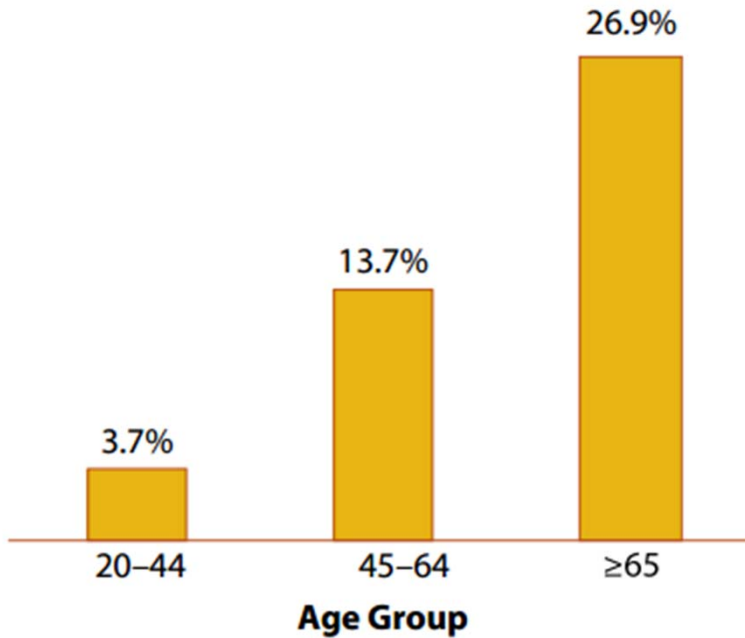
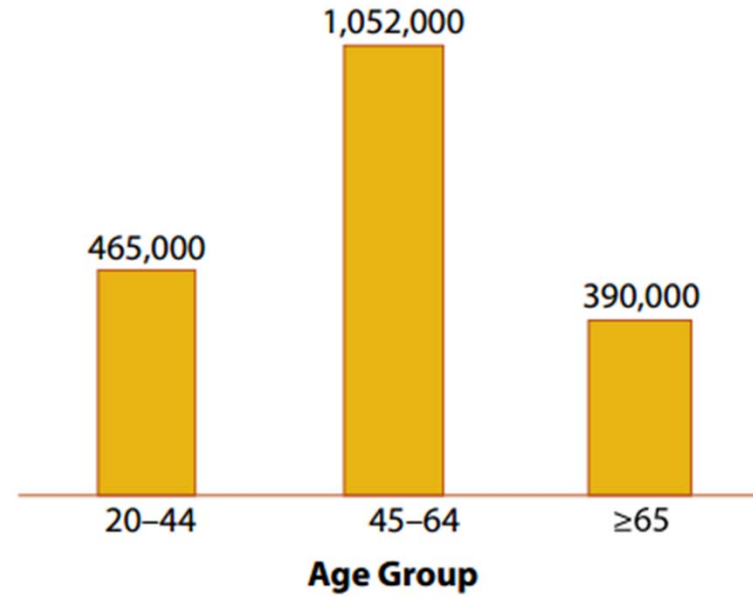


