Synthesizing data for simulating the epidemic

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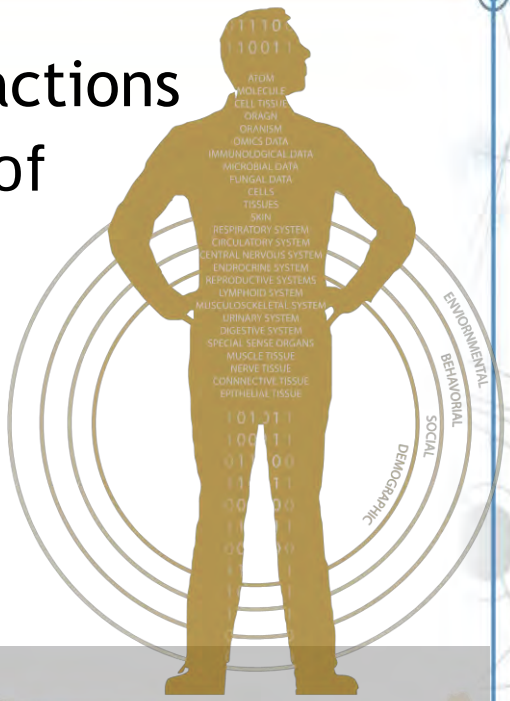
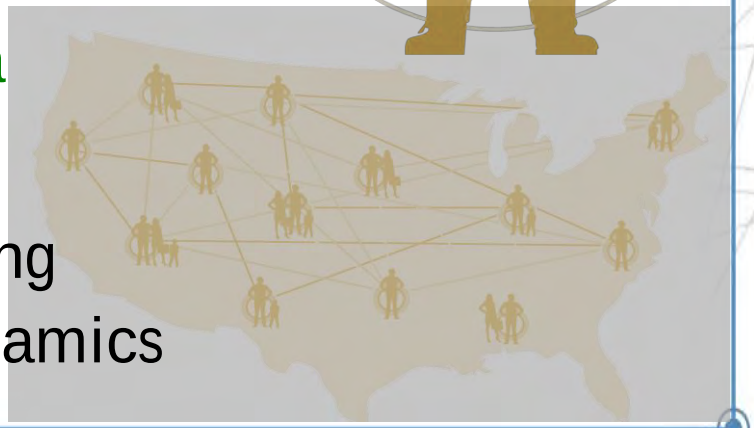
VirginiaTech.
Biocomplexity Institute

