# CS 528 Mobile and Ubiquitous Computing
## Lecture 8a: Wearables, Quantified Self & Physiological Sensing

# Emmanuel Agu

# Tracking Health, Wellness & Quantified Self
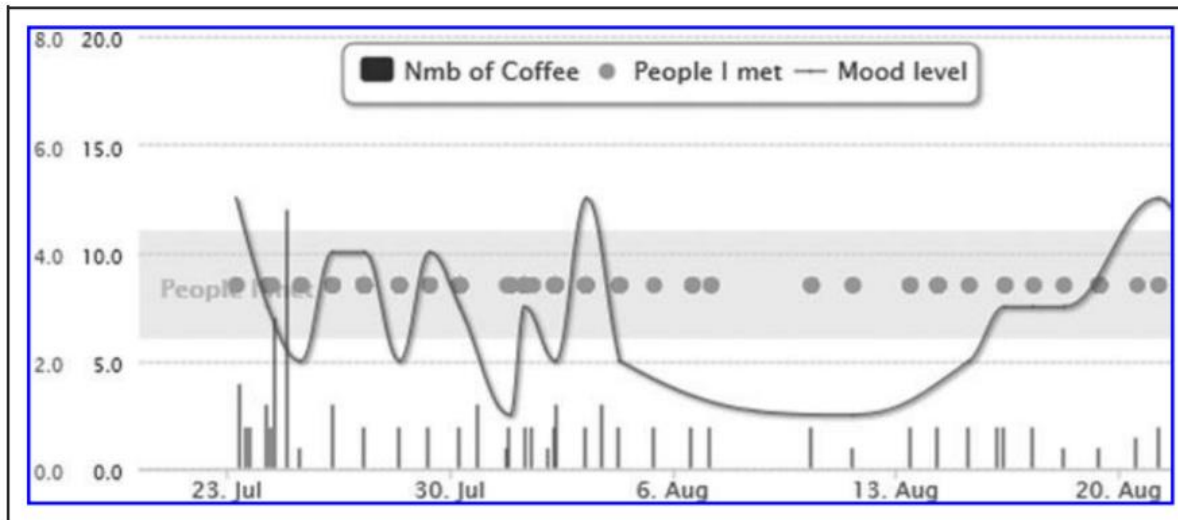
# Quantified Self (QS)

- QS: Community of People who want to measure, log, share metrics about various aspects of their lives. E.g.

- **Defn:** Obtaining self-knowledge through self-tracking

- Also known as personal informatics or lifelogging

  - Sleep, daily step count, food consumed, air quality, mood, etc.

- Measurements typically done using wearables/technology

  - Activity trackers, steps, sleep tracker, calories burned, etc

  - Now more available, cheaper

# QS: Why Track?

- Why track? To figure out causes of certain behaviors, improve health/wellness
  - E.g. Why do I feel tired on Friday afternoons?
- Data to back up your choices/decisions
  - Did that cup of coffee make you more productive?
- Discover new patterns that are fixable
  - Whenever I go to my mother's house, I add at least 5 pounds on Monday morning
  - Am I happier when I meet more people or when I drink more coffee?
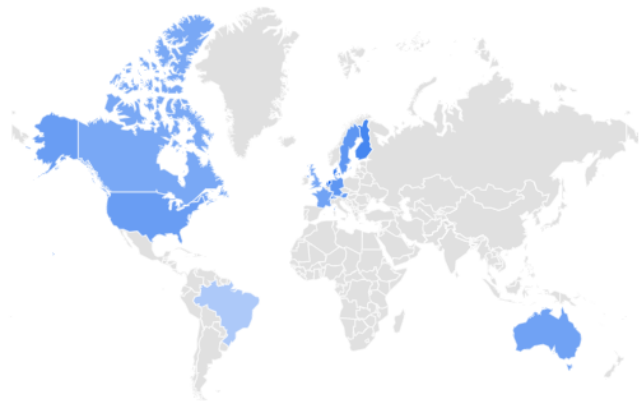


Courtesy
Melanie Swan

# QS: How Popular?

- 69% of US adults already track at least 1 health metric (Pew Research)
- Local meetings, conferences, website
    - quantifiedself.com/

# QS: Google Search Trends

- Google Trends displays how often a term is searched
- "Quantified Self" Searches peaked ~ 2014
- Now more popular in Europe (Netherlands = 1, USA = 8)

Interest over time



| | | |
|---|---|---|
| 6 | Germany | 47 |
| 7 | Austria | 43 |
| 8 | United States | 41 |
| 9 | Australia | 37 |
| 10 | France | 37 |

# QS Wellness Tracking Devices



**Smart fork: eating/calories**



**Sleep manager**



**Bluetooth scale**







**Body worn activity trackers
(steps, activities, calories)**

# Quantified Self Big Picture

## 1. Track

**Physiological**

Eating

Exercise

Sleep

Weight

Blood pressure

Heart rate

Stress

**+ Other Context**

Location

Travel

Calendar

Email

Lab results

## 2. Analyze

**Analytics websites**

Bodytrack.org

**Machine Learning**
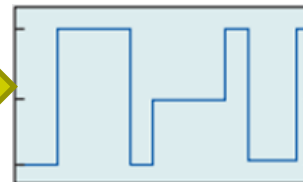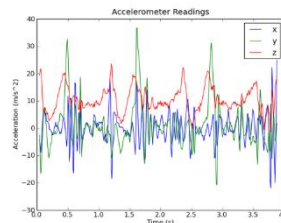


Regression, classification, etc

## 3. Inform

**Mobile App**



**Hire Coach/Dr**

Mymee.com
(data-driven
coaching)

# Bodytrack Project

BodyTrack chest strap:
EKG, respiration, accelerometry; stress, cough/sneeze, snoring

Phone:
Pictures, GPS location, activity; food, events, self-reporting

Actigraphy:
Activity and energy levels

Indoor air quality

BodyTrack Indoor Environmental station:
Temp, humidity, barometric, sound levels, light levels;
Sleep hygiene, air quality (with external sensor), charger and data gateway for chest strap