# Process Control Case Study

# CDC Diabetes Statistics



Source: 2005–2008 National Health and Nutrition Examination Survey

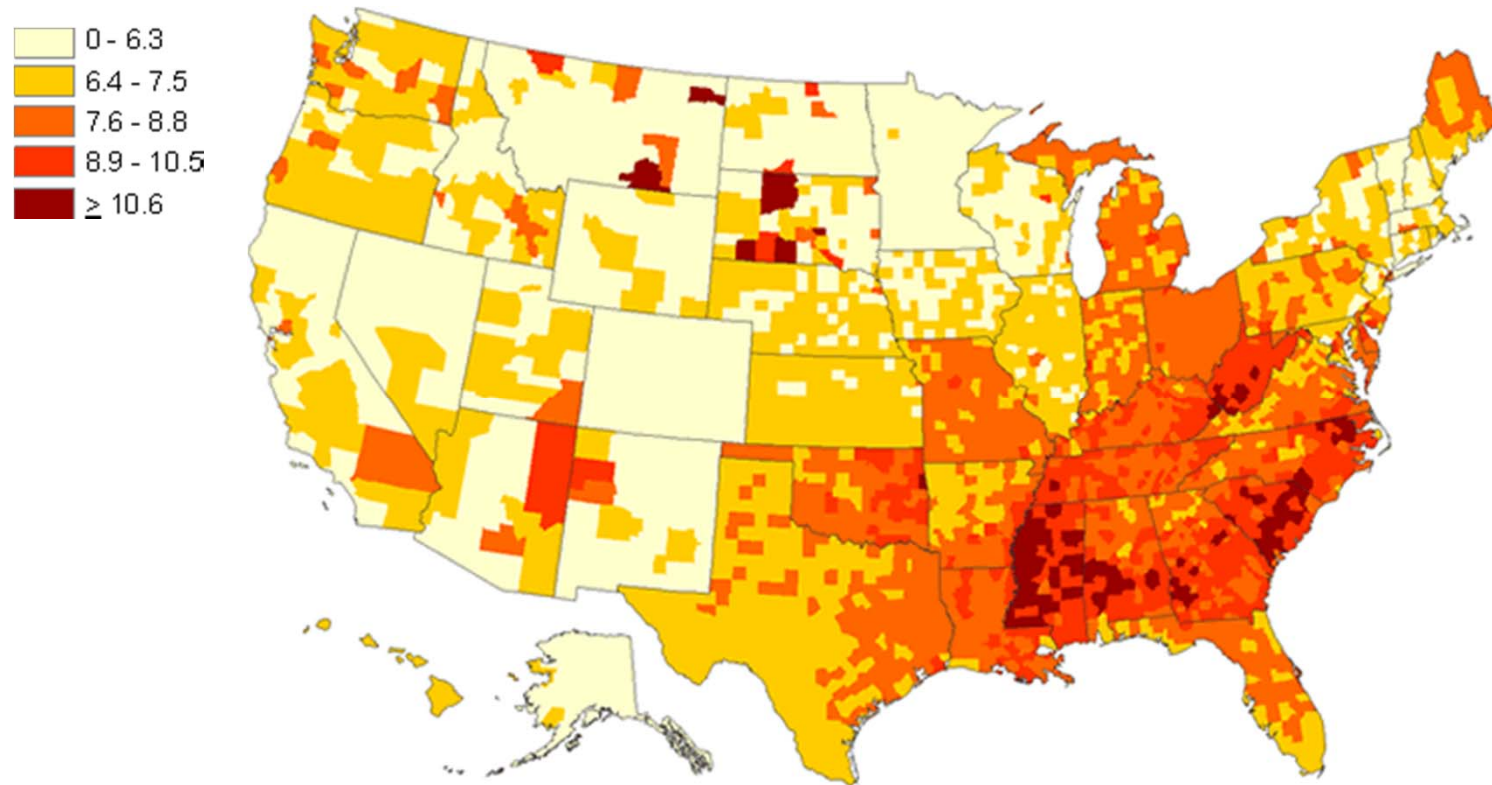


Source: 2007–2009 National Health Interview Survey estimates projected to the year 2010

Diagnosed and undiagnosed diabetes among people aged 20 years or older, United States, 2010	
Group	Number or percentage who have diabetes
Age ≥20 years	25.6 million or 11.3% of all people in this age group
Age ≥65 years	10.9 million or 26.9% of all people in this age group
Men	13.0 million or 11.8% of all men aged 20 years or older
Women	12.6 million or 10.8% of all women aged 20 years or older
Non-Hispanic whites	15.7 million or 10.2% of all non-Hispanic whites aged 20 years or older
Non-Hispanic blacks	4.9 million or 18.7% of all non-Hispanic blacks aged 20 years or older

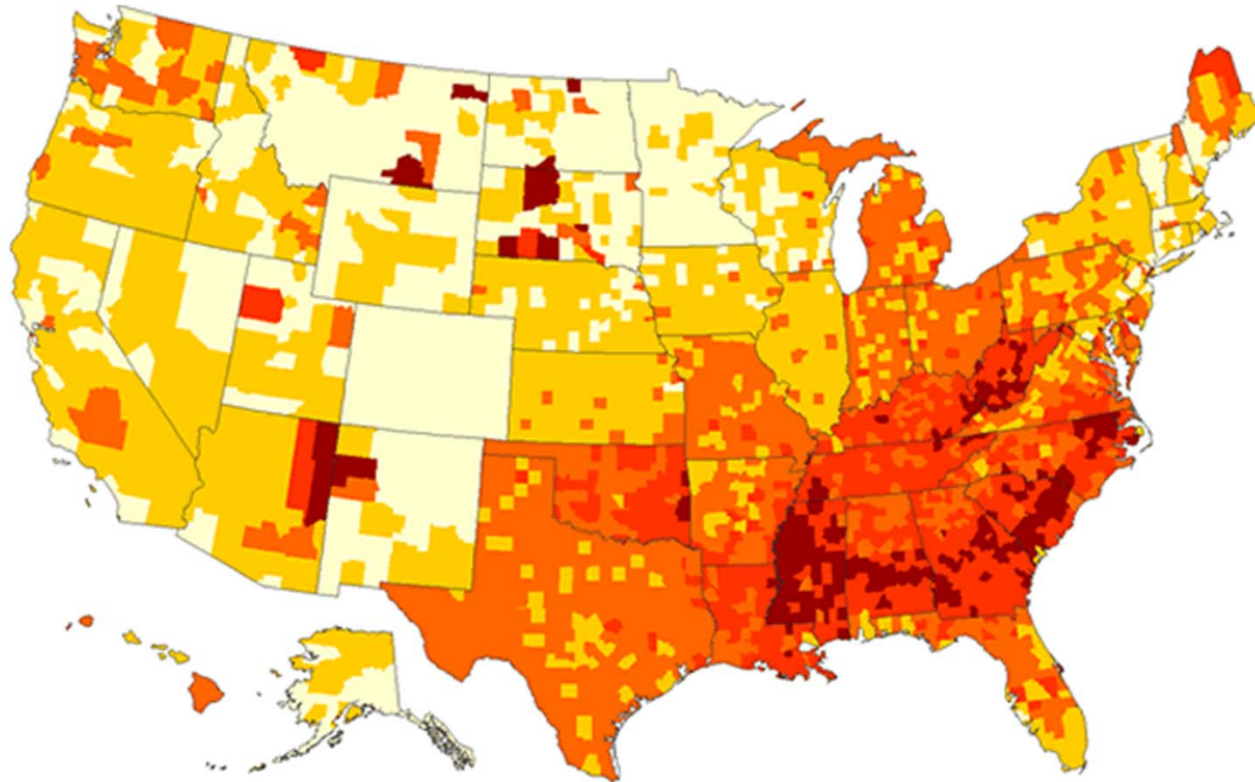
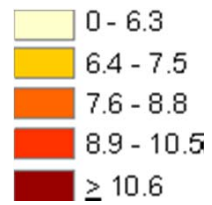
# Diabetes Mellitus

