Conceptual modeling of health surveillance detection of a bioterror event

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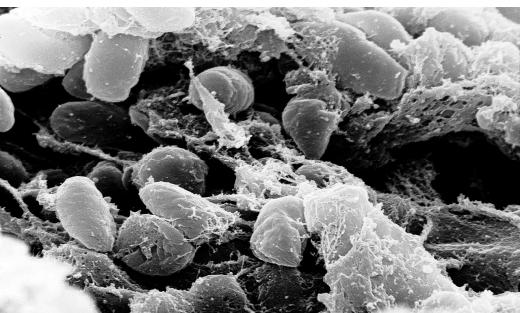
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Introduction

About Me:

- Rising Senior at the University of Washington
  - Major in Public Health
  - Minor in Quantitative Sciences (AKA Statistics)

This Talk:

- Data Streams to Public Health Officials
- Conceptual Model and Sub-Models
- Real-life Examples
- Next Steps

What is the problem?

"Bioterrorism is bad."

– Zack Schiffer, Sandia Intern 2014

Early Detection is Key

-Administer Prophylaxis Sooner

-Decontamination or Quarantine to Prevent Spread

What can be done?

Wait for a Bioterror Event

-OR-

Model the Detection Systems

The Big Questions

- How much time does it take for public health officials to gather enough information to determine that an event has occurred?

- What kinds of information lead to the determination that an event has occurred?

- Where does that information come from?

Methods

- Literature Reviews
  - General Surveys of Systems
  - Specific City Systems
    - New York City
    - Seattle
    - Fort Worth, Texas

- Discussions with experts (Sandians!) in the field

Inputs and Outputs
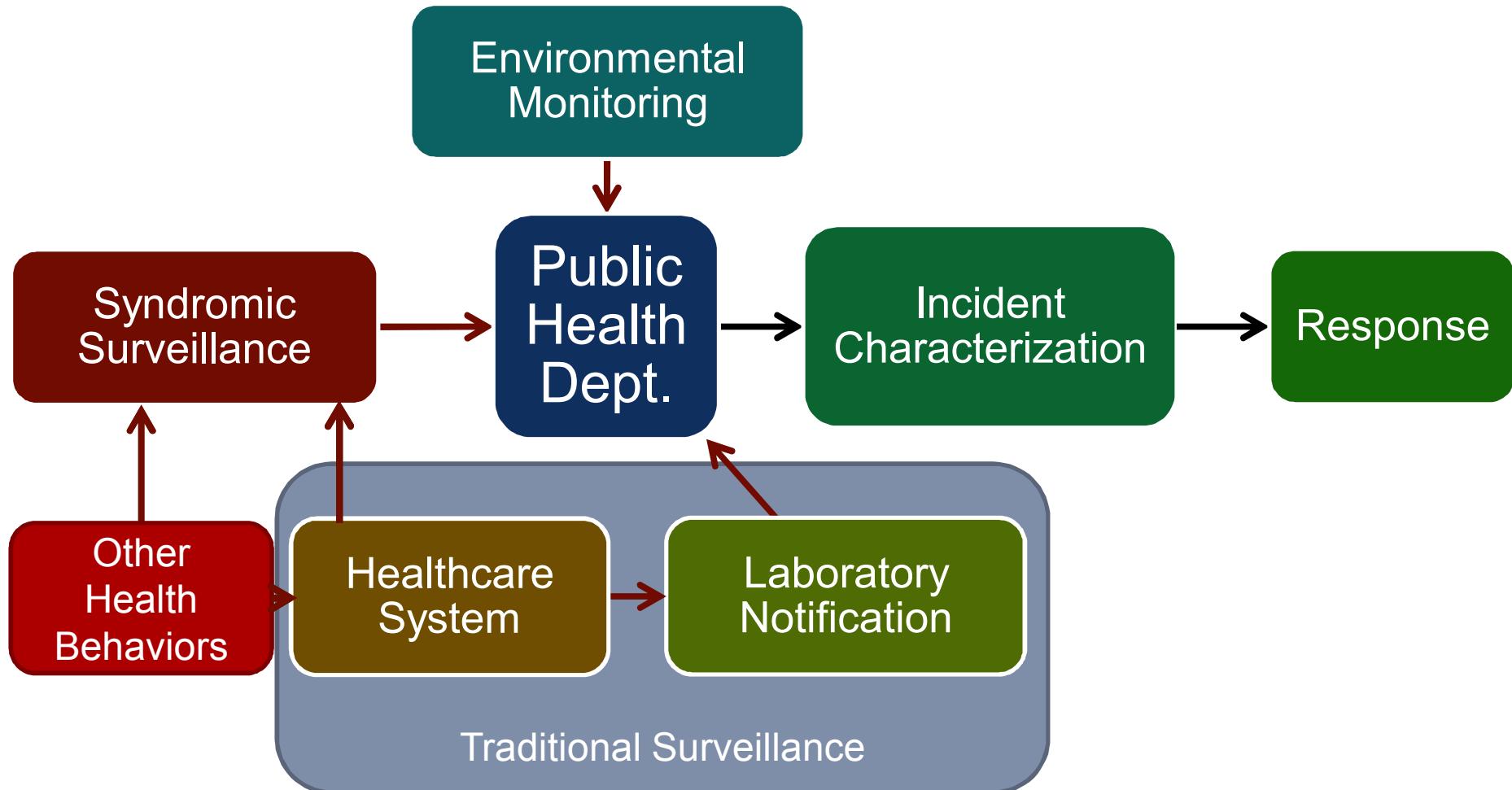
Inputs and Outputs
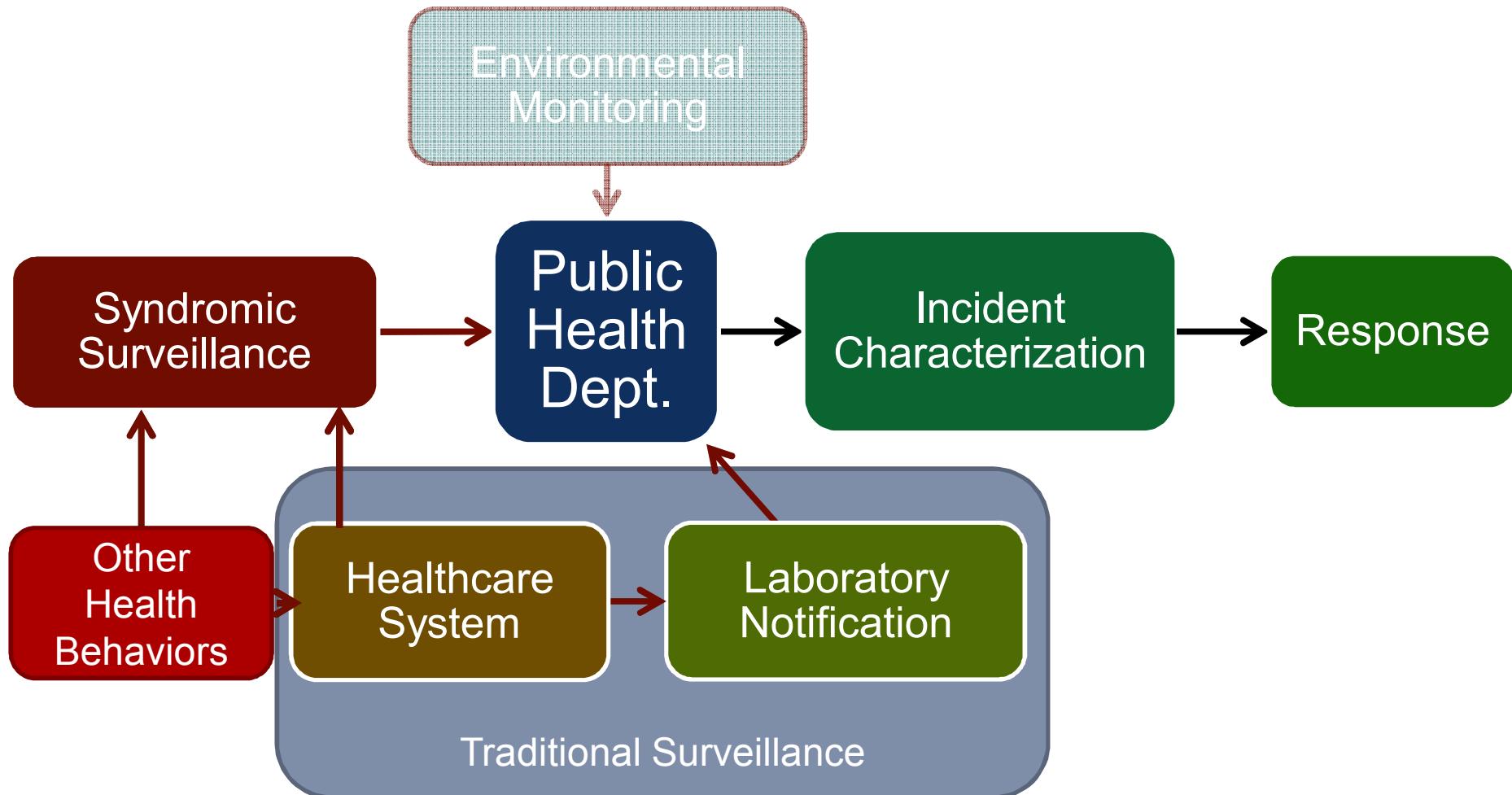
Syndromic Surveillance

The usage of data streams outside of diagnosis to detect matters of public health importance

Syndromic Surveillance Programs vary by Jurisdiction

- Types of Data Streams Utilized
- Frequency of Analysis

Type and Frequency - Nationwide

Type of Data

Data Source	% Utilized
ER Chief Complaint	84%
Outpatient Clinic Chief Complaint	49%
Over-the-Counter Medicine	44%
Absenteeism	35%

Frequency of Analysis

Frequency	%
Daily	72%
Several times a week	17%
Once a week	6%
Less than weekly	3%

Buehler, James, Amy Sonricker, Marc Paladini, Paula Soper, and Farzad Mostashari. "Syndromic Surveillance Practice in the United States: Findings from a State, Territorial, and Selected Local Health Departments." *Advances in Disease Surveillance* 6, no. 3 (2008): 1-20.

