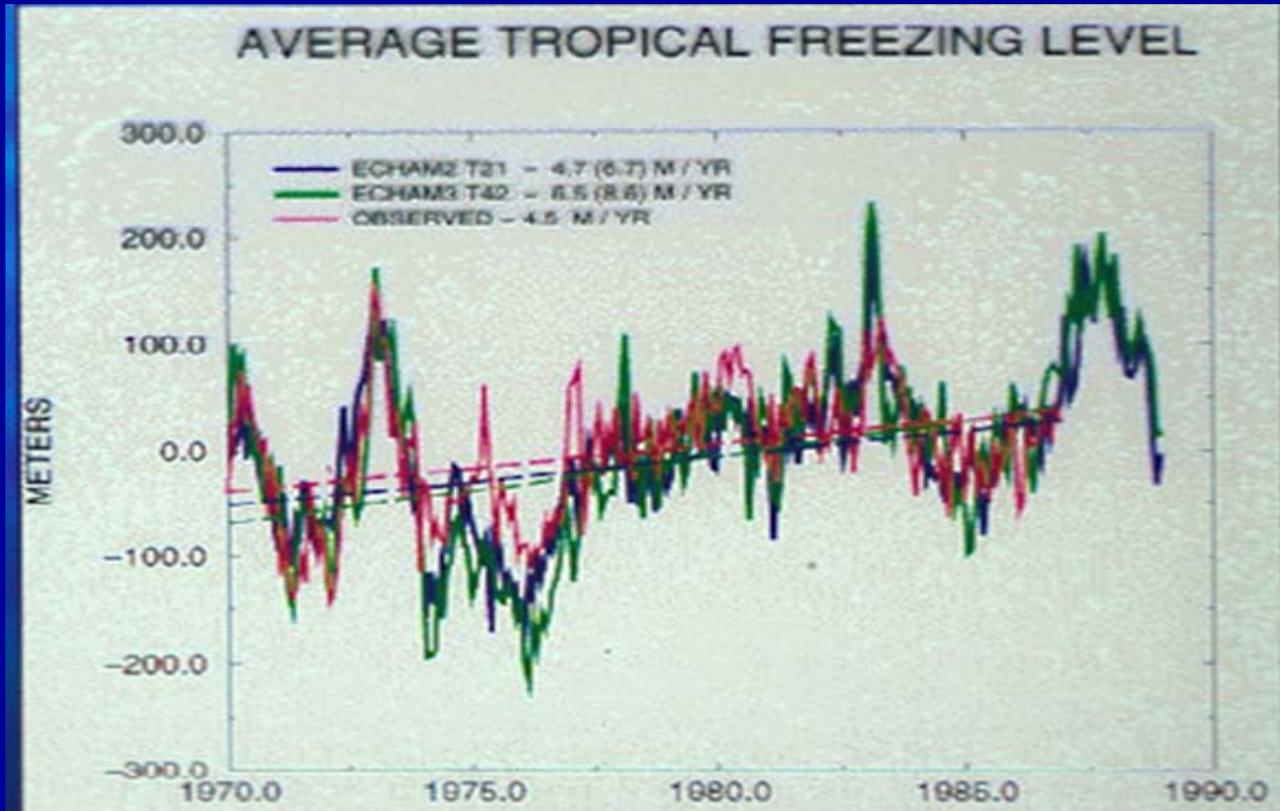
Geographic Shifts of Disease Vectors



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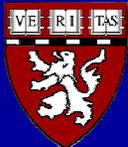
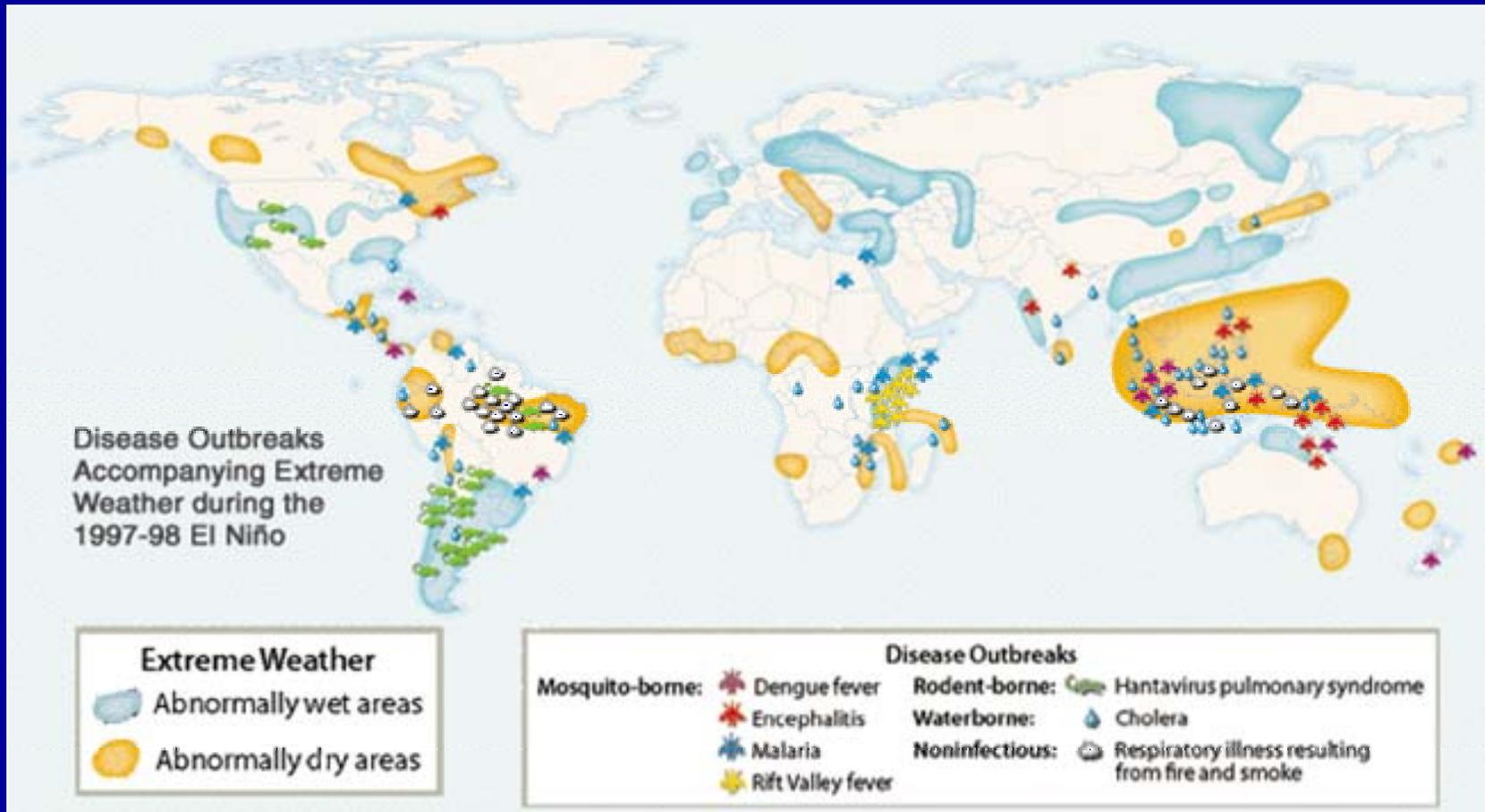
Changes in Permafrost



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HARVARD MEDICAL SCHOOL

Extreme Weather Events & Disease Clusters



Precipitation Extremes

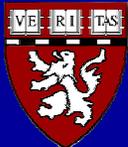
Past century average annual
precipitation: ↑ 7%

“Heavy rain events” (>2”/day):
↑ 14%

“Very heavy rain events”
(>4”/day): ↑ 20%

Western drought – worst in 500
years. Devastating rains 2005

Groisman et al. 2004



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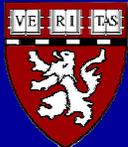
Hurricane Mitch

Impacts On Health and Development

DISEASE CLUSTER

- *Malaria* (>30,000 cases)
- *Dengue fever* (>1,000)
- *Cholera* (>30,000)
- *Leptospirosis*