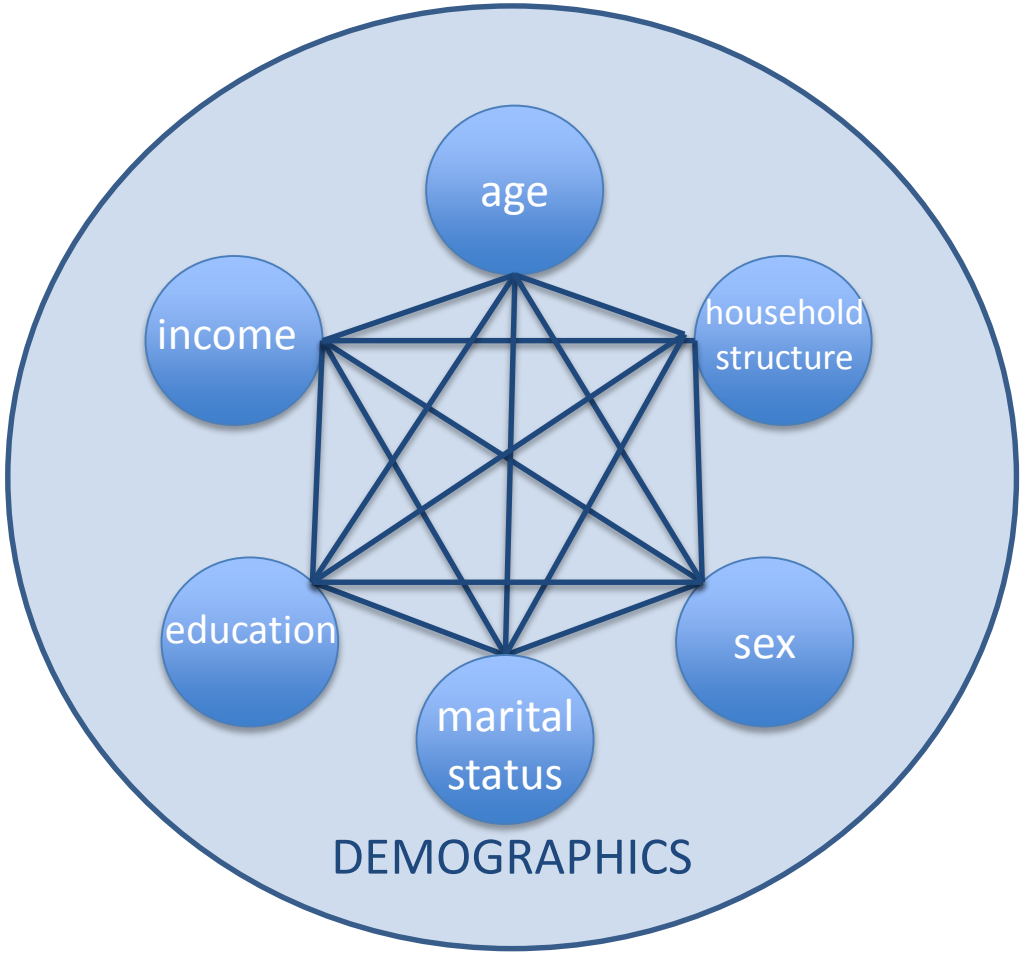
NDSSL NETWORK DYNAMICS & SIMULATION SCIENCE LABORATORY

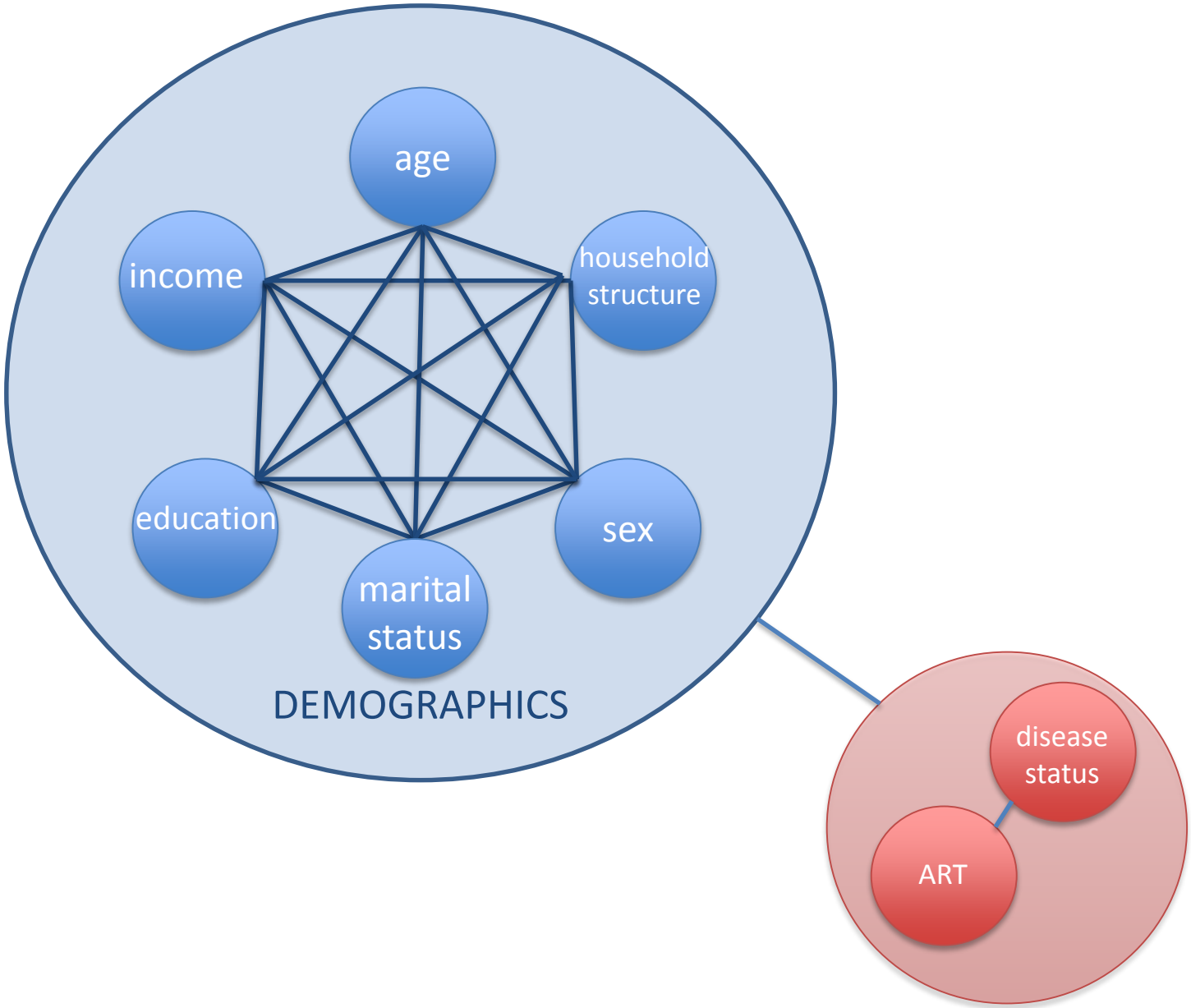
What is synthetic data?

- A *representation* of things' states and interactions that is not intended to match any snapshot of the system, but to provide a statistically accurate overall picture:
  - people, places, things
  - cells, cytokines, organs
  - and their relationships
- A *synthesis* of incommensurate data and models from many domains
- A *coordinate system* for incorporating new information and describing dynamics