Specific Systems

Data Source	Seattle & King County	New York City	Fort Worth (Tarrant County)
School Absenteeism	1 Day Delay	1 Day Delay	1 Day Delay
911 Calls	1 Day Delay	1 Day Delay	
EMS	Real-Time		
Discharge Diagnosis Database (ECC)	1 Day Delay	1 Day Delay	10x a Day
OTC Purchases		1 Day Delay; weekdays only	
ME Reports	1 Day Delay	Up to 3 Day Delay	
Worker Absenteeism		1 Day Delay	

Algorithms

Data Source	Seattle & King County	New York City	Fort Worth (Tarrant County)
School Absenteeism		Sasaki model[6]	ESSENCE[8]
911 Calls	SitFound[2]	Serfling influenza model[5]	
EMS	SitFound[2]		
Discharge Diagnosis Database (ECC)	Generalized Linear Model[7]	SaTScan[4]	RODS[3]
OTC Purchases		Serfling influenza model[5]	
ME Reports			
Worker Absenteeism		CUSUM[1]	

Thresholds

System	Signal	Baseline Measurements
EARS[1]	2 SD above baseline (C_3)	7 days
CUSUM[1]	1 SD above baseline	8 week sliding baseline
SaTScan[4]	Actual count is outside of p value <0.01	14 day baseline
SitFound[2]	5 calls in same zipcode; 2 SD over baseline	14 day baseline
RODS[3]	Actual count is outside of 95% CI (expected count)	3 year baseline
Sasaki model[5]	Z score of at least 3	3 year baseline
Serfling Influenza Model[5]	Difference between observed and expected ratios	4-10 week baseline
Generalized Linear Model/ BioSense[67]		
ESSENCE (2 Algorithms)	(1) Difference between actual and expected (2) weighted moving average	4 weeks; weighted average of all data

Syndromic Surveillance:

The usage of data streams outside of diagnosis to detect matters of public health importance.

Strengths:

-Estimates Prevalence

-Faster than Diagnosis

Limitations:

-Nonspecific

-Noisy Data

Inputs and Outputs
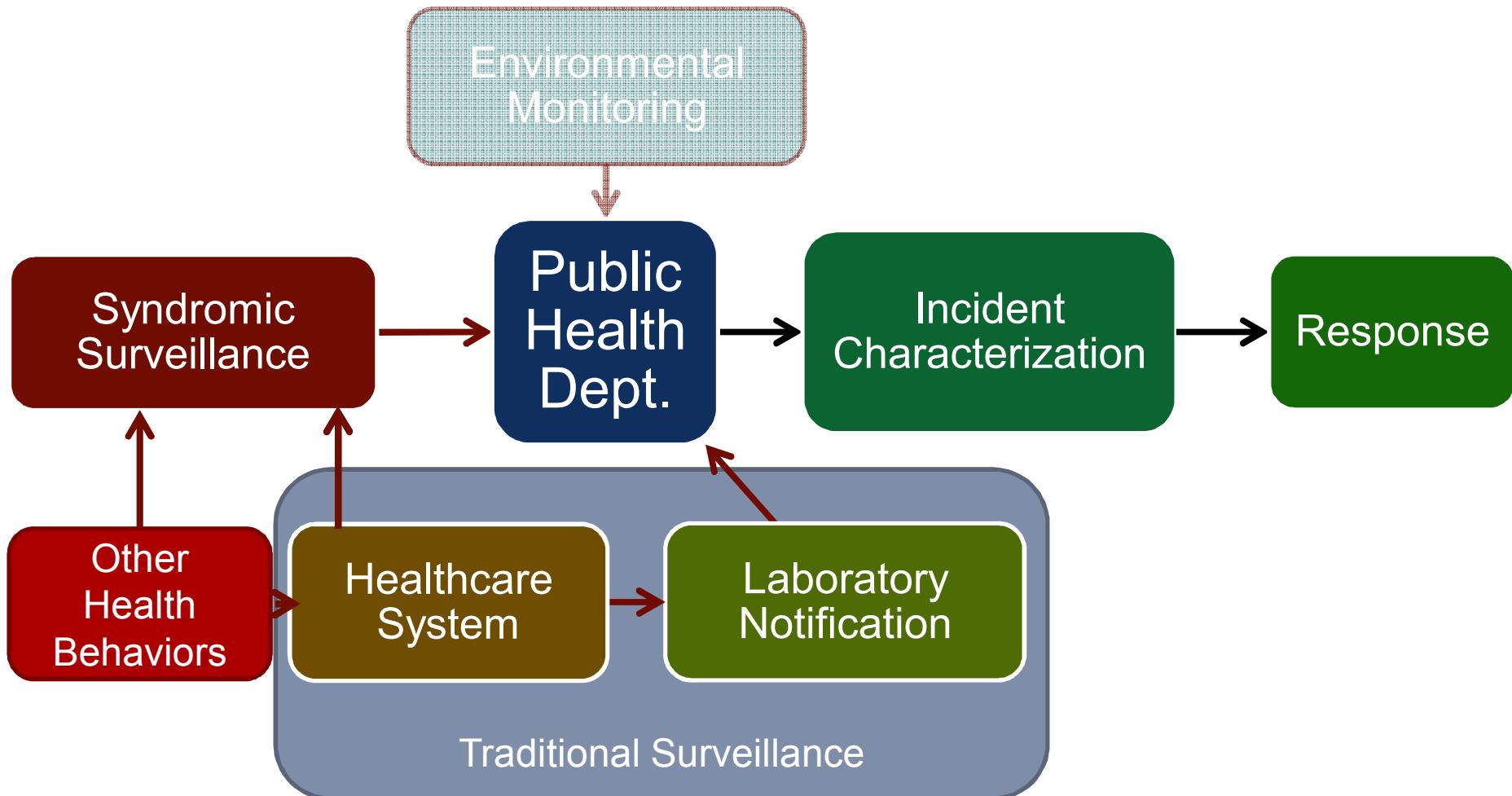
Traditional Surveillance

The collection and analysis of healthcare data by public health officials in order to recognize and prevent issues of public health importance.

- Laboratory Notification Depends On:
  - Astute Physicians
  - Lab Test Turn-Around-Time

Laboratory Response Network

Less than 5 National Labs

150+ Reference Labs

25000+ Sentinel Labs
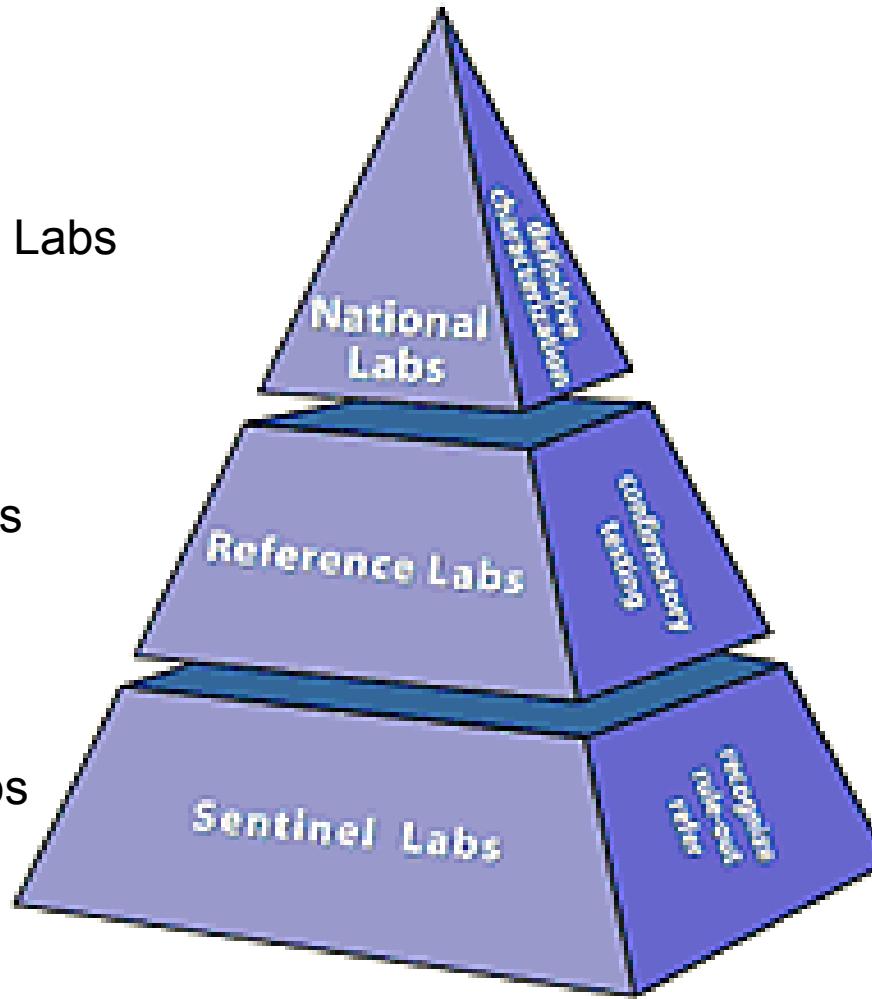
Traditional Surveillance

