NACDD
CDC Division of Diabetes Translation
Pre-conference Session

Making Sense of Systems Dynamics Modeling

April 11, 2011
Minneapolis, MN

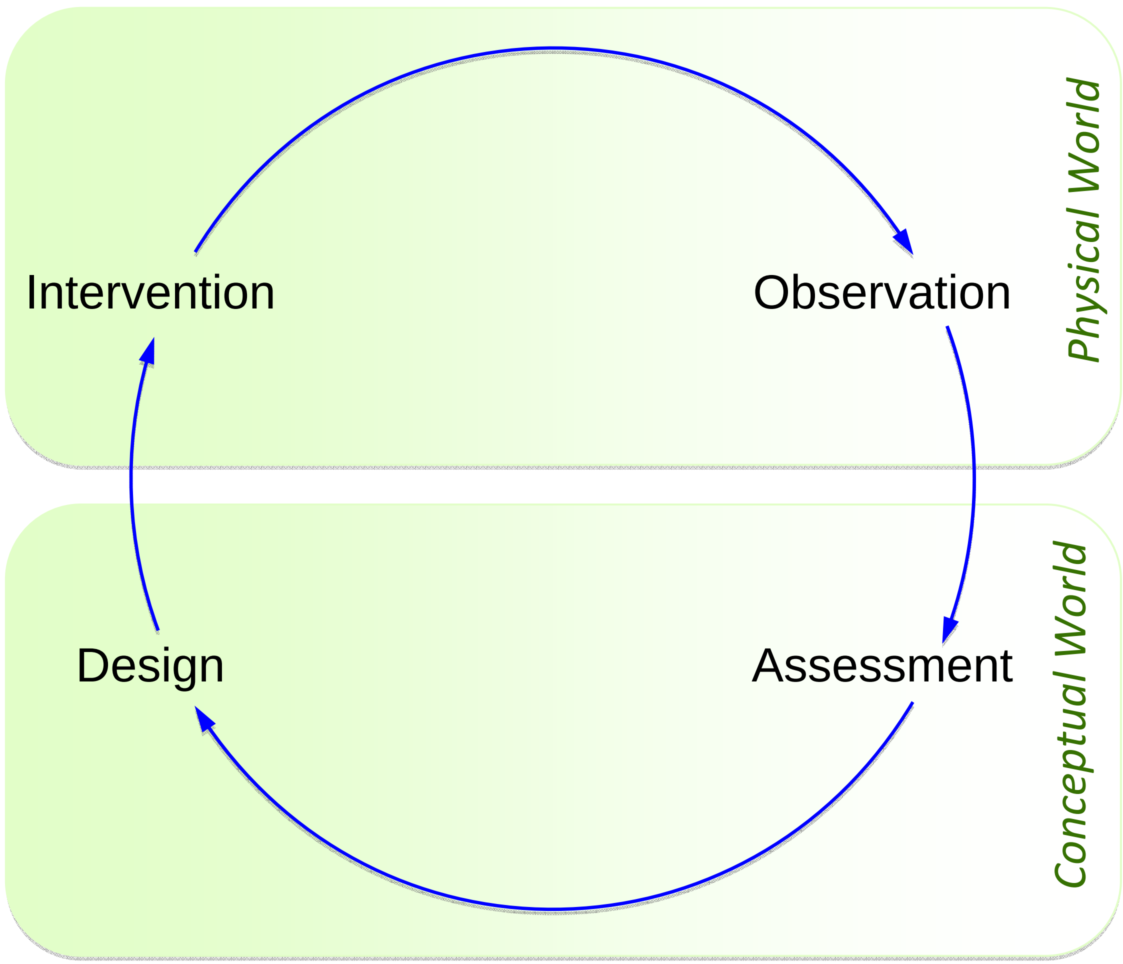
Our agenda

- Introductions
- Why Systems Thinking / System Dynamics?
- How can it be used in strategic planning?
- Introduction to PRISM
- Experimentation with PRISM
- Wrap-up

Why System Dynamics?

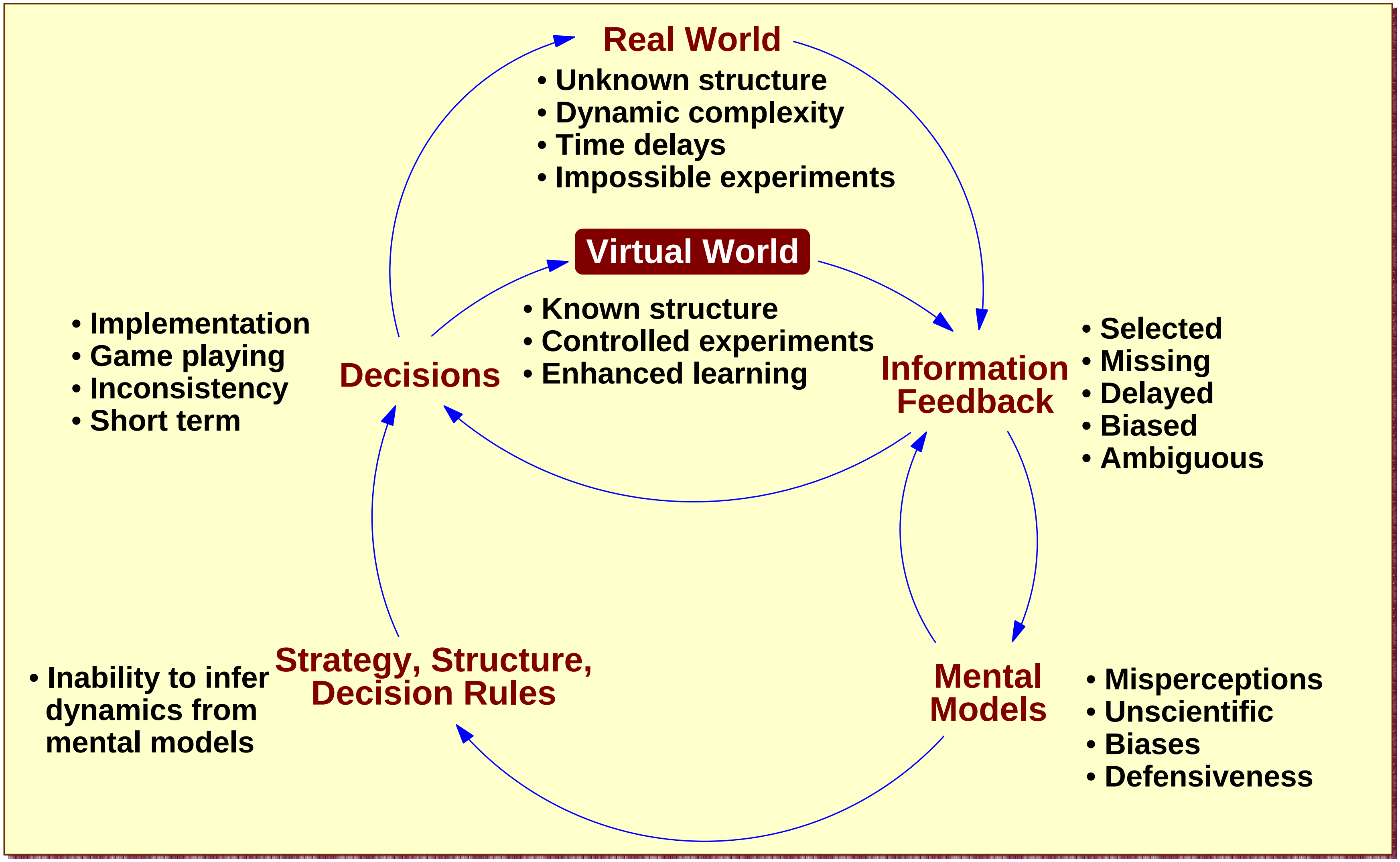
- Why Systems Thinking?
- What is the difference?

Both improve our ability to learn



The Learning Cycle

Learning In and About Dynamic Systems



Sterman JD. Learning in and about complex systems. System Dynamics Review 1994;10(2-3):291-330.

Sterman JD. Business dynamics: systems thinking and modeling for a complex world. Boston, MA: Irwin McGraw-Hill, 2000.

Systems Thinking and System Dynamics are complementary and overlap

Systems Thinking

- A philosophy, a set of thinking practices
- A language of commonly occurring dynamics
- Mapping skills
- Conversation skills

System Dynamics

- Computer simulation modeling
- A related methodology that often incorporates many Systems Thinking principles

Principles and Practices of Systems Thinking

Systems Thinking	Conventional Thinking
Dynamic: Framing a problem in terms of a pattern of behavior over time.	**Static**: Focusing on particular events.
Structure as Cause: Seeing the structures and pressures that drive behavior. Examine the conditions in which decisions are made, as well as their consequences for oneself and others.	**Players as Cause**: Focus on individuals as the sources of behavior. Hold individuals responsible or blame outside forces.
Big Picture: Seeing beyond the details to the context of relationships in which they are embedded. Engaging in active boundary critique.	**Details**: Focusing on the details in order to "know."
Operational Thinking: Understanding how a behavior is actually generated. To forecast milk production, you must consider cows.	**Factors Thinking**: Listing factors that influence, or are correlated with, a behavior. To forecast milk production, consider economic elasticities.
Closed-Loop: Viewing causality as an ongoing process, not a one-time event, with effects feeding back to influence causes, and causes affecting each other, sometimes after long delays.	**Linear**: Viewing causality as running one way, treating causes as independent and instantaneous. Root-Cause thinking.
Quantitative: Knowing how to quantify, even though you cannot always measure.	**Measurement**: Focusing on the things we can measure; seeking precision.
Scientific: Knowing how to define testable hypotheses, not just for research.	**Proving-Truth**: Seeking to prove our models true by validating them with historical data.

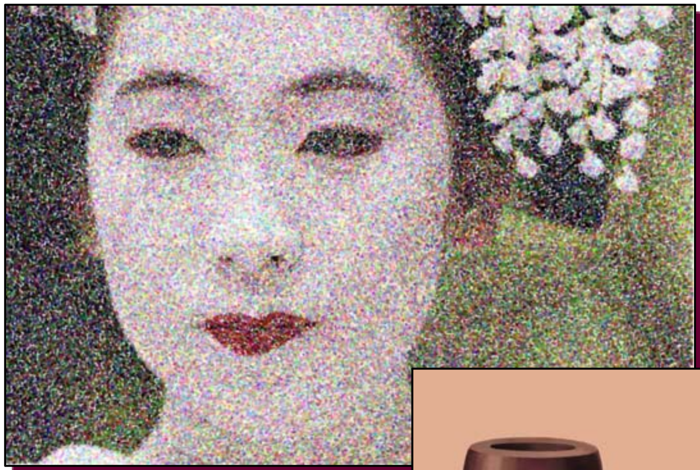
Adapted from: Karash R. The essentials of systems thinking and how they pertain to healthcare and colorectal cancer screening. Dialogue for Action in Colorectal Cancer; Baltimore, MD; March 23, 2005..

Richmond B. Systems thinking: critical thinking skills for the 1990s and beyond. System Dynamics Review 1993;9(2):113-134.

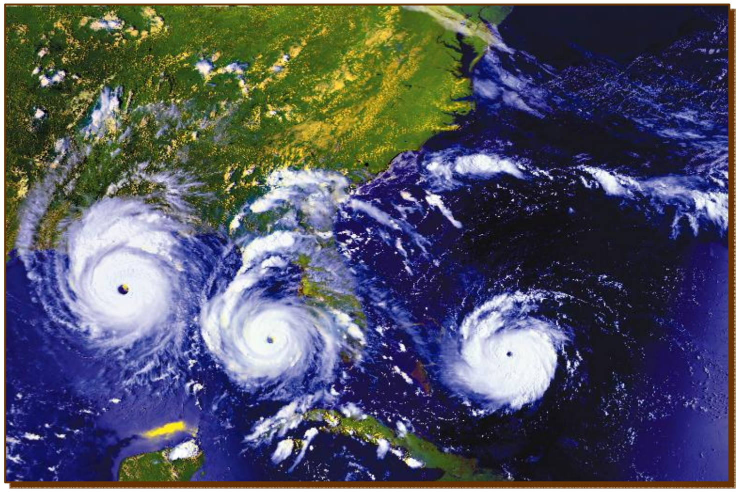
Richmond B. The "thinking" in systems thinking: seven essential skills. Waltham, MA: Pegasus Communications, 2000.

A Model Is…

An inexact representation
of the real thing



They help us understand, explain, anticipate, and make decisions



"All models are wrong, some are useful."

