EMERGING PATHOGENS AND THE ROLE OF NATURAL HISTORY ARCHIVES: THE HANTAVIRUS EXAMPLE.

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Museum of Southwestern Biology

Outline

- Emerging Pathogens
  - Zoonotic diseases/Reservoirs
- Hantavirus example
  - Outbreak investigation
  - Long term ecological studies
- New pathogen discovery
- Archives are critical
  - Natural History Collections

Emerging Pathogens

- Newly appearing or spread of infectious disease.
  - Unrecognized or underreported due to
    - Ignorance of clinical expression.
    - Or lack of a reliable test.
  - Often associated with outbreak scenarios.
- >1400 species of organisms known to be pathogenic to humans
- >60% are zoonotic, 12% considered emergent

Zoonotic Diseases

- Transmitted from animals to people

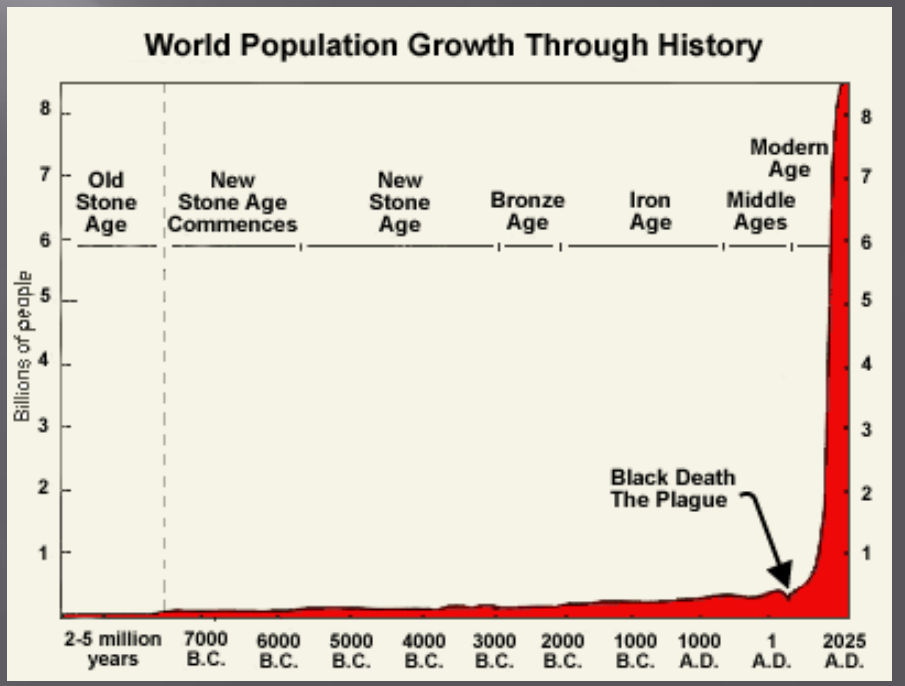
Plague, Malaria, SARS, Chagas, Lyme disease, Ebola, Hantavirus

Why more emerging diseases?

- Increased Human – Animal Contact
  - Increase and spread of human populations
  - Natural areas are home to "reservoir species".
    - Animal populations often immune to symptoms.
- Recognition and diagnosis

7 Billion

- Added 1 billion since 1999
- Current growth –
  - about 235,000/day



Pop Growth Consequences

- Need for space
  - Sprawl
  - Encroachment on natural areas
- Need for food
  - Habitat conversion
  - Forest hunting/Bush meat

Habitat conversion

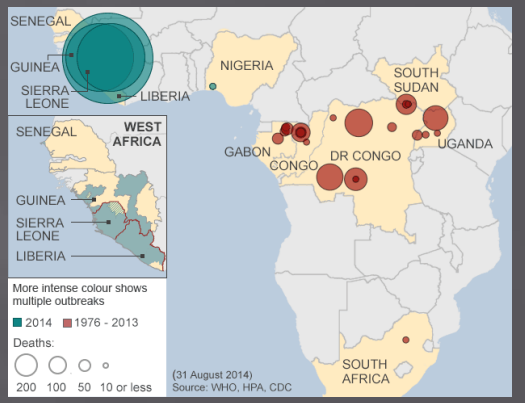
- Ca. 50% of habitable land converted to farming.
  - Predicted another 120 million ha converted by 2050.
  - Will include land with high biodiversity value.
- Large-scale clearing for intensive monocultures.
  - e.g. Amazon and Asian rainforests to oil palm plantations
  - Brazilian savanna to soybean and cattle farms.


Habitat Conversion Effects

- Humans into natural areas
- Reduction in biodiversity, unbalances species communities
- Cleared land/monocultures facilitate population explosions in certain species

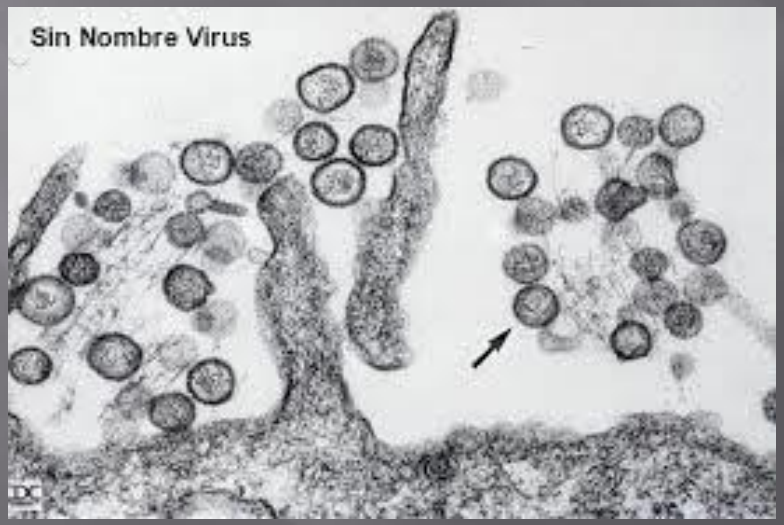
Outbreak scenarios

- Ebola example
  - Reservoirs - Long lived fruit bats
  - Maintain pathogen for long periods in natural areas.
  - Pathogen encountered in natural area.
  - Human to human contact
- Hantavirus example
  - Reservoirs – short lived, prolific rodents
  - Respond rapidly to environmental /ecological changes.
  - 2 types - Ratatas in natural and converted habitat.
  - Pathogen encountered in converted area.
  - Rodent to human contact causes outbreak.



Sin Nombre Hantavirus example

- Case study in working through the process of responding to and understanding the underlying mechanisms of an outbreak.