Astute Physicians

Correct Diagnosis of:

Anthrax- 70.5%

Smallpox- 50.7%

Plague- 16.3%

Lab Tests for Rule Out

Aerobes (Anthrax, Tularemia, Plague)
Gram Stain Reaction
Colony Morphology
Catalase
Oxidase
Motility
Carbohydrate Reactions
Temperature Studies (when pertinent)
Spore Formation (when pertinent)

Washington State Department of Health. "Directory of Services." Washington State Department of Health Public Health Laboratories. http://www.doh.wa.gov/Portals/1/Documents/Pubs/301-016-PHLDirectoryServices.pdf (accessed July 25, 2014).

Cosgrove SE, Perl TM, Song X, Sisson SD. Ability of Physicians to Diagnose and Manage Illness Due to Category A Bioterrorism Agents. *Arch Intern Med.* 2005;165(17):2002-2006. doi:10.1001/archinte.165.17.2002.

Traditional Surveillance:

The collection and analysis of healthcare data by public health officials in order to recognize and prevent issues of public health importance.
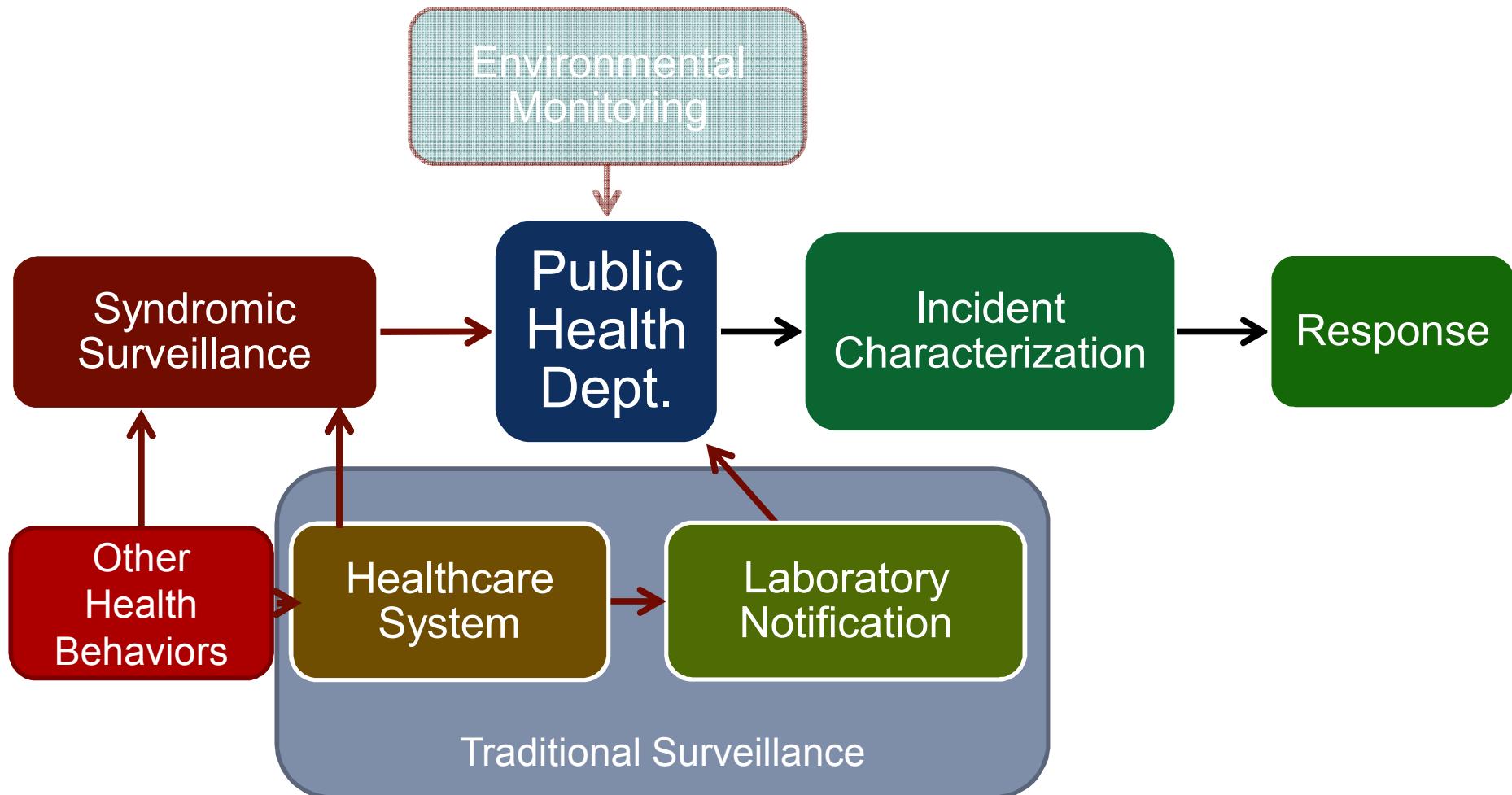

Strengths:

-Lab Confirmation

-Identified Patients

-Broad Coverage

Limitations:

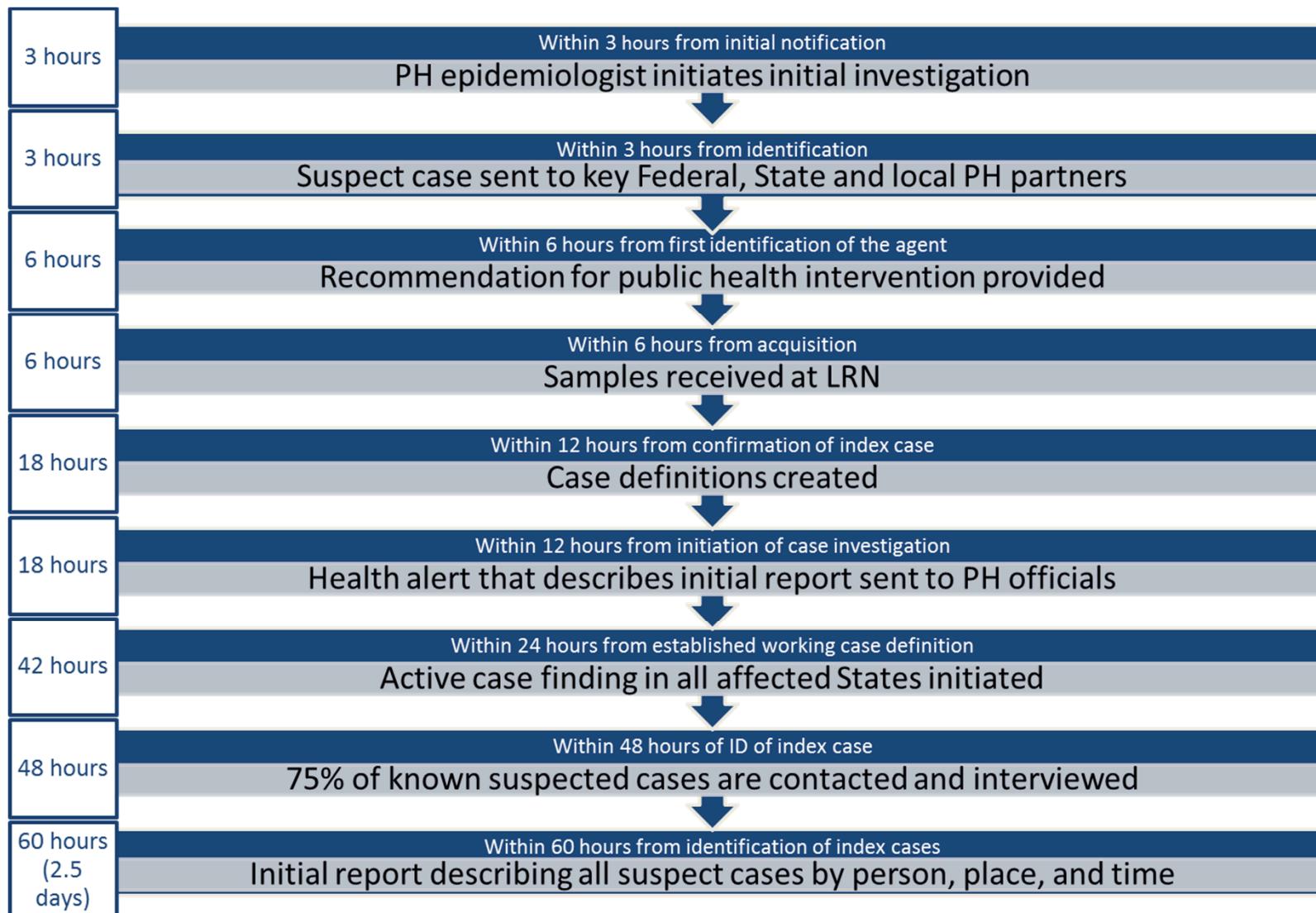-Already Sick

-Lab Test Length

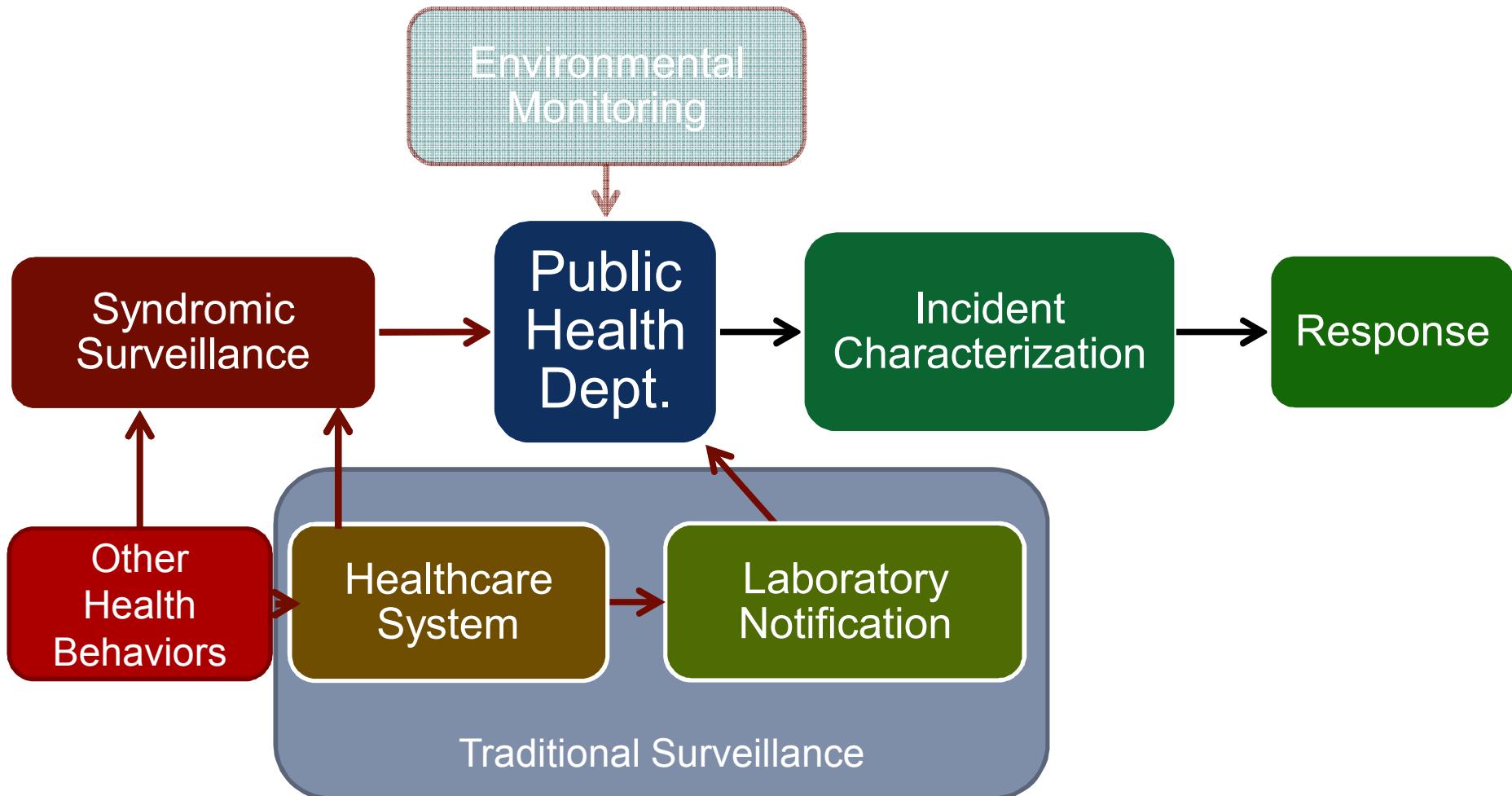# Inputs and Outputs

Incident Characterization

There are many overlapping steps of incident characterization.

- Interview Cases

- Environmental Testing

- Create Case Definition

- Query Syndromic Surveillance

- Communicate with CDC and other Public Health jurisdictions

Epi Investigation

3 hours	Within 3 hours from initial notification PH epidemiologist initiates initial investigation
3 hours	Within 3 hours from identification Suspect case sent to key Federal, State and local PH partners
6 hours	Within 6 hours from first identification of the agent Recommendation for public health intervention provided
6 hours	Within 6 hours from acquisition Samples received at LRN
18 hours	Within 12 hours from confirmation of index case Case definitions created
18 hours	Within 12 hours from initiation of case investigation Health alert that describes initial report sent to PH officials
42 hours	Within 24 hours from established working case definition Active case finding in all affected States initiated
48 hours	Within 48 hours of ID of index case 75% of known suspected cases are contacted and interviewed
60 hours (2.5 days)	Within 60 hours from identification of index cases Initial report describing all suspect cases by person, place, and time

http://www.ema.ohio.gov/documents/pdfs/Target_Capabilities/TCL_Epidemiological_Surveillance_May_2008.pdf
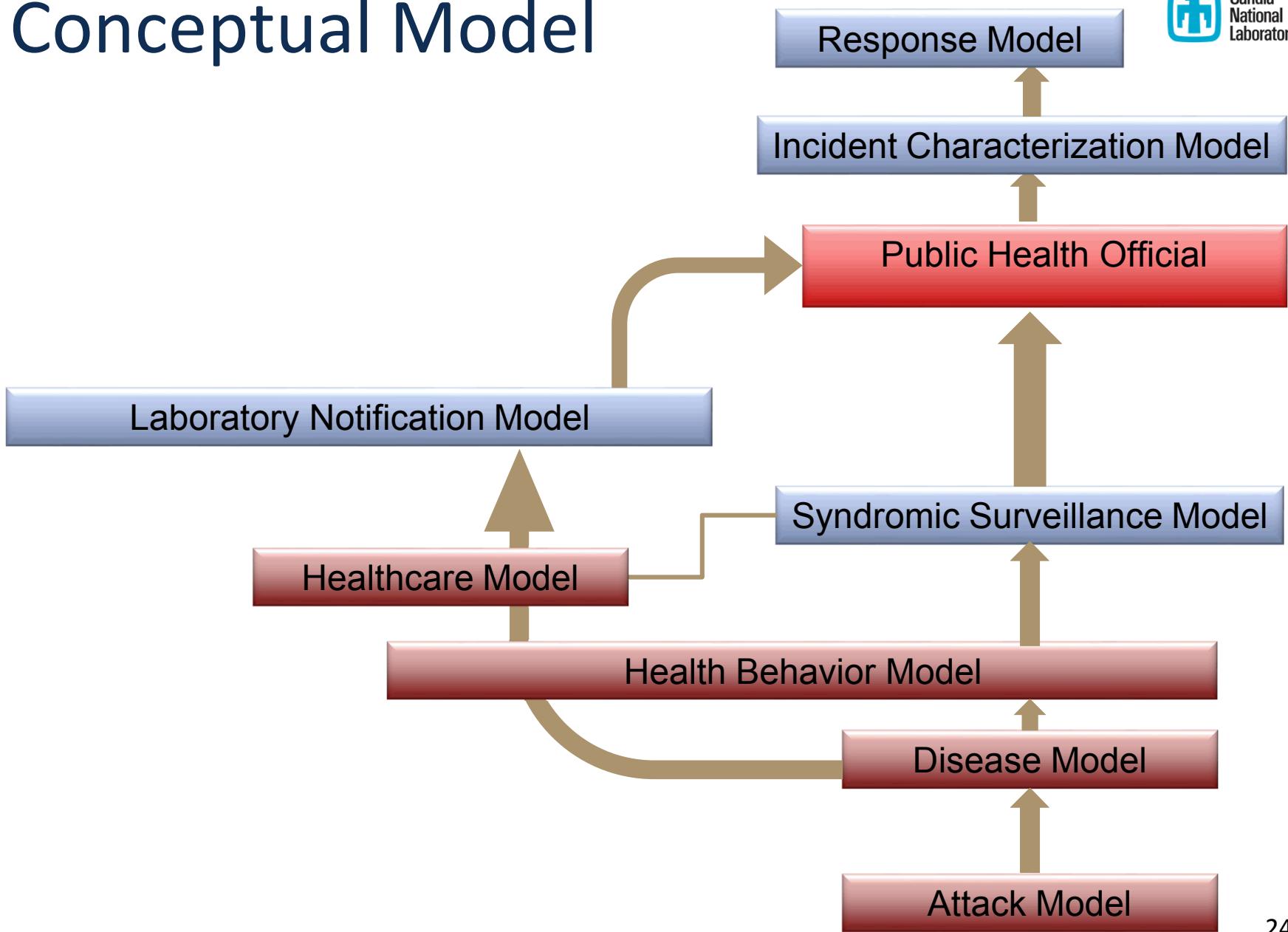
Inputs and Outputs

