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Archimedes, Medicare, and ARCHeS

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MOVING MEDICINE THROUGH MATHEMATICS

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Outline

1. The Archimedes Model
   - Why we built it
   - What it is
   - What it can do
2. An application of the Model: preventing cardiovascular disease in Medicare
3. Making the Model more accessible: ARCHeS

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Why we built the Archimedes Model

- Health care is filled with questions
  - How much will CVD increase over the next 30 years in the Medicare population?
  - There are more than a dozen prevention activities recommended. How many heart attacks could be prevented?
  - What would a full-court press on prevention cost?
  - What is the “cost-effectiveness” of prevention? Would it be worth it?
  - How do the different prevention activities rank? Which should get priority?

How can we answer questions like these?

- Ideally, we would try out each of the prevention activities, alone and in various combinations, and see what happens
  - A series of clinical trials or evaluation studies
- Impossible
  - Too many options, combinations
  - Too much time
  - Too many people
  - Too expensive
  - Too rapid a pace for new technology

Plan B

- Think hard (ask experts)
- Impossible: too many variables
  - Incidence rates
  - Risk factors
  - Multiple causes
  - Variable natural histories, progression
  - Co-morbidities
  - Large number of interventions, combinations
  - Mixed evidence of effectiveness

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A Better Approach

- Mathematical models
  - Used in every other field of human endeavor
  - Airplanes, bridges, transportation, energy, sci-fi movies
- Ideally we want a model that
  - Includes all the important anatomy, physiology, diseases, and treatments
  - Represents people and populations accurately
  - Includes the entire health care system
  - Works at the level of detail at which real decisions are made
  - Accurately simulates the real world

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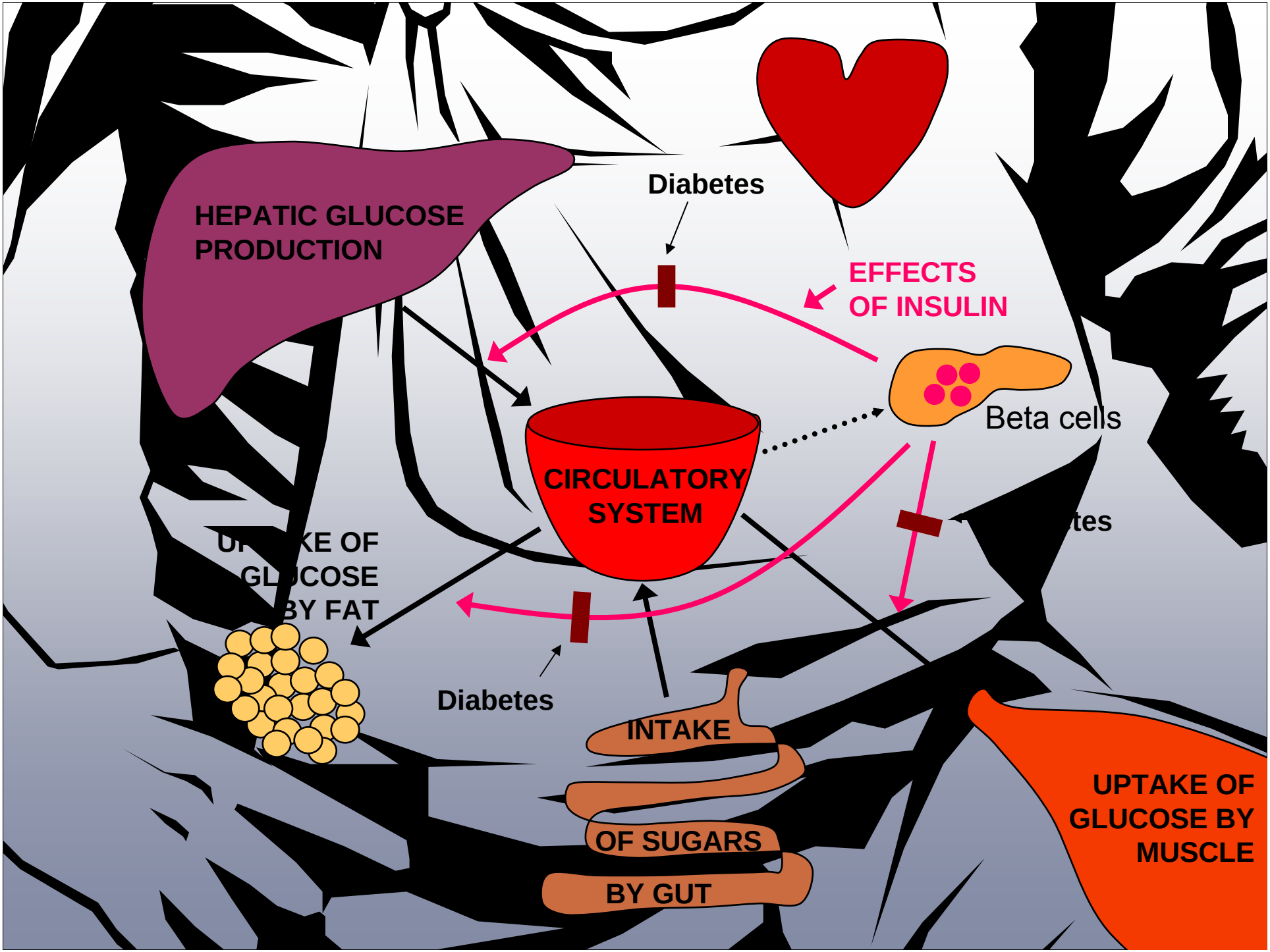
The Archimedes Model was built for this purpose