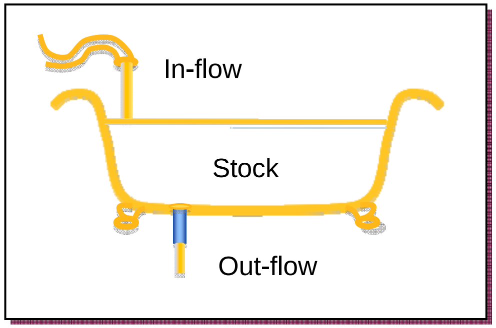
-- George Box

Sterman JD. All models are wrong: reflections on becoming a systems scientist. System Dynamics Review 2002;18(4):501-531. Available at <http://web.mit.edu/jsterman/www/All_Models.html>

Sterman J. A sketpic's guide to computer models. In: Barney GO, editor. Managing a Nation: the Microcomputer Software Catalog. Boulder, CO: Westview Press; 1991. p. 209-229. <http://web.mit.edu/jsterman/www/Skeptic%27s_Guide.html>

What is a System? What are Dynamics?

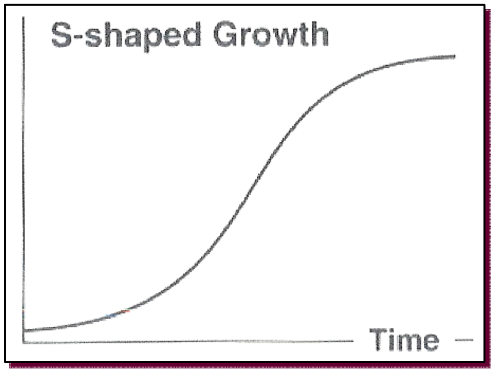
System (a.k.a. Structure) is a *network of Stocks, Flows, Feedback Loops, and other Casual links*



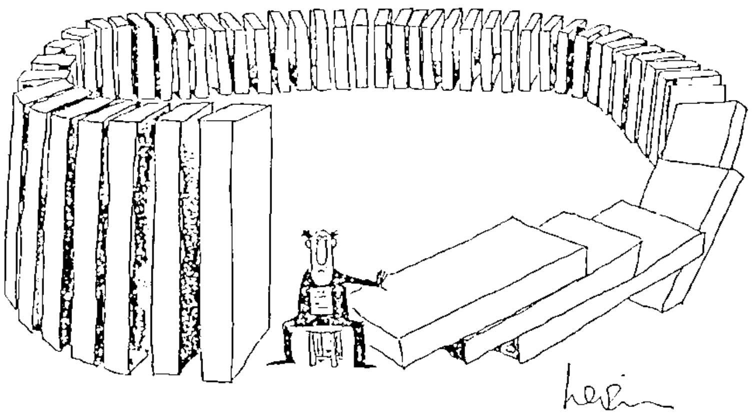
- Stocks are accumulations of flows
(e.g. population, resources, changing goals, perceptions)
- Feedback loops link accumulations back to decisions that alter the flows: 2 types (goal-seeking, self-reinforcing)
- Delays complicate things further
- As do non-linearities (e.g. critical mass, saturation effects)

Dynamics are the resulting *Behavior over time*

- Patterns in time series data (growth, fluctuation, etc.)
- Visible relationships of two or more variables
(move together, move opposite, lead-lag, etc.)



System Dynamics:
Understanding Dynamic Complexity



Drawing by Levin; © 1976 The New Yorker Magazine, Inc.

Origins

- **Jay Forrester, MIT, Industrial Dynamics, 1961 ("One of the seminal books of the last 20 years."-- NY Times)**
- **Public policy applications starting late 1960s**
- **Population health applications starting mid-1970s**

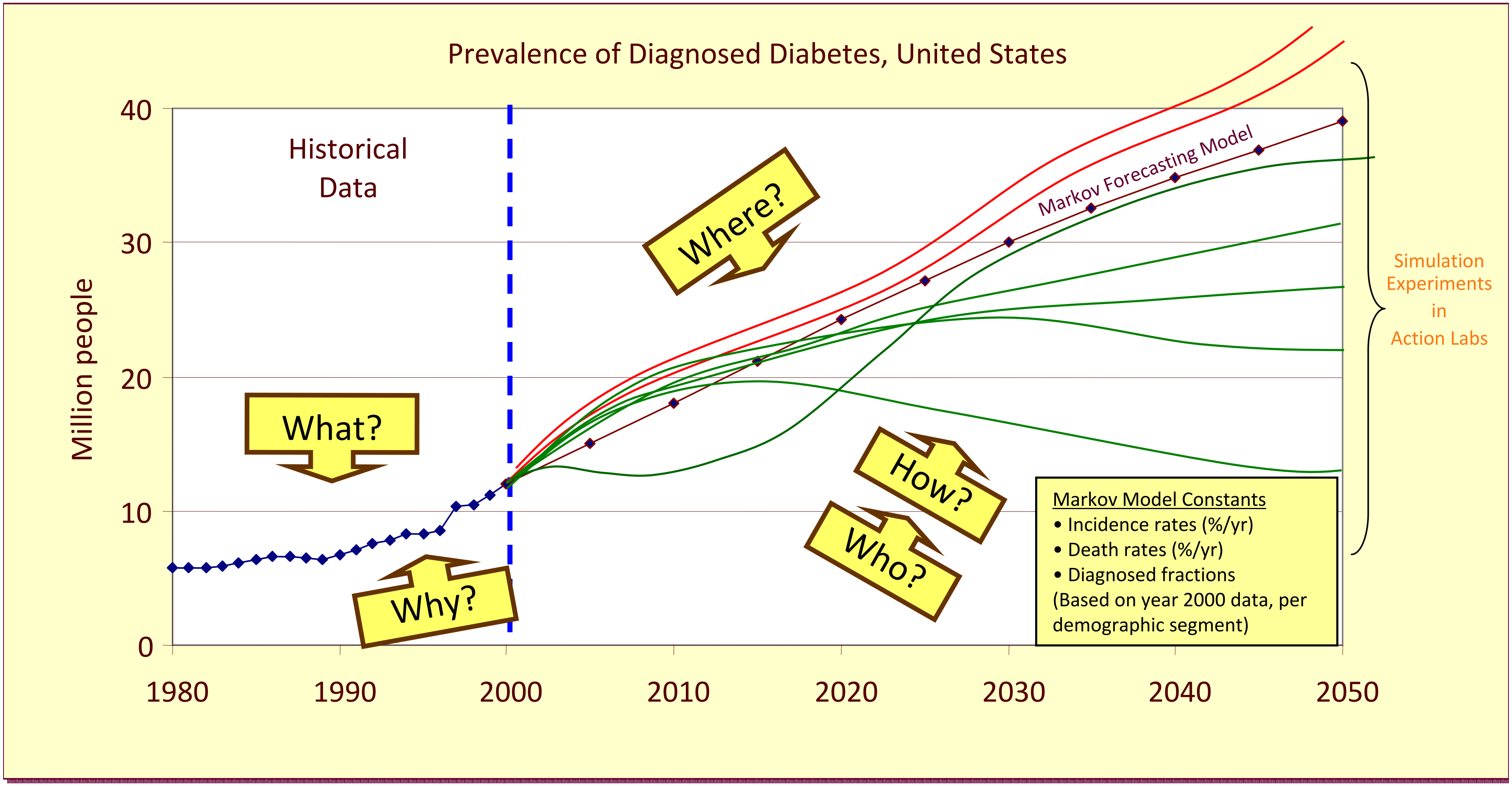
Good at keeping track of many variables

- **Differences between short- and long-term consequences of an action**
- **Time delays (e.g., incubation period, time to detect, time to respond)**
- **Accumulations (e.g., prevalences, resources, attitudes)**
- **Behavioral feedback (reactions by various actors)**
- **Nonlinear causal relationships (e.g., threshold effects, saturation effects)**
- **Differences or inconsistencies in goals/values among stakeholders**

Sterman JD. Business dynamics: systems thinking and modeling for a complex world. Boston, MA: Irwin McGraw-Hill, 2000.

Questions Addressed by Dynamic Modeling

Re-Directing the Course of Change

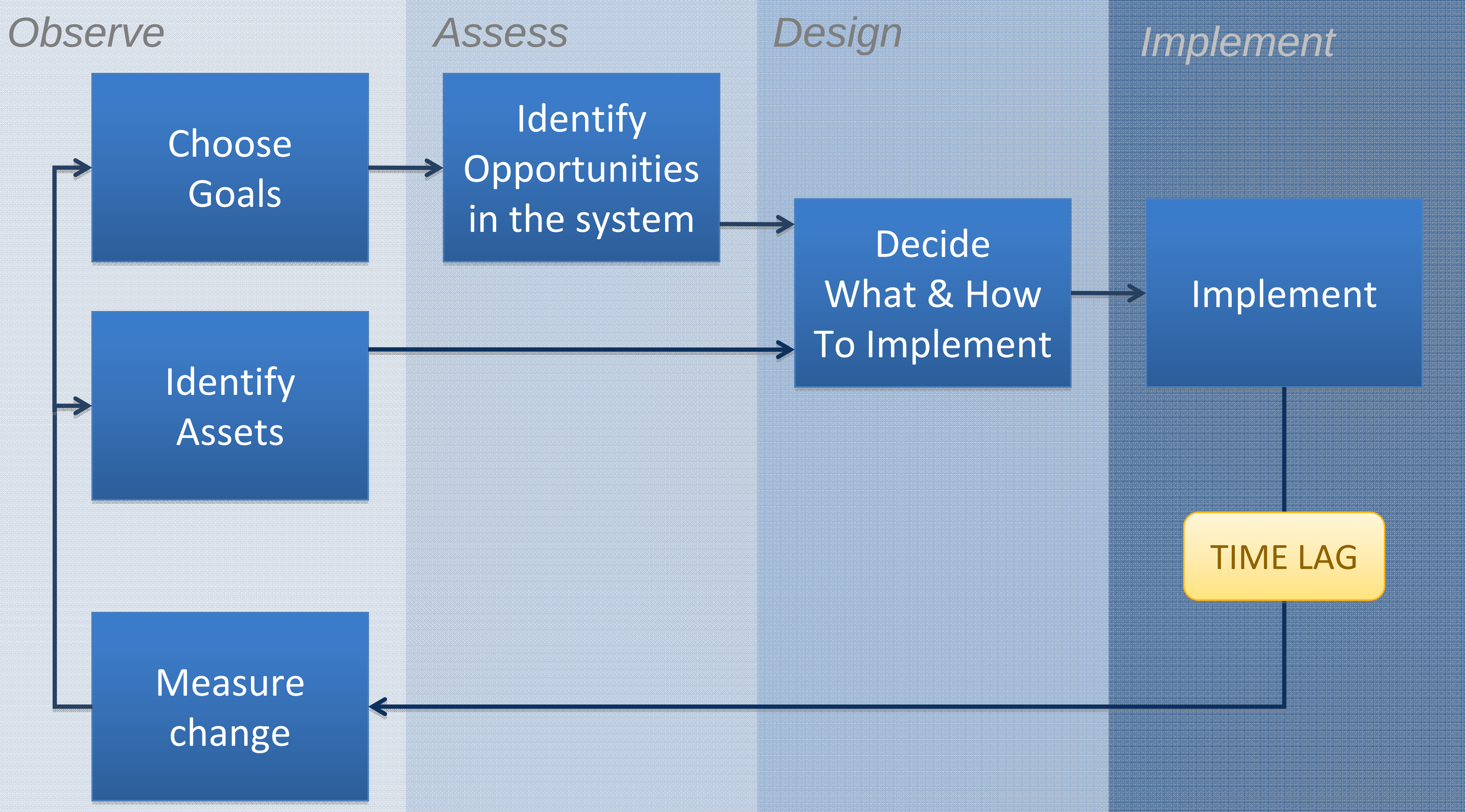


Honeycutt A, Boyle J, Broglio K, Thompson T, Hoerger T, Geiss L, Narayan K. A dynamic Markov model for forecasting diabetes prevalence in the United States through 2050. Health Care Management Science 2003;6:155-164.