- 2004 - CDC Statistics



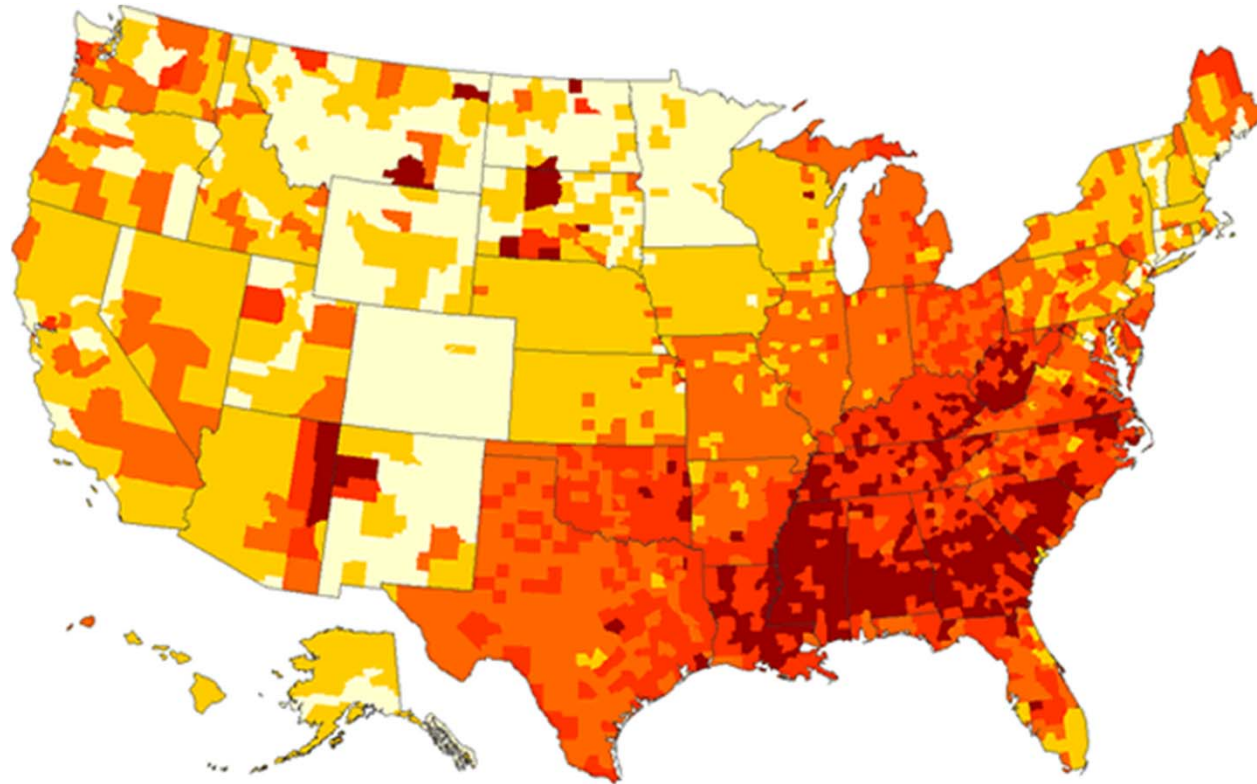
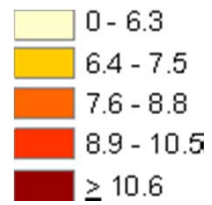
# Diabetes Mellitus