Initial 1993 Outbreak

- Unknown disease emerged in the Southwest, killing 10 people during an 8-week period.
- Flu-like symptoms for several days, but condition suddenly and rapidly deteriorated as lungs filled with fluids.
- Death usually occurred within hours of the onset of this crisis period.
- No treatment, unknown disease agent, 70% mortality, many young and fit.

June 19
Clinic on Navajo Reservati

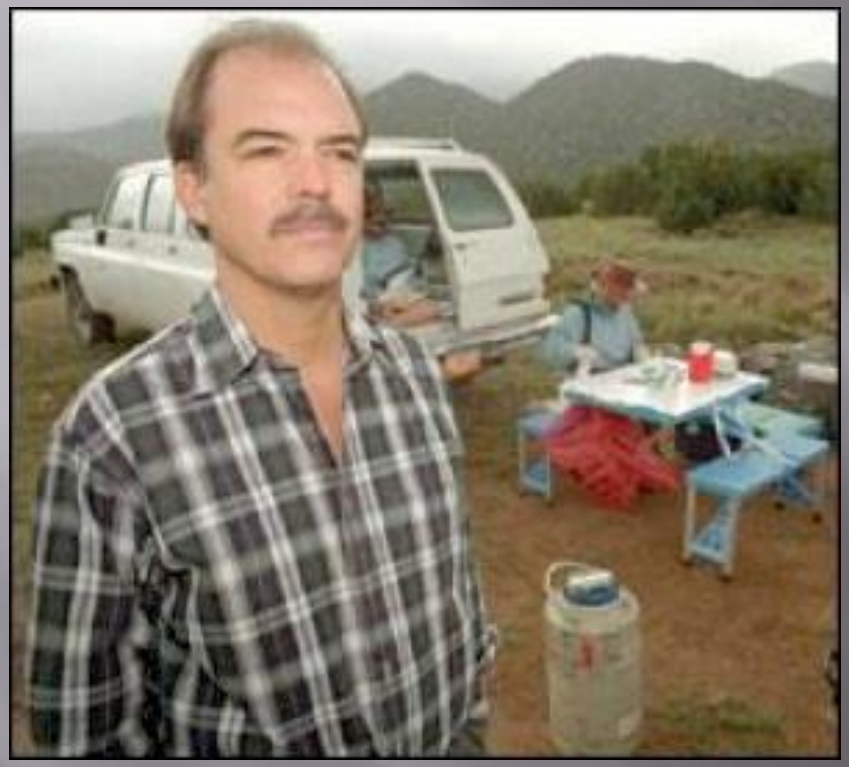
What was the disease agent?

Centers for Disease Control and Prevention

THE UNIVERSITY *of* NEW MEXICO
New Mexico's Flagship University

- Conspiracy theories
- Massive collaboration and a bit of luck
- Virus isolation in human case
- Reservoir ID

Was this something new?

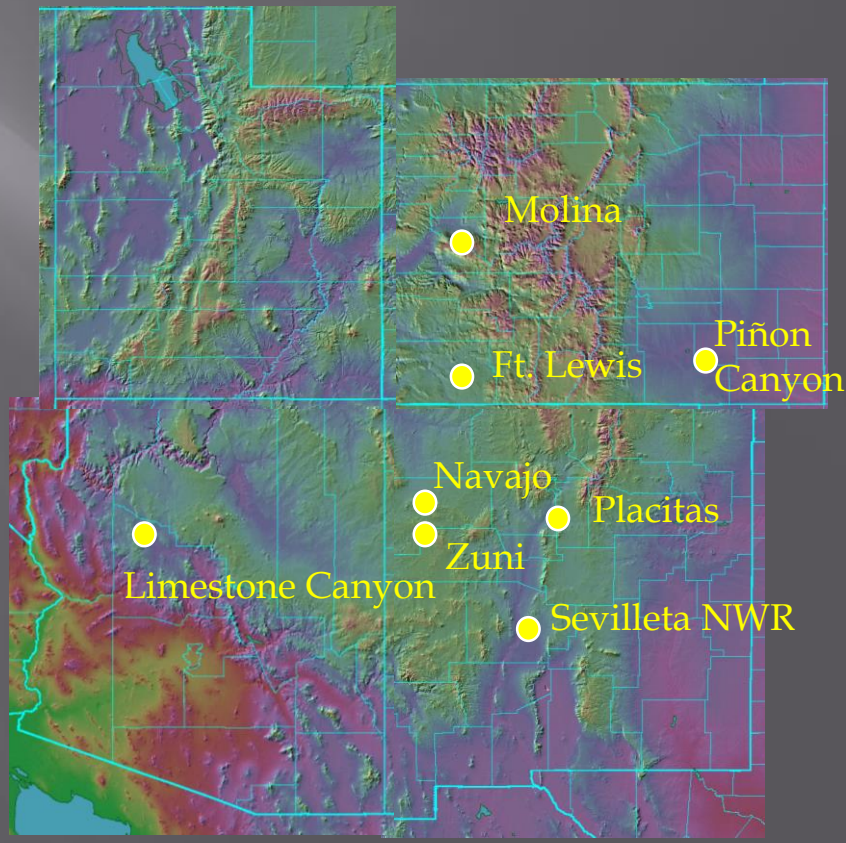


- Terry Yates
- Basic Mammal Field Work
- Tissue collection since 1978
- Unintended Consequences

Why did this occur at this time and place?

- Understanding Reservoir Ecology
- Longitudinal studies (1994-2006)

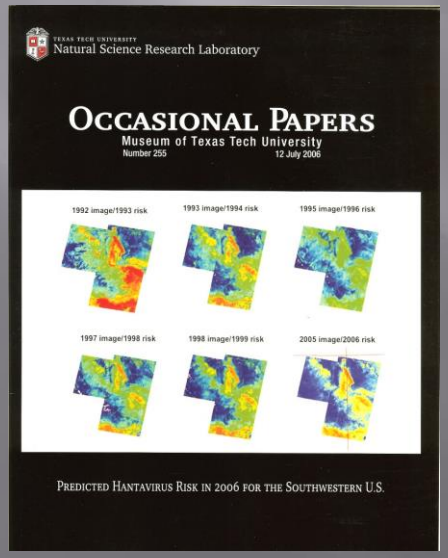
8 sites in SW United States monitoring
- •Small mammal pop
- •Hantavirus prevalence
- •Ecological conditions.



