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Data Analytics

Insight

Data Analytics Insights on Personal Sensor Data

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Personal Data

- Lots of examples of organisations gathering data about us, for their use
- Ostensibly, this is processed to deliver benefit to us, the payback, the “dance with the devil”
- Sometimes ours is aggregated with others, for community benefit, like census
- Sometimes ours is aggregated with others for community **and** individual benefit, like 23andme

- We all also gather personal data – very personal – about ourselves, for our own uses
- Some of it is analog, increasingly it is digital, lifelogging is the extreme
    - Diaries, logs, records
    - Health and physiology measurements
    - Activity levels and activity types
    - Location
    - Personal media like photos, videos
- Sometimes we share this, sometimes we do not, we keep it for ourselves.

Personal data for public good

- Individuals log a variety of health-related data via wearables and apps, as well as passively as we communicate on social networks, shop, work, or leave digital footprints.

- Self-tracking data provides better measures of activities of daily living and lifestyle, filling in gaps from more traditional clinical data collection, giving us a more complete picture of our health.

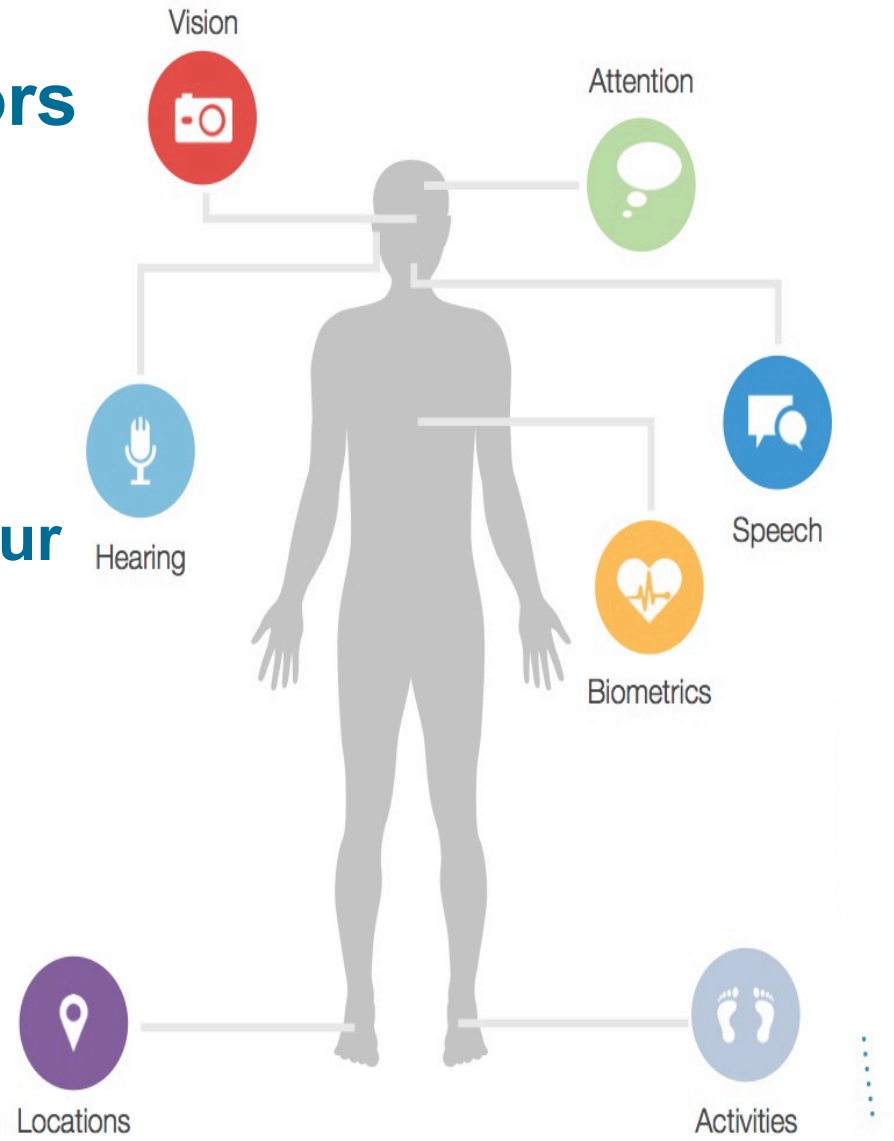
- U. Calif. Irvine study 2014 found
  - *"Individuals were very willing to share their self-tracking data for research, in particular if they knew the data would advance knowledge in the fields related to public health, health care, computer science and social and behavioral science."*

Issues Raised in that Study …

- **Privacy and Data Ownership: the** dominant issue … an assurance of privacy for their data, and +90% said it should be anonymous .. and they wanted to own/share ownership of the data
- **Informed Consent:** whether there is informed consent or … current methods of informed consent are not fit for purpose, new approaches needed
- **Data Sharing and Access:** … growing interest in … willingness … to share personal health data with others … online groups like PatientsLikeMe or Crohnology.
- **Data Quality:** concerns about the lack of standardization of devices needs the consumer health device, apps and services market to mature, to bake in the idea of data sharing.

Kinds of Wearable Sensors

- So many kinds of wearable sensors ...
- ... for so many aspects of our health and wellness



Most common wearable is the Accelerometer

MARKETSANDMARKETS

... market expected to grow from USD 189.4 Million (2015) to USD 1,654.0 Million (2022).

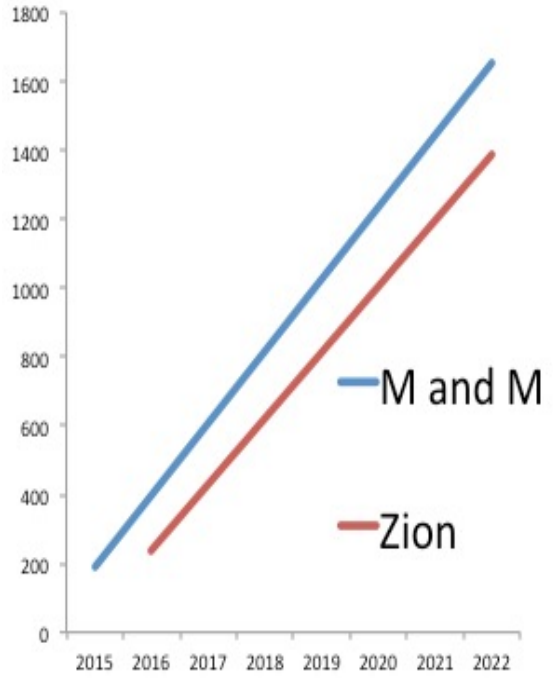
Zion Market Research

… USD 237.93 Million (2016), expected to reach USD 1,387.04 Million (2022).

Gartner

... 310M wearable devices will be sold in 2017 (+16%) with smartwatches (Apple Watch and Samsung Gear) at 41.5M showing highest sales among wearables

Asus, Huawei, LG, Samsung and Sony planning new smartwatch devices



Major factors influencing growth …

- smaller, smarter, cheaper
- Miniaturization of everything
- integration w/ consumer devices
- perceived benefits of wearable devices in healthcare
- prospects for on-board computation

What do *we* do with Accelerometers ?