- "Includes all the important anatomy, physiology, diseases, and treatments"

...DICINE THROUGH MATHEMATICS


HEPATIC GLUCOSE PRODUCTION
Diabetes
EFFECTS OF INSULIN
Beta cells
CIRCULATORY SYSTEM
Diabetes
INTAKE
OF SUGARS
BY GUT
UPTAKE OF GLUCOSE BY MUSCLE

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"Represents populations accurately"

- We can create copies or clones of individual people
- Use data from surveys (e.g. NHANES), Health Risk Appraisals, Personal Health Records, EMRs or other sources
- Match about three dozen variables
  - Demographic characteristics
  - Biological variables
  - Behaviors
  - Symptoms
  - Past histories
  - Current treatments, …
- Capture correlations accurately

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"Includes the entire health care system"

- Anatomy and physiology
- Signs and symptoms
- Patient behaviors
- Care processes and logistics
- Health care personnel
- Tests and treatments, equipment and supplies
- Facilities
- Costs
- Quality of life

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"Works at the level of detail at which real decisions are made"

- The model is built at the level of detail and realism at which clinical and administrative decision-makers make their decisions
  - Blood pressure
  - Cholesterol
  - Admissions
- If they consider it important, we get it in the model …
- … or we explain why we can't
  - Insufficient evidence

