REFLECTIONS ON USING SYSTEMS APPLICATIONS TO INFORM OBESITY SOLUTIONS: A WORKSHOP

Patricia L. Mabry, PhD
Research Investigator
HealthPartners Institute

Presented at: Using Systems Applications to Inform Obesity Solutions: A Workshop (webcast)
Hosted by the Health and Medicine Division of the National Academies of Sciences, Engineering, and Medicine (NASEM)
September 16, 2020

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WORKSHOP HIGHLIGHTS *Plus!*

Jack Homer: Simulation approaches for systems modeling

System Dynamics (SD) Simulation	Discrete Event Simulation	Micro-simulation or Agent-based models
• Compartmental (lumped) • Stock-flow cascades, feedback loops • Continuous time (longer time horizon) • Deterministic, but sensitivity testing gives an envelope of possibilities • 1 run: seconds at most.	• Stochastic, operationally detailed • Discrete time (shorter time horizon) • 1 run can be fast, but many runs required for summary findings.	• Micro-sim: individual actors <u>without</u> interaction (large N) ➢ Diverse patterns of attributes by individual • Agent-based: individual actors <u>with</u> interaction ➢ Diverse patterns of interaction (networks) ➢ Emergence of group or spatial clusters • 1 run: often 1 hour or more.

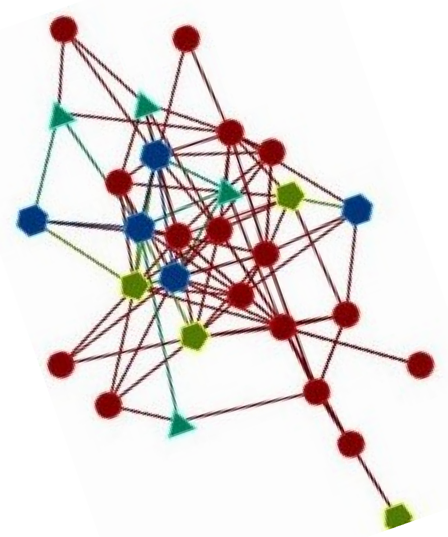
Plus!

Different methods and emphases, but they all agree:
Models should be testable, focused, and developed scientifically.

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

Levy DT, Mabry PL, et al. (2010). Simulation models of obesity: a review of the literature and implications for research and policy. *Obesity Reviews* (17 pp.) doi:10.1111/j.1467-789X.2010.00804

NETWORK SCIENCE

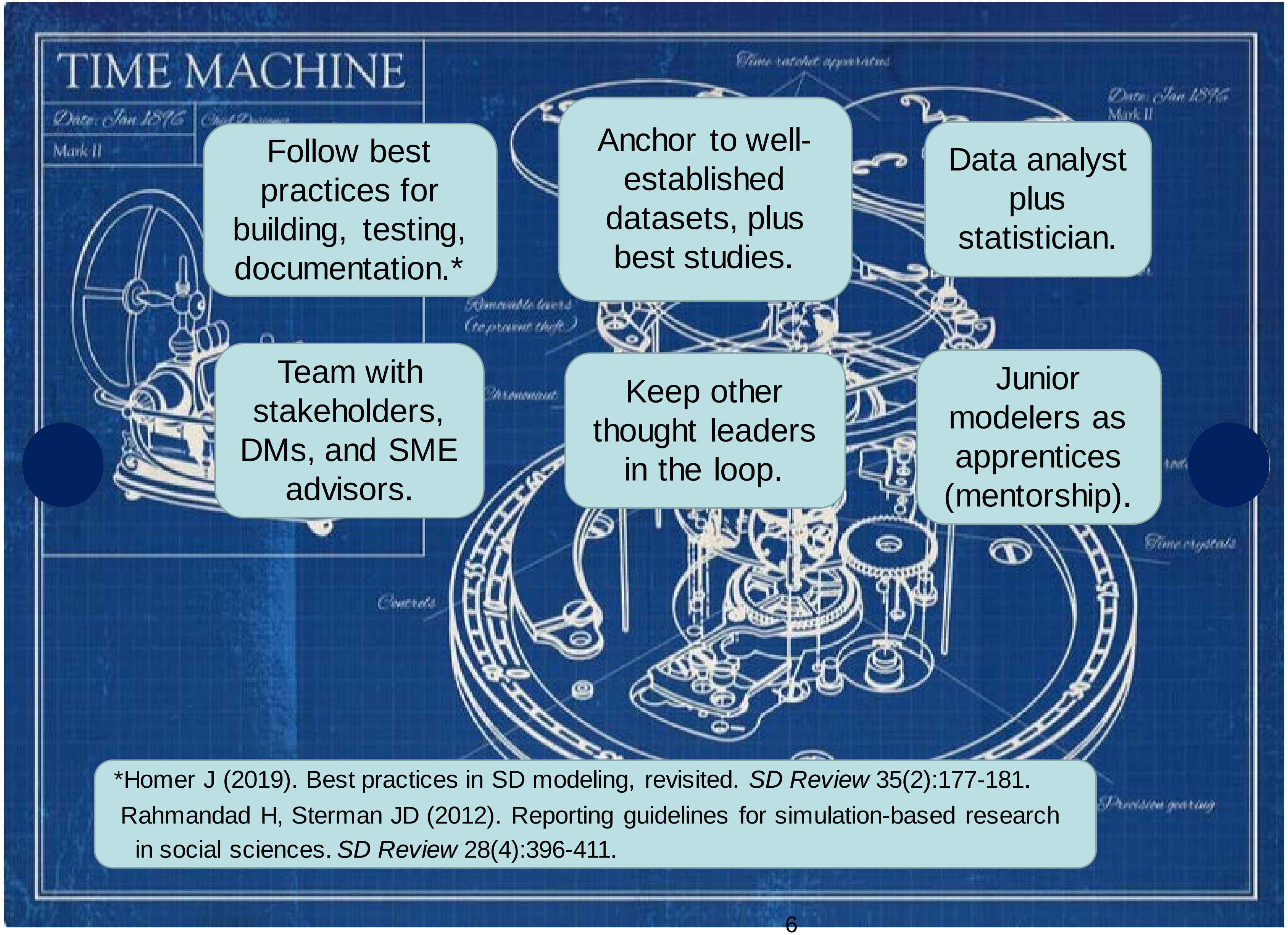


- The United States National Research Council defines network science as "the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena."[1] (source: Wikipedia).
- **Dynamic network analysis** (**DNA**) is an emergent scientific field that brings together traditional social network analysis (SNA), link analysis (LA), social simulation and multi-agent systems (MAS) within network science and network theory. It includes simulation to address issues of network dynamics. DNA networks vary from traditional social networks in that they are larger, dynamic, multi-mode (different types of entities or nodes), multi-plex (different types of edges/ties/relationships) networks, and may contain varying levels of uncertainty. The main difference of DNA to SNA is that DNA takes interactions of social features conditioning structure and behavior of networks into account.