age
income
household structure
education
sex
marital status
DEMOGRAPHICS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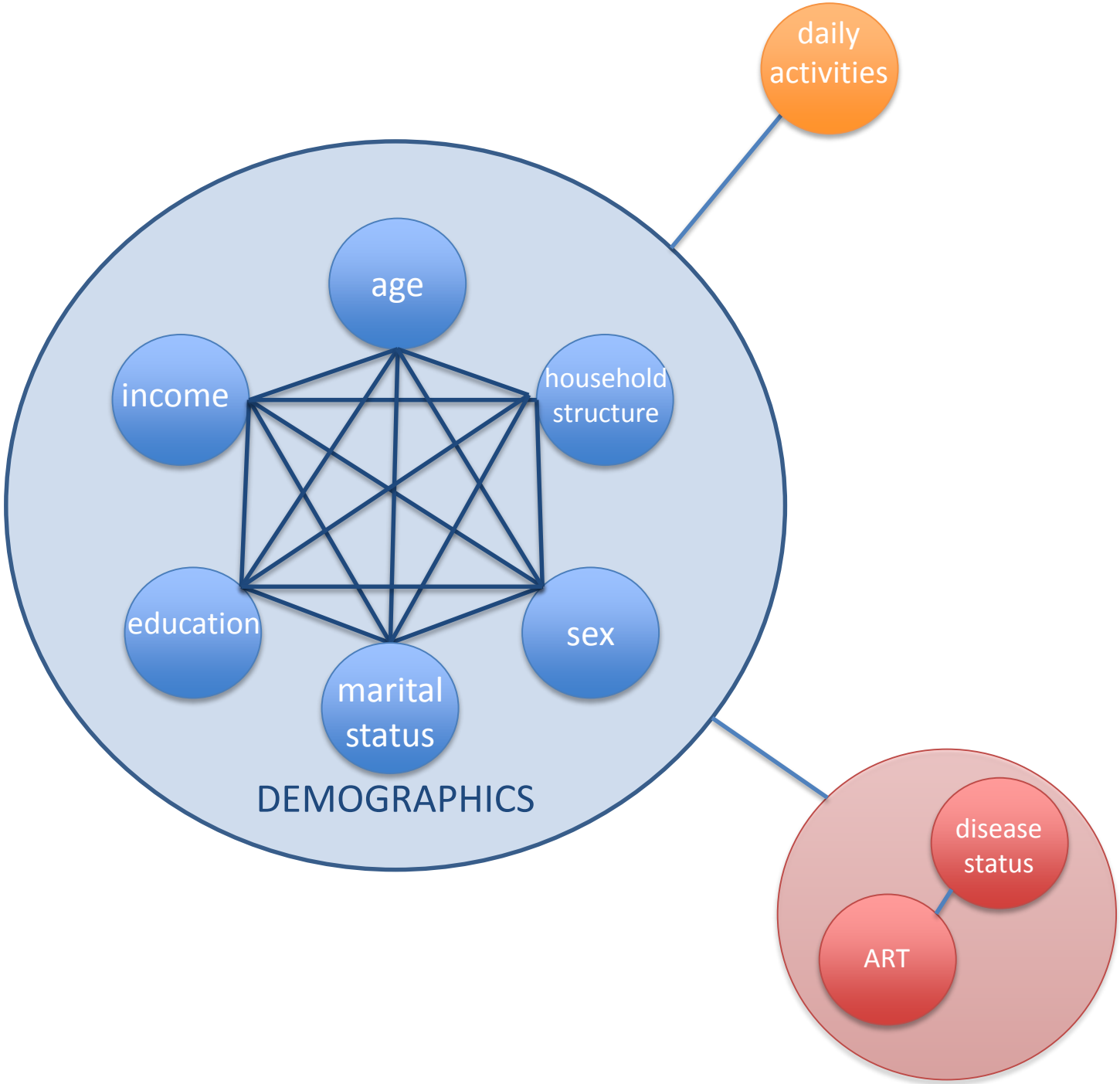
ART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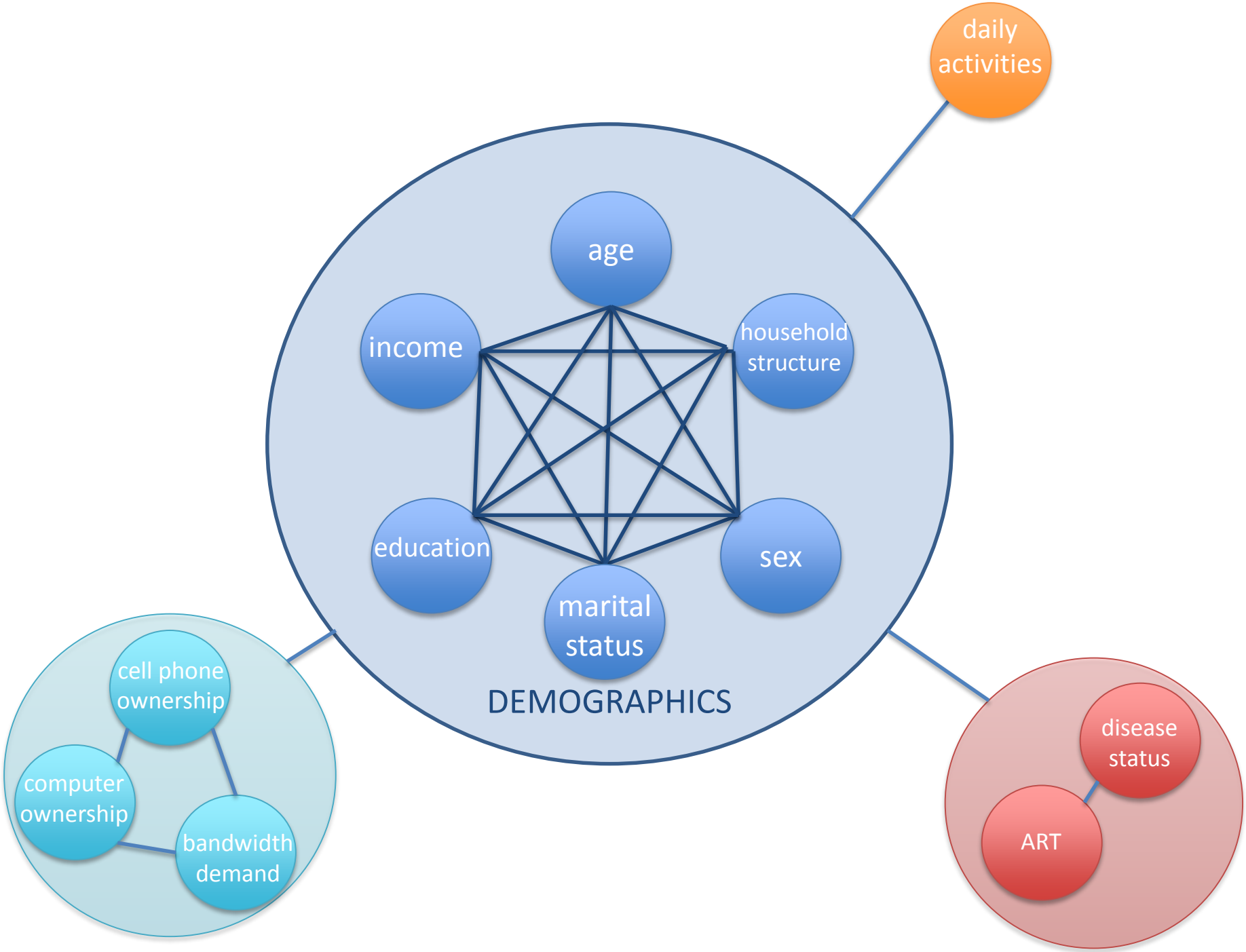
