Selected Topics Communications and Mobile Computing (Smart Health)

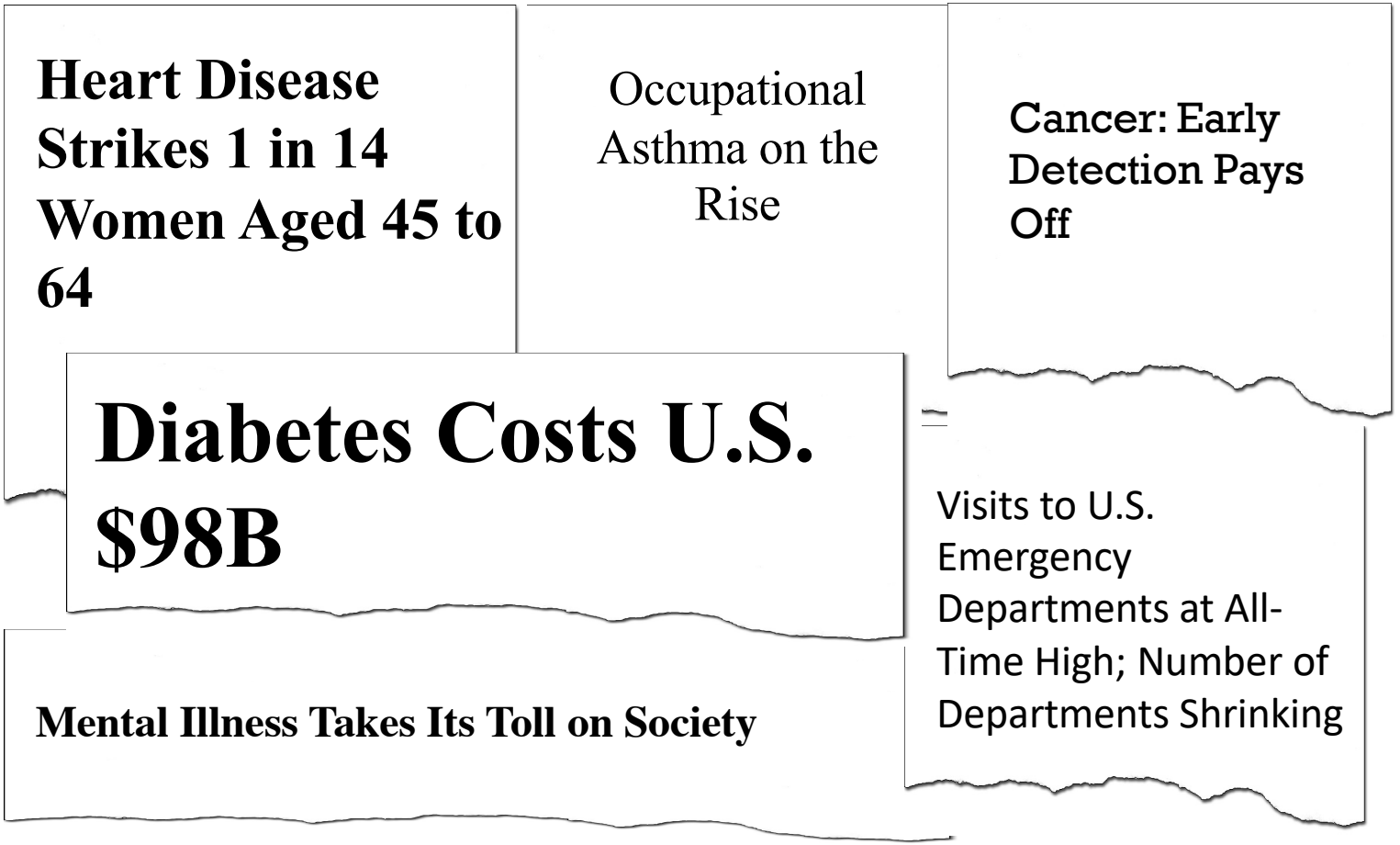
TU Graz

University of Notre Dame

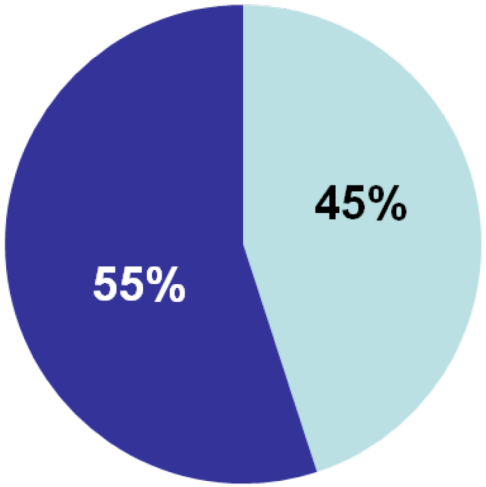
What is a Chronic Disease?

- Chronic diseases are **long-lasting** illnesses such as heart disease, diabetes, asthma, and depression
- Term “chronic” often applied when disease lasts for more than three months
- Most can be prevented with good nutrition, exercising, not smoking, …

Chronic Diseases



Chronic Diseases



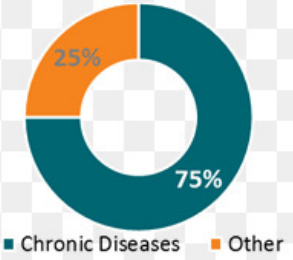
Nearly **half** of all Americans suffer from at least one chronic condition…

…**75 cents** of each dollar spent on health care goes to treat patients with chronic disease

$1.7 trillion

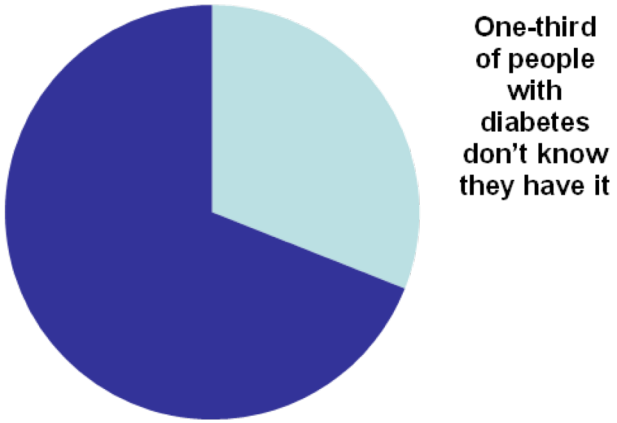
The growing chronic disease burden already represents a **significant portion of healthcare expenditures** in Europe

75% of Europe's healthcare bill is spent on chronic diseases, amounting to **€700 billion annually**[3]