- 2005 - CDC Statistics



# Diabetes Mellitus

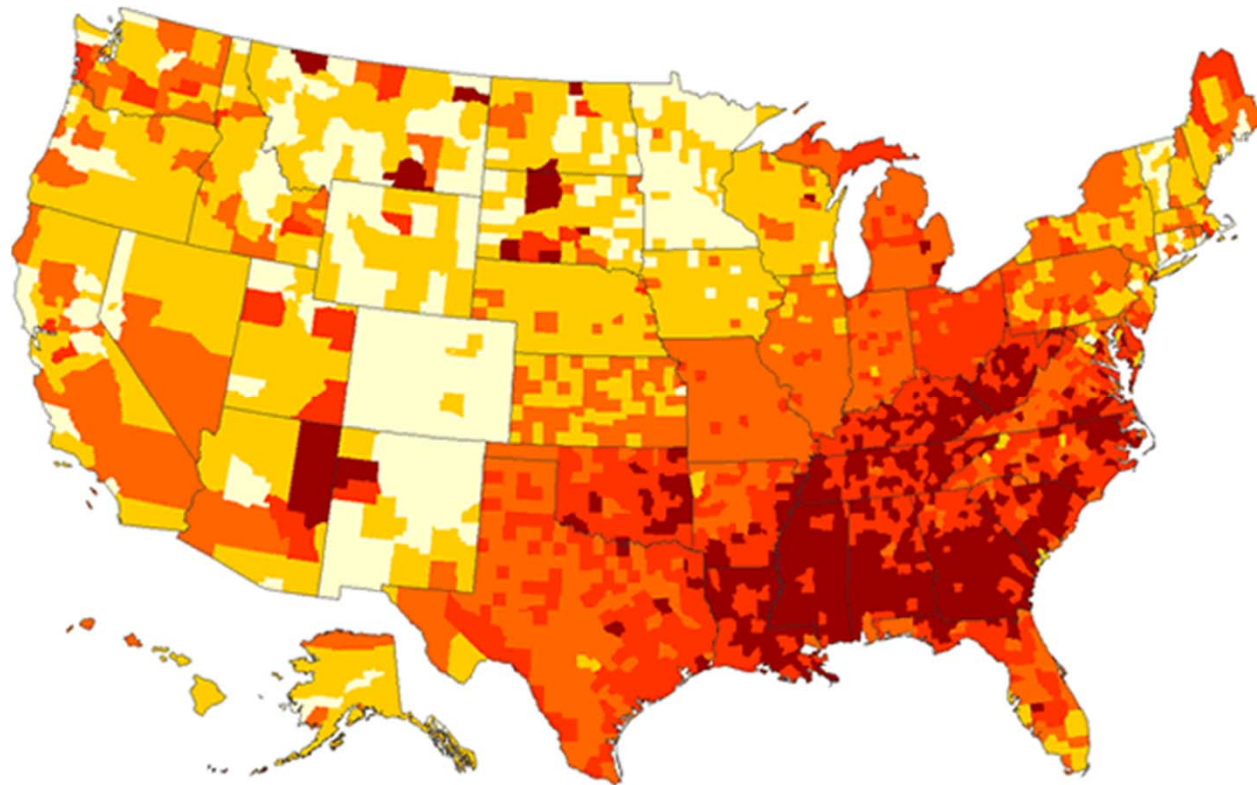
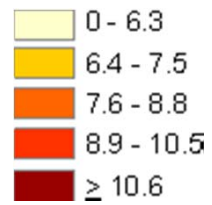
- 2006 - CDC Statistics





