

# **Diabetes Technology Update: Advancement in glucose monitoring & insulin Delivery**

**Abdulmoein Eid Al-Agha, MBBS, FRCPCH  
Professor of Pediatric Endocrinology,  
King Abdulaziz University Hospital**

# Highlights

- Non-invasive glucose monitoring
- Insulin Pumps
  - Evolution of insulin pumps
  - Present smart Pumps
  - Future of pumps
- Artificial Pancreas (closed Loop)

# Glucose Monitoring Invasive Vs Non - Invasive

# Glucose Monitoring : History

From appearance, color, sediment and often taste



Clinitest was introduced by Ames in 1945, and utilised a copper reagent tablet that contained all the reagents required for a urine glucose test.

In 1954 Glucotest/Testape roll



1960's the "dipstix"



# Glucose Monitoring – old time!

## First Glucose Meter



# Current various glucometers

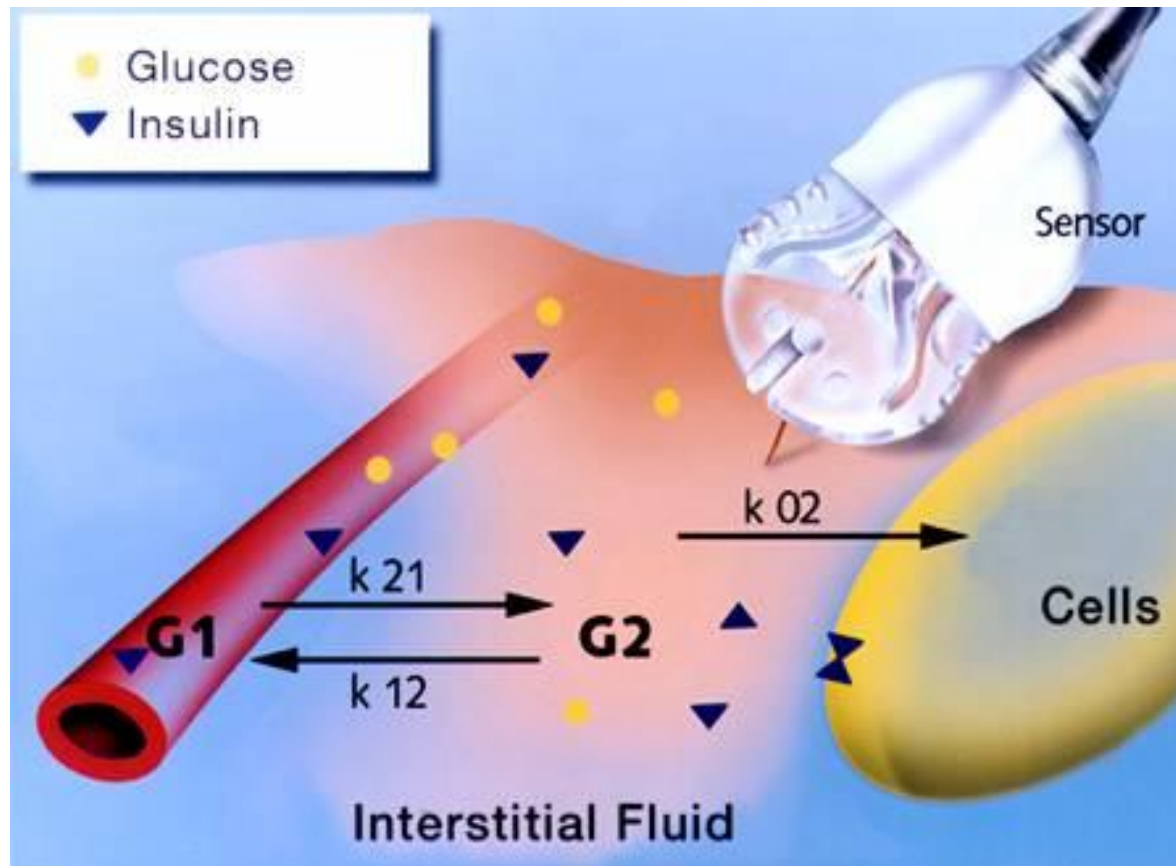




# Non invasive Glucose Monitoring

- Non invasive sensors ,use a plastic needle containing a sensor inserted into the subcutaneous
- Enzymatic sensors using **Glucose Oxidase** are the currently used sensing systems
- Various types/ various companies
- They are replaced every 7 days and require calibration 2-3 times daily with SMBG
- FGMS (free style – Libre) by Abbott , not continuous but has advantages of 14 days sensor and no calibration, with cheapest price among all other non invasive sensors

