turning knowledge into practice

An Ontology for Designing Models of Epidemics

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# Role of the Ontology in Building Models

- Help researchers find relevant models, simulations, and results

- Help modelers find relevant data to build, calibrate, and validate their models

- Use taxonomies that are accepted by the community as a means of accessing data at multiple levels of abstraction

MIDAS
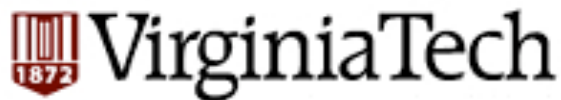
- The Models of Infectious Disease Agent Study (MIDAS) formed in May of 2004 by NIGMS
- The National Institute of General Medical Sciences is one of the NIH institutes
- The NIGMS supports basic biomedical research that increases understanding of life processes and lays the foundation for advances in disease diagnosis, treatment, and prevention.
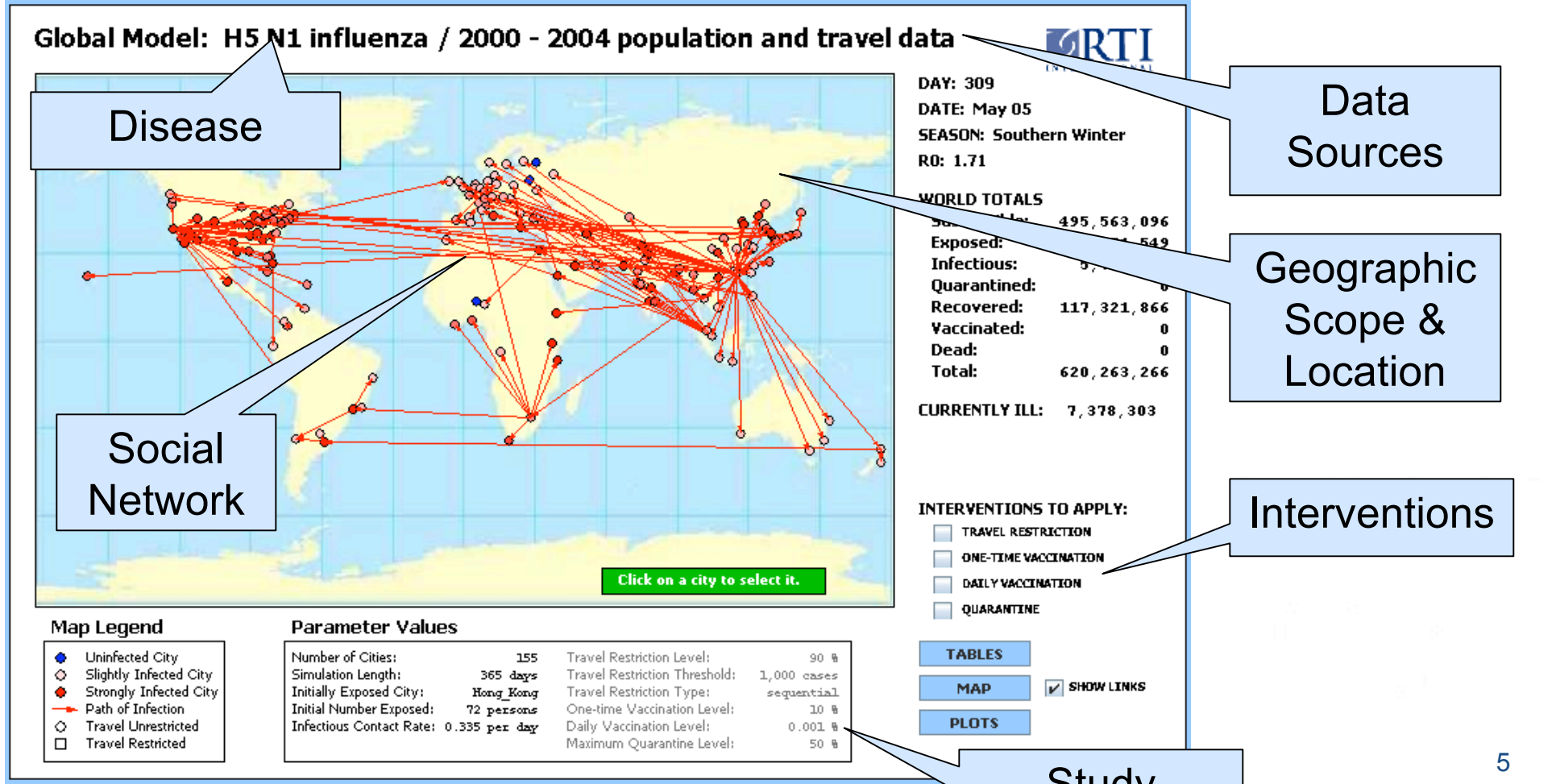- NIGMS contact for MIDAS: Dr. Irene Eckstrand
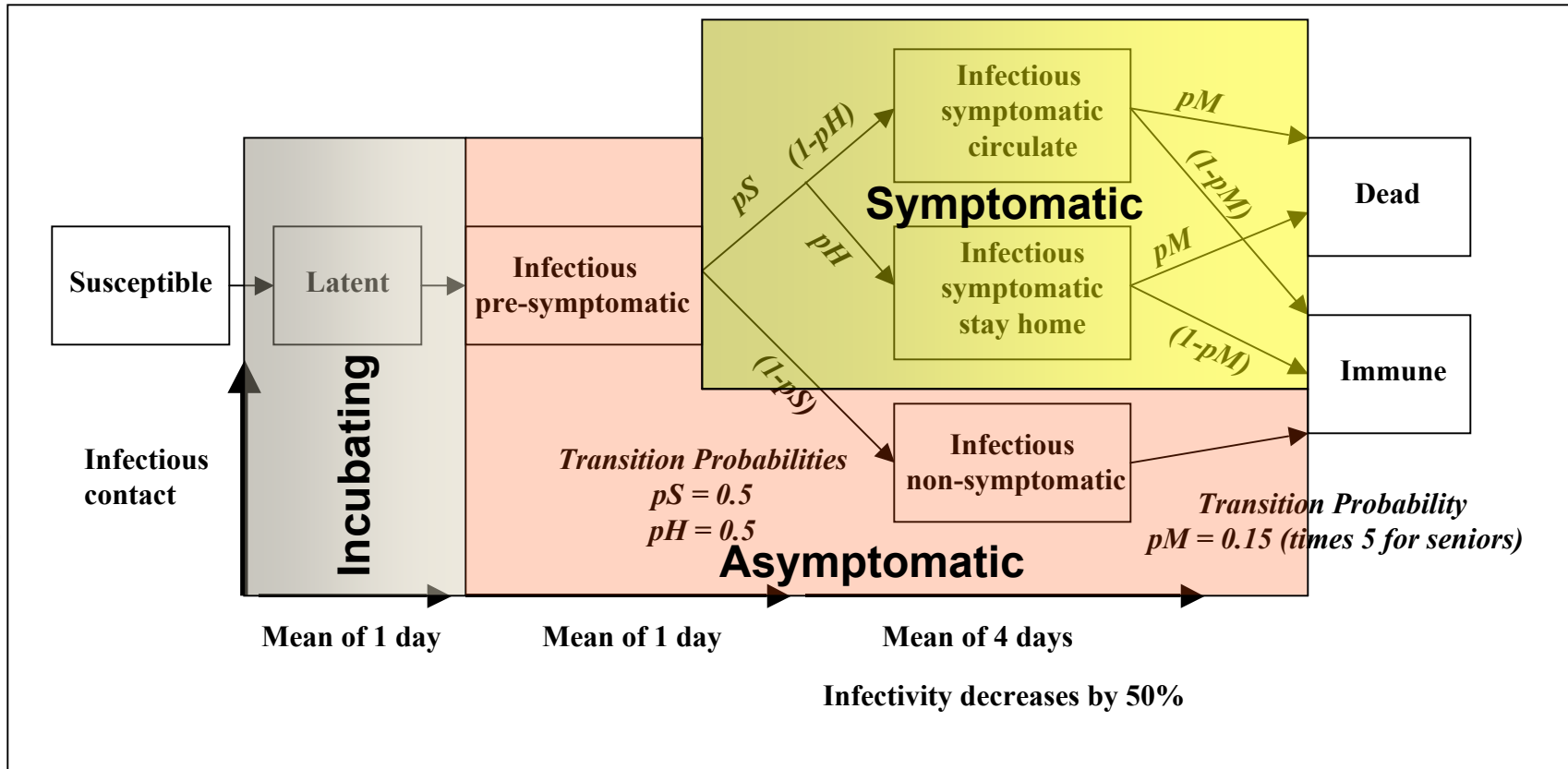
MIDAS Results
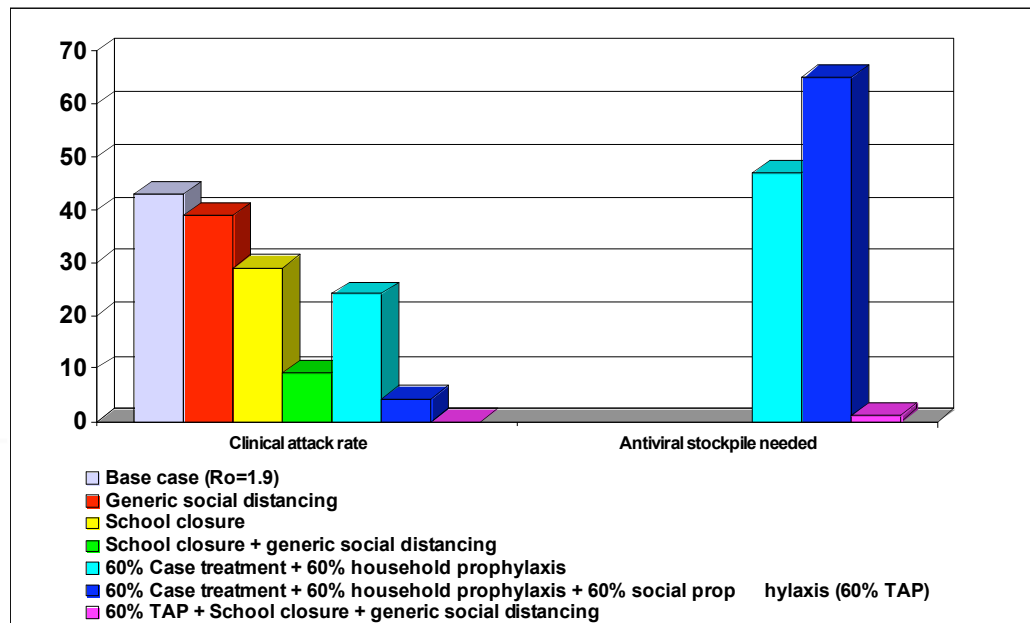
From Longini et al., 2005