Reservoir studies ⇨ Predictive models

Remote Sensors ← Weather

Weather → Vegetation → Rodent Populations → Human Disease (1 year delay)

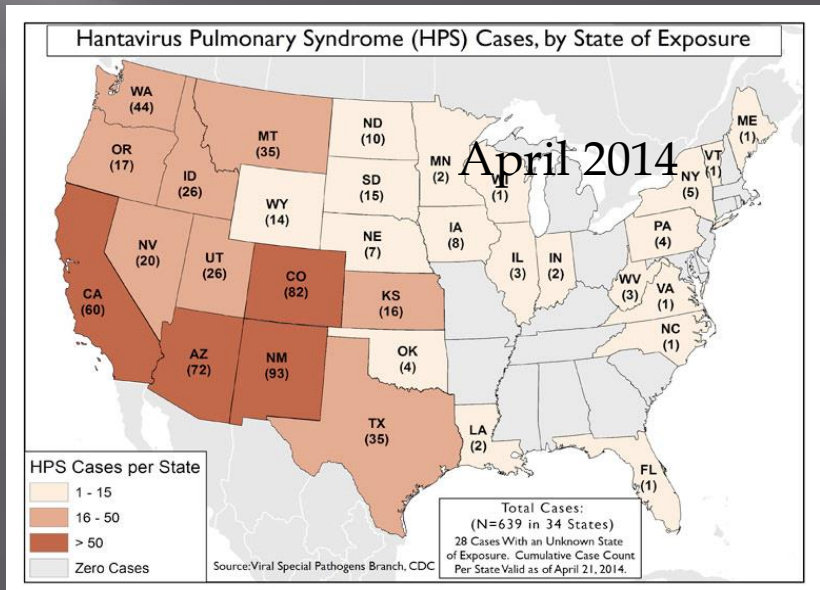


- Data through two El Niños in the SW US
- Precipitation catalyst of a trophic cascade
- Delayed density-dependent rodent response

- Allows prediction of risk for HPS

Today

- 639 cases
- Mortality 30-40%
- Understand reservoir ecology
- Medical community recognition, treatment

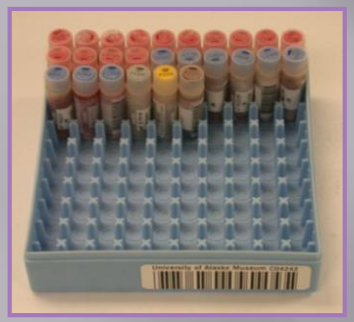


New World Hantaviruses-in 2003

Many new hosts for new Hantaviruses

New discoveries possible with deep, integrated specimen archives

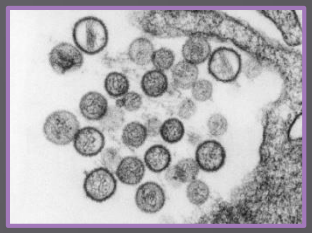
Holistic Voucher



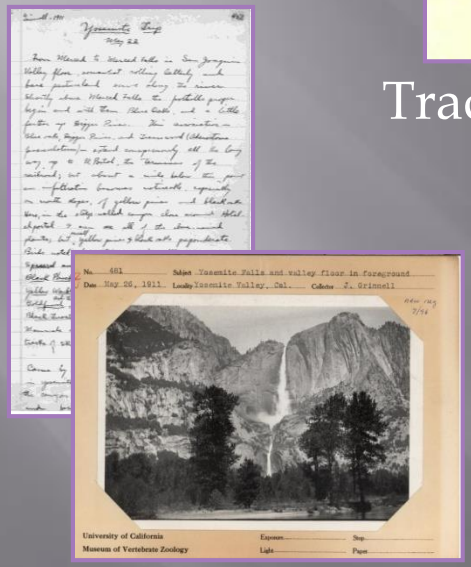
Ultrafrozen tissues

Traditional skin, skeleton or fluid voucher

Ecto & endo parasites

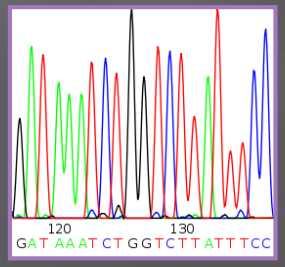


Virus isolates

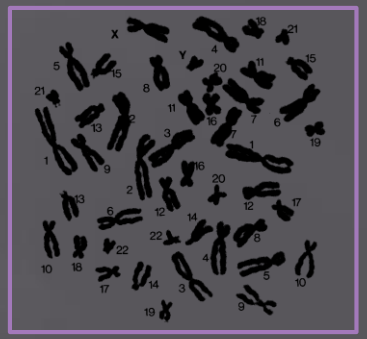


Field notes,
ecological data

Geo-reference



Genomic data



Karyotypes

Integrated Archives

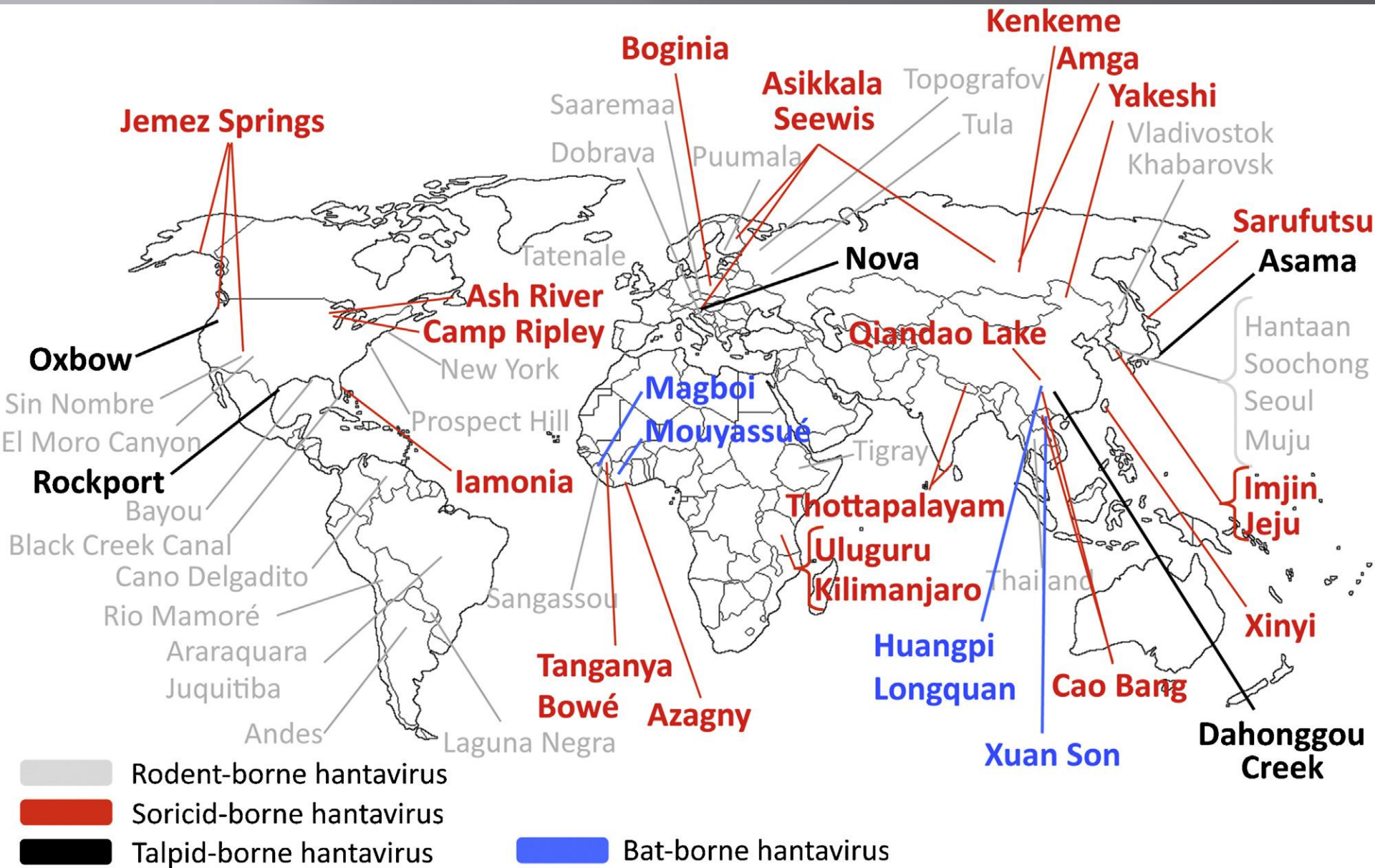
- Temporally Deep
- Geographically Broad, Site Intensive
- Geo-referenced
- Multiple Datasets tied to central voucher specimen
  - Frozen Materials for Molecular Biology
  - Parasites tied to Hosts