(source: Wikipedia).

1. Committee on Network Science for Future Army Applications (2006). *Network Science*. National Research Council. doi:10.17226/11516. ISBN 978-0309653886.

Jack Homer: Blueprint for an ideal (well-funded, year-plus) systems modeling project



Follow best practices for building, testing, documentation.*

Anchor to well-established datasets, plus best studies.

Data analyst plus statistician.

Team with stakeholders, DMs, and SME advisors.

Keep other thought leaders in the loop.

Junior modelers as apprentices (mentorship).

*Homer J (2019). Best practices in SD modeling, revisited. *SD Review* 35(2):177-181.
Rahmandad H, Sterman JD (2012). Reporting guidelines for simulation-based research in social sciences. *SD Review* 28(4):396-411.

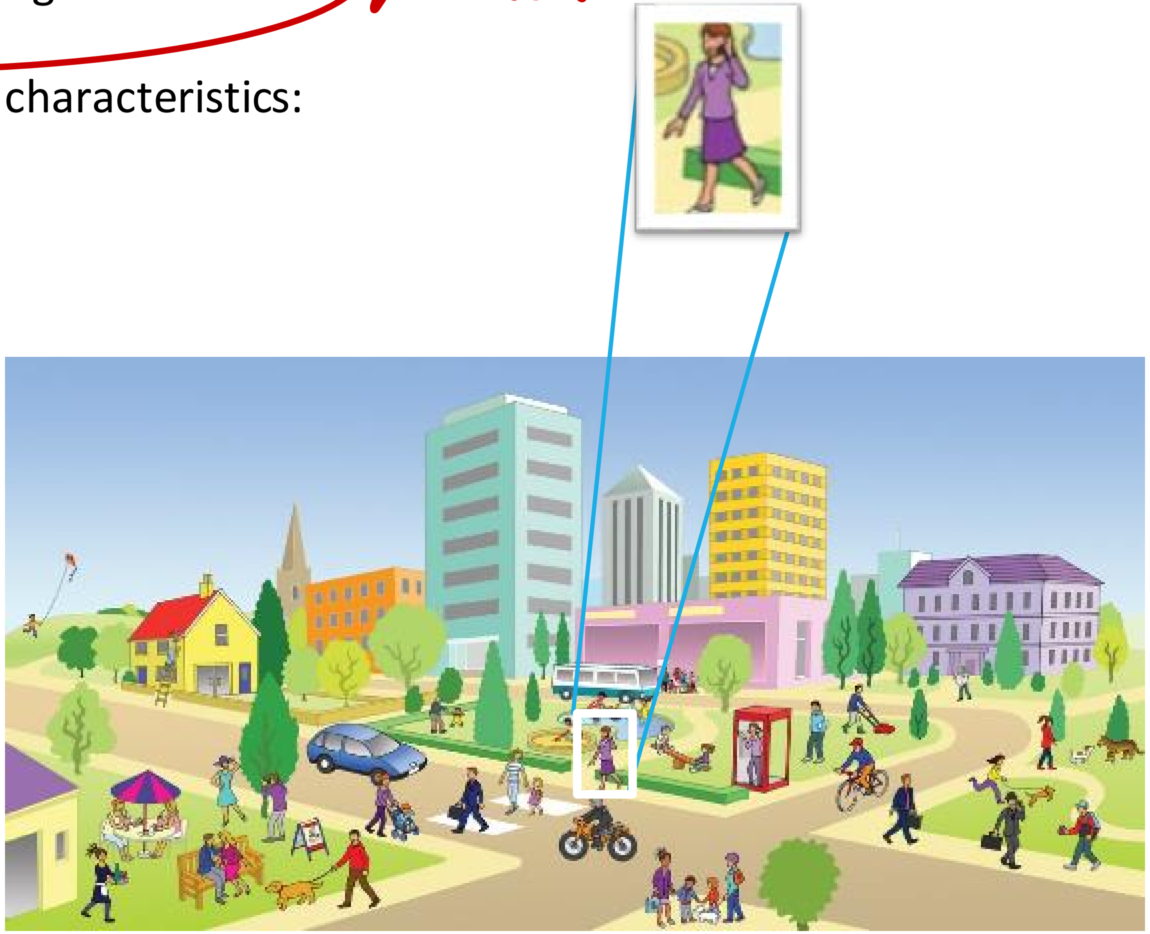
Plus!

Educate the model consumer

EACH PERSON REPRESENTED BY COMPUTATIONAL AGENT

Synthetic population built using census data

Plus! Secondary Data Sources:



Each agent has the following characteristics:

- Age
- Gender
- Race/Ethnicity
- Socio-economic status
- Home assignment
- School assignment
- Height
- Weight

Data specific to Baltimore allows the model to truly analyze the systems within Baltimore

SOURCES OF DATA TO POPULATE MODELS

Synthetic agents for an ABM

- Miller, Ian & Cupchik, Gerald. (2016). A Synthetic World Population for Agent-Based Social Simulation. 10.6084/M9.FIGSHARE.3427460.

  https://www.researchgate.net/publication/309287649_A_Synthetic_World_Population_for_Agent-Based_Social_Simulation

- RTI U.S. Synthetic Household Population™ https://www.rti.org/impact/synthpop

  Practical Application: The Neighborhood Map of U.S. Obesity
  Using the methods described here, we developed an example dataset called the Neighborhood Map of U.S. Obesity.

- Social Science One – data from private industry
  https://socialscience.one/

SyntheticMass https://synthea.mitre.org/about

SyntheticMass contains realistic but fictional residents of the state of Massachusetts. The synthetic population aims to statistically mirrors the real population in terms of demographics, disease burden, vaccinations, medical visits, and social determinants. SyntheticMass establishes a risk-free environment for experimenting with large-scale HL7 FHIR® data.

- Realistic data for fictional patients
- Data that is free of protected health information (PHI) and personally identifiable information (PII) constraints
- Datasets periodically updated over time based on clinical healthcare models and epidemiological models of population health.