- Analysis of air travel restrictions to prevent pandemics
- Analysis of targeted intervention strategies for controlling avian flu pandemics for the US Department of Homeland Security
- Analysis of vaccine and antiviral medicine stockpiling for the World Health Organization

Components of an Epidemic Model

Global Model: H5N1 influenza / 2000 - 2004 population and travel data

Disease

Social Network

DAY: 309
DATE: May 05
SEASON: Southern Winter
R0: 1.71

WORLD TOTALS
Susceptible: 495,563,096
Exposed: 549
Infectious:
Quarantined: 0
Recovered: 117,321,866
Vaccinated: 0
Dead: 0
Total: 620,263,266

CURRENTLY ILL: 7,378,303

Click on a city to select it.

INTERVENTIONS TO APPLY:
☐ TRAVEL RESTRICTION
☐ ONE-TIME VACCINATION
☐ DAILY VACCINATION
☐ QUARANTINE

TABLES
MAP   ☑ SHOW LINKS
PLOTS

Data Sources

Geographic Scope & Location

Interventions

Map Legend
◆ Uninfected City
◇ Slightly Infected City
● Strongly Infected City
→ Path of Infection
◇ Travel Unrestricted
☐ Travel Restricted

Parameter Values

|			
Number of Cities:	155	Travel Restriction Level:	90 %
Simulation Length:	365 days	Travel Restriction Threshold:	1,000 cases
Initially Exposed City:	Hong_Kong	Travel Restriction Type:	sequential
Initial Number Exposed:	72 persons	One-time Vaccination Level:	10 %
Infectious Contact Rate:	0.335 per day	Daily Vaccination Level:	0.001 %
		Maximum Quarantine Level:	50 %