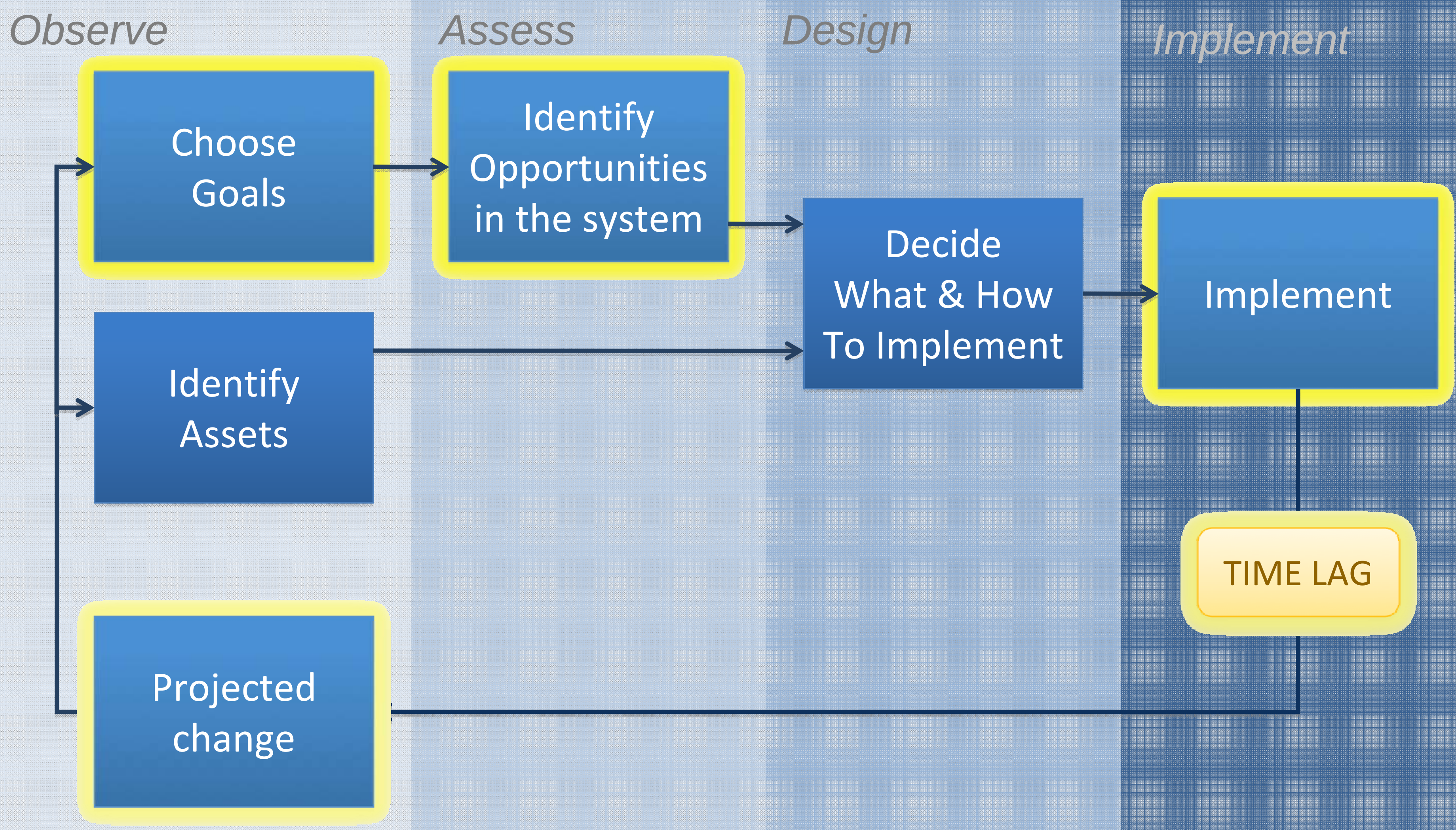
Jones AP, Homer JB, Murphy DL, Essien JDK, Milstein B, Seville DA. Understanding diabetes population dynamics through simulation modeling and experimentation. American Journal of Public Health 2006;96(3):488-494.

How can dynamic models be used for program planning?

Strategic Planning Cycle



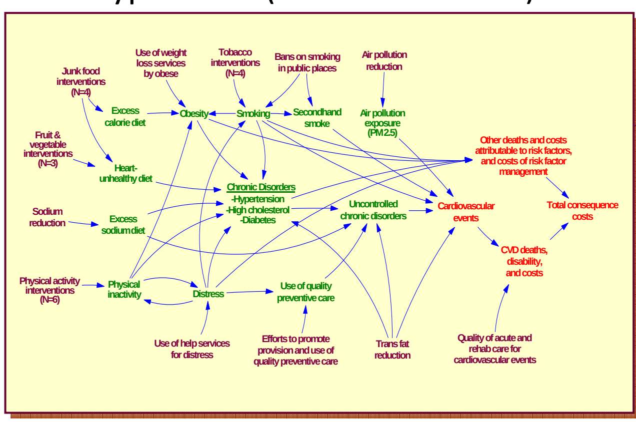
Strategic Planning Cycle



Models Help to ASSESS COMPLEXITY AND OPTIONS for Action

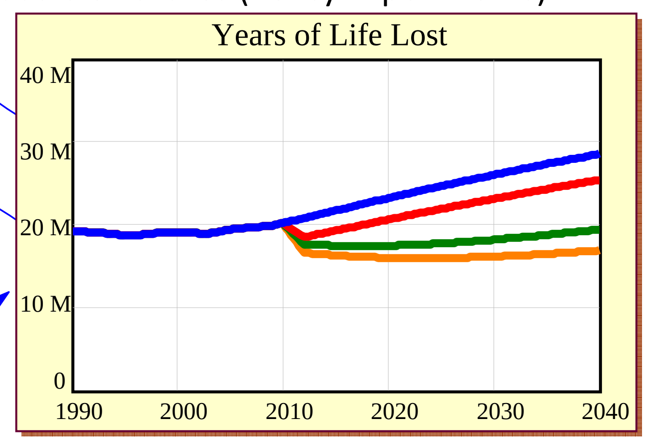
What to do first?
What to do together?
Likely consequences?
Costs? Time-frame?
How to catalyze action?

Dynamic Hypothesis (Causal Structure)



System

Plausible Futures (Policy Experiments)

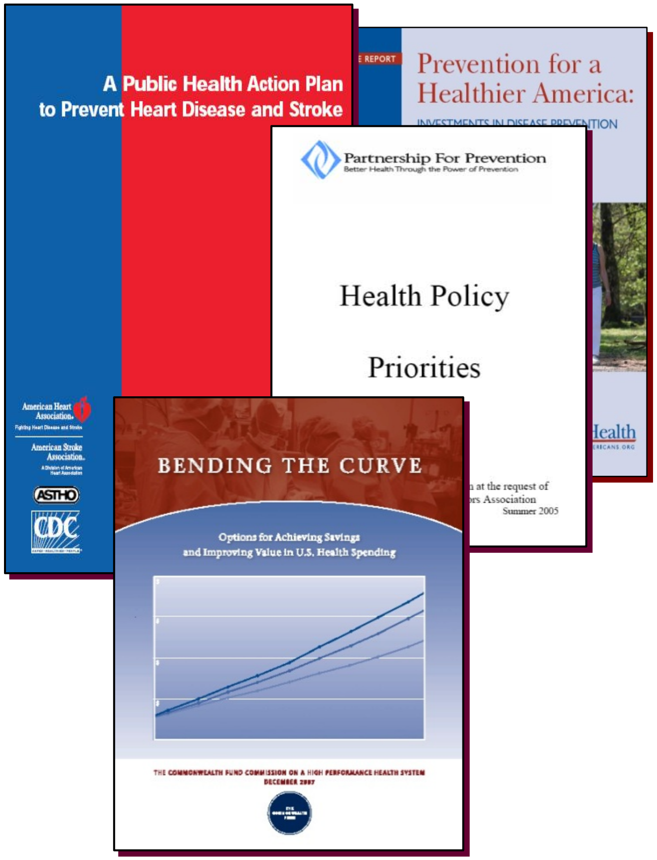


Dynamics

Homer JB. Why we iterate: scientific modeling in theory and practice. System Dynamics Review 1996;12(1):1-19.

Why Create Interactive Policy Simulators?
To Build Foresight, Experience, and Motivation to Act