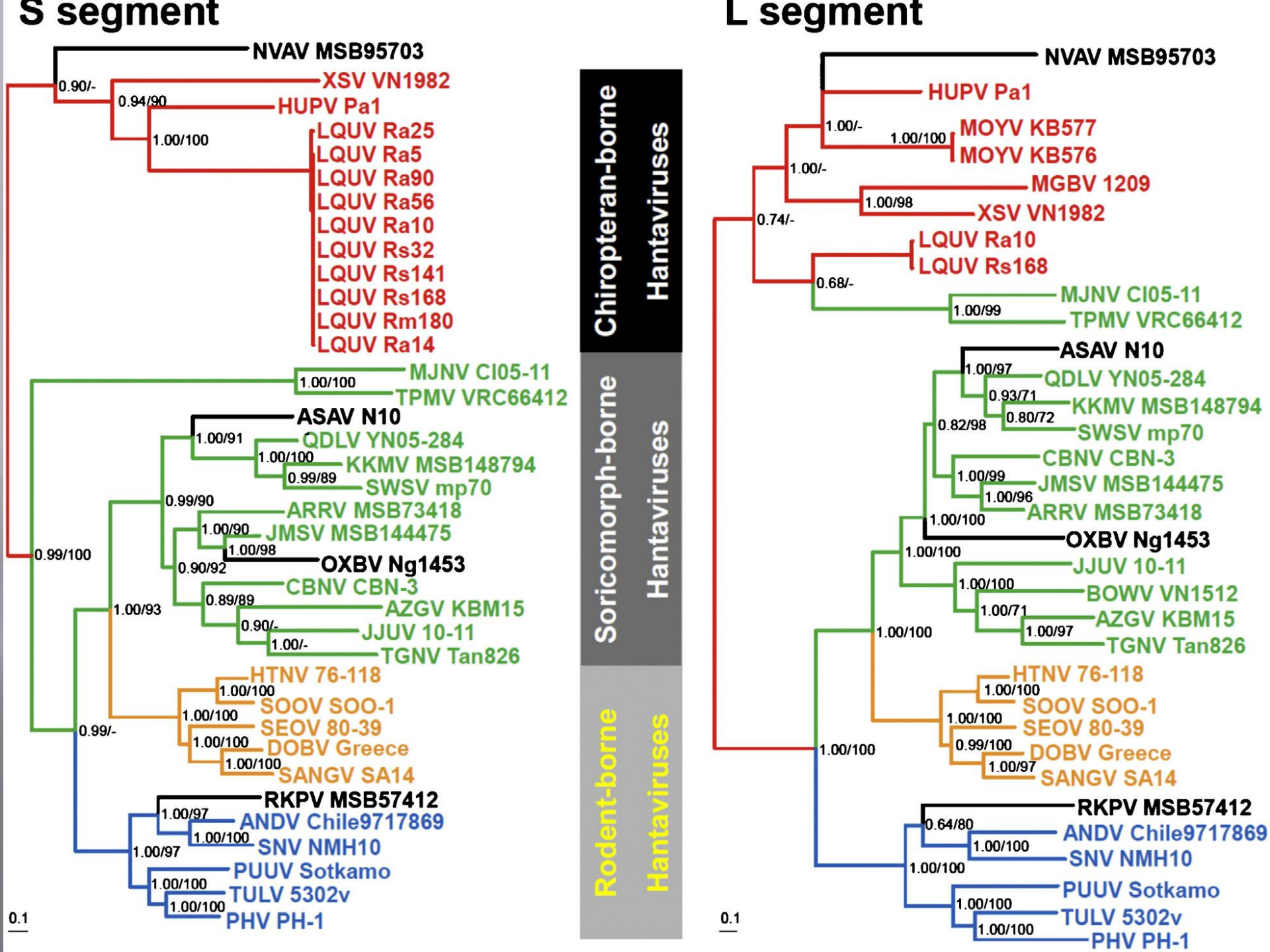
Global Collections from Emerging Pathogens Research

PROJECT	# SPECIMENS
Sweden 1993, 1999 – Hantavirus	400
Bolivia 1994 - Hemorragic fever	185
Zaire 1995 –Ebola virus	600
Nicaragua 1995– Hantavirus	50
Paraguay 1995 – Hantavirus	135
Bolivia 2000 – Machupo virus	330
Chile 1997-2007 – Hantavirus	7300
Panama 2000-2014 – Hantavirus	7000
Panama 2009 - SIGEO climate change/ emerging diseases	160
Mongolia 1999, 2009-2013 – Hantavirus	5000
China 1999, 2006 – Emerging diseases	500