Study Parameters

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The Disease Model

A Compromise between Ferguson 2005, Nature; Longini et al., 2005, Science; and Longini et al., 2004, Am J Epidemiology
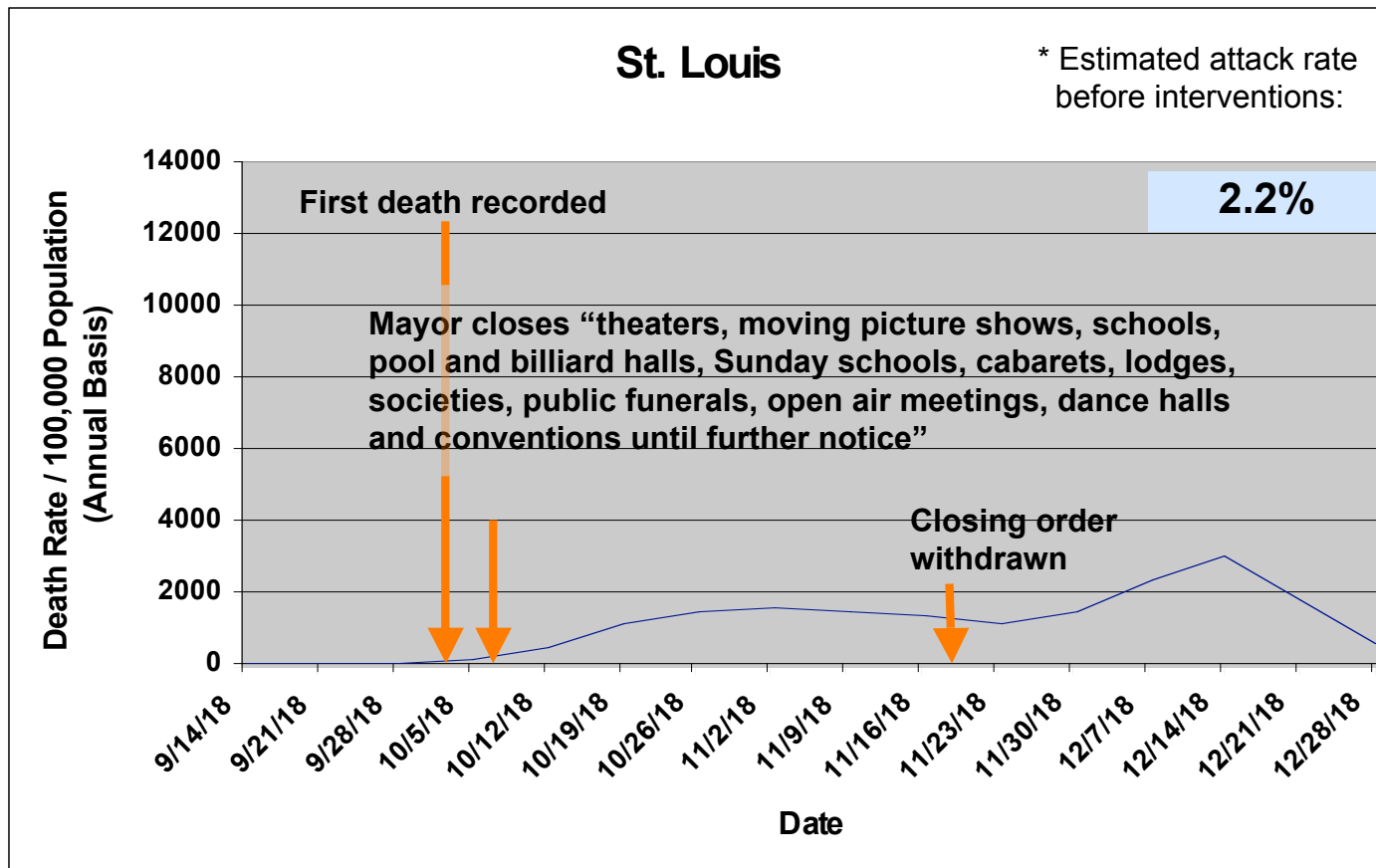
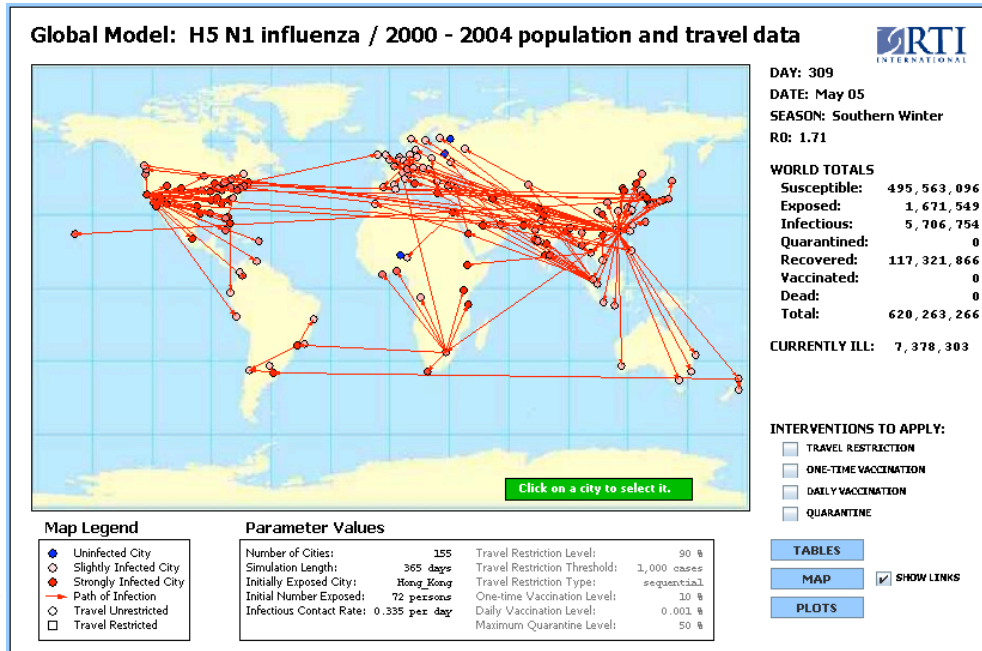# A Geo-Referenced Social Network Model
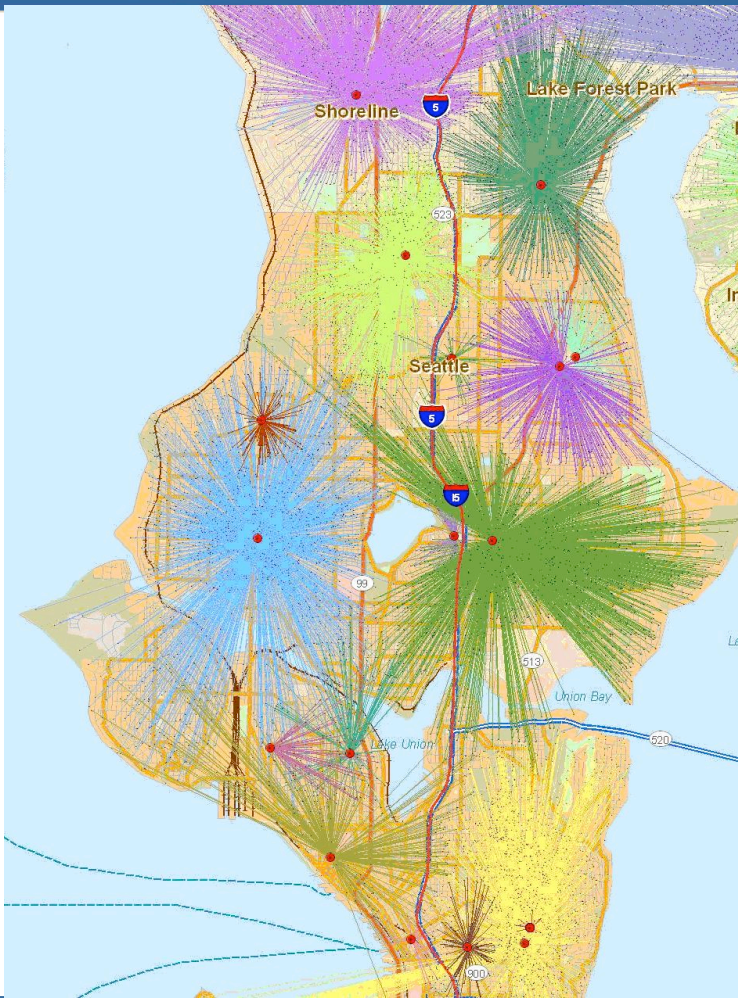
- **Households**
  - Household population