Response

Response happens on a case-by-case basis

- Communicate to Public
- Order Strategic National Stockpile
- Quarantine/Isolation

Conceptual Model

Response Model

Incident Characterization Model

Public Health Official

Laboratory Notification Model

Syndromic Surveillance Model

Healthcare Model

Health Behavior Model

Disease Model

Attack Model

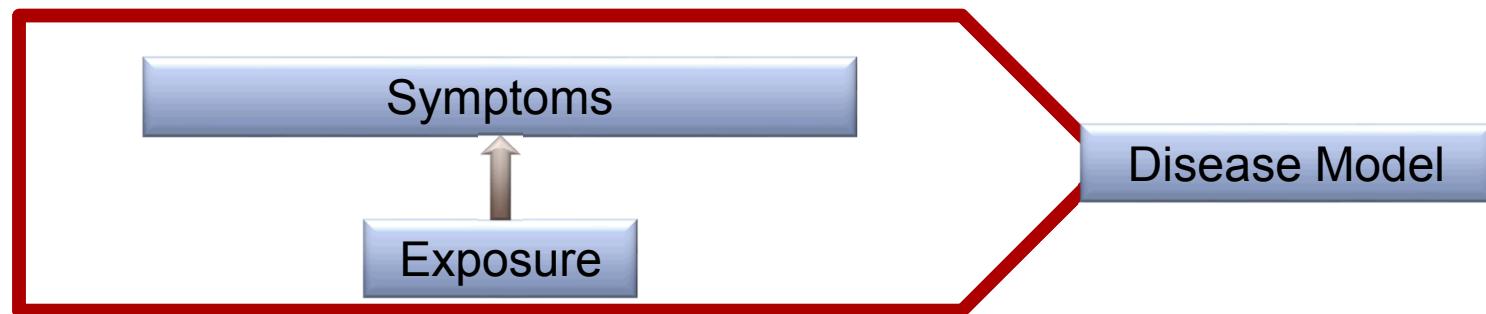# Attack Model

Parameters:

Pathogen

Geography

Population Size

Amount Released

Weather Patterns

Particle Size

Disease Model

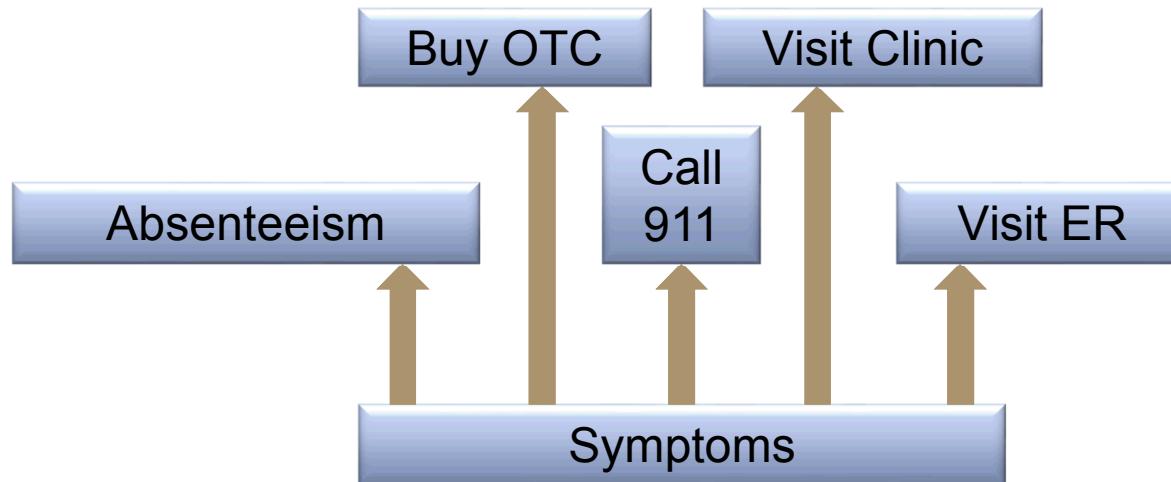# Disease Model Parameters

Pathogen	Incubation	Symptoms	Treated Mortality
Anthrax	3 Days	Respiratory Illness	45%
Smallpox	12 Days	Rash	30%
Tularemia	4 Days	Respiratory Illness	2%
Plague	2 Days	Respiratory Illness	57%

Health Behavior Model

Health Behavior Model Parameters

Behavior	% Reported
Absenteeism	32.6%
Buy Over the Counter Medicine	53.2%
Visit Clinic	29.1%
Visit ER	8.8%