- 22,000 specimens; 300 species

Hantavirus Discovery----multiple mammalian hosts




S segment
L segment
Chiropteran-borne Hantaviruses
Soricomorph-borne Hantaviruses
Rodent-borne Hantaviruses
NVAV MSB95703
XSV VN1982
HUPV Pa1
LQUV Ra25
LQUV Ra5
LQUV Ra90
LQUV Ra56
LQUV Ra10
LQUV Rs32
LQUV Rs141
LQUV Rs168
LQUV Rm180
LQUV Ra14
MJNV CI05-11
TPMV VRC66412
ASAV N10
QDLV YN05-284
KKMV MSB148794
SWSV mp70
ARRV MSB73418
JMSV MSB144475
OXBV Ng1453
CBNV CBN-3
AZGV KBM15
JJUV 10-11
TGNV Tan826
HTNV 76-118
SOOV SOO-1
SEOV 80-39
DOBV Greece
SANGV SA14
RKPV MSB57412
ANDV Chile9717869
SNV NMH10
PUUV Sotkamo
TULV 5302v
PHV PH-1
MOYV KB577
MOYV KB576
MGBV 1209
0.90/-
0.94/90
1.00/100
1.00/91
1.00/100
0.99/89
0.99/90
1.00/90
1.00/98
0.90/92
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1.00/-
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0.68/-
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1.00/97
0.93/71
0.80/72
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Integrated Archives

- Temporally Deep
- Geographically Broad, Site Intensive
- Geo-referenced
- Multiple Datasets tied to central voucher specimen
  - Frozen Materials for Molecular Biology
  - Parasites tied to Hosts

- Searchable Web-based Databases
  - Research, Policy, Education

Arctos Home

http://arctos.database.museum/home.cfm

arctos museum

Arctos

Multi-Institution, Multi-Collection Museum Database

Help ~ Username

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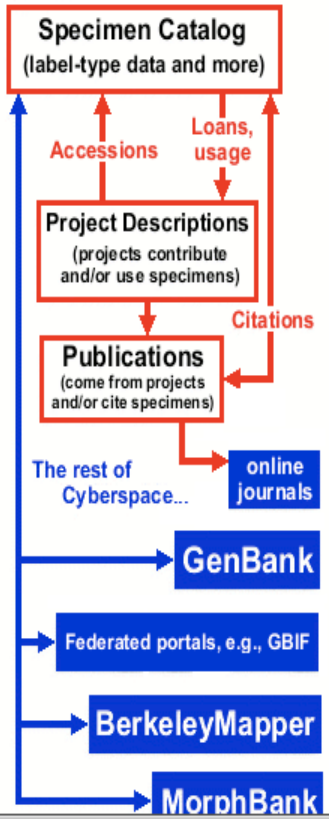
- Participation
- Components
- System Requirements
- Browser Compatability
- Data Usage
- FAQ
- Suggestions?
- Search:
  - All Collections
  - University of Alaska Museum
    - UAM Bird more...
    - UAM Bryophytes more...
    - UAM Earth Science more...
    - UAM Fish Observation more...
    - UAM Fishes more...
    - UAM Herbarium more...
    - UAM Herpetology more...
    - UAM Insect Observation more...
    - UAM Insects more...
    - UAM Insects and Observations
    - UAM Invertebrates more...
    - UAM Mamm Observation more...
    - UAM Mammals more...
  - Museum of Southwestern Biology

Arctos is an ongoing effort to integrate access to specimen data, collection-management tools, and external resources on the internet. Nearly all that is known about a specimen can be included in Arctos, and, except for some data encumbered for proprietary reasons, data are open to the public.

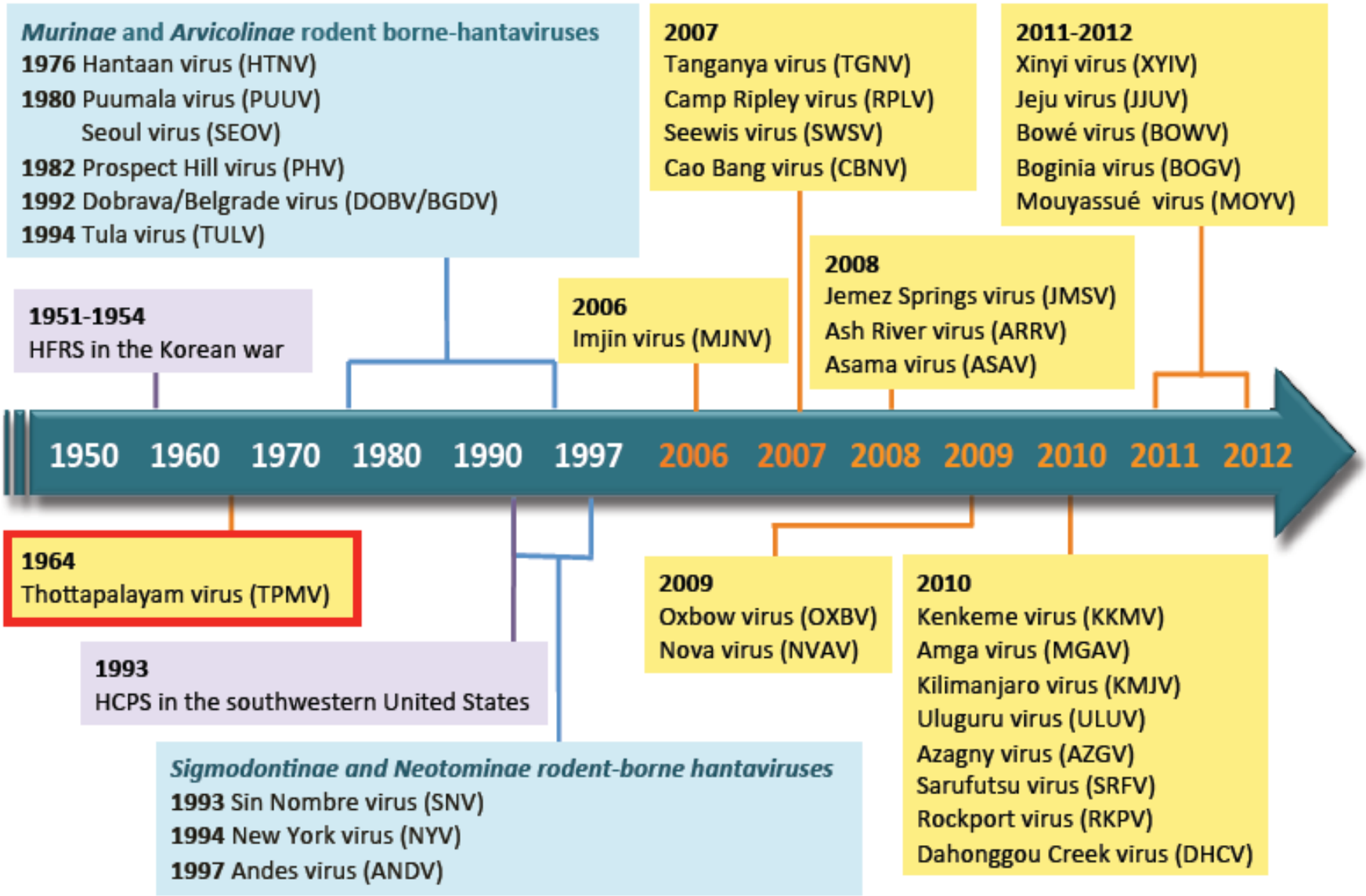
Features:

- Vaporware-free since 2001. All this stuff and much more really exists in a usable state, and we'll never claim proposed or limited funtionality exists.
- Media link images, movies, sound files, and documents to specimens, taxonomy, publications, projects, events, or people.
  Multi-page documents organize, paginate, and print PDFs of scanned media such as field notes. TAGs comment on specific areas of images, or relate them to nodes such as specimens, places, and people.
- Users may annotate specimens, taxonomy, projects, publications, and media.
- Virtual Private Databases (VPD), also known as Row-Level Security (RLS), allow collections to maintain control of their data while sharing certain nodes, such as Agents and Taxonomy. The cool kids call this Cloud Computing or Grid Computing. It allows us to confidently support most any application, not just the ones we write.
- Everything is over the web in real time, and independent of client-side operating systems. You need moderate bandwidth, a modern browser,

Arctos...



Hantavirus Milestones



WHAT IS THE TIME-SCALE OF HANTAVIRUS EVOLUTION?

Zhang, Y-Z., Holmes, E.C., 2014.
What is the Time-Scale of Hantavirus Evolution?
Infection, Genetics and Evolution

2000 years to 50 million years?

What went right?

- Integrated Archives Available
  - Diverse tissues across time and space
- Integration across disciplines
  - Systematics, Virology, Public Health, Geography, Ecology, Sociology
- Coordination across multiple agencies and others
  - State, federal, tribal, universities, museums

What went wrong?

- Durable infrastructure **lacking**---deep (temporal) & wide (spatial)

  Why?

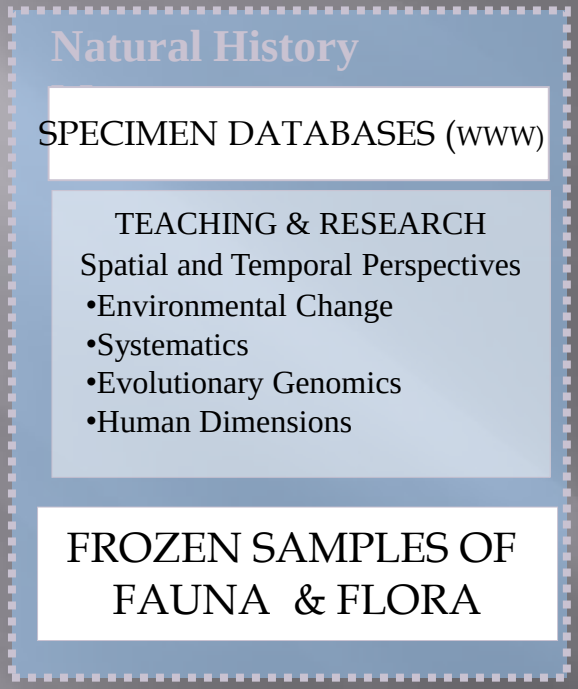
  •Focus on hypothesis driven science
    - Funding availability
    - Narrower scope of new collections
    - Resources shifted to public programs

  •Reluctance of museums to engage other communities

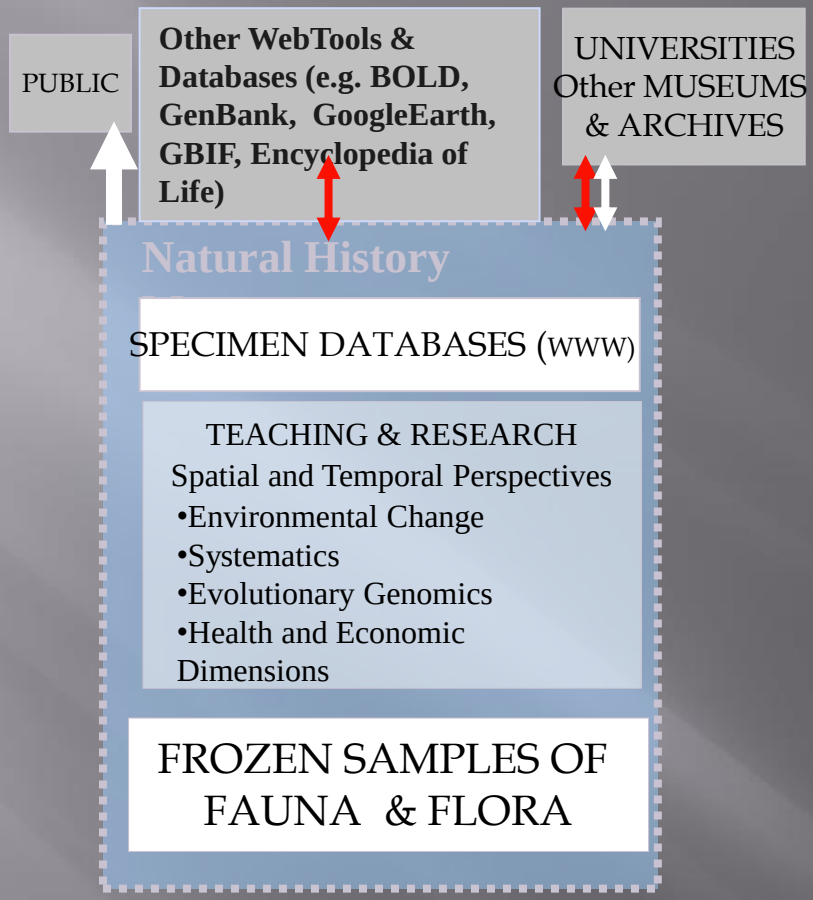
  •Slow response of museums to build integrated resources

  •Communication—on line open, resources (internet)

  •Data models are weak for many institutions
    - Tracking data & data availability
    - Tie big data together, place specimens as central
      - e.g., GenBank to GoogleEarth through specimens