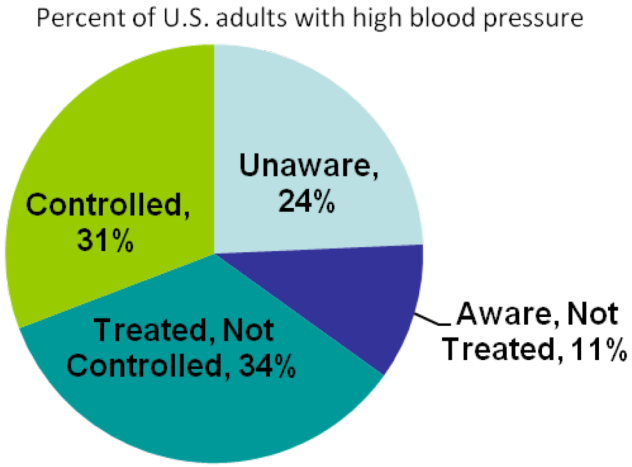


Chronic Diseases

Many chronic conditions go undiagnosed

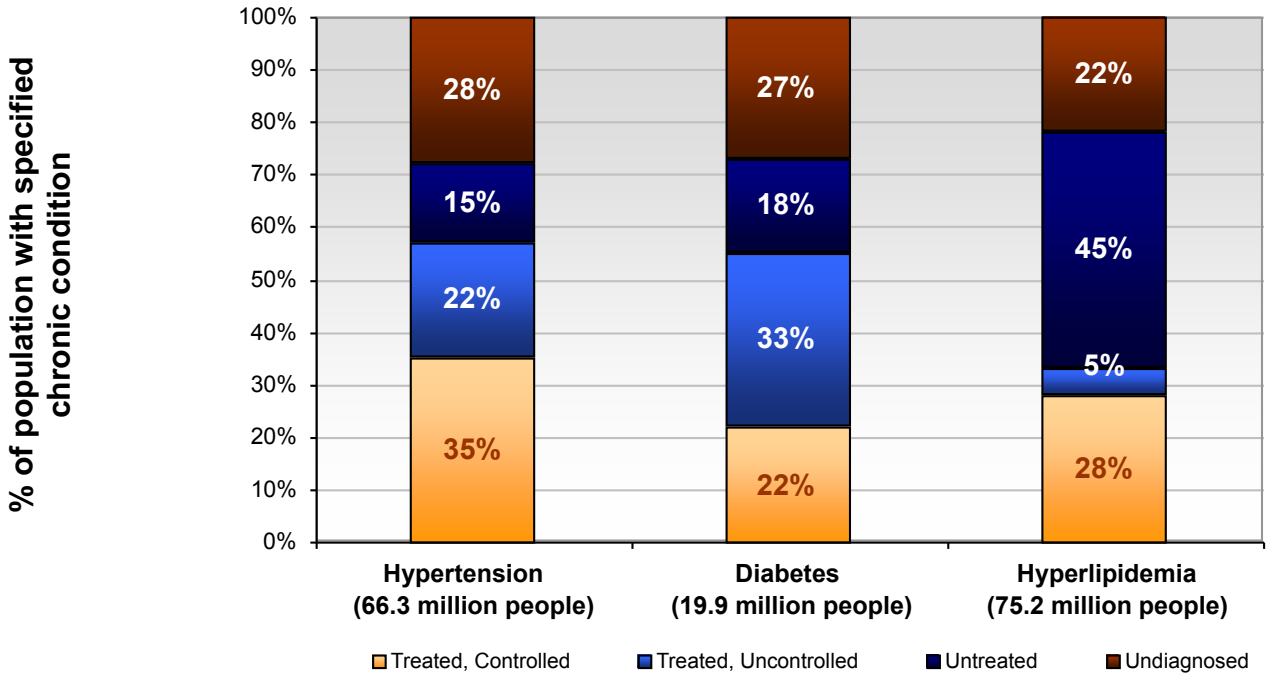


Others are diagnosed, but not well controlled



Chronic Diseases

Millions of American adults remain undiagnosed or untreated, or their chronic conditions are not effectively controlled

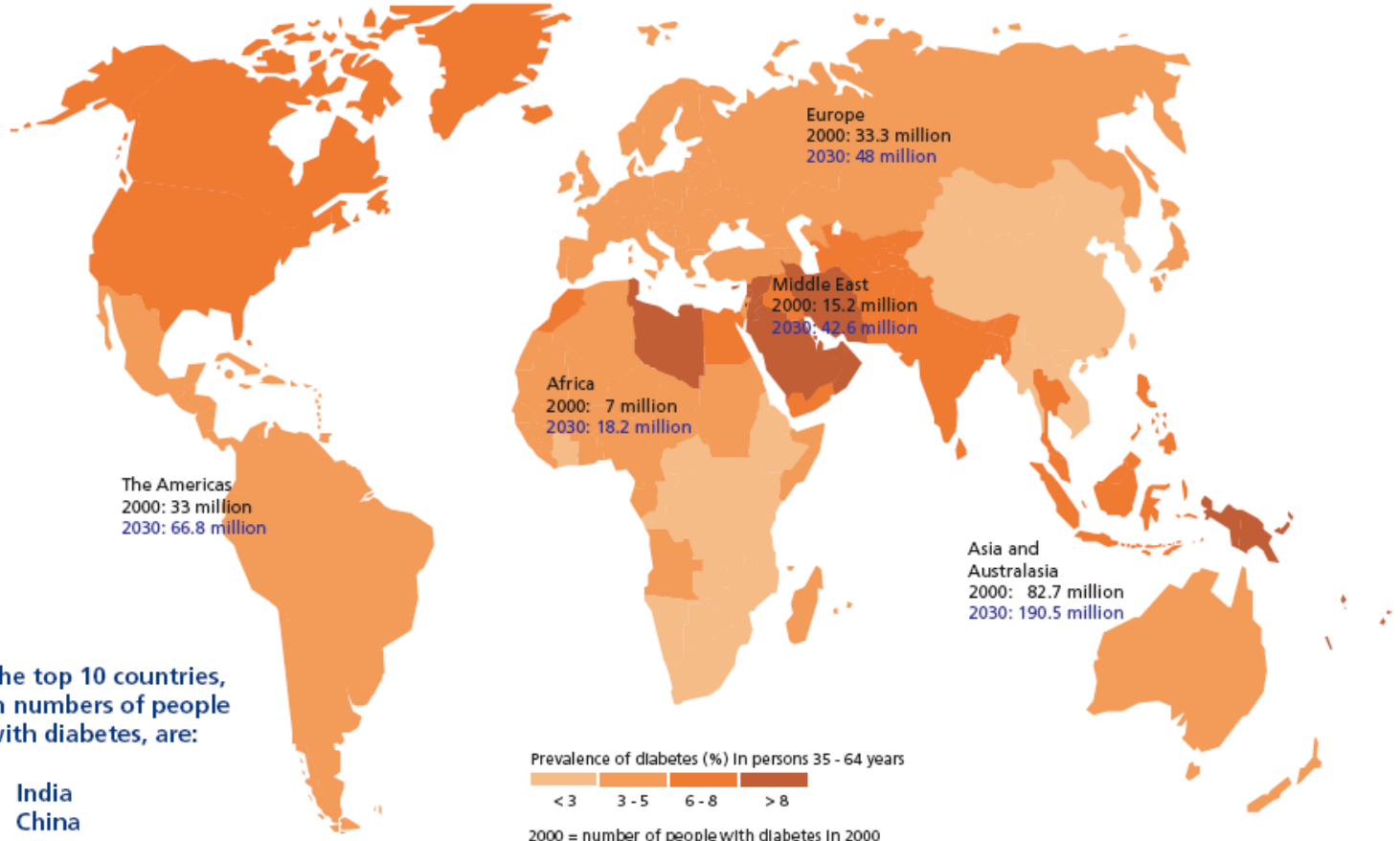


Chronic Diseases

- 1900 – 1950: Infectious Diseases
- 1950 – 2000: Episodic Care
- 2000 – 2050: Chronic Care

- Need for chronic care will continue to increase:
  - Formerly lethal diseases, conditions, and injuries are now chronic conditions (success of healthcare)
  - Reduction of premature mortality and increase of longevity
  - Increase in unhealthy behaviors (nutrition, physical activity, etc.)

Prevalence of diabetes

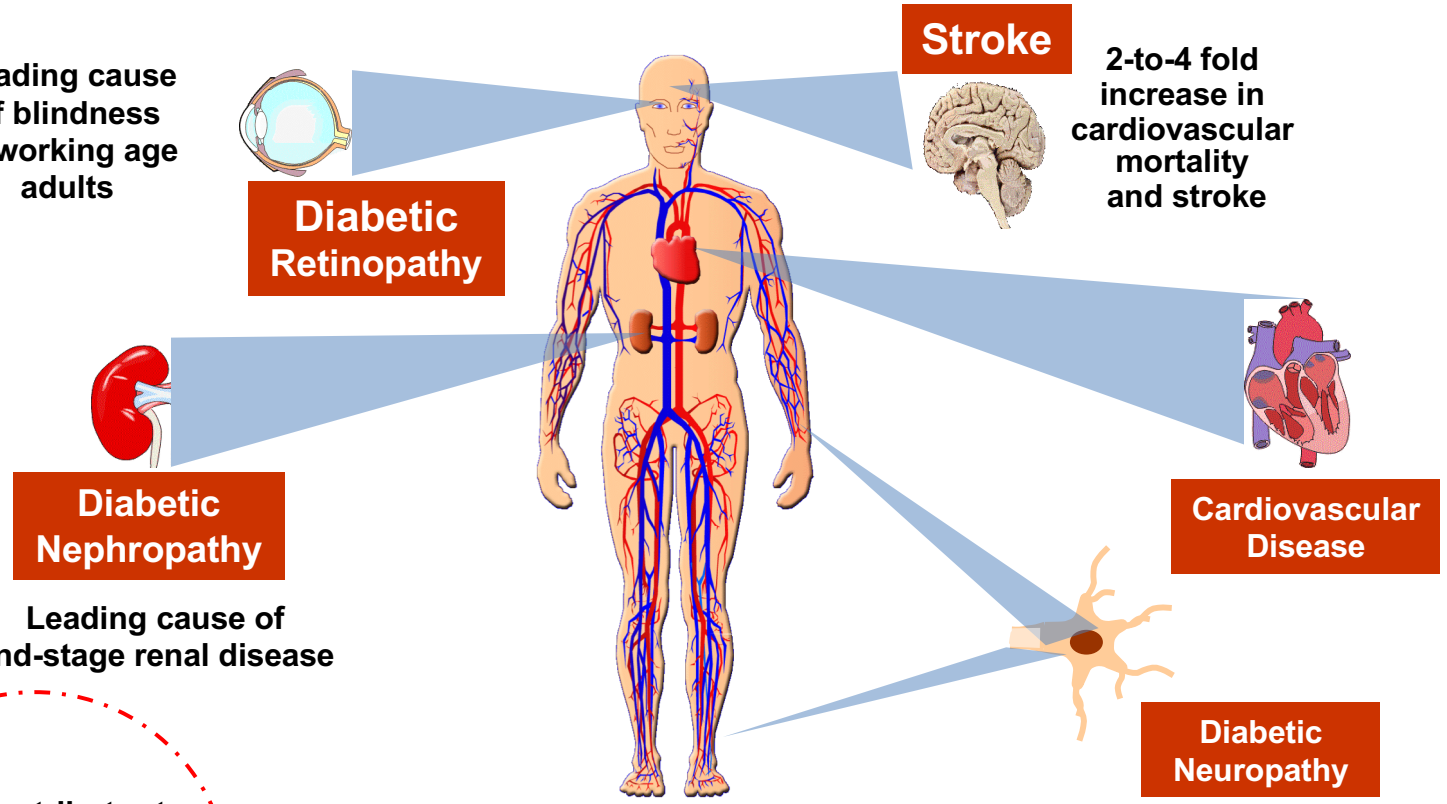


The top 10 countries, in numbers of people with diabetes, are:

India
China
USA
Indonesia
Japan
Pakistan
Russia
Brazil
Italy
Bangladesh

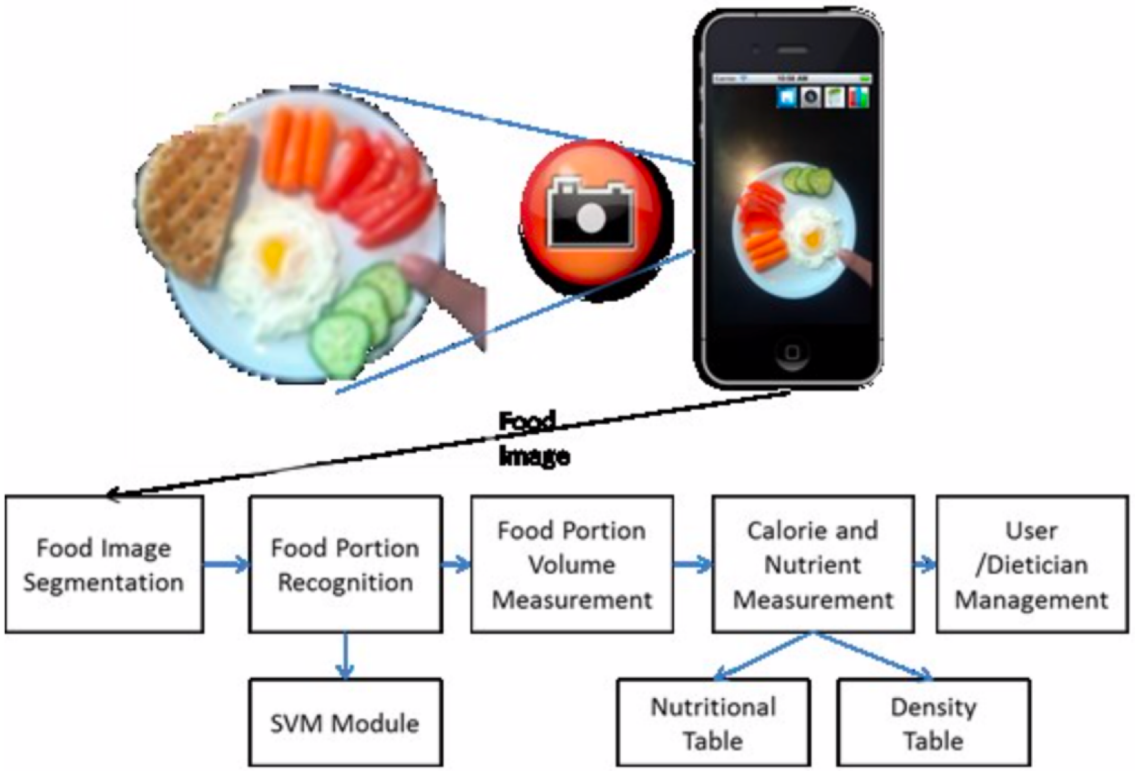
Year		2000	2030
Ranking	*Country*	*People with diabetes (millions)*	
1	India	31.7	79.4
2	China	20.8	42.3
3	United States of America	17.7	30.3

Human Cost of Diabetes



Nutrition

- Measuring calories and nutrition from food images



Nutrition


1:34 PM
Carrier
Rice
Fried Chicken
Carrots
Fried Chicken
Lettuce
Rice
Lettuce

Nutrition

No.	*Food items*	*Recognition Rate (%)*					
		Using Color Features	*Using Texture Features*	*Using Size Features*	*Using Shape Features*	*Using All Features*	*Using All Features (10 fold cross-validation)*
1	Apple	60.33	85.25	31.22	22.55	97.64	91.41
2	Orange	65.38	79.24	41.04	71.33	95.59	90.19
3	Corn	52.00	81.93	71.33	34.61	94.85	97.00
4	Tomato	71.29	69.81	48.09	45.01	89.56	79.82
5	Carrot	74.61	79.67	69.30	65.19	99.79	92.34
6	Bread	56.11	61.56	35.55	35.20	98.39	93.50
7	Pasta	71.22	81.57	52.09	48.30	94.75	96.10
8	Sauce	72.45	78.45	40.56	55.00	88.78	85.00
9	Chicken	69.81	71.45	28.02	34.27	86.55	84.52
10	egg	45.12	75.71	31.00	48.37	77.53	92.53
11	Cheese	61.67	83.62	42.67	33.65	97.47	93.43
12	Meat	75.38	71.67	55.00	44.61	95.73	97.73
13	Onion	45.81	79.98	31.78	22.59	89.99	84.48
14	Bean	76.80	79.55	76.71	65.11	98.68	96.73
15	Fish	58.55	64.81	18.96	62.73	77.70	81.50
Total Average		**63.76**	**76.28**	**44.88**	**45.90**	**92.21**	**90.41**

Nutrition

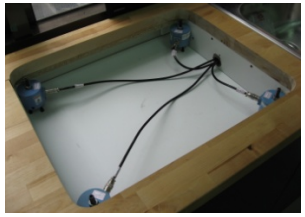
Food Portions	*Weight (grams)*	*Calculated Calorie*	*Real Calorie*	*Absolute Accuracy (%)*
Cake	100	275	250	90
Egg	150	15	17	88
Apple	200	100	114	87
Tomato	150	23	30	76
Cucumber	100	27.5	30	91
Bread	100	21	17	76
Banana	150	140	157	89
Orange	160	98	90	91
Average Accuracy				**86**

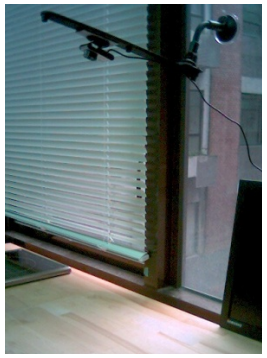
Nutrition

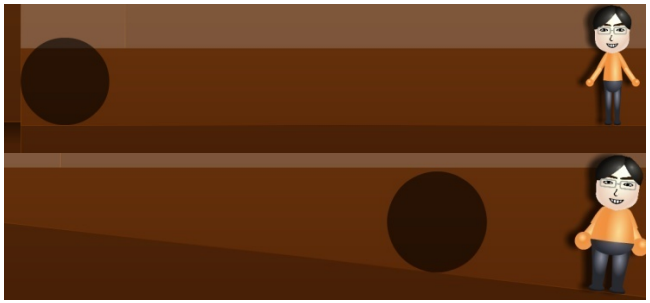
- Sense to recognize child's behavior
  - Weight sensor underneath the tray to sense eating actions
  - Eating actions as game input
- Play to engage behavior change
  - Interactive games: coloring cartoon character or penguin fishing

Nutrition

- Sense to recognize behavior
  - Combine weight and camera sensors to detect cooking actions (change food ingredients)
  - Voice input for food ingredient label
  - Food ingredients -> meal calories
- Play to engage behavioral change
  - Too many calories -> overweight family member
  - Imbalanced seesaw board -> big boulder sliding down