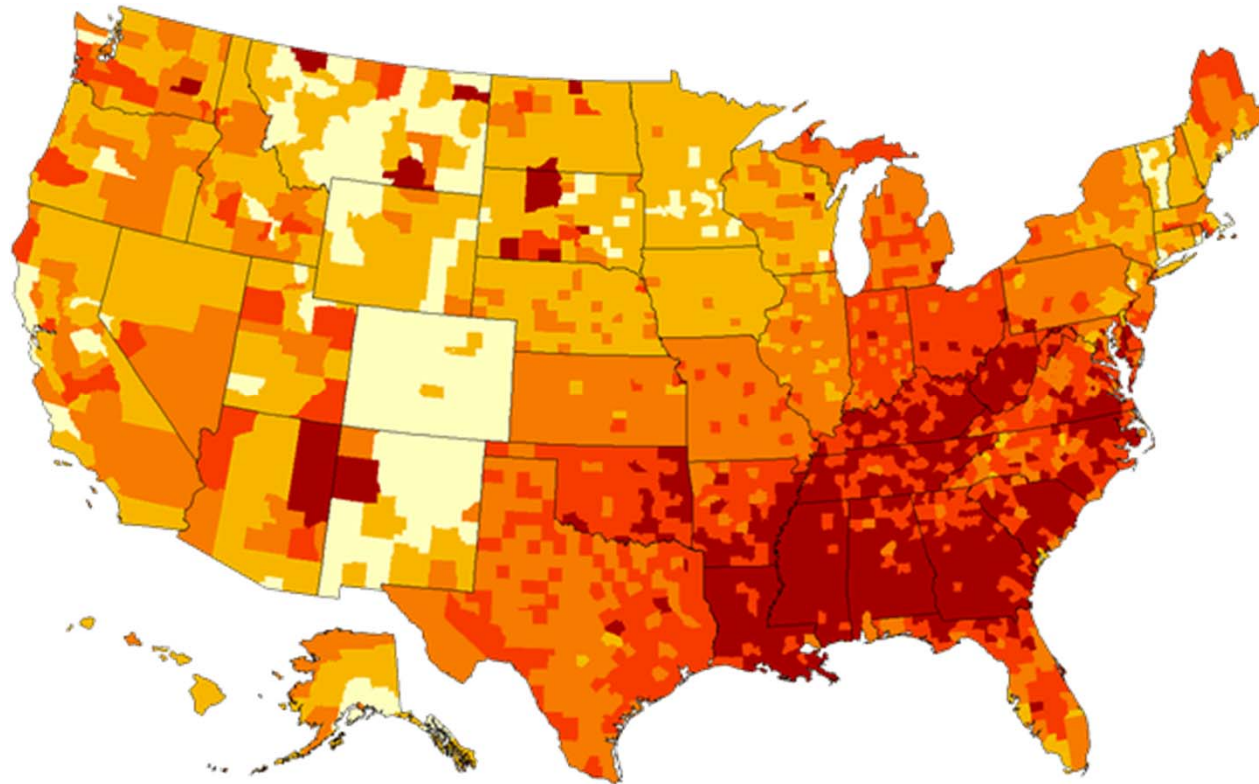
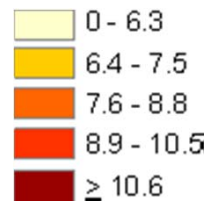
# Diabetes Mellitus

- 2007 - CDC Statistics



# Diabetes Mellitus

- 2008 - CDC Statistics



# Diabetes Mellitus

- 26 million Americans (8.3%)
- 79 million with pre-diabetes (25%)
- 33% with diabetes by 2050 if trend continues

## Estimated diabetes costs in the United States, 2007

<b>Total (direct and indirect)</b>	\$174 billion
<b>Direct medical costs</b>	\$116 billion  After adjusting for population age and sex differences, average medical expenditures among people with diagnosed diabetes were 2.3 times higher than what expenditures would be in the absence of diabetes.
<b>Indirect costs</b>	\$58 billion (disability, work loss, premature mortality)

*Medical expenses for people with diabetes are more than two times higher than for people without diabetes.*