Quantified Self

20.5 °C

Weight

Sleep logging

Regional air quality:
Particulates, other pollutants, pollen, mold

# FluxStream QS Visualization



Fluxstream Unified QS Dashboard

October 28, 2013
QS Big Data

Source: http://johnfass.wordpress.com/2012/09/06/bodytrackfluxtream/

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# QS: Other Personal Data Sources

- Social media: Facebook, Twitter, Foursquare

- Search engines: Google, Bing

- E-commerce sites: Amazon, Airline sites

- Entertainment/game sites: Netflix

- Email: Outlook, gmail, etc

# The Future: Precision Medicine

- In future combine data from quantified self + medical data + genomics data = Precision medicine



| New "Omics" Data Streams | Traditional Data Streams | Quantified Self Data Streams |
|---|---|---|
| Genome -SNP mutations ✓ -Structural variation -Epigenetics | Personal and Family Health History ✓ | Self-reported data: health, exercise, food, mood journals, etc. ✓ |
| Microbiome ✓ | Prescription History ✓ | |
| Transcriptome | | Mobile Application Data ✓ |
| Metabolome | Lab Tests: History and Current ✓ | |
| Proteome | Demographic Data ✓ | Quantified Self Device Data ✓ |
| Diseasome ✓ | | |
| Environmentome ✓ | Standardized Instrument Response ✓ | Biosensor Data Objective Metrics |

Legend: Consumer-available ✓

# Smartwatches + Wearables

# Main Types of Wearables

- **Activity/Fitness Trackers:**
  - physiological sensing (activity, step count, sleep duration and quality, heart rate, heart rate variability, blood pressure, etc)
  - E.g. Fitbit Charge 2
- **Smartwatches**
  - Some activity/fitness tracking
  - Also programmable: notifications, receive calls, interact/control smartphone
  - E.g. Apple watch, Samsung Gear
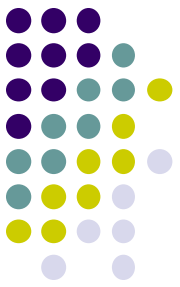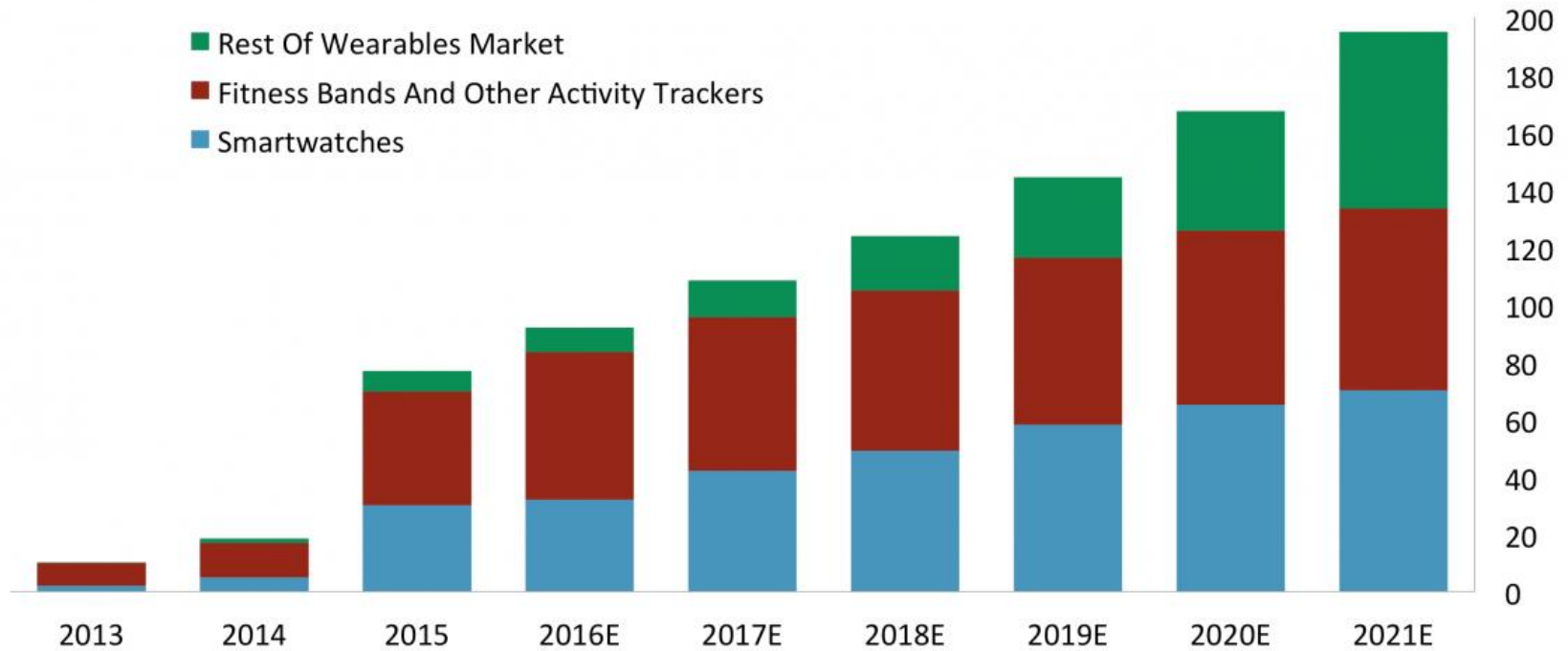
Fitbit Charge 2

Apple Watch

Samsung Gear 2 SmartWatch

# How Popular are Smartwatches/Wearables?

## Global Wearables Shipment Forecast, By Device
*Millions*



Legend:
- Rest Of Wearables Market
- Fitness Bands And Other Activity Trackers
- Smartwatches

