# Blood Supply Modeling: Smallpox vaccination example and Applications for Pandemic Influenza

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# Blood Supply Modeling for emerging infectious agents

- **Smallpox vaccination example**
  - Effect of 21 day vaccination campaign on blood supply an **ACUTE** challenge
  - Period of vaccination impact on blood supply short ~ 45d
  - More certainty implementing vaccination campaign

- **Pandemic influenza**
  - Significant UNCERTAINTY of epidemic, duration, etc.
  - Effect of Pandemic on blood supply **SUSTAINED** and **LONGTERM** challenge (6 months to 18+ months)
  - Incorporate Blood Center / Support / healthcare staffing
  - Our modeling efforts influenza & blood supply – initial stages

# Smallpox Vaccination

- Since 2001 Government agencies developed plans to vaccinate US population should smallpox emerge
- Live virus vaccine -Vaccinia virus (cow pox)
- Viremia - vaccinia bloodstream 3-10 days post-vaccination
- Vaccinia transfused into immunocompromised may have serious consequences (generalized vaccinia, etc.)
- Assume minimum 21 days for vaccination recovery and deferral

# Blood supply modeling question

- What would be the impact of a 21 day smallpox vaccination campaign on the US blood supply?

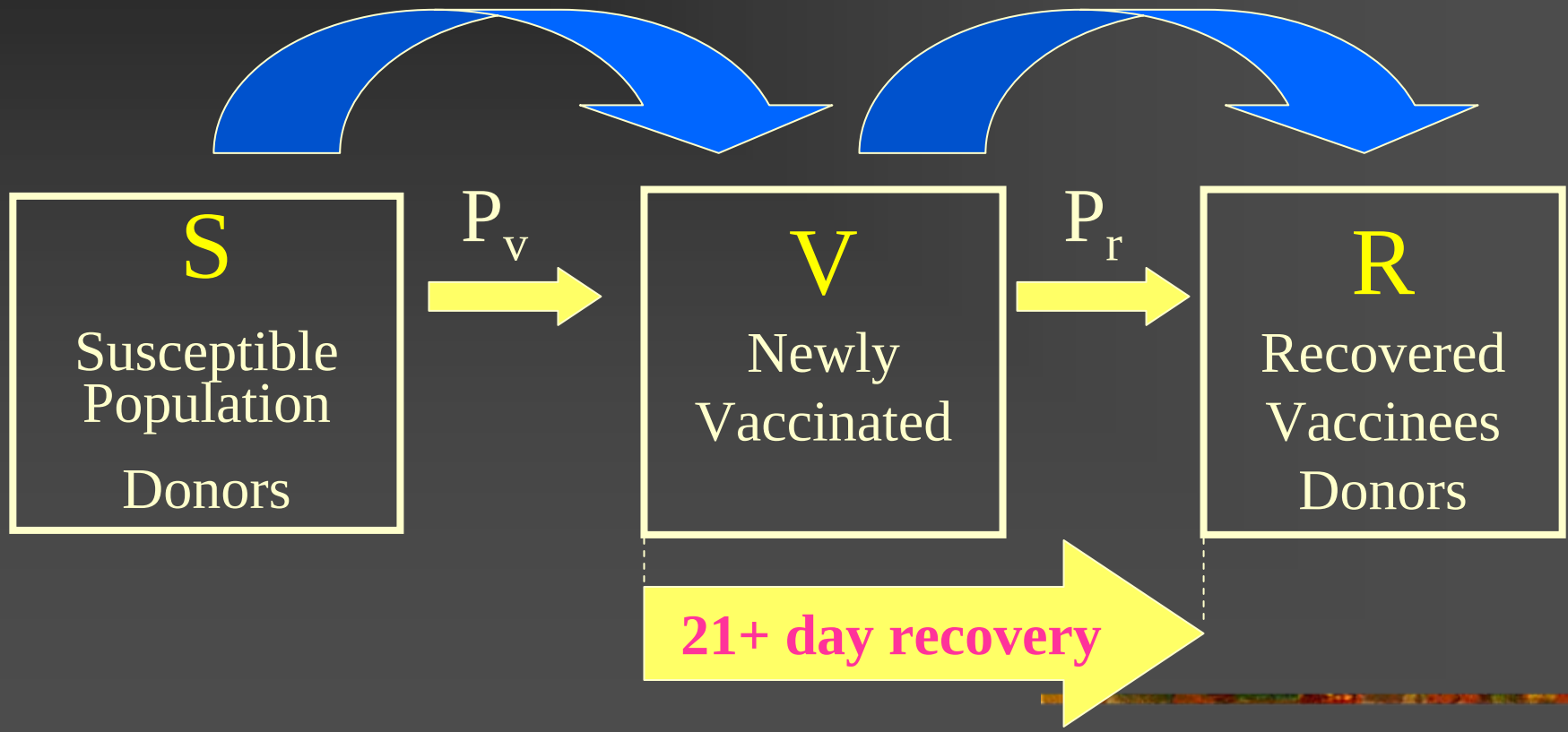
# Modeling Approach

Combine

- A. **Infectious Disease Model**
  - Number donors affected vaccination and deferred
- Link results with
- **B. Blood Supply Model** (Supply and Demand)
  - Supply - Collection from capable donors
  - Demand – Need / Utilization by patients, etc.