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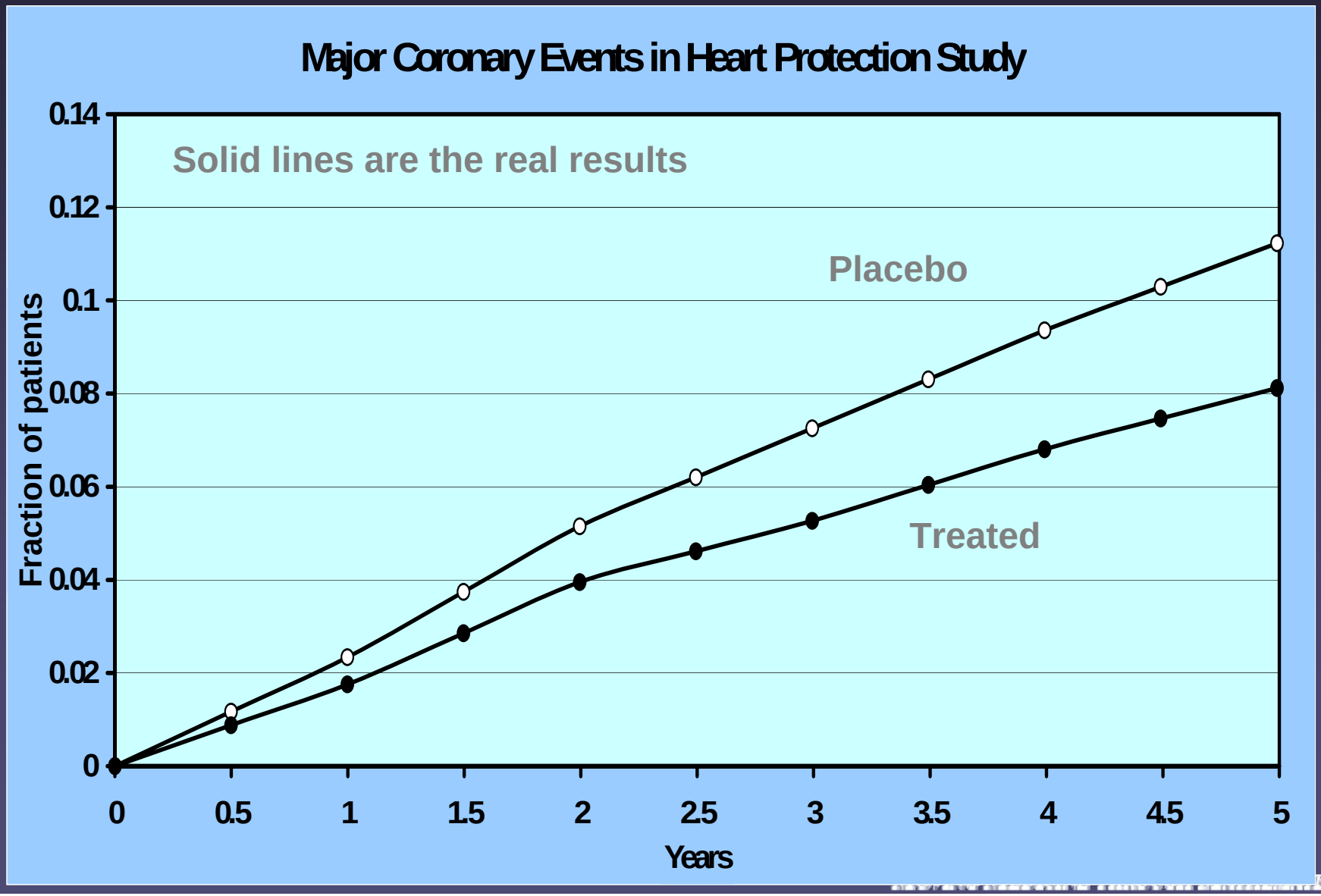
"Accurately simulates the real world"