Years: 2013, 2014, 2015, 2016E, 2017E, 2018E, 2019E, 2020E, 2021E
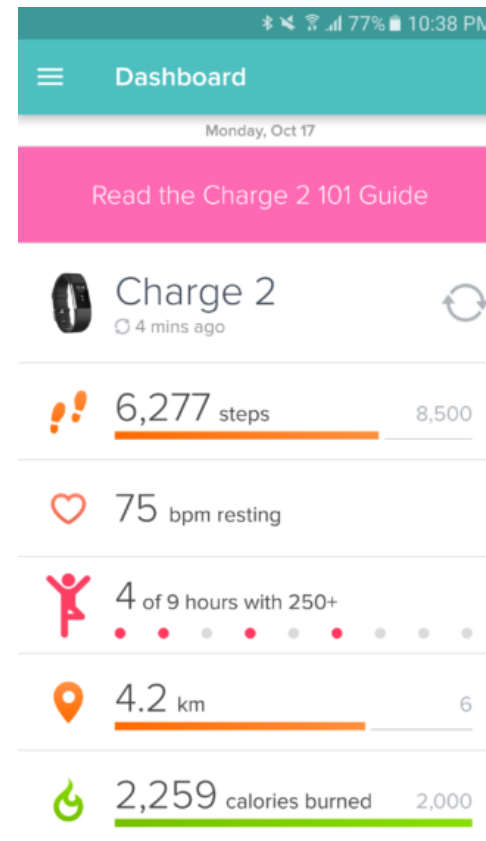
Source: IDC, BI Intelligence estimates

BI INTELLIGENCE

# Wearables Example: Fitbit Charge 2



Fitbit Charge 2

synchronize

Smartphone companion app
(displays all variables tracked)

# Example: Samsung Gear SmartWatch Uses



Image credits: Samsung
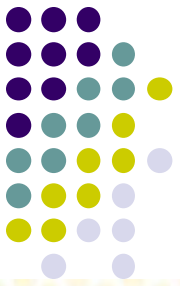
# SmartPhone Vs Smartwatch

- Smartphone:
    - More processing power, memory, sensors
    - More programming APIs

- Smartphone Cons:
    - Sometimes not carried (Left on table, in pocket, bag, briefcase, gym locker)
        - Smartphone within arms reach, on person ~50% of the time (Anind Dey *et al*, Ubicomp 2011)
    - Why? Sometimes inconvenient, impossible (e.g when swimming)
    - Consequence: Missed activity (steps, activity, etc), incomplete activity picture

- Smartwatch:
    - Lower processing power, memory, sensors, but
    - Always carried/worn
    - Can sense physiological variables continuously, or require contact (e.g. skin temperature)

# Programming Android Wearables

- Programmable using Android Wear (latest version is 2.0)
- Supported by Android Studio
- Needs to be connected to a smartphone (via Bluetooth)
- Architecture:
  - **Node API:** tracks all connected/disconnected nodes (E.g. wearables, smartwatches)
  - **Message API:** Used to send messages between wearable and smartphone
  - **Data API:** Used to synch data between app and smartwatch
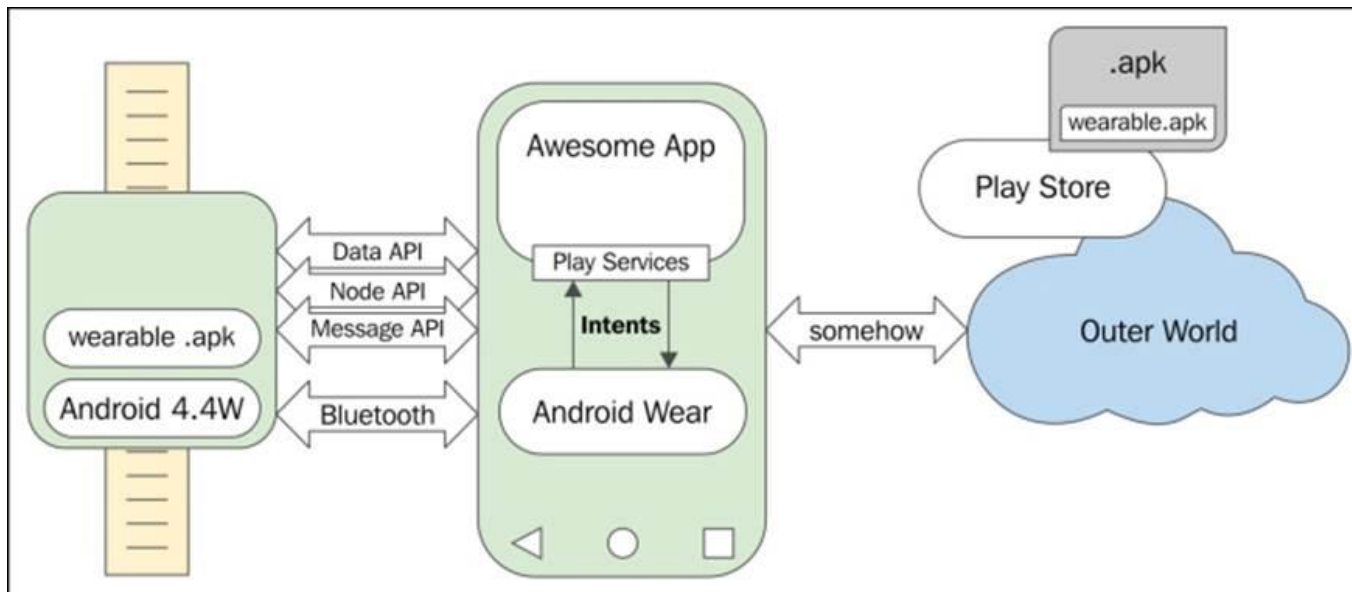


A bit outdated, but nice overview for Android Wear for kitkat Android 4.4W

# Android Wear Evolution

https://en.wikipedia.org/wiki/Android_Wear



| Android Wear Version | Android Smartphone Version | Release Date | Major New Features |
|---|---|---|---|
| 4.4W1 | 4.4 | June 2014 | Initial release at Google I/O 2014 |
| 4.4W2 | 4.4 | Oct 2014 | GPS support, music playback |
| 1.0 | 5.0.1 | Dec 2014 | Watch face API ( face design) Sunlight & theater modes, battery stats |
| 1.1 | 5.1.1 | May 2015 | WiFi, Drawable Emojis, Pattern Lock, swipe left, wrist gestures |
| 1.3 | 5.1.1 | Aug 2015 | Interactive Watch Face, Google Translate |
| 1.4 | 6.0.1 | Feb 2016 | Speaker support, send voice messages |
| 1.5 | 6.0.1 | June 2016 | Restart watch, Android security patch |
| 2.0 | 7.1.1 | Feb 2017 | UI (material design, circular faces), watch keyboard, handwriting recognition, cell supp. |