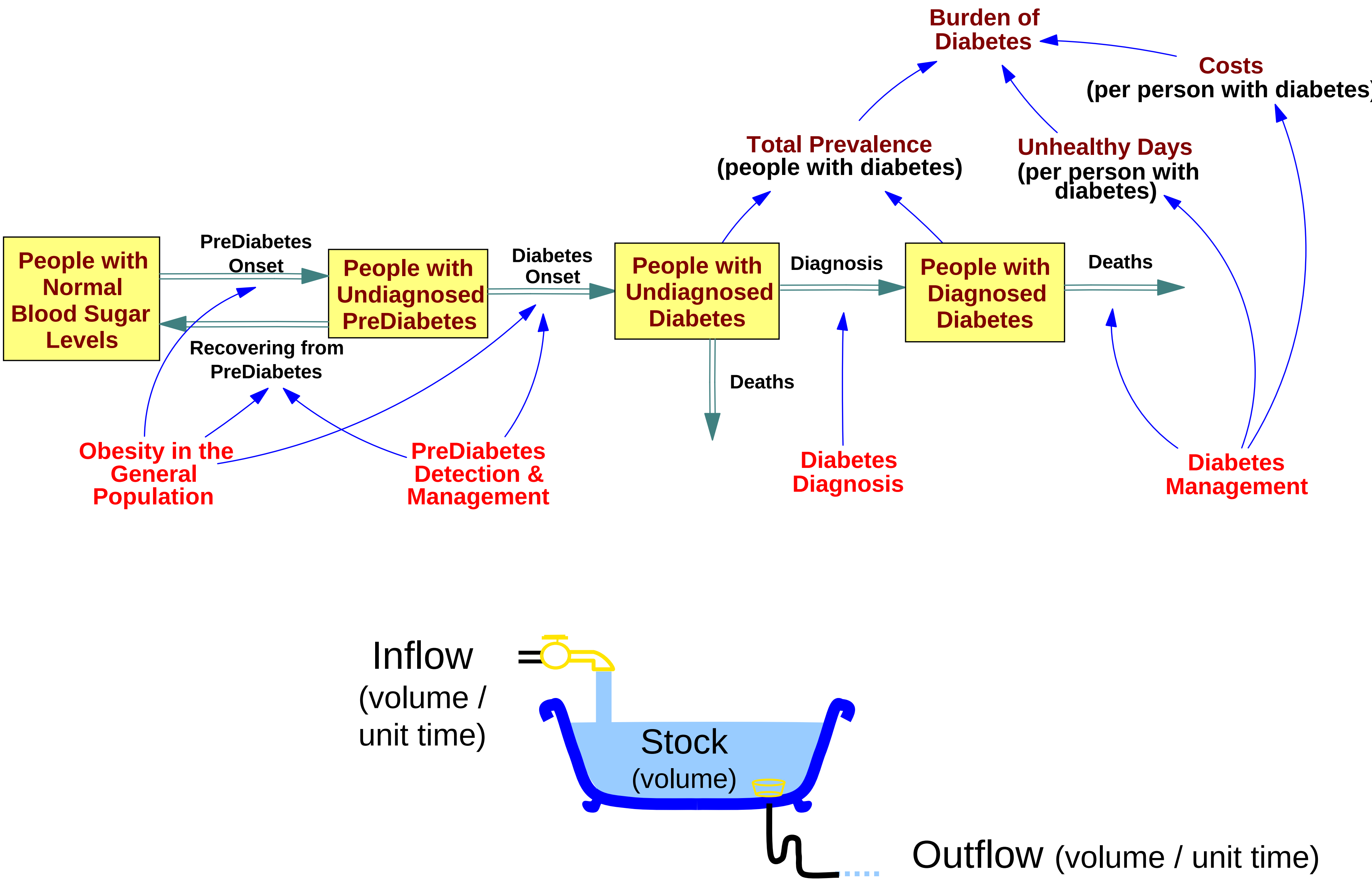
Expert Recommendations



Experiential Learning

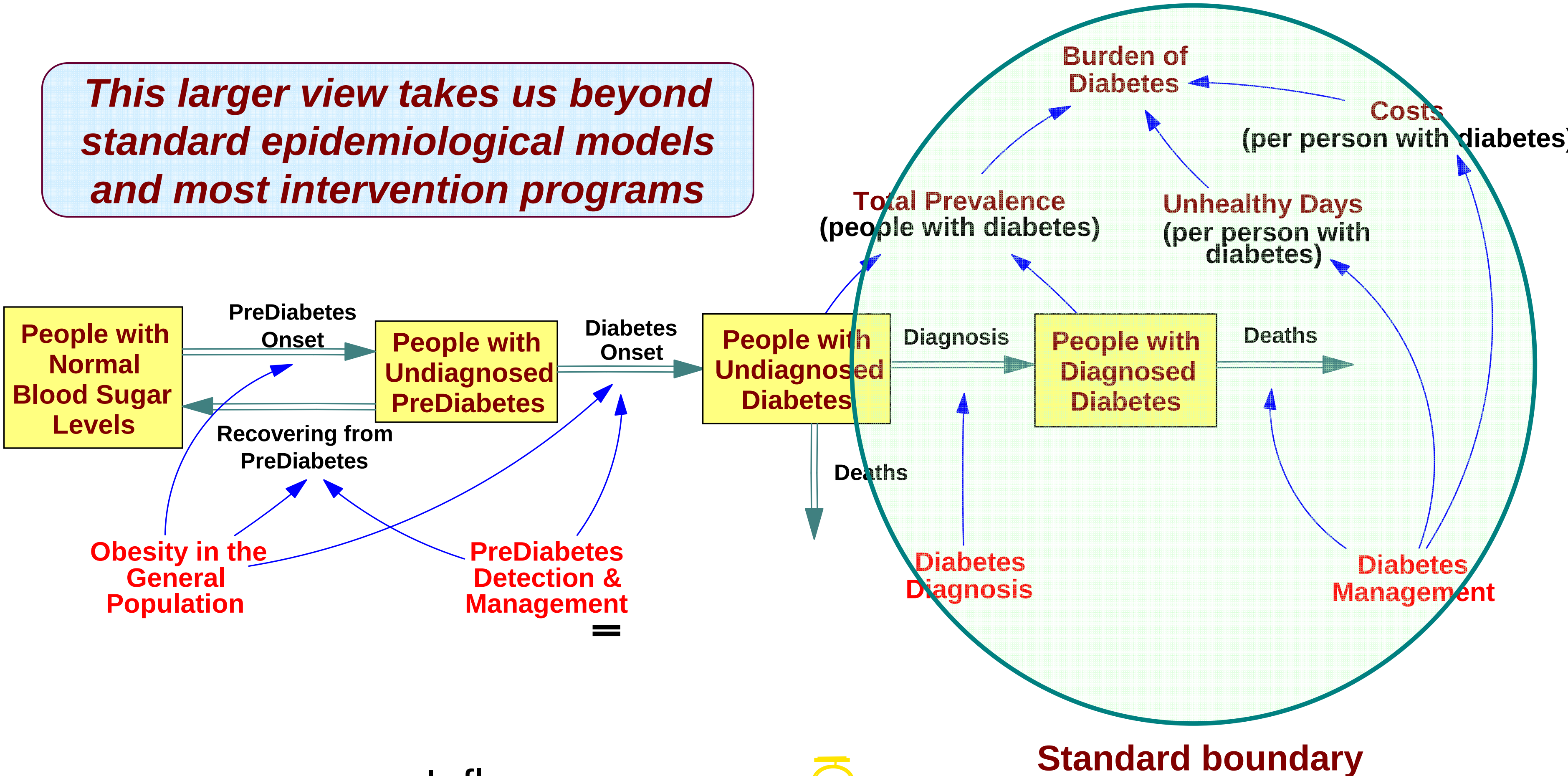
Change agents need more than authoritative advice. They want to see plausible pathways and discover, for themselves, how to make a difference

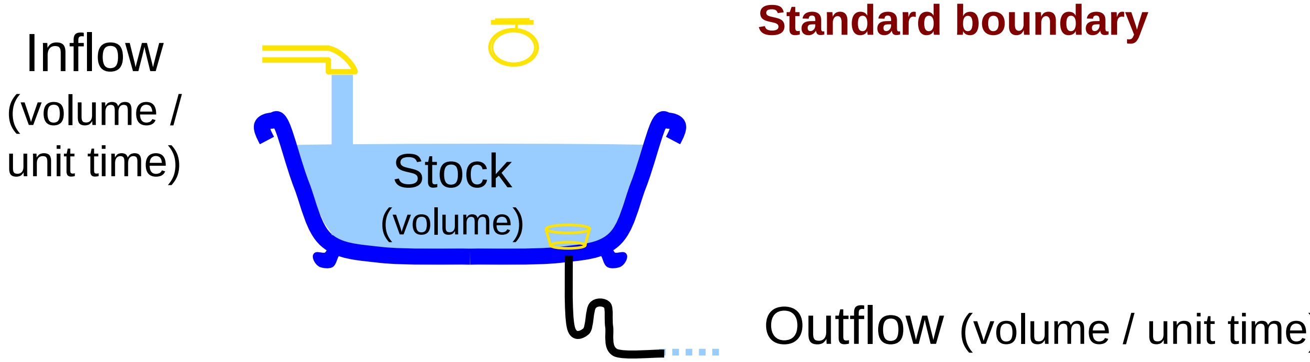
Diabetes Burden is Driven by Population Flows



Diabetes Burden is Driven by Population Flows

This larger view takes us beyond standard epidemiological models and most intervention programs

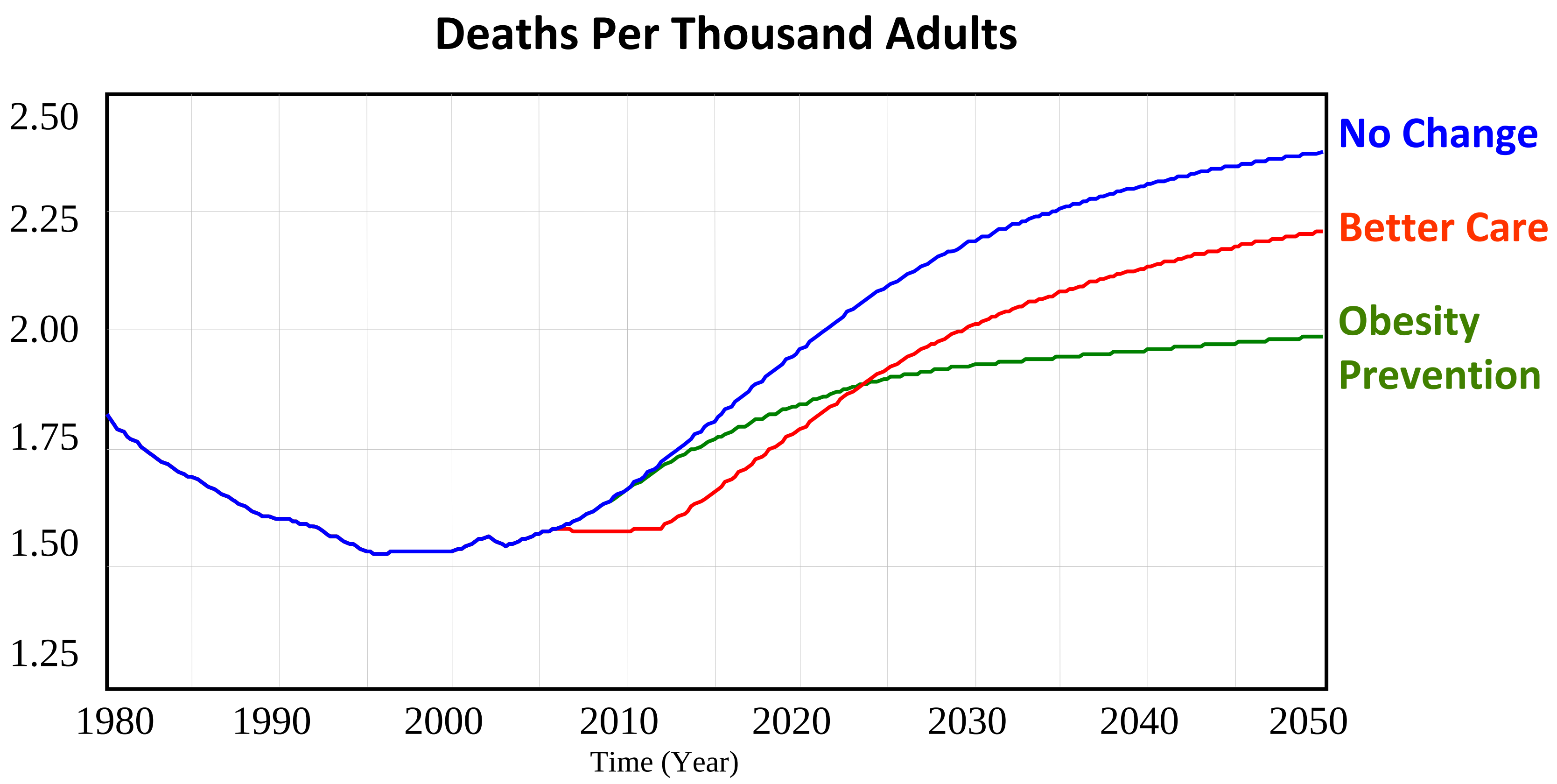




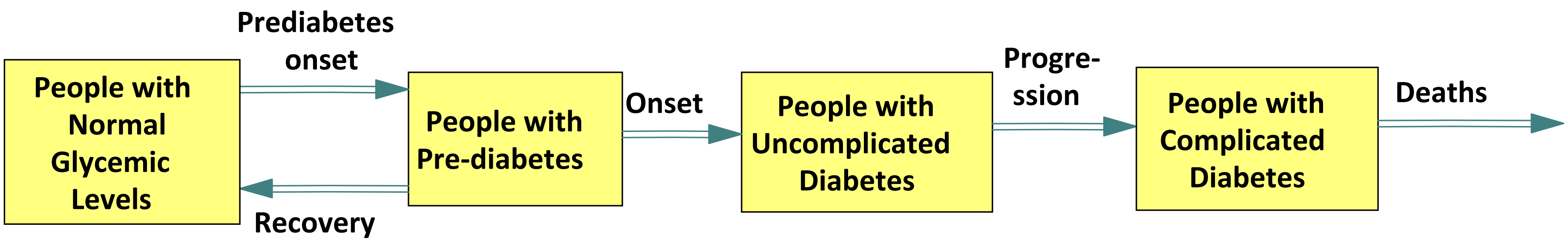
Vermont

- Used System Dynamics Modeling for
  - Setting goals/strategic plan
  - Integration of prevention
- Benefits
  - Framework
  - Connections/sequencing
  - Forces full continuum thinking
  - Impact over time—30 years
  - Clever, invites participation
  - Setting realistic goals
  - Invites reflection
- SDM used along with Chronic Care, Social-Ecologic, and Logic models; all have different purposes

