Real-World Use (and feedback) of a hybrid closed loop artificial pancreas system

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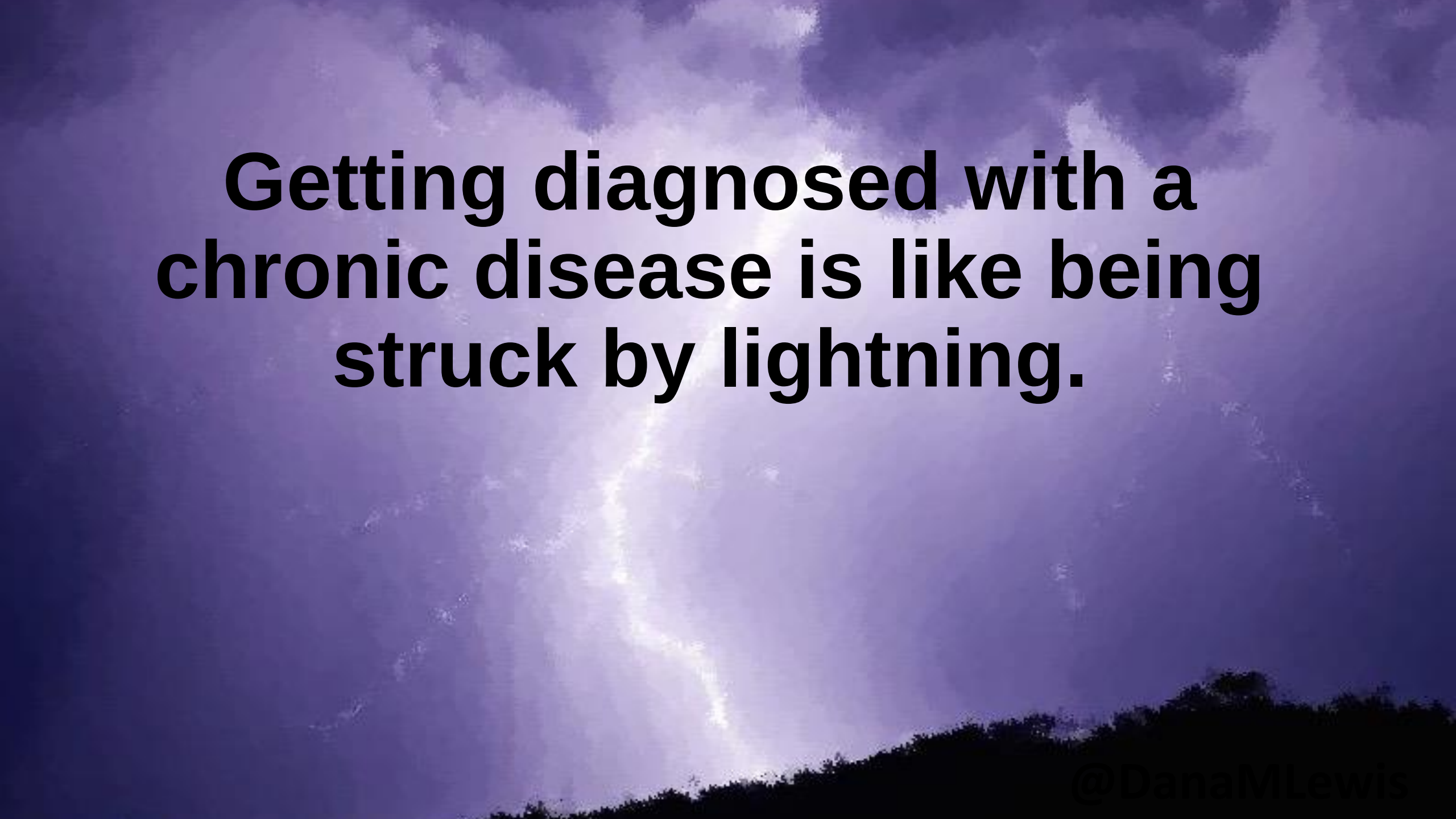
Getting diagnosed with a chronic disease is like being struck by lightning.
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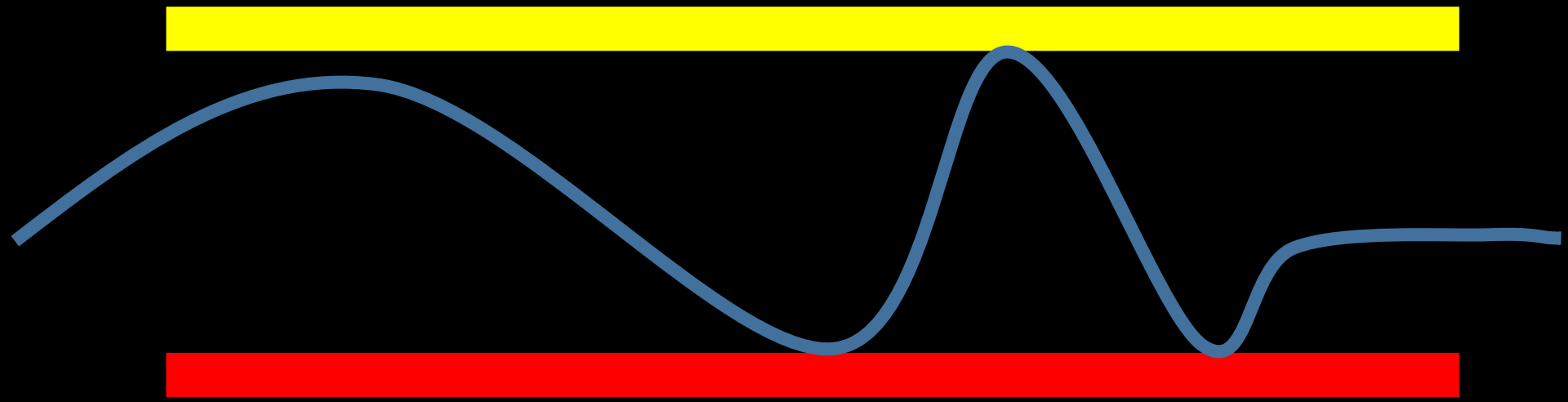
Food, hormones, sickness, stress



Insulin, exercise, sickness, stress

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“Diabetes is the ultimate DIY. *It has to be* – people make up to 300 decisions daily that impact their blood glucose.”

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An artificial pancreas is the closest thing to a self-driving car for diabetes.

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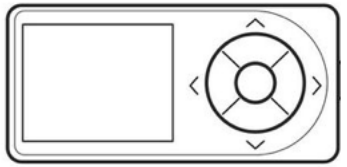
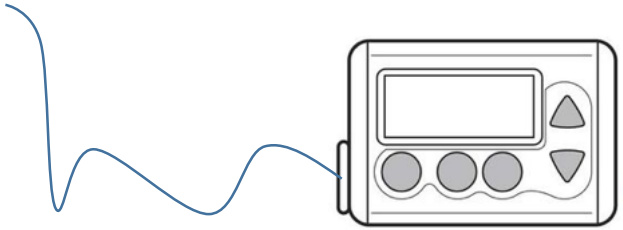
The tools I had were not perfect….