**Evolved into Google Wear OS in June 2018!!**

# Physiological Sensing

# Wearables for Physiological Sensing

- Some wearables measure more physiological signals
  - Cardiac rhythms (heartbeat), breathing, sweating, brain waves, gestures, muscular contractions, eye movements, etc

- Basis Health tracker: heart rate, skin temperature, sleep

- Microsoft Band 2: Heart rate, UltraViolet radiation, Skin conductance
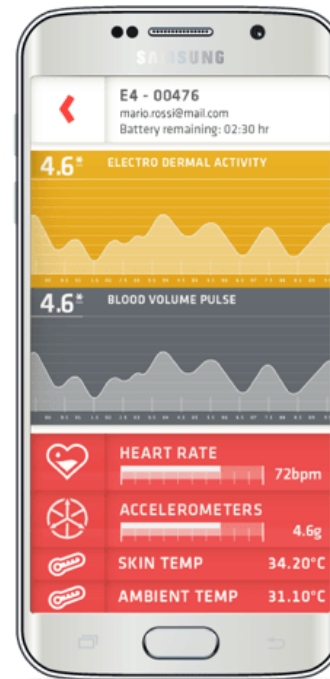


Basis Health tracker
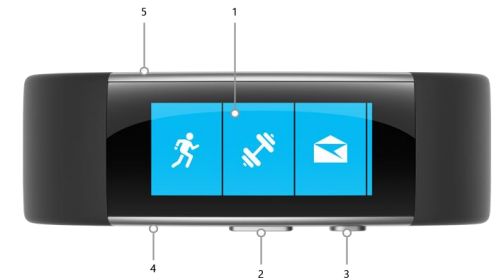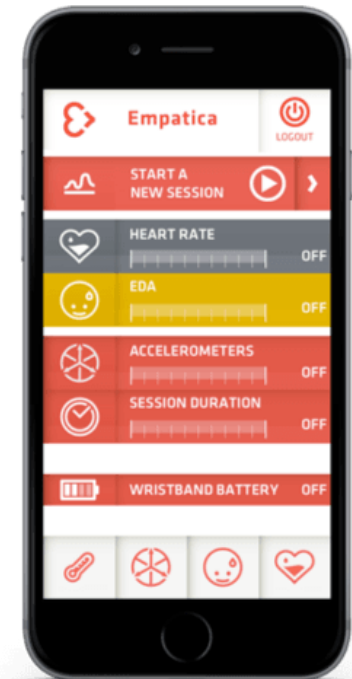
Microsoft Band 2

# Empatica E4 WristBand

- Wristband measures physiological signals real time (PPG, EDA, accelerometer, infra-red temperature reader)



**E4 wristband**

**Companion app**

# Myo Armband

- Measures muscle contraction (electromyography or EMG), to detect gestures
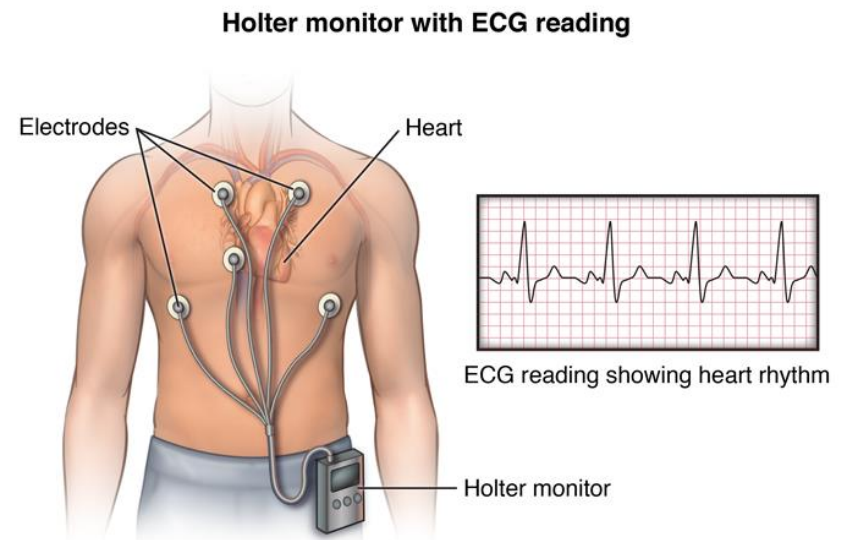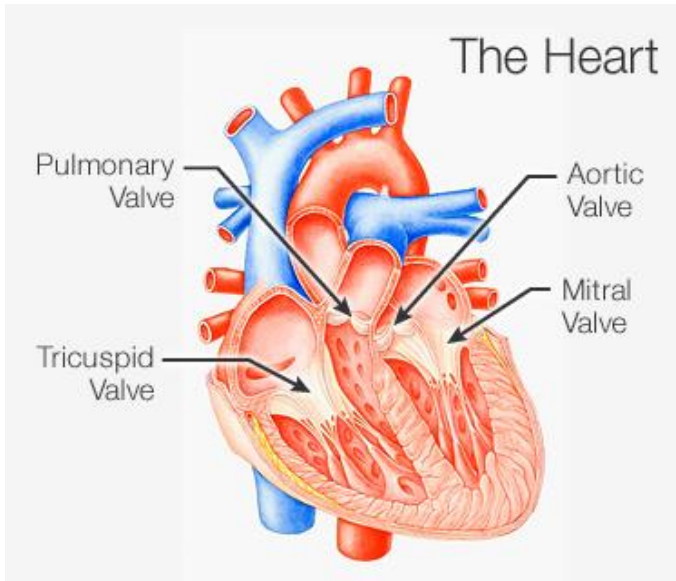- EMG measures electrical activity, used to assess health of muscles
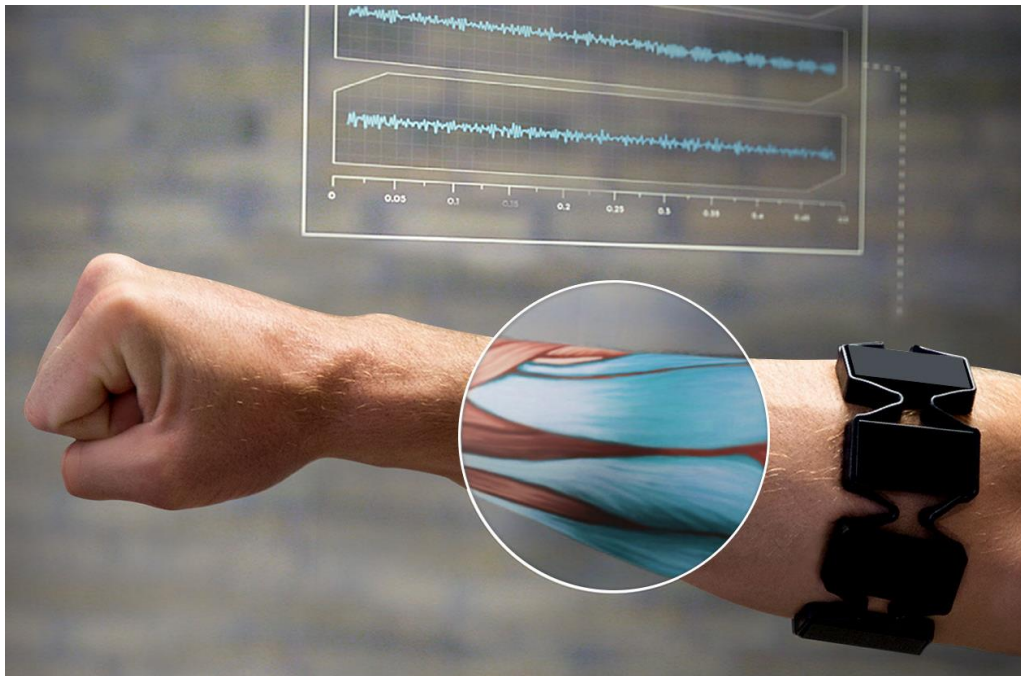
# Electrocardiogram (ECG)