Reducing diabetes deaths: options



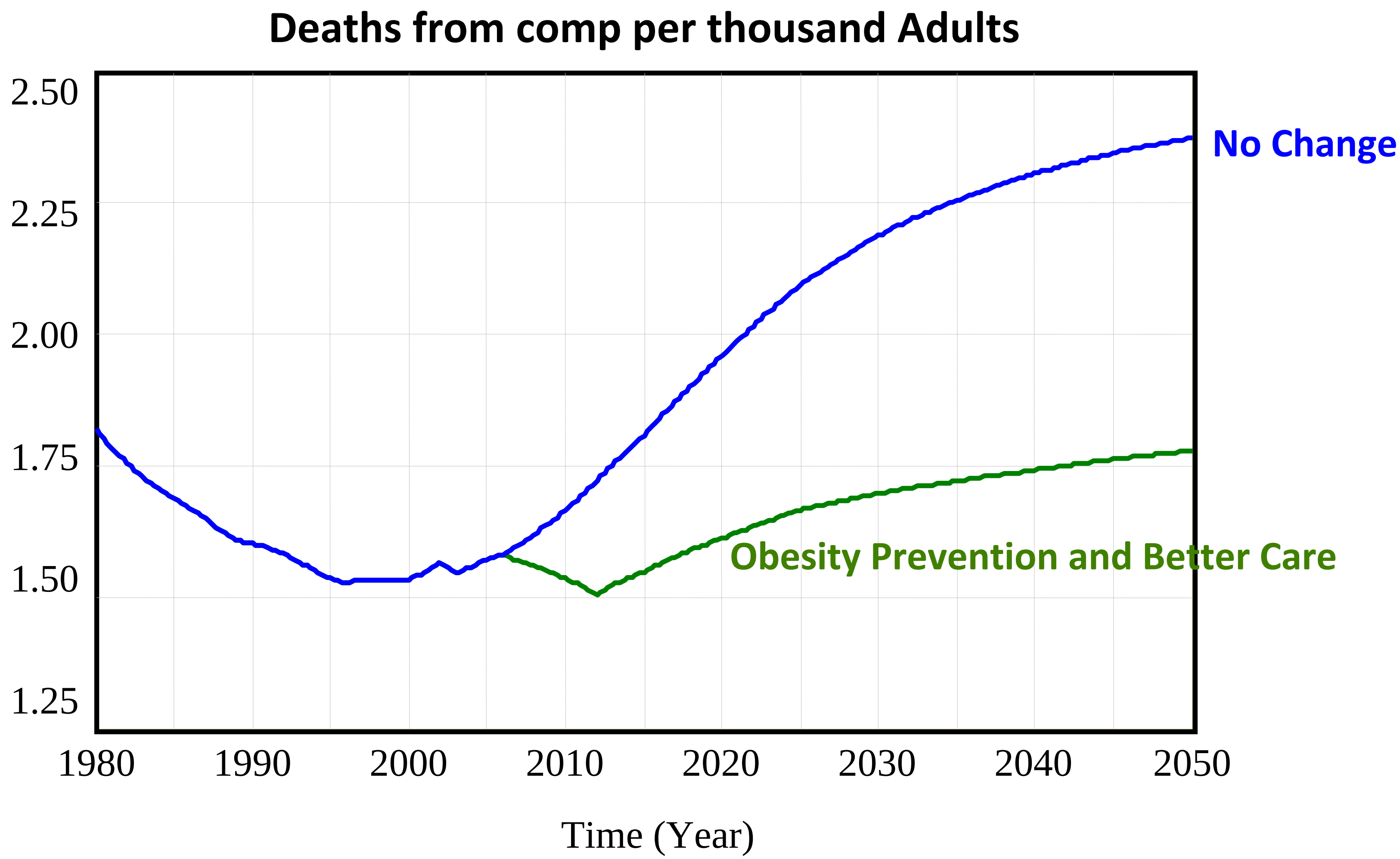
Upstream vs downstream



Work upstream and reduce the burden after decades but with significant long term impact

Work downstream and reduce the burden soon but with modest long term impact

Reducing diabetes deaths: upstream and down



Minnesota

- Used to support policy change: statewide funding for prevention and health promotion
- Developed diabetes case study for legislative Task Force working on state health care reform
- Case study illustrated importance of prevention
  - Illustrated potential impact of addressing prediabetes
- Helped support dedicating $47 million over 2 years for obesity and tobacco use prevention as a part of state health care reform legislation passed in 2008

Figure 1

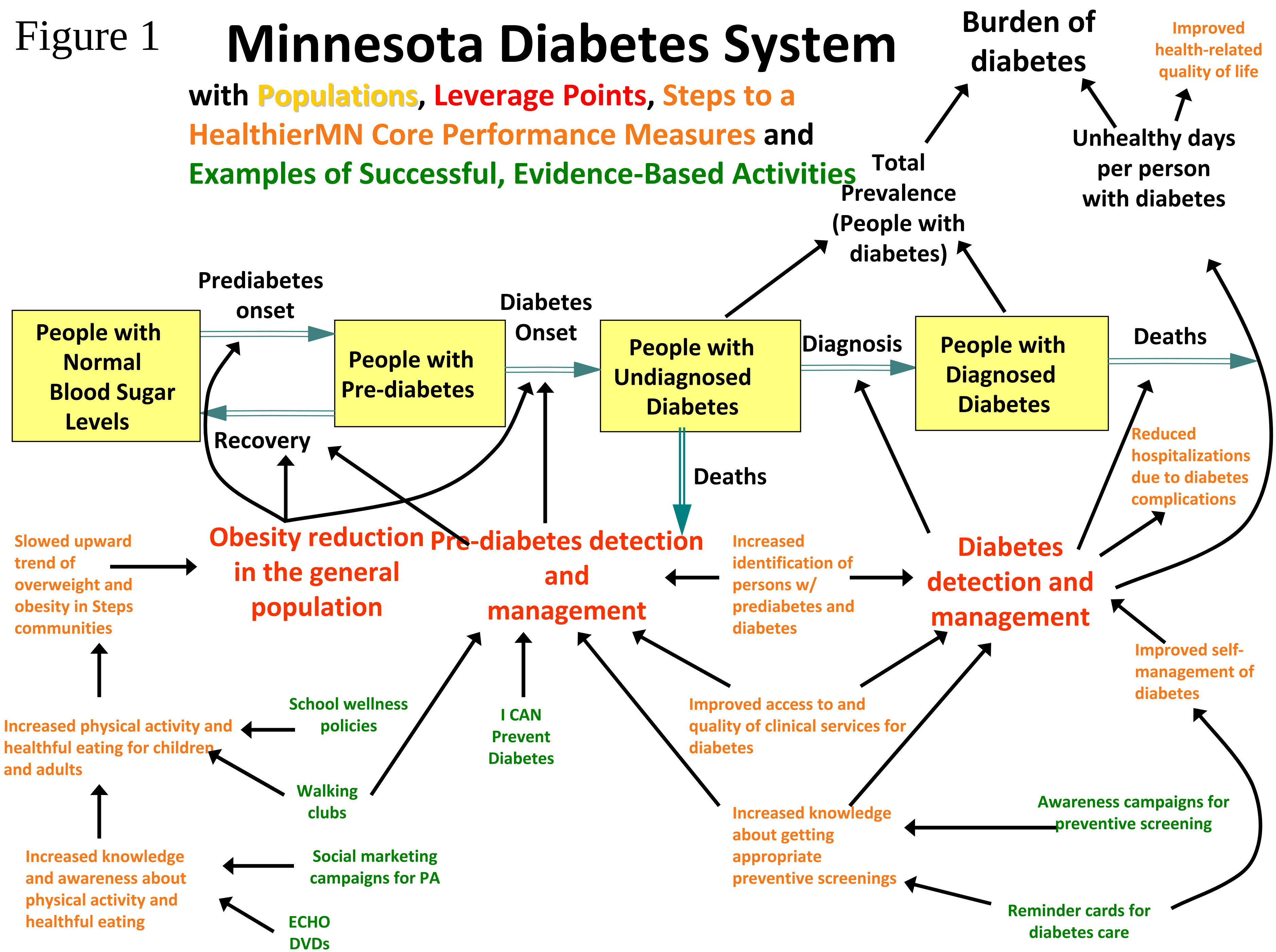
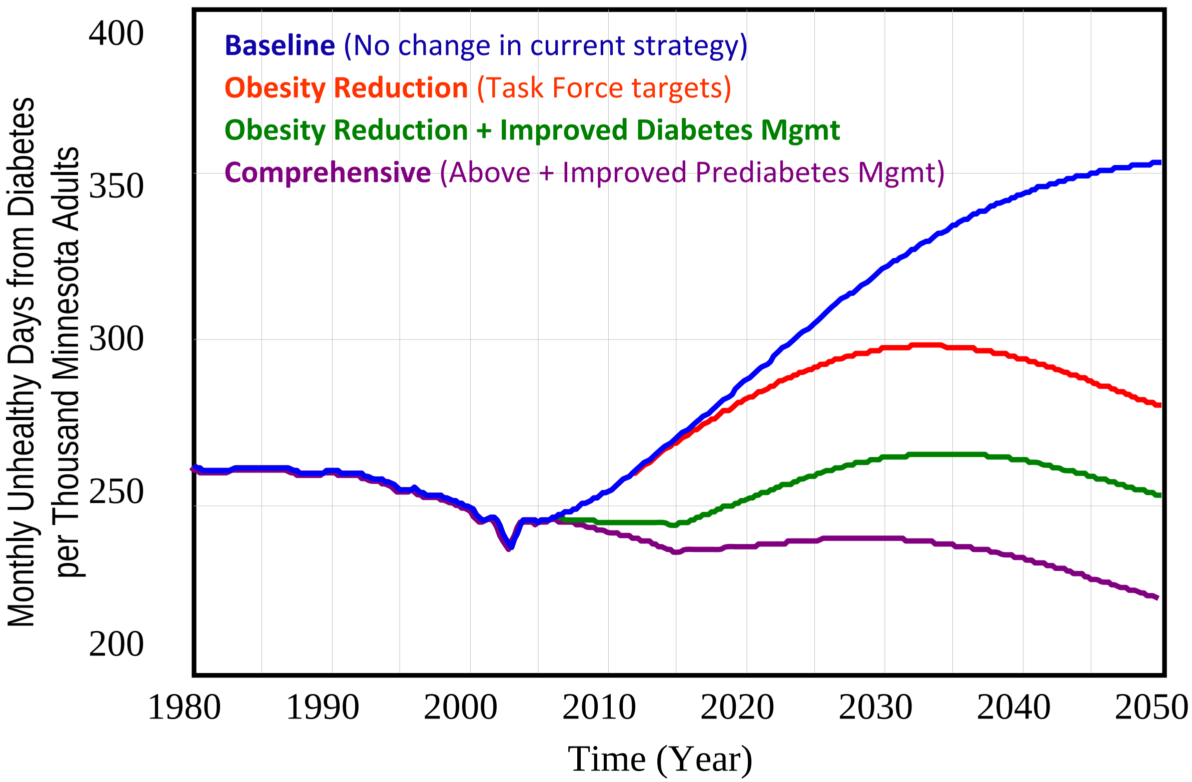

Minnesota Diabetes System
with Populations, Leverage Points, Steps to a HealthierMN Core Performance Measures and Examples of Successful, Evidence-Based Activities
Burden of diabetes
Improved health-related quality of life
Unhealthy days per person with diabetes
Total Prevalence (People with diabetes)
Prediabetes onset
Diabetes Onset
Diagnosis
Deaths
People with Normal Blood Sugar Levels
People with Pre-diabetes
People with Undiagnosed Diabetes
People with Diagnosed Diabetes
Recovery
Deaths
Reduced hospitalizations due to diabetes complications
Slowed upward trend of overweight and obesity in Steps communities
Obesity reduction in the general population
Pre-diabetes detection and management
Increased identification of persons w/ prediabetes and diabetes
Diabetes detection and management
Improved self-management of diabetes
School wellness policies
Increased physical activity and healthful eating for children and adults
Walking clubs
I CAN Prevent Diabetes
Improved access to and quality of clinical services for diabetes
Increased knowledge about getting appropriate preventive screenings
Awareness campaigns for preventive screening
Increased knowledge and awareness about physical activity and healthful eating
Social marketing campaigns for PA
ECHO DVDs
Reminder cards for diabetes care

Figure 2

Diabetes Unhealthy Days in Minnesota: Three Scenarios



Unhealthy days averted: By 2013: 10 thousand By 2050: 69 million (7%)

Unhealthy days averted: By 2013: 2.7 million By 2050: 137 million (13%)

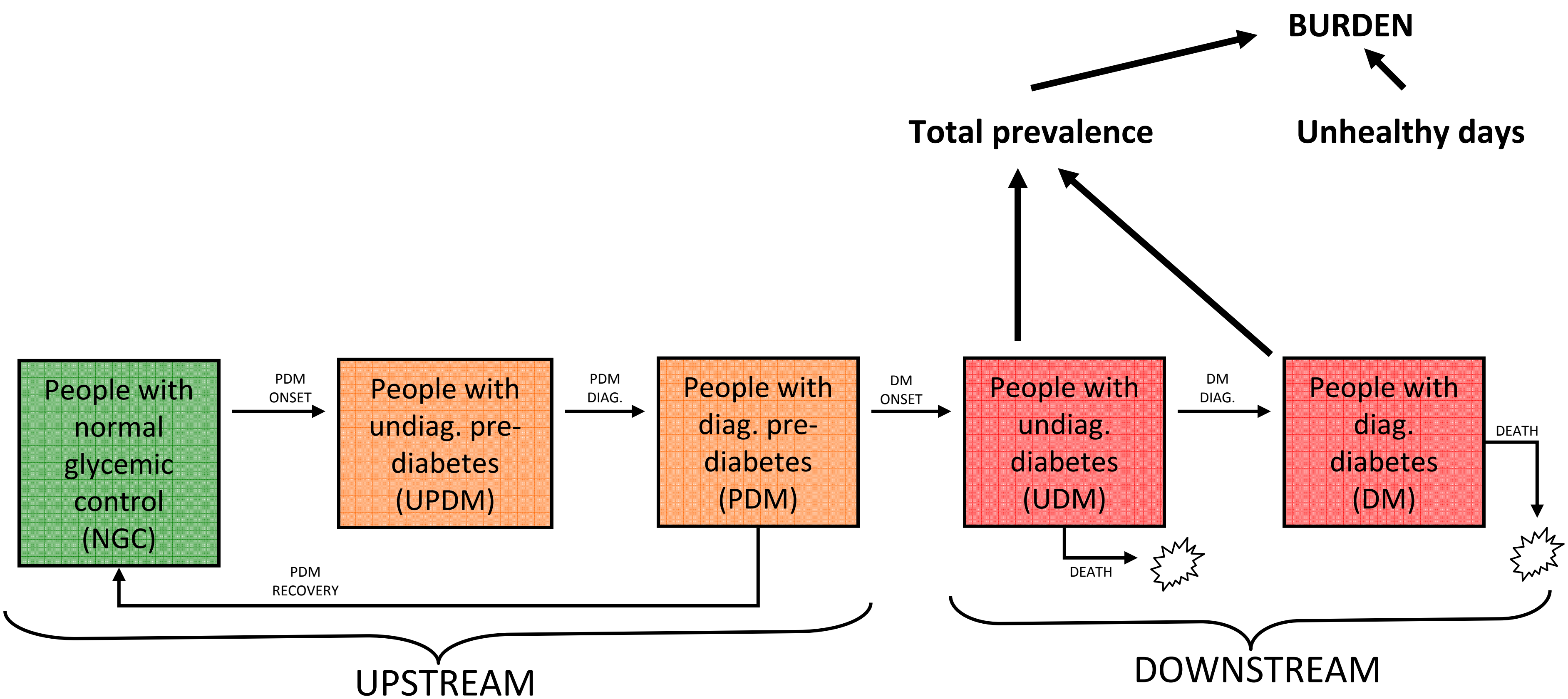
Unhealthy days averted: By 2013: 3.4 million By 2050: 186 million (18%)