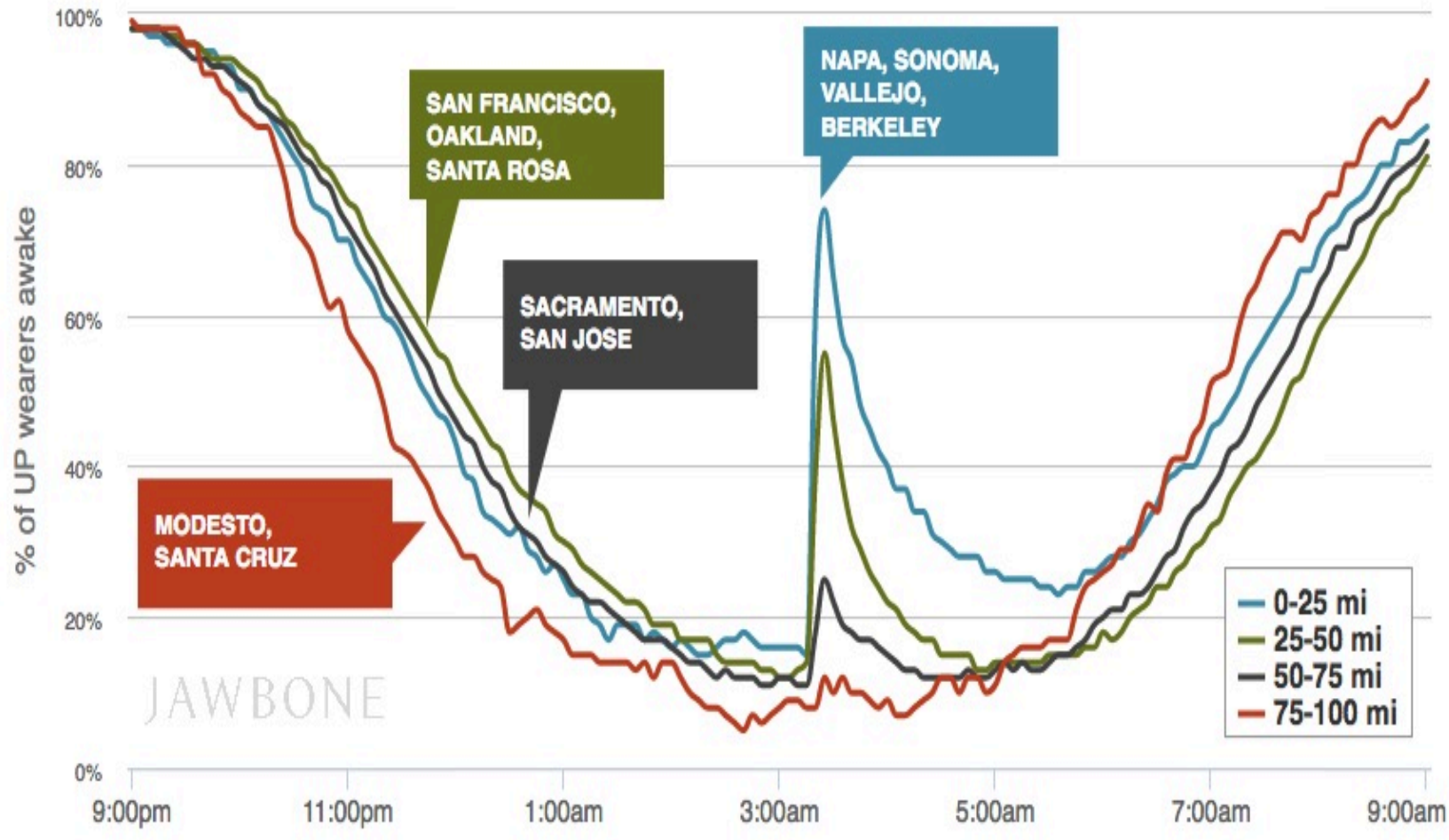
- Accelerometer ... count steps, measure distance walked, add up energy expenditure, set targets and challenges, assess sleep quality ... that's it !
- We can also longditudinally track behaviour and detect change, but only for
  - Weight loss programs
  - Smoking cessation programs
  - Food intake improvement, etc.
- Beyond that ... monitoring your health ?
  - 2 year annual check-up ✔
  - Doctor visit when feeling ill ✔
  - Hospital for emergency situations ✔
  - Your own personal, healthcare professional, monitoring and advising, doing preventative maintenance on your health ✗

Example: sleep monitoring

Sleep monitoring - unanticipated

- In Sept 2014 at 3:20am, Northern California earthquake, strongest in 25 years
- Magnitude 6.0, epicenter was 6 miles SW of Napa
- No casualties, just minor injuries … really ?
- 93% of Jawbone UP wearers in the immediate area woke up, 45% of them within 15 miles stayed up all night (55% went back to sleep !)

A building downtown at 2nd and Brown sustained damage from the 6.0 earthquake in Napa. (Steve Rhodes/Demotix/Corbis)


100%
80%
60%
40%
20%
0%
% of UP wearers awake
SAN FRANCISCO, OAKLAND, SANTA ROSA
NAPA, SONOMA, VALLEJO, BERKELEY
SACRAMENTO, SAN JOSE
MODESTO, SANTA CRUZ
JAWBONE
0-25 mi
25-50 mi
50-75 mi
75-100 mi
9:00pm
11:00pm
1:00am
3:00am
5:00am
7:00am
9:00am

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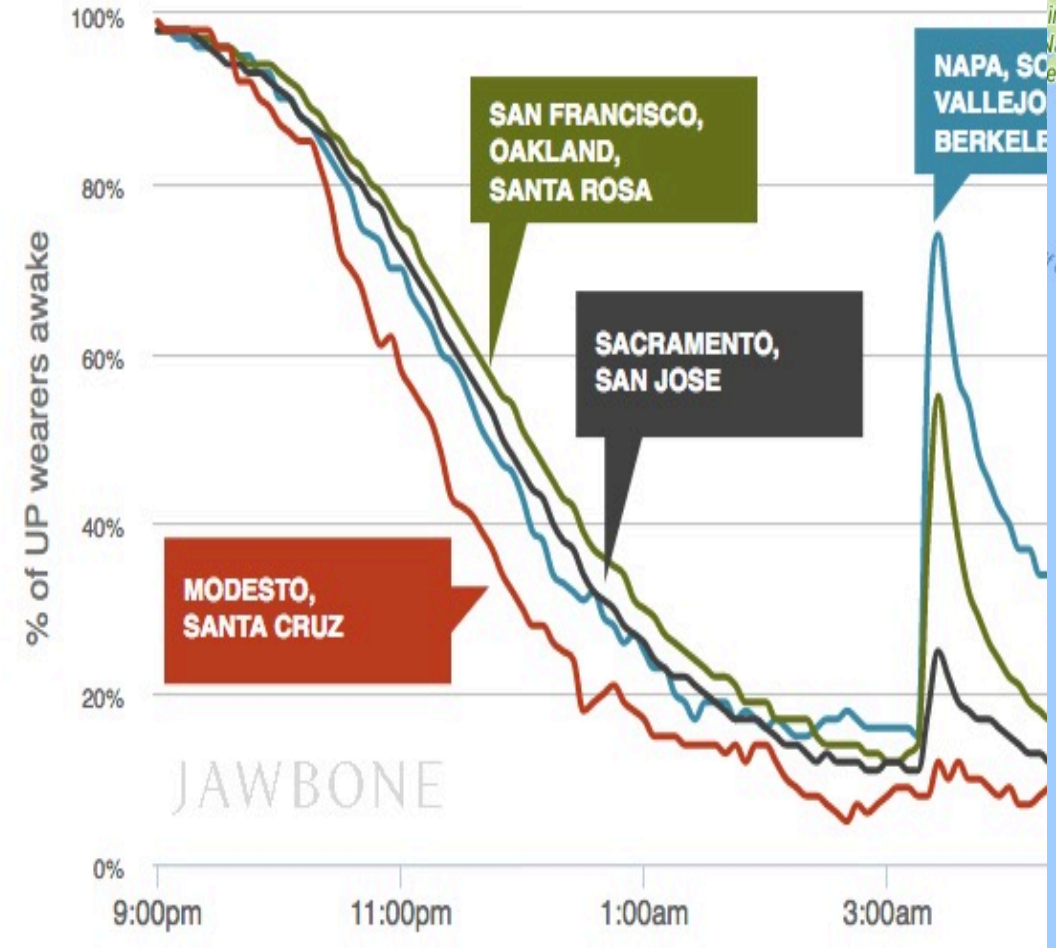
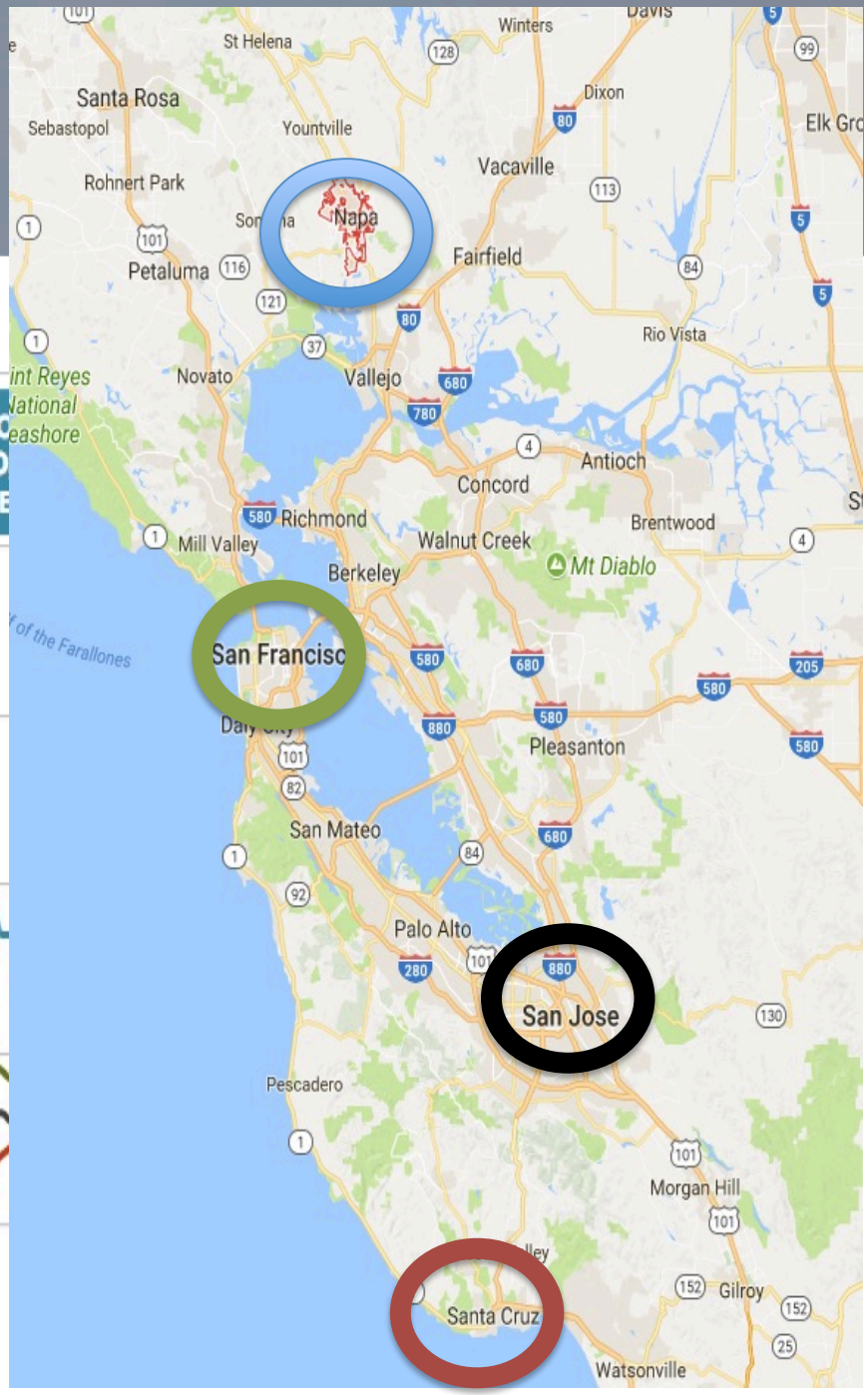