- ECG (or EKG): recording of electrical activity of the heart
- Each heartbeat causes electrical signal to spread from top to bottom of heart
- Electric Signal
  - is rhythmic, causes heart to contract and pump blood
  - Can be measured electric activity between 2 electrodes placed on chest

The Heart

Pulmonary Valve

Aortic Valve

Mitral Valve

Tricuspid Valve

Holter monitor with ECG reading

Electrodes

Heart

ECG reading showing heart rhythm
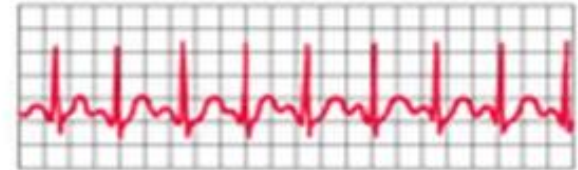
Holter monitor

# Electrocardiogram (ECG)

- ECG shows:
  - How fast the heart is beating
  - Rhythm of heartbeat (steady vs irregular)
  - Strength and timing of electrical signals

- **Arryhthmia:** fast or irregular heartbeat, can cause stroke or heart failure
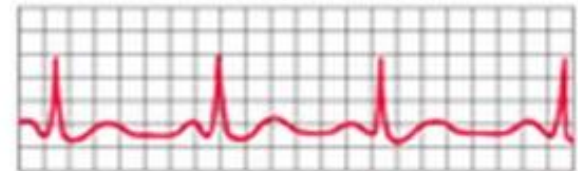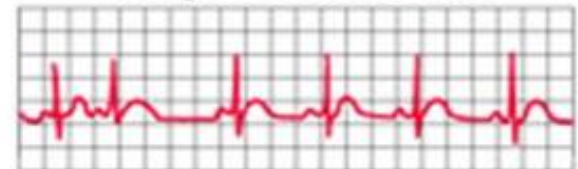
**Normal Heartbeat**
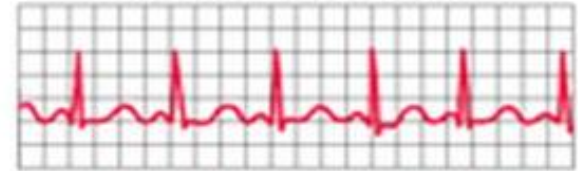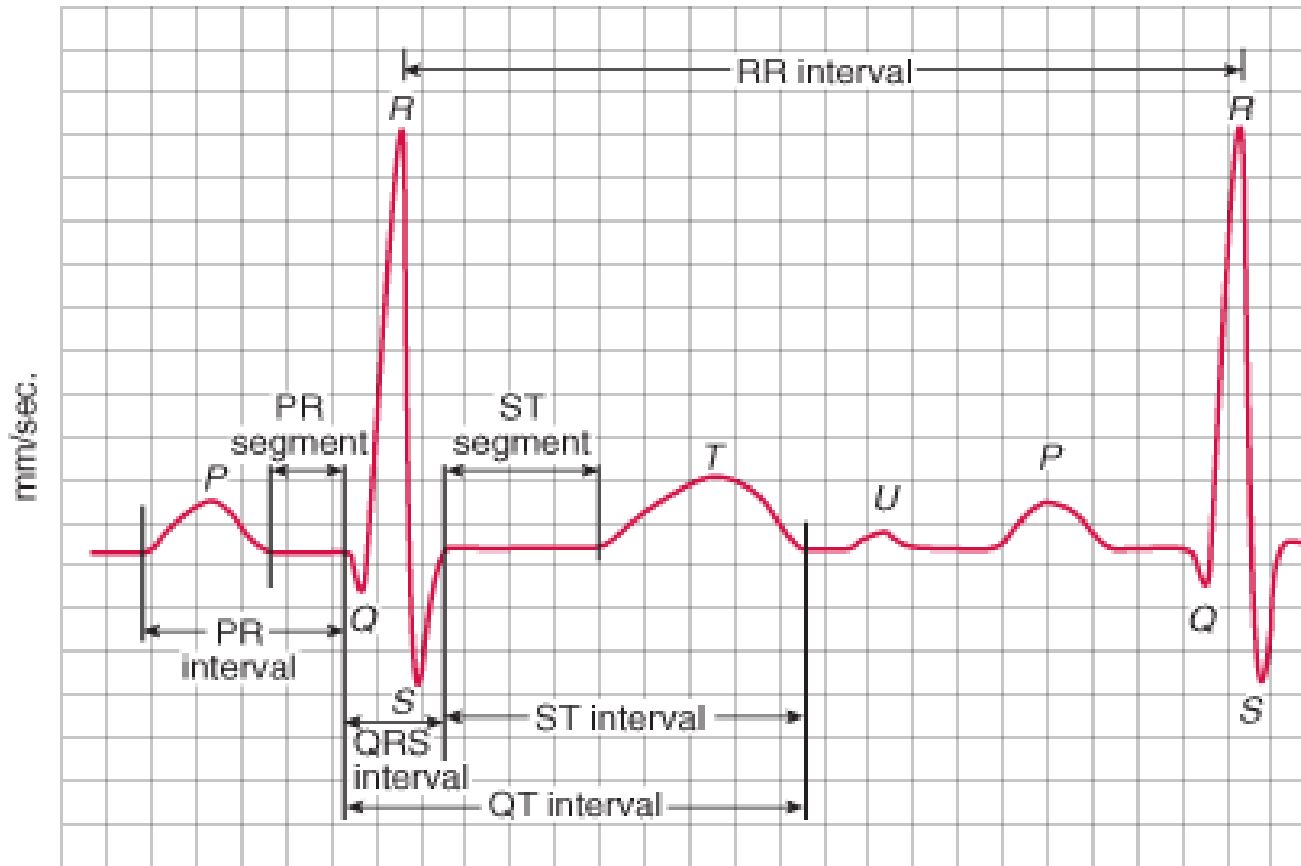