Nutrition

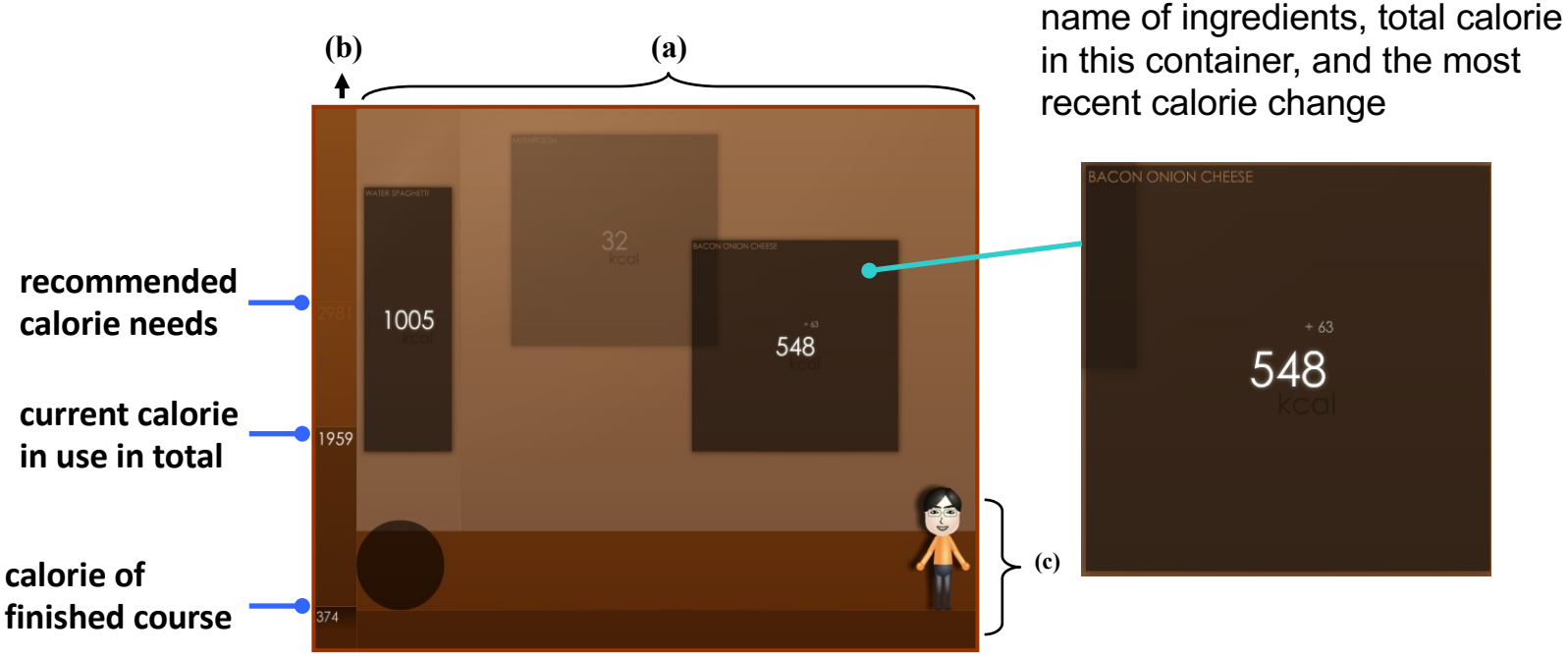
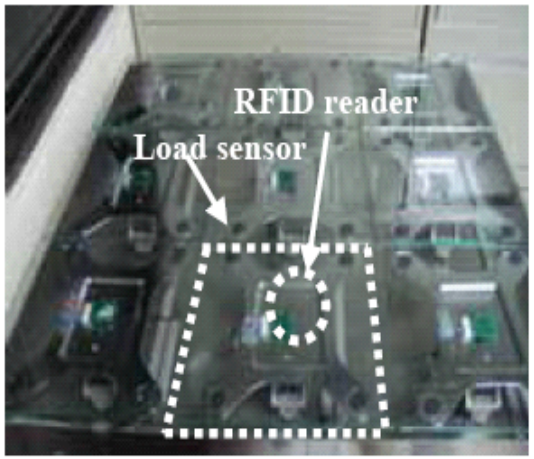


Figure 7. User interface of Calorie-aware Kitchen, including (a) overview of calorie in the system; (b) recommended calorie needs and current used calories; (c) a calorie-aware game with a beloved family member to bring enjoyment of calorie control

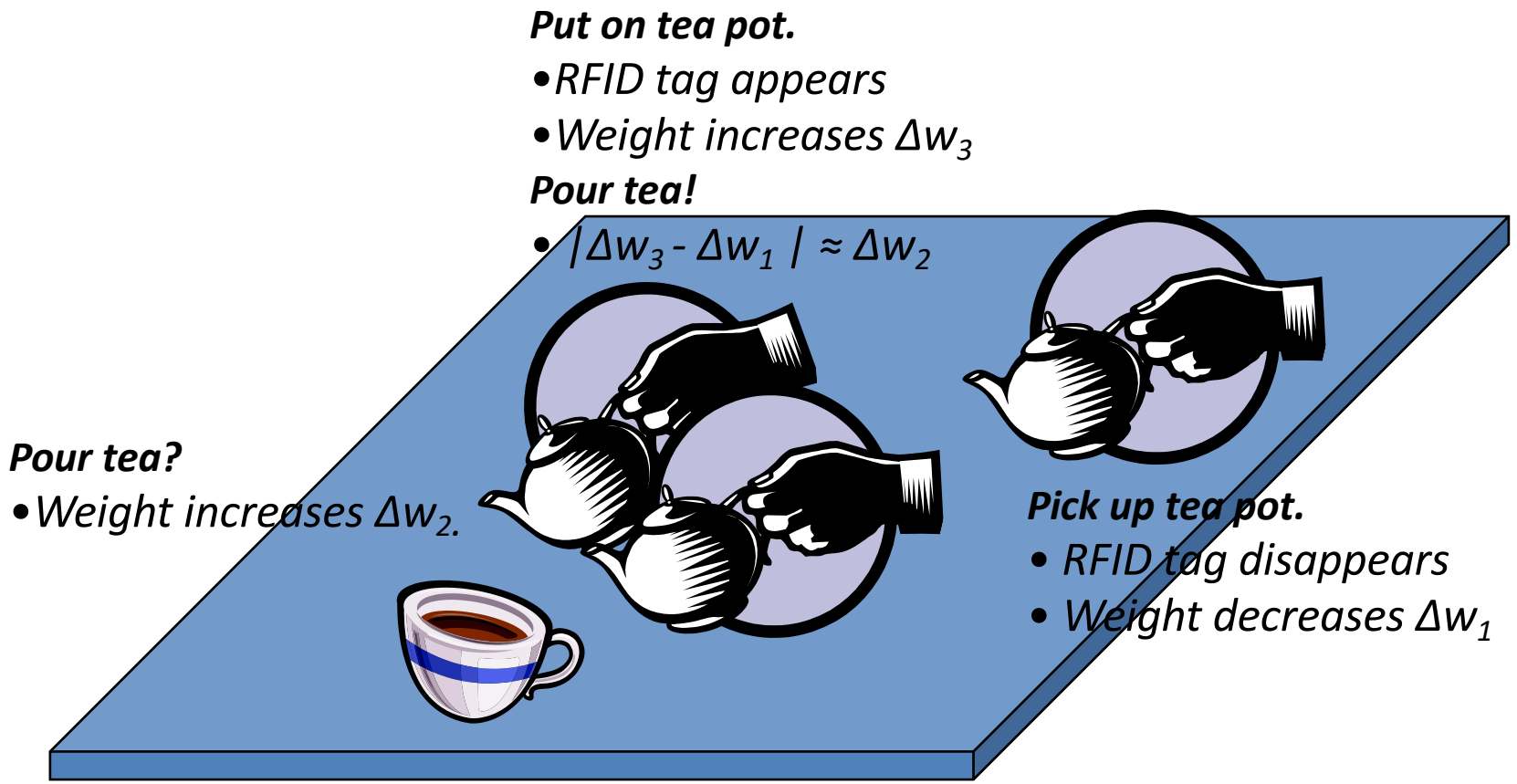
Nutrition

- Sensing to recognize behavior
  - Combine weight sensor and RFID sensors to track food transfer among containers
- Interaction
  - Natural user eating behaviors become system input (no need to operate any devices).
  - How do you design a user interface without affecting one's appetite?