To contribute, please contact the Synthea Development Team.

FHIR® is a registered trademark of HL7 and is used with the permission of HL7.

SYNTHEA

Synthea™ is a Synthetic Patient Population Simulation that is used to generate the synthetic patients within SyntheticMass. Synthea outputs synthetic, realistic (but not real) patient data and associated health records in a variety of formats. Read our wiki for more information.

Currently, Synthea™ features:

- Birth to Death Lifecycle
- Configuration-based statistics and demographics (defaults with nationwide US Census data)
- Drop in Generic Modules
- Primary Care Encounters, Emergency Room Encounters, and Symptom-Driven Encounters
- Conditions, Allergies, Medications, Vaccinations, Observations/Vitals, Labs, Procedures, CarePlans

U.S. Department of Health & Human Services > National Institutes of Health

NIH National Institutes of Health
All of Us Research Program

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The future of health begins with you.

The *All of Us* Research Program is inviting one million people across the U.S. to help build one of the most diverse health databases in history. We welcome participants from all backgrounds. Researchers will use the data to learn how our biology, lifestyle, and environment affect health. This could help them develop better treatments and ways to prevent different diseases.

JOIN NOW

https://allofus.nih.gov/get-involved/opportunities-researchers

About the Research Hub

The *All of Us* Research Hub is your gateway to participant data. Visit the Research Hub to:

- Use the interactive Data Browser. The *All of Us* Research Program announced the beta release of the Data Browser in May 2019 to provide a first look at the data that participants are sharing for health research.
- View Data Snapshots. Updated regularly, these snapshots provide visualizations of participant demographics, geographic distribution, and more.
- Read about *All of Us* data sources and methods of data curation.
- Find information about privacy and security processes that help keep participant data safe.

The Research Hub also houses the Workbench platform and its suite of custom tools. The Workbench offers access to additional levels of data, workspaces, a cohort builder, and an interactive notebook environment. These tools are now available to registered and approved *All of Us* researchers.

All of Us is a broad program that can support research on many aspects of health, not just a single medical or biological research question. The data platform enables research that can:

- Increase wellness and resilience, and promote healthy living
- Reduce health disparities and improve health equity in populations that are historically underrepresented in biomedical research (UBR)
- Develop improved risk assessment and prevention strategies to preempt disease
- Provide earlier and more accurate diagnosis to decrease illness burden
- Improve health outcomes and reduce disease impact through improved treatment and development of precision interventions

https://allofus.nih.gov/get-involved/opportunities-researchers

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Benefits for Researchers

All of Us offers two different access tiers: one for the general public and a second, restricted tier for registered researchers. Researchers have opportunities to:

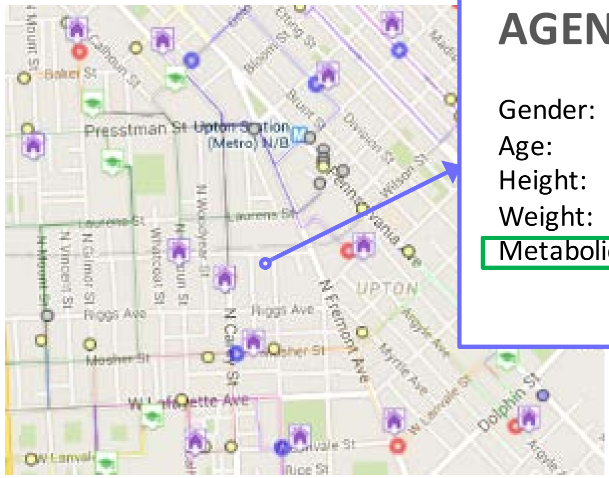
- Save time and resources and accelerate research breakthroughs by accessing:
  - A rich data resource, including biospecimens and increasingly robust electronic health records
  - A longitudinal dataset that will follow participants as they move, age, develop relationships, get sick, and try treatments
  - A diverse cohort of participants
  - Raw data and data that are already cleaned and curated
  - Robust computing and analytic tools to support complex data analyses in a secure data environment
  - A group of engaged participants who may be interested in participating in ancillary studies
- Share workspaces and analyses with research partners and reviewers
- Learn from the program's pilots and experiments
- Leverage innovations of other studies and cohorts

Learn more about what the *All of Us* Research Program is doing to work with researchers as partners.

https://allofus.nih.gov/get-involved/opportunities-researchers

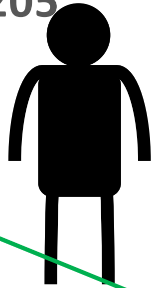
EACH AGENT IS EMBEDDED WITH A PERSONALIZED METABOLIC MODEL

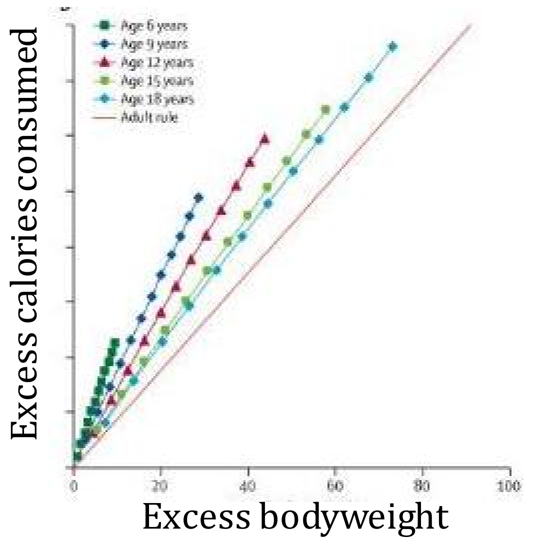
THE ASPEN INSTITUTE PROJECT PLAY



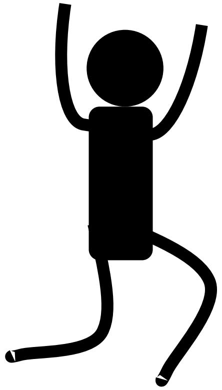
AGENT 241,205

Gender: *M*
Age: *12*
Height: *60*
Weight: *95*
Metabolic model

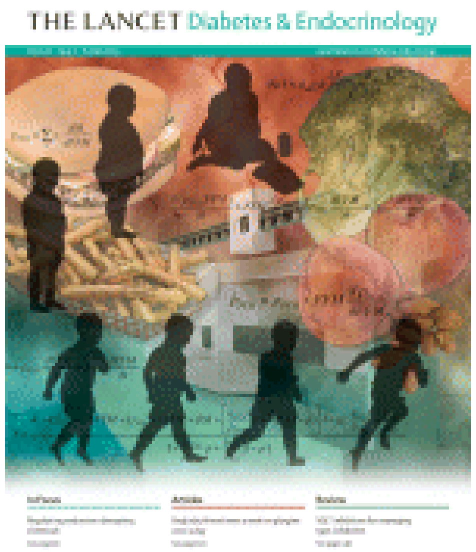




Hall et al, 2014



Calories Eaten - Calories Burned = Weight Gain or Loss



Hall, K. D., Butte, N. F., Swinburn, B. A., & Chow, C. C. (2013). Dynamics of childhood growth and obesity: development and validation of a quantitative mathematical model. *The lancet Diabetes & endocrinology*, *1*(2), 97-105.