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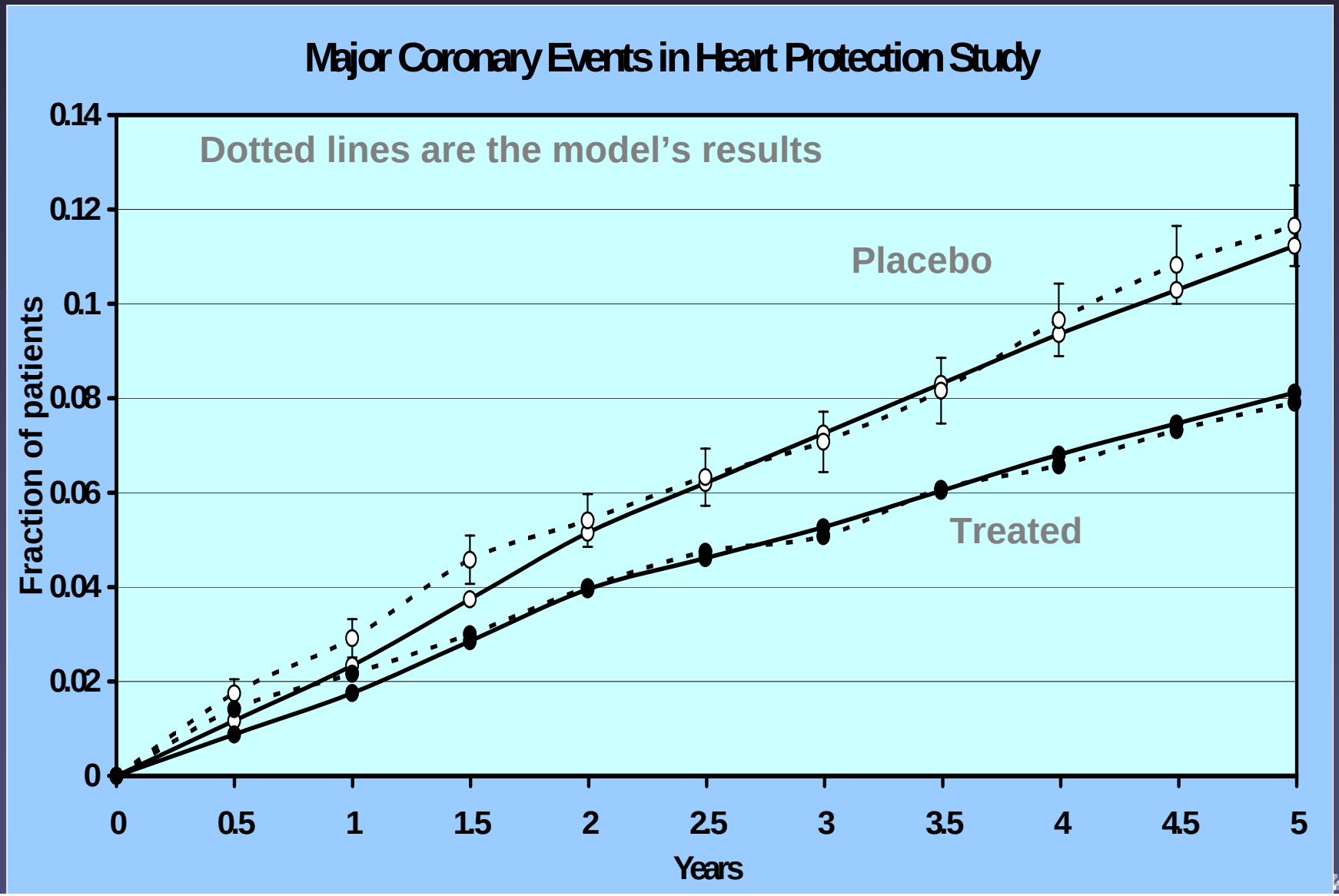
Cholesterol: secondary prevention