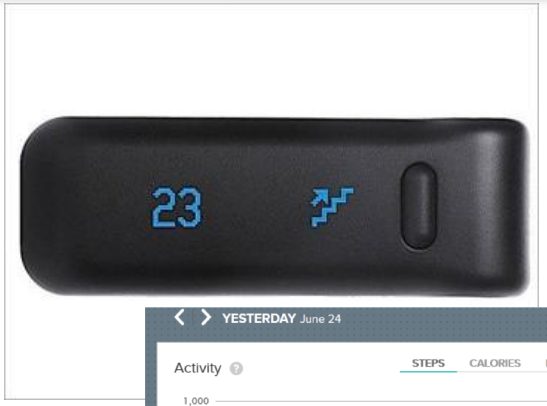


Nutrition

- Person pours tea from the tea pot to personal cup, and drinks it



Exercise

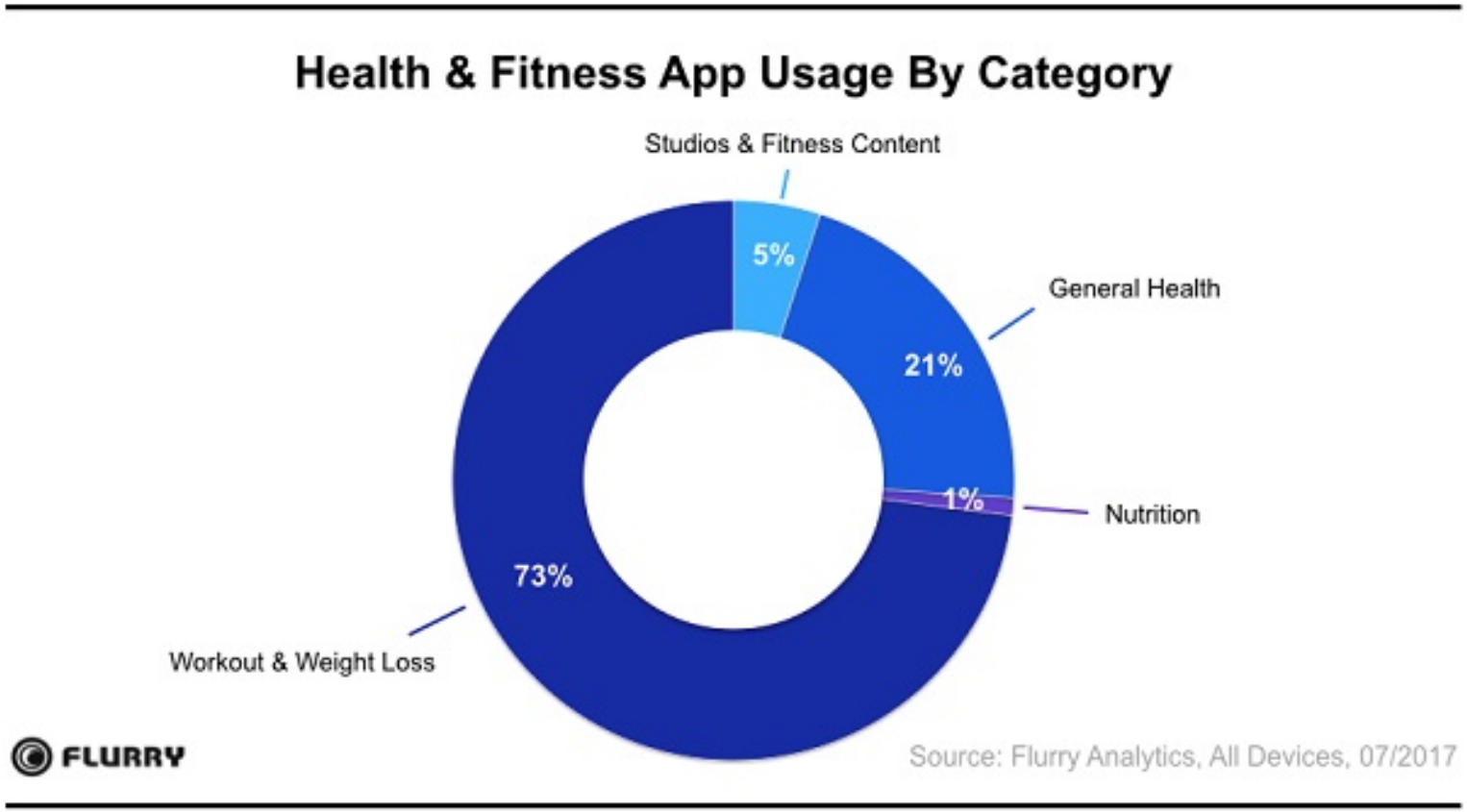

23


BODYMEDIA

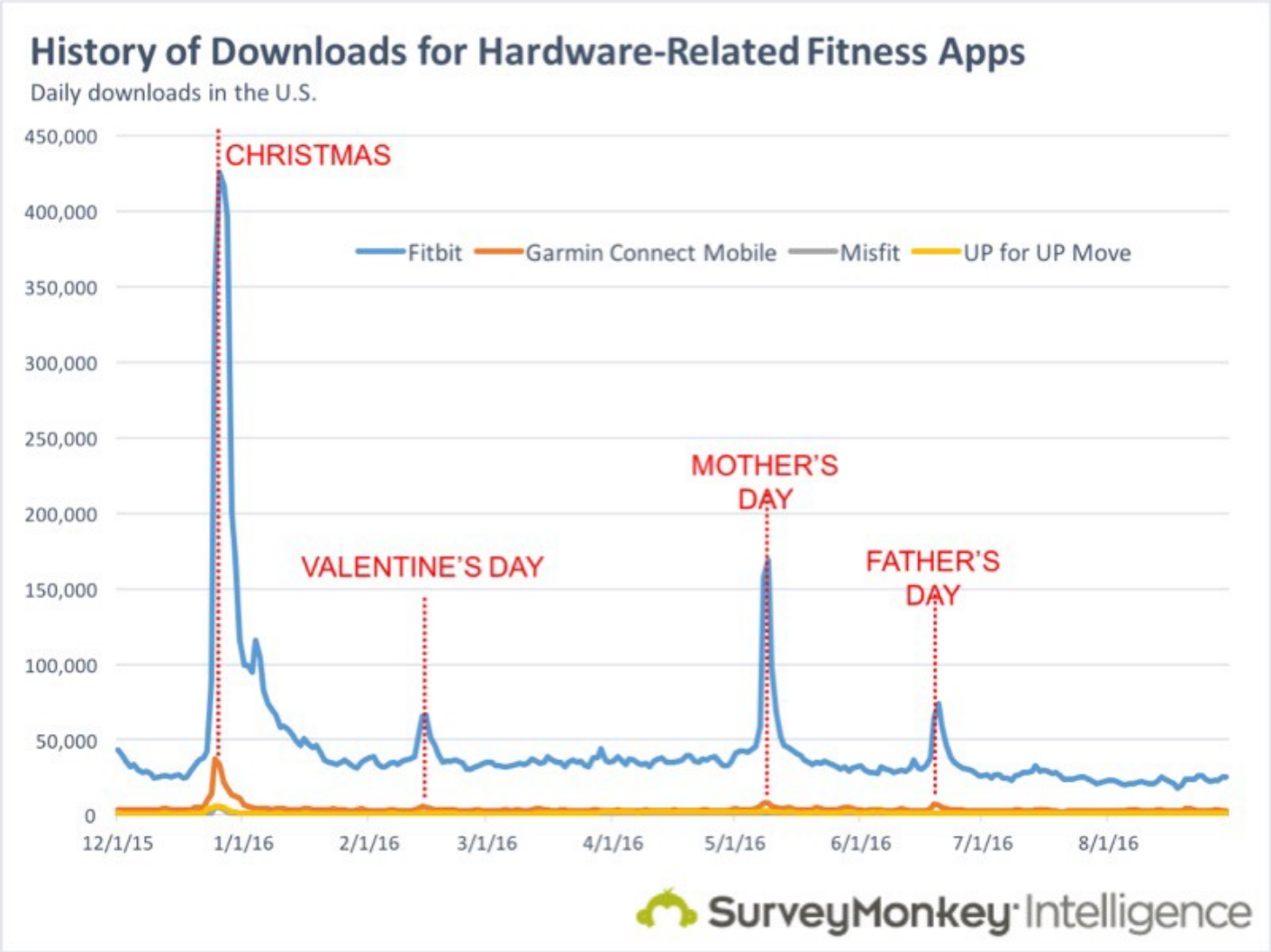

POLAR
WALK
POLAR
CALS


YESTERDAY June 24
Activity
STEPS
CALORIES
FLOORS
1,000
500
0
AM
Noon
PM
Steps
8972
Friends
Previous days aren't viewable for this tile.
Calories
3094
Champ!
weight / lbs
227.0 lbs
29.5% body fat
Distance / Miles
4.29
Very Active Mins
19 m
Food Plan
How much can you eat?
See how many calories you can eat each day to meet your weight goal.
Start a Food Plan
Floors
0
Sleep
7 h 18 m

Exercise


Health & Fitness App Usage By Category
Studios & Fitness Content
5%
General Health
21%
1%
Nutrition
73%
Workout & Weight Loss
FLURRY
Source: Flurry Analytics, All Devices, 07/2017

Exercise


History of Downloads for Hardware-Related Fitness Apps
Daily downloads in the U.S.
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
CHRISTMAS
VALENTINE'S DAY
MOTHER'S DAY
FATHER'S DAY
Fitbit
Garmin Connect Mobile
Misfit
UP for UP Move
12/1/15
1/1/16
2/1/16
3/1/16
4/1/16
5/1/16
6/1/16
7/1/16
8/1/16
SurveyMonkey Intelligence

Exercise

Figure 1. The BodyScope prototype. It consists of a Bluetooth headset, a microphone (embedded in the headset), and the chestpiece of a stethoscope.