- **Workplaces**
  - Workplace mapping
  - Hospitals, schools, & hotels

- **Schools**
  - School assignments

- **Communities**
  - Hospitals
  - Hotels

- **Group Quarters**
  - Dormitories, barracks, prisons, nursing homes

Intervention Models

St. Louis

* Estimated attack rate before interventions:

2.2%

First death recorded

Mayor closes "theaters, moving picture shows, schools, pool and billiard halls, Sunday schools, cabarets, lodges, societies, public funerals, open air meetings, dance halls and conventions until further notice"

Closing order withdrawn

Death Rate / 100,000 Population (Annual Basis)

Date

Study Design: Parameters and Output

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DATE: May 05
SEASON: Southern Winter
R0: 1.71

WORLD TOTALS
Susceptible: 495,563,096
Exposed: 1,671,549
Infectious: 5,706,754
Quarantined: 0
Recovered: 117,321,866
Vaccinated: 0
Dead: 0
Total: 620,263,266

CURRENTLY ILL: 7,378,303

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Click on a city to select it.

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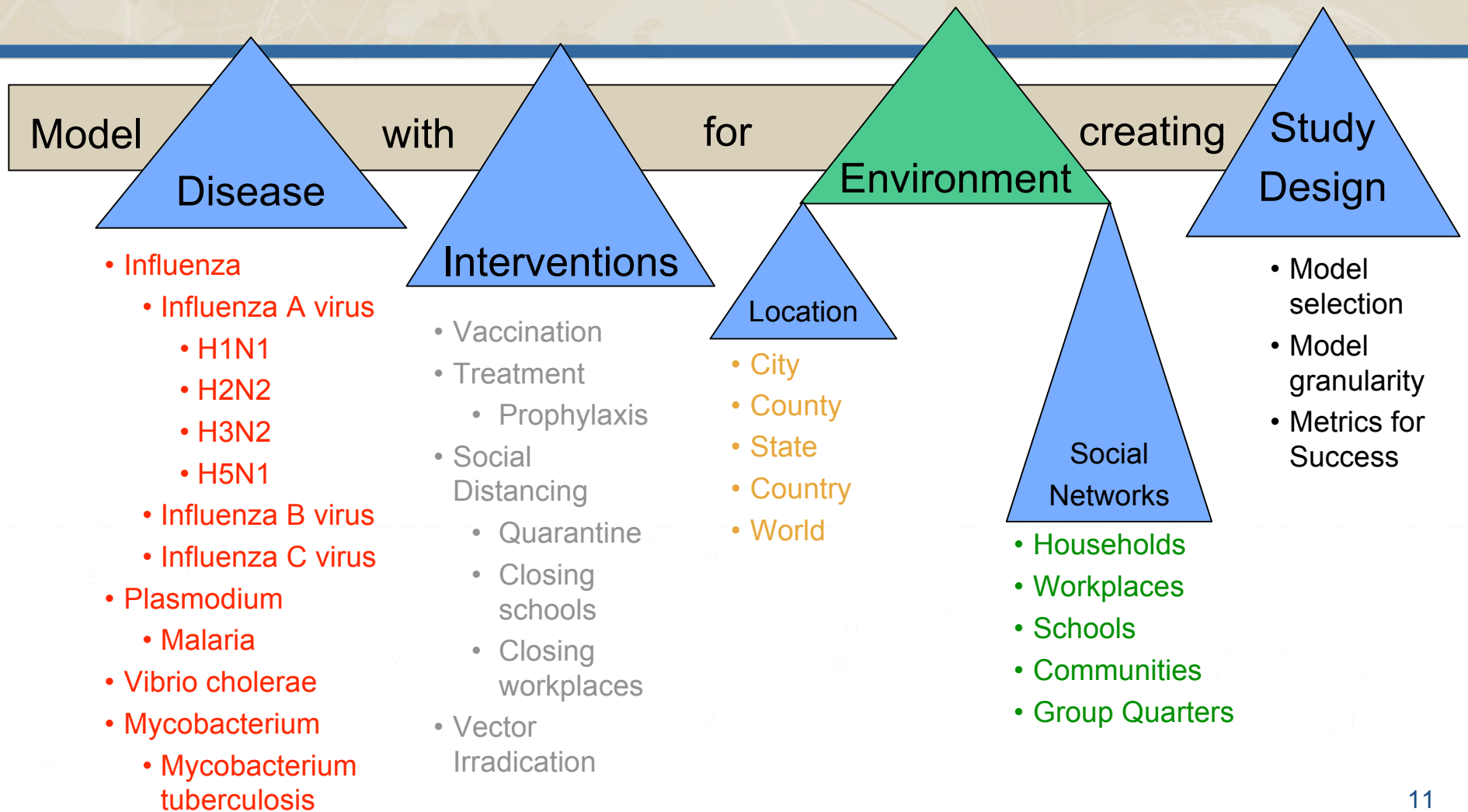
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MAP   ☑ SHOW LINKS
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- **Initial Conditions**
  - Initial infection location
  - Infection rates (R_0)
  - Time frame
- **Calibration Parameters**
  - Outputs to calibrate
  - Historical data
  - Calibration targets
- **Output Variables**
  - Morbidity by age
  - Mortality by age
  - Economic effects
- **Output Displays**
  - Plots
  - Map Displays

Computational Framework

- Differential Equation Models

- Hybrid Models
  - Data driven differential equation models

- Agent-Based Models
  - Discrete-time stochastic agent models
    - Modeling all agents
    - Modeling only infected agents
  - Event-driven agent models