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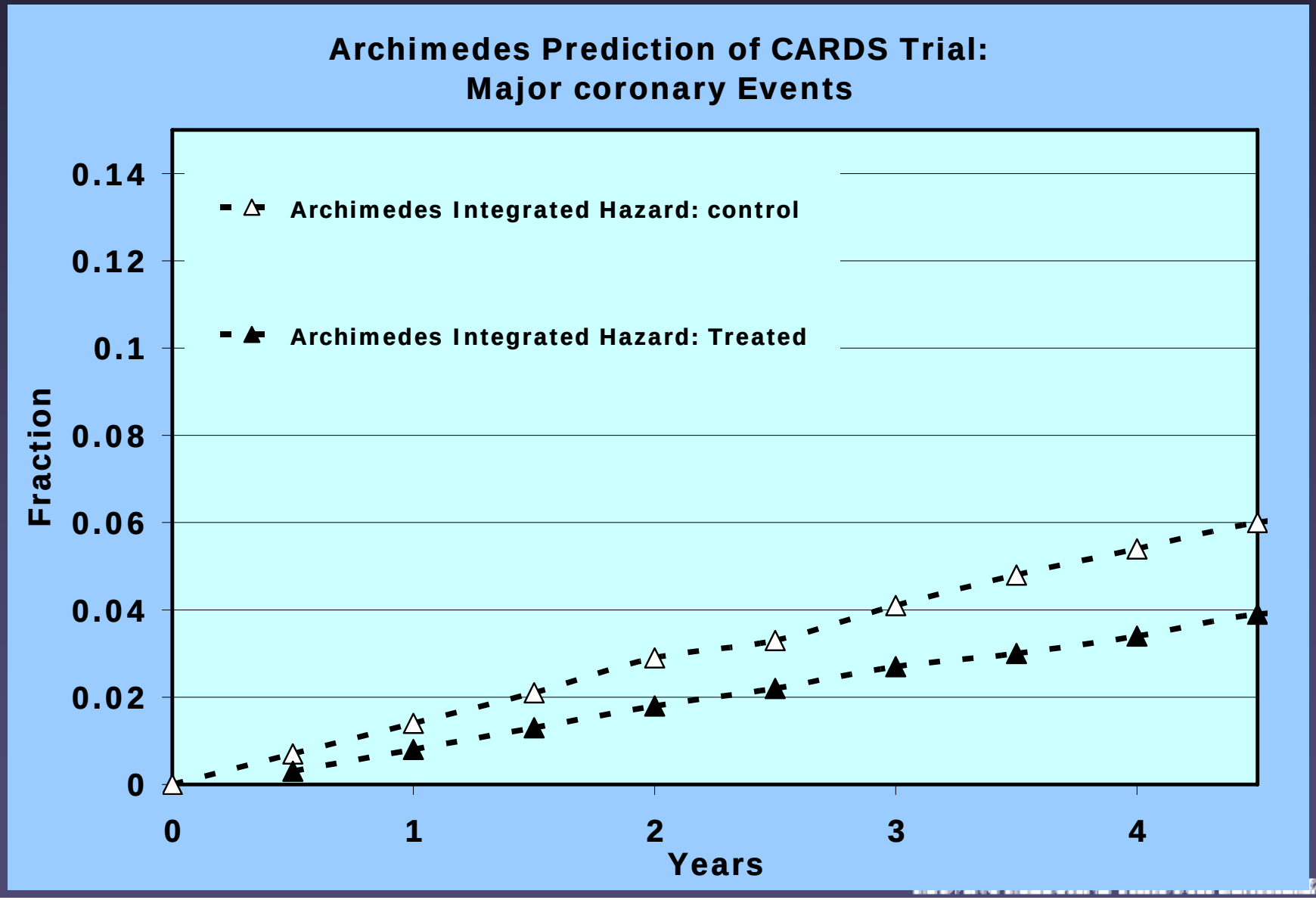
Cholesterol and CVD in Diabetics