Dynamics of childhood growth and obesity: development and validation of a quantitative mathematical model

CrossMark

Kevin D Hall, Nancy F Butte, Boyd A Swinburn, Carson C Chow

Summary

Background Clinicians and policy makers need the ability to predict quantitatively how childhood bodyweight will respond to obesity interventions.

Methods We developed and validated a mathematical model of childhood energy balance that accounts for healthy growth and development of obesity, and that makes quantitative predictions about weight-management interventions. The model was calibrated to reference body composition data in healthy children and validated by comparing model predictions with data other than those used to build the model.

Findings The model accurately simulated the changes in body composition and energy expenditure reported in reference data during healthy growth, and predicted increases in energy intake from ages 5–18 years of roughly 1200 kcal per day in boys and 900 kcal per day in girls. Development of childhood obesity necessitated a substantially greater excess energy intake than for development of adult obesity. Furthermore, excess energy intake in overweight and obese children calculated by the model greatly exceeded the typical energy balance calculated on the basis of growth charts. At the population level, the excess weight of US children in 2003–06 was associated with a mean increase in energy intake of roughly 200 kcal per day per child compared with similar children in 1971–74. The model also suggests that therapeutic windows when children can outgrow obesity without losing weight might exist, especially during periods of high growth potential in boys who are not severely obese.

Interpretation This model quantifies the energy excess underlying obesity and calculates the necessary intervention magnitude to achieve bodyweight change in children. Policy makers and clinicians now have a quantitative technique for understanding the childhood obesity epidemic and planning interventions to control it.

Funding Intramural Research Program of the National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases.

Lancet Diabetes Endocrinol 2013; 1: 97–105

Published Online July 30, 2013 http://dx.doi.org/10.1016/S2213-8587(13)70051-2

This online publication has been corrected. The corrected version first appeared at thelancet.com/diabetes-endocrinology on September 20, 2013

See Comment page 80

National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, MD, USA (K D Hall PhD, C C Chow PhD); Baylor College of Medicine, Houston, TX, USA (Prof N F Butte PhD); and School of Population Health, University of Auckland, Auckland, New Zealand (Prof B A Swinburn MD)

Correspondence to: Dr Kevin D Hall, National Institute of Diabetes and Digestive and Kidney Diseases National Institutes of Health, 12A South Drive, Bethesda, MD 20892-5621, USA

Introduction

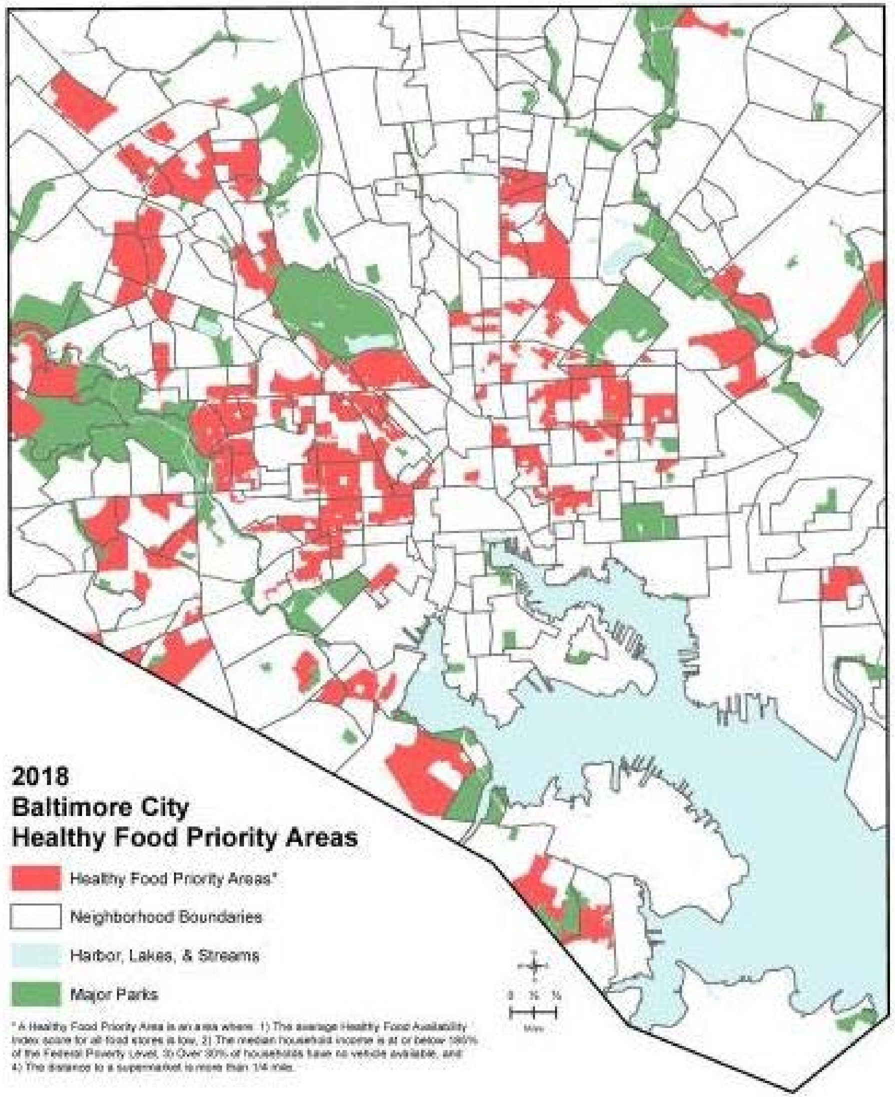
One of the most disconcerting aspects of the global obesity epidemic[1] is the high prevalence of childhood

Previous models for estimation of energy imbalances in children who are of healthy weight, overweight, or obese[9–15] could

HEALTHY FOOD PRIORITY AREAS

Plus!

