METABOLIC COMPASS

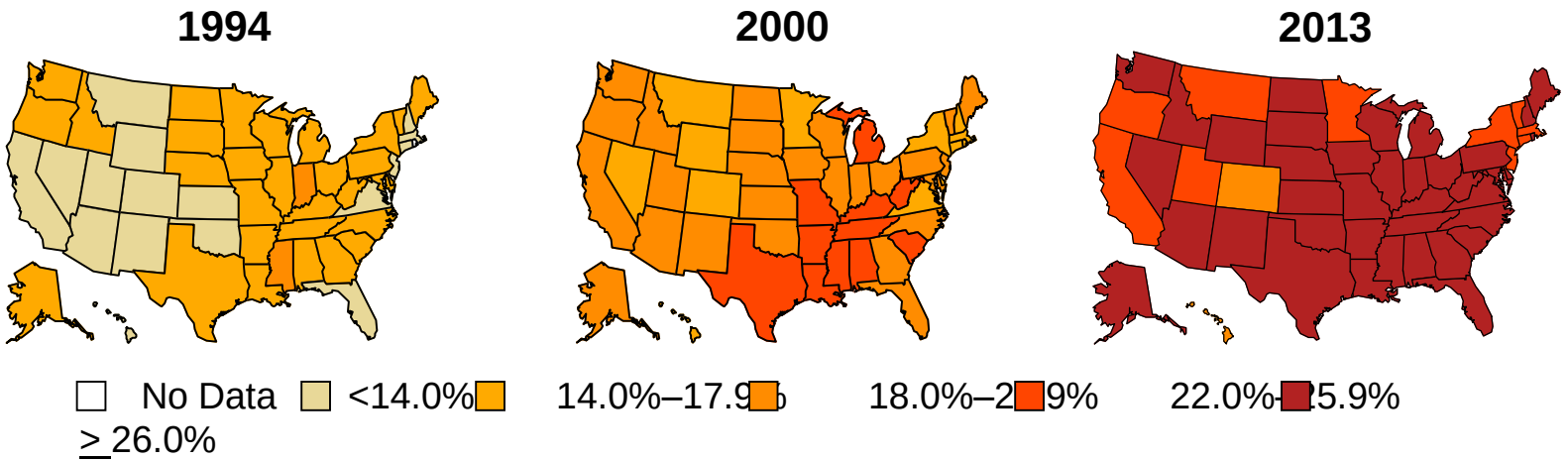
A Mobile Health Platform for Understanding the Impact of Circadian Behaviors on Metabolic Syndrome, and Obesity

Jeanne Clark, Dept. of Medicine (GIM)
Tom Woolf, Dept. of Physiology
Yanif Ahmad, Dept. of Computer Science
https://metaboliccompass.com

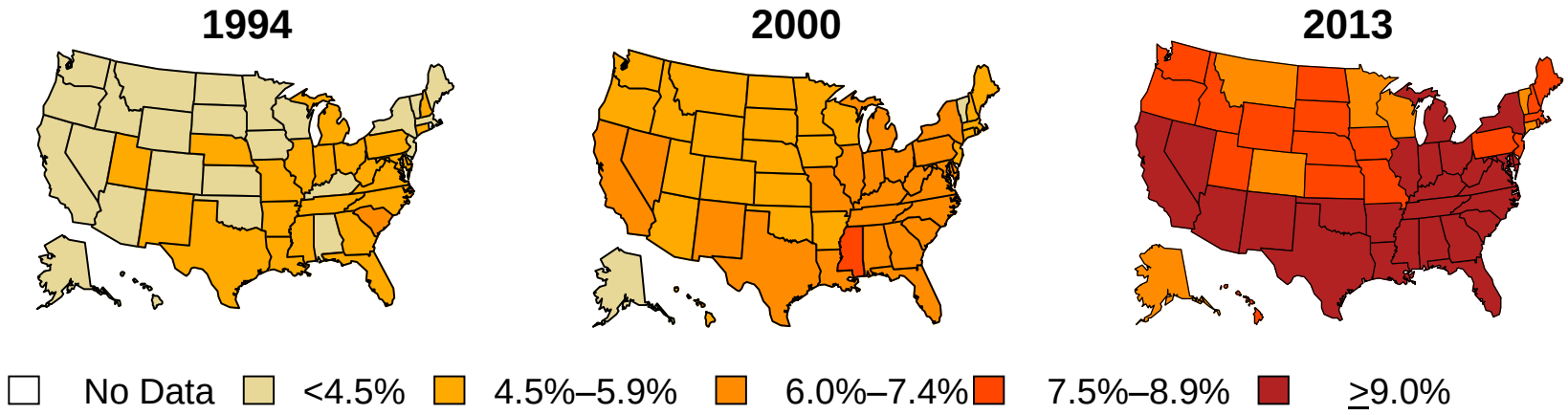


Age-adjusted Prevalence of Obesity and Diagnosed Diabetes Among US Adults

Obesity (BMI ≥30 kg/m^2)



Diabetes



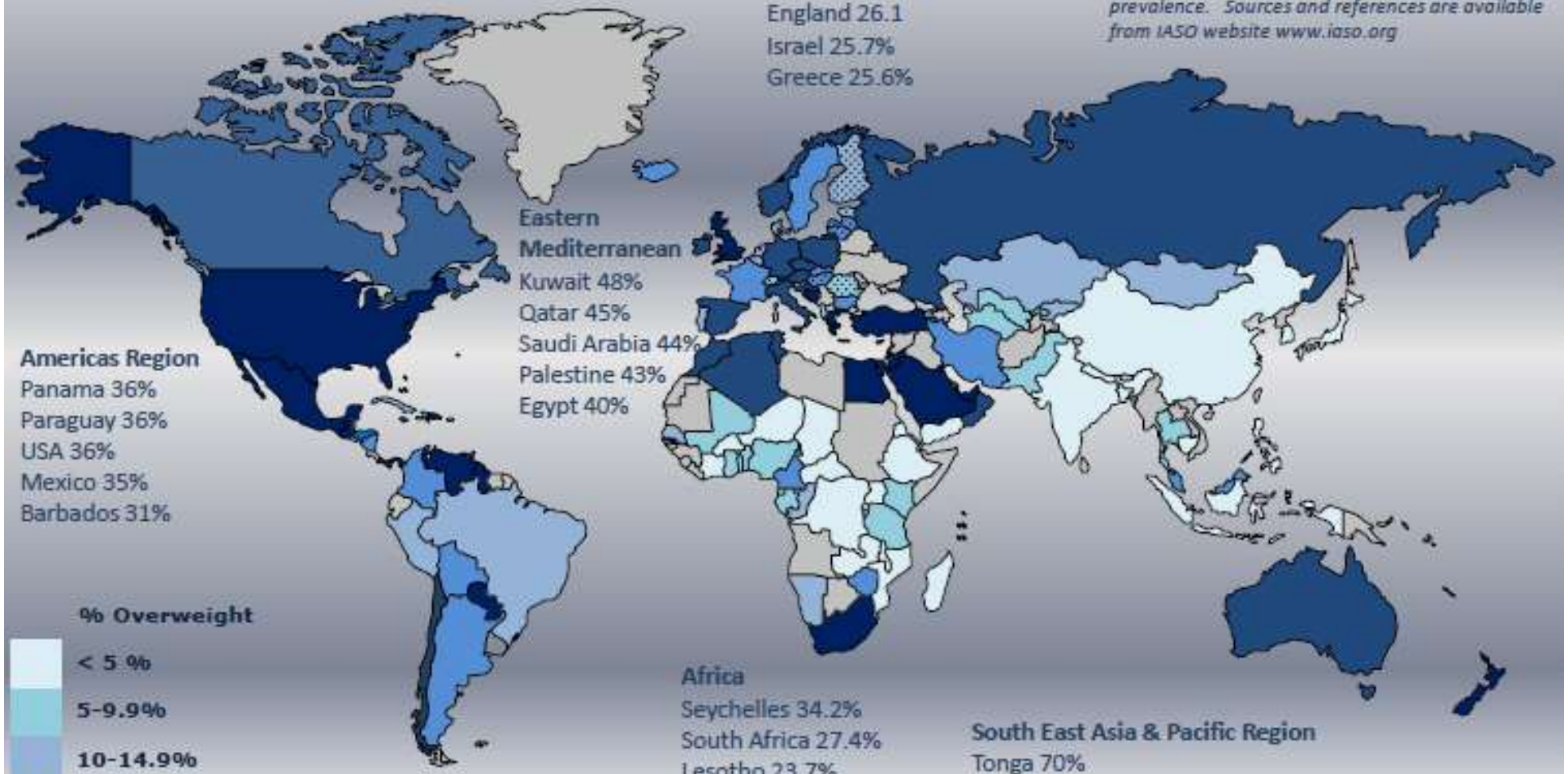
CDC's Division of Diabetes Translation. National Diabetes Surveillance System available at http://www.cdc.gov/diabetes/statistics

Global Prevalence of Obesity in Adult Females

With examples of the top 5 Countries in each Region (based on data available at the time)

European Region
Turkey (Urban) 29.4%
Scotland 28.1%
England 26.1
Israel 25.7%
Greece 25.6%

With the limited data available, prevalence's are not age standardised. Self reported surveys (marked with dots) may underestimate true prevalence. Sources and references are available from IASO website www.iaso.org



Eastern Mediterranean
Kuwait 48%
Qatar 45%
Saudi Arabia 44%
Palestine 43%
Egypt 40%

Americas Region
Panama 36%
Paraguay 36%
USA 36%
Mexico 35%
Barbados 31%

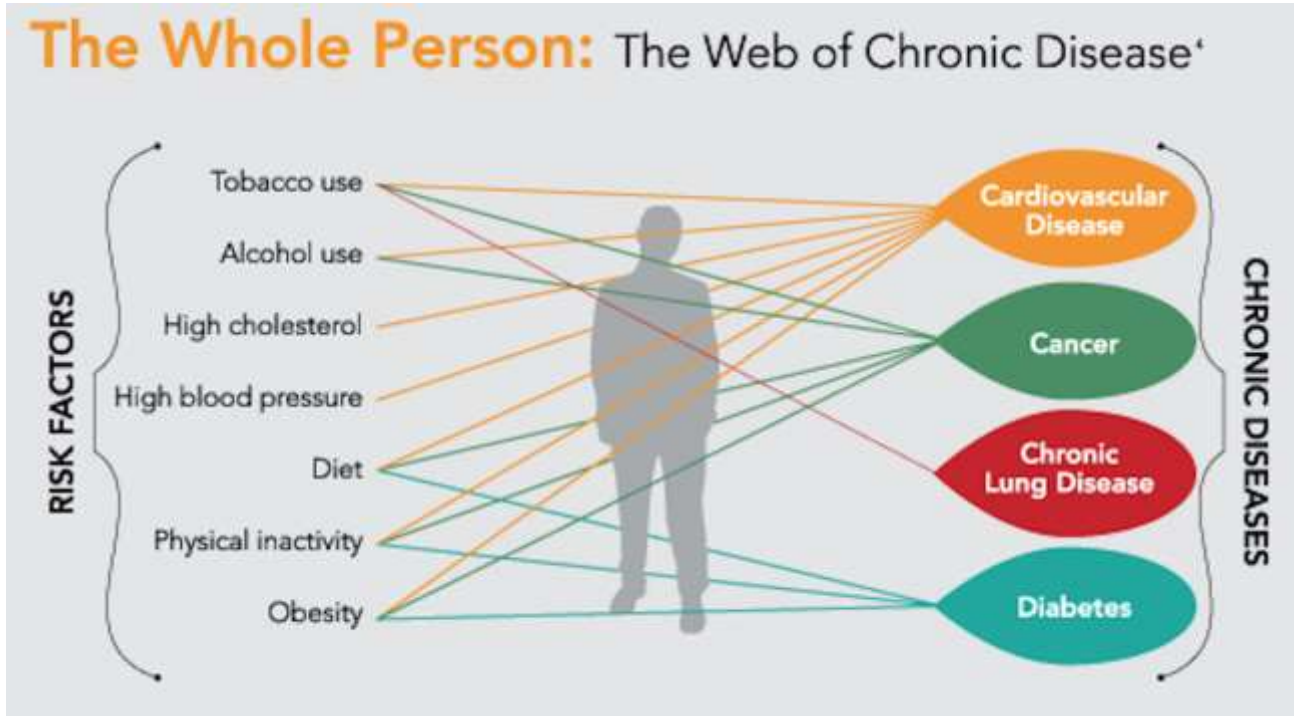
% Overweight
- < 5 %
- 5-9.9%
- 10-14.9%
- 15-19.9%
- 20-24.9%
- ≥25%