Sleep


zzzZ
YOUR SLEEP EFFICIENCY
96%
Your sleep pattern
asleep
active
12am
1am
2am
3am
4am
5am
6am
7am
You went to bed at
11:18PM
Time to fall asleep
12min
Times awakened
12
You were in bed for
8hrs 13min
Actual sleep time
7hrs 40min


Sleep
April 12, 2017, 10:51 PM - 6:40 AM
fitbit
6 hr 33 min
10:51 PM
6:40 AM
1h 16m
Awake
1h 41m
REM
2h 55m
Light
1h 57m
Deep

Smoking, Alcohol, Drugs

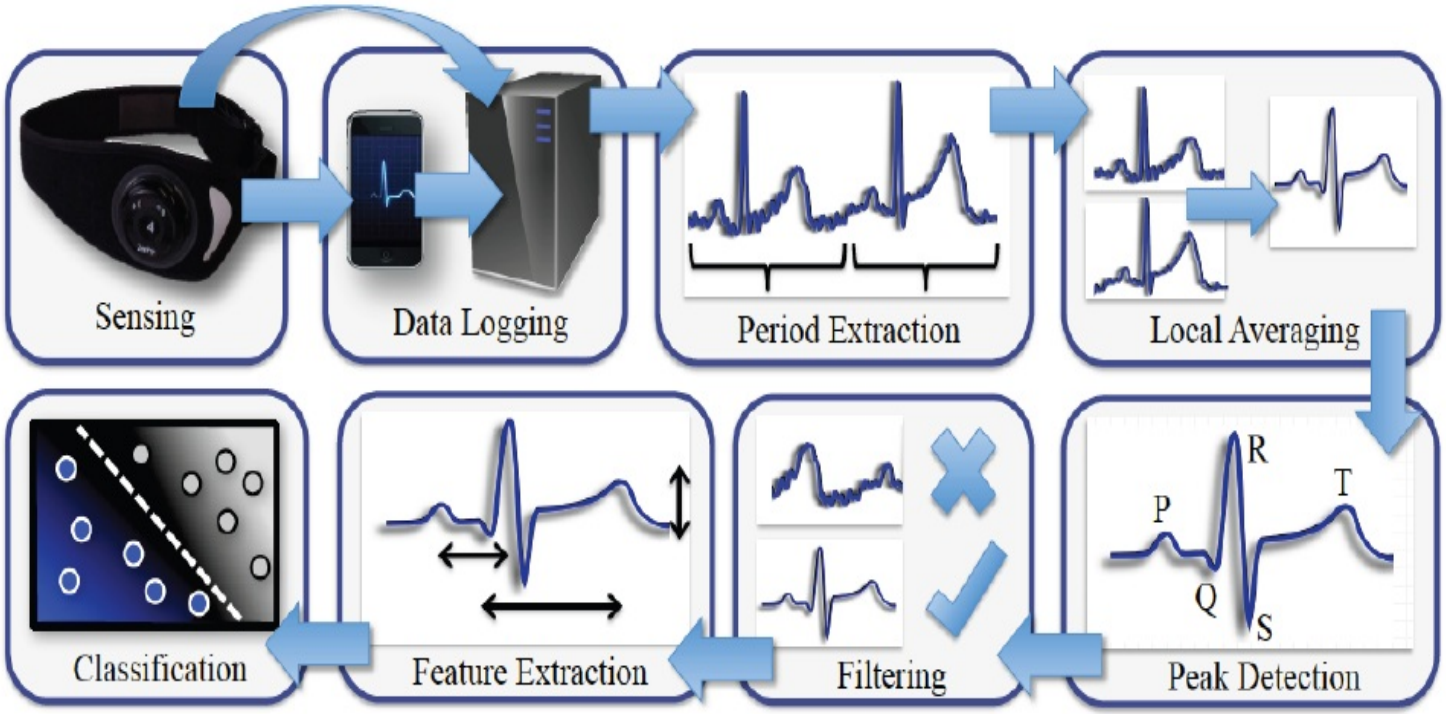


Figure 3. This figure illustrates the primary steps in our sensing, data acquisition and data processing pipeline. Raw ECG measurements are transmitted wirelessly to a smartphone and also downloaded directly to a server to provide redundancy. We first segment ECG periods using RR intervals. To deal with noise in the signals, we compute local averages over 30 second sliding windows. We apply peak detection to the smoothed waveforms and discard those that do not have the correct configuration of peaks and troughs. We apply feature extraction and standardization followed by classification. The above steps apply only to features in the knowledge-based framework. For features in the data-driven framework the local averaging step is directly followed by classification

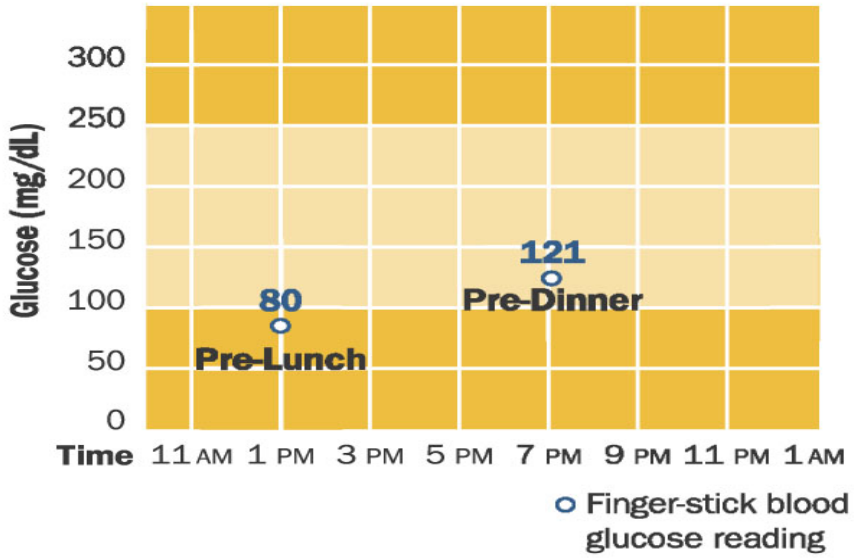
Disease Management

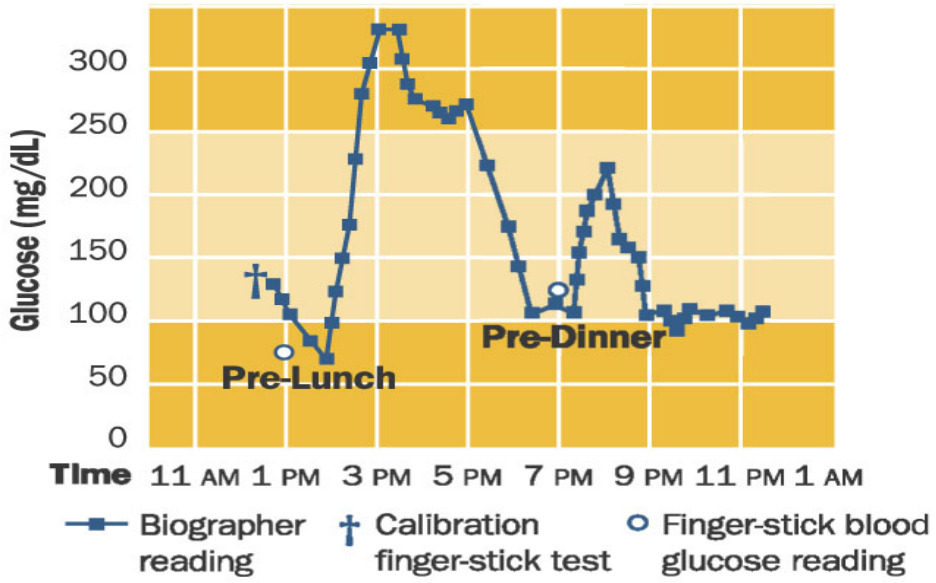
- Many glucose tracker apps
- Integrate with blood glucose devices (e.g., BLE)
- Track many other things (nutrition, exercise, weight)
- Provide information and resources
- Social networking features

Disease Management

- Continuous Glucose Monitoring (CGM)
  - A device that provides “real-time” glucose readings and data about trends in glucose levels
  - Reads the glucose levels under the skin every 1-5 minutes (10-15 minute delay)
  - Provides alarms for high and low glucose levels and trend information
  - Helps prevent high/low glucose levels and minimize fluctuations
  - Helps with behavior modification
  - Helps prevent complications