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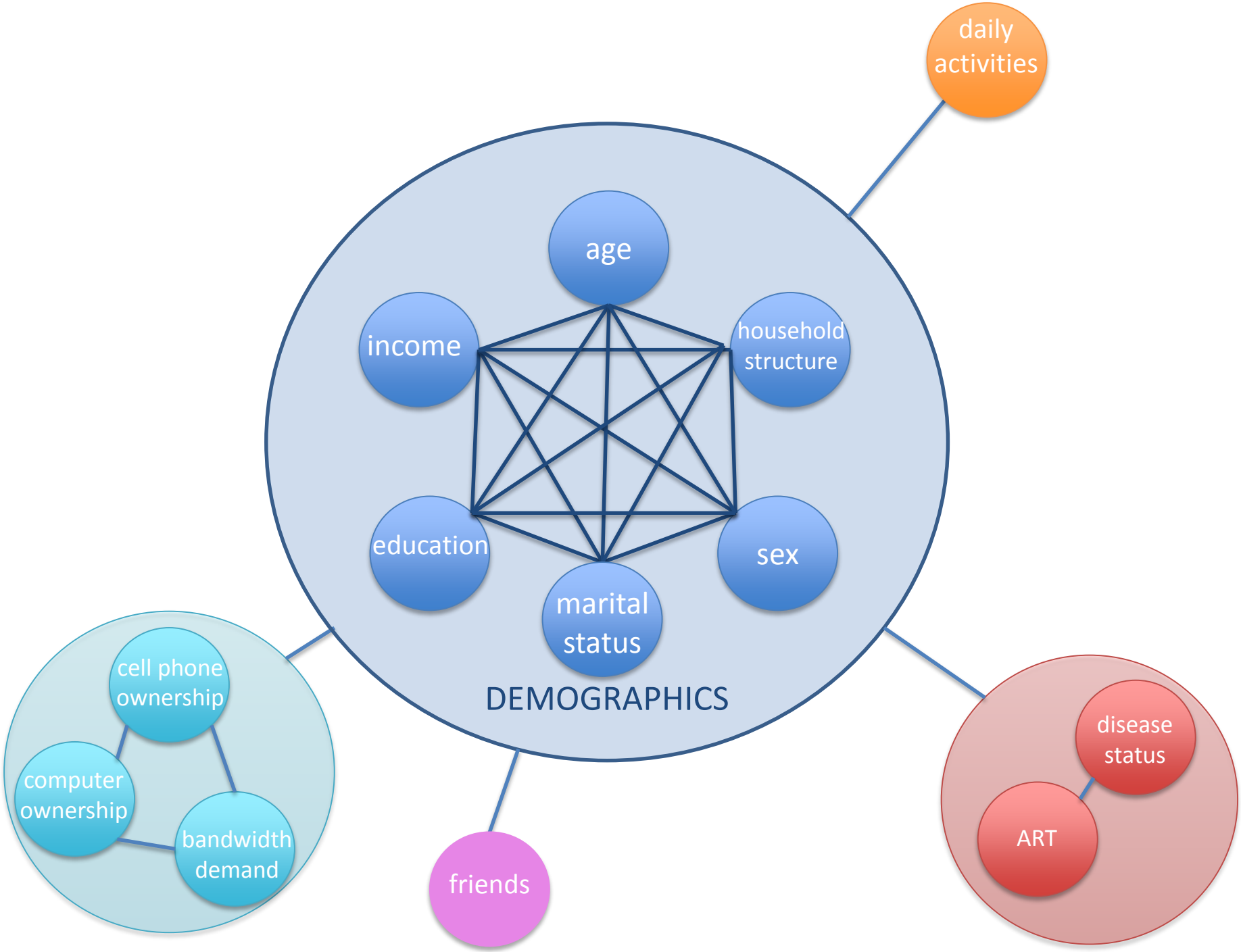
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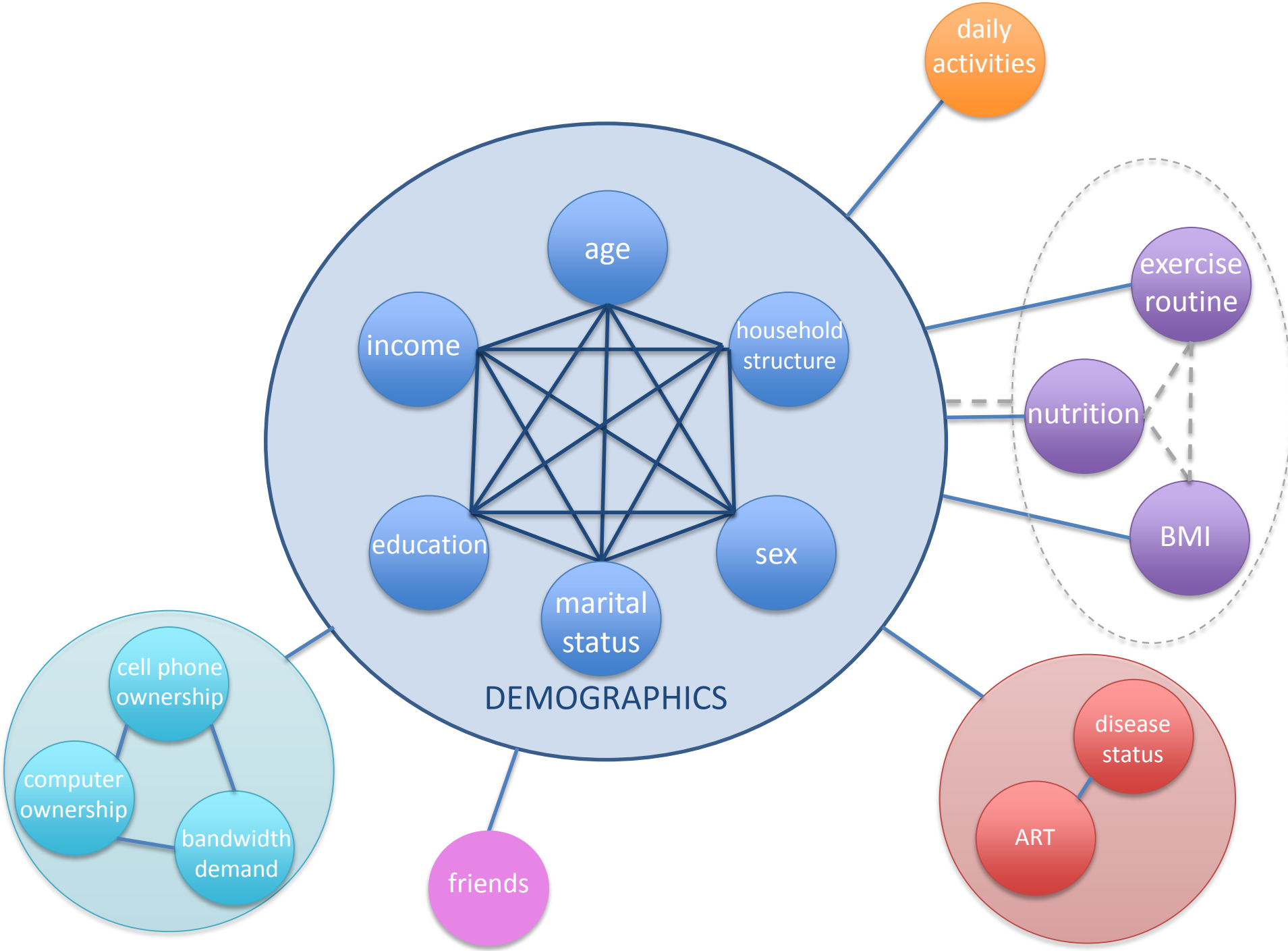
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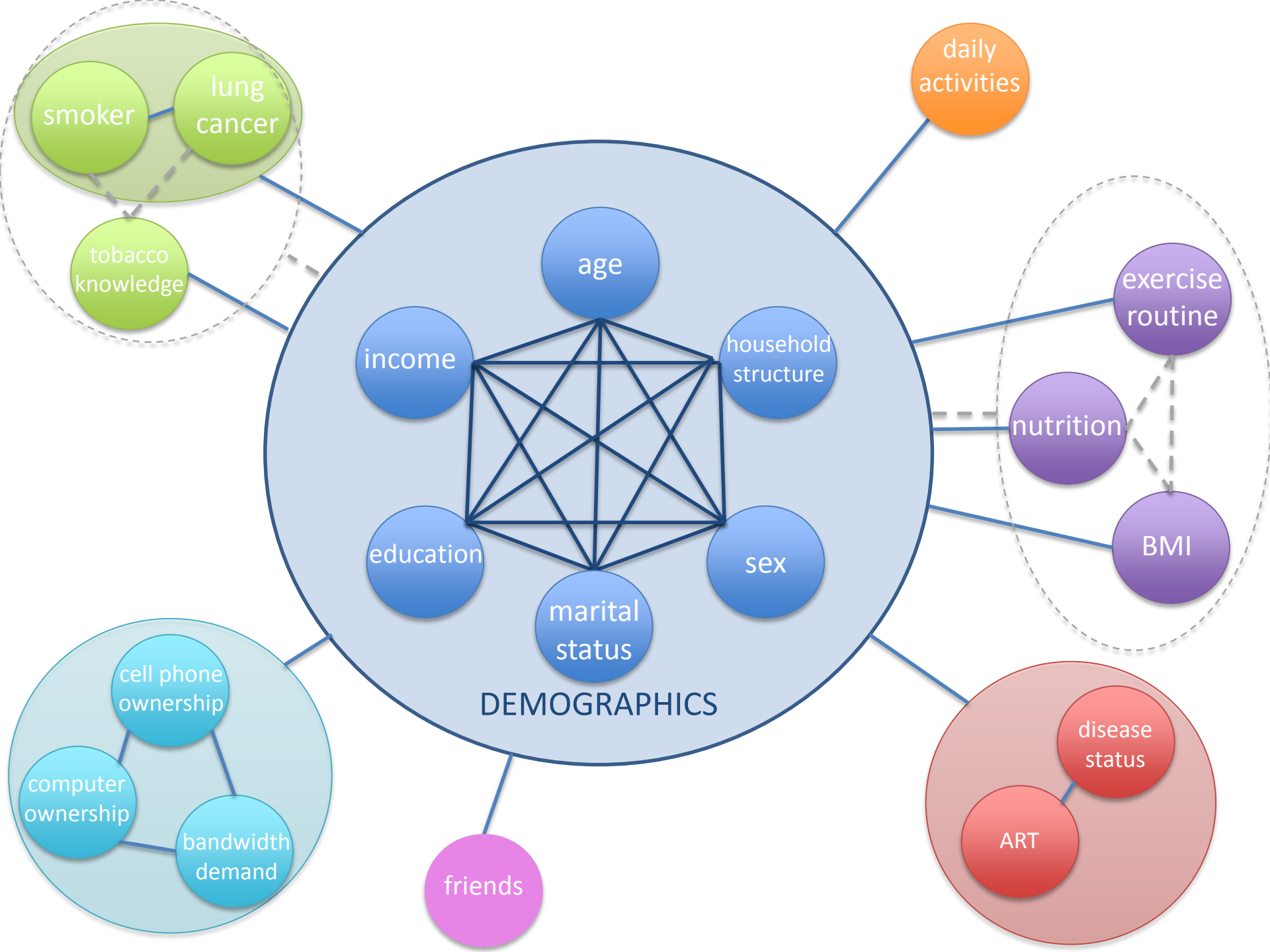