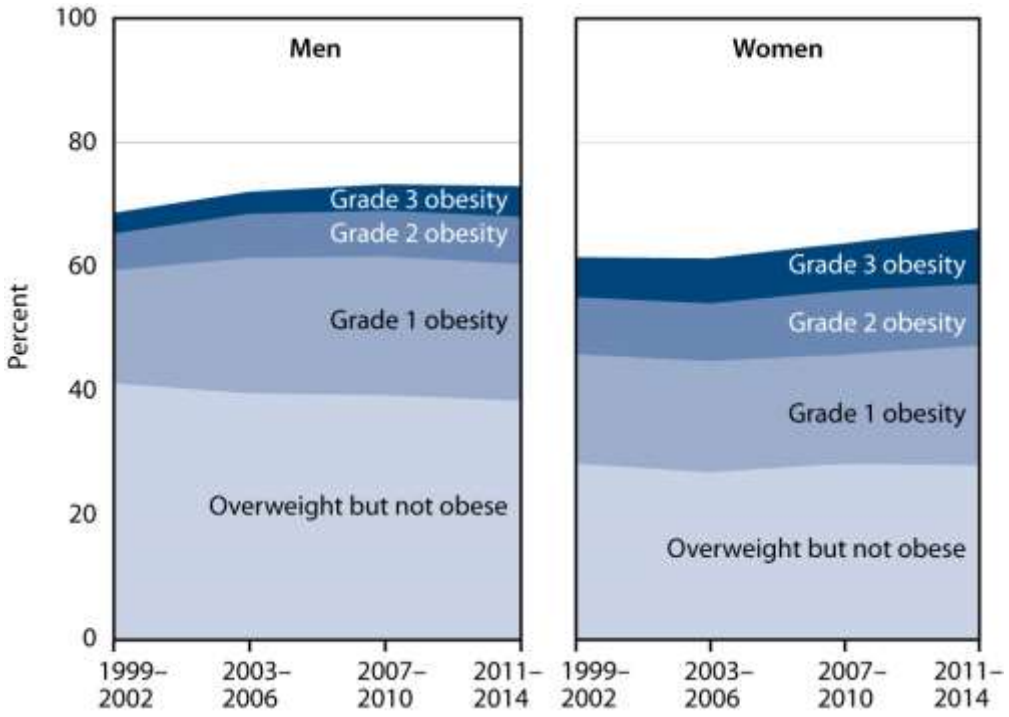
Africa
Seychelles 34.2%
South Africa 27.4%
Lesotho 23.7%
Algeria 21.4%
Mauritius 20%

South East Asia & Pacific Region
Tonga 70%
Samoa 63%
Nauru 61%
Niue 46%
French Polynesia 44%

iaso

Chronic Disease is often a job of **Managing Risk**

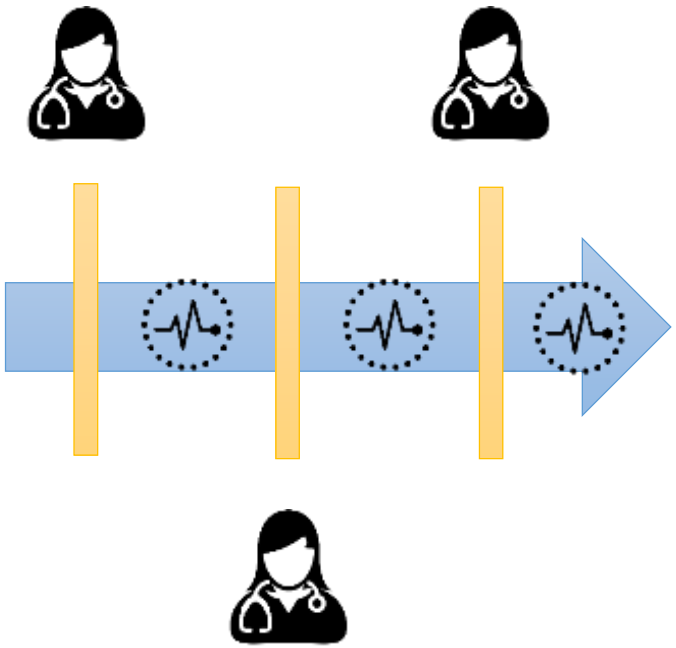


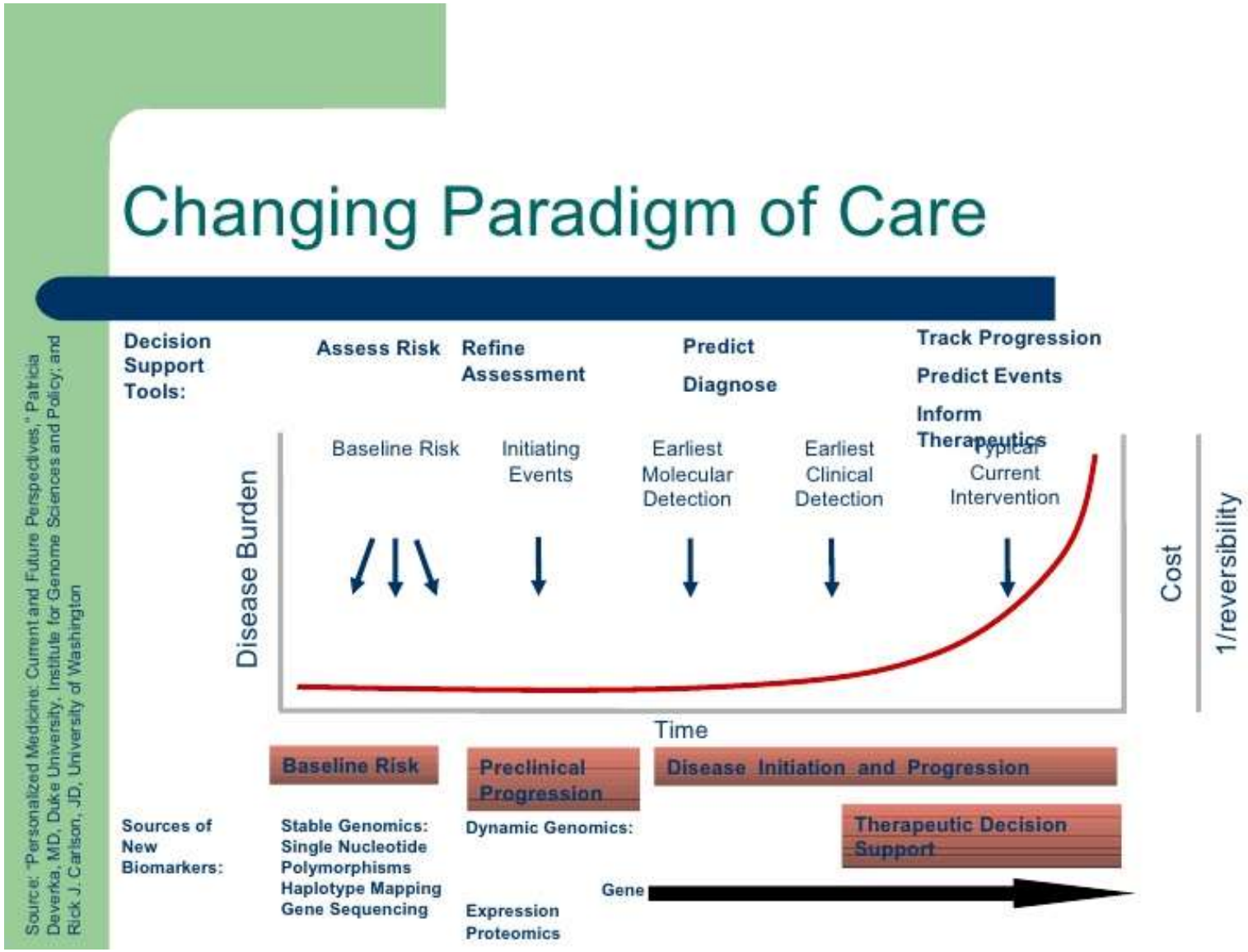


Adults with overweight and obesity: Aged 20+

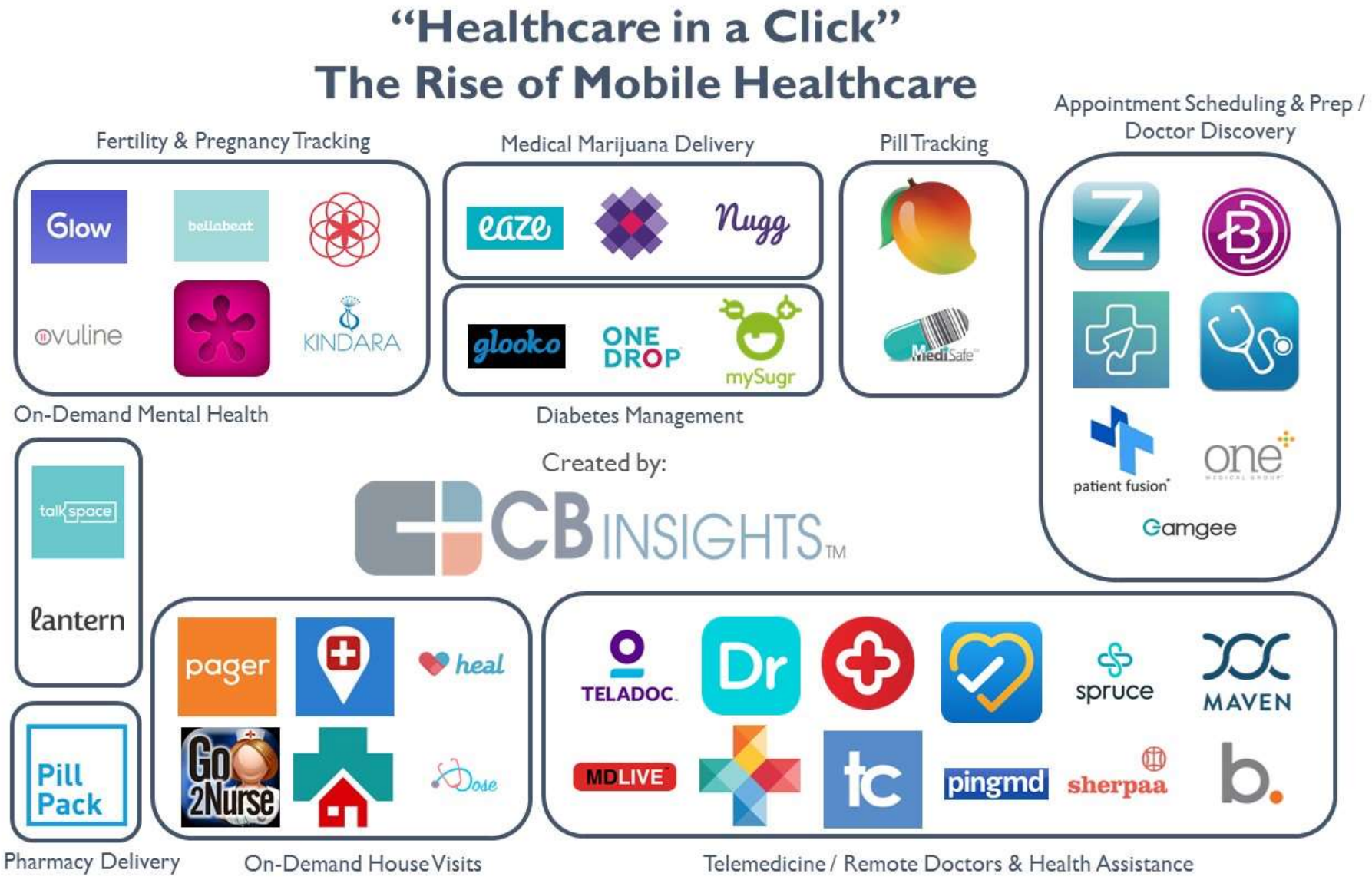
NOTES: BMI is body mass index. Overweight but not obese (25 ≤ BMI < 30); Grade 1 obesity (30 ≤ BMI < 35); Grade 2 obesity (35 ≤ BMI < 40); Grade 3 obesity (BMI ≥ 40).
SOURCE: CDC/NCHS, *Health, United States, 2015*, Figure 9 and Table 58. Data from the National Health and Nutrition Examination Survey (NHANES).