A successful **comprehensive** approach to prevention can hold the line on the diabetes burden in Minnesota

Florida

- Used ST/SDM in Statewide Assessment
- Staff engaged in learning/teaching
- Convened joint strategic/action planning among DPCP and 2 Advisory Bodies
  - Developed complementary work plans focused on
    - Pre-diabetes
    - Diabetes Self Management Education
- Produced additional partner engagement and opportunities

The question becomes…



WORK UPSTREAM AND REDUCE THE BURDEN AFTER DECADES BUT WITH SIGNIFICANT LONG-TERM IMPACT?

AND/OR

WORK DOWNSTREAM AND REDUCE THE BURDEN RELATIVELY SOON BUT WITH MODEST LONG-TERM IMPACT?

Aha Moments for Partners

- Population flow map
- Relationships:
  - Prevalence – Burden – Unhealthy days
  - Data – analysis – praxis
    - Are you answering the questions you asked?
- "Good" things and "bad" things
  - (Short-term) increases in prevalence - good
  - Long-term increase in burden will result due to balanced approach

And here is the action part…
Phase 1: Macro-level efforts

- Where can we influence the system?
  - How do we stop the outcomes & which ones do we stop?
- Who needs to be at the table to help make effective decisions?
  - Who are the necessary participants?

What about the future?

- HP 2010: 38% reduction in prevalence of diagnosed diabetes (types 1&2)
- Is this achievable considering…
  - Due to disease management efforts, people with diabetes are living longer?
  - Due to the rise in obesity, more people are developing diabetes?
  - Due to educational efforts and practice guidelines, more people with diabetes are (we assume) getting diagnosed?

What is PRISM Online?

A Growing Portfolio of CDC Efforts are Incorporating Systems Science

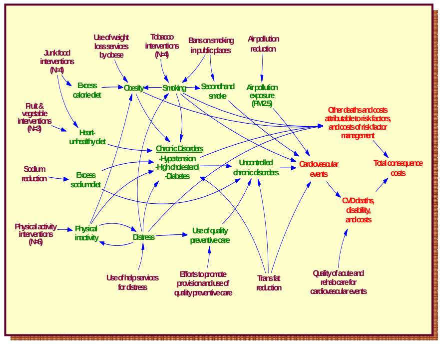
- **Infection dynamics**
  Smallpox, anthrax, HIV, STD, TB, polio, SARS, influenza, malaria, MRSA, healthcare-associated infections, etc.
- **Chronic diseases and risks**
  Diabetes, obesity, hypertension, heart disease, stroke, tobacco, diet, physical activity, stress, alcohol, oral health, sleep, preventive care, etc.
- **Mental he lth**
  Continuum sitive well-being to mental disor the life-course
- **Environmental**
  Air, water, soil, h climate change, et
- **Preparedness**
  Biological, radiolog environmental, etc.

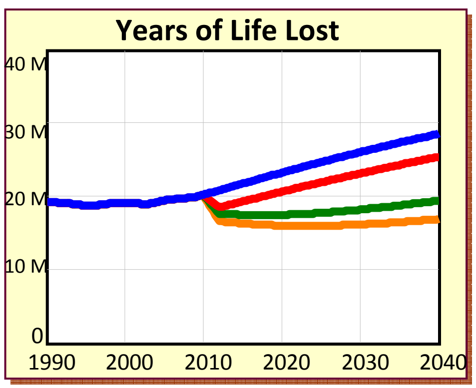
- **Violence and Injury**
  Child maltreatment, sexual assault, etc.
- **Reproductive health**
  Fetal and infant health
- **Urban health**
  Immigration, ethnic diversity, poverty, housing, employment, education, land use, and health
- **Grantmaking Strategy**
  Timing and sequence of outside eaders
- **am Effort**
  eatment with n
- **ormance**
  Relationships among access, cost, quality, equity, and health

PRISM
Prevention Impacts Simulation Model

PCD: Jan, 2010
Online: Soon

Prevention Impacts Simulation Model (PRISM)





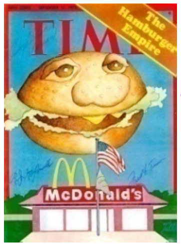
- Represents interacting risks and interventions for heart disease, stroke, and related chronic diseases: medical, behavioral, emotional, environmental
- Engages subject matter experts, policy officials, and practitioners, including a deep collaboration with leaders in Austin, TX and the Mississippi Delta
- Integrates best available information into a single testable model for prospective planning/evaluation
- Explores likely effects of 22 potential interventions
- Approximately 1,000 users to date
  - Anchors long-term evaluation for ARRA/CPPW
  - Policy tests by CDC, HHS, AHA, NACDD, NIH, Kaiser Permanente, others…
  - Custom calibrations for local stakeholders
- *PRISM Online* release in Summer 2011

Homer J, Milstein B, Wile K, Trogdon J, Huang P, Labarthe D, Orenstein D. Simulating and evaluating local interventions to improve cardiovascular health. Preventing Chronic Disease 2010;7(1). Available at http://www.cdc.gov/pcd/issues/2010/jan/08_0231.htm

Homer J, Milstein B, Wile K, Pratibhu P, Farris R, Orenstein D. Modeling the local dynamics of cardiovascular health: risk factors, context, and capacity. Preventing Chronic Disease 2008;5(2). Available at http://www.cdc.gov/pcd/issues/2008/apr/07_0230.htm`

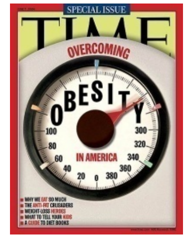
The Popular and Professional View of Chronic Disease Challenges is Largely One Headline after Another