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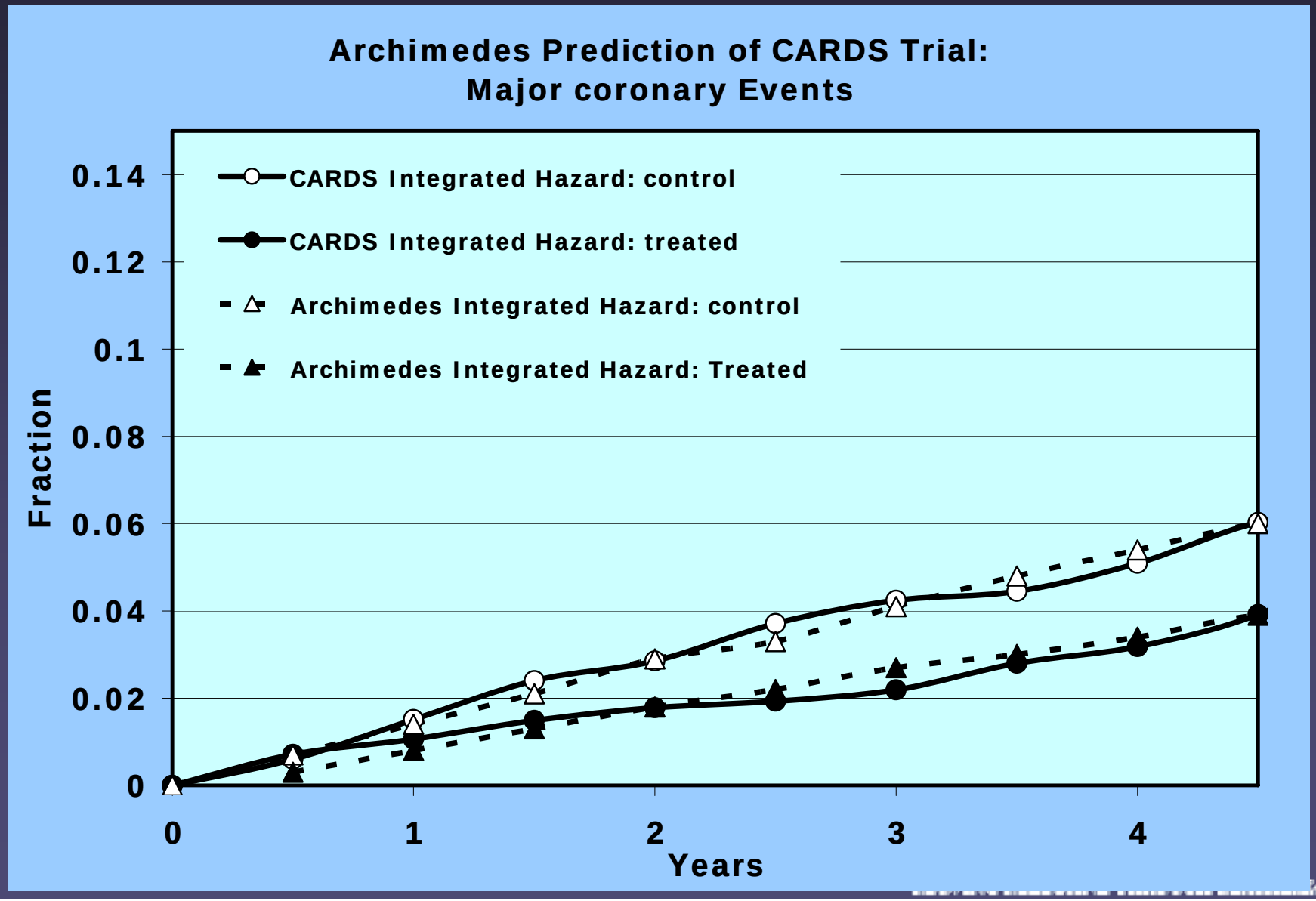
Cholesterol and CVD in Diabetics