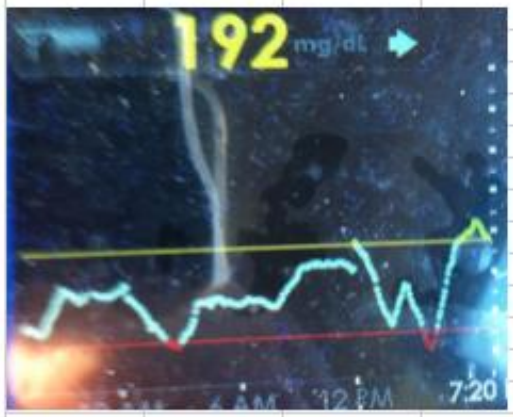


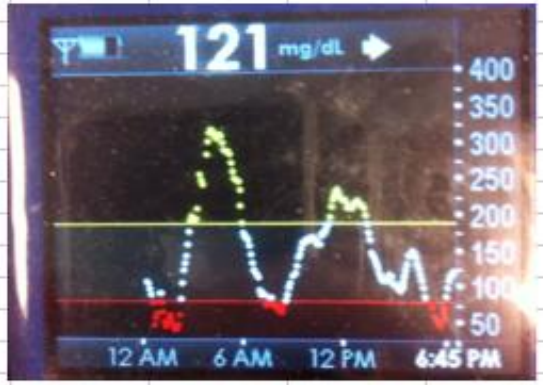
Continuous Glucose Monitor (CGM)

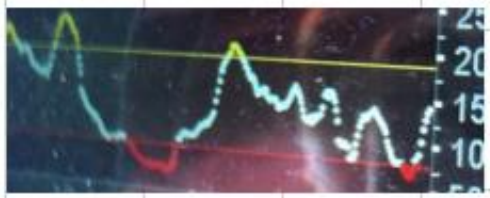


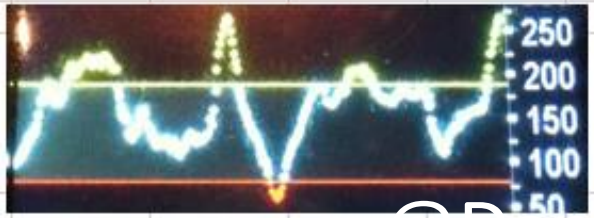
Insulin Pump

Leaving me often with this:

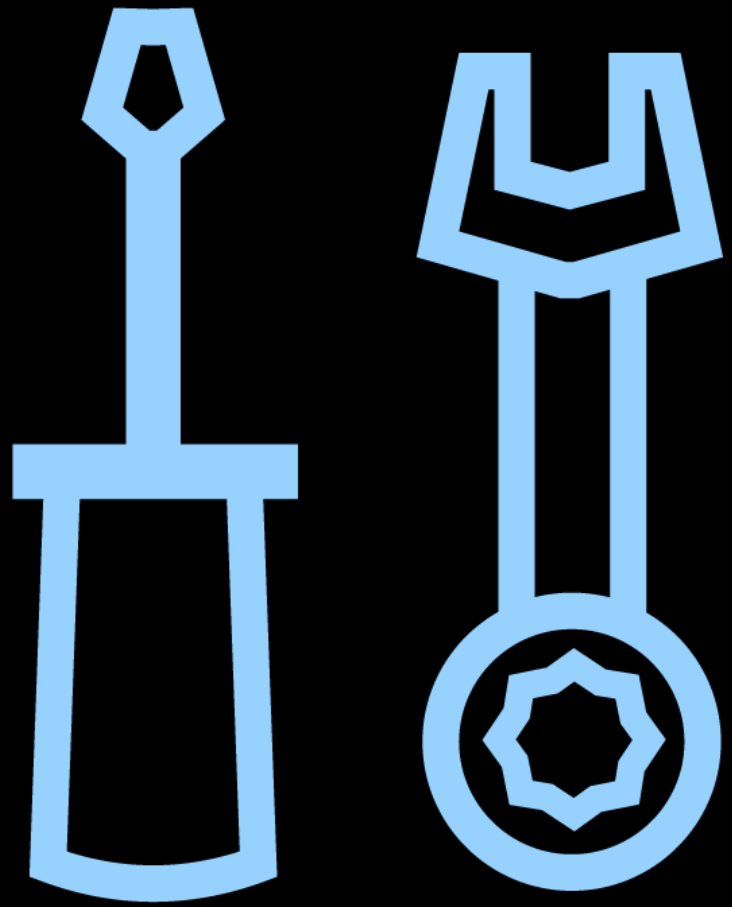








4-Jul	7-Jul
salad	banana
frozen dinner	hamburger, salad, ice cream
cheese & crackers	steak/rice/beans bowl
	7/8 - 4 mile run, transmitter died
5-Jul	9-Jul
bacon & eggs	bacon & eggs
chicken & rice	tomato soup
larabar & sausage	cheese & crackers
6-Jul	10-Jul
banana	yogurt
doritos	bacon & eggs
ham/cheese lettuce wrap with yogurt, cheetos	
steak & potato	chicken & rice



If we can't change existing devices…

what if we could add *new* tools?