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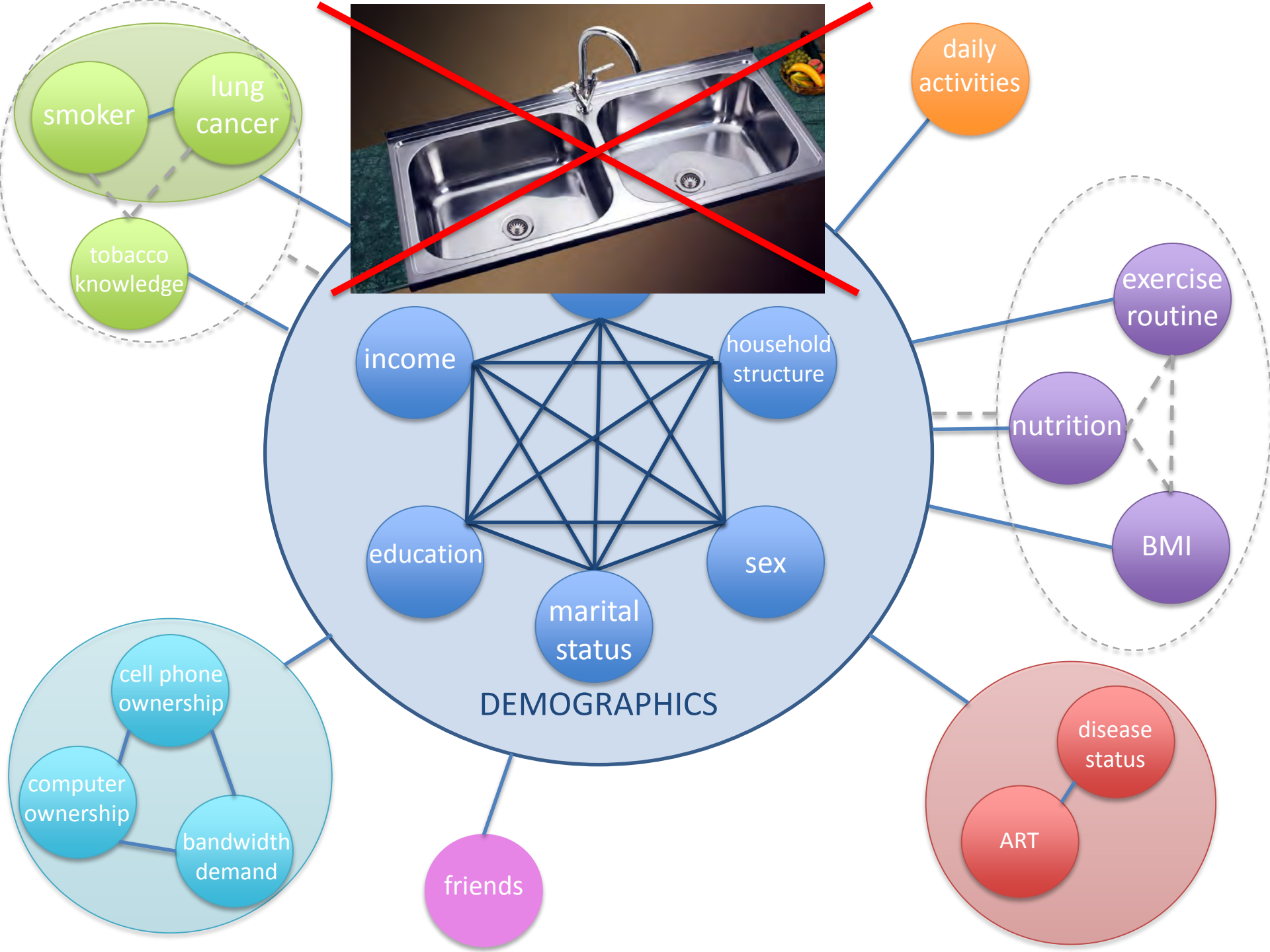
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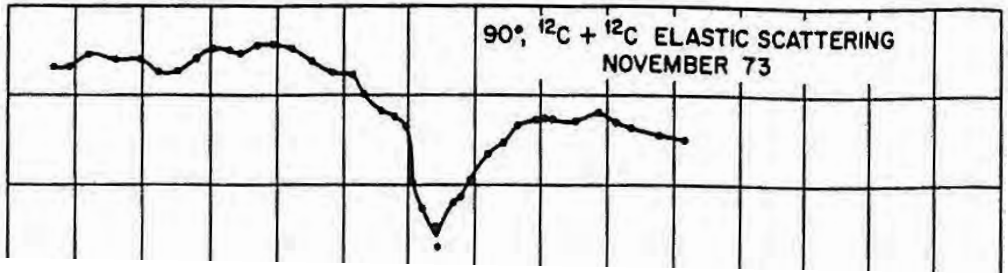
Why speak to IeDEA about *synthetic* data?