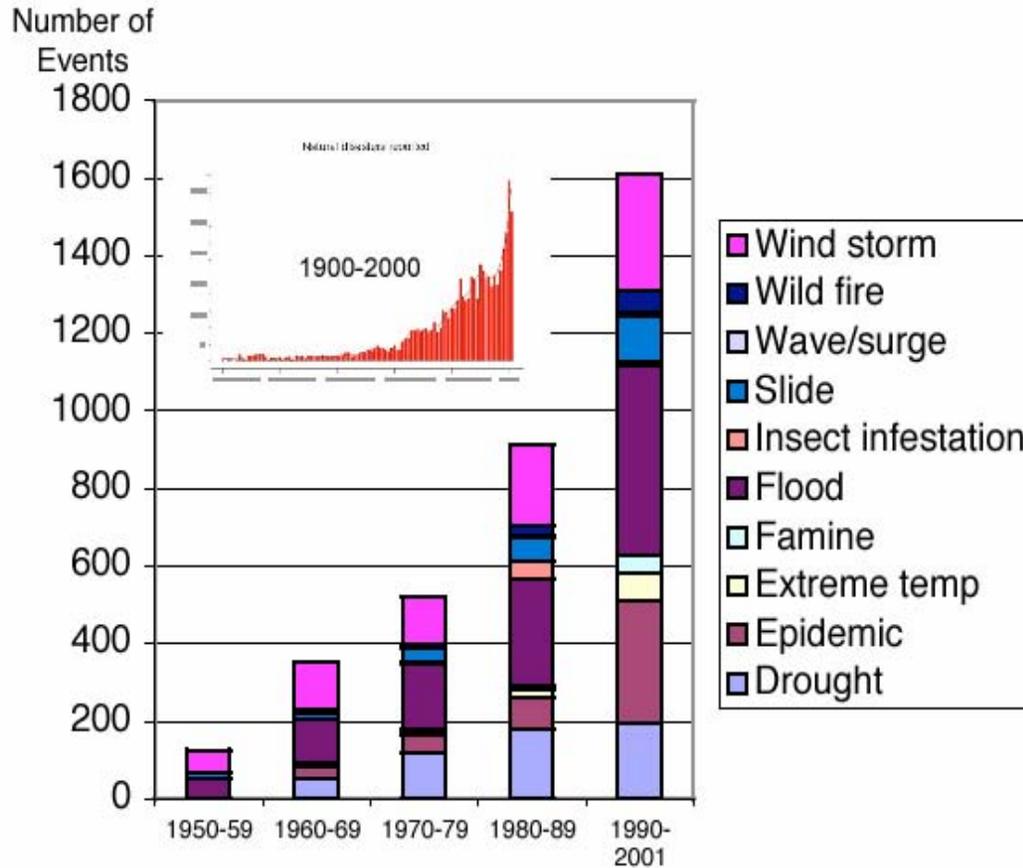
Source: Juan Almandares



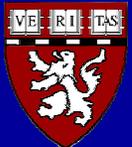
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Changing Nature and Structure of Events



Sources: OFDA / Center for Research in the Epidemiology of Disasters (CRED) Intl database of Disasters



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HARVARD MEDICAL SCHOOL

WNV: Meteorological Factors

(Factor - 1)

MILD WINTER

More mosquitoes than usual survived the winter in sewers, damp basements and other sources of still water

Mosquito population flourished in spring and summer

(Factor - 3)

JULY HEAT WAVE

Once mosquitoes infected with the West Nile virus appeared, the heat caused the virus to proliferate rapidly inside them

(Factor - 2)

DRY SPRING AND SUMMER

Many birds congregated at dwindling water sources

Lack of rain killed predators of mosquitoes (frogs, lacewings, ladybugs)

As water in breeding sites evaporated, organic compounds became concentrated, nourishing mosquito larvae

DRENCHING AUGUST RAINS
Downpours formed new breeding sites for mosquitoes, yielding a new crop of the insects

MOSQUITO POPULATION GREW LARGE

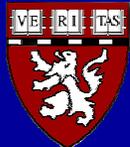
(Factor - 4)