Overview of the Ontology

Model   with   for   creating   Study Design

Disease

- Influenza
  - Influenza A virus
    - H1N1
    - H2N2
    - H3N2
    - H5N1
  - Influenza B virus
  - Influenza C virus
- Plasmodium
  - Malaria
- Vibrio cholerae
- Mycobacterium
  - Mycobacterium tuberculosis

Interventions

- Vaccination
- Treatment
  - Prophylaxis
- Social Distancing
  - Quarantine
  - Closing schools
  - Closing workplaces
- Vector Irradication

Environment

Location

- City
- County
- State
- Country
- World

Social Networks

- Households
- Workplaces
- Schools
- Communities
- Group Quarters

Study Design

- Model selection
- Model granularity
- Metrics for Success

Generic Class Rules

- Part_Of structures
  - Every study and document appears in exactly one sub element
  - Each part has a menu
  - Top level structures are parts: disease, interventions, environment, study design
  - Location and social networks are parts of environment

- (Choice) Is_A structure
  - A study or document appears in exactly one sub element
  - Exactly one item can be selected from the menu
  - Disease and Geographic Location are choices

- (Option) Is_A structure
  - A study or document appears in some or none of the sub elements
  - Any number of items can be selected from the menu
  - Interventions and Social Networks are options

Class Structures for Taxonomies

- Model search menu generation

- Study and documentation query generation

- Mapping of data to the taxonomies
  - Studies
  - Documentation (Historical data for calibration)
  - Output visualizations

- Ontology structure validation
  - Uniqueness of the mappings
  - Completeness of the mappings

Example Taxonomy Structure

```
- <Parts>
  - <OntoObj id="IN:0000001" name="inputs" label="Static Parameters for a Study">
    - <Parts>
    + <OntoObj id="ID:0000098" name="infectious disease" label="collections of etiologically connected cases of
        infectious disease in a given population">
    + <OntoObj id="MD:0000001" name="geographic data" label="Geographic data">
    - <OntoObj id="MD:0000002" name="Social Groups" label="Social Goups">
      - <Parts>
        - <OntoObj id="DD:0010000" name="households" label="Family Household Groups">
          - <Choices>
            + <OntoObj id="DD:0010001" name="No household model" label="No household model">
            + <OntoObj id="DD:0010002" name="Family households" label="Family household">
            + <OntoObj id="DD:0010003" name="Neighborhood and households" label="Neighborhood and
                household groups">
          </Choices>
        </OntoObj>
        - <OntoObj id="DD:0020000" name="school groups" label="School Groups">
          - <Choices>
            - <OntoObj id="DD:0020001" name="No school groups" label="No school groups">
              <Study id="40" co="14" disease="Pandemic Flu" location="World" label="GlobalModel"
                method="GlobalModel V1" math="stochastic, equation-based epidemic model"
                documentation="../Documentation/RTI
                Publications/Global_Epidemic_Model_Manual.htm#LinkTarget_7514" />
```

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Taxonomy Dependencies

- RDF-like relations between taxonomies

- Define menu constraints

  - System implements dynamic menu options

- Dependency functions

  - Option/Choice T1 requires Option/Choice T2

    - Disease Malaria requires Intervention Vector Control Options

  - Choice T1 prevents Option/Choice T2

    - Intervention Group Quarters Quarantine prevents No Group Quarters Option

Application: User Interface to the MIDAS Repository

- Access to MIDAS Studies
- Access to historical data collected for MIDAS
- Ontology generates the menus
- Ontology generates the queries

Conclusions

- Infectious disease models are a good subject for an ontology for epidemiology
  - The models and historical data can be tagged by multiple taxonomies

- An ontology provides a good basis for searching a repository of epidemiology models
  - An ontology captures the relationships between taxonomies that can reduce the search space

- The ability to link to other ontologies through standard taxonomies is key to leveraging additional data sources