Need for spatial models.



Type of Stores	Avg HFAI Score
Small Grocery and Corner Stores	
525	9.1
Convenience Stores	
183	9.3
Public Markets	
6	14.0
Supermarkets	
47	27.7

JOHNS HOPKINS CENTER for A LIVABLE FUTURE

BALTIMORE CITY HEALTH DEPARTMENT

Communities (Baltimore)

15

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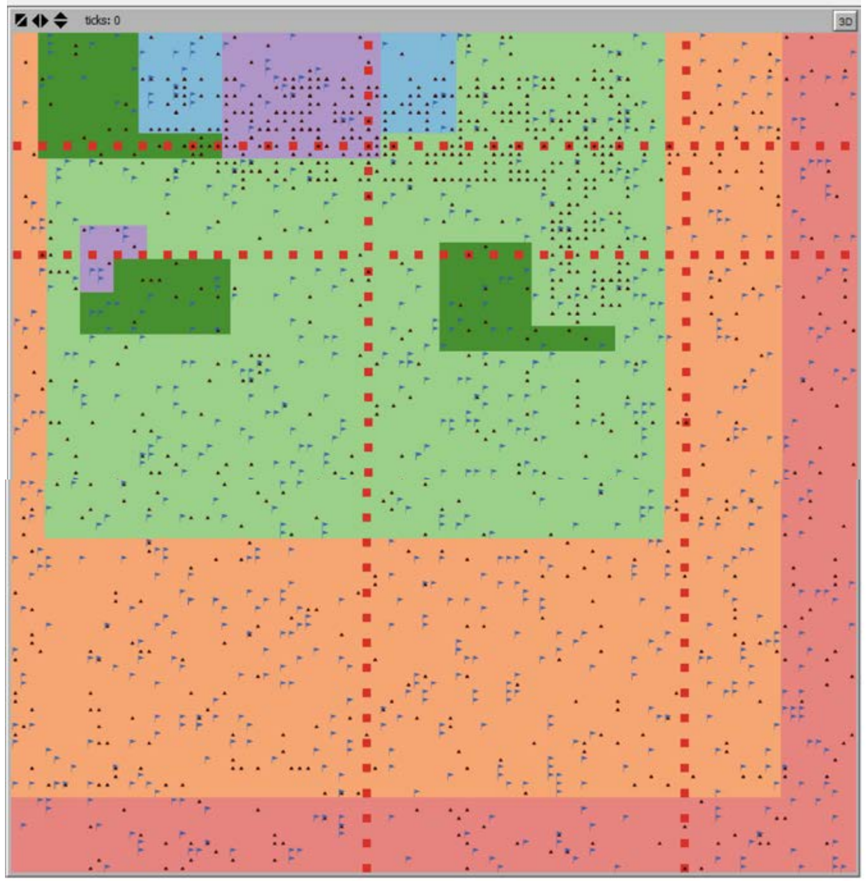
Urban transport and mobility policy

Design

- Spatially explicit model – virtual city with realistic socioeconomic segregation
- Agents make a daily commute between their home and workplace



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Why we need systems approaches for a community settings

Plus!

Systems Science Methods are Motivated by Complexity in Behavioral & Social Science (and more!) Data

- Temporal Properties (on multiple scales)
- Spatial Properties
- Network Structures
- Hierarchical, Nested Structures
- Feedback Loops
- Individual Level Variation (Observed *and* Unobserved)
- Group Level Variation (Observed *and* Unobserved)
- Mediating & Moderating Variables
- Non-Linear & Non-Parametric Properties