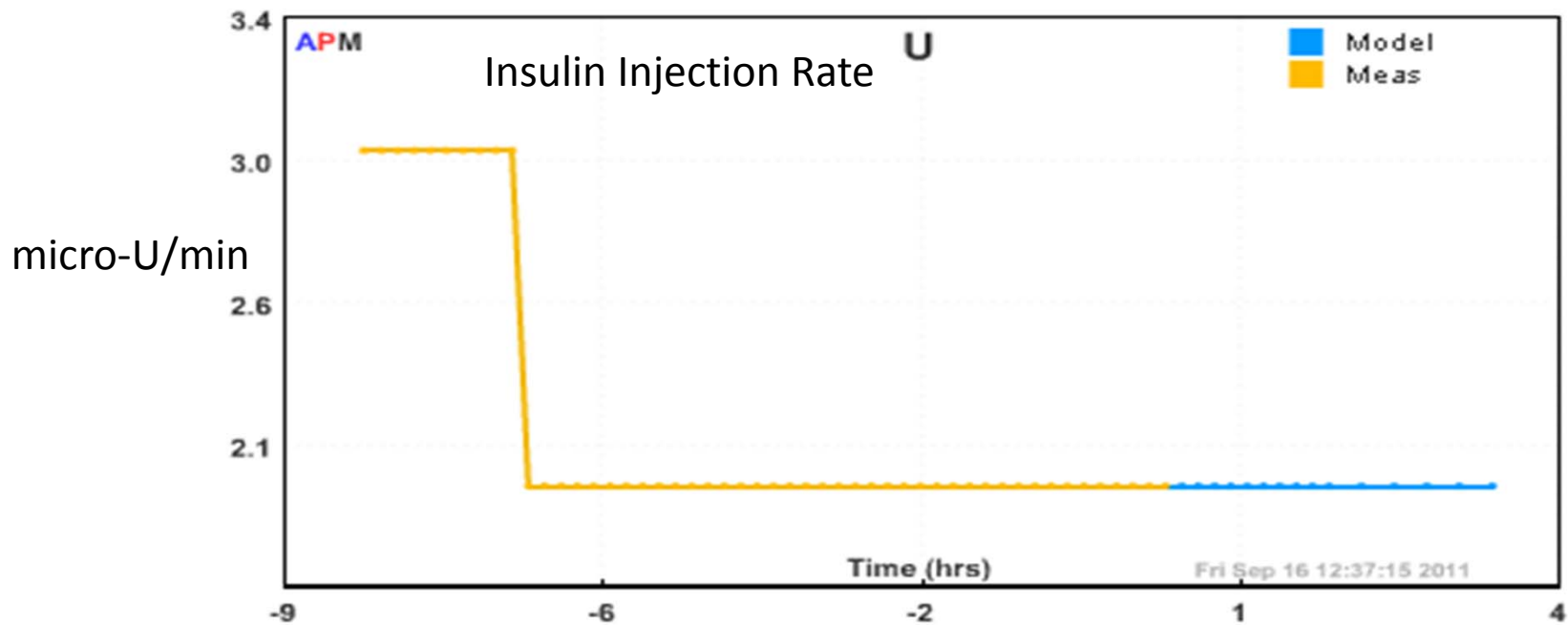
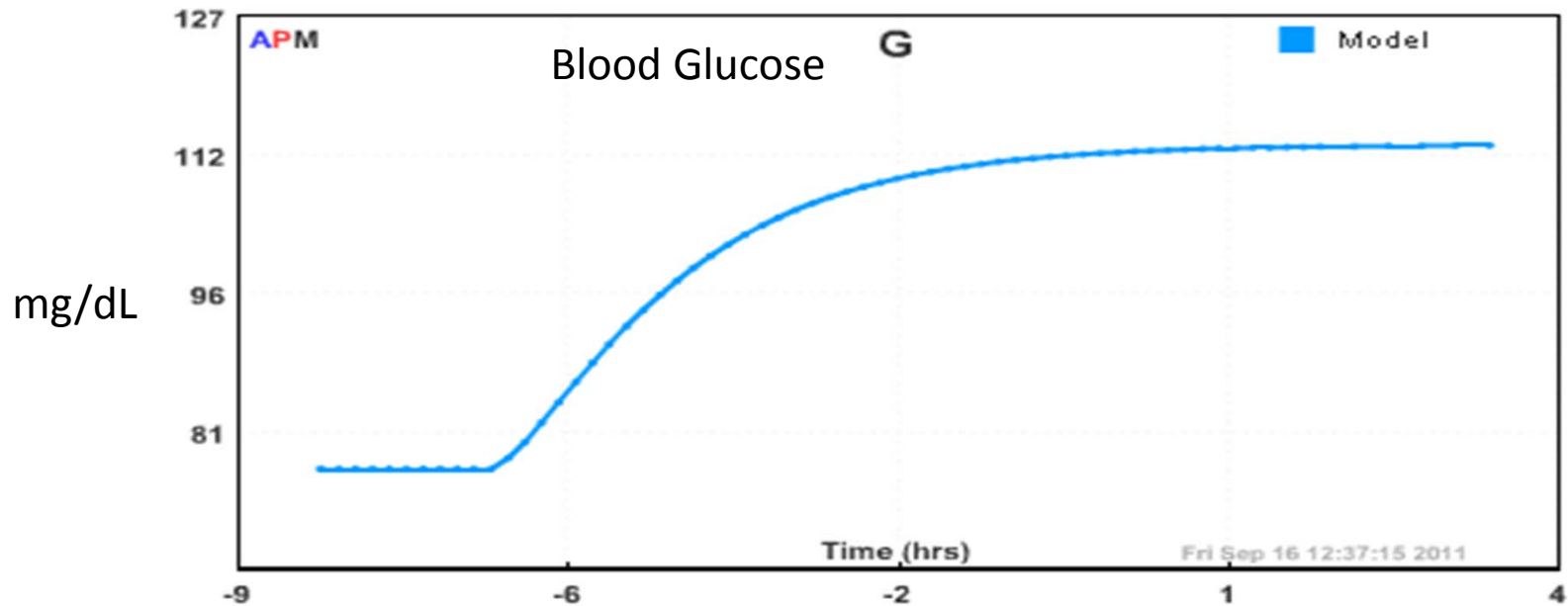