and care is moving from Episodic to Continuous



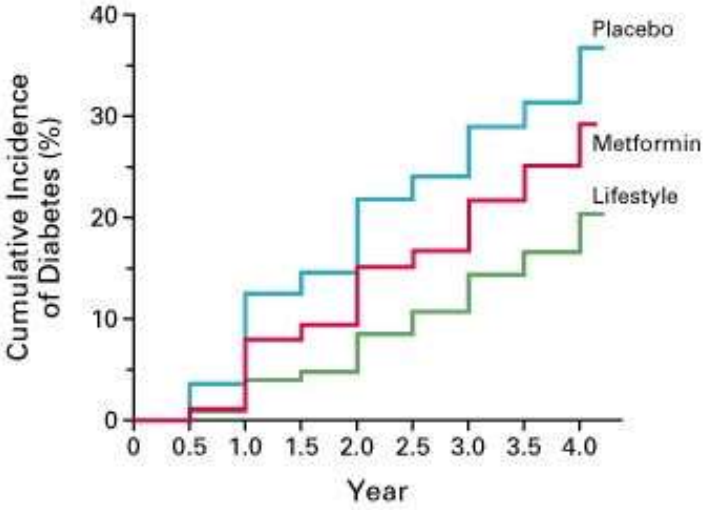


Technology is likely to be an important player: Digital Therapeutics



A Hopkins Connected Success Story:

Diabetes Prevention Program

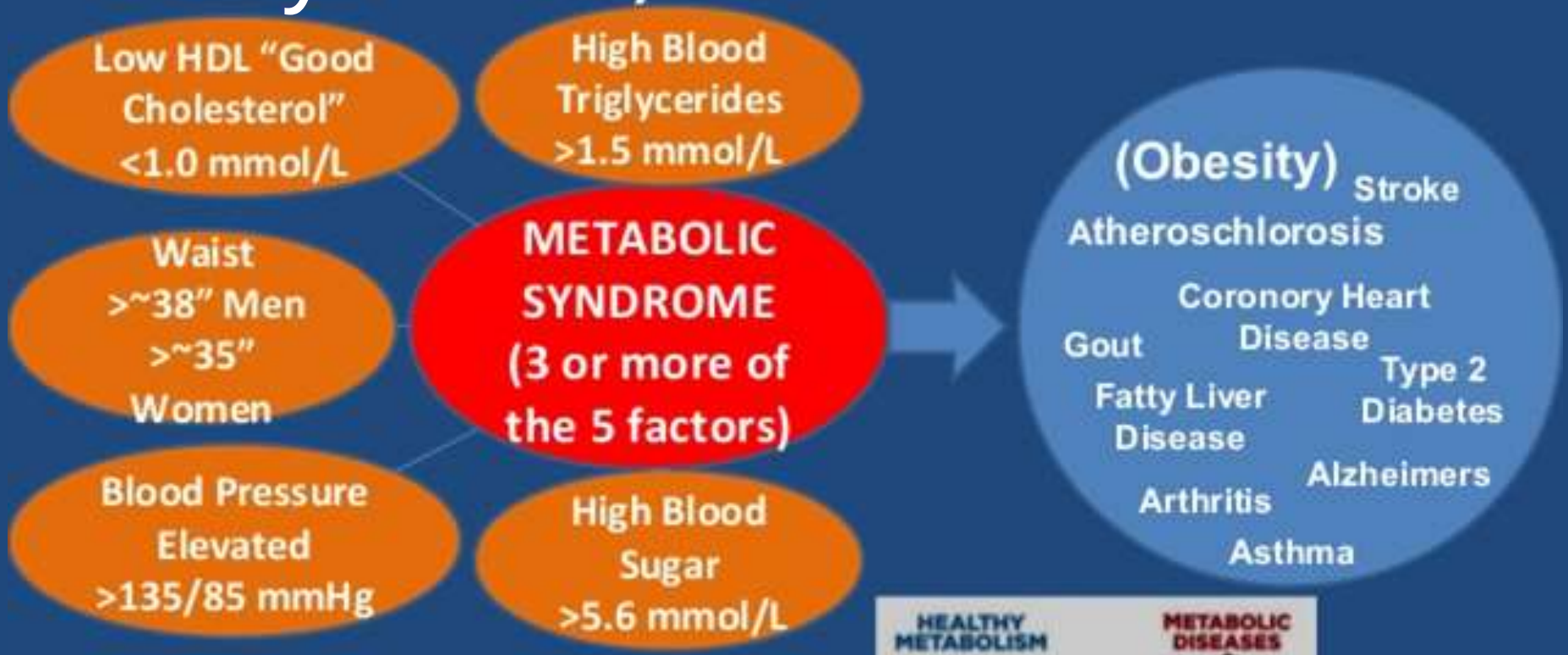


Diabetes Prevention Program Research Group. N Engl J Med 2002;346:393-403.

Omada Health, Noom, and others

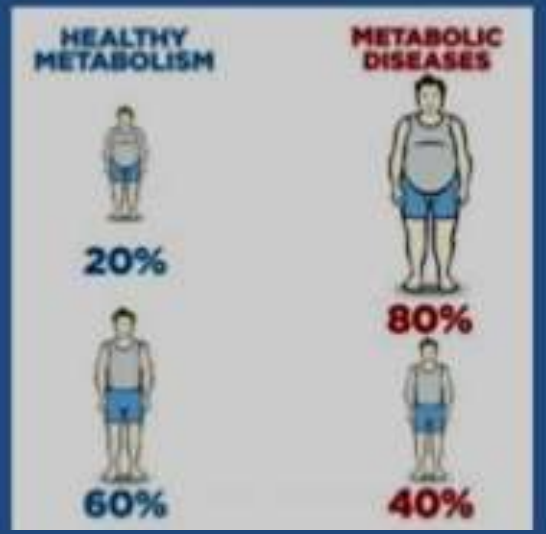
(https://nccd.cdc.gov/DDT_DPRP/City.aspx?STATE=OTH&CITY=OTH)

Metabolic Syndrome



How many people have it then? It's not too common, right?

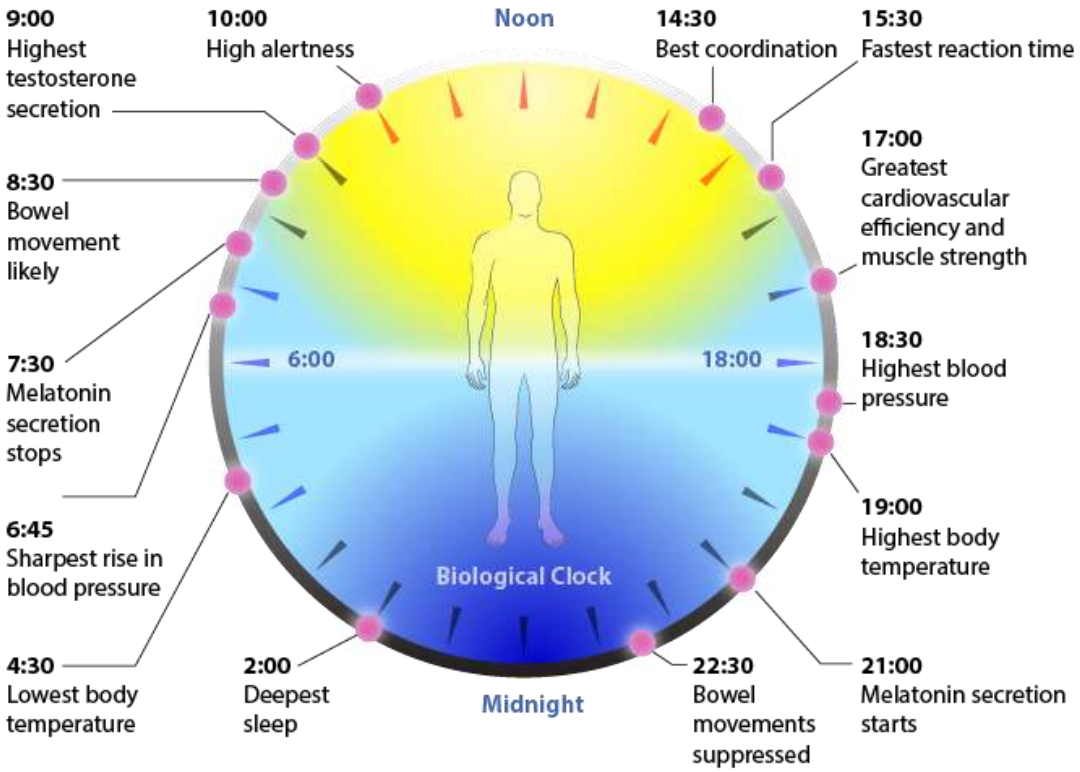
How does > 30% of the US population strike you?