VICIOUS CYCLE BEGAN

Infected mosquitoes transmitted the virus to initially uninfected birds

Initially uninfected mosquitoes picked up the virus from infected birds

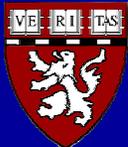
INFECTION SPREAD TO PEOPLE
As more and more mosquitoes became infected, they spread the virus to still more birds and ultimately to people



WNV: A Disease Of Wildlife

230 SPECIES 44 STATES, DC, 5 CANADIAN PROVINCES

- 138 Bird *spp.*, RAPTORS
 - 37 *spp.* of mosquitoes
- HORSES
- ZOO animals
- REPTILES



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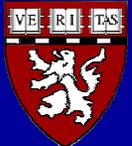
Ecological Ripples

Infectious Diseases As Forces Of Global Change

↓ Raptors

↑ Rodents

Lyme disease
Hantaviruses
Arenaviruses
Leptospirosis
Toxoplasmosis
Plague



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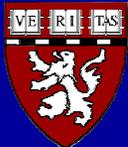
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Weather Anomalies, Travel Hazards And Trauma

- Fog, Ice Storms & Road Travel
- Floods & Mudslides
- Ice Instability, Heavy Precipitation
& Avalanches
- Infrastructure Damage and Water
Q&Q



HEALTH & ECONOMIC
IMPACTS



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Range Expansion of Soybean Rust

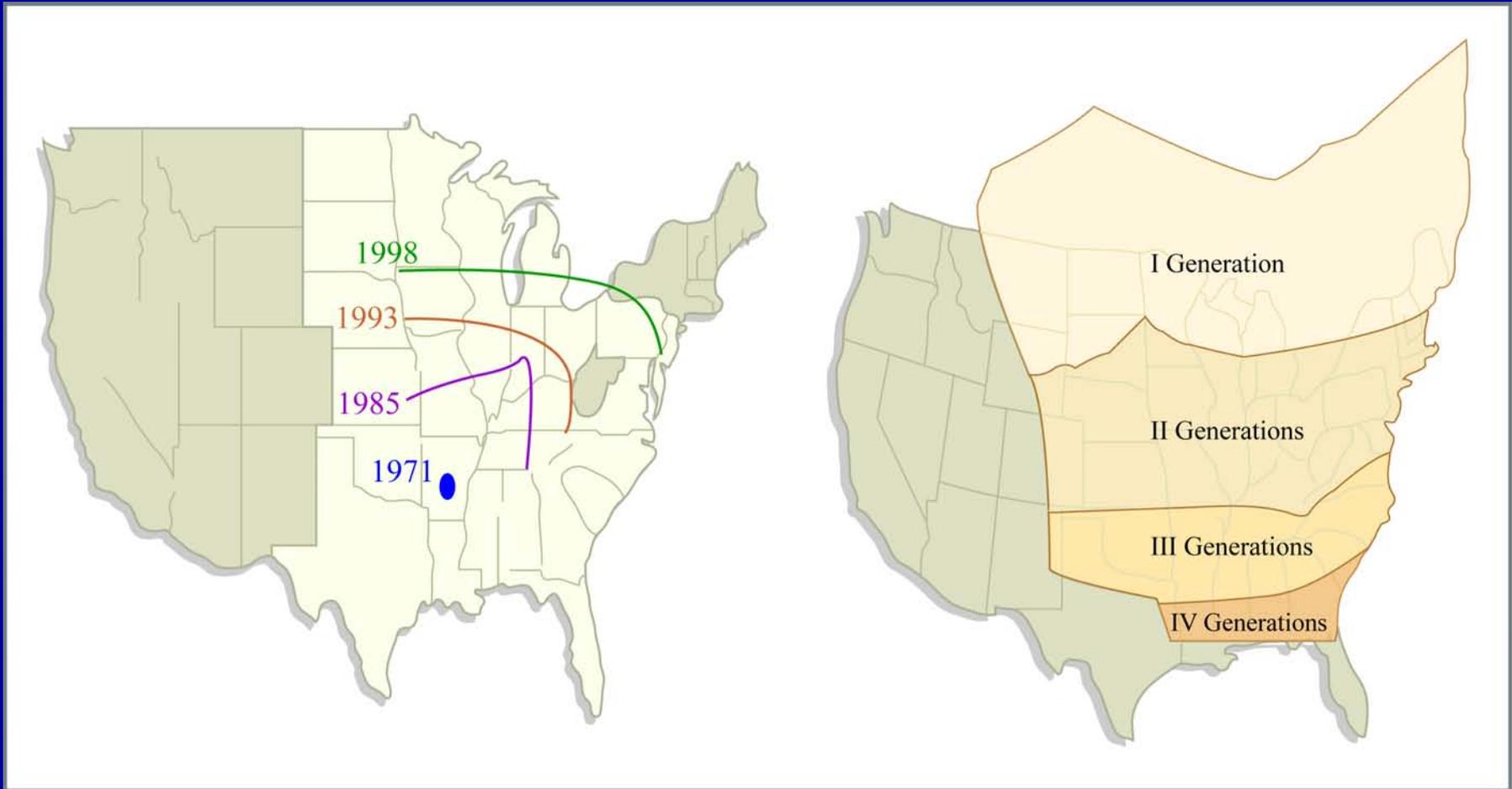
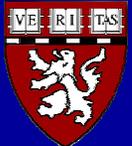