Tobacco



Junk Food

Physical Activity



Obesity

Heart Disease & Stroke

Air Pollution

Healthy Food

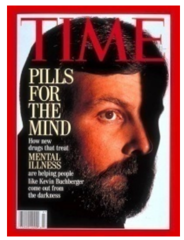
Weight Loss

Diabetes

Cancer

Stress

Sodium



Mental Health Services

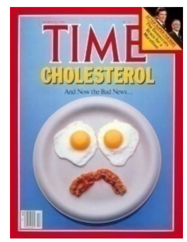
Blood Pressure

Health Care Cost

Alcohol

Trans fat

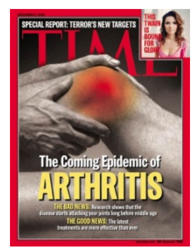
Primary Care



Cholesterol

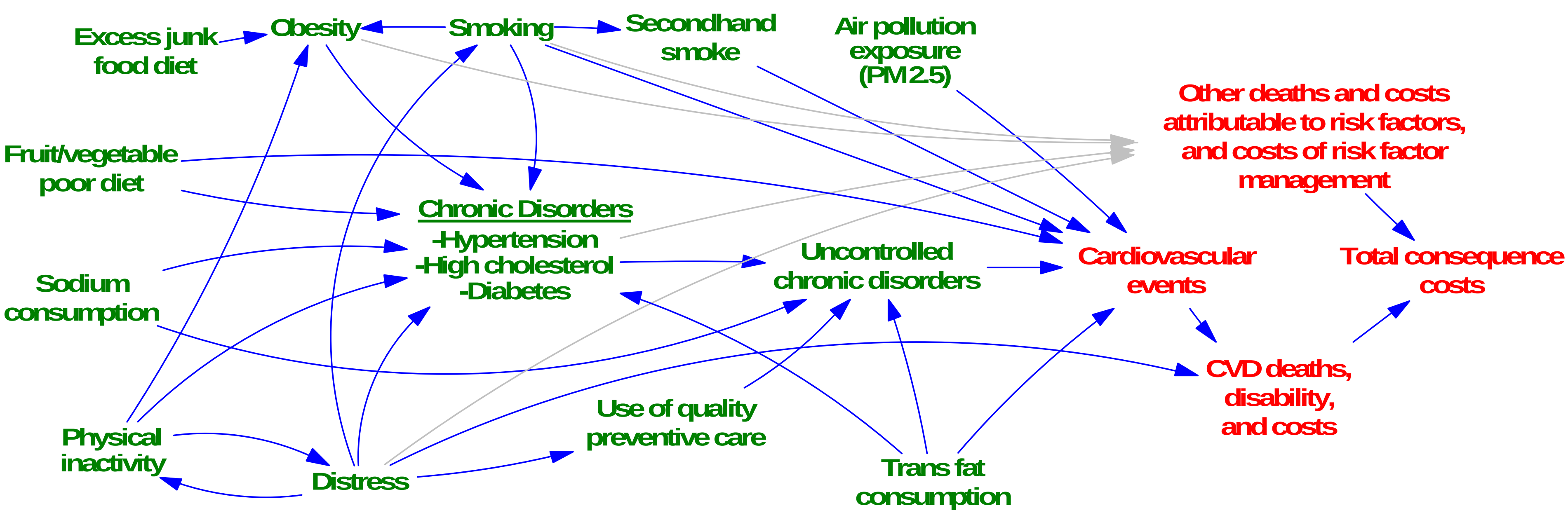
Sleep

Emergency & Rehab Care

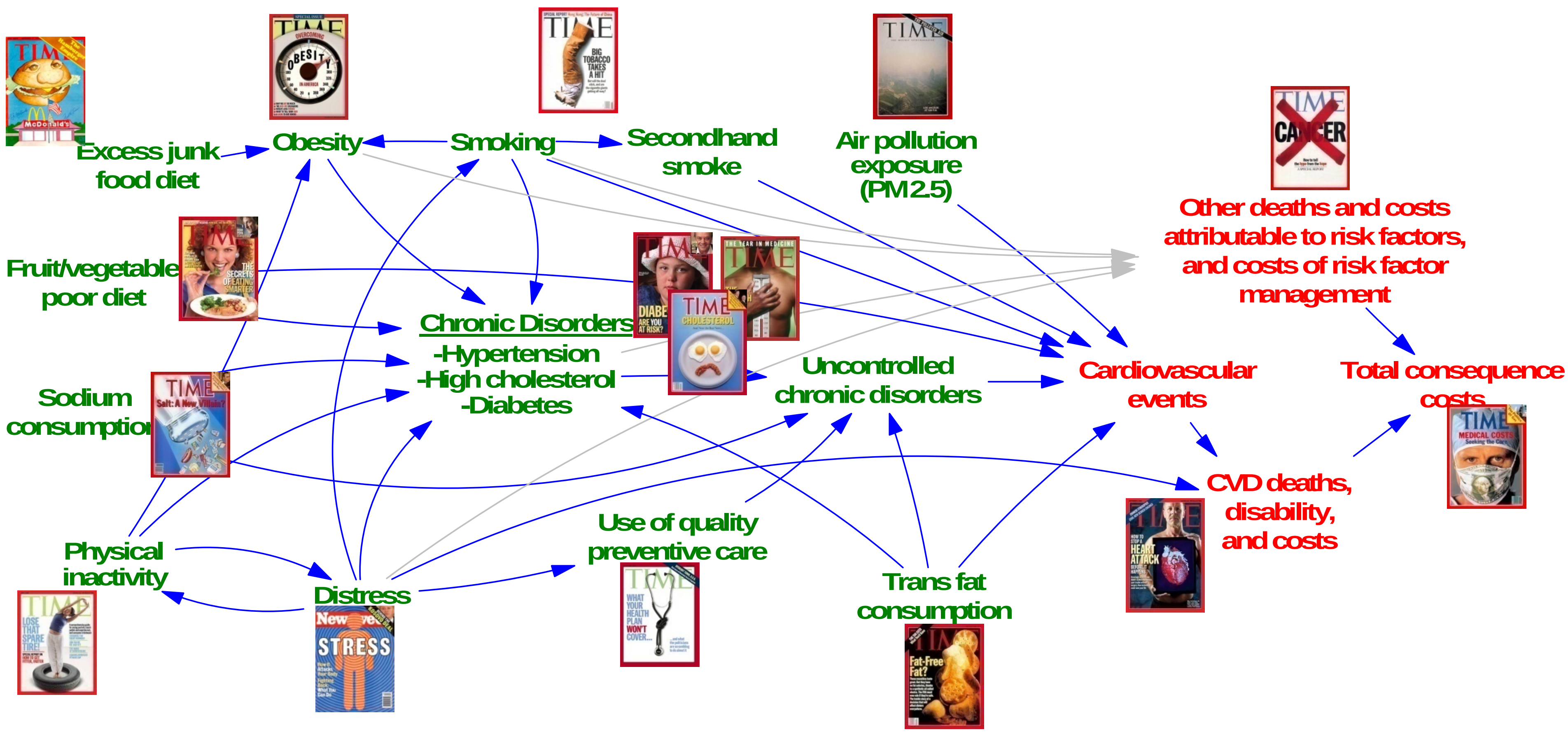


Arthritis

PRISM Situates Multiple Medical, Behavioral, and Environmental Factors Into a Single Set of Causal Pathways

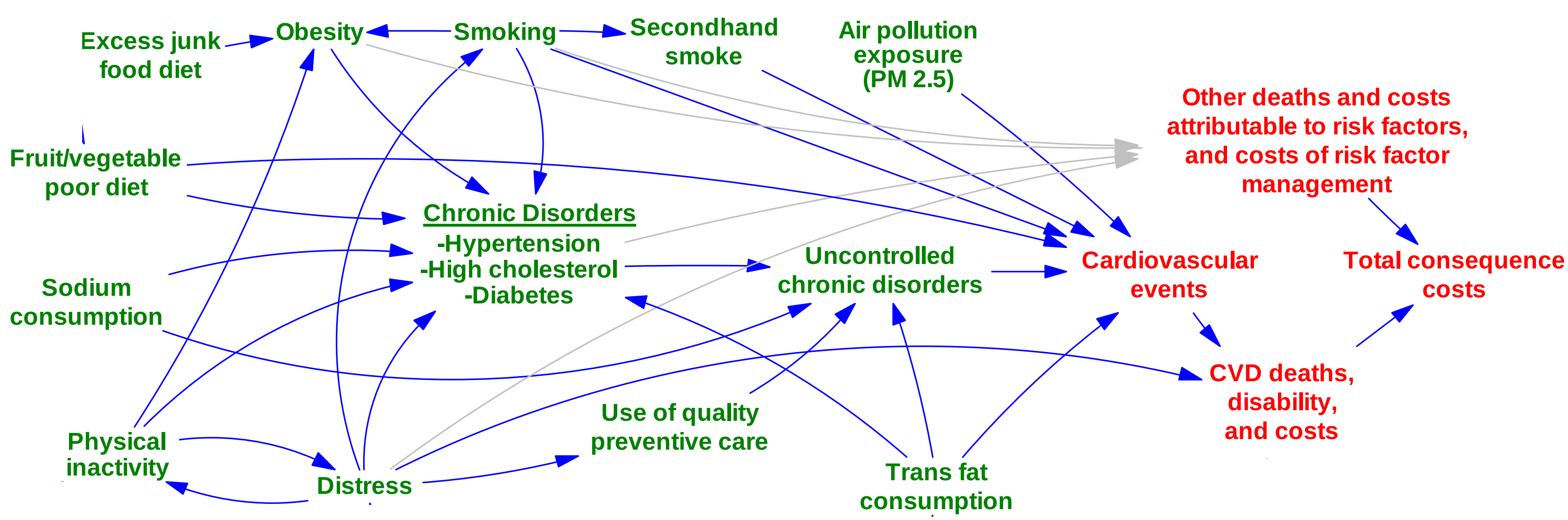


PRISM Situates Multiple Medical, Behavioral, and Environmental Factors Into a Single Set of Causal Pathways

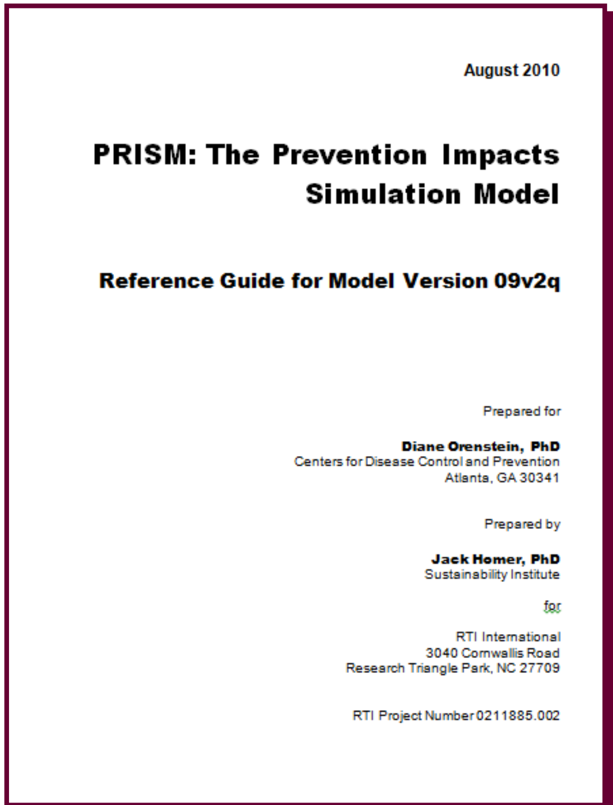


PRISM Also Includes Frontiers for Community Action

Local Context for Health Services



Methodological Details are Described in a Reference Guide



August 2010

PRISM: The Prevention Impacts Simulation Model

Reference Guide for Model Version 09v2q

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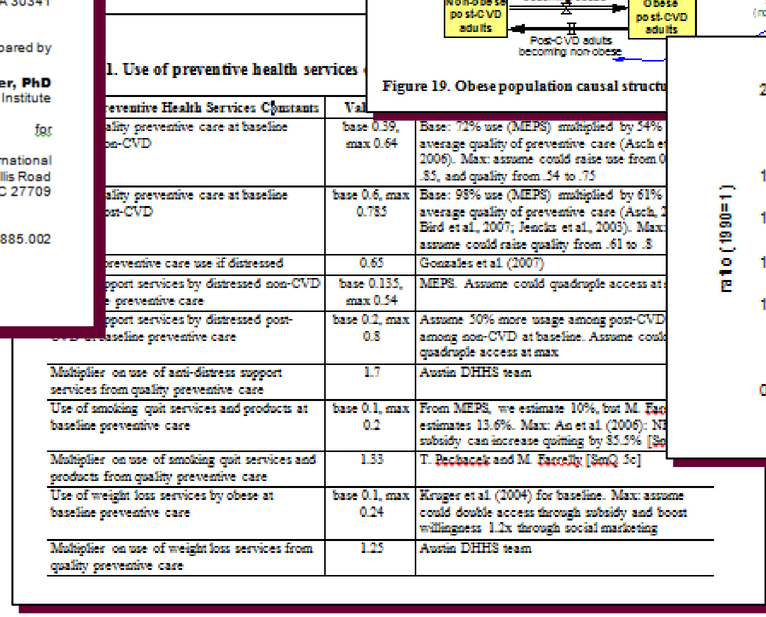
RTI Project Number 0211885.002



...1. Use of preventive health services ...

...reventive Health Services Constants	Val...	
...ality preventive care at baseline ...on-CVD	base 0.39, max 0.64	Base: 72% use (MEPS) multiplied by 54% average quality of preventive care (Asch et... 2006). Max: assume could raise use from 0... .85, and quality from .54 to .75
...ality preventive care at baseline ...ost-CVD	base 0.6, max 0.785	Base: 98% use (MEPS) multiplied by 61% average quality of preventive care (Asch, 2... Bird et al., 2007; Jencks et al., 2003). Max: assume could raise quality from .61 to .8
...reventive care use if distressed	0.65	Gonzales et al (2007)
...pport services by distressed non-CVD ...e preventive care	base 0.135, max 0.54	MEPS. Assume could quadruple access at...
...pport services by distressed post-CVD at baseline preventive care	base 0.2, max 0.8	Assume 50% more usage among post-CVD among non-CVD at baseline. Assume could quadruple access at max
Multiplier on use of anti-distress support services from quality preventive care	1.7	Austin DHHS team
Use of smoking quit services and products at baseline preventive care	base 0.1, max 0.2	From MEPS, we estimate 10%, but M. Fa... estimates 13.6%. Max: An et al (2006): N... subsidy can increase quitting by 85.5% [S...
Multiplier on use of smoking quit services and products from quality preventive care	1.33	T. Pechacek and M. Farrelly [SmQ 5c]
Use of weight loss services by obese at baseline preventive care	base 0.1, max 0.24	Kruger et al (2004) for baseline. Max: assume could double access through subsidy and boost willingness 1.2x through social marketing
Multiplier on use of weight loss services from quality preventive care	1.25	Austin DHHS team

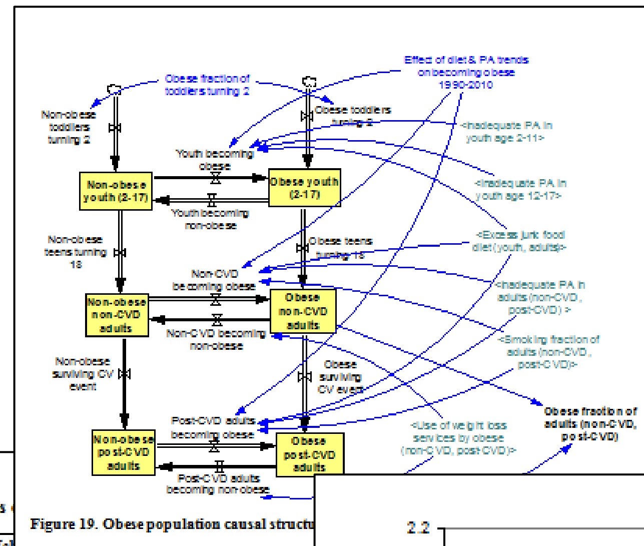
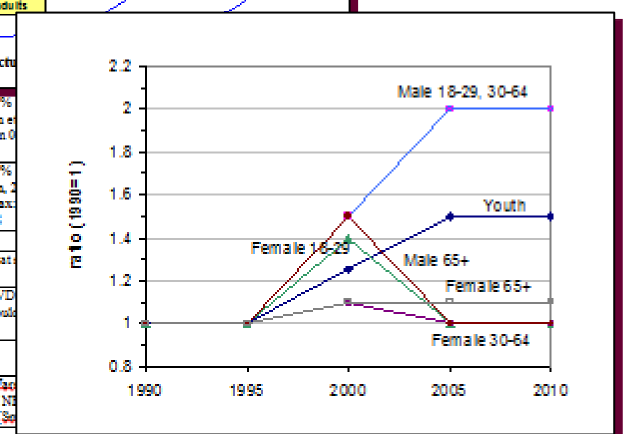


Figure 19. Obese population causal structu...