# A. Infectious Disease Modeling of US donor population

Susceptible, Vaccinated (Infected), Recovered (SV(I)R)



# B. Blood Supply Modeling: Key Variables

- Total Amount of blood available ($B_a$)
- Amount (or rate) of daily blood collected ($B_c$)
- Susceptible daily donor pool (un-vaccinated) (S)
- Recovered daily donor pool (R)
- Amount (or rate) daily blood utilized ($B_u$)

# B. Blood Supply Modeling (cont'd)

Model estimates cumulative total amount of blood available on a given day:

$$B_a = \sum (B_c)(S) + (B_c)(R) - B_u$$

**Collections (supply)**

**Utilized (demand)**

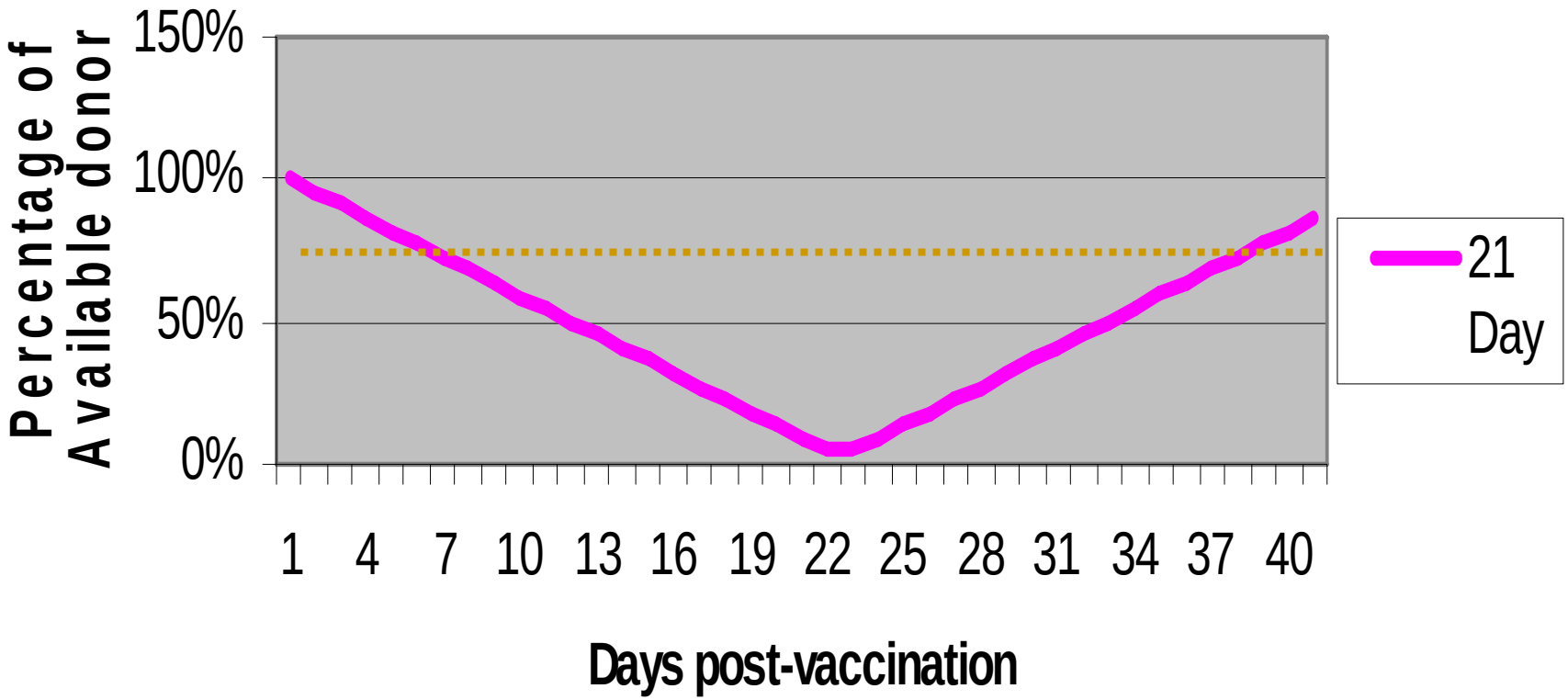
Model provides graphical output of available blood units for US