Nobel Laureates in Medicine 2017

From left: Dr. Rosbash, Dr. Young and Dr. Hall.

Bill Sikes/Associated Press; Mario Morgado/The Rockefeller University, via Associated Press; Chinese University of Hong Kong

Nobel Laureates in Medicine 2017

- Jeffrey C. Hall of the University of Maine, Michael Rosbash of Brandeis University, and Michael W. Young of Rockefeller University — *"were able to peek inside our biological clock and elucidate its inner workings*," the Nobel Prize Committee 2017
- Long known that we're controlled by a circadian rhythm but Nobel Committee says *"circadian biology has developed into a vast and highly dynamic research field, with implications for our health and wellbeing."*
- Researchers have discovered that each of us have a unique, genetically determined "chronotype," or clock that programs our ideal sleep time in the 24-hour cycle. This discovery helped clarify why there are true "*morning people*" and true "*night owls*," and why some argue that we should be able to set our own work schedules

Circadian clo

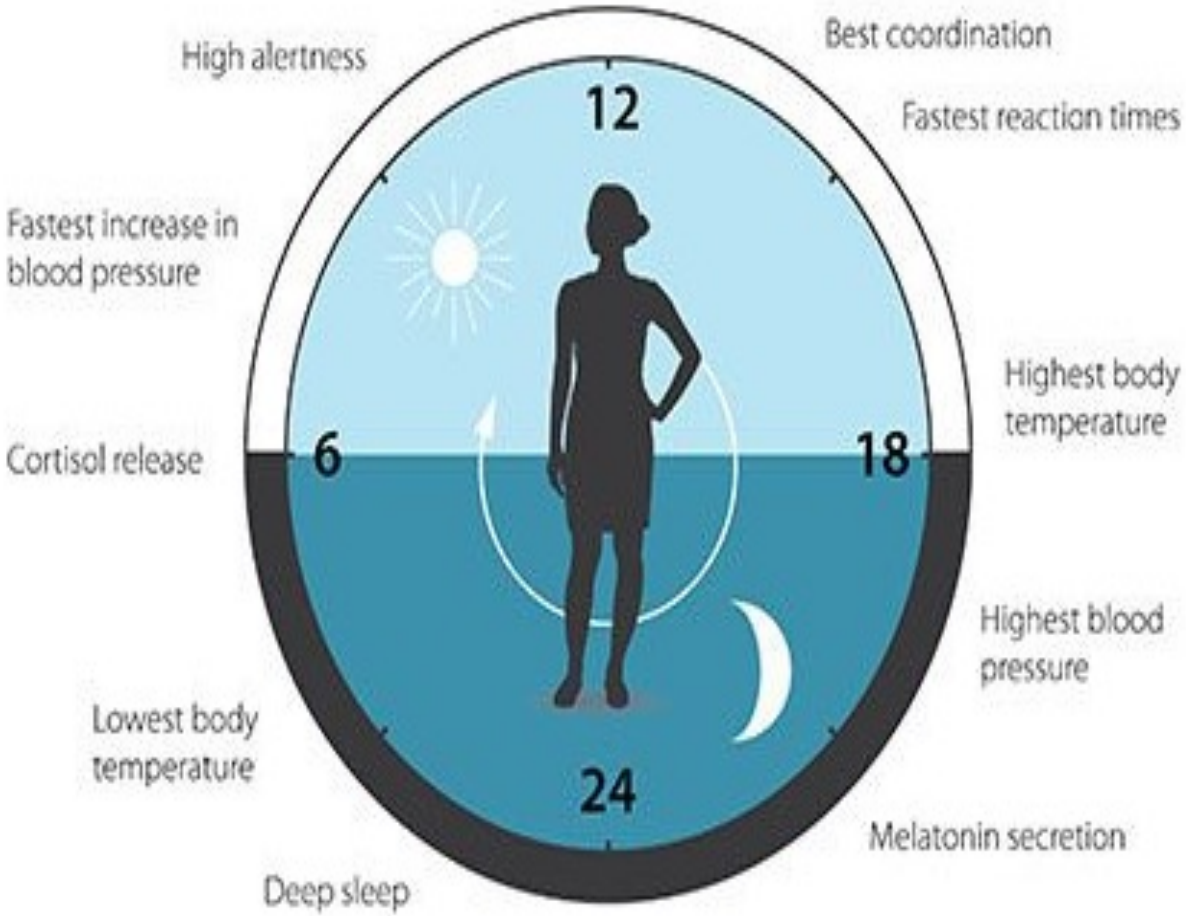


Image courtesy of Mattias Karlén/Nobel Prize

Circadian clock

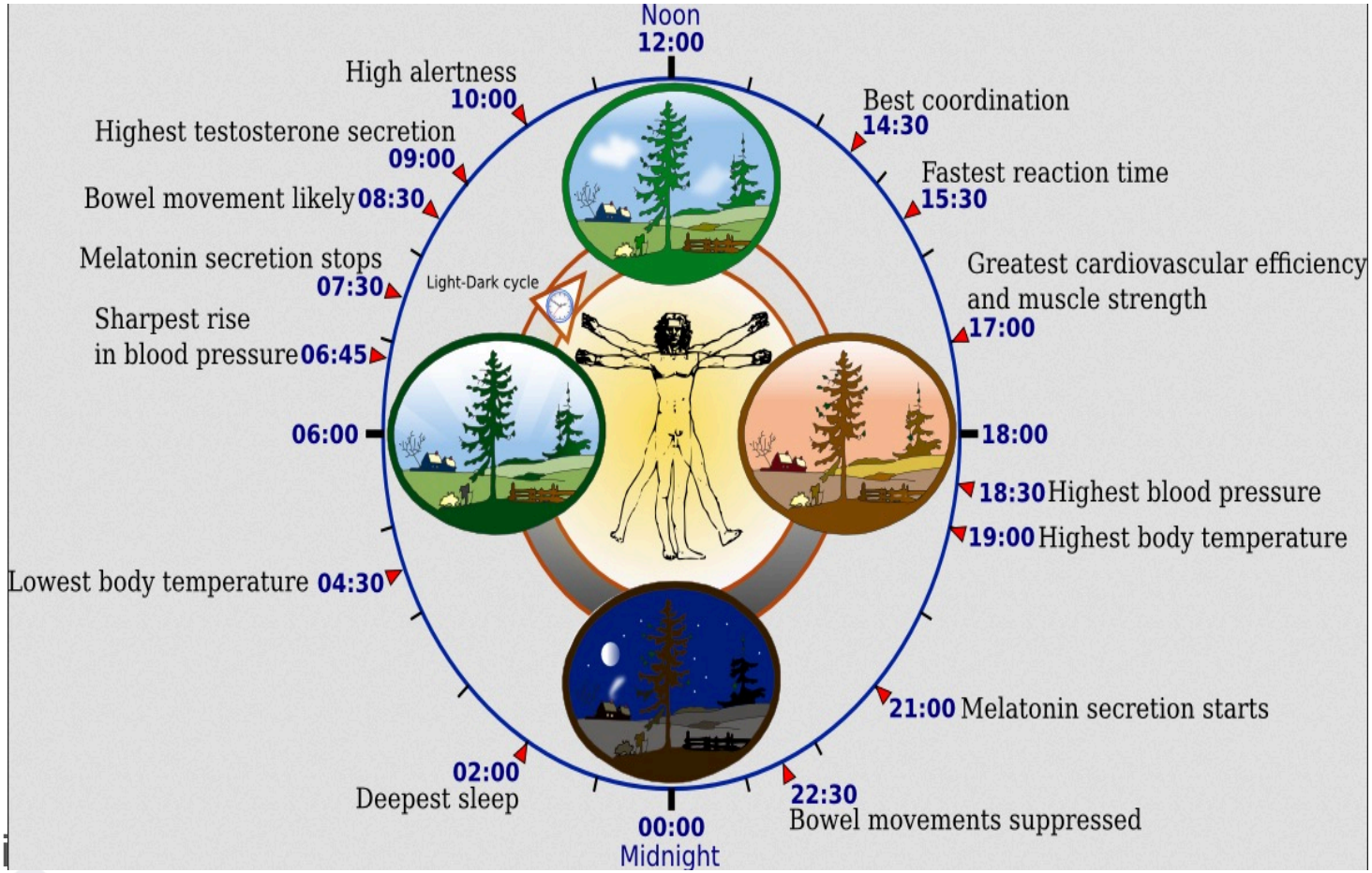
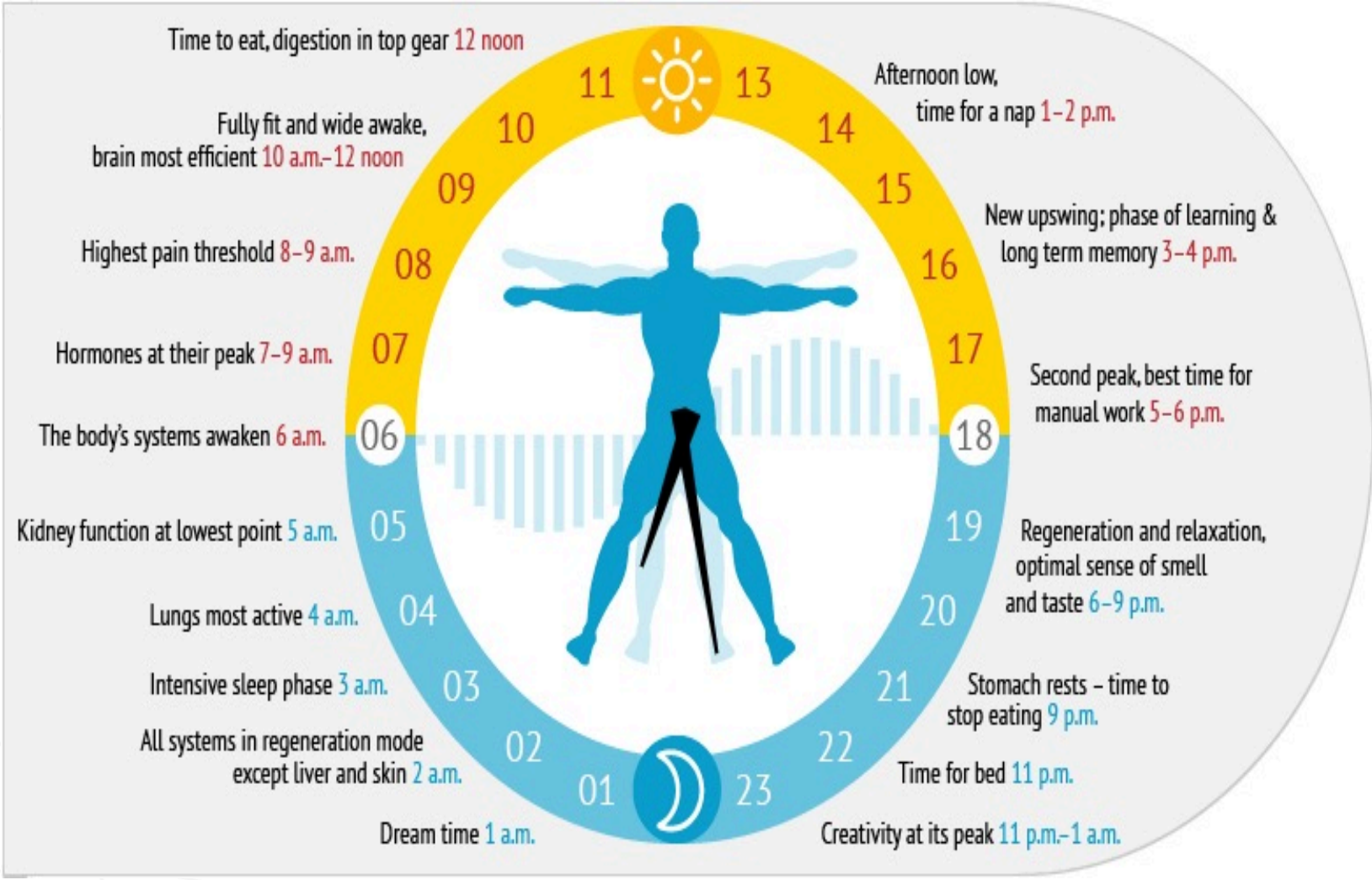


Image from Wikipedi


Time to eat, digestion in top gear 12 noon
Afternoon low, time for a nap 1–2 p.m.
Fully fit and wide awake, brain most efficient 10 a.m.–12 noon
New upswing; phase of learning & long term memory 3–4 p.m.
Highest pain threshold 8–9 a.m.
Hormones at their peak 7–9 a.m.
Second peak, best time for manual work 5–6 p.m.
The body's systems awaken 6 a.m.
Kidney function at lowest point 5 a.m.
Regeneration and relaxation, optimal sense of smell and taste 6–9 p.m.
Lungs most active 4 a.m.
Intensive sleep phase 3 a.m.
Stomach rests – time to stop eating 9 p.m.
All systems in regeneration mode except liver and skin 2 a.m.
Time for bed 11 p.m.
Dream time 1 a.m.
Creativity at its peak 11 p.m.–1 a.m.
11
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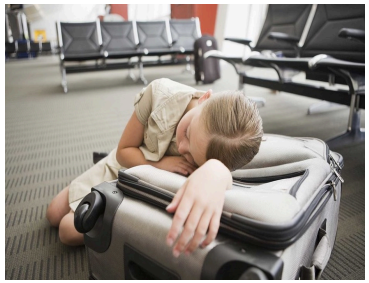
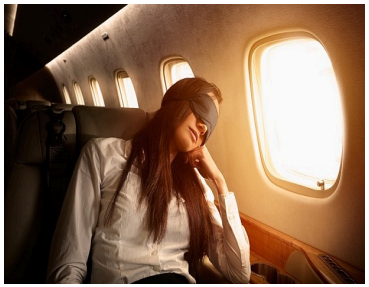
Consequences of disruption to the cycle …