- "Real" system is one instance of a time-varying, random process in a huge space only partly observed.
- Planning relies on counterfactual analysis.
- Most alternatives sweep known errors under the rug.
- Synthesis provides a way to leverage data collection and harmonization efforts.

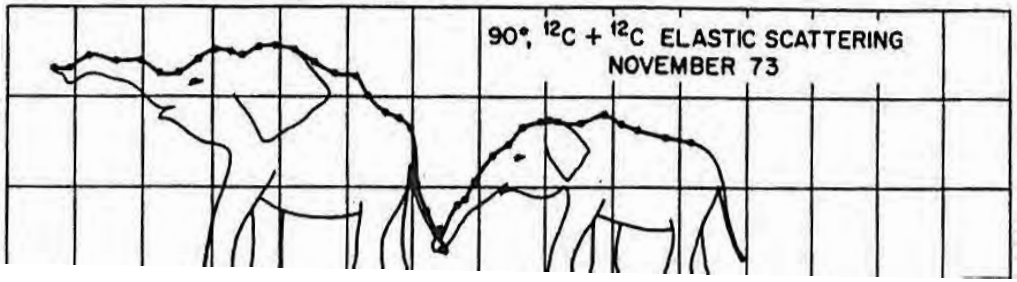
The real world is complicated

- "estimate engagement in care … in resource limited setting, … the outcome itself was missing due to loss to follow-up."
  Rebora, Paola et al. *BMC Medical Research Methodology* 16 (2016): 5
- "genetic …, viral … and environmental … factors influence CD4 recovery. These factors differ markedly around the world …"
  Geng, Elvin H et al. *International Journal of Epidemiology* 44.1 (2015): 251–263
- "…many practical studies assume away interference for the sake of simplicity. … ignoring interference can lead to completely wrong conclusions." Van der Laan, Mark J. *Journal of causal inference* 2.1 (2014): 13-74. *PMC*.
- "[W]e re-estimate the duration and relative infectivity of the acute phase, while accounting for … the retrospective cohort exclusion criteria and unmeasured heterogeneity in risk."
  Bellan SE, et al. (2015) PLoS Med 12(3): e1001801.
- "a significant proportion of seroconversion events in serodiscordant couples may be unlinked." Eshleman et al. J Infect Dis. (2011)

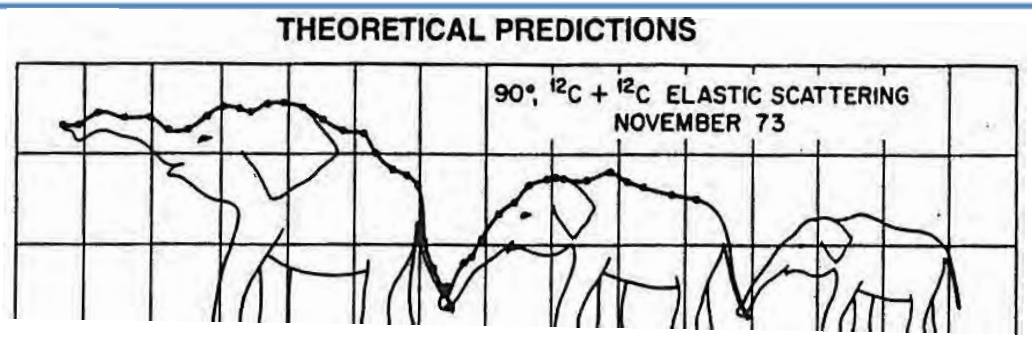
EXPERIMENTAL DATA



THEORETICAL FITS



An overly complex model has no predictive power!