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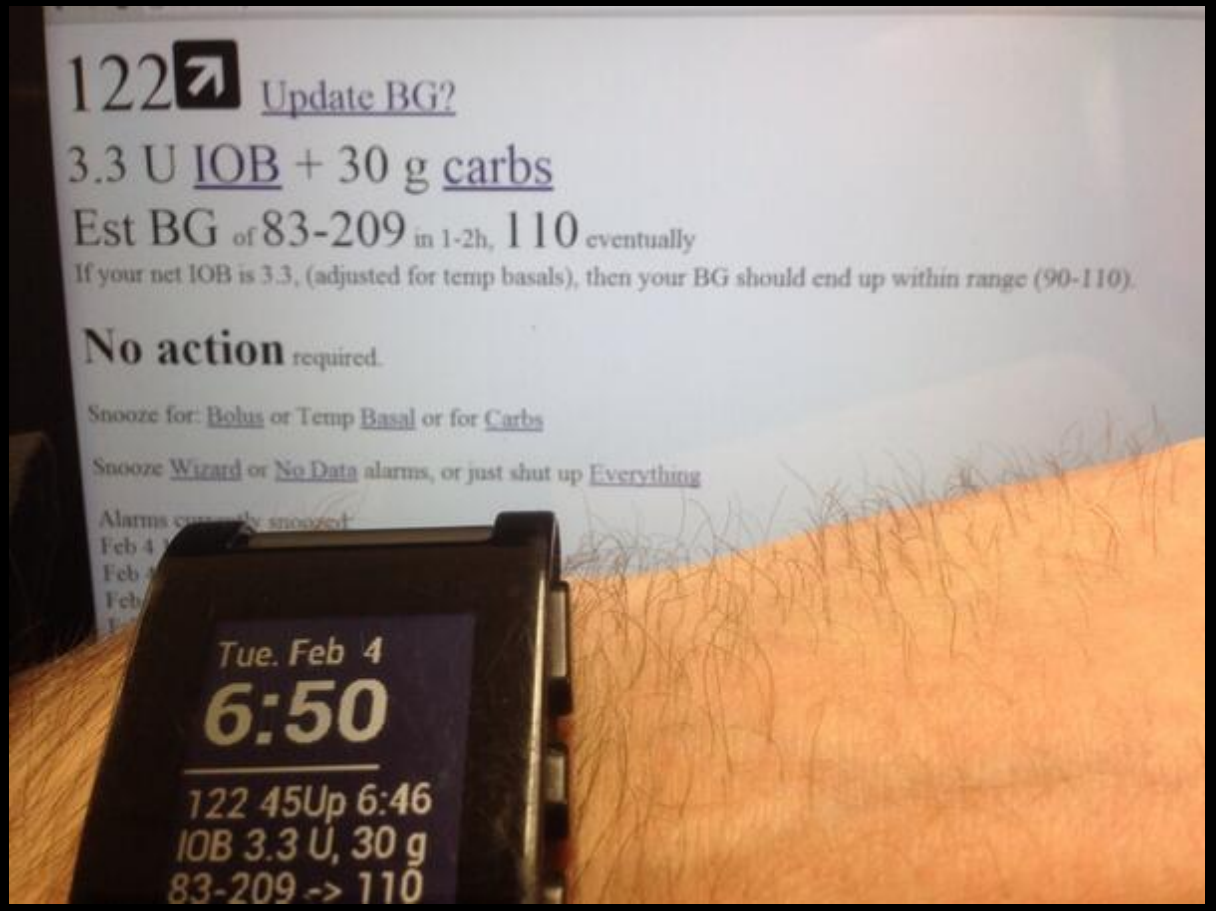
From reactive to predictive: an “open loop”



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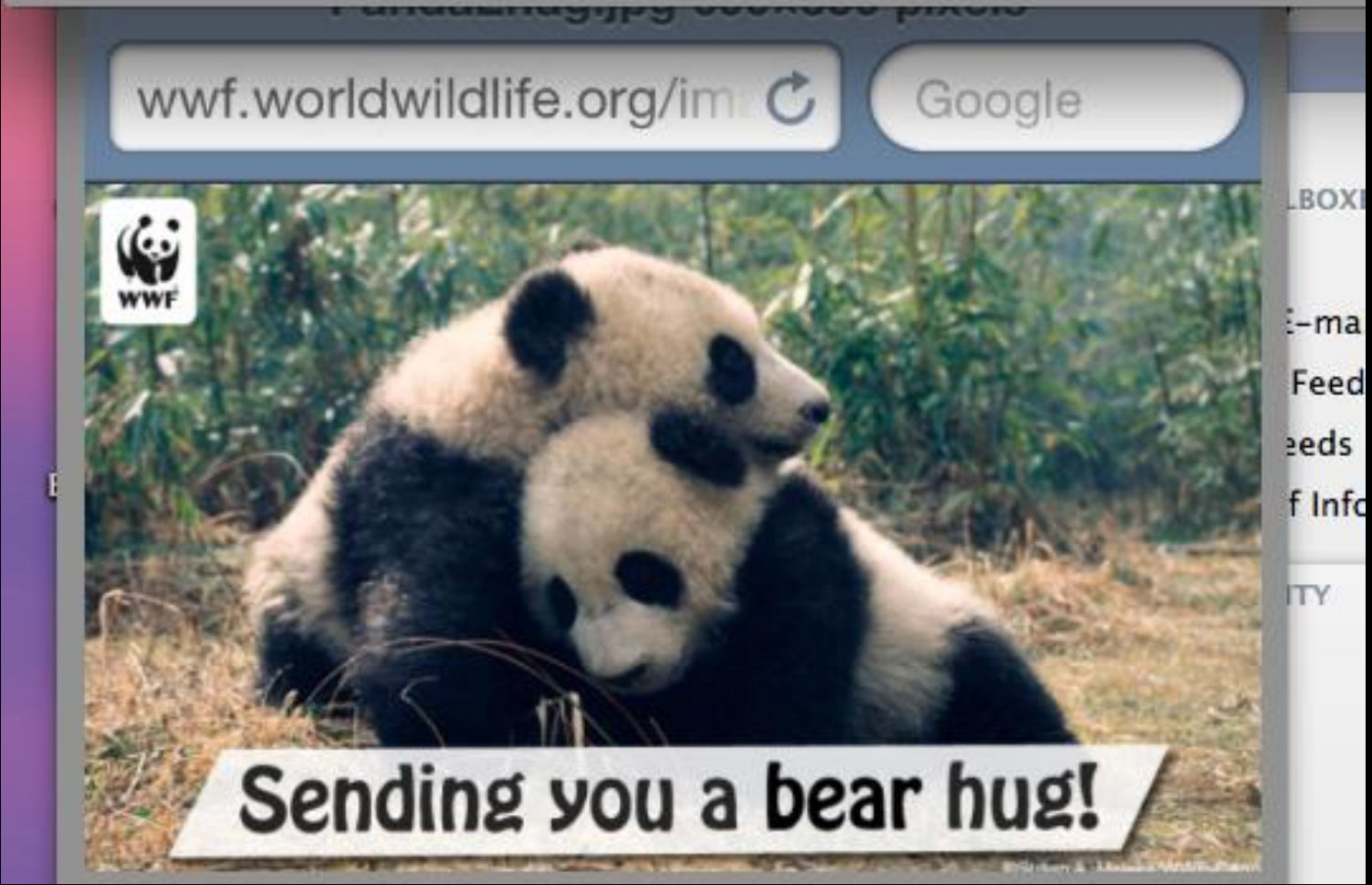
34 carbs and 1 hug recommended