- Researchers studying chronobiology found that eating at night can be problematic for health since our bodies aren't primed to cope with the glucose load from food in the evening.
  - We usually eat a meal after waking up, so our bodies adapted to produce the most insulin in the morning.
- Jet lag describes the effects of shifting one's sleep cycle by even a couple of hours. (Even moving people's sleep cycle by one hour each day made participants in a study look prediabetic after a three-week trial.)

Periodicity Disruptions



- Jet lag disruption includes fatigue, malaise and poor concentration, deviating from our circadian rhythm
- Known relationship between sleep, sunlight, mood and melatonin (sleep regulating hormone)



MM'2017 Audience by next Wednesday afternoon ?

Periodicity … the natural tendency to recur at regular intervals

- Examples of periodic phenomena in nature
  - Day/night cycle (rotation of earth)
  - Season (revolution of the earth)
  - Tides and the 29.5 day lunar cycle
  - Pendulums (pendula ?) and other swinging movements
  - Ocean waves
  - Birth/marriage/death cycle
  - Menstrual cycle
  - Eating and sleeping cycle
  - Heartbeat and breathing
  - Animal calls
  - Musical rhythm
  - Linguistic rhythm
  - Dribbling, juggling
  - Calendars
  - Fashion cycles, for example, skirt lengths or necktie widths
  - Economic and political cycles, for example, boom and bust economic periods, right-wing and left-wing political tendencies
- Every periodic phenomenon involves variables which characterize the repeating phenomenon (displacement, speed, light intensity, pitch, loudness, wakefulness, necktie width) and a period, the length of time required for cycle

Human Periodicity

- We once rose, ate and went to bed at the same time every day
- Now it's difficult to keep a regular schedule, especially true of mealtimes.
- Many eat on their feet at erratic hours, putting off meals and generally not keeping set meal times.
- The effect on our waistlines is well documented but on our biological clocks is not as well known. Does our circadian rhythm become dysregulated with delayed meal times?