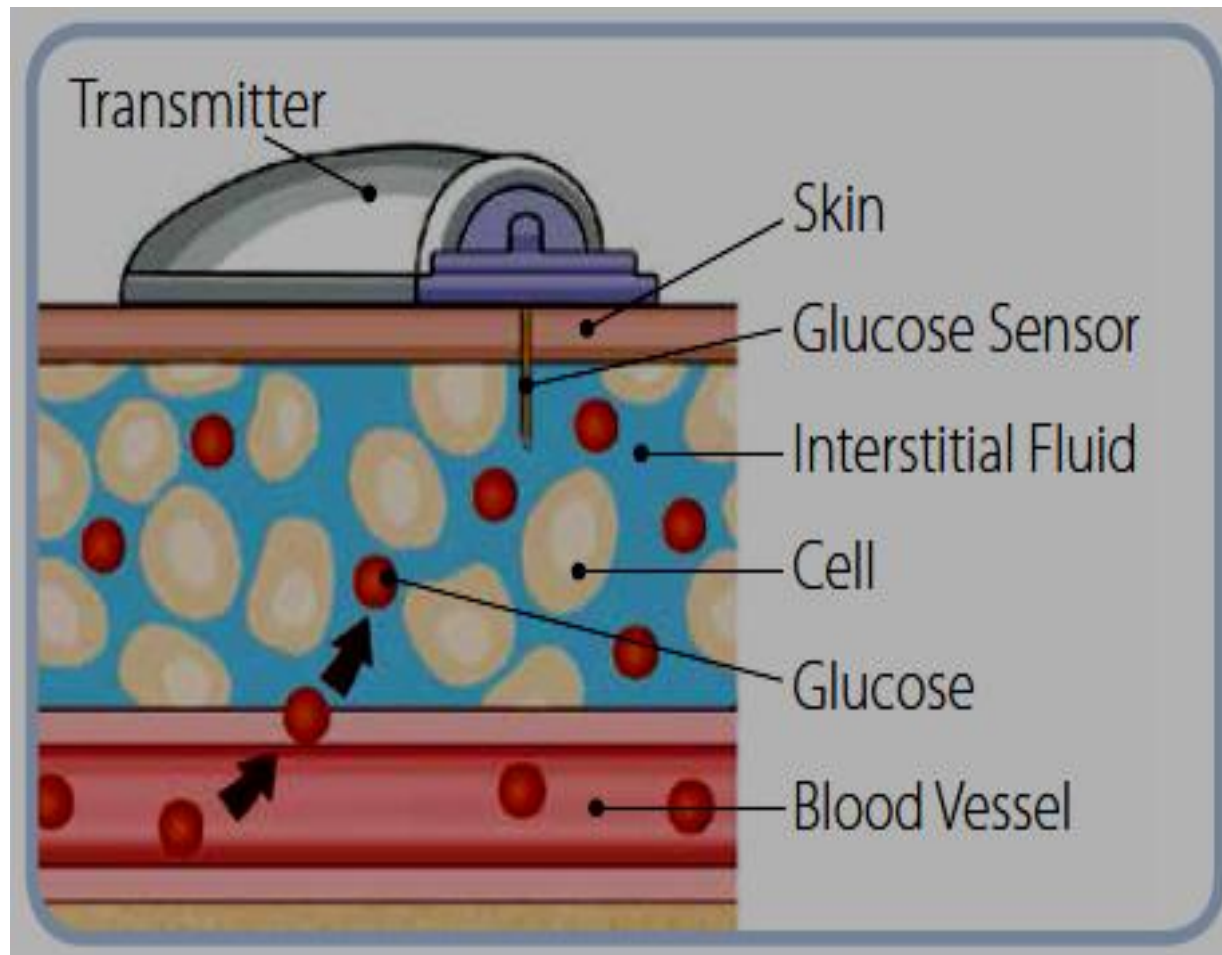
# Interstitial Fluid Glucose Measurement



Interstitial fluid glucose ( $G_2$ ) is almost always comparable with blood glucose ( $G_1$ )



- CGM Measures Interstitial Glucose Interstitial glucose is related to capillary glucose, however CGM values usually lag behind blood glucose.
- There is a physiologic delay associated with the transfer of glucose from the blood to the interstitial compartments .

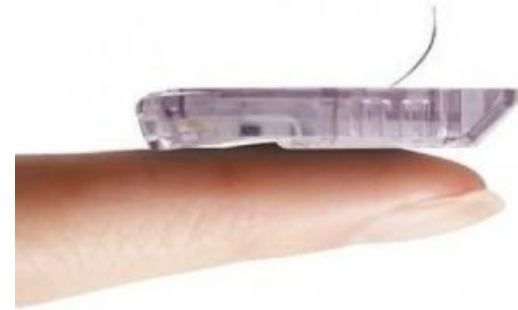


# CGM Provides More Information than SMBG

- Up to 288 readings per day with No pain
- Glucose trends/arrow systems
- Alerts and alarms with low and high
- Remote monitoring