Modeling done using Microsoft Excel

# US Whole Blood System Assumptions used in Supply Model

- Approximately 14 million units donated / yr
- ~ 38,500 units donated / day (Bc)
- ~30,500 units utilized / day (Bu)
- Approximately 5% population donate
- About 60% of population qualified donors
- Store refrigerated for 42 days
- Can donate once every 56 days

# Donor Availability - during a 21 day vaccination program



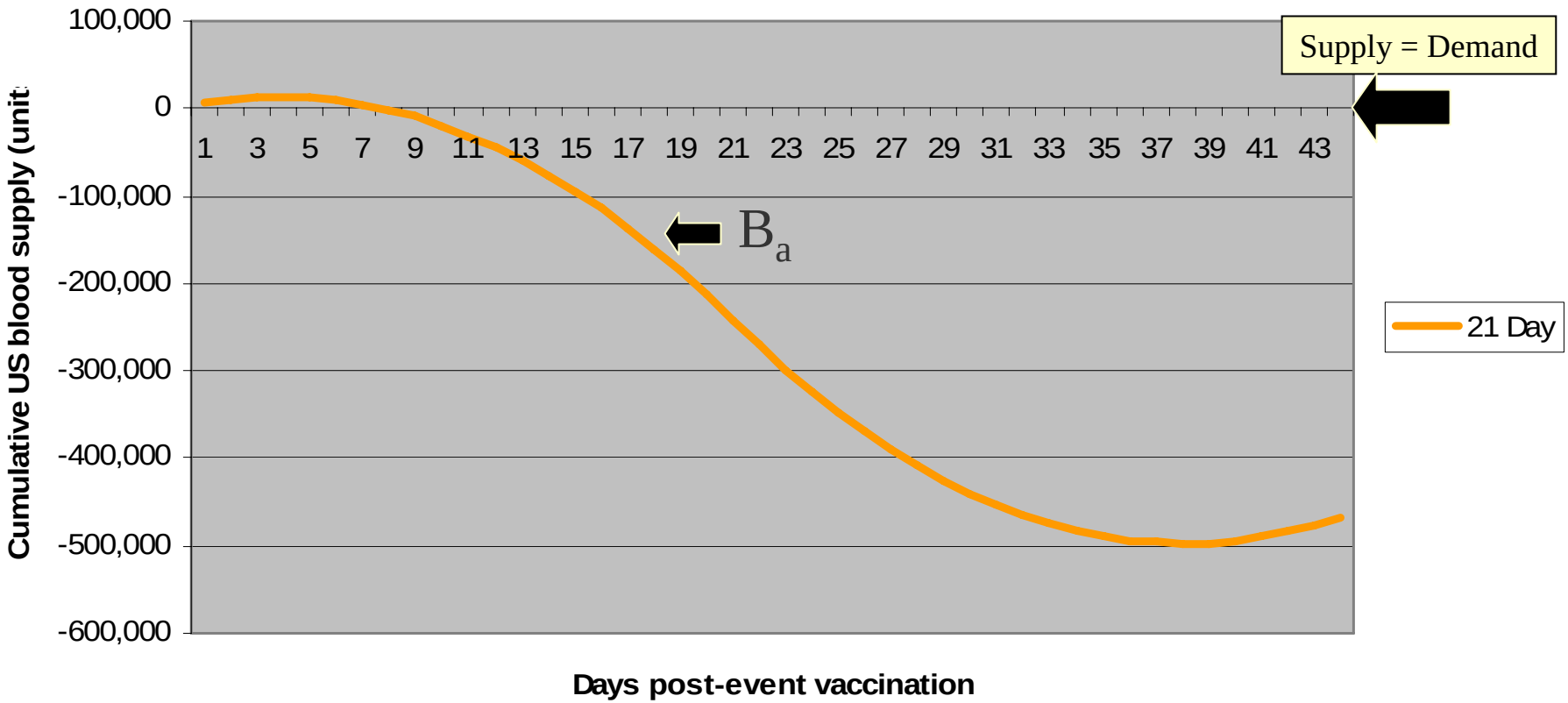
Modeling can evaluate interventions to preserve blood supply

prior to potential smallpox event:

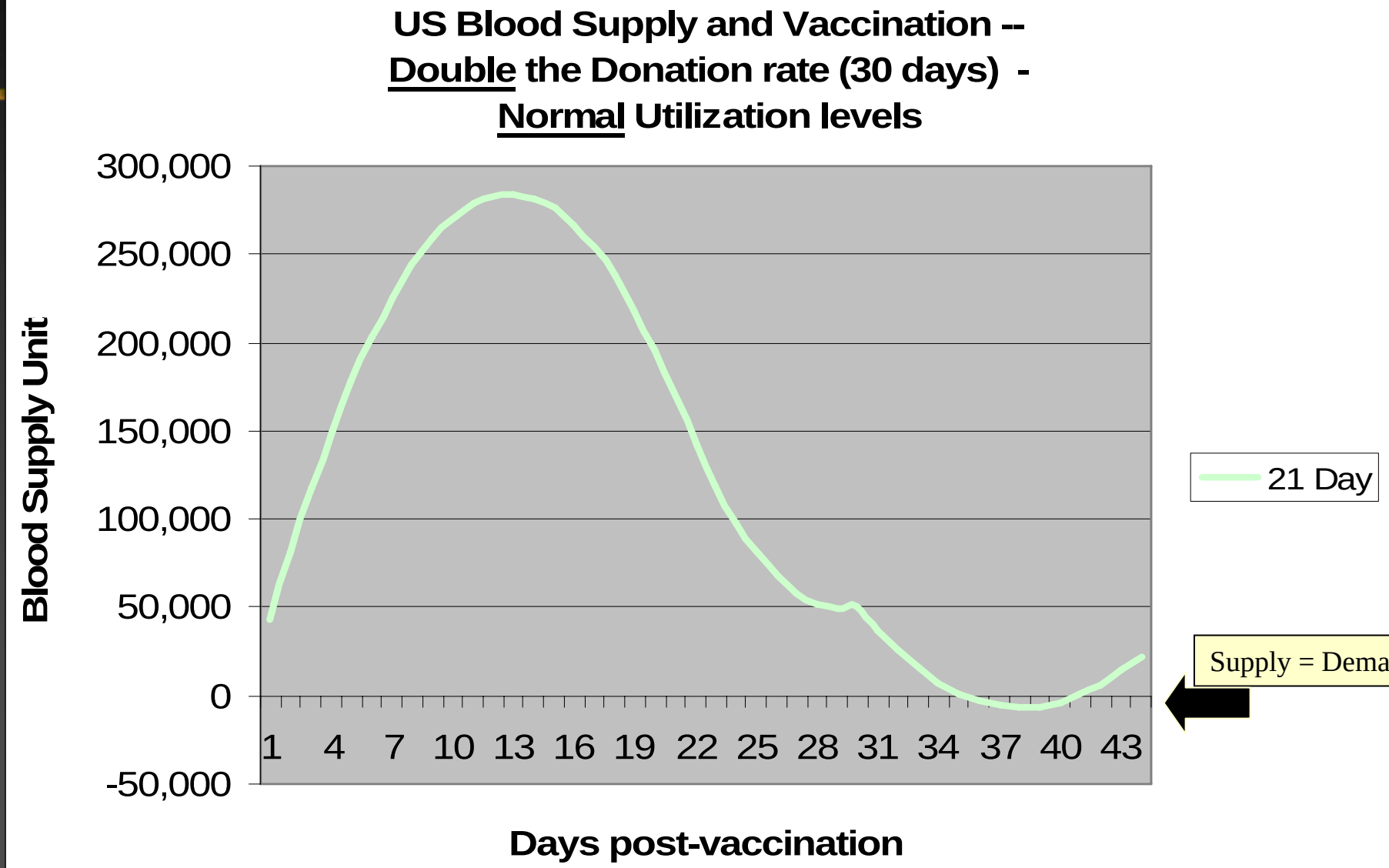
1. **Policy that increased donation rate by 200%**