Human Periodicity

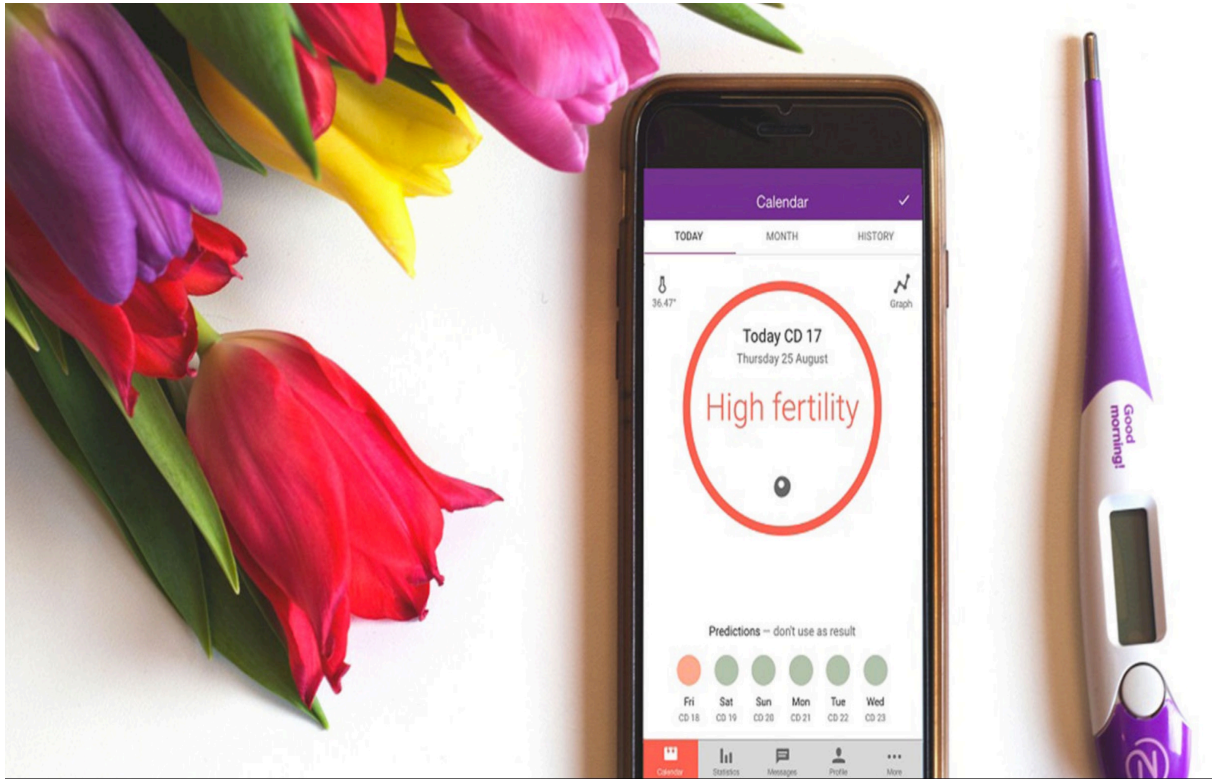
- The human microbiome is made from bacteria, archaea, viruses and eukaryotic microbes in and on our bodies.
- These microbes impact our physiology, both in health and in disease
- Metabolic functions, protect against pathogens, educate the immune system and affect directly or indirectly most of our physiologic functions

Why chronobiology ?

- Chronobiology the branch of biology concerned with natural physiological rhythms and other cyclical phenomena - solar and lunar-related rhythms
- Occurs in all animals - eating, sleeping, mating, hibernating, migration, cellular regeneration, etc.
- More recently, light therapy and melatonin are studied as a means to reset animal and human circadian rhythms but effects on our microbiome are unknown

Periodicity Predictions (for Good)

Natural Cycles, a fertility tracking app, 100,000 users worldwide, now approved as a medical device for female contraception in the EU



Using wearable sensors to collect data, even with gaps, we can detect periodicities

Periodogram

- A **periodogram** calculates the significance of different frequencies in time-series data to identify any intrinsic periodic signals. A **periodogram** is similar to the Fourier Transform,
- Used to identify the dominant periods (or frequencies) of a time series. This can be a helpful tool for identifying the dominant cyclical behavior

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Wrist-worn accelerometer data – 20 US Veterans – 13 weeks each – 24x7 – with sleep problems and sleep interventions

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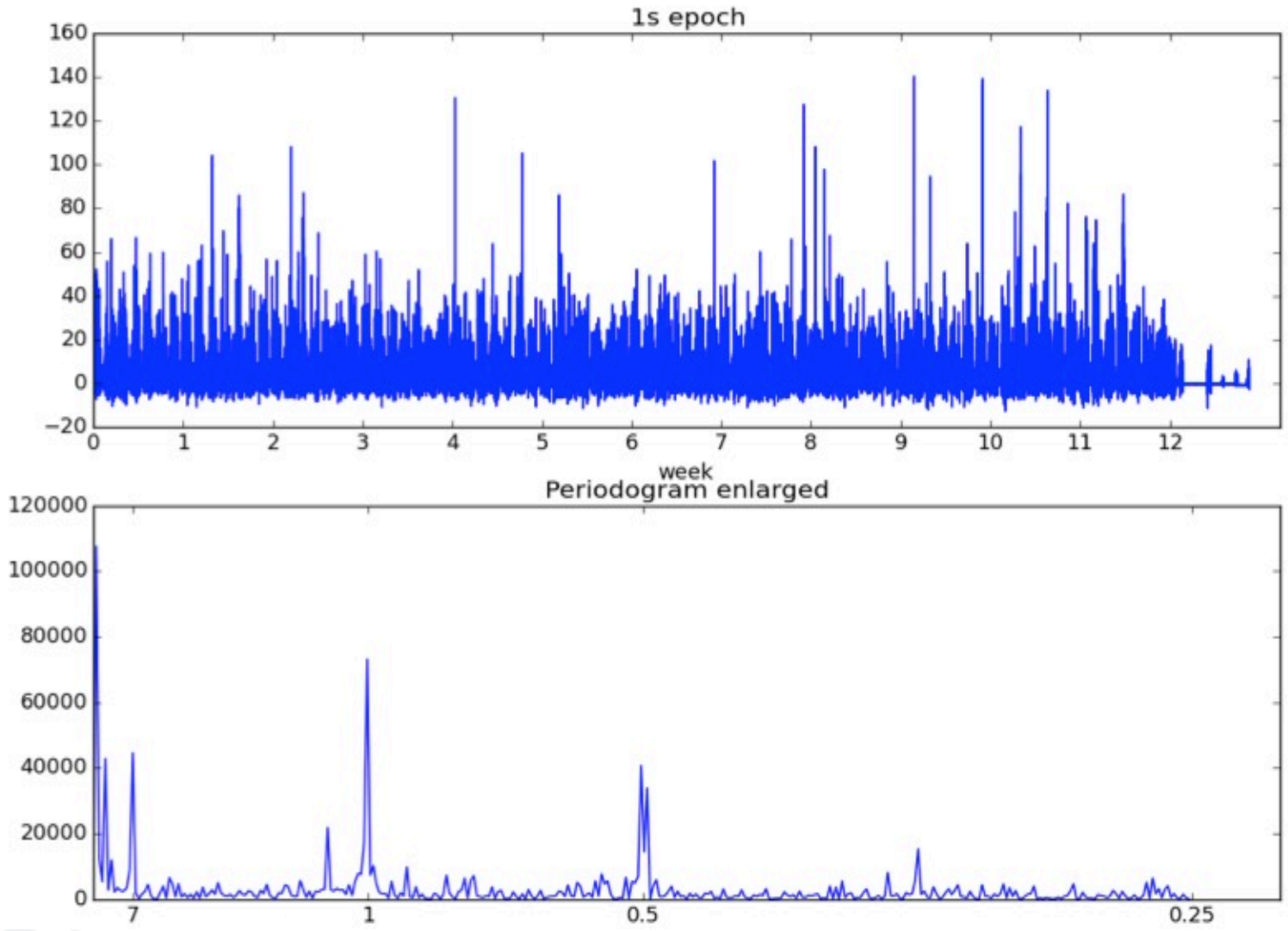
Raw accelerometer data and periodicity

...