Science with a Smile,
Subramanian Raman

- Usual Lessons:
  - Occam's razor
  - Information criteria for complexity control

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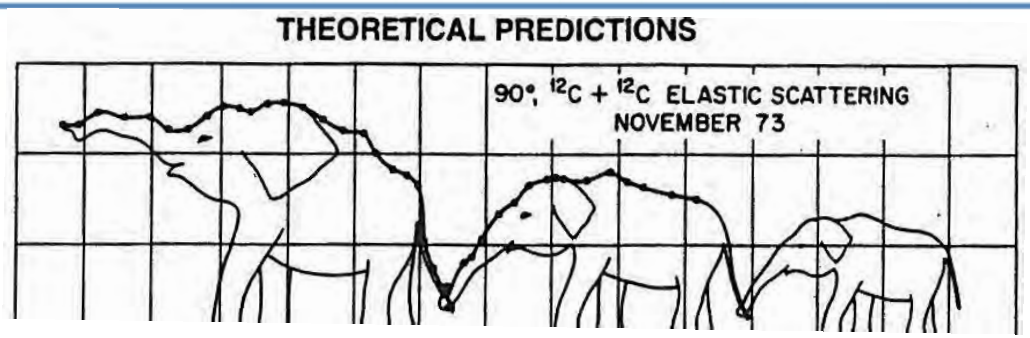

Science with a Smile,
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- Alternative Lesson:
  - Use causal / generative / mechanistic models
  - Representing arguably relevant mechanisms
  - To simulate alternatives and compare to data

An overly complex model has no predictive power!

Unless it’s the correct model…

The spherical elephant

several parameters

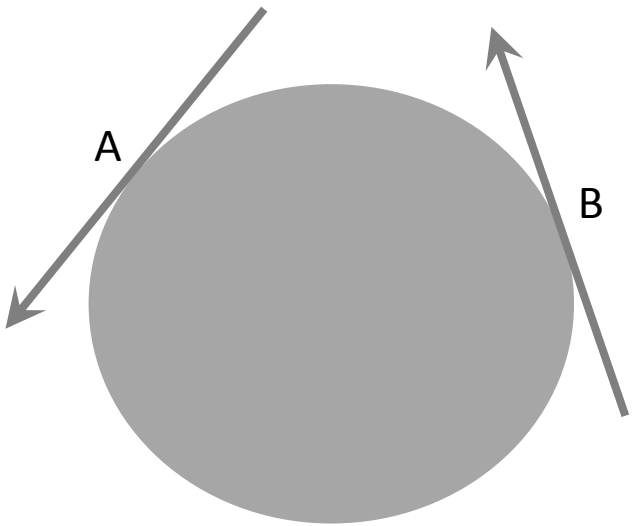
The spherical elephant and an even simpler, linear model

one parameter: slope

several parameters

The spherical elephant and an even simpler, linear model

one parameter: slope can be calibrated to data at A or B



The spherical elephant and an even simpler, linear model

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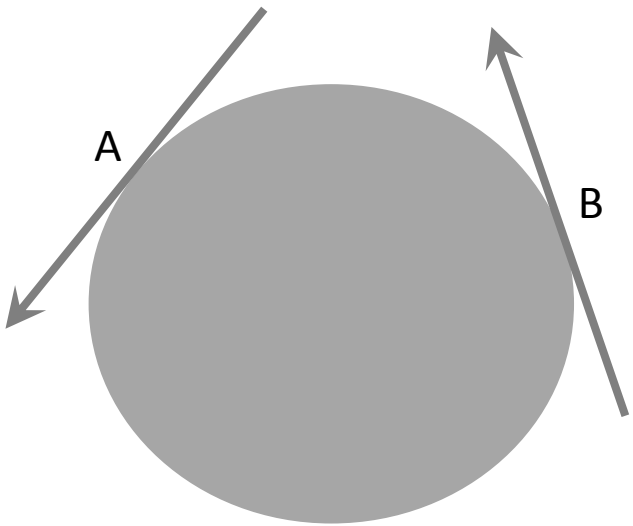


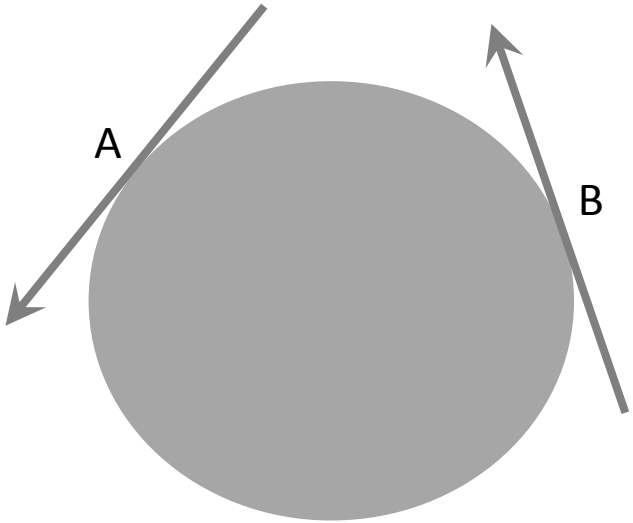
… with diametrically opposed implications for interventions

Is moving left a good way to get off the elephant?
That depends on where you are.