Data is based off 2003 flu season

Toughing it out

There is always a time gap between the first symptoms and when a person visits the doctor…
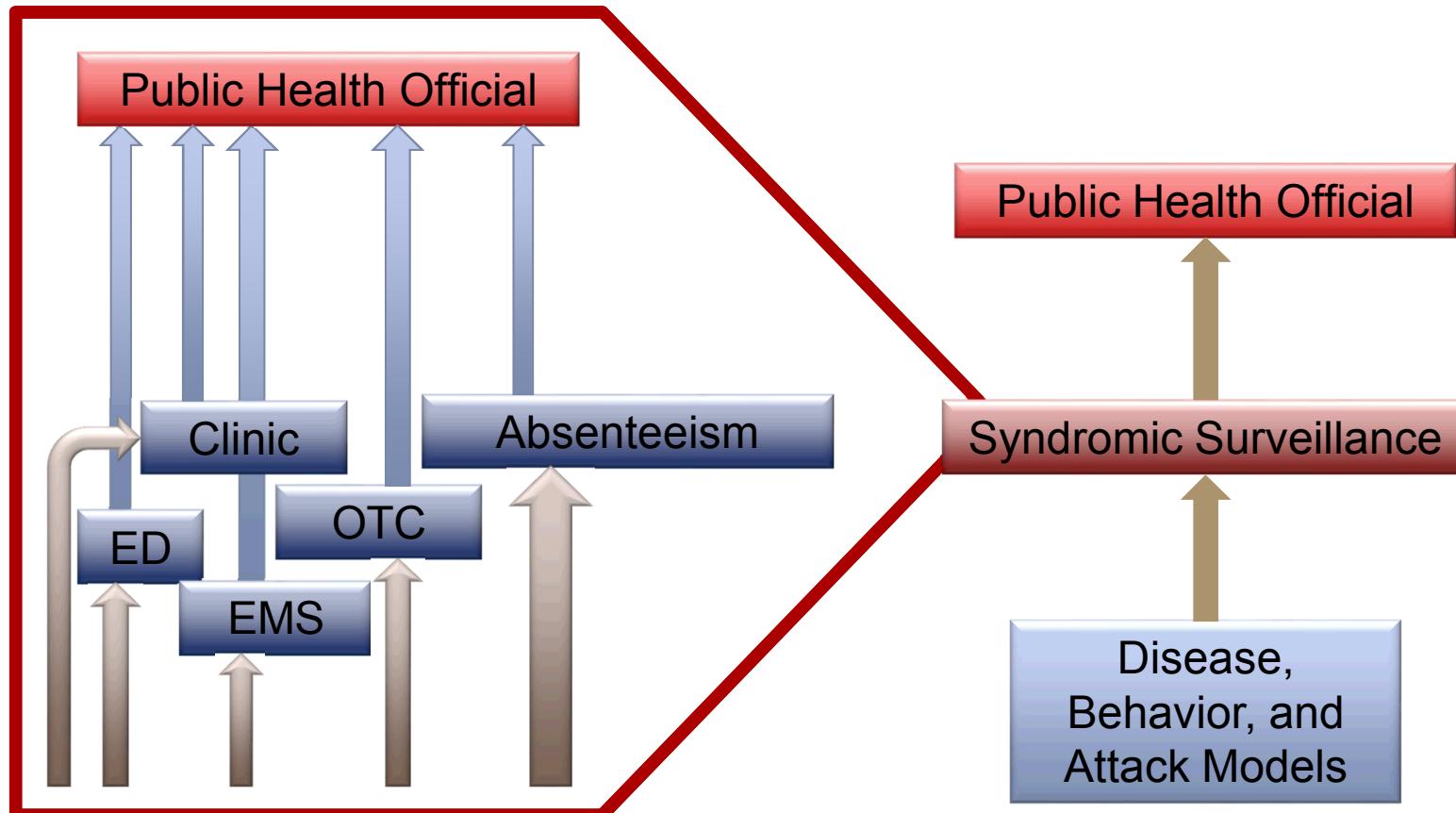
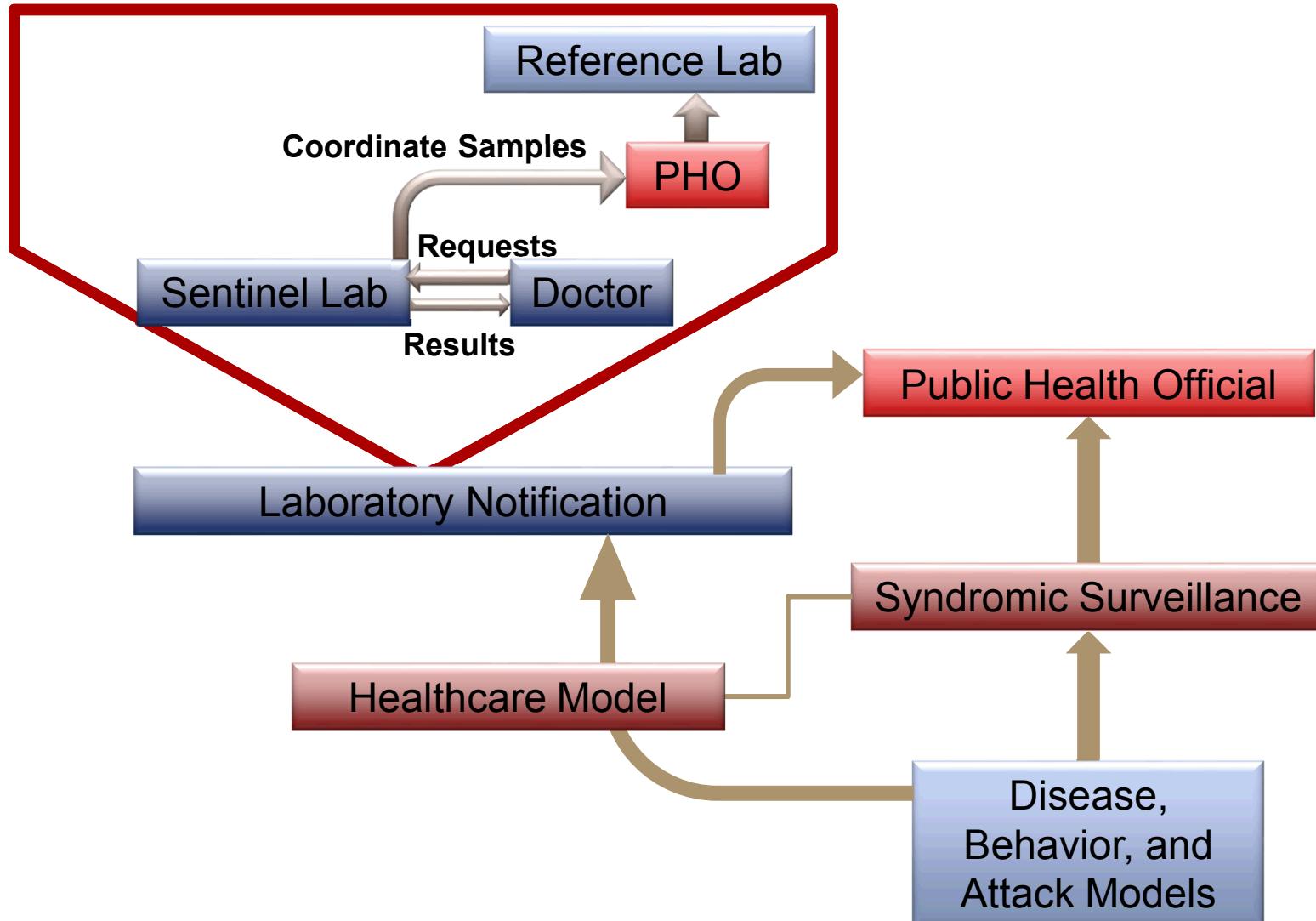-Varies by disease