The Complex Context of Health Disparities and Obesity

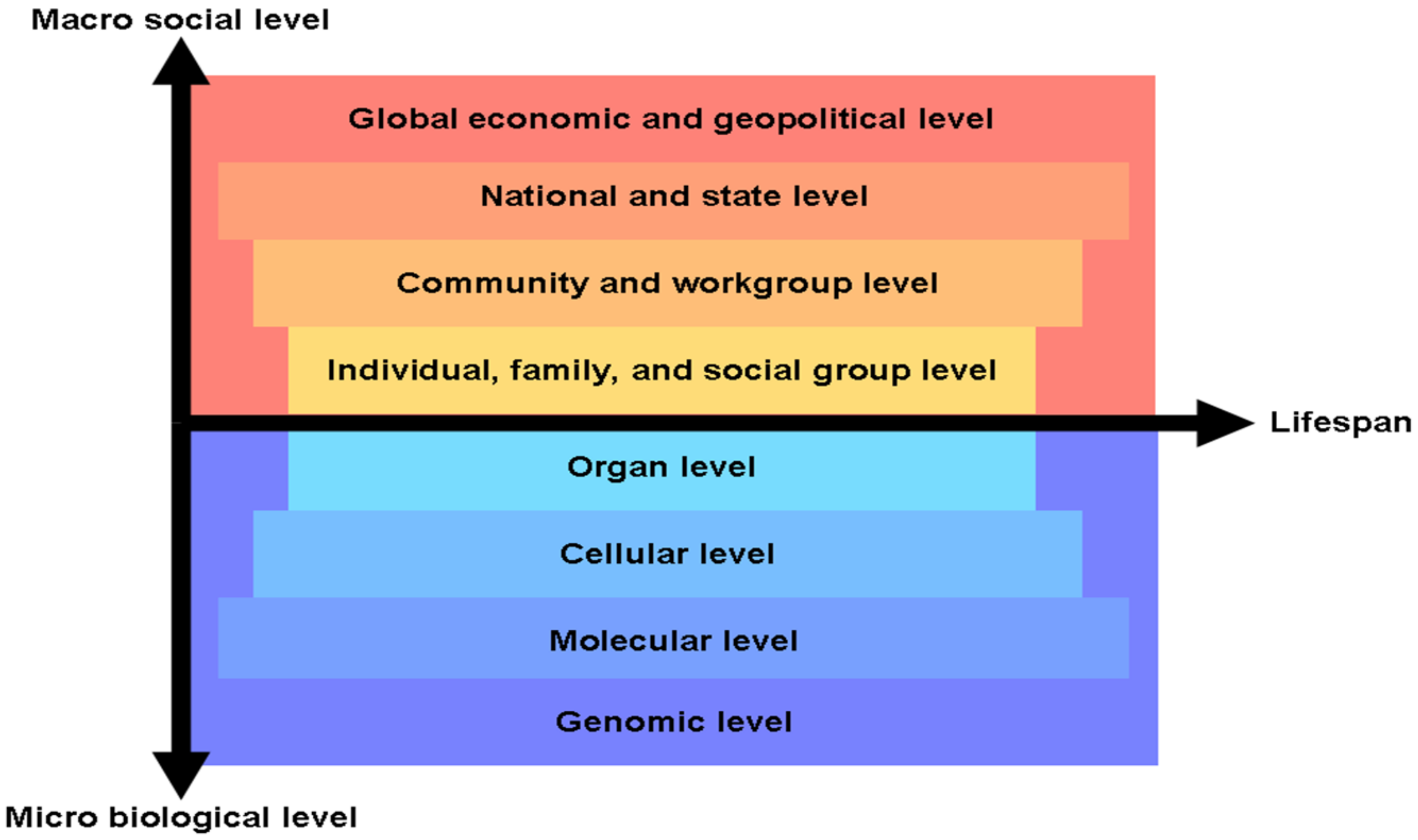
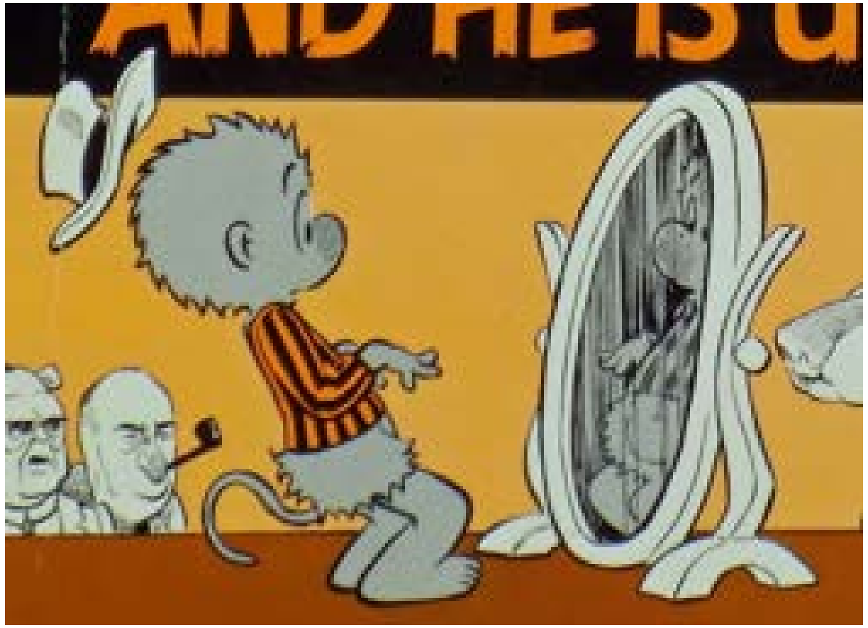


Figure 1. Health as a continuum between biological and social factors across the lifespan. (Adapted from Glass & McAtee, 2006).

SOLVING COMPLEX PROBLEMS IS HARD WORK!



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OPPORTUNITIES ARE USUALLY DISGUISED AS HARD WORK, SO MOST PEOPLE DON'T RECOGNISE THEM

- Ann Landers

By definition, pursuing low-hanging fruit should be a no-brainer for any business. An easy opportunity simply waiting to be seized. Little sweat, all reward!

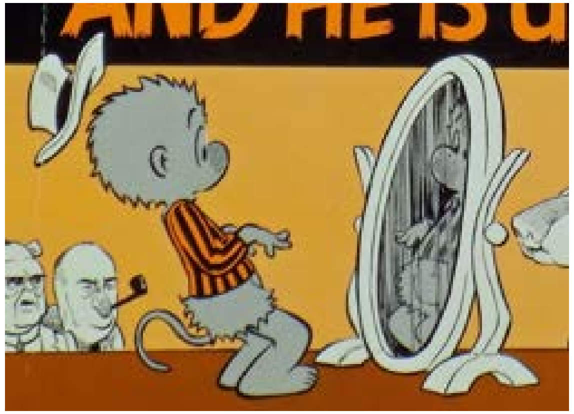
Jason Fried. The myth of low-hanging fruit
The Medium. Blog Post. 9/02/2016.
https://medium.com/signal-v-noise/the-myth-of-low-hanging-fruit-443459fe205a

PLACES TO INTERVENE IN A SYSTEM (IN INCREASING ORDER OF EFFECTIVENESS)