Snooze for: Bolus or Temp Basal or for Carbs



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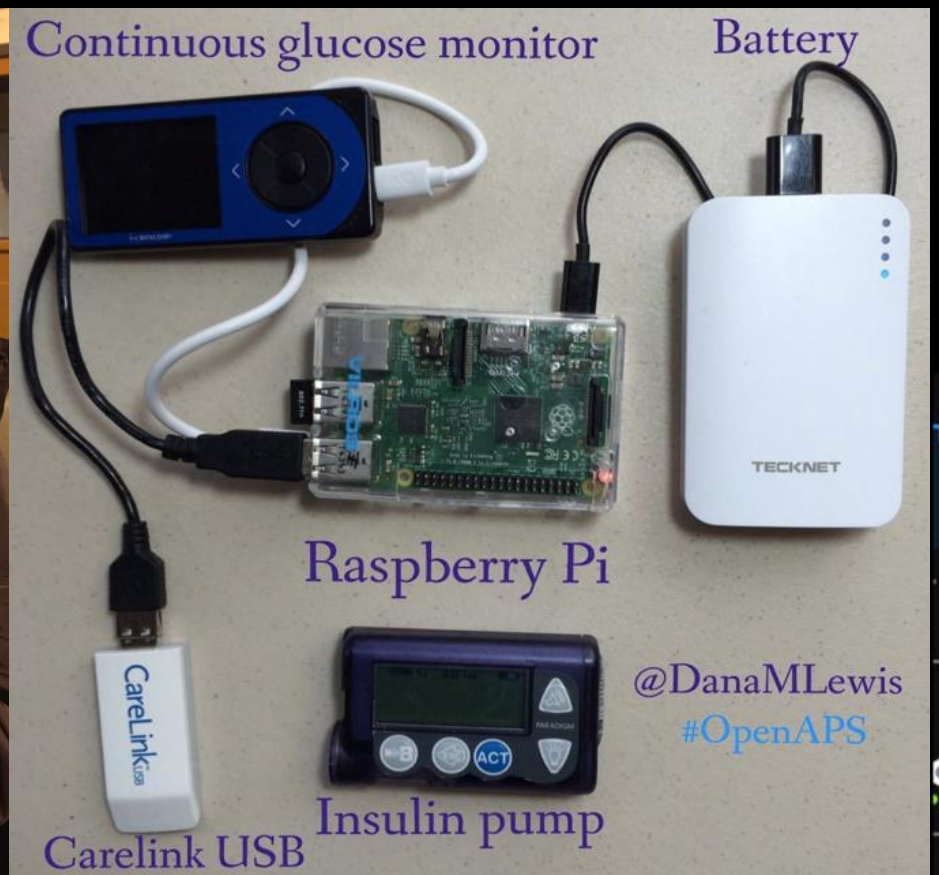
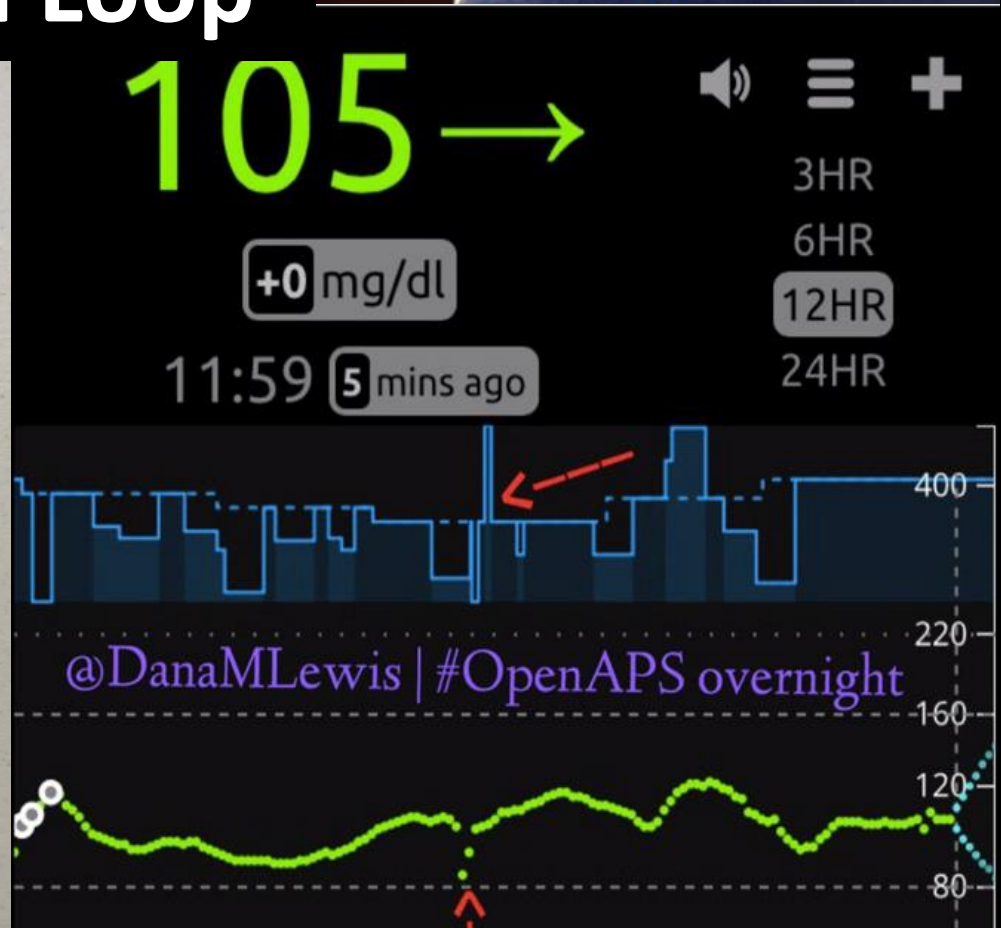
Life with a DIY Closed Loop





#OpenAPS

is an open and transparent effort to make safe and effective basic Artificial Pancreas System (APS) technology widely available to reduce the burden of Type 1 diabetes.

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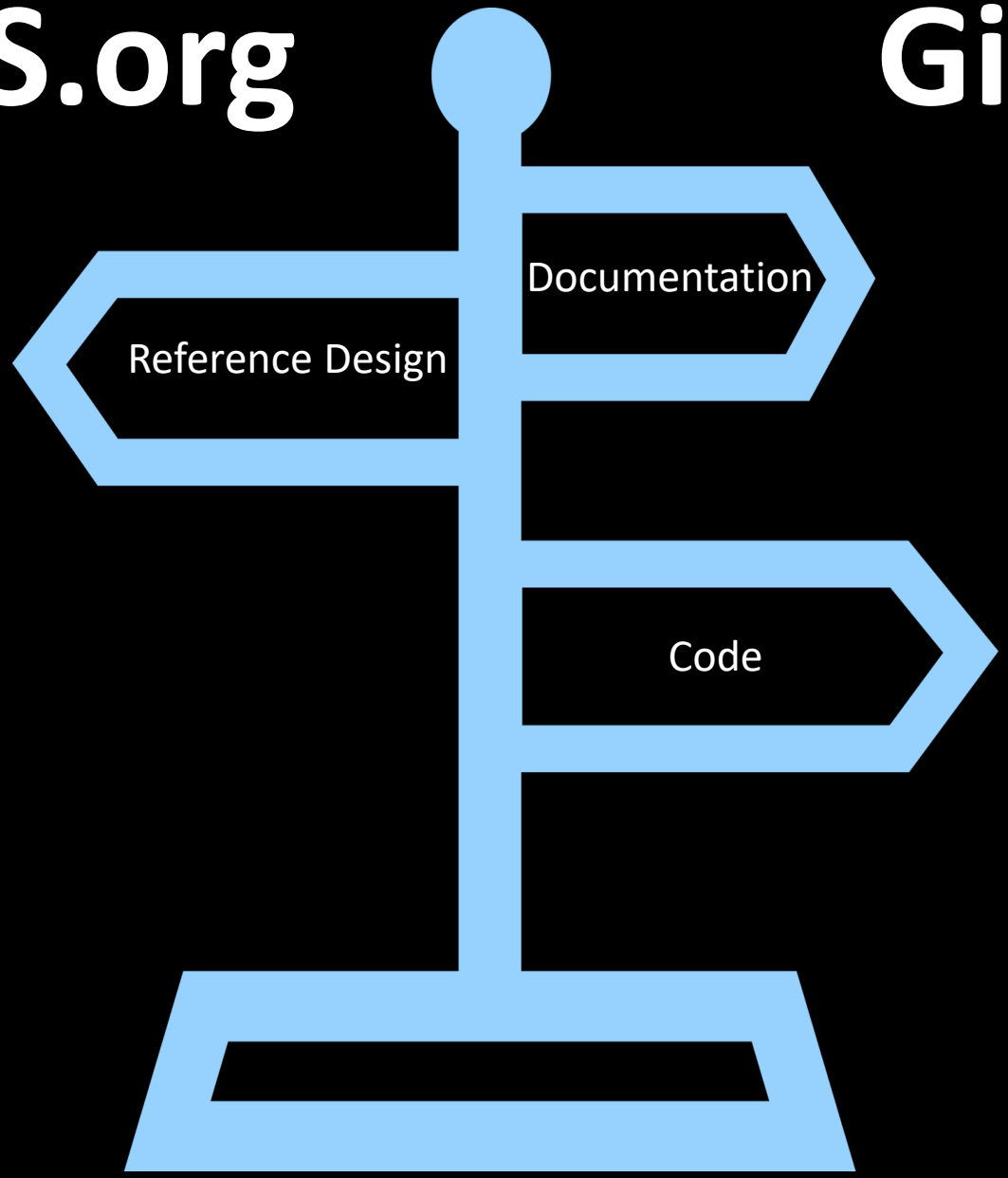
OpenAPS.org