2. **Emergency utilization policy (50% reduction utilization)**

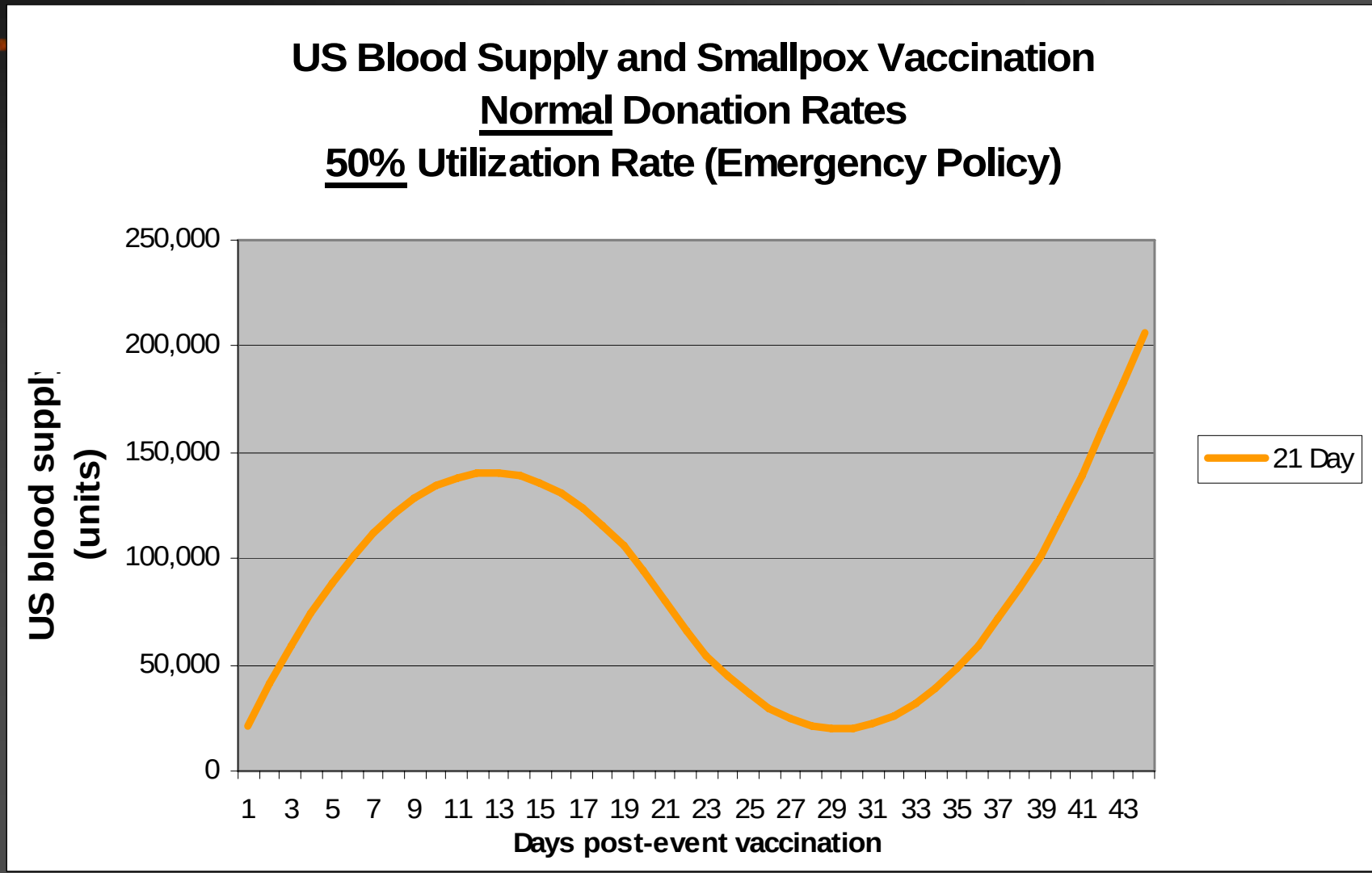
# Vaccination: Assuming no interventions to preserve supply (unlikely scenario)