... 13 weeks, 24x7 wrist-worn accelerometer data



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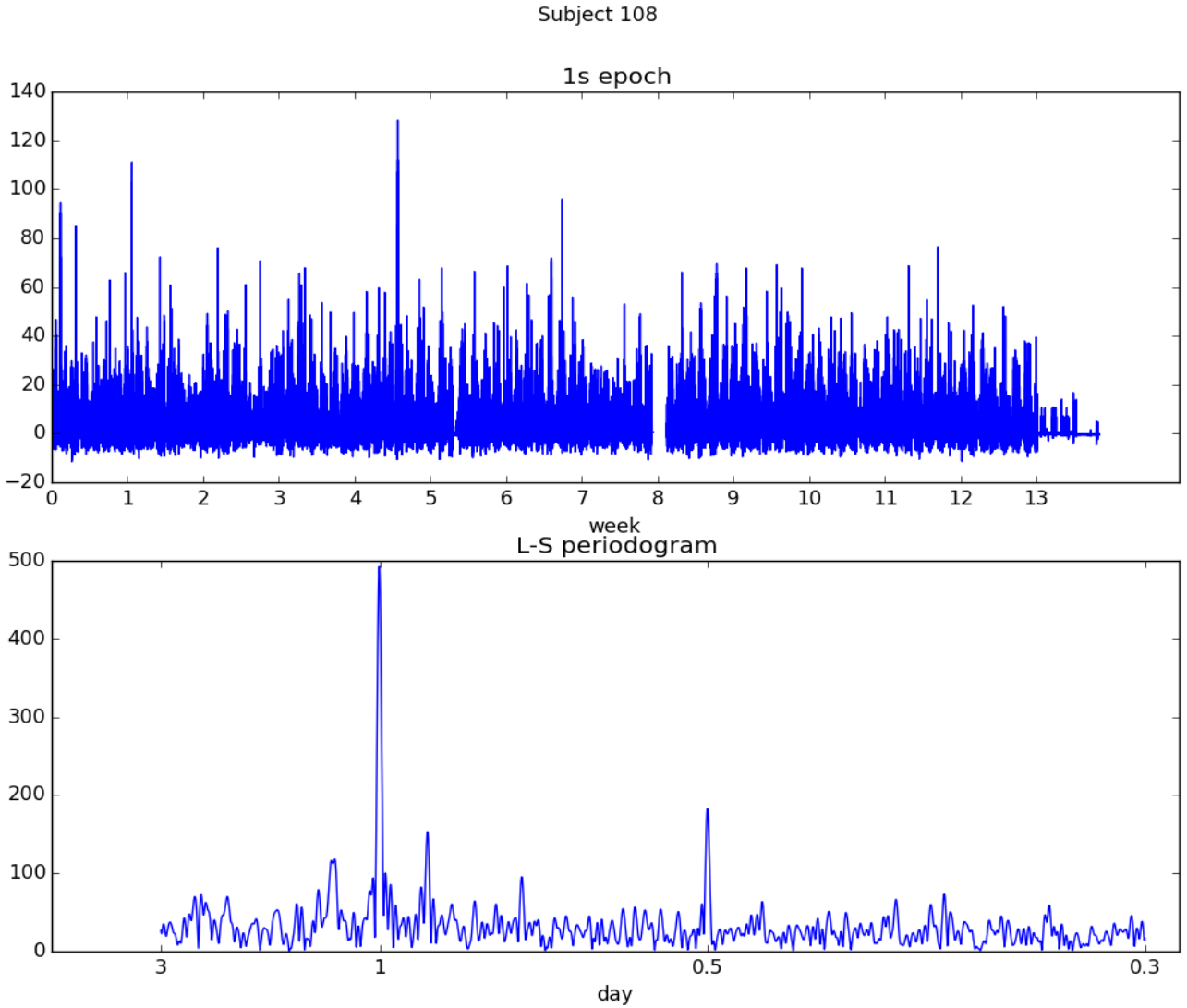


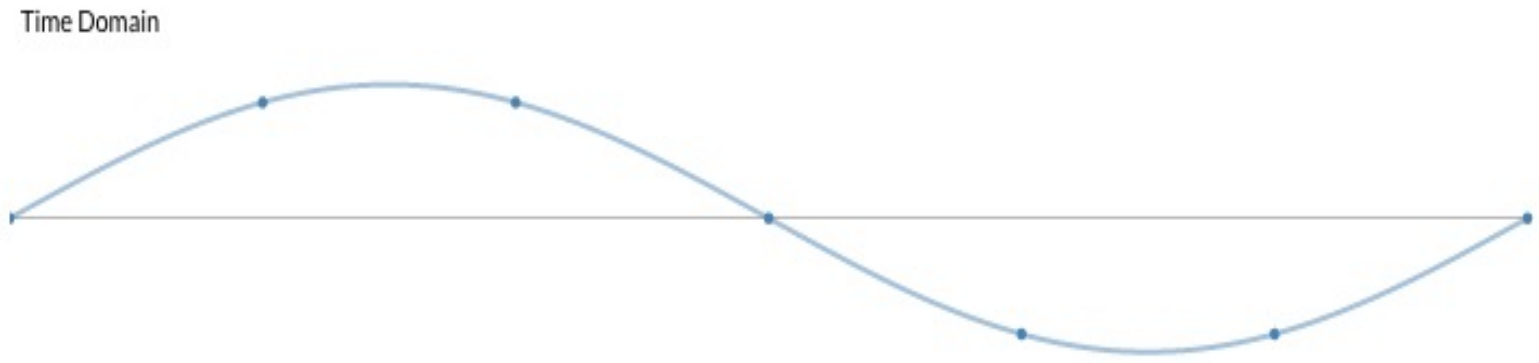
Periodogram artefacts

- **The Sampled Sine Wave Theorem** says given a sampling rate of **SR** hertz, and an integer **k**, a sine wave at a frequency of **F** is indistinguishable from a sine wave at a frequency of **F + (k × SR)** after sampling.

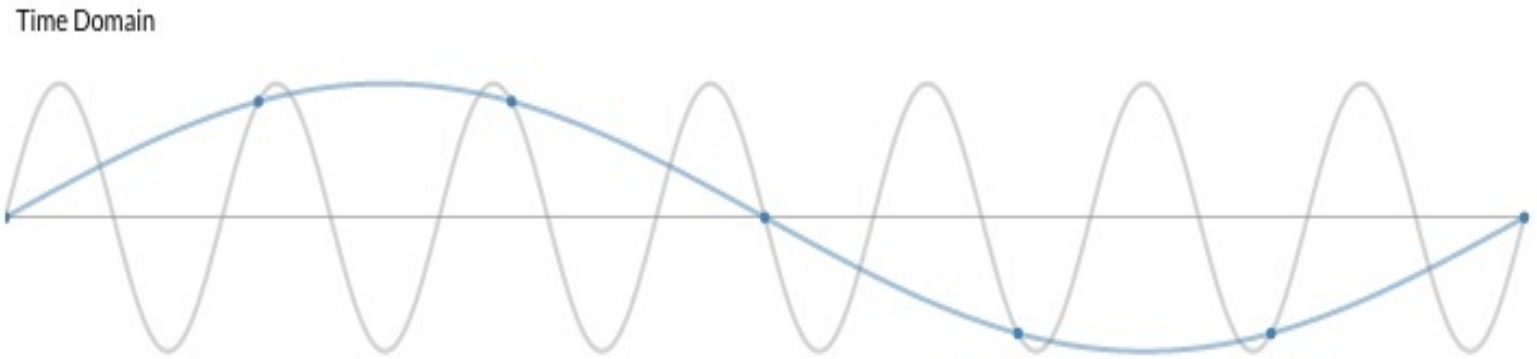
- If we're sampling at a rate of 6 Hz, this tells us that **a sine wave with a frequency of 1 Hz is indistinguishable from sine waves at 7 Hz, 13 Hz, 19 Hz** and so on after sampling.

- So *every* sampled sine wave has an *infinite* number of aliases.