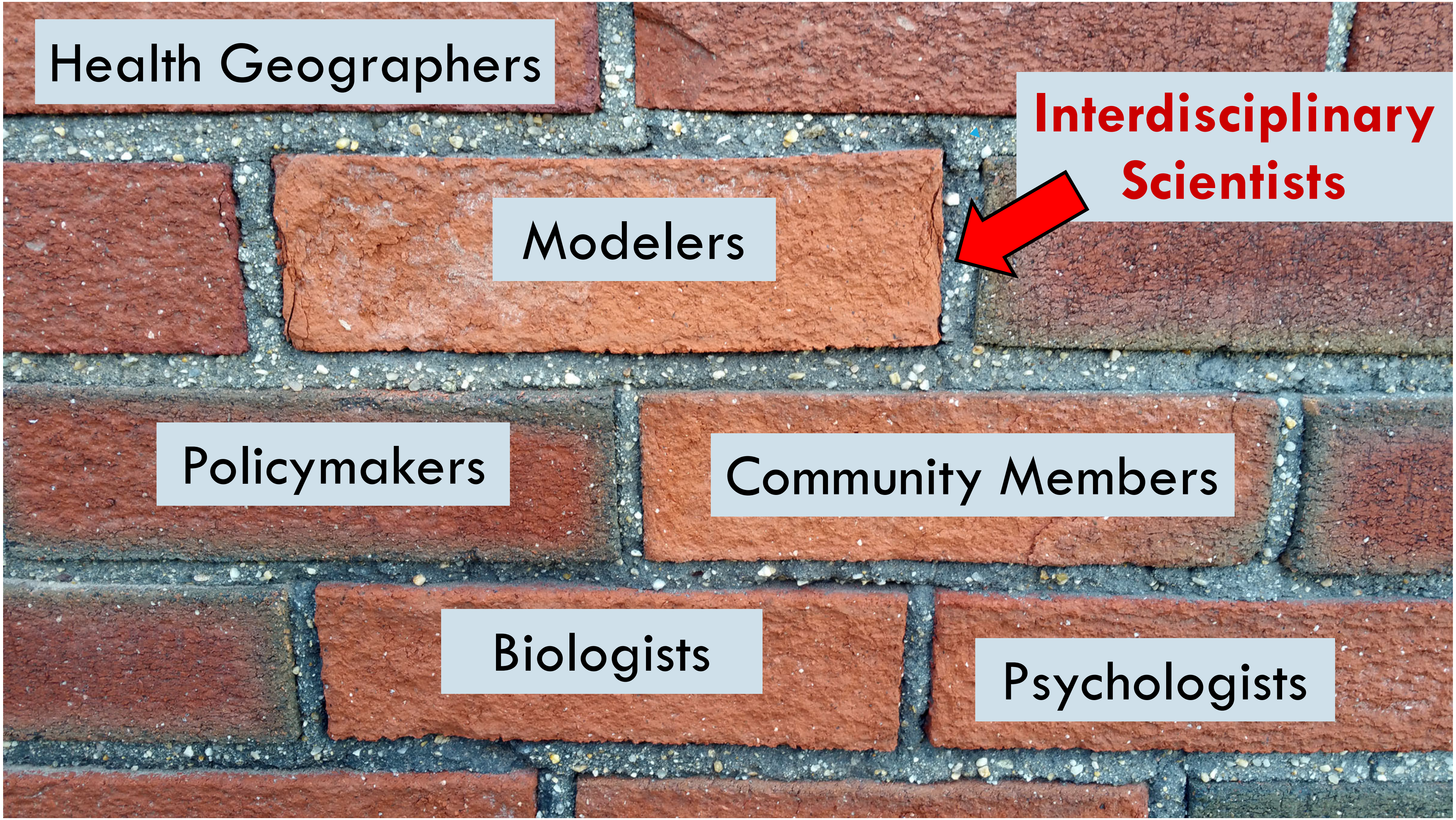
9. Constants, parameters, numbers (subsidies, taxes, standards).
8. Regulating negative feedback loops.
7. Driving positive feedback loops.
6. Material flows and nodes of material intersection.
5. Information flows.
4. The rules of the system (incentives, punishments, constraints).
3. The distribution of power over the rules of the system.
2. The goals of the system.
1. The mindset or paradigm out of which the system — its goals, power structure, rules, its culture — arises.

Meadows, D. H. (2008). Thinking in systems: A primer. Chapter 6. Leverage Points: Places to intervene in a system (pp. 145-165). chelsea green publishing. http://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/

WHAT MAKES SYSTEMS MODELING SO HARD?



- Getting good appropriate sources of data, including longitudinal data,
- Stakeholder engagement, policymakers, healthcare systems, businesses
- Impatience
- Interdisciplinary team building, communication across disciplinary boundaries
- Lack of self-efficacy. Doing what we know instead of learning what we should be doing.
- Bucking the culture of science – worshiping the RCT as the gold standard
- Following through on the course of action models indicate – can go against ideology
- Prevention conundrum - difficult to prove that the intervention indicated by the model avoided the impending doom.


Health Geographers
Interdisciplinary Scientists
Modelers
Policymakers
Community Members
Biologists
Psychologists

About the Social Determinants of Health Project

PhenX Measures for Social Determinants of Health

In 2018, the National Institute on Minority Health and Health Disparities (NIMHD) funded an administrative supplement to the PhenX project to select high-quality standard measures related to social determinants of health (SDOH) for inclusion in the PhenX (consensus measures for **Phen**otypes and e**X**posures) Toolkit (www.phenxtoolkit.org). The goal of the PhenX Measures for SDOH project is to establish a *common currency* of measurement protocols that will help inform effective interventions to reduce health disparities. In addition, consistent use of standard measurement protocols will improve the quality and consistency of data collection and facilitate collaboration. The ability to easily share and combine data from multiple studies has the potential to increase the scientific impact of individual studies.

Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

Sources for Data on Social Determinants of Health

Data can be a catalyst for improving community health and well-being. Understanding data on social determinants of health, such as income, educational level, and employment, can help focus efforts to improve community health. The following tools are supported by CDC resources; some tools include references to data sources outside of CDC.

- Chronic Disease Indicators
    - **Level of data: state, territory, select large metropolitan areas**
    - The Chronic Disease Indicators enable public health professionals and policy makers to retrieve state and selected metropolitan-level data for chronic diseases and risk factors, including overarching conditions that are SDOH.
- Chronic Kidney Disease (CKD) Surveillance System
    - **Level of data: national**
    - This interactive, comprehensive, systematic surveillance system documents the burden of CKD and its risk factors in the US population over time. It also tracks progress of efforts to prevent, detect, and manage CKD and its complications. Newly included in the system are trends in CKD and household food insecurity score.
- Compendium of Federal Datasets Addressing Health Disparities
    - **Level of data: multiple**

Most data on SDOH are at the aggregate level. We need data at the individual level.

OTHER TOPICS

- How to decide when there are many evidence-based options and limited resources?
  Models help us prioritize which action to take

- Models help us prioritize what future research to pursue.

- Models help us evaluate programs/interventions before they are completed.

- Models help us set realistic targets and tell us what resources it will take to get there.

- Model sharing and reuse.
  - Bruce, is the Project Play ABM available for reuse?
    - Lee, B. Y., Adam, A., Zenkov, E., Hertenstein, D., Ferguson, M. C., Wang, P. I., ... & Falah-Fini, S. (2017). Modeling the economic and health impact of increasing children's physical activity in the United States. *Health Affairs*, *36*(5), 902-908.
  - Barton, C. M., Alberti, M., Ames, D., Atkinson, J. A., Bales, J., Burke, E., ... & Feng, Z. (2020). Call for transparency of COVID-19 models. *Science*, *368*(6490), 482-483.

ADDITIONAL RESOURCES

- Nathaniel Osgood, PhD, U of Saskatchewan; Tutorial Class Videos & Materials
  https://www.cs.usask.ca/faculty/ndo885/Classes/index.html

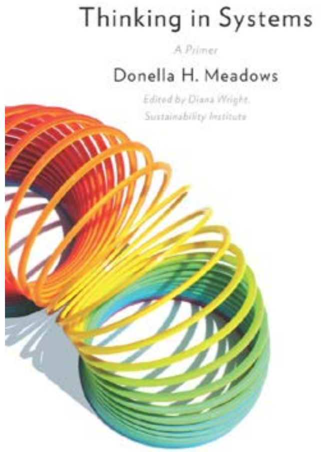
- NIH Institute on Systems Science and Health

- 2007 NIH Symposium Series on Systems Science and Health
  https://www.preventionresearch.org/conferences/training/2007-symposia-series-on-systems-science-and-health/

- Envision https://www.nccor.org/envision/
  - Mabry, Patricia L., and Regina M. Bures. "Systems science for obesity-related research questions: an introduction to the theme issue." (2014): 1157-1159.
- https://healthmodeling.org/ Funded by NIH R25 – resources for systems modeling in health
- Sterman, J. D. (2006). Learning from evidence in a complex world. *American journal of public health*, *96*(3), 505-514.