# Increased Donation Rate by 200%

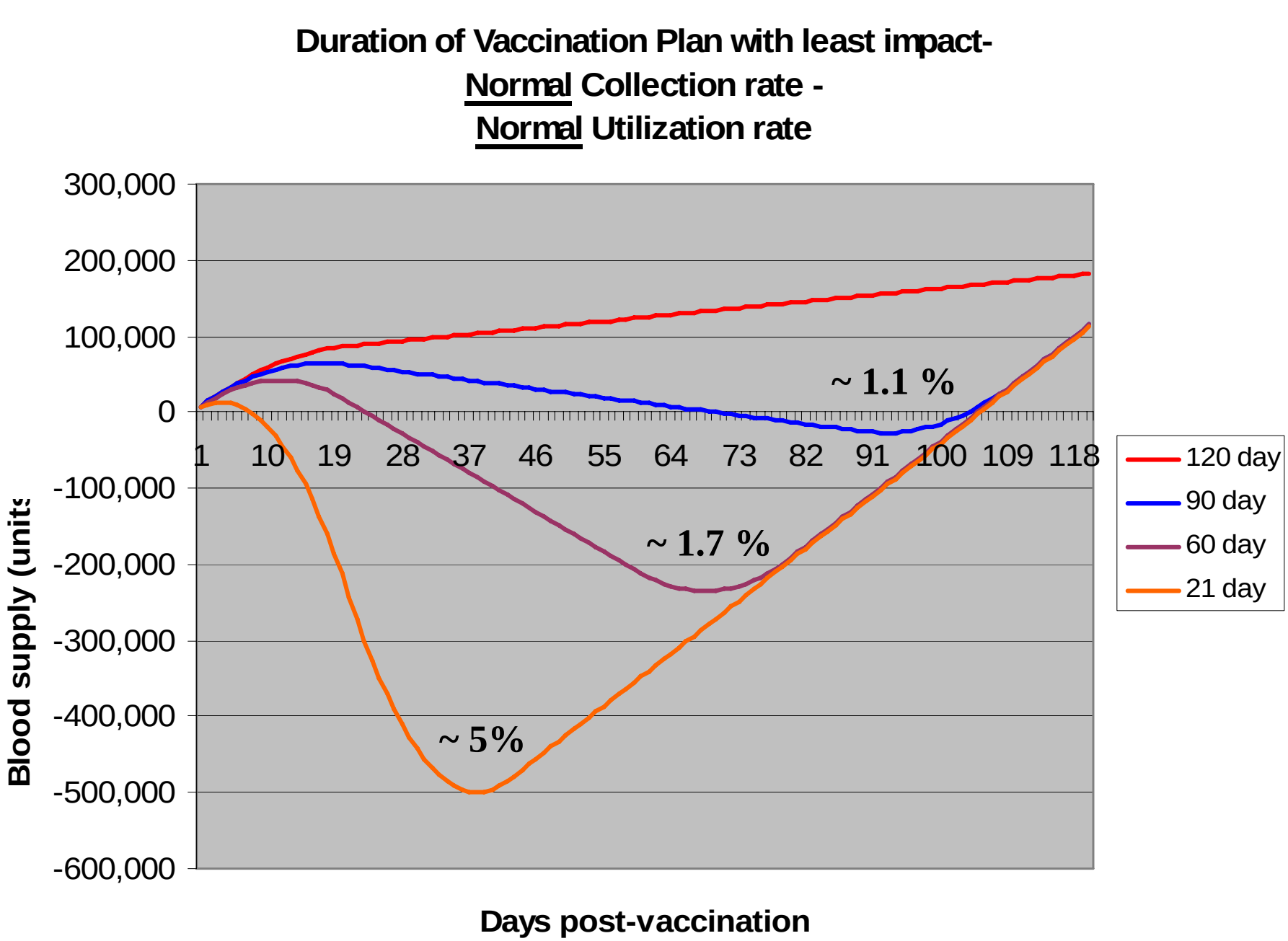


# Emergency utilization policy (50% reduction utilization)



# Question:

What duration of vaccination program will result in little or no disruption of the US blood supply?


Duration of Vaccination Plan with least impact-
Normal Collection rate -
Normal Utilization rate
300,000
200,000
100,000
0
-100,000
-200,000
-300,000
-400,000
-500,000
-600,000
1
10
19
28
37
46
55
64
73
82
91
100
109
118
~ 1.1 %
~ 1.7 %
~ 5%
120 day
90 day
60 day
21 day
Blood supply (units
Days post-vaccination

# Summary

- Modeling can provide important information for decision makers into the impact of vaccination or an infectious agent on the blood supply
- Models can identify strategies to mitigate impact of vaccination on the blood supply
- Smallpox vaccination campaign >20 days may require 1 or a combination of interventions to maintain supply
- Campaign >90 days may have little impact on the blood supply

# Pandemic Influenza

# Pandemic Influenza Considerations for Modeling

- UNCERTAINTY, UNCERTAINTY, UNCERTAINTY
- Viremia – possible?  if so, duration?
- Pathogenesis – mortality rate, age specificity, etc.
- Deferrals –
  - Flu symptoms – fever, etc.
  - Exposure – family members, etc.

- Fear  - Individuals fear of public places
- Effect on blood collection centers/support infrastructure and healthcare providers

# **Proposed** Modeling Approach: Influenza Impact on Blood Supply

Combine

- **Infectious Disease Model**
  - Number donors affected by Influenza
  - Calculate susceptible, infected, recovered populations based on
    - Historical trends
    - Published literature – Influenza modeling (Longini, Halloran, Meltzer, Valleron, others)
  - Issues – incubation period, duration of epidemic, etc.

Link results with

- **Blood Supply Model** (Supply and Demand)
  - Supply - Collection from capable donors
  - Demand – Need / Utilization by patients, etc.