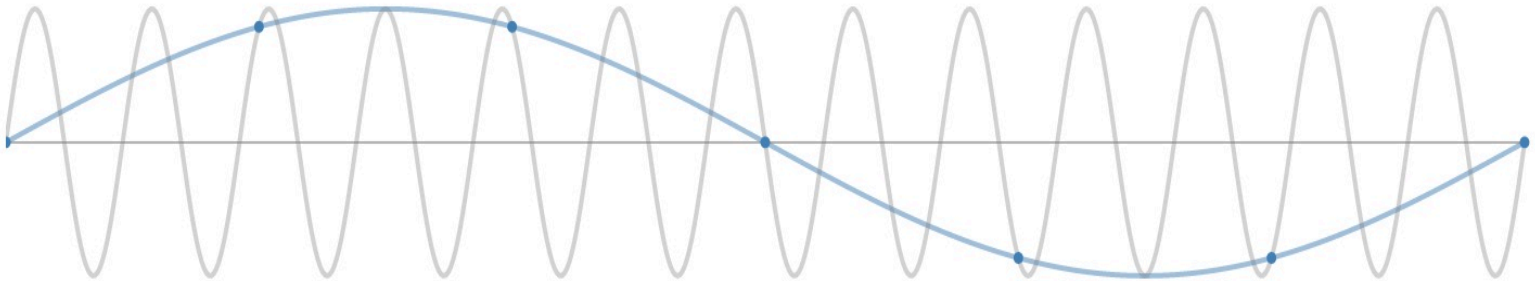
- 1Hz sine wave sampled at 6Hz



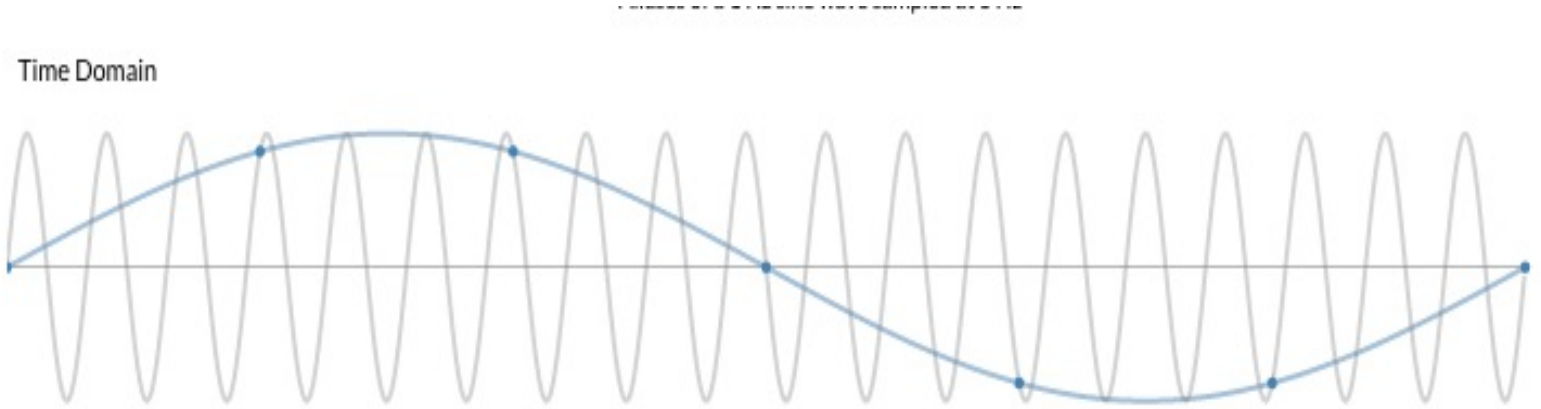
- 7 Hz alias



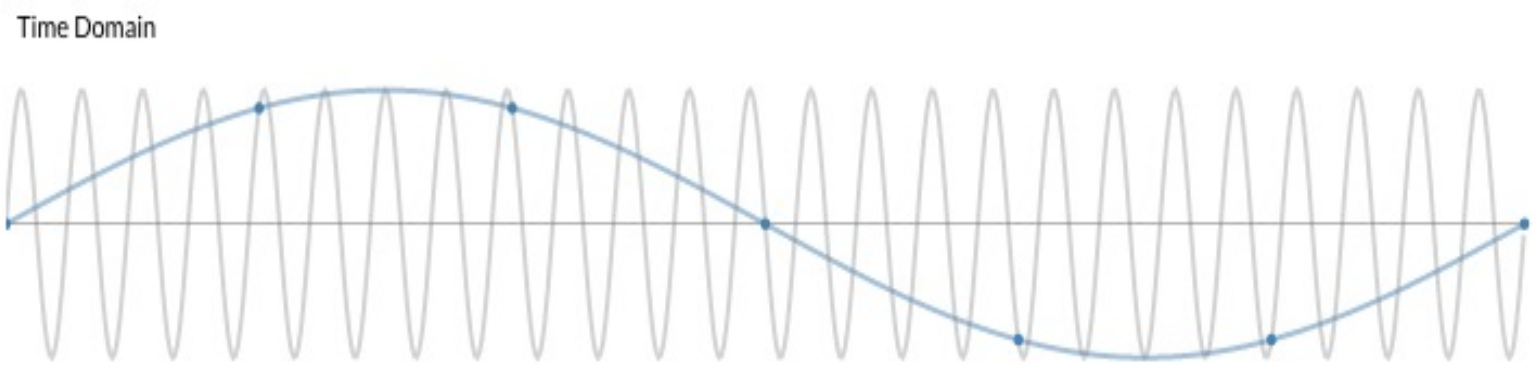
- 13 Hz alias



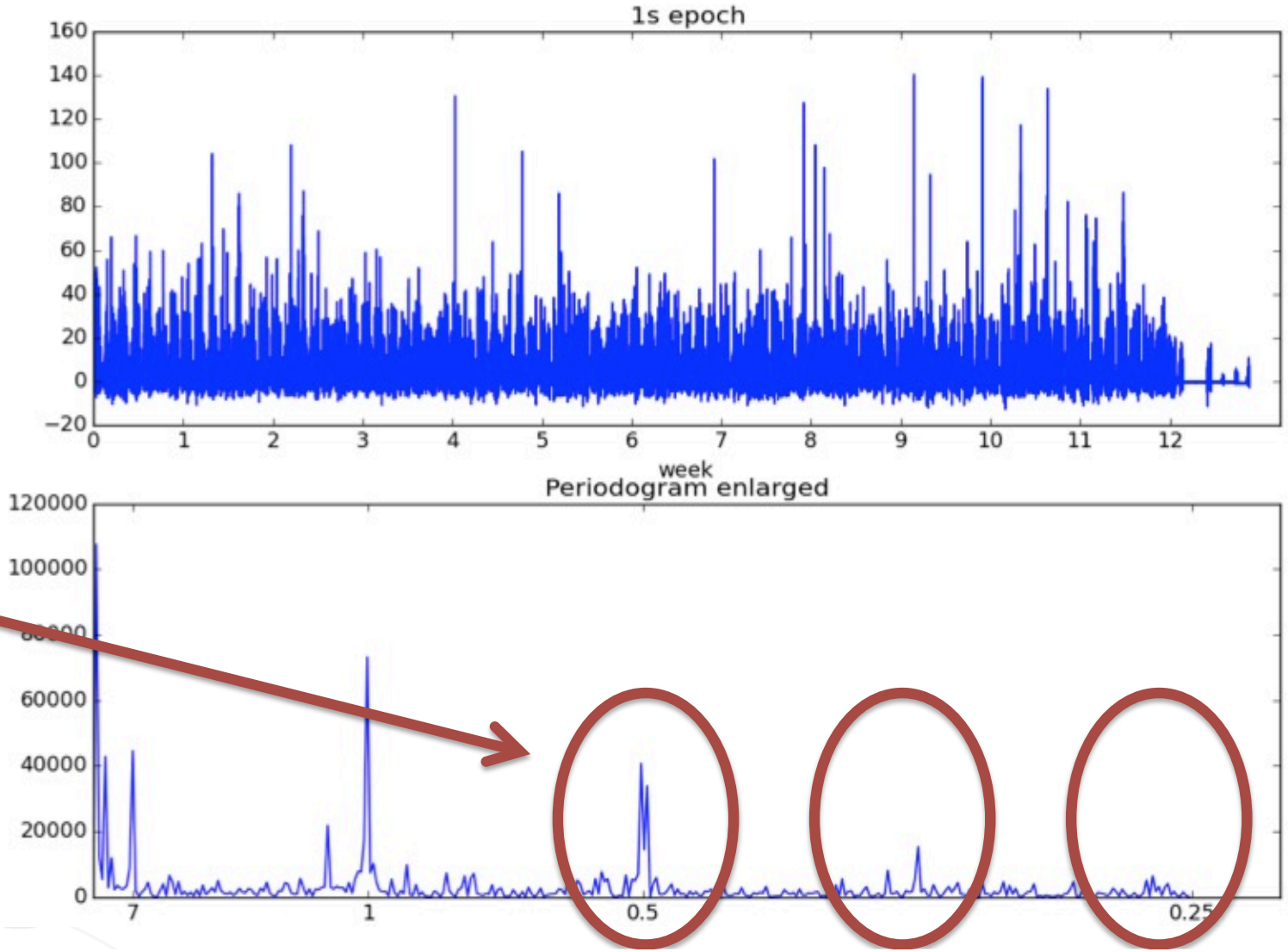
- 19 Hz alias



- 25 Hz alias



So the "alias" phenomenon is why we get these



What about measuring the strength/intensity of periodicity over a time period ?

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Wrist-worn accelerometer data – 20 US Veterans – 12 weeks each – 24x7 – with sleep problems and sleep interventions