Plague: 1-2 days

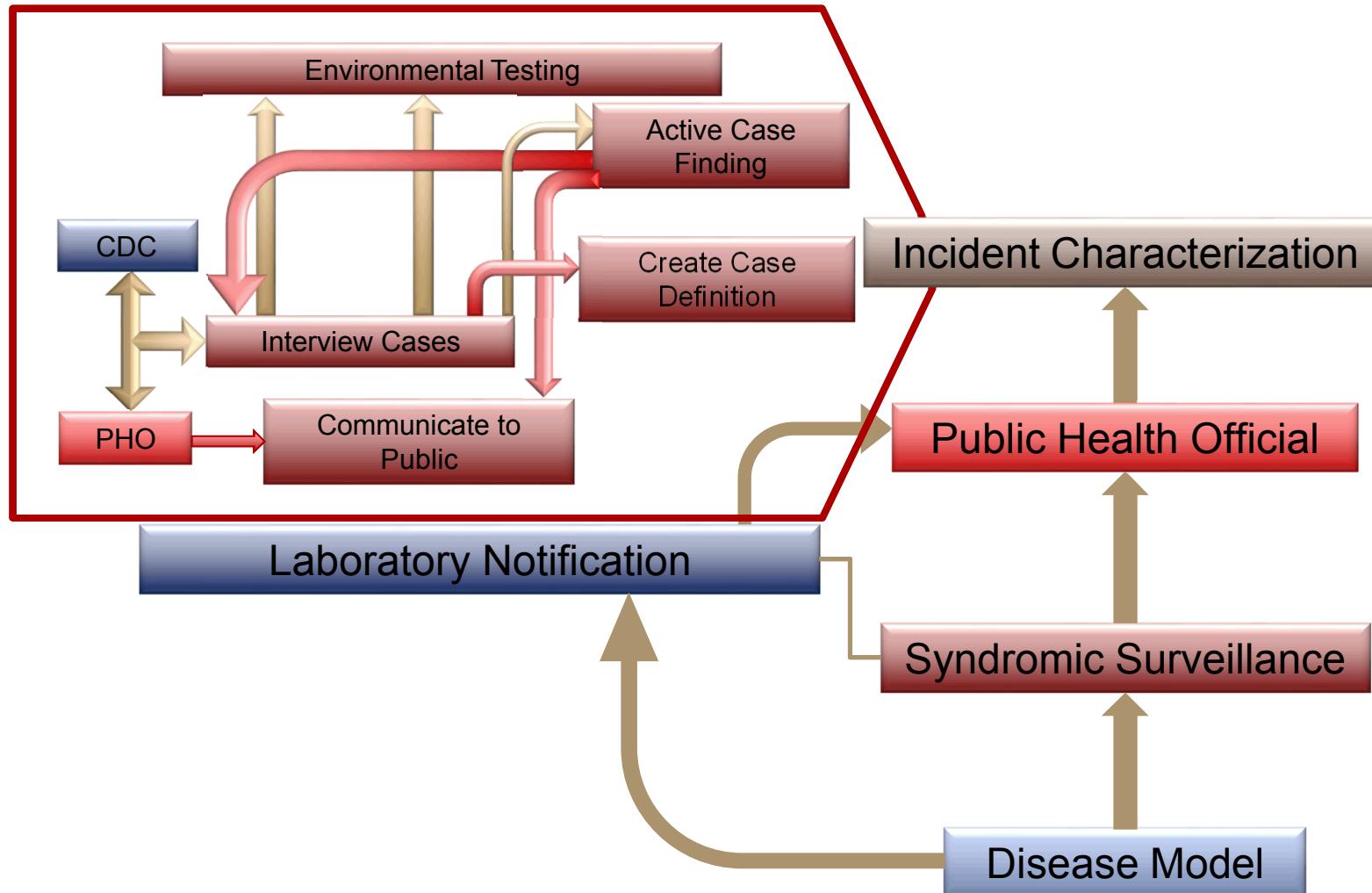Anthrax: 3-4 days

Monkeypox (proxy for smallpox): 2-4 days

Syndromic Model

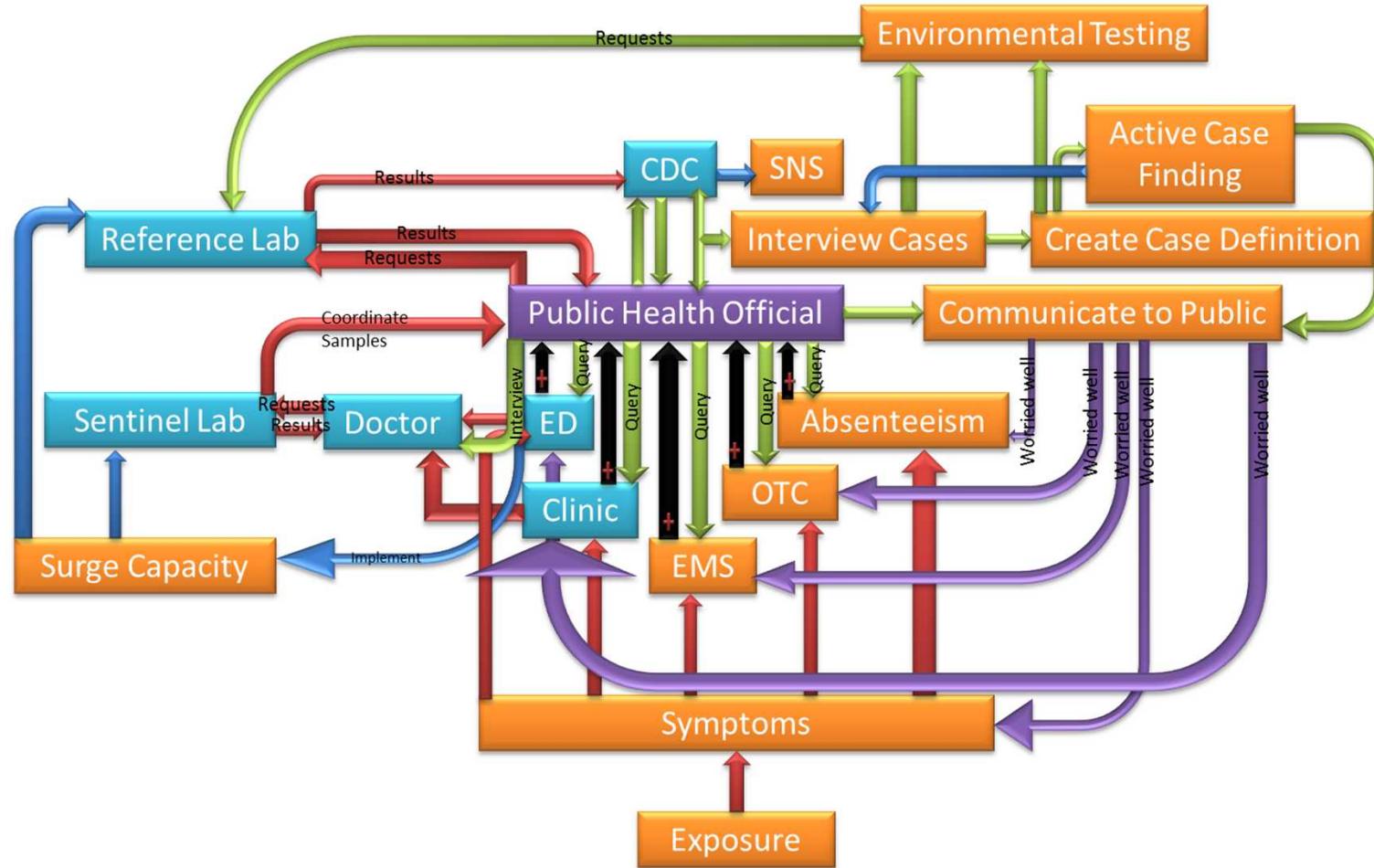# Laboratory Model

Characterization Model

Timeline and Conceptual Model

$$T_{total}=T_{incubation}+T_{time\ to\ seek\ treatment}+T_{doctor\ visit}+T_{culture}+T_{reference\ lab\ culture}+T_{incident\ characterization}$$

How does detection play out in the real world?

Naturally occurring outbreaks happen all the time

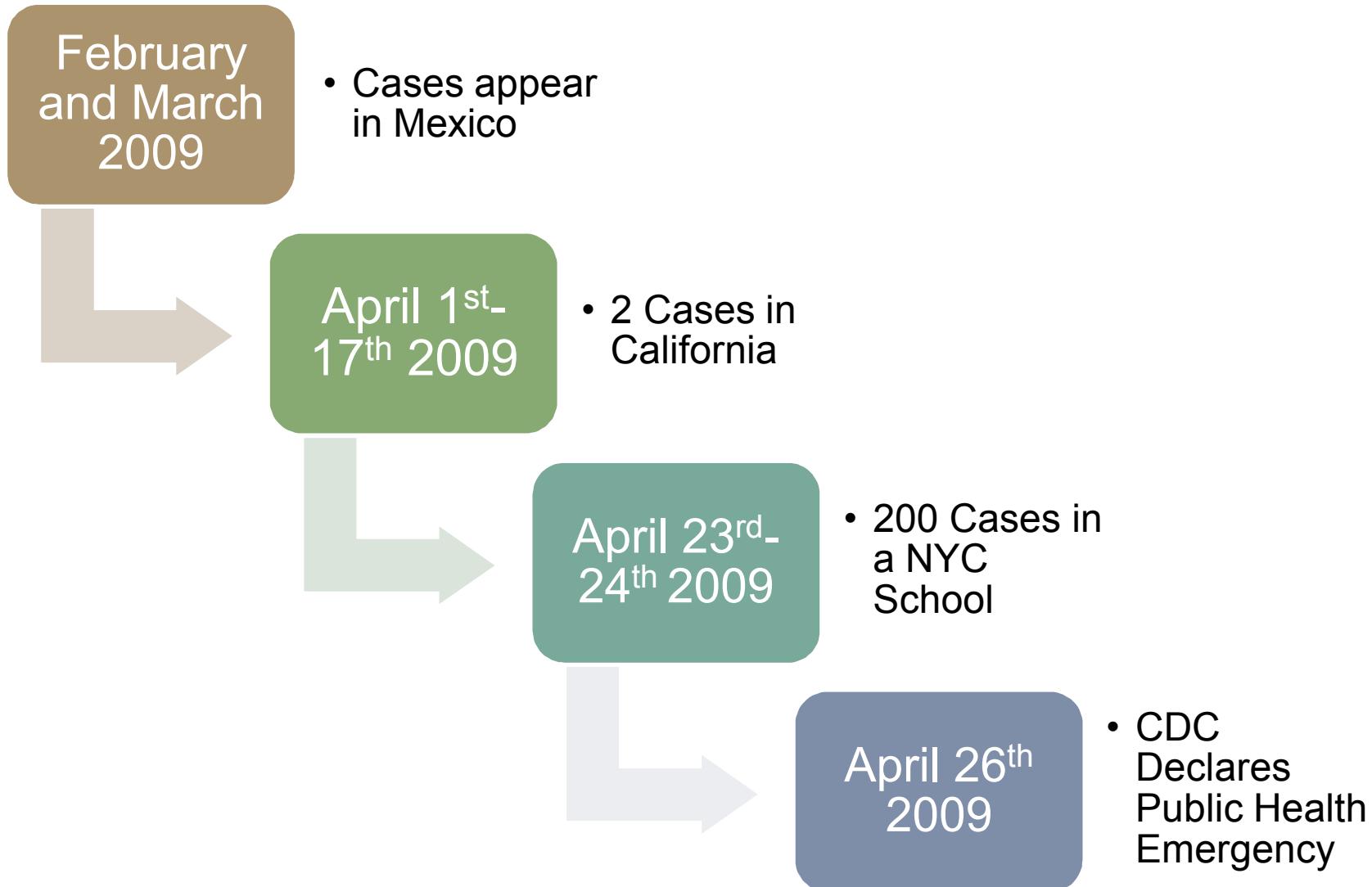- 2009 H1N1 Pandemic

- 2006 Norovirus Epidemic

There has only been one fatal bioterror attack in the US

- 2001 Amerithrax Attacks

2009 H1N1 Pandemic

- Also known as swine flu

- Strain had never been seen in people

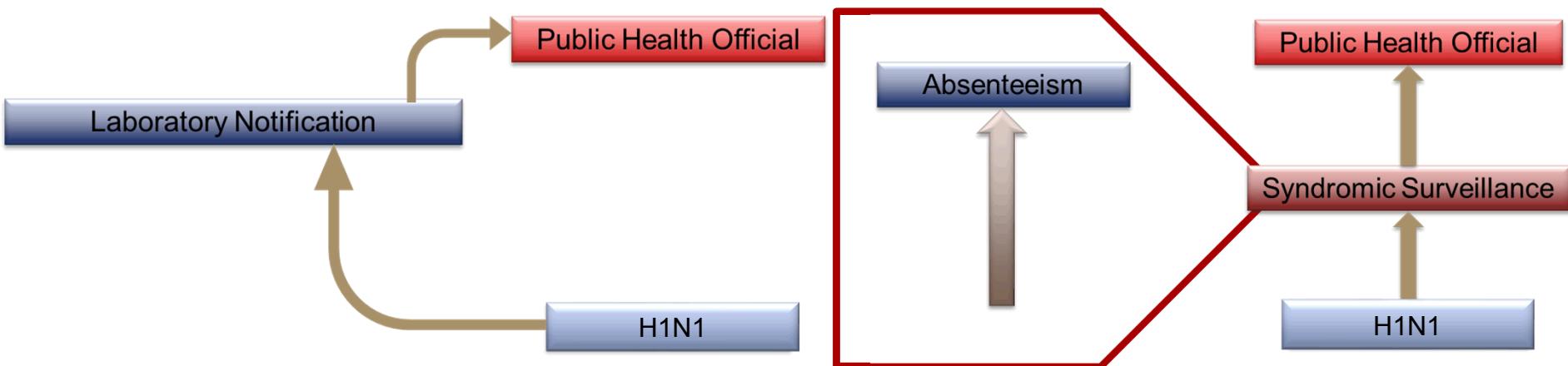- A variety of different surveillance systems led to discovery of pandemic