Github.com/openaps



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There are now (n=1)*369+ people with DIY closed loops in the world.

(That's something like

1,650,000+

hours of DIY closed loop experience.)

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Some of the #OpenAPS community:

















... although not a cure,
it makes it a lot better
than it used to be.

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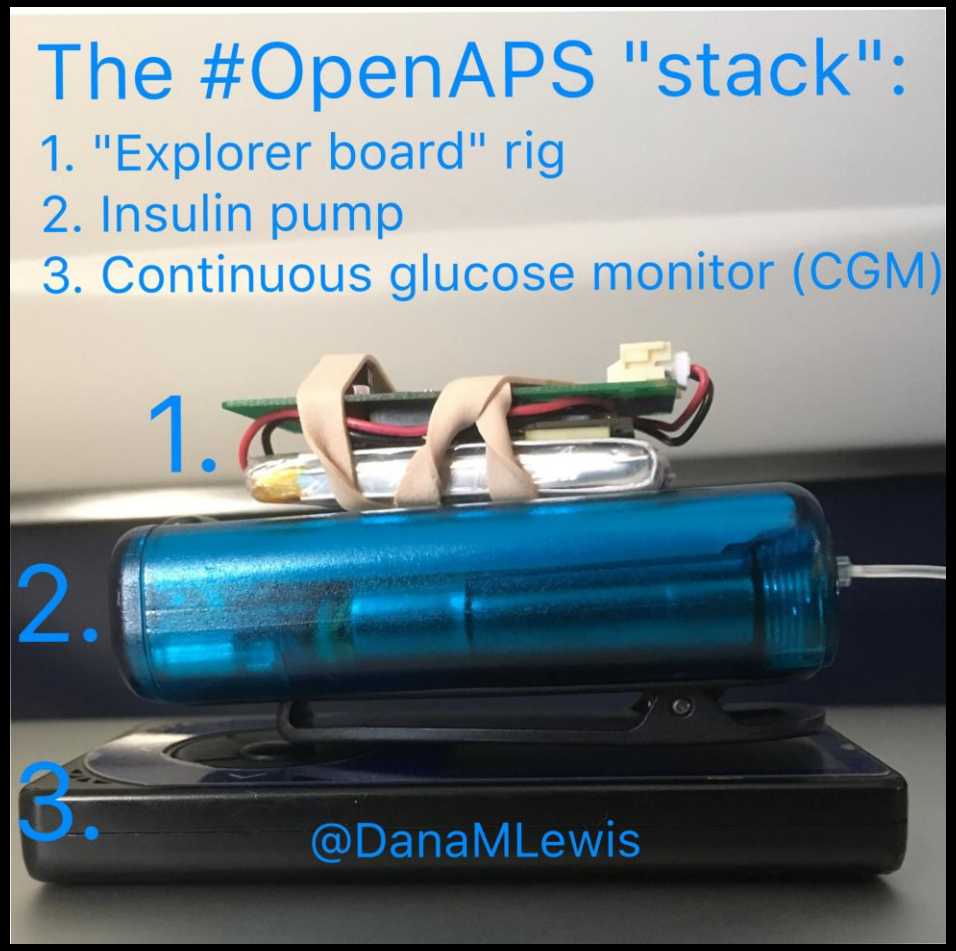
An even smaller pancreas than before:



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How do we want to control our pancreas?

From whichever device the user prefers.