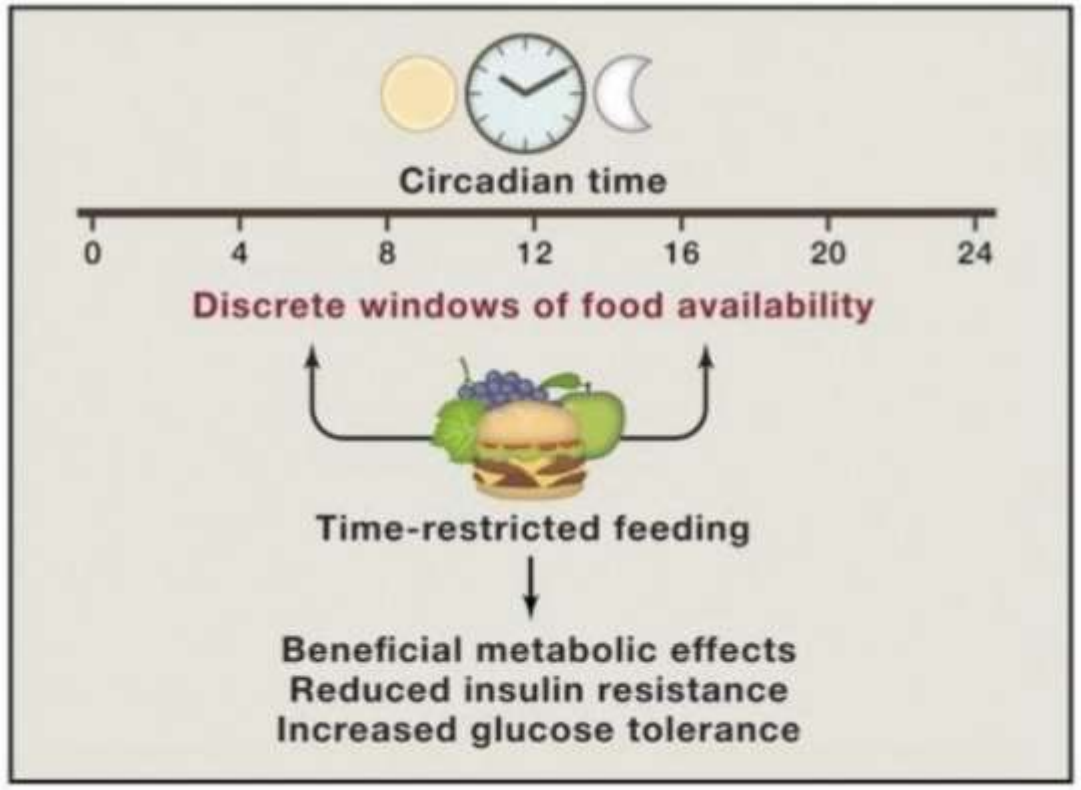


20% of the "Fat" are "Fit"

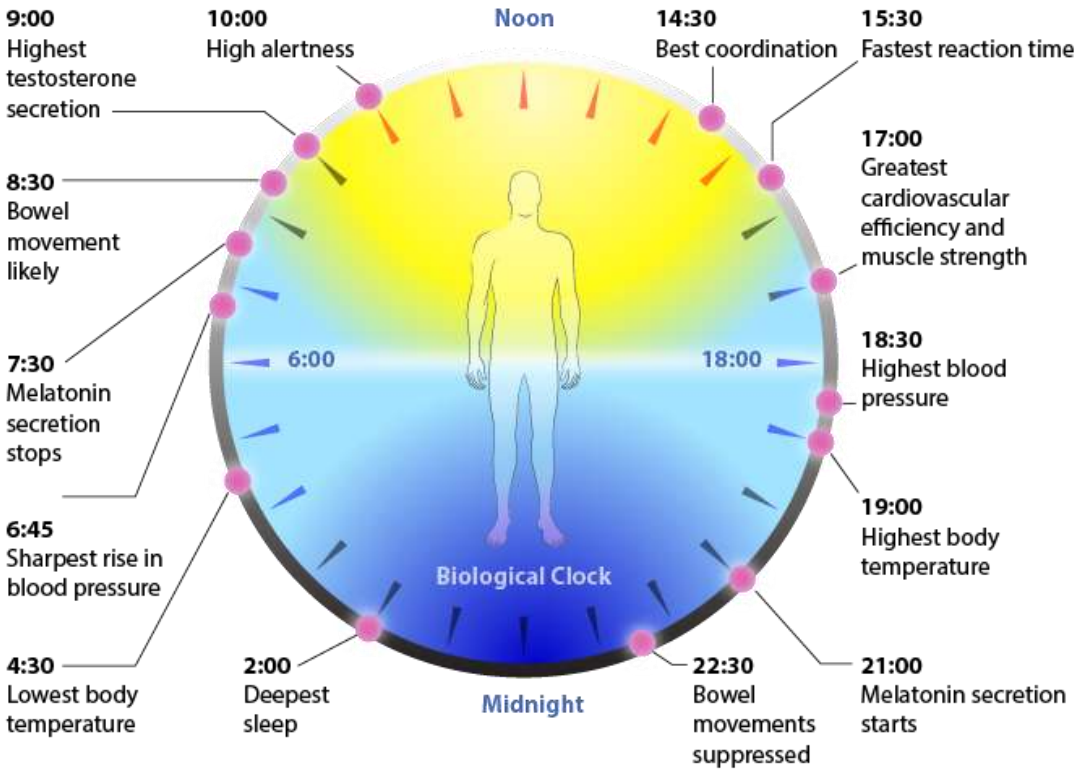
40% of the "lean" are unhealthy

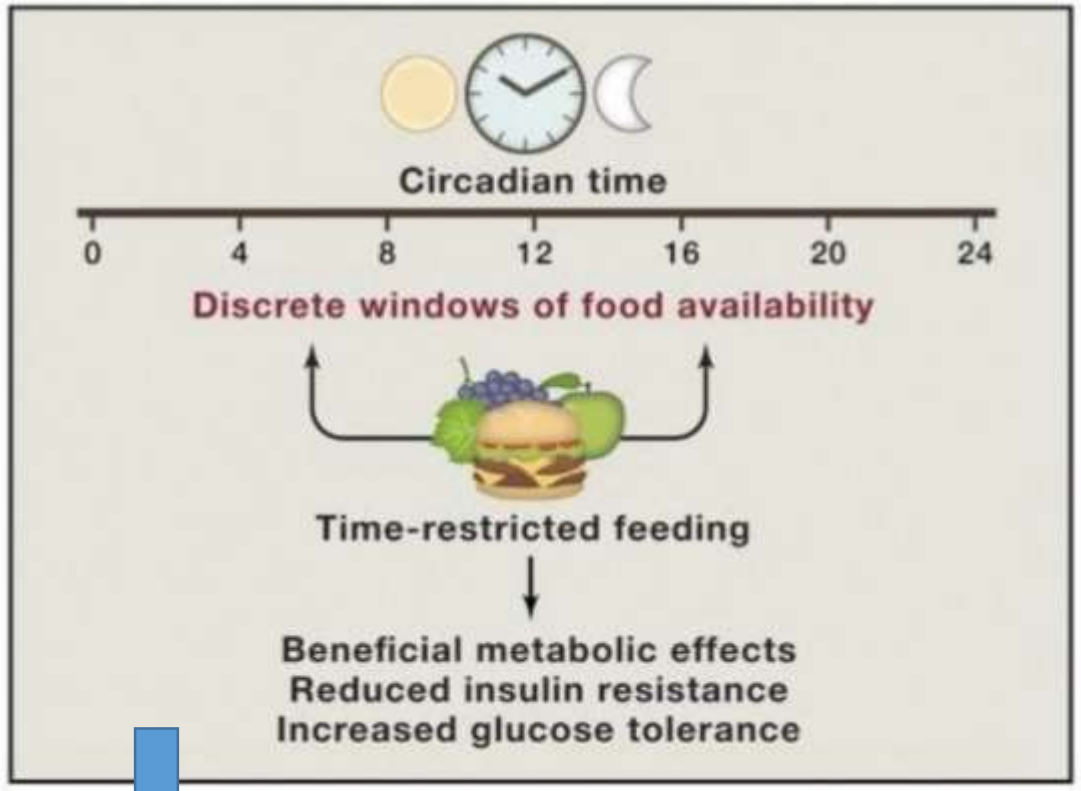
Circadian Rhythms & Time-Restricted Feeding

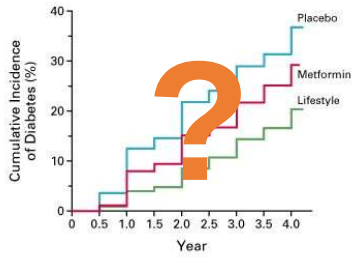




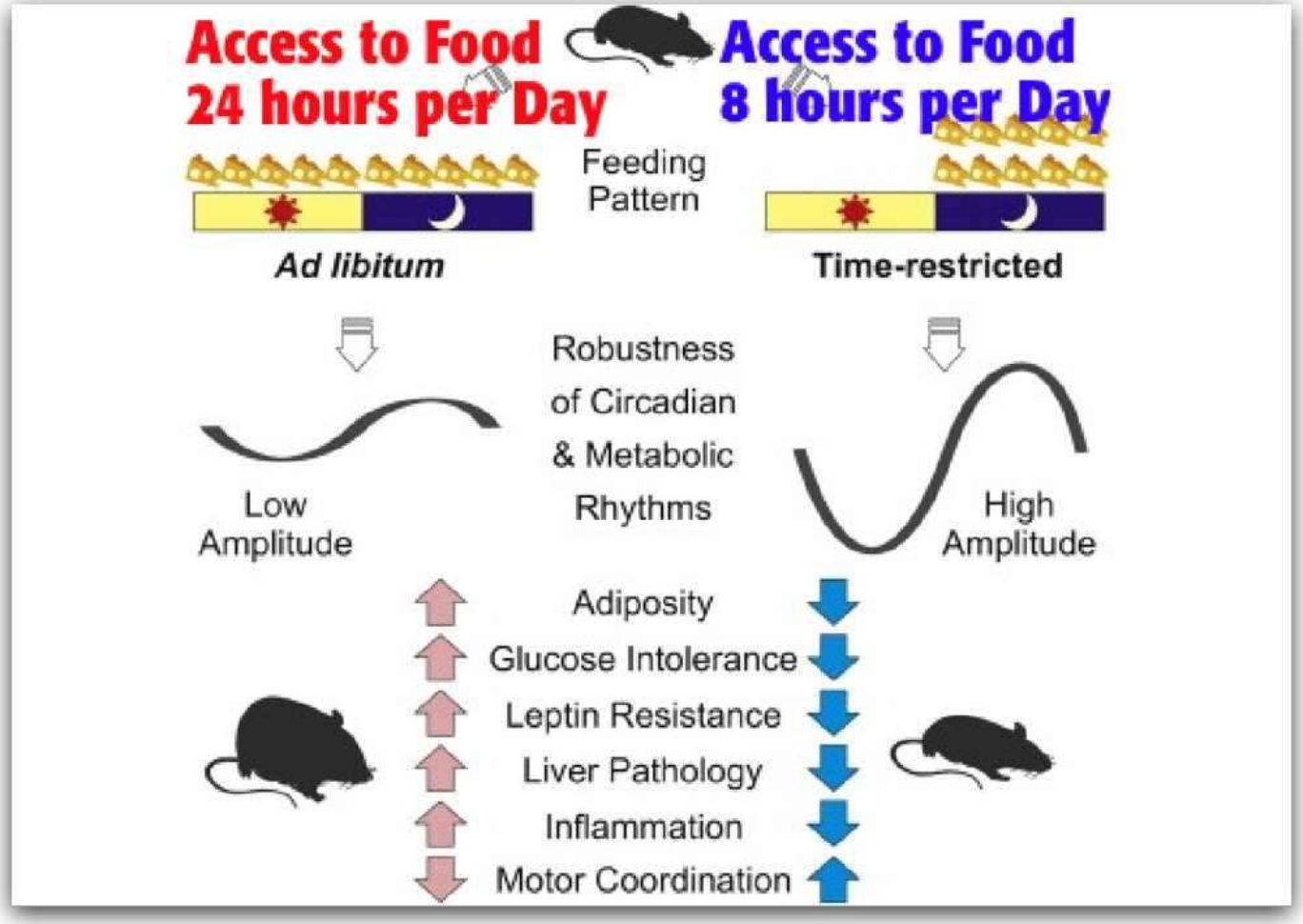
Circadian Rhythms & Time-Restricted Feeding