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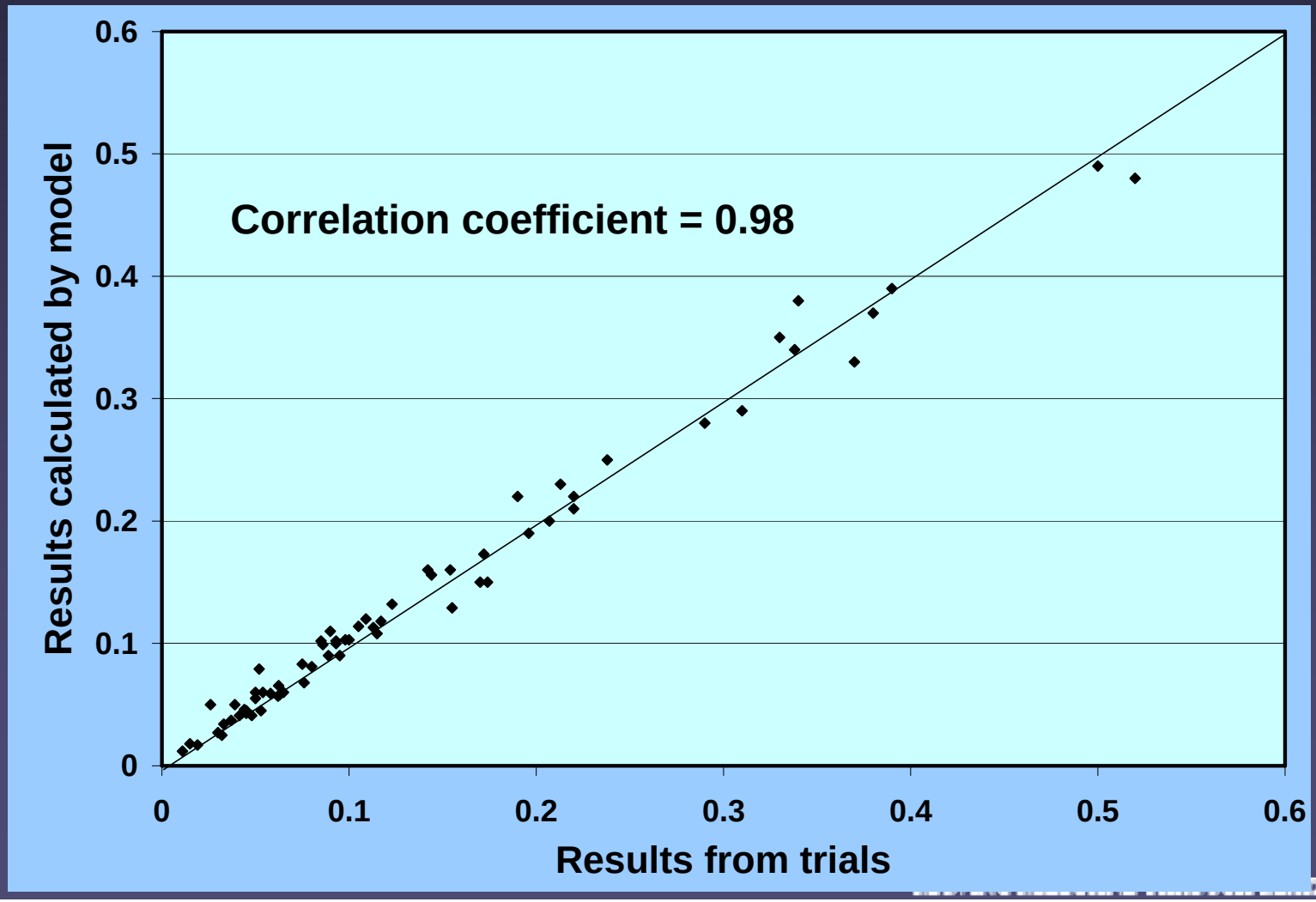
Comparison of model and trials: more than 100



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How we build it

- Publicly available information
  - Basic physiology studies
  - Epidemiological studies
  - Clinical trials
  - Large surveys
- Calculus
  - gratis Archimedes, Newton
- Object oriented programming
- Distributed computing

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A virtual world

- Virtual people
- who have virtual physiologies
- get virtual diseases
- have virtual signs and symptoms
- go to virtual doctors
- get virtual tests and treatments
- and have virtual outcomes

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Use the virtual world to study problems that can not be feasibly studied in the real world

- Clinical trials
- Guidelines
- Performance measures
- Incentives
- Priorities
- Strategic goals
- Prevention programs

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An Example: Preventing CVD in the Medicare Population

- An analysis for the
  - American Heart Association
  - American Cancer Society
  - American Diabetes Association

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The Problem

- Medicare faces a huge burden
  - Currently covers more than 42 million people
  - Annual expenditures exceed $400 billion
  - About a half of all heart attacks, strokes, and complications of diabetes occur in the Medicare population
- It is going to get worse rapidly
  - The size will increase rapidly as the baby boom moves through
  - Many risk factors are getting worse (e.g. diet, obesity)
  - Health care costs are growing faster than general inflation

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The solution?