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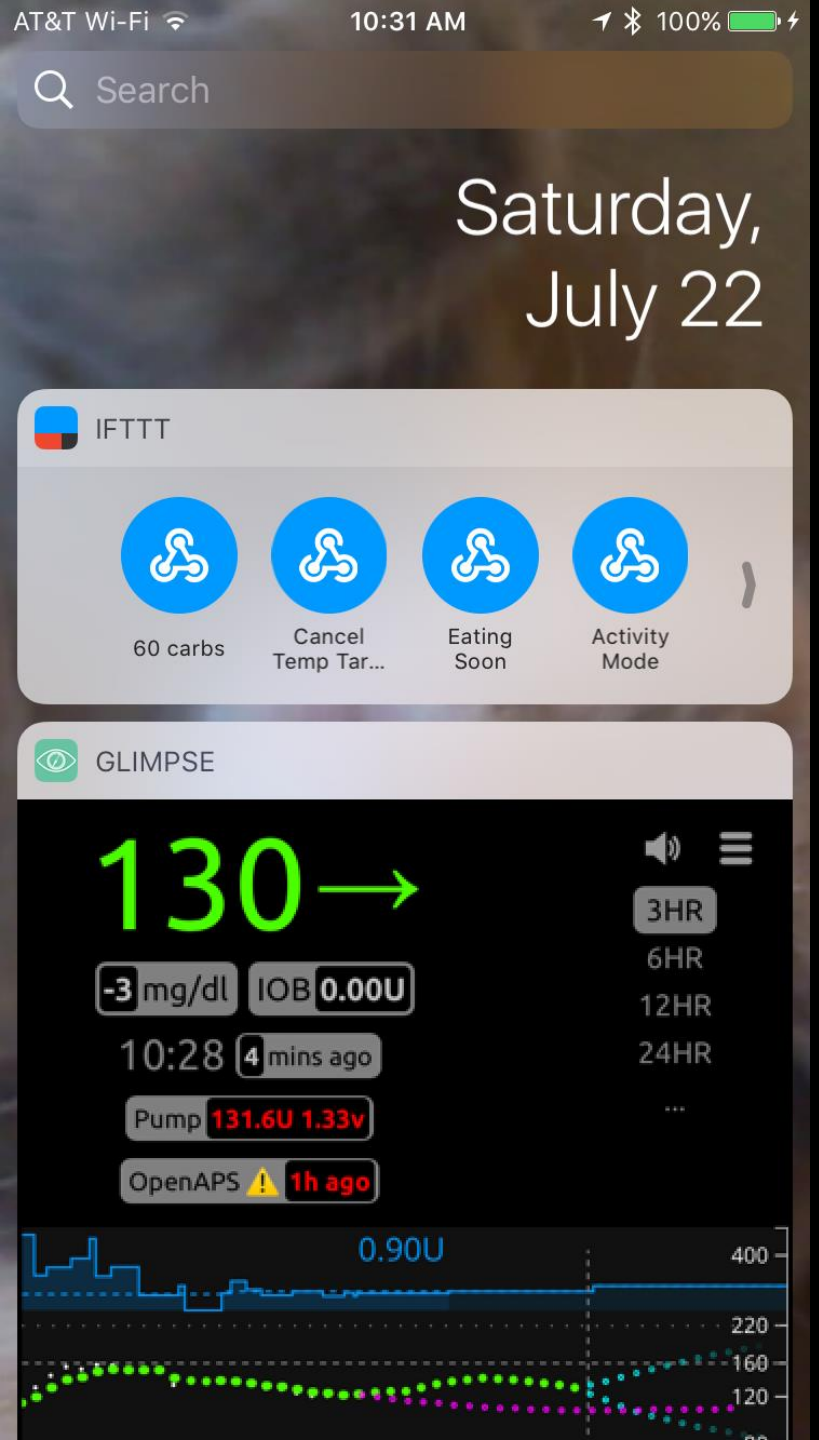

We have multiple medical devices, why should we use one app per device?

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Quality of life improvements

- Sleep
  - For the PWD
  - For loved ones (spouses, parents)
- ”Time on task”
  - Less time away from work or school
  - Less time spent doing diabetes calculations all day
- Ability to visualize data and change behaviors
  - “Eating soon” mode, etc.
- Outcomes
  - Less time high and low (improved overall time in range)
  - A1c/eAG

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“I was pretty happy with my 5.8% from a couple months of SMB, which has included the 2 worst months of eating habits in years. It almost feels like a break from diabetes, even though I’m still checking hourly to make sure everything is connected and working etc and periodically glancing to see if I need to do anything. So much of the burden of tight control has been lifted, and I can’t even do a decent job explaining the feeling to family.”

“

We used to battle 220s at this time of day (showing a picture flat at 109). Four basal rates in morning. Extra bolus while leaving house. Several text messages before second class of day would be over. Crazy amount of work [in the morning].

Now I just have to brush my teeth.

”

“

I don’t know if I’ve ever gone 24 hours without ANY mention of something that was because of diabetes to (my child).

”

Outcomes with #OpenAPS

- 18 users (out of 40 users total using the system at the time) shared and self-reported their data and experiences from using the system in 2016.

- OpenAPS users (18 respondents, 67% male / 33% female, 61% adults / 39% children, median 27 years old (SD 14.5 years), 15 years with diabetes (SD 11.7 years), 10 years on pump therapy (SD 3.6 years), 3 years on CGM (SD 2.5 years)) were surveyed on quantitative and qualitative measures of their experience using their self-built APS. While using OpenAPS, **self-reported outcome measures showed median HbA1c dropped from 7.1%** (SD 0.8%) **to 6.2%** (SD 0.5%), and **median percent time in range** (80-180 mg/dL) **increased from 58%** (SD 14%) **to 81%** (SD 8%). All but one respondent reported some improvement in sleep quality, and 56% reported a large improvement.