**Fast Heartbeat**



**Slow Heartbeat**



**Irregular Heartbeat**

# Electrocardiogram (ECG)

- ECG waveform comprises sequence of peaks and trough (P,Q,R,S,T), which repeats
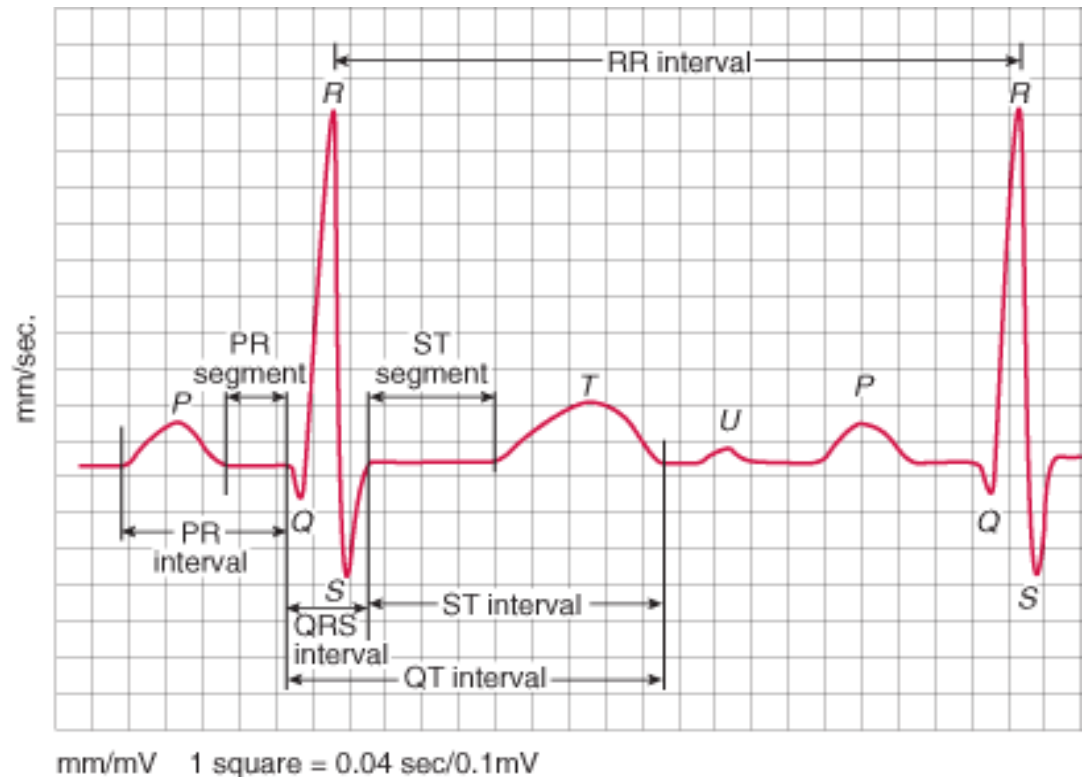  - Occasionally a U wave after T



mm/mV    1 square = 0.04 sec/0.1mV

# ECG Features for Classification

- From a waveform with at least 5 peaks, can extract as features for classification, the following timing intervals

    - RR interval

    - PR interval

    - QRS interval

    - QT interval, etc

- Heartrate is number
  of RR intervals/min

  = 60 / RR

- Note: RR is in seconds

# Trends: Mobile ECG

- E.g. AliveCor kardia ECG
  - Hold 2 fingers on metal plates (ECG recorder) for at least 30 seconds

# Photoplethysmography (PPG)

- **PPG:** Non-invasive technique for measuring blood volumes in blood vessels close to skin

- Now popular non-invasive method of extracting physiological measurements e.g. heart rate or oxygen saturation