- There are more than a dozen prevention activities that can help prevent cardiovascular disease

1. If BP >140/90, then reduce to <140/90
2. If diabetes and BP >130/80, then reduce to <130/80
3. If have acute MI, then give beta blockers after discharge, forever
4. If diabetes and HbA1c >7, then reduce to < 7
5. If smoke, then stop smoking
6. If BMI >25, then reduce to <25

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The solution?

- More prevention activities

7. If “prediabetes”, FPG between 110 and 125, then reduce to <110
8. If HDL <40 for males or <50 for females, then increase to >40 for males or >50 for females
9. If triglycerides >150, then reduce to <150
10. If MI risk > 10%, then take aspirin

The solution?

- More prevention activities

11. If LDL >160 and zero or one risk factors (see below), then to <160
12. If LDL >130 and two or more risk factors, then reduce to <130
13. If LDL >100 and history of MI, then reduce to <100
14. If LDL >100 and diabetes, then reduce to <100
    - Risk factors for LDL control
      - BP >140/90
      - HDL<40
      - Family history of MI before age 55
      - Male >45 or female >55

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Questions

- How much will CVD increase over the next 30 years in the Medicare population?
- How much CVD could be prevented with a full-court press?
- What would a full-court press on prevention cost?
- What is the “cost-effectiveness” of prevention?
- How do the different prevention activities rank? Which should get priority?

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Specific methods

- Create a simulated population representative of the Medicare population
  - Create clones of randomly chosen people in US (NHANES 4)
  - Preserve the distributions and correlations of all the important variables
  - Preserve the current use of prevent activities and levels of control
- Create a copy of a “typical” delivery system
  - National treatment guidelines
  - Current levels of performance
  - Resource based costs
  - Kaiser Permanente as illustration

Specific methods

- Create a series of simulated clinical trials
  - "Status quo" arm
    - Current use of prevention activities and levels of control of risk factors
  - "Intervention" arms
    - Each of the prevention activities one-by-one
    - All the prevention activities given together

Specific methods

- Run the trials for 30 years
- Measure everything in sight
  - Clinical outcomes (e.g. MIs, strokes,…)
  - Logistics outcomes (e.g. PTCAs, bypasses)
  - Economic outcomes
- Look at annual outcomes

Results

- On separate slides

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ARCHeS

- Would you like to be able to do this type of analysis yourself?
- The Medicare analysis
  - Cost in the hundreds of thousands of dollars
  - Took several months
  - Required very high level scientists
- What we need is a Web-based, user-friendly interface to the Archimedes Model

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ARCHeS will do this

- It will be available to any organization
- It will enable them to
  - Tailor Archimedes to its population and setting
  - And set up a wide variety of analyses
  - And get answers
  - In hours
- …At a much lower cost

- ARCHeS will be built with support from the Robert Wood Johnson Foundation

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ARCHeS

- Development has just begun
- Should be available by 2012
- Think of
  - Air traffic control
  - Houston Space Center
  - FedEx or UPS tracking systems
  - Sci-Fi movies
  - A Medicare “command and control” center

Things you can do

- Help make better data available for building and validating models
  - Person-specific, longitudinal data
  - Electronic medical records
  - Clinical trials
- "Rapid Learning"

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Summary

- A full-scale, physiologically accurate, system wide, validated model is feasible, and real today
  - The Archimedes Model
- It can fundamentally change how we plan and make decisions in health care
- It is in the process of being made widely available through the generous support of the Robert Wood Johnson Foundation
  - ARCHeS