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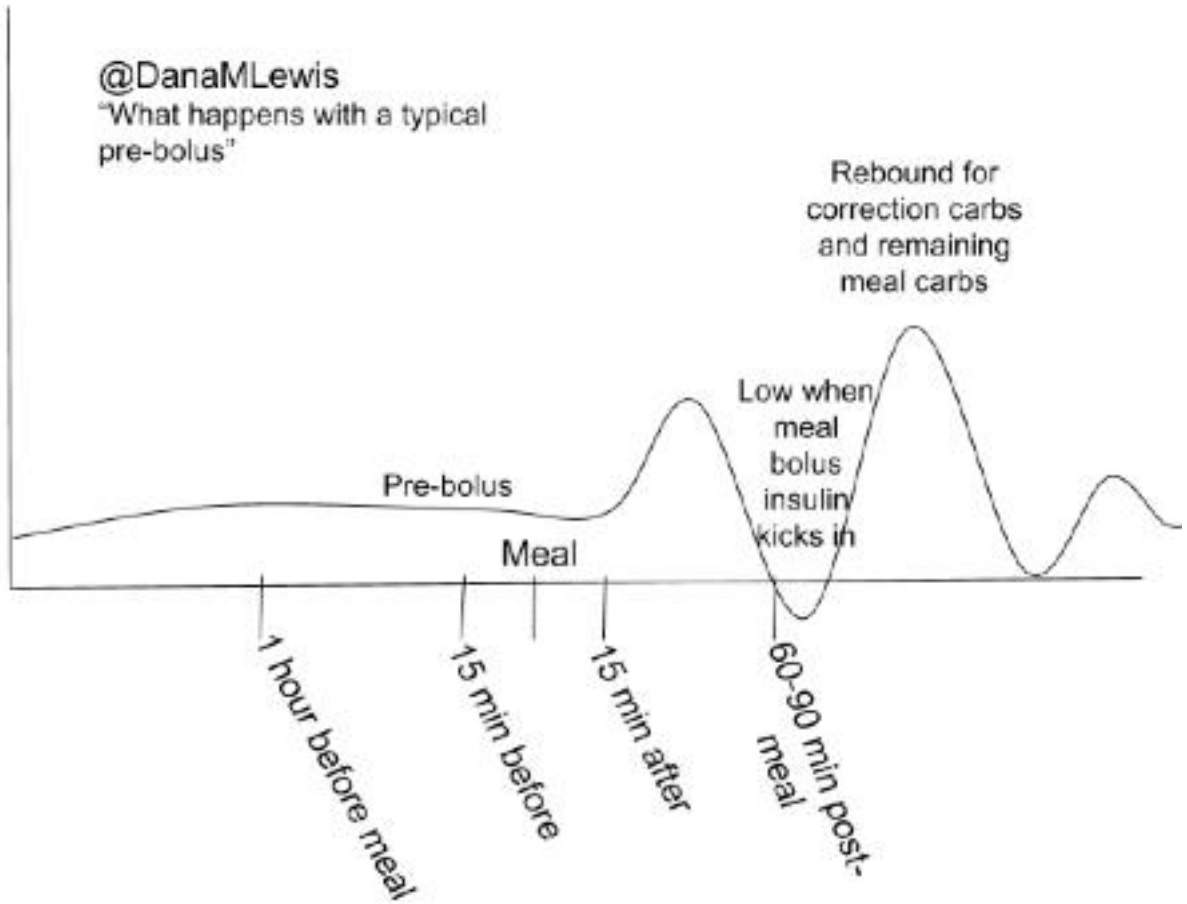
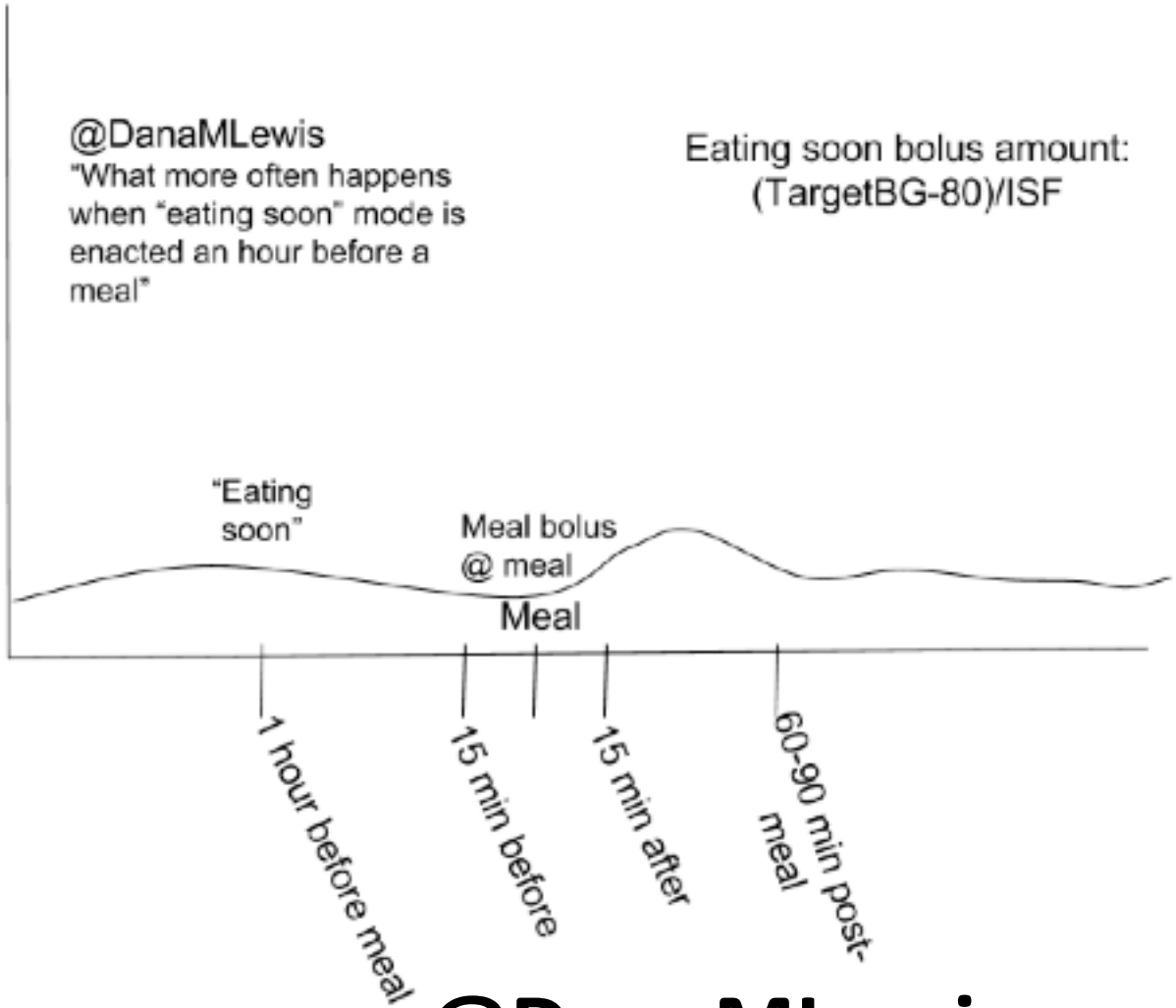
Flexibility

- User-set targets
  - Temporarily adjustable from device of choice
- Monitoring and data entry from device of choice
  - Both local monitoring and remote monitoring abilities
- Regular iteration & improvements in algorithms
  - New features developed, tested, used in cycle of weeks or months, not years
- Scratch your own itch
  - Design things to be the way you want them

”eating soon” mode:





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Parameter	Current	Autotune	
ISF	40.000	46.790	←ISF recommended to be adjusted up because more sensitive
CSF	n/a	4.029	
Carb Ratio	10.000	11.613	←Carb ratio recommended to be adjusted up
Basal Profile			
00:00	1.150	1.112	←Basal close enough
00:30			
01:00		0.999	
01:30			
02:00		1.045	
02:30	1		←Basal close enough
03:00		0.958	
03:30			
04:00		0.981	
04:30	0.85		
05:00		0.848	
05:30			
06:00		0.807	
06:30			
07:00		0.834	
07:30	1		←Morning basal probably should be lowered or shifted later
08:00		0.858	
08:30			
09:00		0.878	
09:30	1.3		←Another morning basal probably should be lowered or shifted later
10:00		1.134	
10:30			
11:00		1.280	
11:30			
12:00		1.315	
12:30			
13:00	1.050	1.084	←Basal close enough
13:30			
14:00		1.066	
14:30			
15:00	0.900	0.933	←Basal close enough
15:30			
16:00		0.930	
16:30			
17:00	1.200	1.216	←Basal close enough
17:30			
18:00		1.195	
18:30			
19:00		1.148	
19:30			
20:00		1.153	
20:30			
21:00		1.162	
21:30	1.3		←Basal close enough
22:00		1.336	
22:30			
23:00		1.284	
23:30			

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Meet "Autotune"

("tune" basal rates, ISF, and carb ratio)