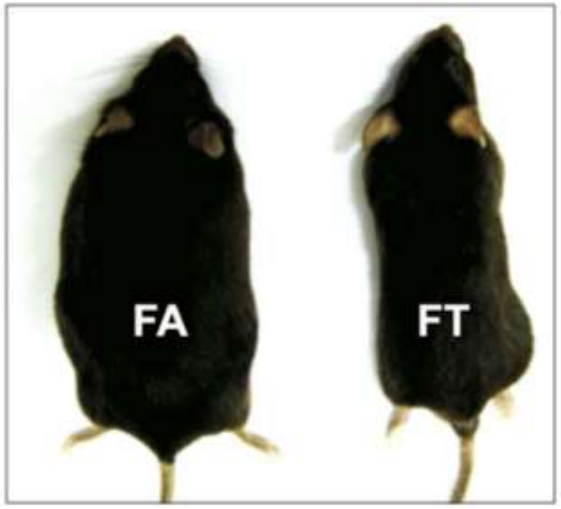




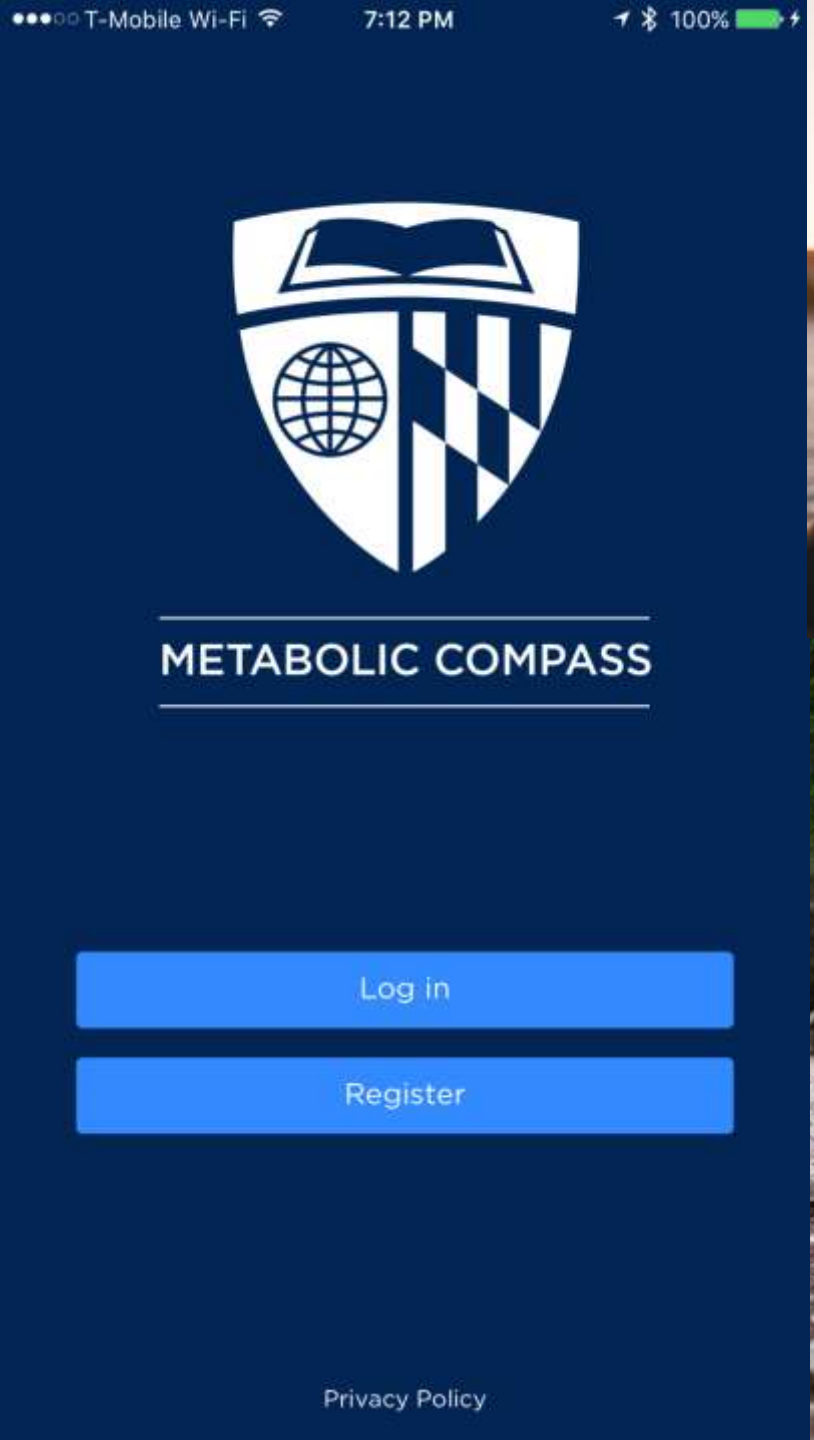


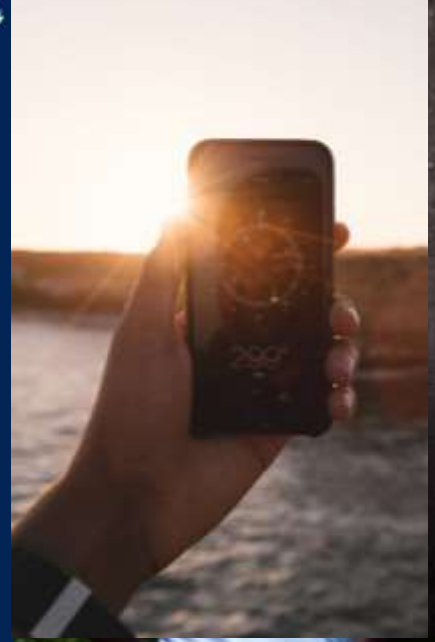
Results from Mouse Studies





Satchin Panda: Salk


T-Mobile Wi-Fi
7:12 PM
100%
METABOLIC COMPASS
Log in
Register
Privacy Policy




T-Mobile Wi-Fi
1:11 PM
100%
DASHBOARD
Comparison
Balance
Body Clock
Aug 27 th
Aug 26 th
Aug 25 th
Aug 24 th
Aug 23 rd
Aug 22 nd
Aug 21 st
0 2 4 6 8 10 12 14 16 18 20 22 24
Sleep
Eating
Exercise
Fasting
00 h 45 m
Daily Eating
23 h 15 m
Max Daily Fasting
00 h 00 m
Last Ate
Dashboard
Chart
Analysis
Settings

Data Representation for Behavior Change:

Circadian Behavior Patterns

Mobile Health Frameworks

Apple iOS: HealthKit, ResearchKit

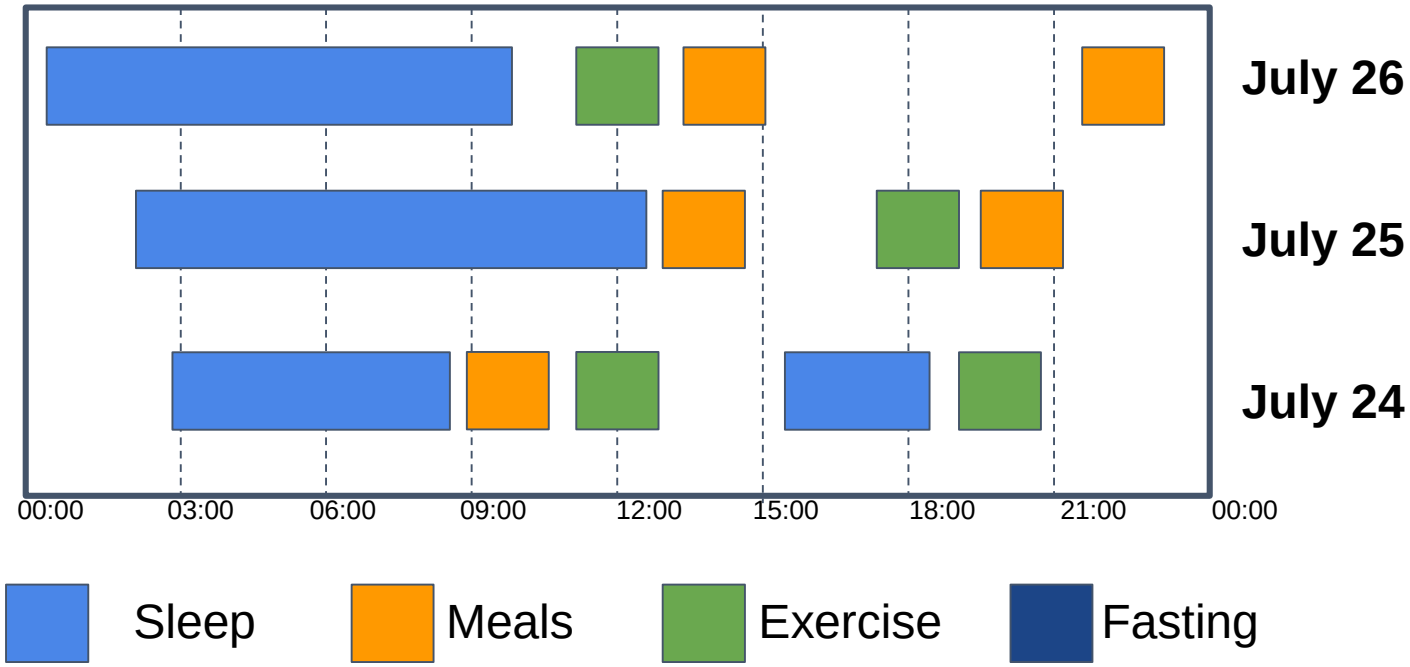
Google Fit, ResearchStack

Electronic consent

HealthKit: ~70 physiological datatypes, no cloud storage/compute

Google Fit: ~40 physiological datatypes, no HIPAA-compliant cloud

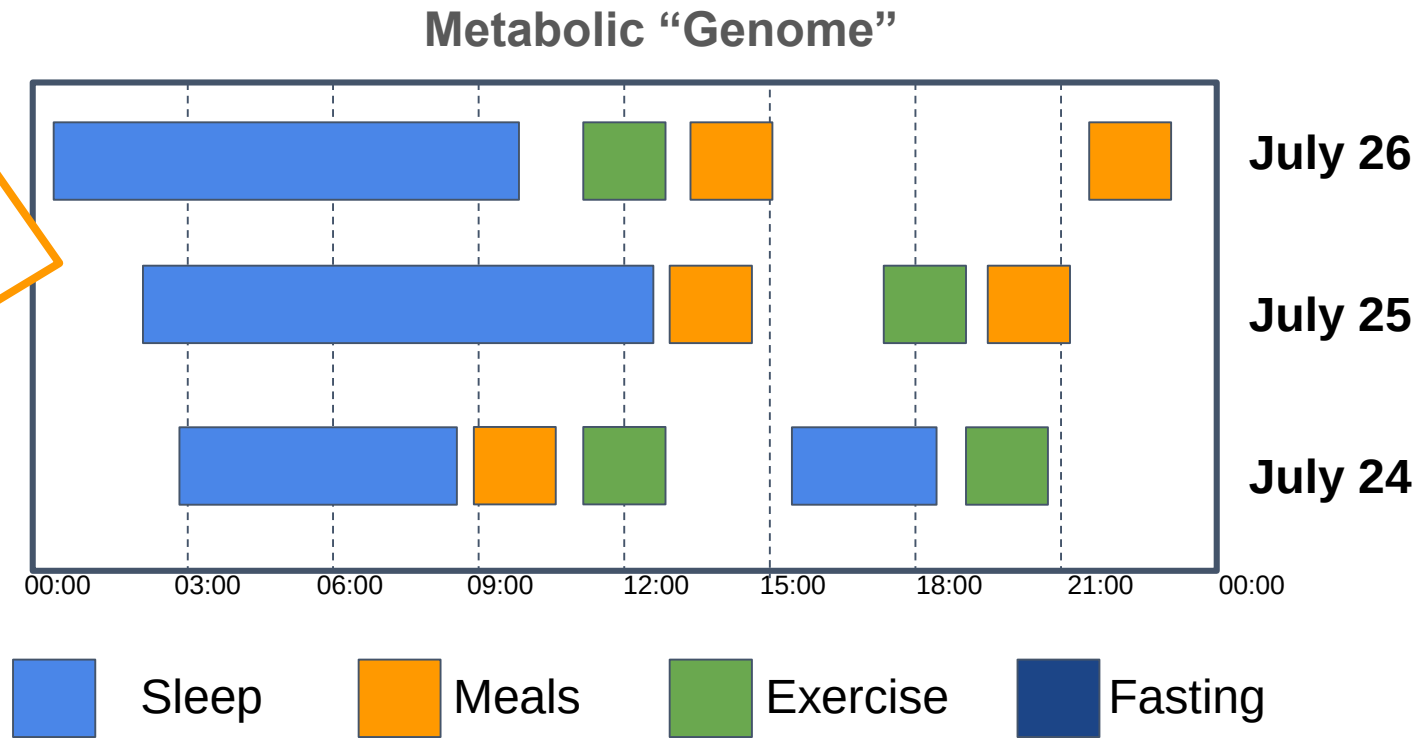
Metabolic “Genome”



Data Representation for Behavior Change:

Circadian Behavior Patterns

- Less of the day spent eating
- Greater time interval between last meal and sleep
- Having the largest meal at midday, rather than after dark
- Eating fewer sugars and carbs late in the day
- Heart-rate timing for a sustained peak value



Data Representation for Behavior Change:

Circadian Behavior Patterns

Behavioral Variables

Circadian activity timings
Engagement: collection rates, sessions
Adherence: on circadian plans and goals

Physiological Variables

Weight, heart rate variability, blood pressure, nutrition, etc.

Recruiting now: Large population observational study

Data Representation for Behavior Change:

Circadian Behavior Patterns

Behavioral Variables

Circadian activity timings
Engagement: collection rates, sessions
Adherence: on circadian plans and goals

Physiological Variables

Weight, heart rate variability, blood pressure, nutrition, etc.

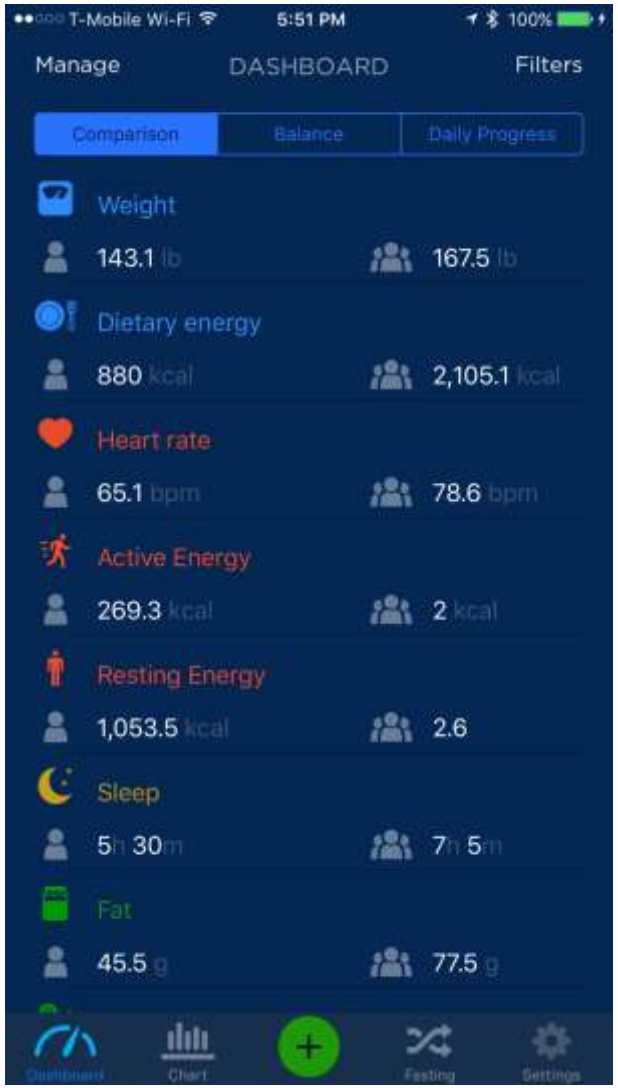
Feedback

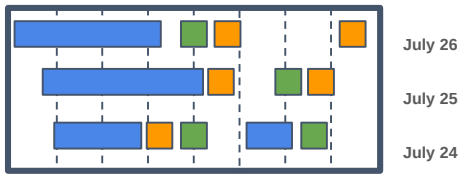
Just-in-time Feedback
Notifications
Self-established Goals
Group & cohort Messaging

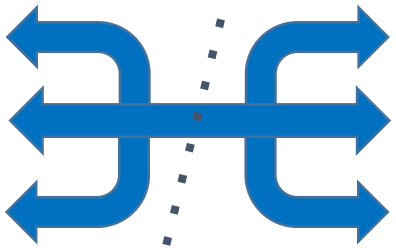
Recruiting now: Large population observational study

Lifestyle modification and behavior change

Metabolic Compass Architecture





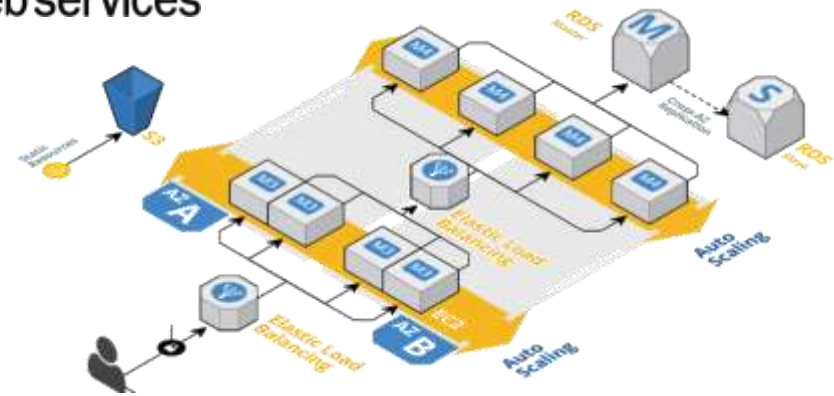


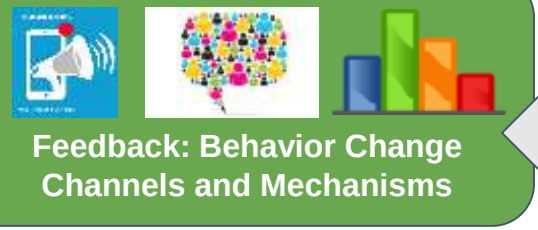
Real-time messaging

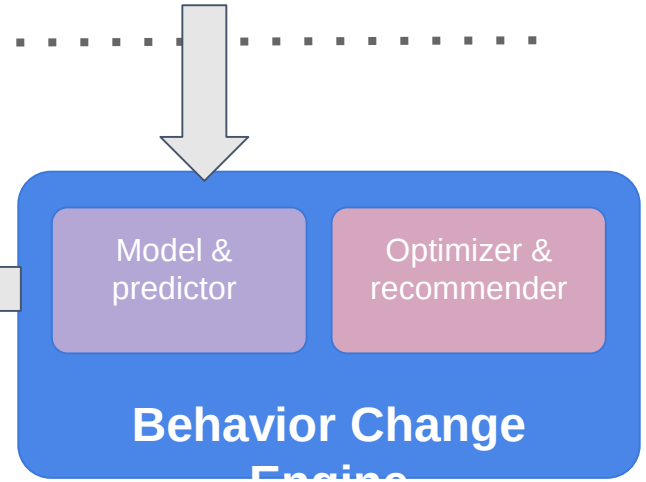
Web Tier
Node.js, React

Database Tier
Postgres RDS

Analytics Tier
Spark & Redshift

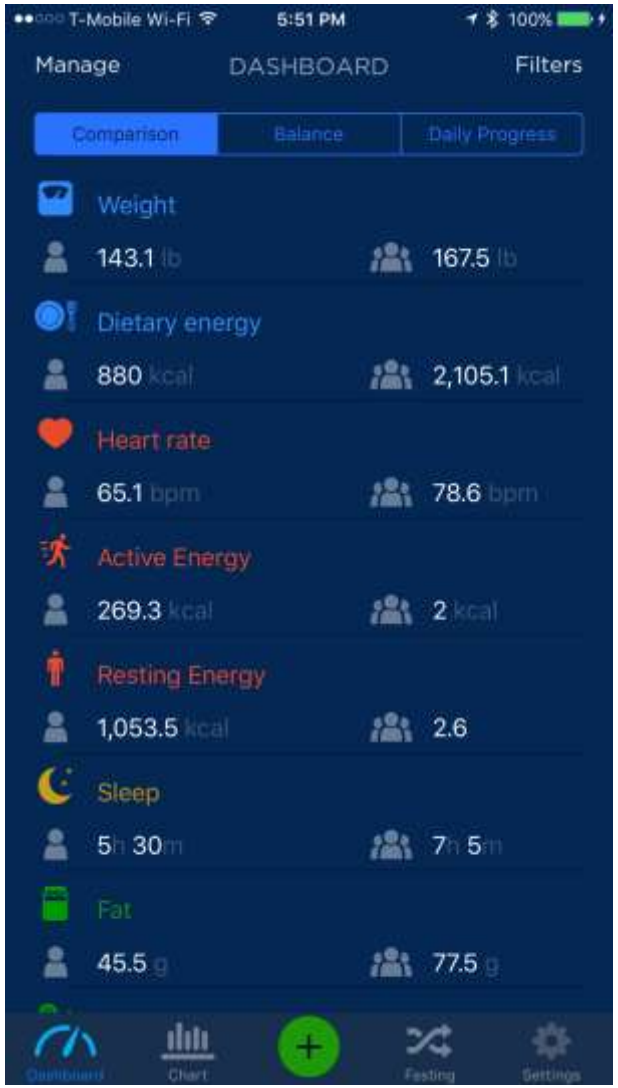


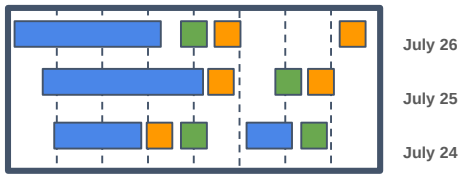


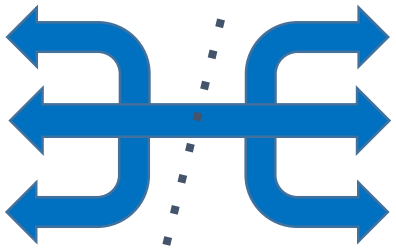


(Open source: https://github.com/yanif/circator)