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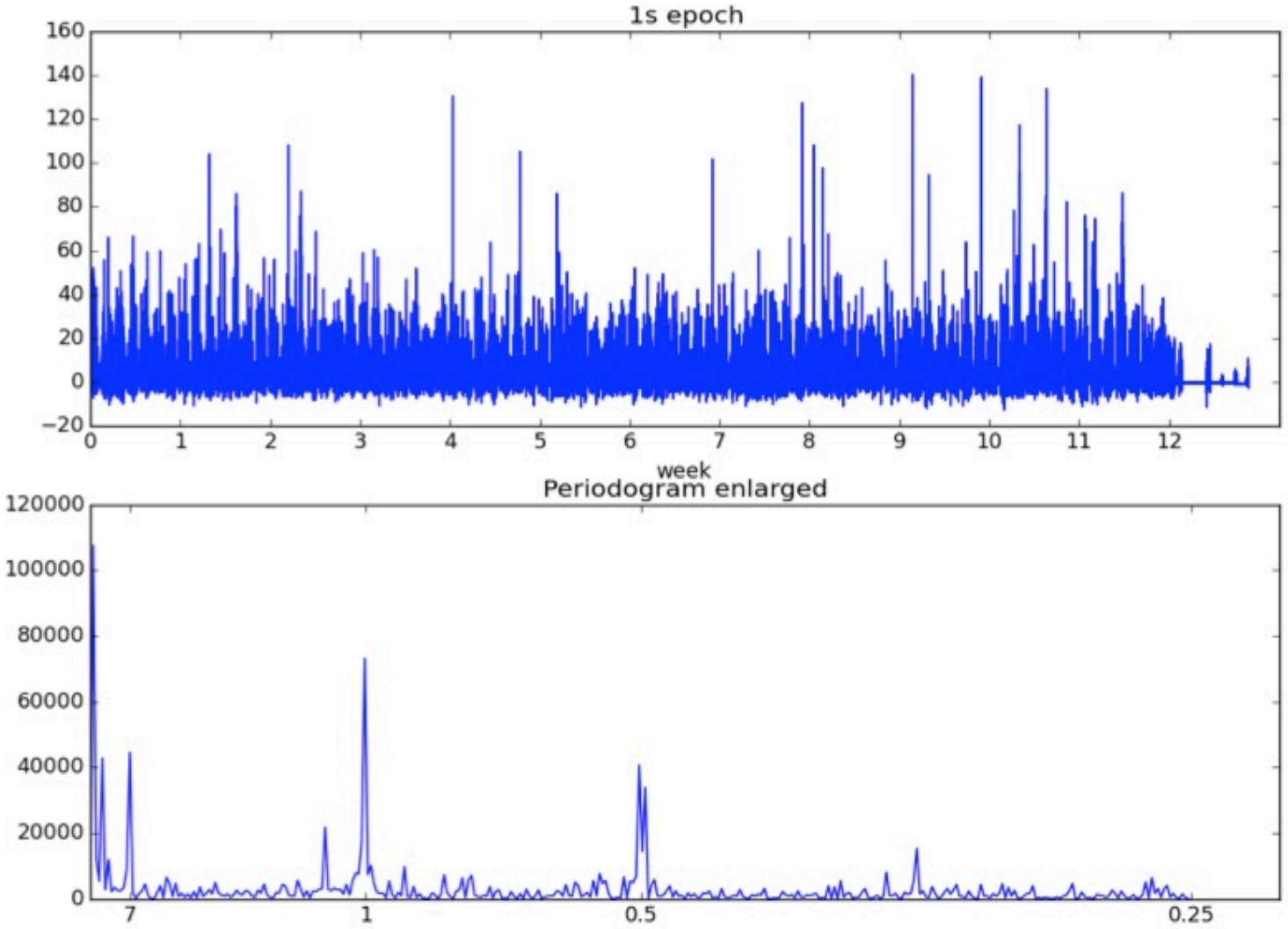

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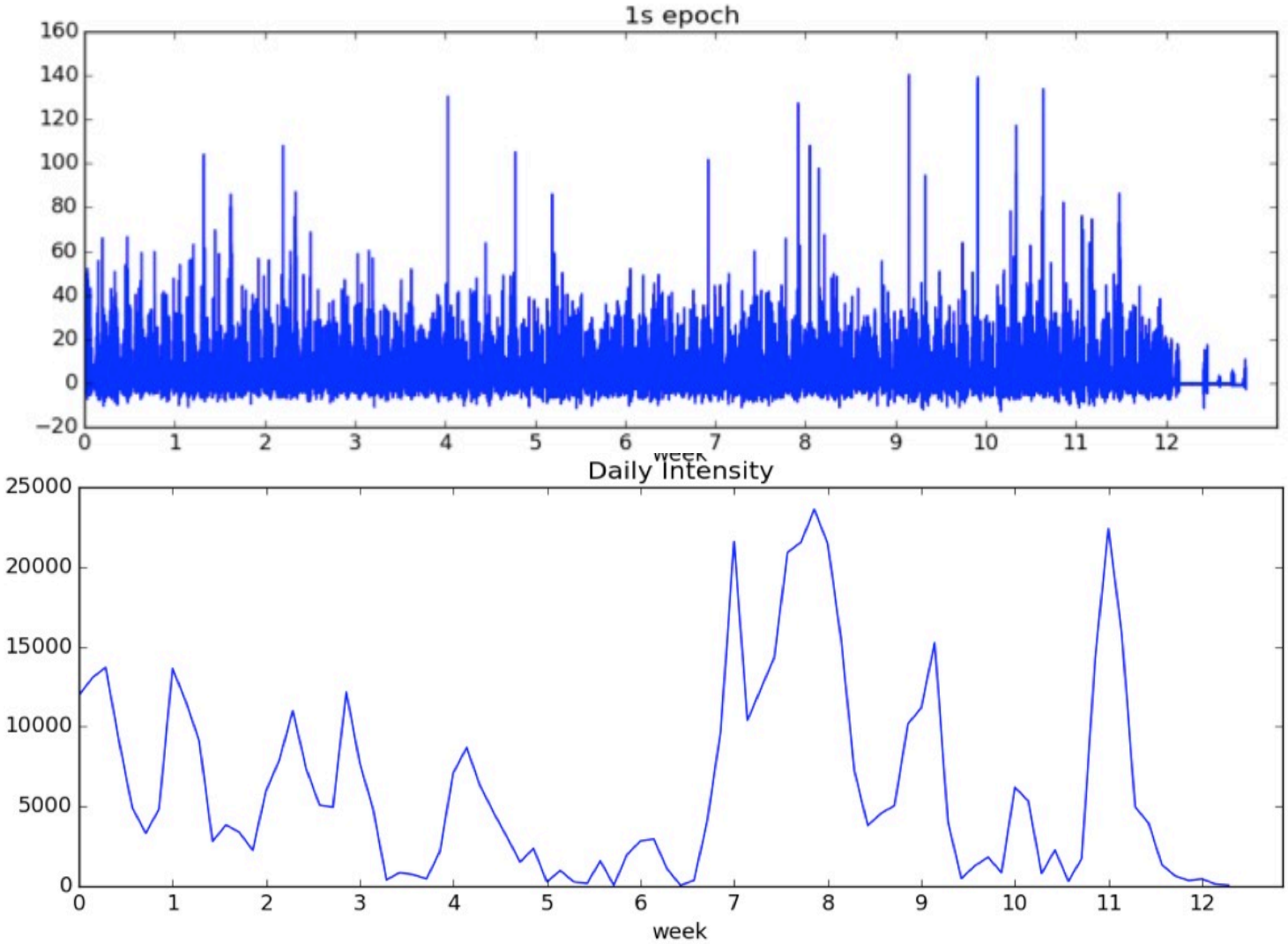
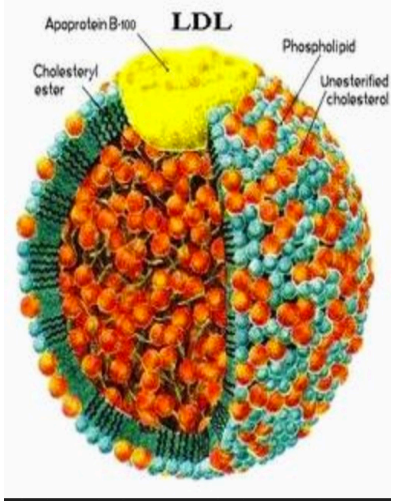


creating a data-driven society

Further Investigation

- US Veterans' data also had regular blood draws
- We discovered a correlation between shifts in periodicity intensity throughout the 13 weeks, and some cardio-metabolic biomarkers which are health-related quality of life indices:
    - LDL cholesterol



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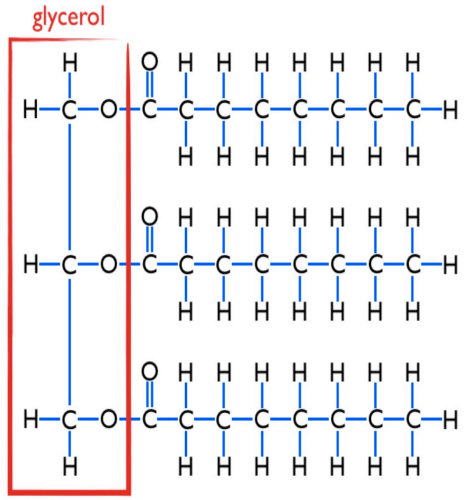

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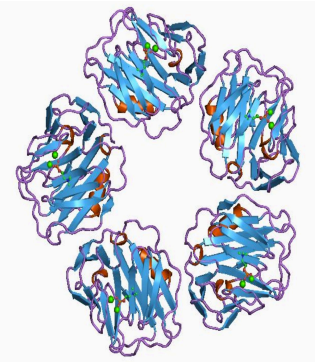
  - hc-CRP (C-Reactive Proteins)
  - Indicators of inflammation, self-protection, raised immune response
  - Inflammation associated with several factors



Further Investigation

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    - LDL cholesterol
    - Triglycerides (body fat level)
    - hc-CRP (C-Reactive Proteins, indicators of inflammation)
- This is a surprising result ... cardio-metabolic health feedback based on data-driven analytics of accelerometer data ?

Current work

Number of participants	100,000
Number of days each	7
Hours in a day	24
Minutes in an hour	60
Seconds in a minute	60
Hz (samples/sec)	100
Number of axes	3
Number of datapoints	**18,144,000,000,000**

biobank uk
Improving the health of future generations

This is data analytics…

- … on personal data
  ... from simple devices
  ... for health and wellness
  ... gaining insights not visible otherwise