PRISM Online Simulates 22 Intervention Strategies

Custom Settings for Each Intervention

- **Ramp-in time**
- **Duration**
- **Direct effect size (within a plausible range)**

Health Domains

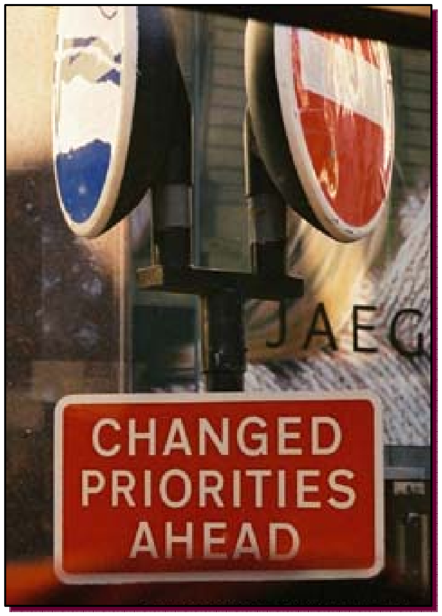
- Air pollution
- Diet
- Distress
- Medical care
- Physical activity
- Tobacco
- Weight loss services

Intervention Types

- Availability
- Price (tax/subsidy)
- Promotion, counter-marketing
- Bans, regulations, restrictions
- Social supports
- Individual services

Experimenting with PRISM

Base Case Scenario –
the the comparative referent to assess intervention affects

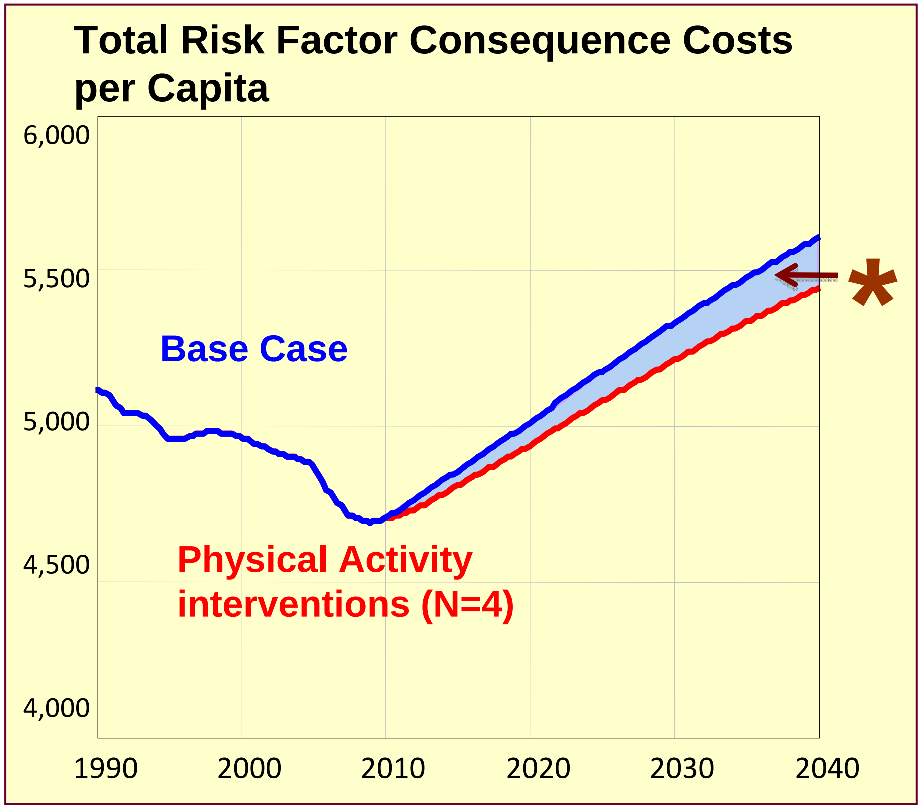


- **Assume no further *changes* in the contextual factors that affect risk factor prevalences**
- **Any changes in prevalences after 2009 are due to "inflow/outflow" adjustment process and population aging**
- **Result: Past trends level off after 2009, after which results reflect only slow adjustments in risk factors**
  - **Increasing high BP and diabetes**
  - **Decreasing smoking**
  - **Increases in risk factors and population aging lead to eventual rebound in attributable deaths**

Interpreting Cost Results

- These costs are for both CVD and non-CVD related complications, and include direct health-related costs, as well as lost productivity costs.
- Heath-related costs include office visits, medications, as well as costs of risk factor-related hospitalizations.

- When intervention costs are less than baseline, the difference is the per capita *health cost savings* per year – the maximum economically justifiable annual spending for the intervention



* = Average annual savings of $ 108 per capita from interventions to increase physical activity from 2010 - 2040.

PRISM Intervention Levers

1. Tax tobacco
2. Restrict tobacco sales & marketing
3. Increase tobacco counter-marketing
4. Ban workplace smoking
5. Increase use of smoking quit services
6. Reduce air pollution (PM2.5)
7. Tax junk food
8. Increase junk food counter-marketing
9. Expand access to fruit &vegetables
10. Promote fruit & veg consumption
11. Reduce sodium consumption
12. Reduce trans fat consumption
13. Increase use of weight loss services by the obese
14. Expand access to physical activity spaces
15. Promote physical activity
16. Require more physical activity in school
17. Require more physical activity in childcare
18. Increase use of quality preventive care, no CV event
19. Increase use of quality of preventive care, post CV event
20. Increase quality of acute and rehab care for CV events
21. Increase use of help services for distressed, no CV event
22. Increase use of help services for distressed, post CV event

Estimating Intervention Strengths

- **Reach** of interventions may not extend to entire population.
  – Reach is the fraction of population affected by the intervention.
- **Effectiveness** of interventions may not be maximum possible.
  – 100% effectiveness refers to the most effective interventions that have been documented to date. Effects of interventions account for change resistance in the population.
  – Many interventions can be quantified e.g. tax rates, access, use, nutrient reduction.
- **Intervention Reach x Effectiveness = Intervention Strength**
  – e.g. estimate for promotion: 90% of population reached x 30% effectiveness = estimated 27% strength

Testing the effects of sample interventions.

Although it is in pre-release form, it can be helpful for planning and evaluation.

1. In your browser, go to: http://forio.com/simulate/simulation/cdc/prism/
2. Log in as one of the following temporary accounts:

cdc1@forio.com password is **health**

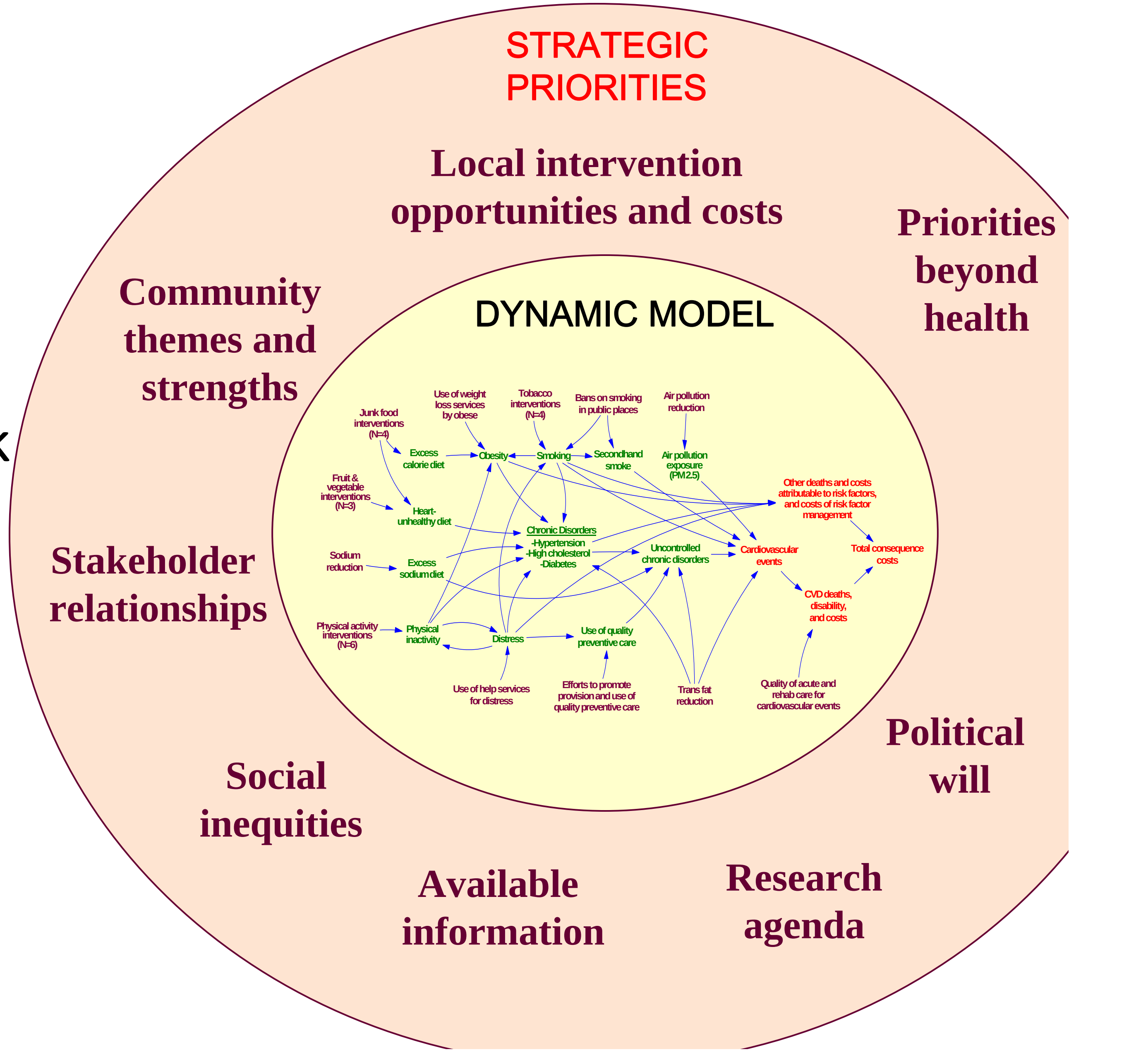
cdc2@forio.com “

thru

cdc10@forio.com

Conversations Around the Model

- **What's in the model does not define what's in the room**
- Simulations intentionally raise questions to spark broader thinking and judgment
- Boundary judgments follow from the intended purpose and users

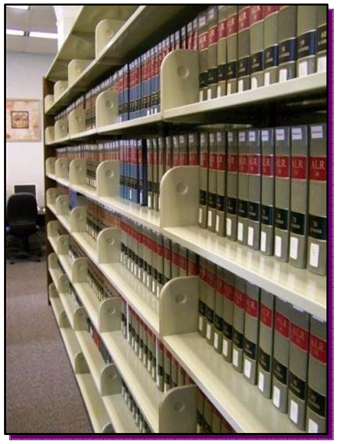


Wrap-up

- Your questions and ideas?
- Possible next steps
  - for Act on Data
  - others?

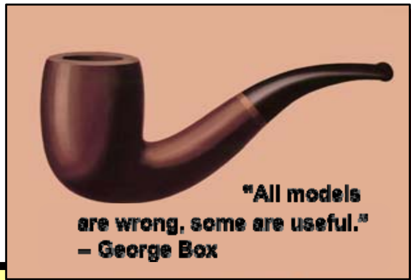
EXTRAS

Primary Information Sources



- Census
  - Population, deaths, births, net immigration
- American Heart Association & NIH statistical reports
  - Cardiovascular events, deaths, and prevalence
- National Health and Nutrition Examination Survey (NHANES)
  - Risk factor prevalence by age and sex
  - Diagnosis and control of hypertension, high cholesterol, and diabetes
- Medical Examination Panel (MEPS), National Health Interview (NHIS), Behavioral Risk Factor Surveillance System (BRFSS), Youth Risk Behavior Survey (YRBS)
  - Medical and productivity costs attributable to risk factors
  - Prevalence of distress in non-CVD and post-CVD populations
  - Primary care utilization
  - Extent of physical activity
- Research literature
  - CVD risk calculator (Framingham)
  - Relative risks from secondhand smoke, air pollution, obesity, poor diet, inactivity, distress
  - Quality of diet (USDA Healthy Eating Index)
  - Medical and productivity costs of cardiovascular events
  - Effect sizes of behavioral interventions
- Expert judgment
  - Effect sizes of behavioral interventions

Determining a system dynamics model's value…
and the need for further improvement



	MODEL STRUCTURE	MODEL BEHAVIOR
ROBUSTNESS	• Adequate boundary to address all questions • Equations allow for extreme possibilities	• Plausible behavior even under extreme conditions • Policy findings insensitive to uncertainties
REALISM	• Recognizable structures (transparency) • Plausible input values	•Replicate history •Plausible future behavior
USEFULNESS	• Adequate structure and policy levers for intended audiences	• Unexpected, insightful results •Quick testing turnaround

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In: Legasto A, Forrester JW, Lyneis JM, editors. System Dynamics. New York, NY: North-Holland; 1980. p. 209-228.

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