ADDITIONAL RESOURCES

- Thinking in Systems: A Primer, Donella Meadows



- Collaboration – SIPHER https://sipher.ac.uk/ SIPHER will deliver cost-benefit evidence on the complex, interlinked and long-term consequences of policy decisions across sectors.

UKPRP Prevention Research Partnership

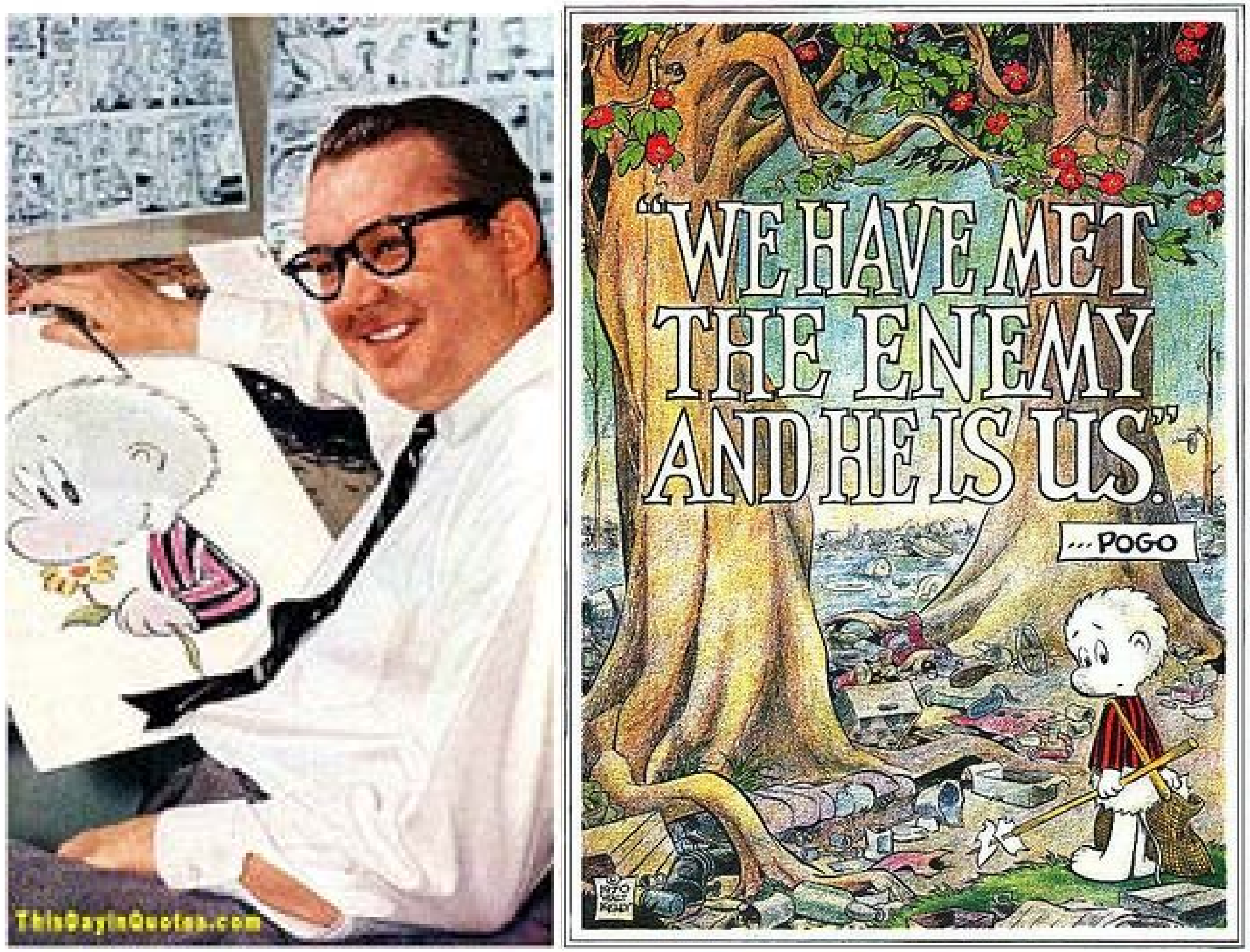
SIPHER Consortium

Systems science
In Public Health and
Health Economics Research

- Collaboration – CSART. http://www.csart-world.com/ Computer Simulation & Advanced Research Technologies is a not-for-profit organization working to build global capacity in the use of computer simulation and advanced research technologies to support policy and planning decisions that better address our most complex, persistent health and social problems.
- Drexel short courses
- Daniel Kim, forthcoming, book on applications of modeling and simulation methods to public health and social epidemiology, funded by the National Library of Medicine and to be published by Wiley & Sons

FUTURE DIRECTIONS

- Addressing the root causes of inequalities in the distribution of obesity – need to measure, need data, including longitudinal data
- Cross-sectoral stakeholder engagement, policymakers – especially related to health inequalities.
- Geographically explicit models to get at disparities. Involve health geographers
- Finding funding to form community based research relationships.
- Pressure our funders for education, to use systems science to inform research priorities
- More comparative modeling efforts, e.g., MIDAS, CISNET
- Leverage artificial Intelligence and data science in modeling
- Keep learning – read and use the resources available
- Deliberately seek to cross disciplinary boundaries and bring in interdisciplinarians.
- Build a community of systems science. More coordination and reuse of research assets. Self-organize!
- Realign the incentives in our system! Science of Science



Walt Kelly (1913-1973) and his famous poster for the first Earth Day on April 22, 1970

DEDICATED TO TWO OF THE GIANTS

David Bishop Lombard, PhD
aka “Pop”
Pogo Fan, nuclear physicist, father
Taught me critical thinking

Donnella Meadows, PhD
aka “Dana”
Founder Sustainability Institute, author of Thinking in Systems: A Primer

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HealthPartners Institute | make good happen