- Traditional device for PPG is pulse oximeter
  - Measures concentration of oxygen in the blood
  - Low oxygen levels (< 80%) can compromise organs, lead to heart attack , etc
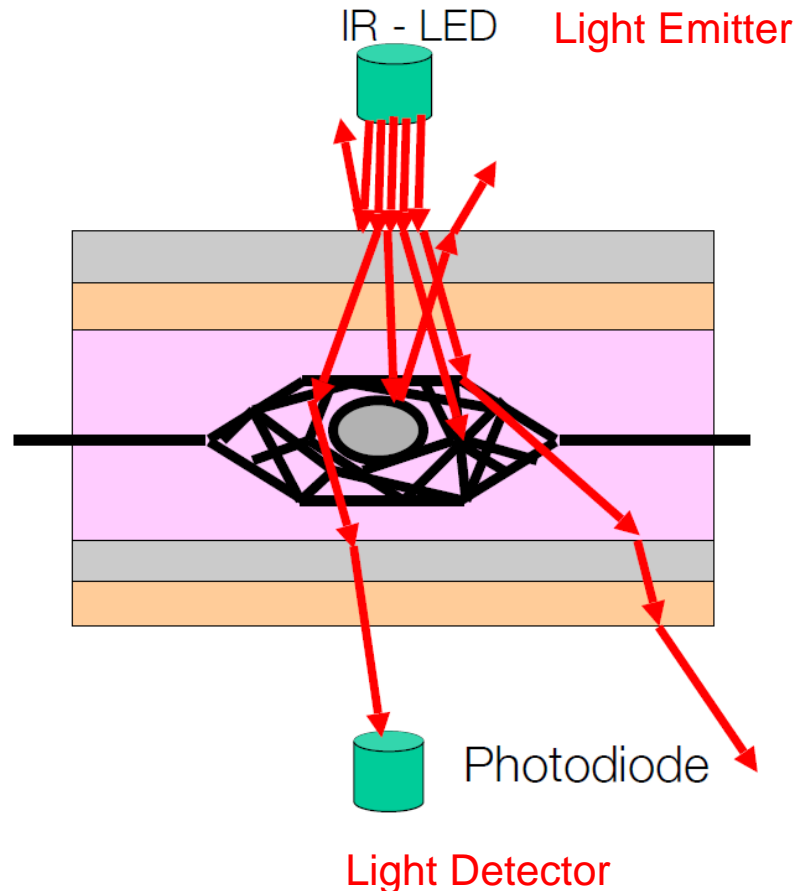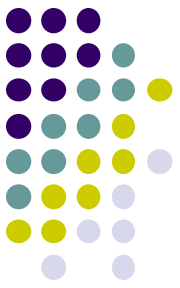


**Pulse Oximeter**

# Pulse Oximeter PPG

- Amount of oxygen in the blood determines how much infared light absorbed, scattered, passes through (from LED to photodiode)



IR - LED    Light Emitter

Photodiode

Light Detector

# Smartphone/Smartwatch PPG: Estimating HR

- **Principle:**
  - Blood absorbs green light
  - LED shines green light unto skin (back of wrist)
  - Blood pumping changes blood flow and hence absorption rhythmically
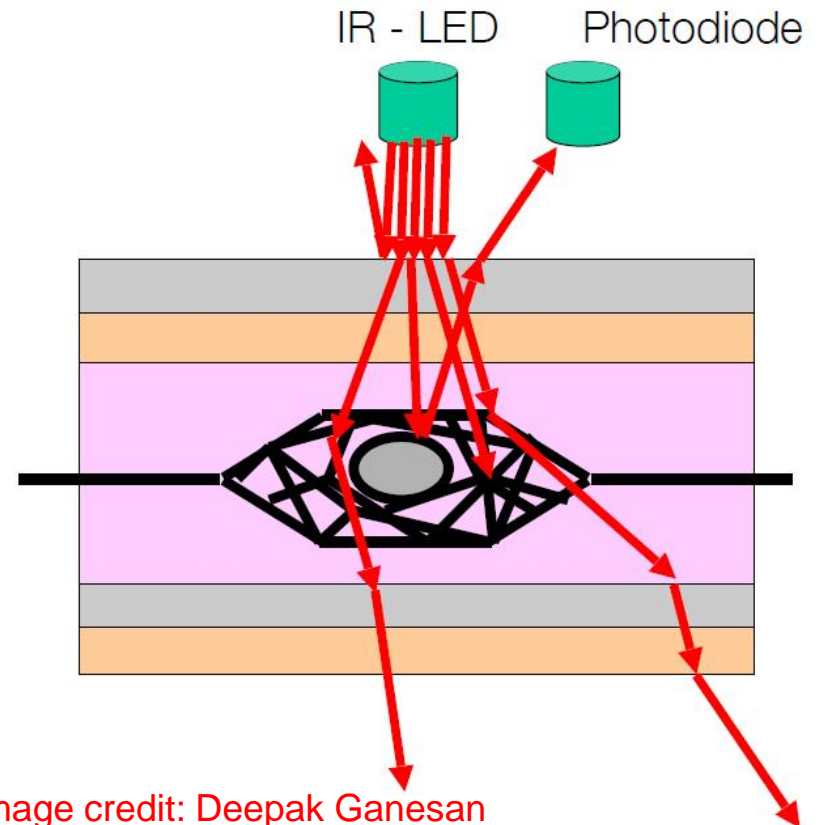  - Photodiode measures rhythmic changes in green light absorption => HR
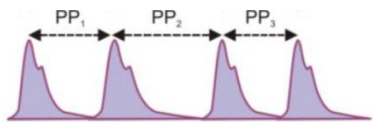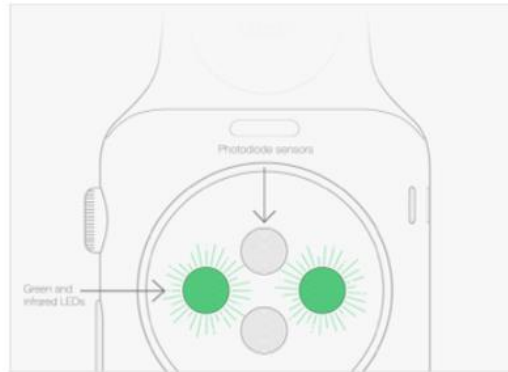
Image credit: Deepak Ganesan

# Smartphone PPG: Heart Rate Detection

- Like smartwatch, use camera flash (emitter), camera as detector

- Place finger over smartphone's camera, shine light unto finger tip

- Heart pumps blood in and out of blood vessels on finger tip
    - Changes how much light is absorbed  (especially green channel in RGB)
    - Causes rhythmic changes of reflected light