2009 H1N1 Pandemic Timeline

February and March 2009

- Cases appear in Mexico

April 1st-17th 2009

- 2 Cases in California

April 23rd-24th 2009

- 200 Cases in a NYC School

April 26th 2009

- CDC Declares Public Health Emergency

2009 H1N1 Pandemic Awareness
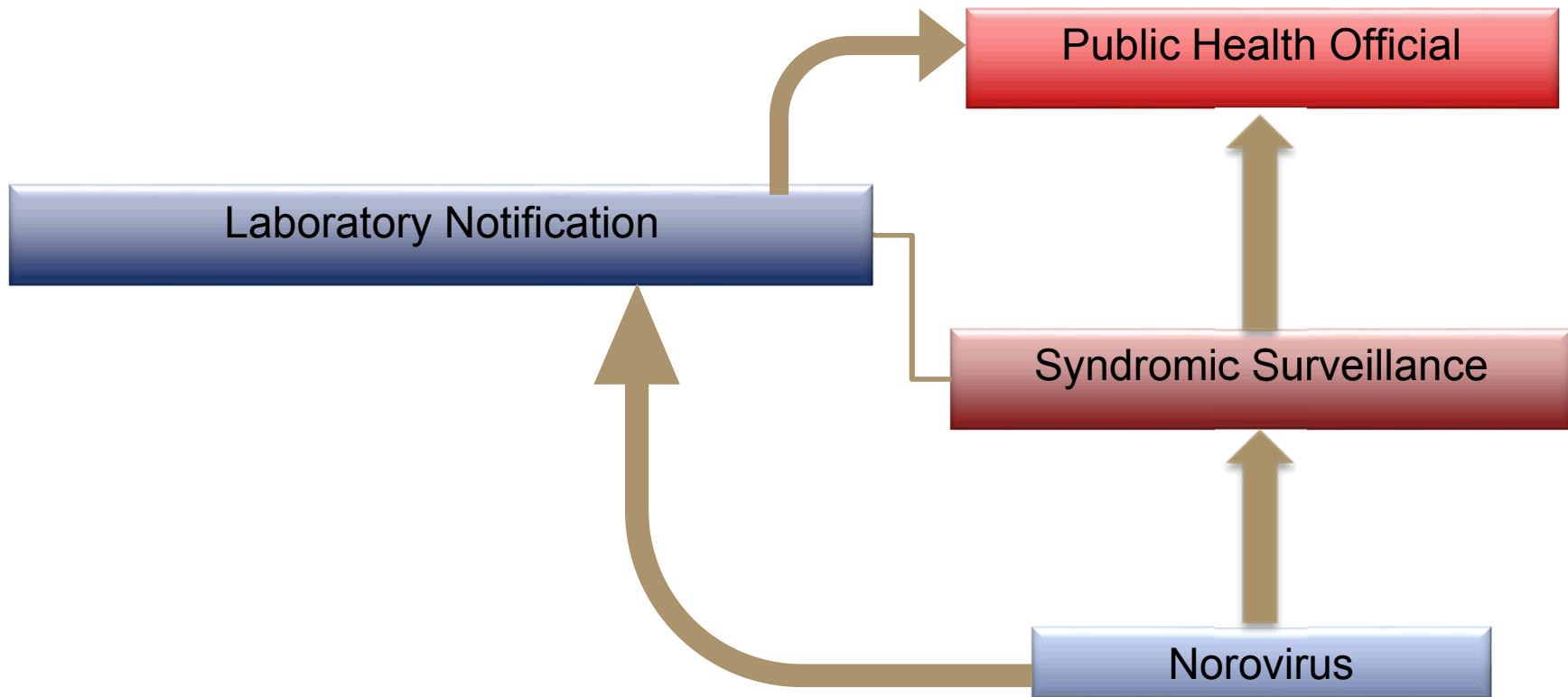
2 Cases in California   **200 Cases in NYC School**

2006 Norovirus Outbreak

- Most common stomach virus

- 19-21 million cases every year

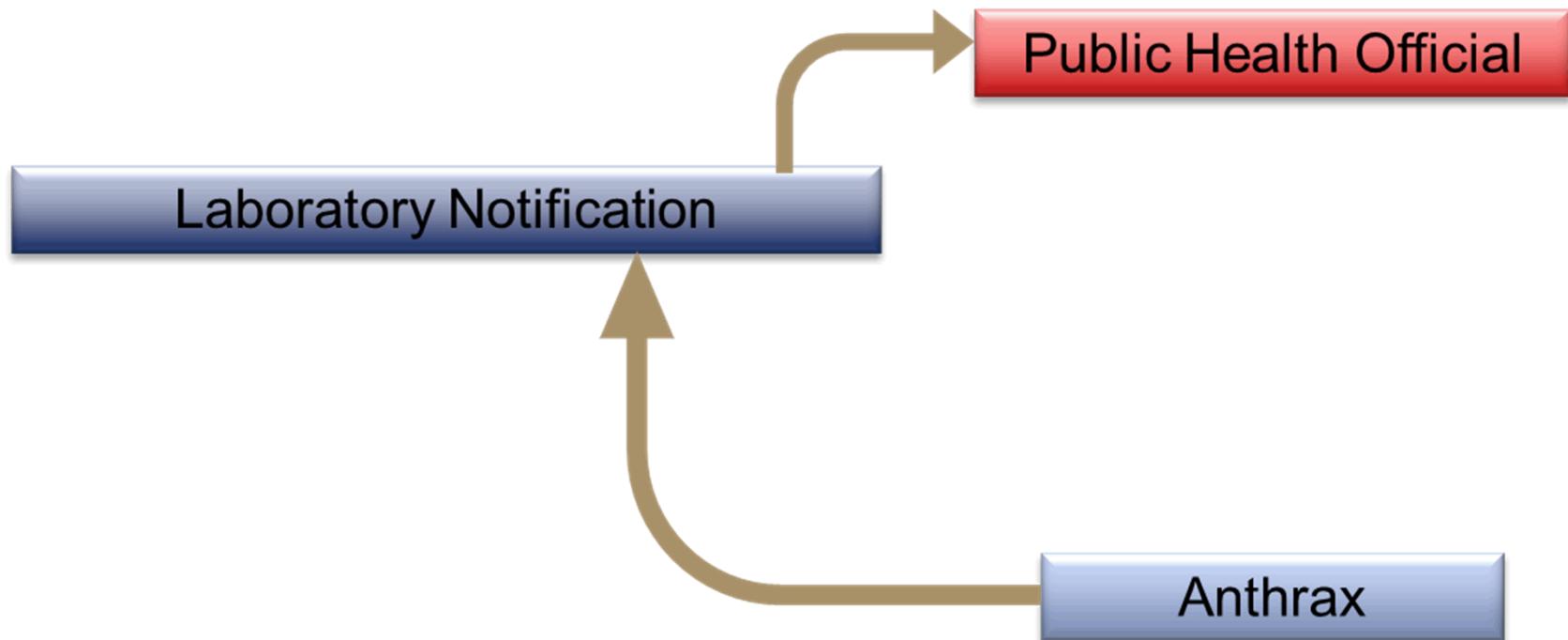- Commonly reported in healthcare facilities

2006 Norovirus Outbreak

2001 Amerithrax Attacks

- October 2001

- 22 cases
  - 11 inhalation anthrax cases (5 deaths)
  - 11 cutaneous anthrax cases (0 deaths)

2001 Amerithrax Attacks

Wrap Up and Next Steps

This is the start of building a conceptual and computer model.

Limitations of the model:

- Very little data to base assumptions
- Public Health Department response plans are often not available to the public

More work needs to be done on:

- Vetting Numbers
- Vetting Decision Making Processes
- Playing out example scenarios

Acknowledgements

I'd like to thank my awesome mentors:

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> Dr. Meghan Peterson

> Dr. Donna Edwards

And all the other wonderful Sandians and interns who made this summer fantastic!

And California for being sunny every day of my internship