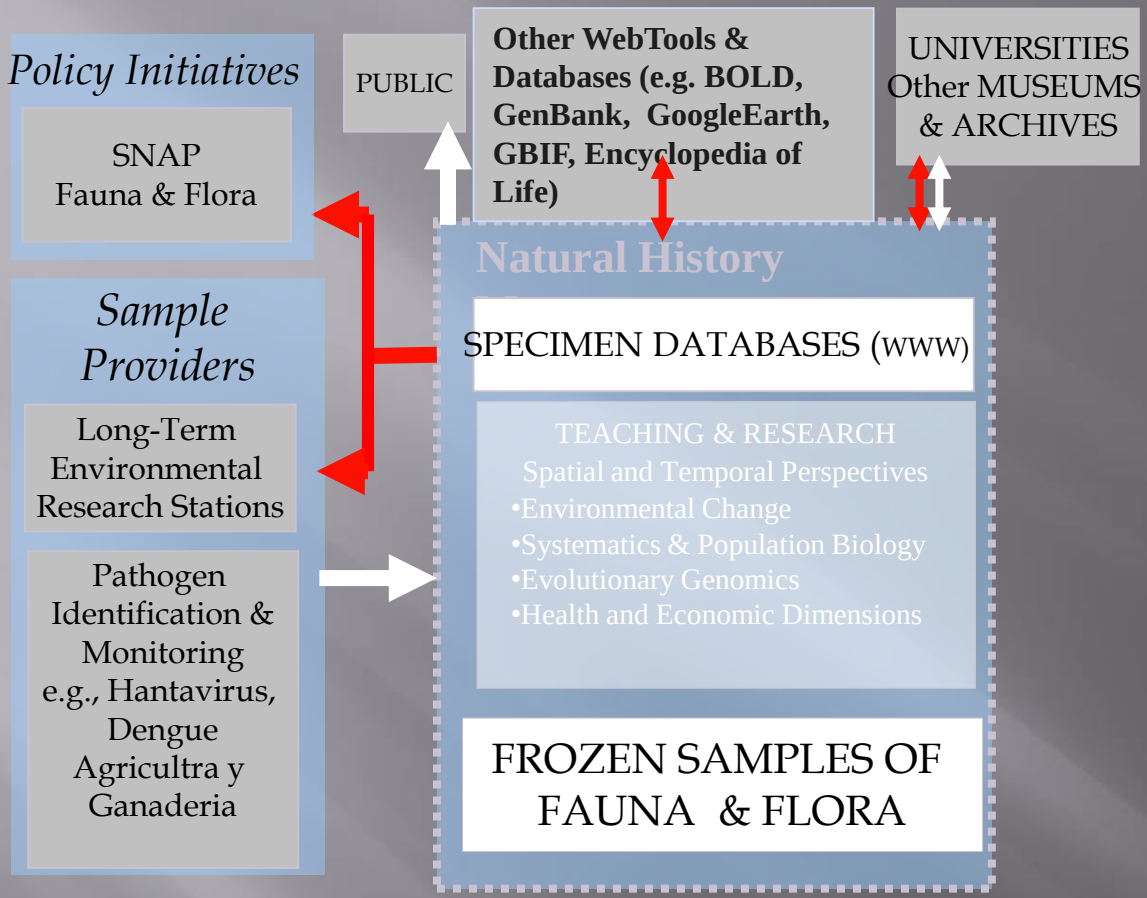
A Museum Approach to Pathogen Observatories



specimens & samples

specimen data and project metadata

A Museum Approach to Pathogen Observatories



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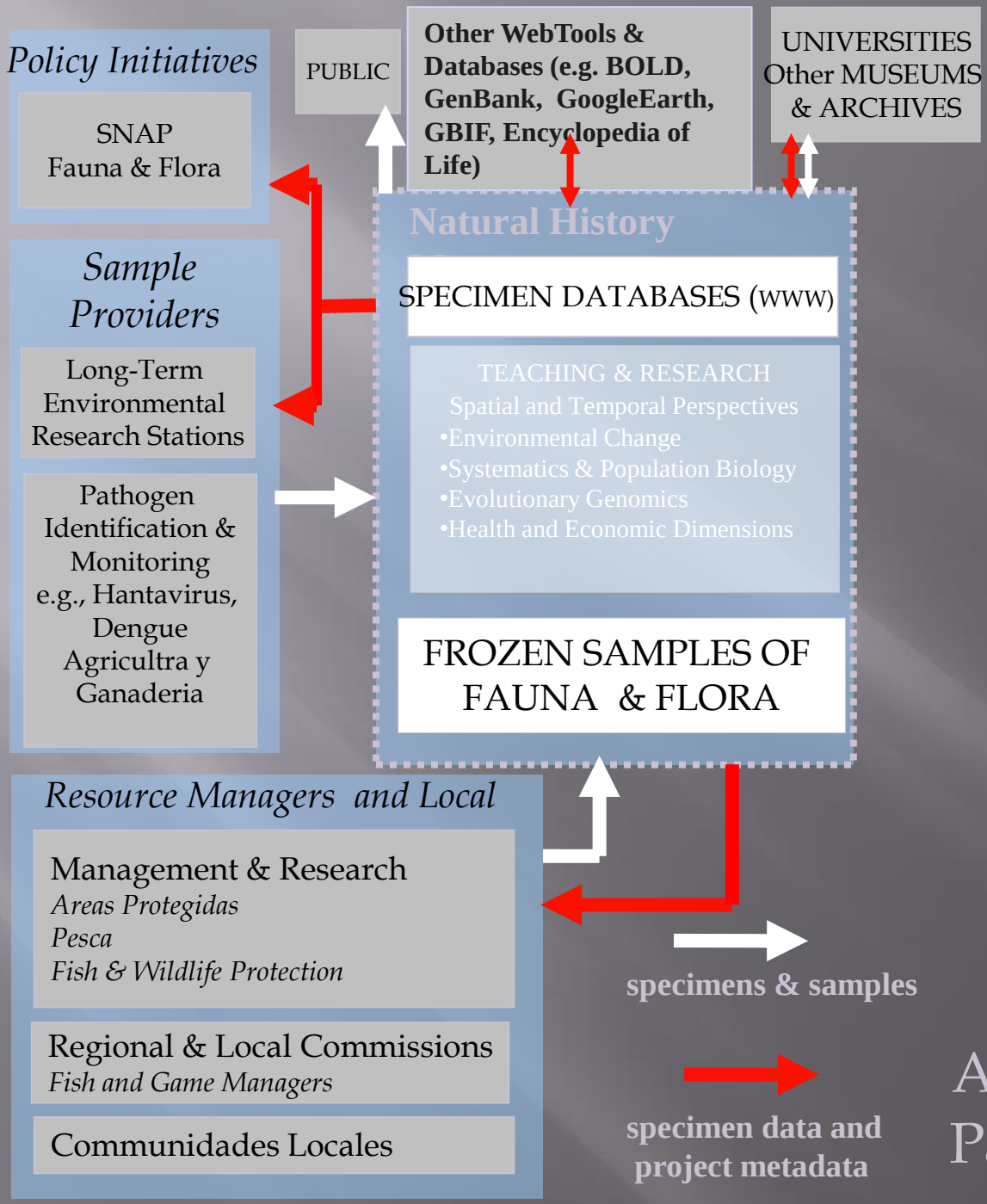