# Can We Design an Artificial Pancreas?

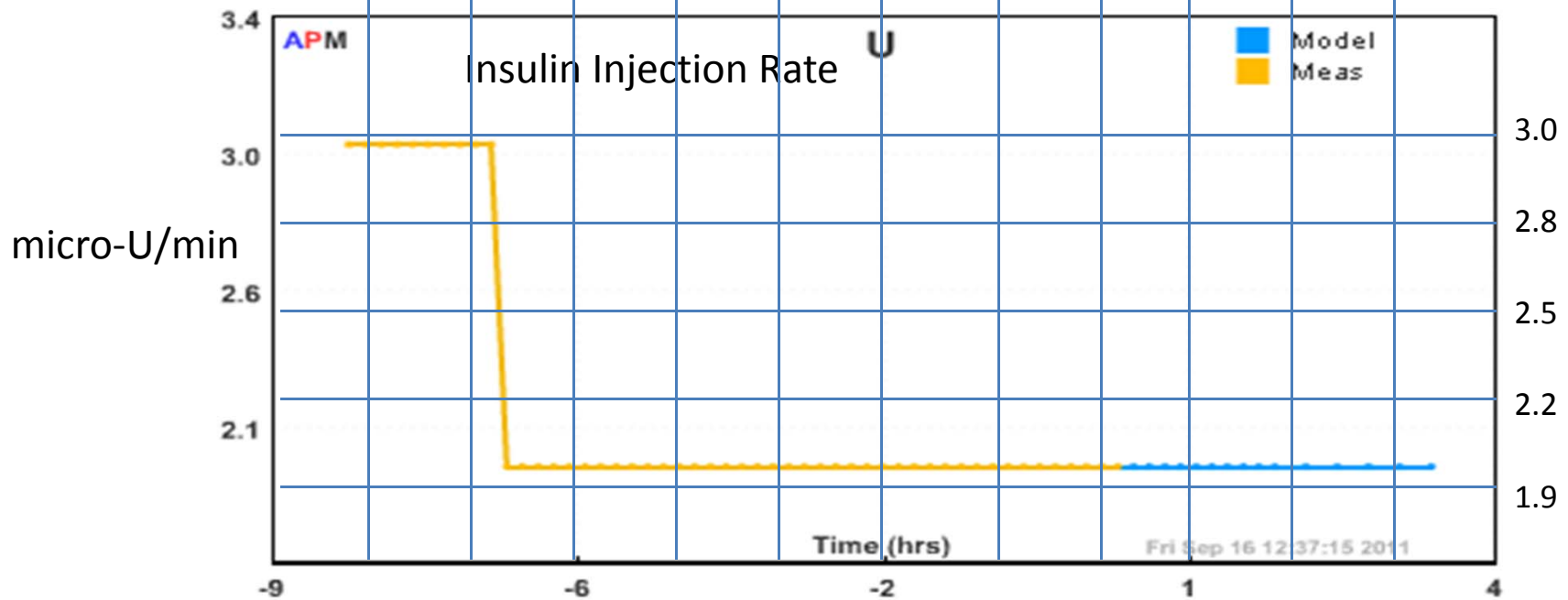
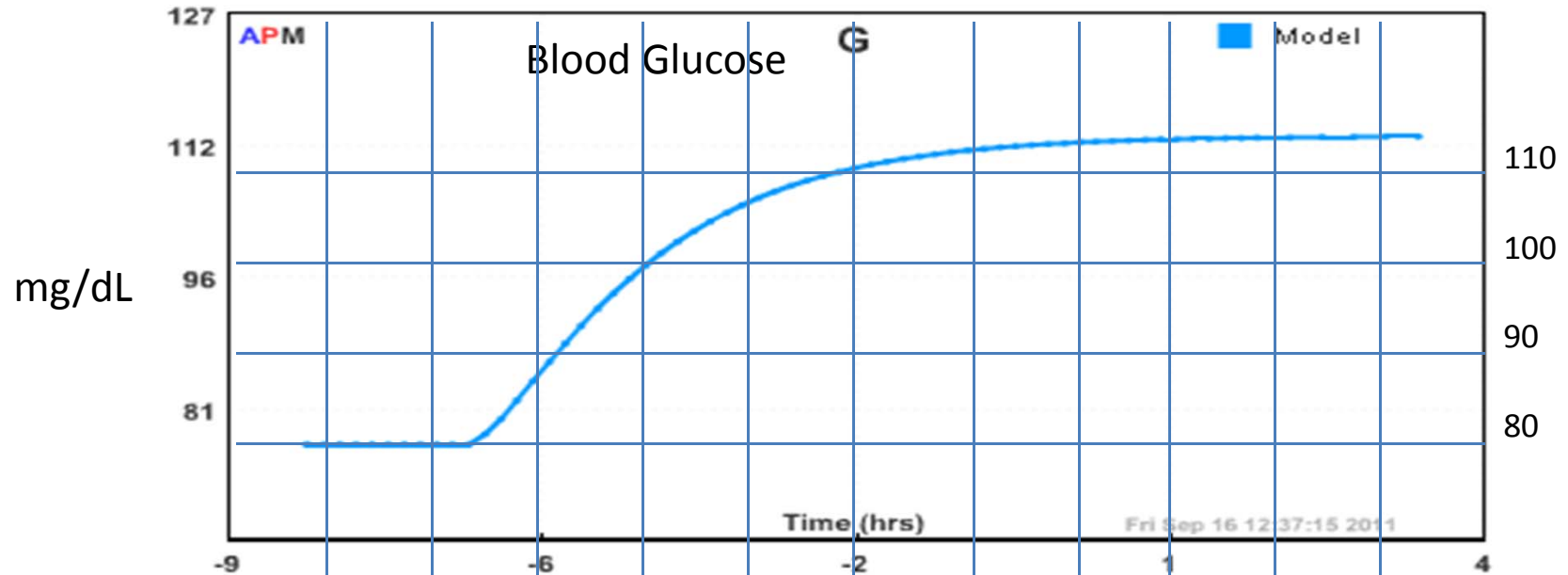