# A. Infectious Disease Modeling of Influenza and US donor population

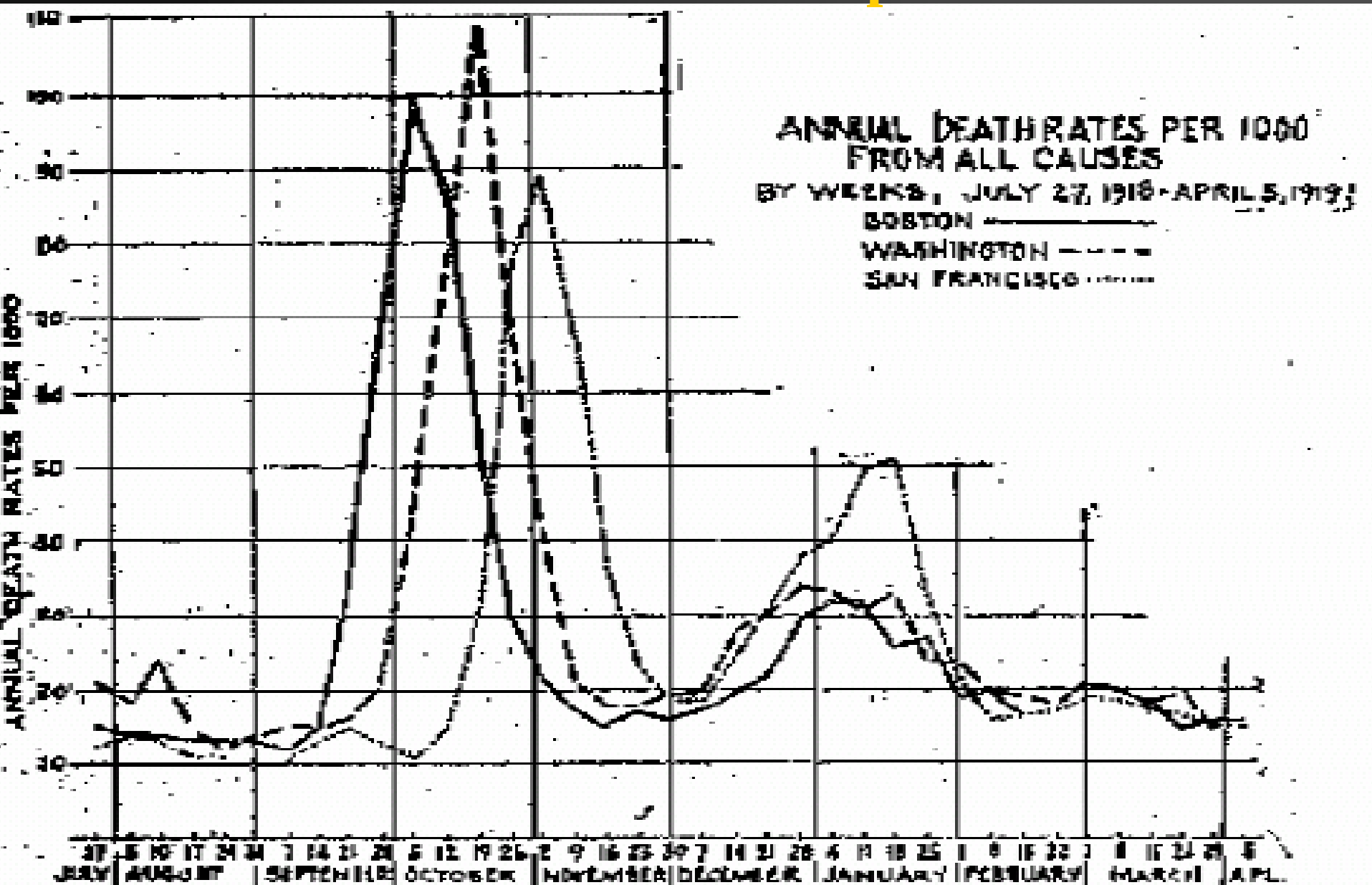
**Approach:**

- Assume up to one-third US population affected (100 million)

- **Working with DHHS, Government agencies, stakeholders other partners**
  **Develop multiple epidemic scenarios based on historical trends and / or published literature**
  - **Most likely**
  - **Worst case (for blood supply)**
  - **Interventions**