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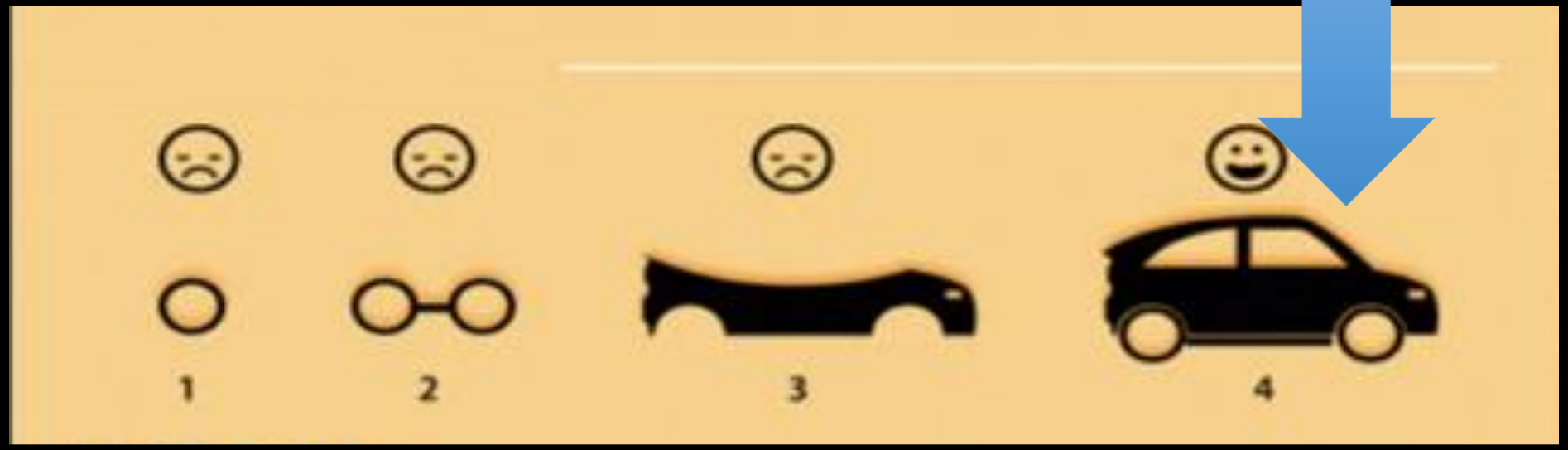
Traditional innovation



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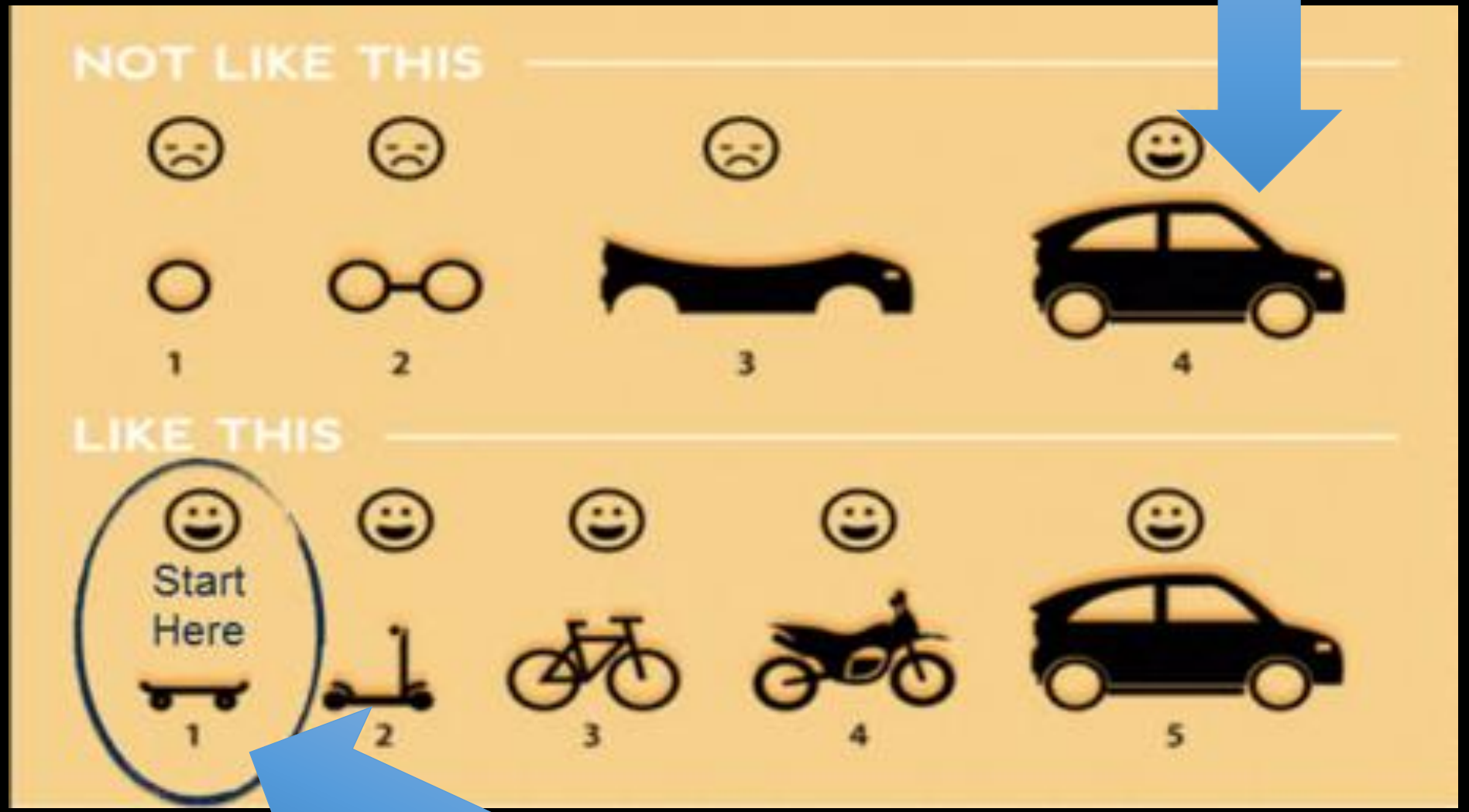
Traditional innovation



User-driven innovation

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(It's not "rocket science")

```
28
29  if (predBG < min) { // low-temp for 30m (to zero or as required to get predBG up to min)
30      var rate = Math.max(0, $basal-2*(min-predBG)/isf); // calculate required low-temp rate
31      var duration = 30; // always set temps to the minimum duration supported by the pump
32      if (! typeof currentTempRate === 'undefined' && rate < currentTempRate) {
33          setTemp(rate, duration);
34      }
35  } else if (predBG < target) { //cancel any high-temp; let any low-temp run
36      if (! typeof currentTempRate === 'undefined' && currentTempRate > basal) {
37          setTemp(0, 0); // cancel temp
38      }
39  } else if (predBG > max) { // high-temp as required to get predBG down to max (up to basal+highTempMax U/hr)
40      var rate = $basal + Math.min(highTempMax,2*(predBG-max)/isf)
41      if (! typeof currentTempRate === 'undefined' && rate > currentTempRate && iob < maxIOB) {
42          setTemp(rate, duration);
43      }
44  } else if (predBG > target) { //cancel any low-temp; let any high-temp run
45      if (! typeof currentTempRate === 'undefined' && currentTempRate < basal) {
46          setTemp(0, 0); // cancel temp
47      }
48  }
```

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1. You don’t know what you can do until you try.

2. Anything is better than nothing.

3. “Pay it forward” is a powerful magnifier.

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#WeAreNotWaiting

(because we don't have to - we now have a choice)

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