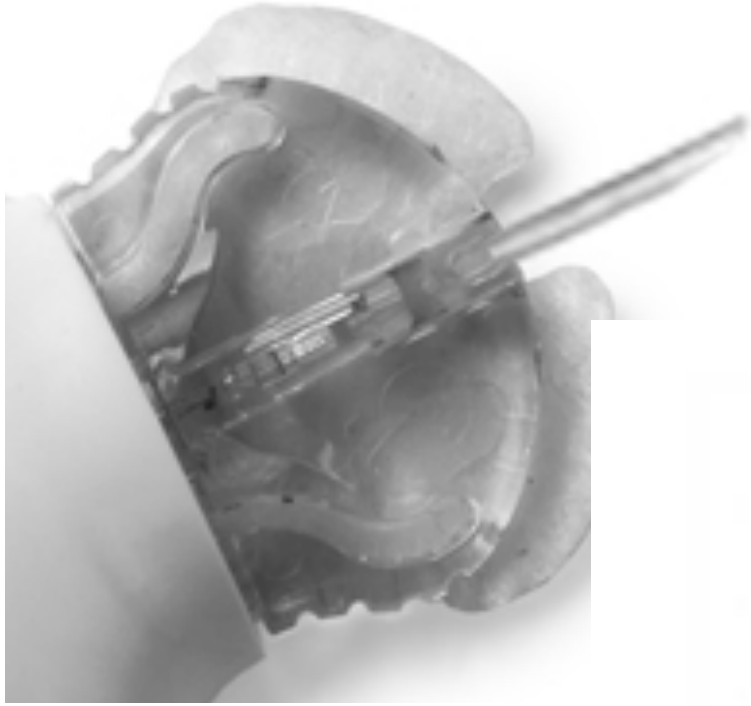
Disease Management





Disease Management

- Sensor



Disease Management

- Transmitter

Disease Management

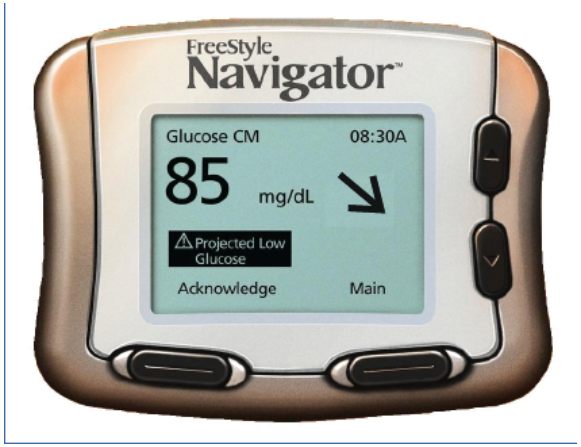
- Receiver/Monitor

Disease Management

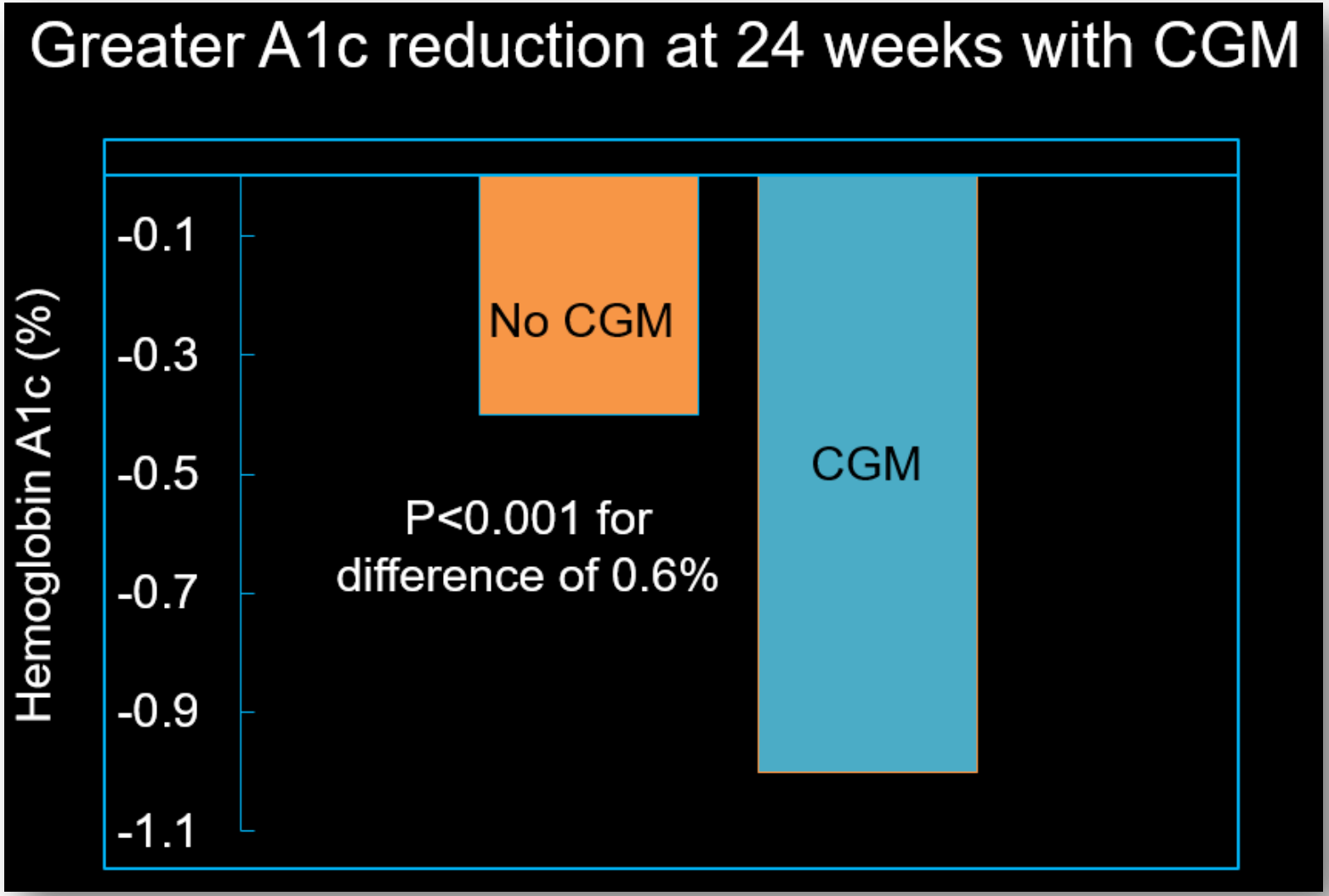
- Requires calibration
  - Calibration is a process that provides a fingerstick BG value to the CGM system so the values will align with each other
  - Number of calibrations vary by device
  - Best times to calibrate are when the BG values are stable: before meals and before bed

Disease Management

- Monitor outputs:
  - Trends (more important than individual values; does it go up or down)
    - Graphs
    - Arrows
  - Alarms (exceeding thresholds)