Figure by MIT OCW.

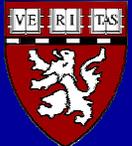
Crop Pests:
Generations/Year



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Drought, Bark Beetles & Fires



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Coral Bleaching: Warming and Microbes

Vibrio coralyticus

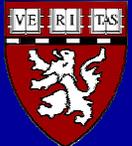
- lysis at 29°C
 - release of zooxanthellae
 - infection and immunity

Kushmaro et al., Int J Syst Evol Microbiol 2001; 51:1383

Ray Hayes

Coral diseases

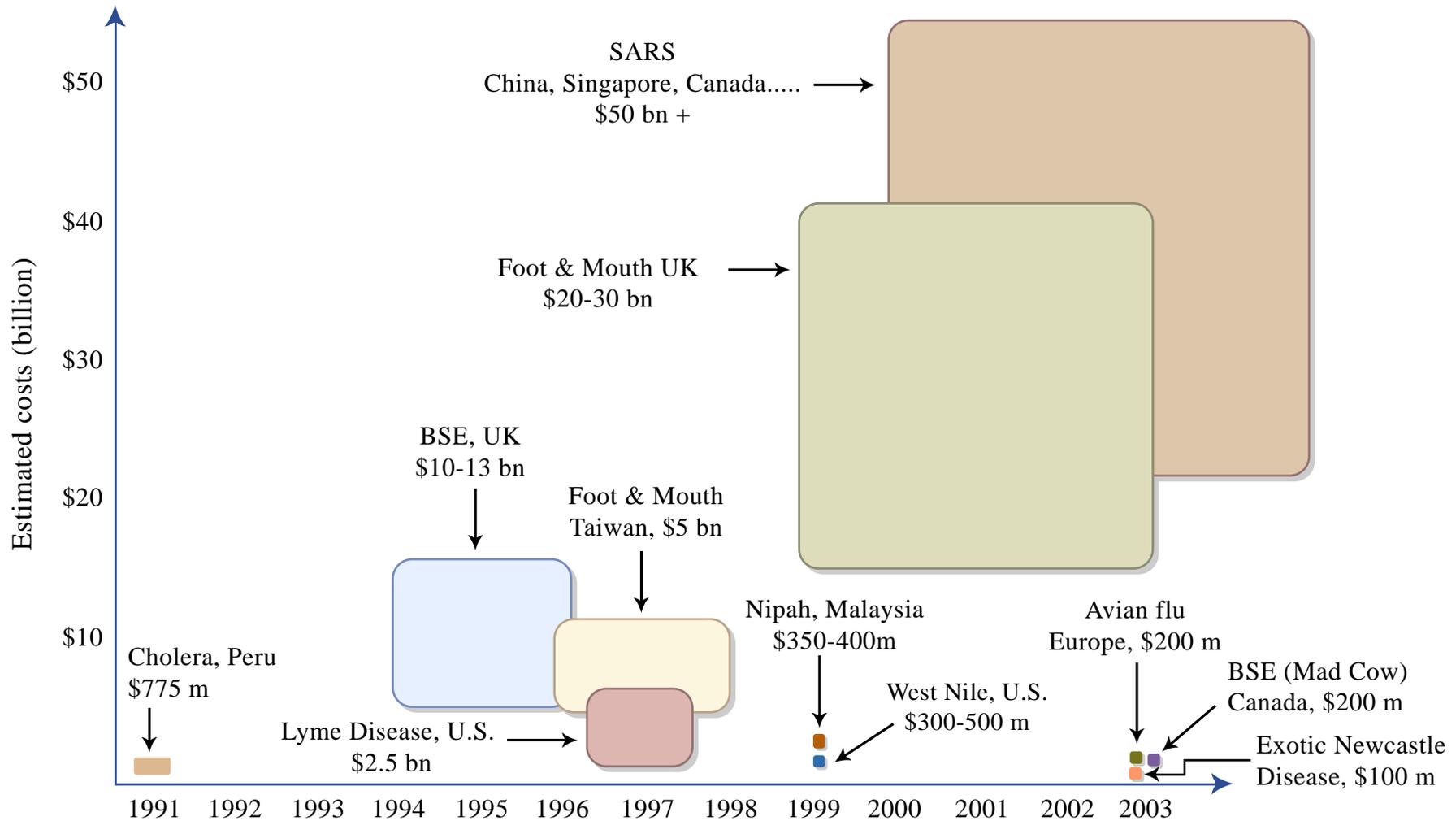
-Patterson et al., PNAS 2002;99:872



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Costs of Emerging Infectious Diseases



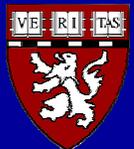
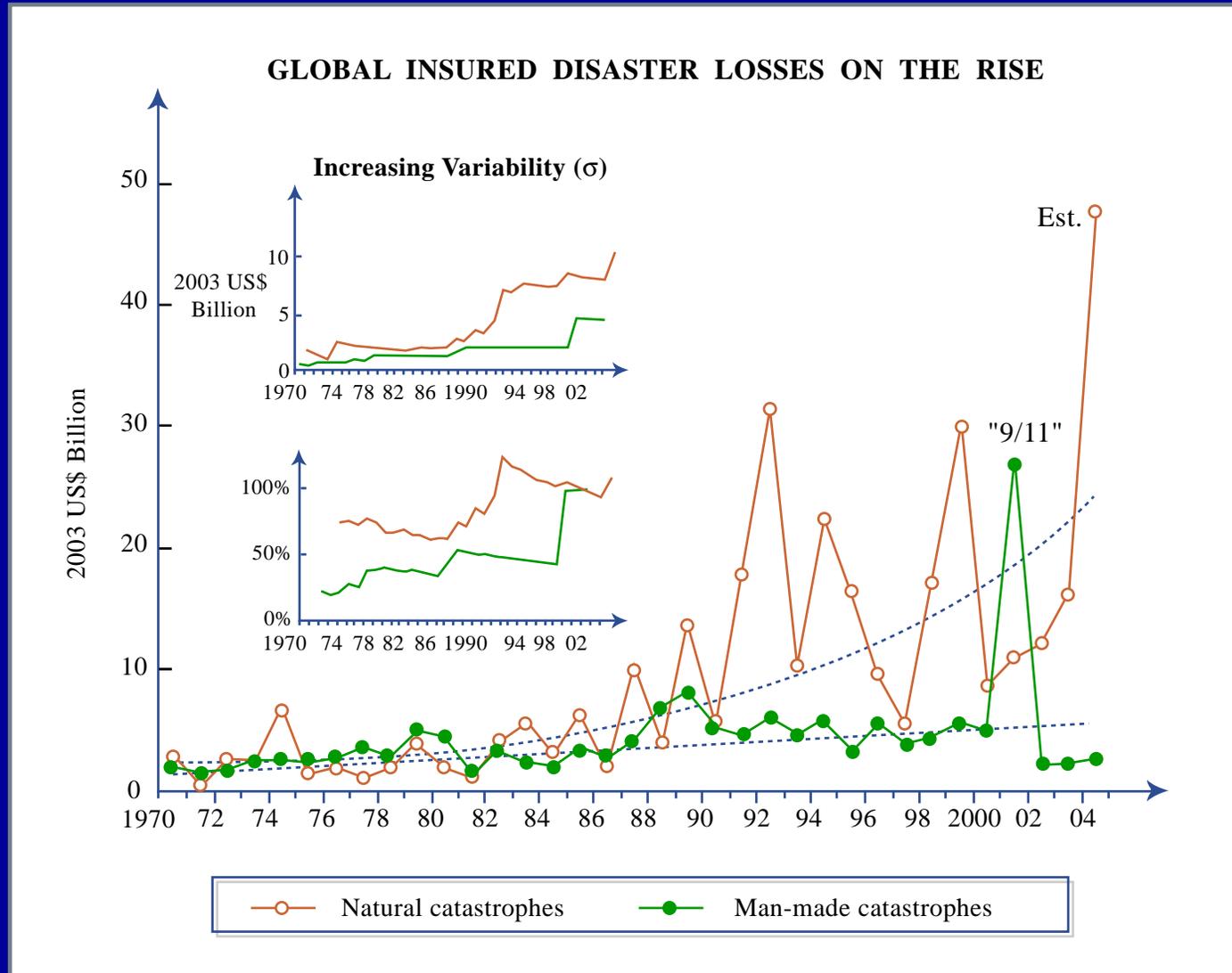
Figures are estimates and are presented as relative size.