The spherical elephant and an even simpler, linear model

Is PrEP a good way to reduce morbidity?
That, too, depends on where you are.

one parameter: slope can be calibrated to data at A or B



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Is moving left a good way to get off the elephant?
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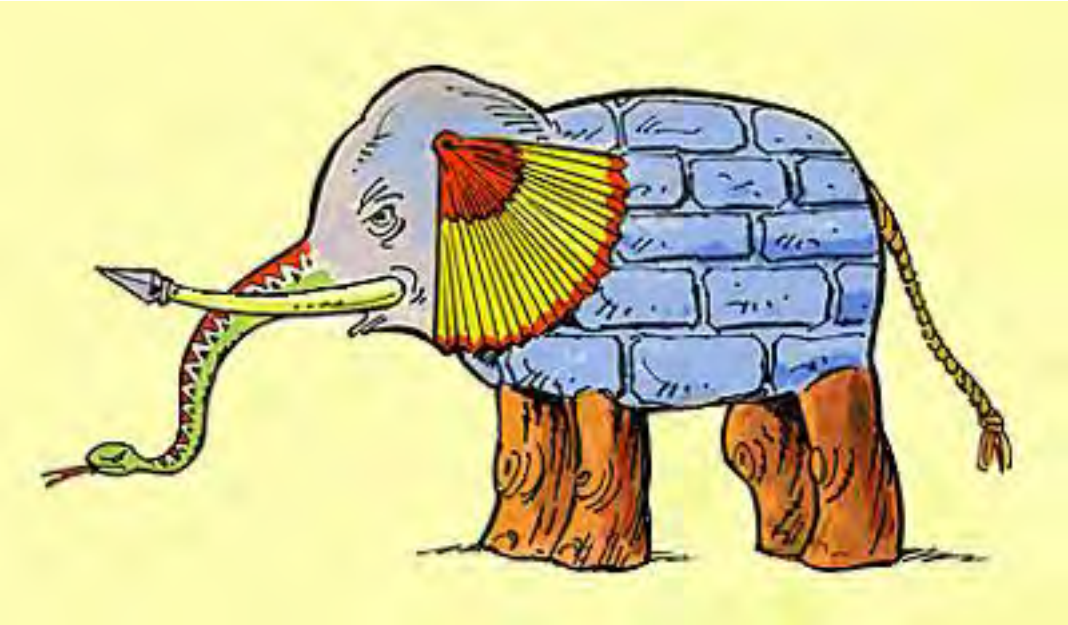
Overly simple models …

… lead to incorrect conclusions
even when they are locally correct.



Symptom: long-running disagreements,
with all sides supported by “the evidence”

Overly simple models …

… are *guaranteed* to mis-specify complex systems.
But there's not enough data for a complex model.
So we'll be satisfied with a mis-specified one.

Making effective use of data

To understand a property of the system:

- Sample the property
- Model its distribution
- Reason about the implications of the distribution

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In data-poor contexts, prior knowledge is key

e.g. parameterized distributions

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In data-poor contexts, prior knowledge is key
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Worry about confounding, independence:
interactions among properties

Making effective use of data

To understand interactions among properties:

- Sample them
- Model their joint distribution
- Reason about the causal dependencies

In data-poor contexts, prior knowledge is key
e.g. synthetic data from simulated interactions

Simulation: approximate answers to real questions,
not exact analysis for the wrong questions

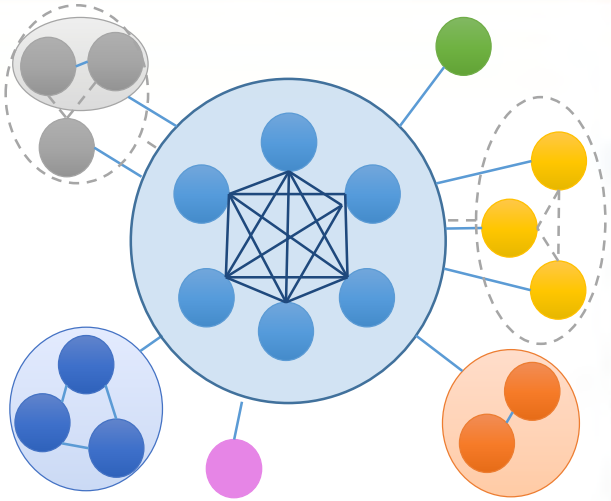
Why treat synthetic information as data?

With trust, provenance, dynamic updates, simulation, …

- Assumptions are on the table, subject to tinkering
- Users need not understand models to use data
- Results are not "thrown over the fence"
- Experts in specific domains embed context in data that is transparent to experts in other domains:

demography → trial design
pharmacodynamics + social psych → implementation

Characteristics of an ideal information resource



- Natural representation encourages transdisciplinary team science & communities of practice
- Attribution is easy, even automatic
- Models and results are reproducible
- Assumptions & limits on appropriate use are transparent
- Alternative hypotheses (models) are easily tested
- Supports an *abductive* reasoning loop: hypothesize, test, correct

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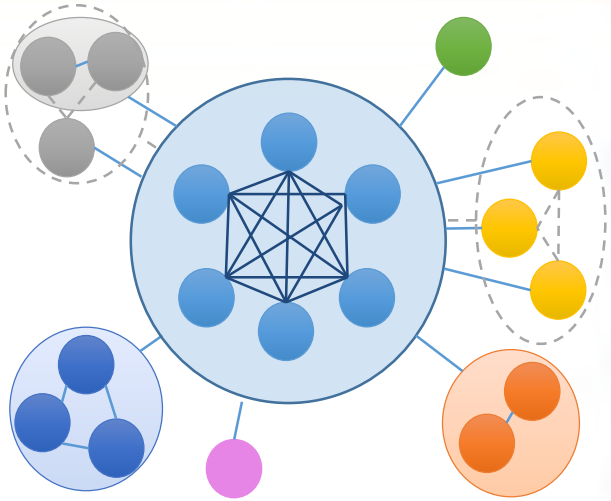

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Building such a thing is still a research problem!

Why haven't we done this already?

Computational issues are as hard as statistical ones:

- scalable digital library
- efficient algorithms to access & process Big Data
- data sleuthing & licensing / Data Use Agreements
- testing & maintaining provenance at all stages
- designing systems for non-computing-experts

Conclusions

- $N \to \infty$, p-values $\to 0$, anything is publishable!!

Conclusions

- ~~$N \to \infty$, p values $\to 0$, anything is publishable!!~~
- IeDEA provides unique opportunities to study demographically, geographically targeted interventions.
- Synthetic information sets, e.g. populations, can complement the data collected in IeDEA.
- Fully realizing the promise of IeDEA will require new kinds of data management platforms.