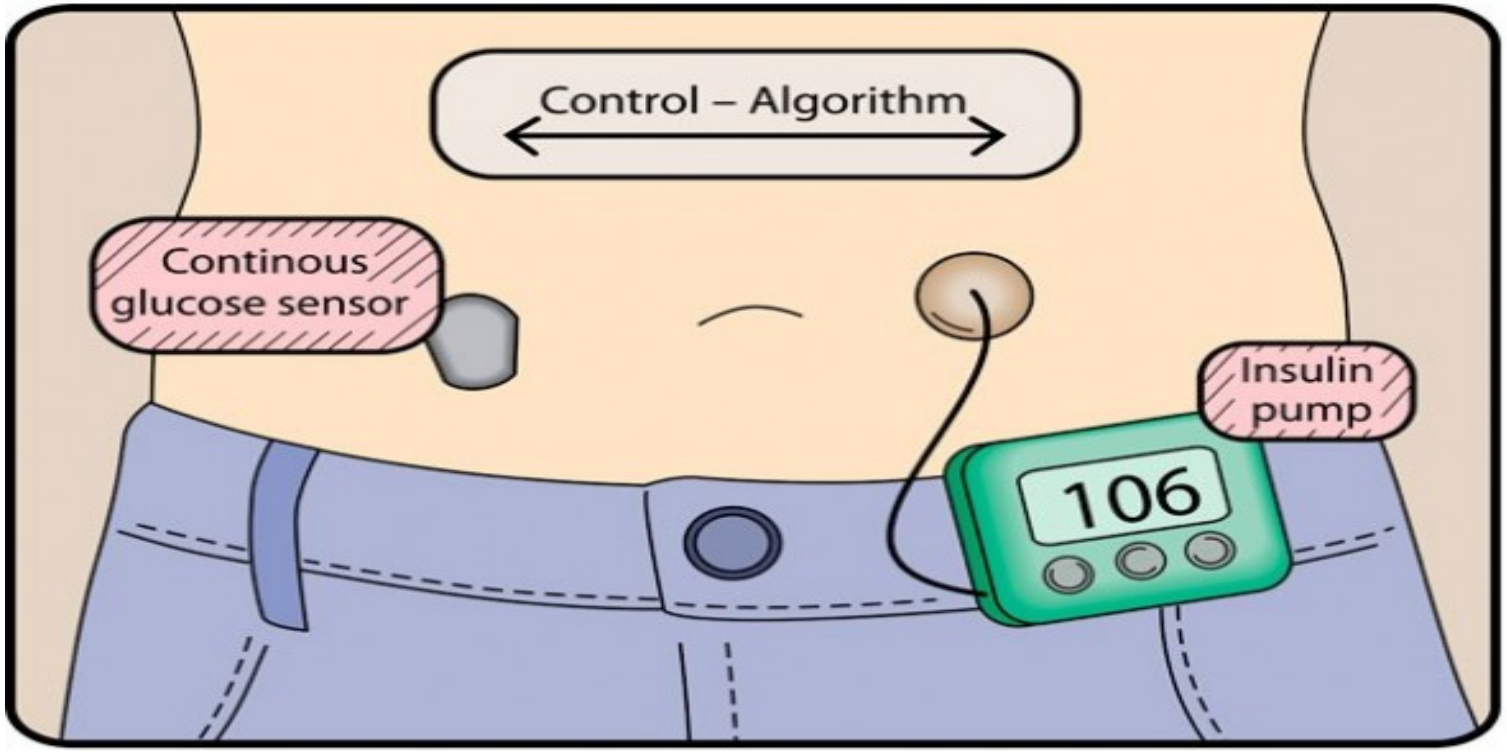
Disease Management



Disease Management

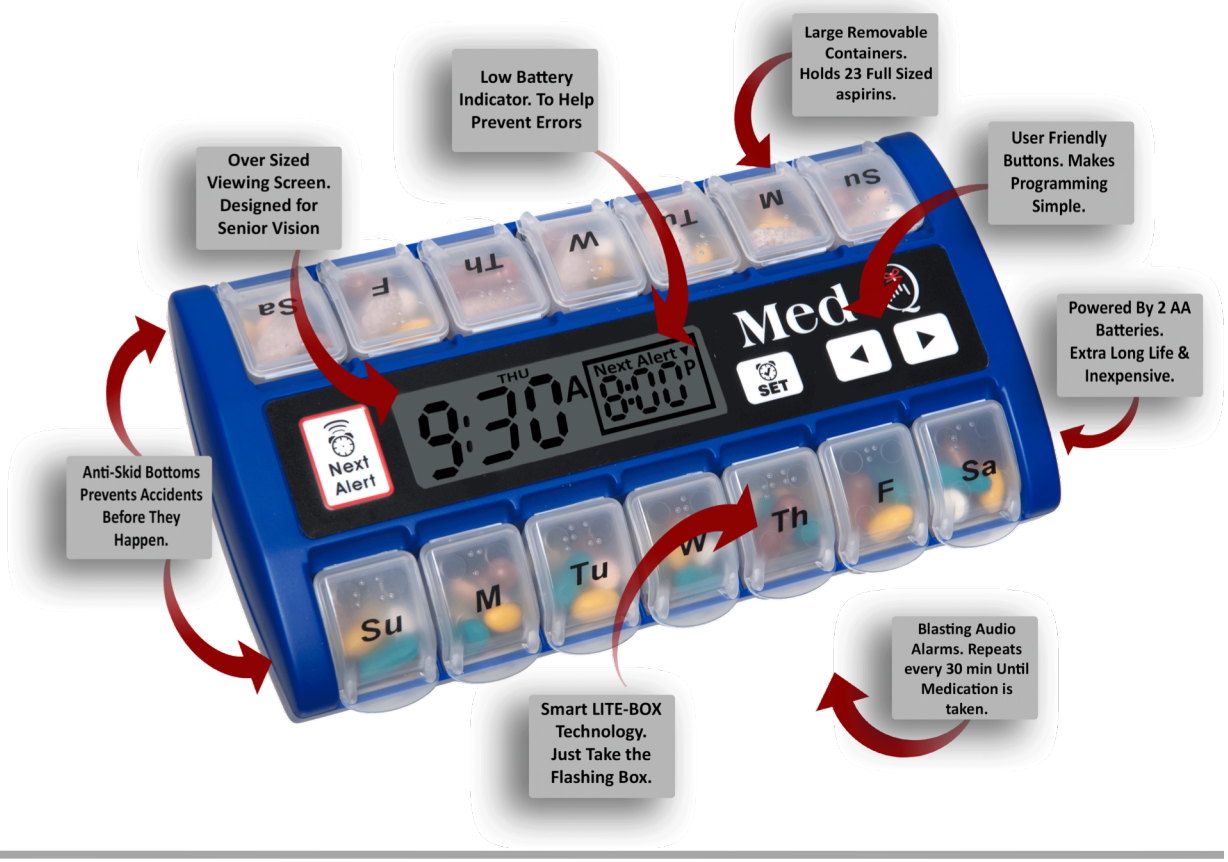
Pros	Cons
Alerts patients to • Episodes of hypoglycemia and hyperglycemia • *Predicted* episodes of hypoglycemia and hyperglycemia	Issues related to • Accuracy • Comfort • Convenience • Patient acceptance • Expense
Device displays help patients with clinical decision making	Most devices require frequent calibration

Closed-Loop System



Disease Management

- Medication Management
  - Solutions designed to monitor the adoption of medicines, improve compliance, provide automatic reminders, and reduce errors



Disease Management

- Proteus “Smart Pills”
  - Microchipped medication tablets that track patient adherence with a smartphone app
  - Can also detect information about the body’s response to the medicine

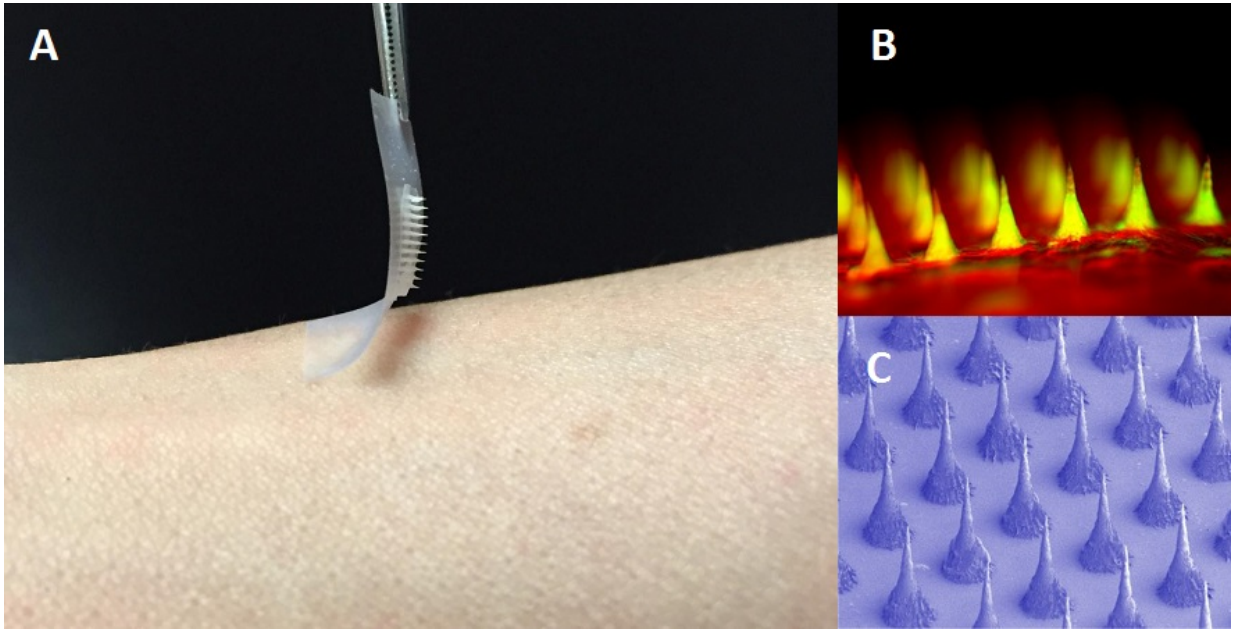
Disease Management

- Intranasal glucagon
- Approved in EU, not yet in US

	Caregivers		**Acquaintances**	
	Locemia	Injection Kit	Locemia	Injection Kit
% Who gave correct dose	94%	**13%**	93%	0%
Average time to dose given	**16 seconds**	2 -5 minutes	26 seconds	2 minutes, 24 seconds

Disease Management

- Smart insulin patch
  - Smaller than stamp; 100+ needles (each of which is loaded with insulin and glucose-sensing enzymes that rapidly release insulin when blood sugar levels too high)



Disease Management

- Artificial pancreas
  - When blood sugar flows inside the capsule, it stimulates the cells to produce insulin to control sugar levels
  - The device has nano pores, pores so small that the body's antibodies cannot get in to attack the cells, but large enough that the insulin can flow out and into the body