Uncertainty: Physical Financial

“Catastrophe insurers can't simply extrapolate past experience.”
 - Warren Buffett (1992)

Note: plot shows only large events and excludes health/life losses. Including small-scale events would double these numbers; health-related losses unknown



Harmonizing Adaptation with Mitigation

Distributed Generation

Water:

Purification

Pumping

Irrigation

Desalinization

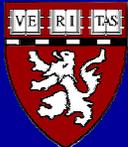
Clinics

Homes

Schools

Computers

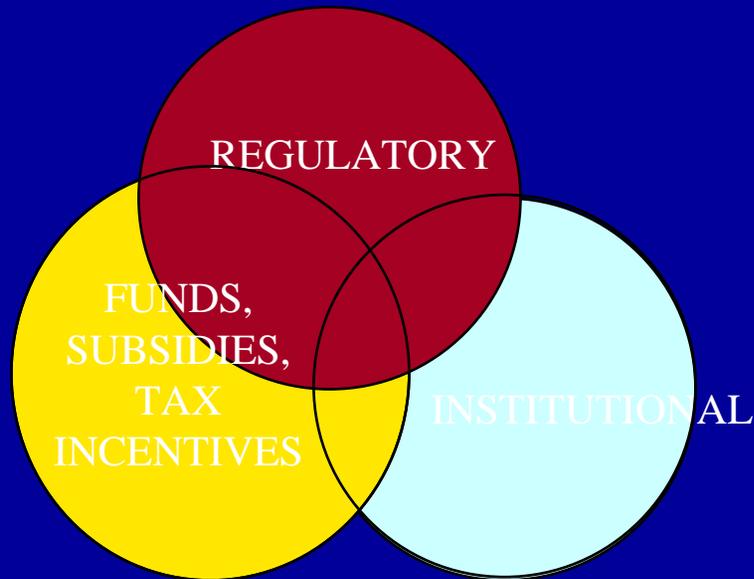
Cooking



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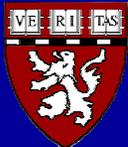
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Enabling Financial Architecture For Sustainable Development



- EE, RE and DG
- “Green Buildings” & Smart Growth
- Rationalized Transport & Transit
- Retrofitting Infrastructure
- Ecological Reconstruction

THE ENGINE OF
GROWTH
for the
21st CENTURY



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