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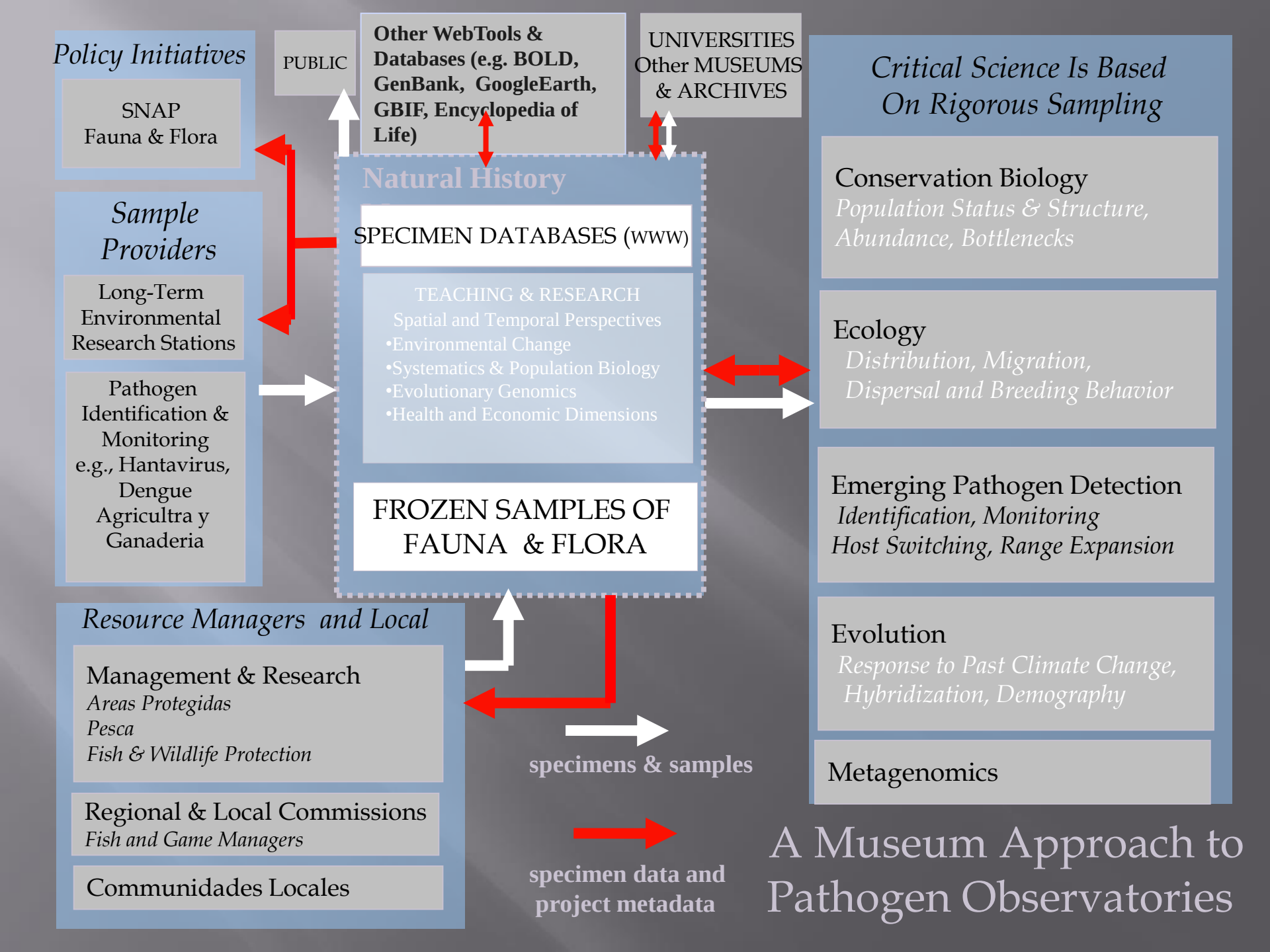
Policy Initiatives
SNAP
Fauna & Flora
PUBLIC
Other WebTools & Databases (e.g. BOLD, GenBank, GoogleEarth, GBIF, Encyclopedia of Life)
UNIVERSITIES
Other MUSEUMS & ARCHIVES
Critical Science Is Based On Rigorous Sampling
Natural History
SPECIMEN DATABASES (WWW)
TEACHING & RESEARCH
Spatial and Temporal Perspectives
•Environmental Change
•Systematics & Population Biology
•Evolutionary Genomics
•Health and Economic Dimensions
FROZEN SAMPLES OF FAUNA & FLORA
Sample Providers
Long-Term Environmental Research Stations
Pathogen Identification & Monitoring e.g., Hantavirus, Dengue Agricultra y Ganaderia
Conservation Biology
Population Status & Structure, Abundance, Bottlenecks
Ecology
Distribution, Migration, Dispersal and Breeding Behavior
Emerging Pathogen Detection
Identification, Monitoring
Host Switching, Range Expansion
Evolution
Response to Past Climate Change, Hybridization, Demography
Metagenomics
Resource Managers and Local
Management & Research
Areas Protegidas
Pesca
Fish & Wildlife Protection
Regional & Local Commissions
Fish and Game Managers
Communidades Locales
specimens & samples
specimen data and project metadata
A Museum Approach to Pathogen Observatories

"At this point I wish to emphasize what I believe will ultimately prove to be the greatest value of our museum. This value will not, however, be realized until the lapse of many years, possibly a century, assuming that our material is safely preserved. And this is that the student of the future will have access to the original record of faunal conditions."

Joseph Grinnell, 1910
"The Uses and Methods of a Research Museum"
Popular Science Monthly

Next Steps for Pathogen Discovery and Mitigation?

Information & Technology Needs

- **Increased Growth of Collections**
  - **Could be stimulated by digitization efforts**
  - **Unintended Consequences**

- **Increased Human Capacity**
  - **Broadening Participation**
  - **Revitalizing & Integrating Medical & Biology Education**

Travel Channel's Mysteries at the Museum

http://www.travelchannel.com/shows/mysteries-at-the-museum/video/four-corners-outbreak