Metabolic Compass Architecture





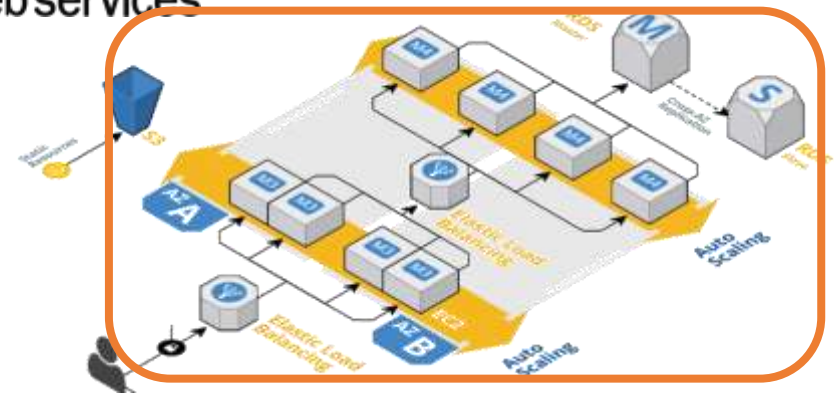


Real-time messaging

Web Tier
Node.js, React

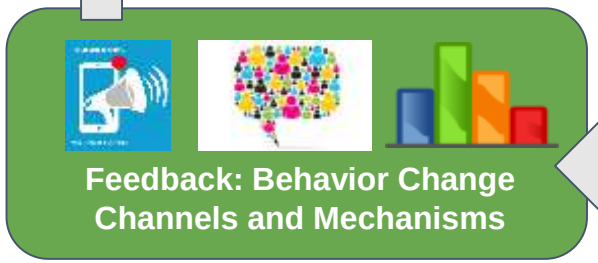
Database Tier
Postgres RDS

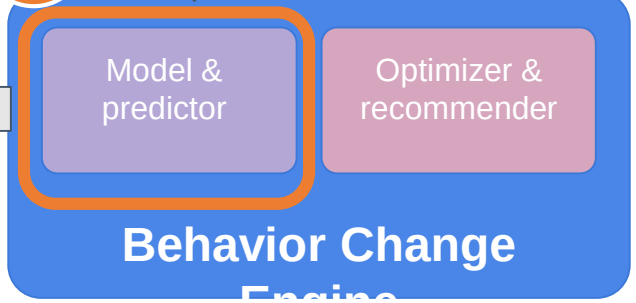
Analytics Tier
Spark & Redshift



1

2

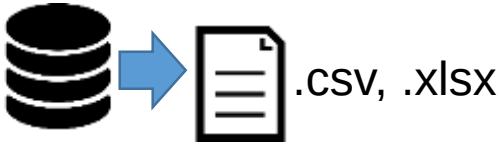


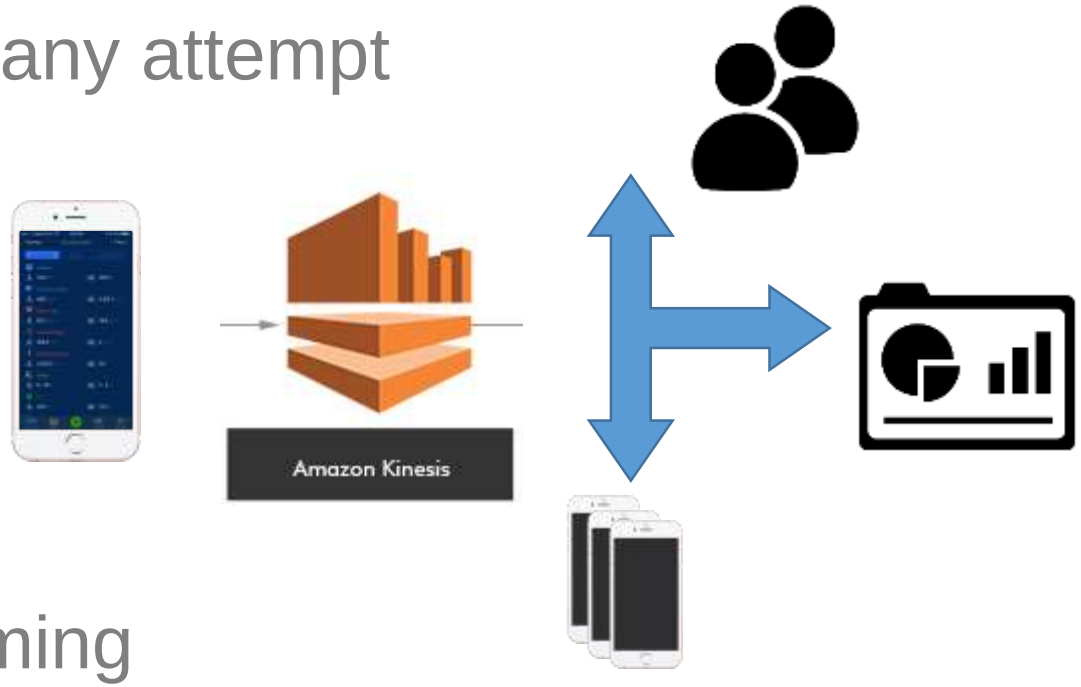


(Open source: https://github.com/yanif/circator)

Open Data Delivery

Data access agreement prohibits any attempt to reidentify datasets





Snapshots

- Compressed, anonymized behaviors and measures
- Sampling facilities

Streaming

- Real-time dissemination of anonymized behaviors and measures
- Delay and replay facilities

Data Synchronization and Extraction Services

Delay-tolerant, order-aware client libraries

Server

Data and units standardization

Append-only in-memory arena for high-throughput writes

Robust multi-device data replication

Write boundary

Extensible in-database extraction for conflict-free time series

Dedup

Impute

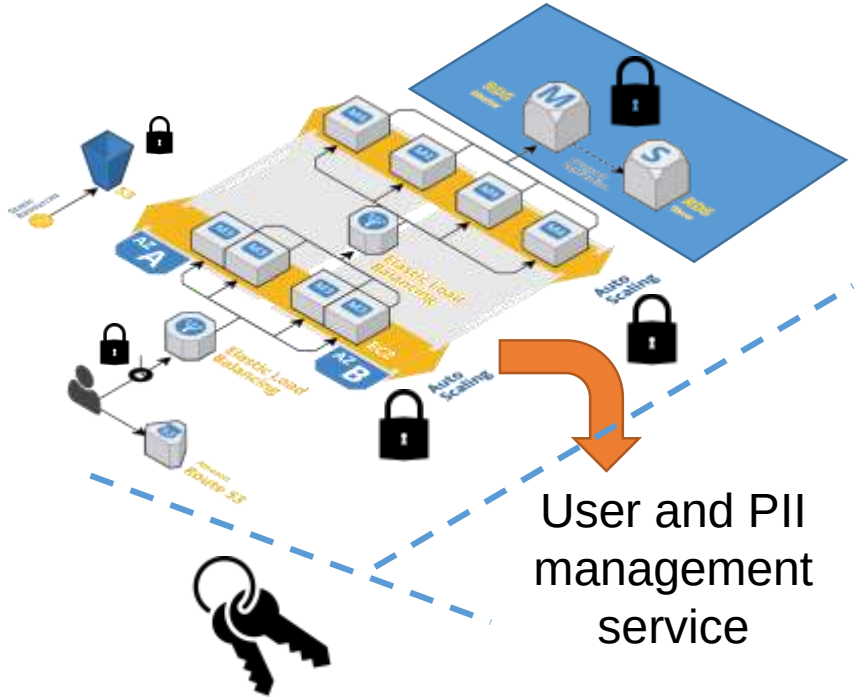
Structured data boundary

Sparse time series schema, grouped by physiological relevance, partitioned by user ids

Incremental views for population statistics

Data Security & Privacy

- Anonymized, encrypted-at-rest, HIPAA compliant
- In-flight separation of PII, and physiological & behavior data



User and PII management service

Just-in-Time Metabolic Feedback

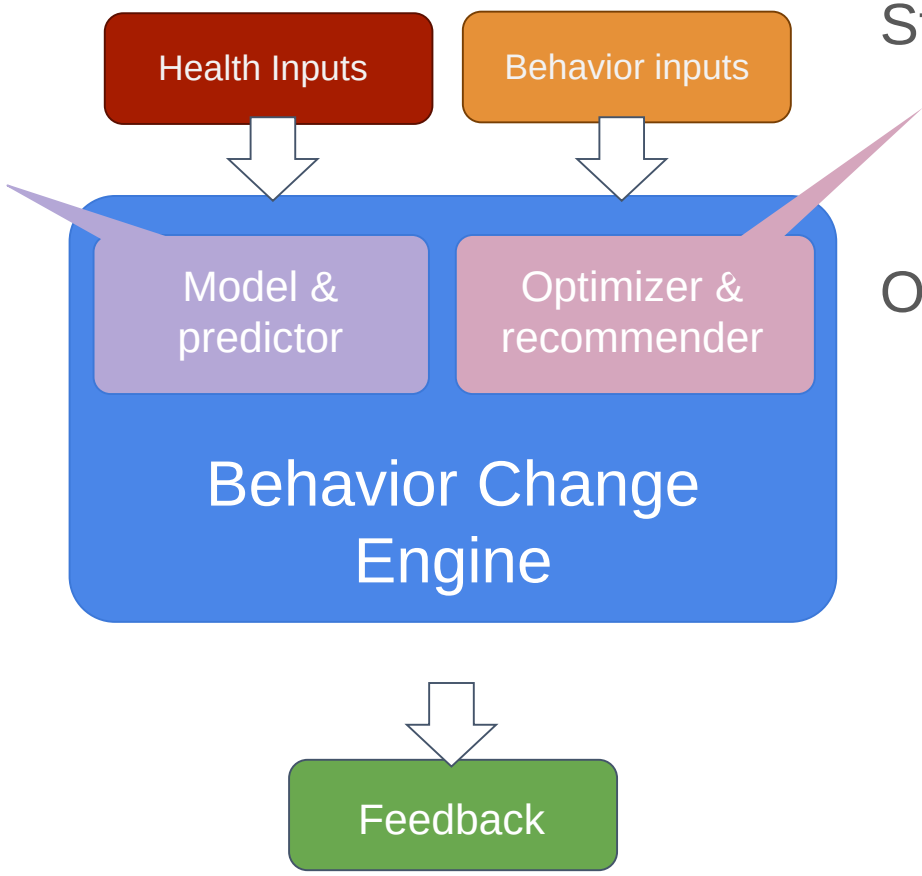
Towards the right behavior at the right time

Sequence prediction goal:

Learn the distribution of future circadian patterns from users' health and behavioral history

Prediction techniques:

- Recurrent neural nets/LSTMs
- Extended Kalman filter
- Markovian models



Stochastic optimization goal:

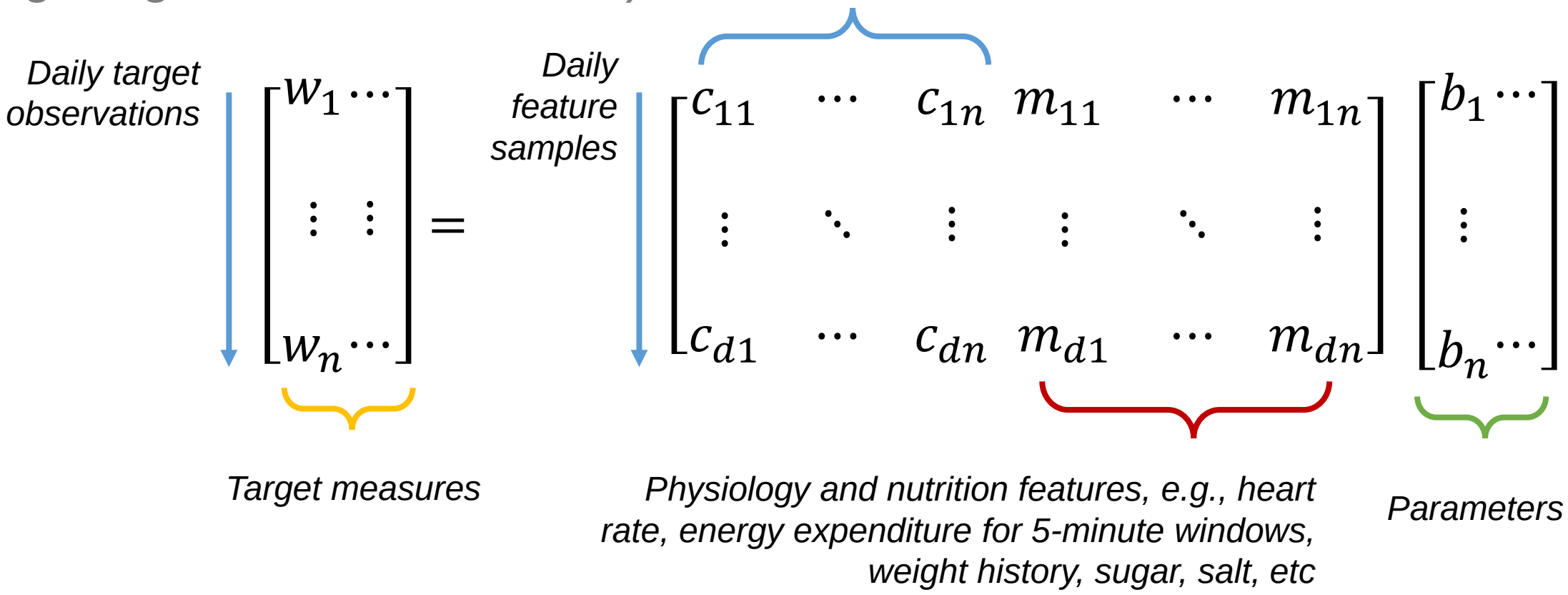
Optimize over all possible future circadian patterns

Objective design, factoring in:

- Adherence, to drive "sticky" behavior change
- Assimilation, to drive messaging that "sinks in"
- Acquisition, via reminders

Analytics Data Model

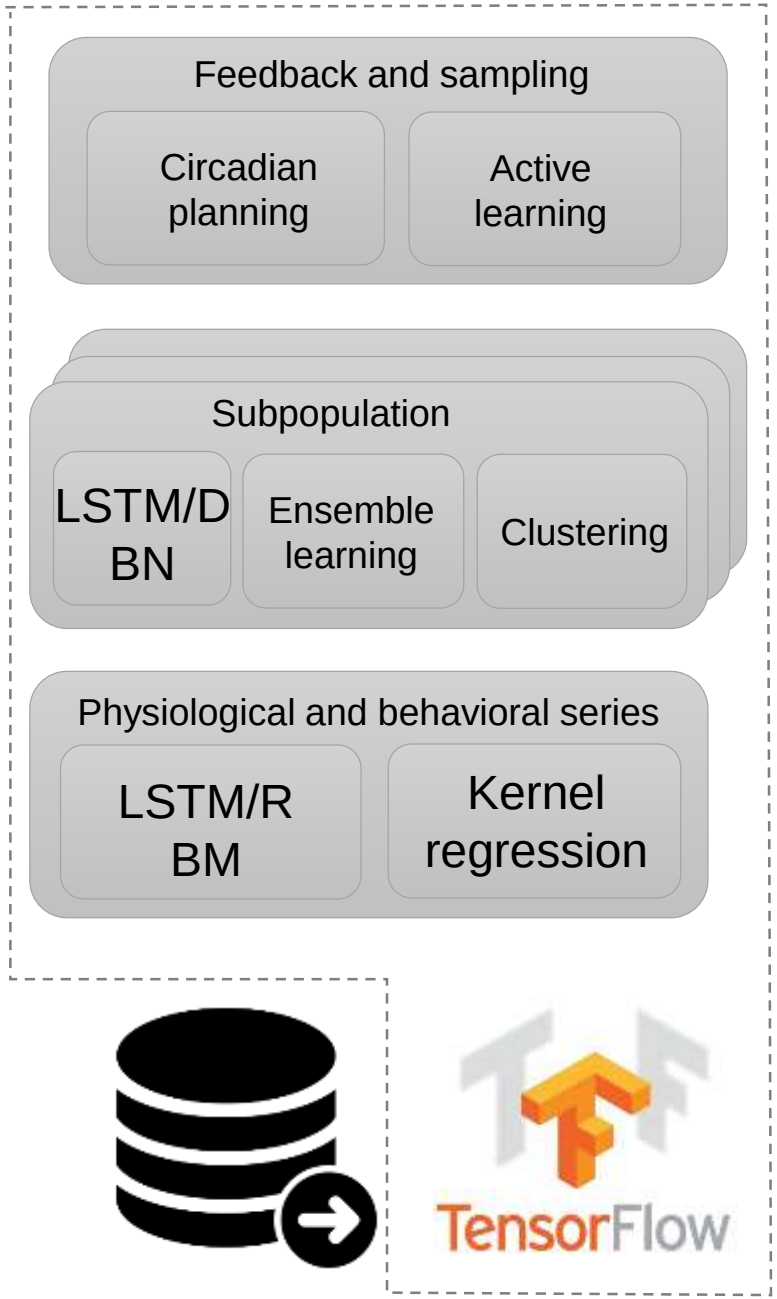
- Viewed as a regression problem (e.g., a general linear model)



Analytics Workflow

Workflow Design Challenges:

- Model granularity
  - User-specific
  - Subpopulation
- Subpopulation identification
  - Top-down
  - Bottom-up
- Self-reporting validation
- Adaptation and feedback
- Scalable inference



Circadian Planning

Challenge: from notifications to modeling behavior vectors

$$\min_{c^*,m^*} \begin{bmatrix} C & M \\ c^* & m^* \end{bmatrix} B - \begin{bmatrix} W \\ w^* \end{bmatrix} + \epsilon$$

Trained parameters

User, or physician-driven

Optimization desiderata:

- Regularization term
- Adherence/compliance likelihood term
- Constraints to reject undesirable behavior solutions
- Yield multiple solutions for user consideration

Recruitment Roadmap

Current status:

- Beta test (TestFlight), seeking 2000 iOS users
- Developing a “champions”-network

Phase 1 (general population):

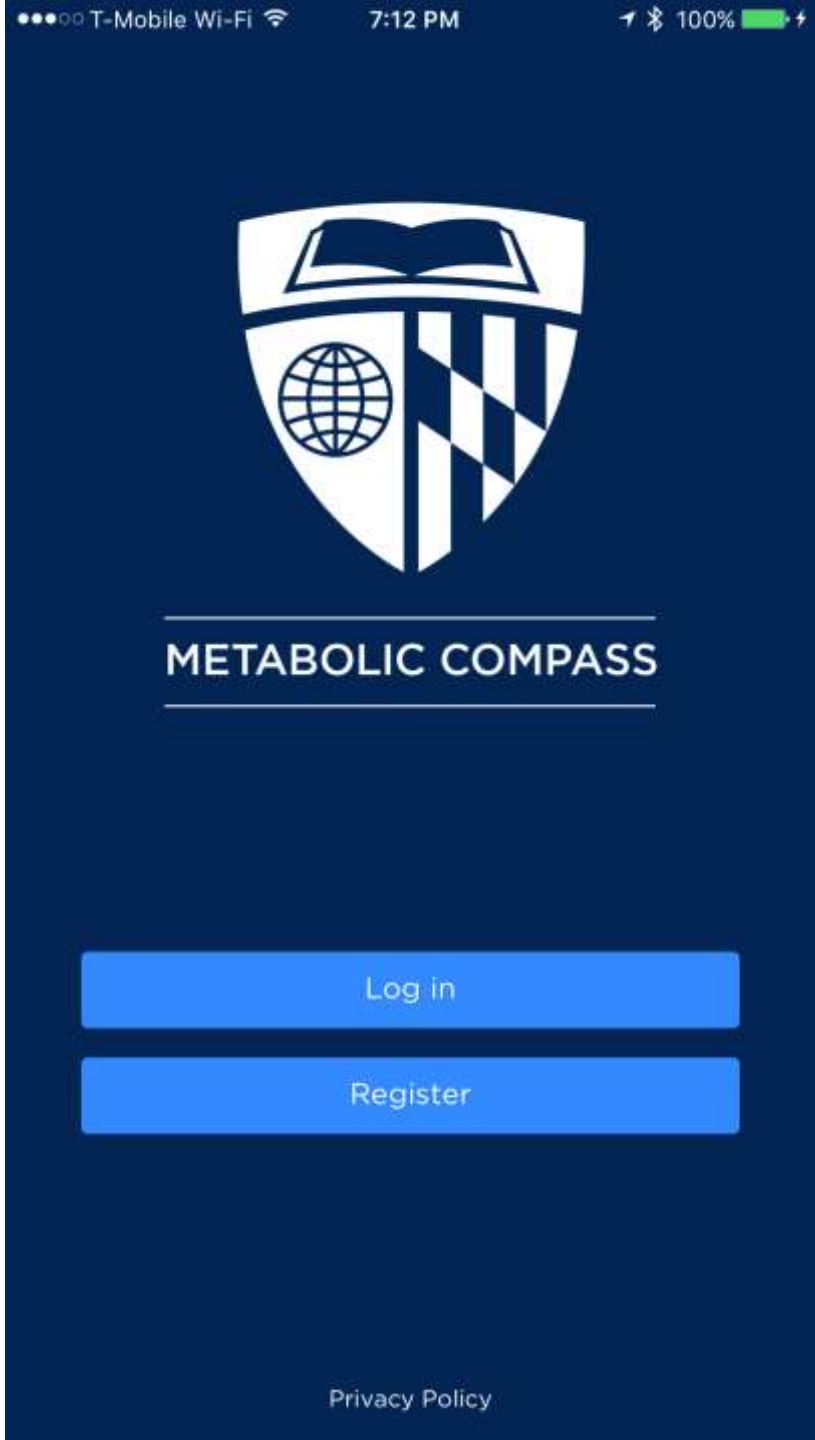
- Apple App Store release
- Android / Google Play Release

Phase 2 (early-adopters):

- Quantified-Self communities
- Ketogenic diet communities

Phase 3 (clinical):

- In-clinic flyers
- PaTH network
- AHA Strategically Focused Research Network on Obesity



Contribute Today!

https://metaboliccompass.com

METABOLIC COMPASS

A RESEARCHKIT APP FOR TRACKING AND UNDERSTANDING YOUR METABOLIC HEALTH.

Thank you!

idies

LEARN MORE