- Closed-loop control requires:
  - Actuator: Insulin pump
  - Sensor: Blood glucose sensor technology
  - Control Validation (low tolerance for mistakes):
    - Sensor validation
    - Robustness under uncertainty
    - Insulin / blood glucose dynamic model

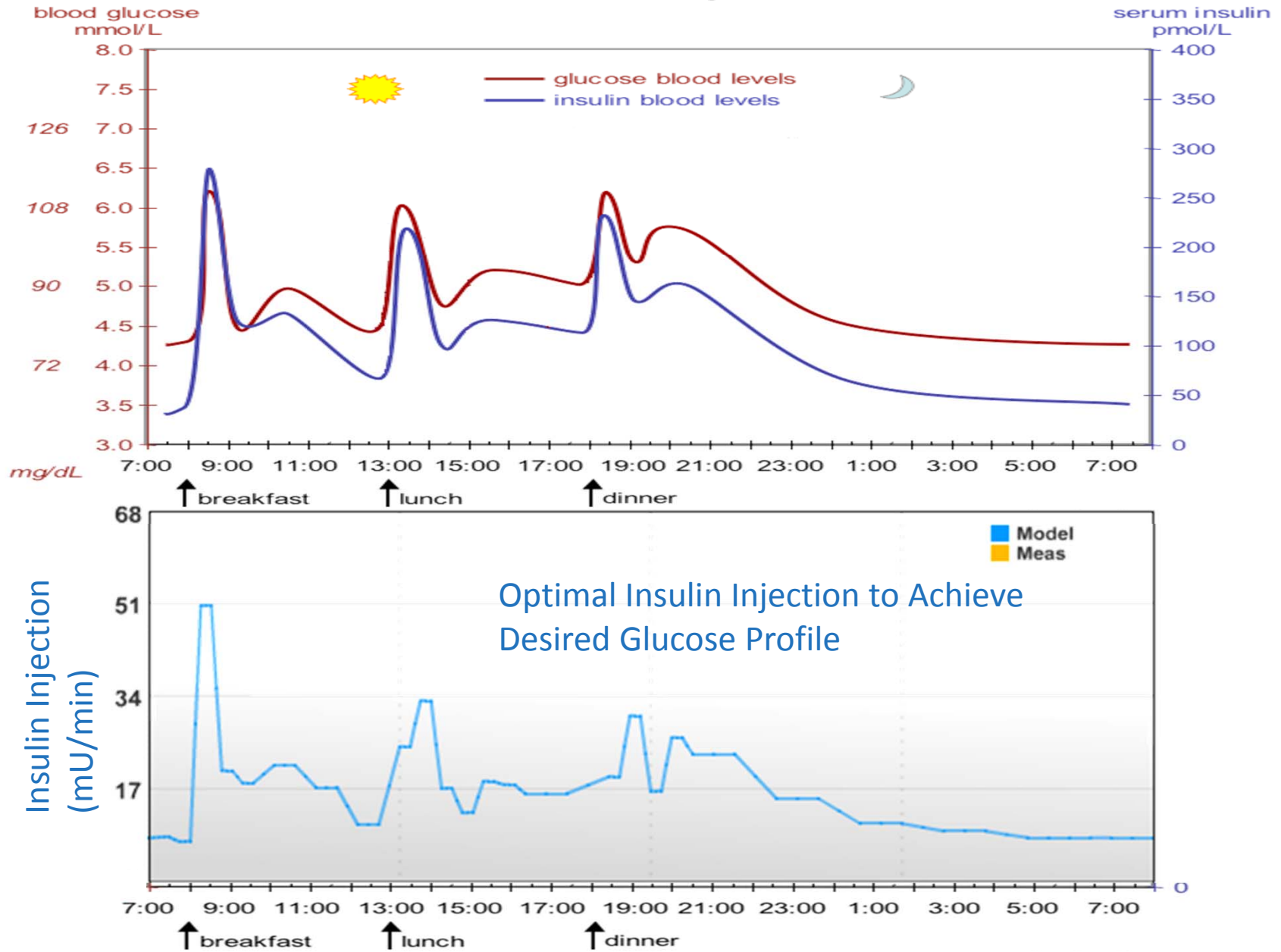
# Fit FOPDT Model & Obtain PID Tuning Parameters



# Fit FOPDT Model & Obtain PID Tuning Parameters



# Artificial Pancreas Design Considerations



## Case Study Activity

1. Obtain FOPDT parameters

$K_p$

$\tau_p$

$\theta_p$

2. Obtain PID Tuning Parameters (ITAE Disturbance Rejection and SP Tracking)

$K_c$

$\tau_I$

$\tau_D$

3. Simulate Closed-Loop Response and Tune Controller

4. Other Ideas: ???