- **Ref:** Scully CG, Lee J et al."Physiological parameter monitoring from optical recordings with a mobile phone", IEEE Trans Biomed Eng, 2012 Feb;59(2):303-6
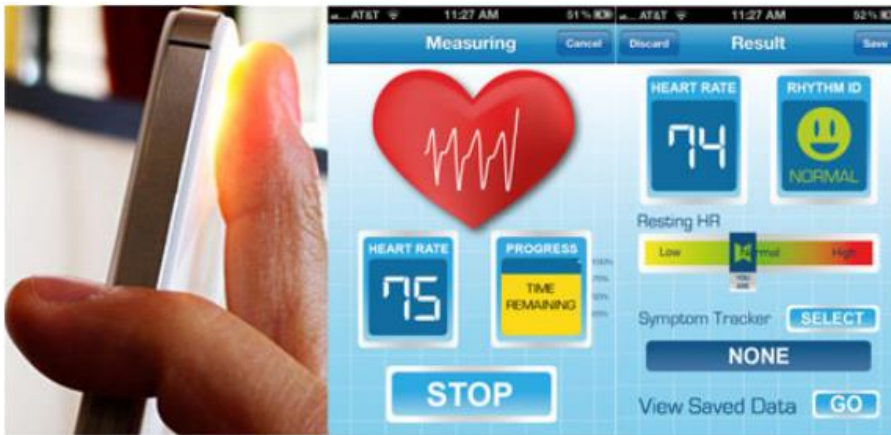
# Smartphone PPG: Heart Rate Detection

- **Idea:**
  - Color expressed as (R G B)
  - Track intensity of Green channel of Camera response
  - Use peak finding algorithm (similar to step counter)
  - Time between peak is 1 cycle
  - Heart rate = cycles per minute = 60 / time for 1 cycles
- Can also extract breathing rate, heart rate variability

# PPG: Final Words

- PPG (or similar ideas) have been attempted:
  - on other body parts (ear lobes, face)
  - from video frames (detect, magnify small changes in facial color 100x)
  - Using other ubiquitous devices (e.g. Medical Mirror, Poh *et al*)



H.Y Wu, M. Rubinstein, E. Shih, J. Guttag, F. Durand,
W.T. Freeman, Eulerian Video Magnification for Revealing Subtle
Changes in the World. SIGGRAPH 2012
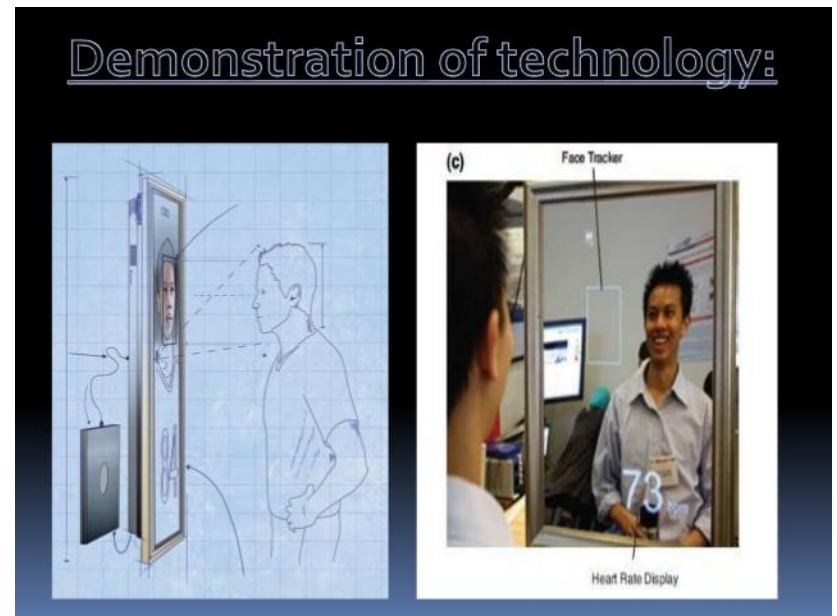


MZ **Poh**, D McDuff, R Picard A medical **mirror** for non-contact
health monitoring, ACM SIGGRAPH 2011 Emergin

# Electrodermal Activity (EDA)

- When people experience emotional arousal (e.g. danger), stress, cognitive load or physical exertion => increased sweating

- Increased sweating changes electrical conductance of skin

- Sometimes called Galvanic Skin Response (GSR)

- This response cannot be controlled by person
  - Hence, widely used in emotion/lie detection

# EDA Features

- Features useful for classifying measured human EDA response
  - **Latency:** time between stimulus and response
  - **Rise time:** time for skin conductance to peak
  - **Amplitude:** Height of conductance signal
  - **Half recovery time:** Time for conductance signal to lose half of its peak value
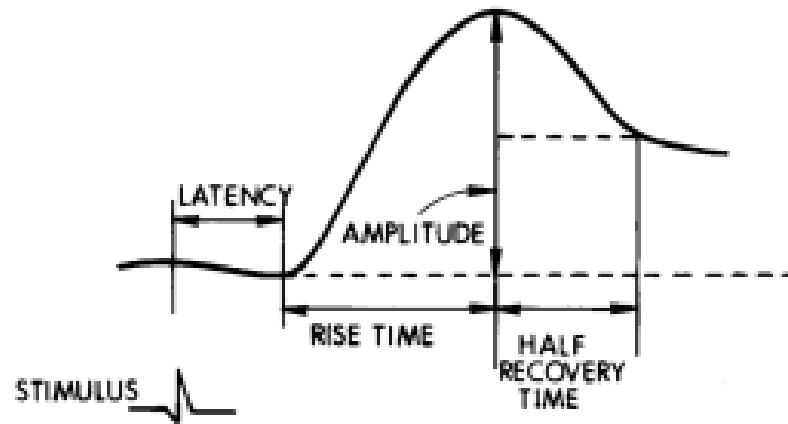
Figure 5. Graphical representation of principal EDA components.

# References

- Deepak Ganesan, Behavioral Health Sensing, Course Notes Fall 2015
- Melania Swan, The Quantified Self: Fundamental Disruption in Big Data Science and Biological Discovery,
- BBC, Quantified Self – The Tech-based Route to Better Life
- NY Times, The Data-Driven Life
- The Ultimate Guide to The Quantified Self
  http://www.slideshare.net/ramykhuffash/the-ultimate-quide-to-the-quantified-self