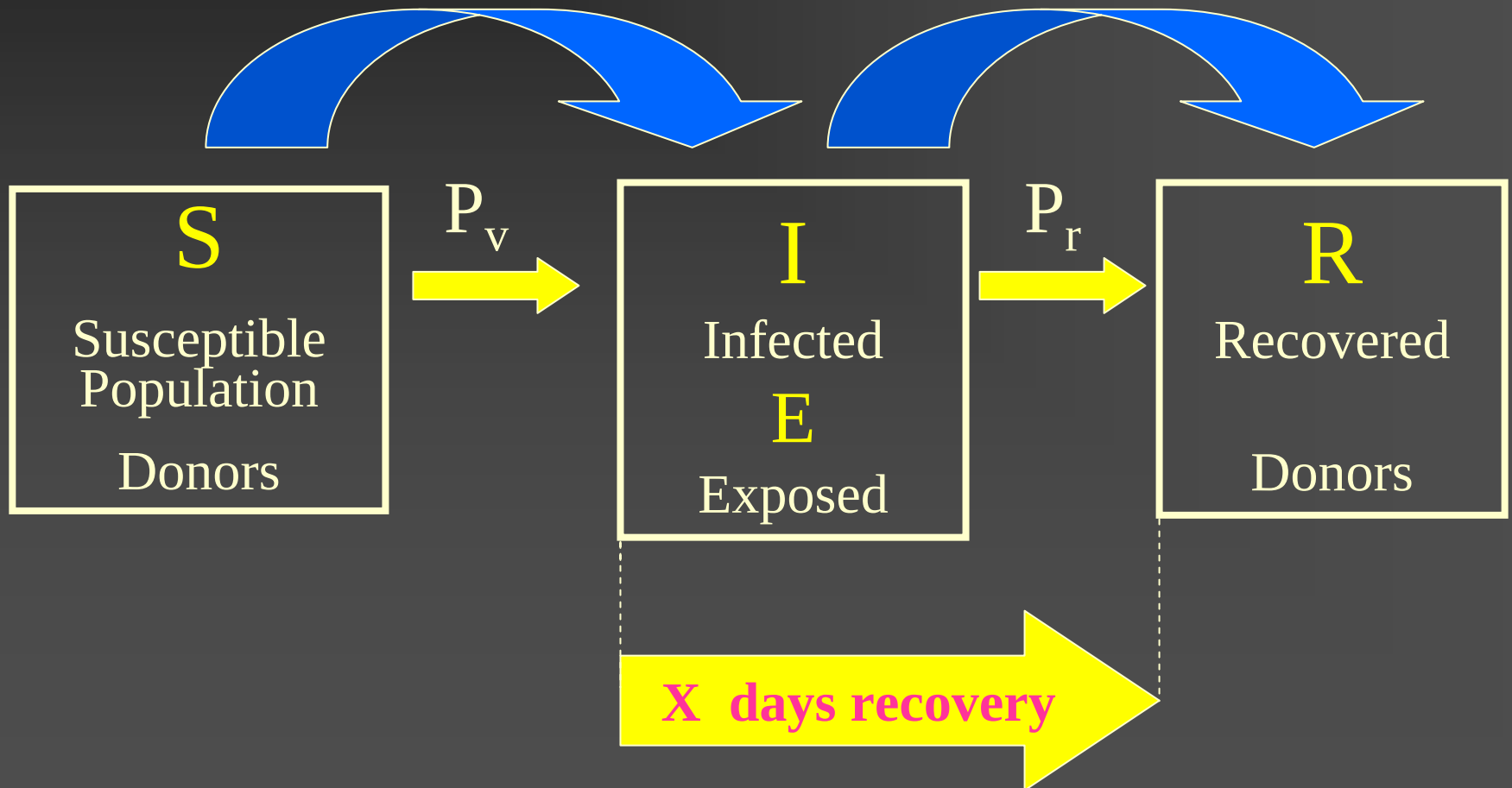
- Example scenario:
  Do a proportional fit of 100 million influenza cases to infection/mortality curves for 1918 influenza and determine impact on current US blood supply

# 1918 Influenza: Death Rates for 3 US Cities
## Two waves of epidemic



# A. Infectious Disease Modeling of Influenza and US donor population

Susceptible, Infected (Exposed), Recovered (SI(E)R)



# Pandemic Influenza Possible Assumptions

## DHHS Pandemic Influenza Plan

- Susceptibility Universal
- One-Third US population affected (100 million)
- Incubation time approximately 2+ days
- Multiple waves of illness (2 – 3 mos per wave)
- 50% will seek outpatient care
- 1% – 10% hospitalized
- Infection provides immunity
- Many others

# Pandemic Influenza Additional Aspects to add to model

**Infectious Disease Model**

- Antiviral treatment
- Vaccination

**Blood Supply Model**

- Impact on blood center staff and collections
- Age groups ( ≥18yrs, >65yrs, etc. )
- ABO and Rh+/-
- US geographic regions
- Seasonality

# Modeling Pandemic Influenza and Blood Supply: Potential Outcomes

- Pandemic influenza may have a sustained, long-term impact on donor population and blood supply
- Modeling can estimate potential effects on blood supply
- Identify interventions to maintain supply
- Interventions may utilize flu-recovered populations as potential donors, esp in later stages of pandemic

# Summary: Pandemic Influenza and Blood Supply

- Modeling of potential influenza scenarios and impact on blood supply in initial stages
- Considerable uncertainties in course and evolution of pandemic and effect on blood supply
- Influenza/Blood supply modeling will require input from many sources – DHHS, stakeholders, academics, others
  - Require Data and Research
  - **Modeling is RESEARCH**
- Generate a useful product and outputs to inform planning efforts to maintain blood supply

# Thanks !