# CGMS Parts

- Sensors



- Transmitters



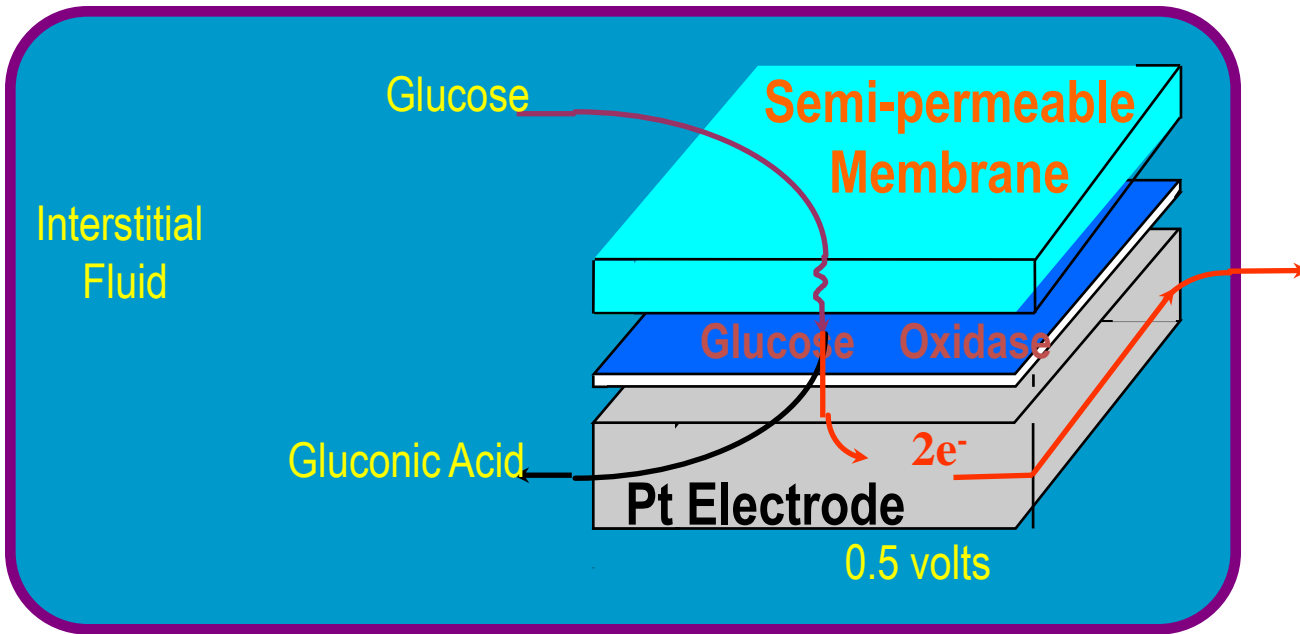
- Receivers



- Inserters



# Needle-type Subcutaneous Glucose Sensor



To Monitor



**CGMS<sup>®</sup>, Medtronic**



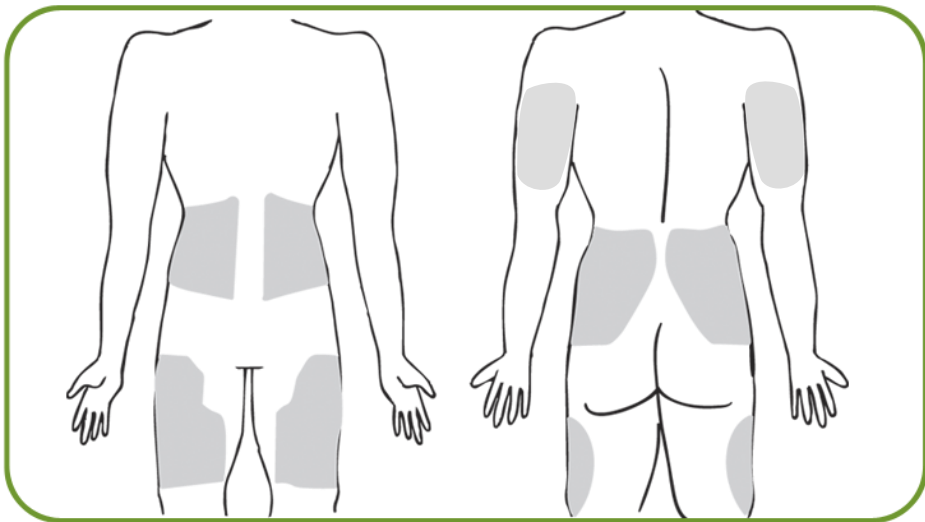
**Guardian RT<sup>®</sup>, Medtronic**



**STS<sup>®</sup>, DexCom**

# Sensor Sites

- Change every 6-7 days, per manufacturer guidelines
- Adhesive wipes (Skin Tac, IV Prep) and tapes (Tegaderm, IV 3000) may be helpful to keep the sites
- For pain with insertion, try numbing with EMLA/Lidocaine cream or the Synera patch – ask MD/NP for prescription



# The first Glucose Sensors

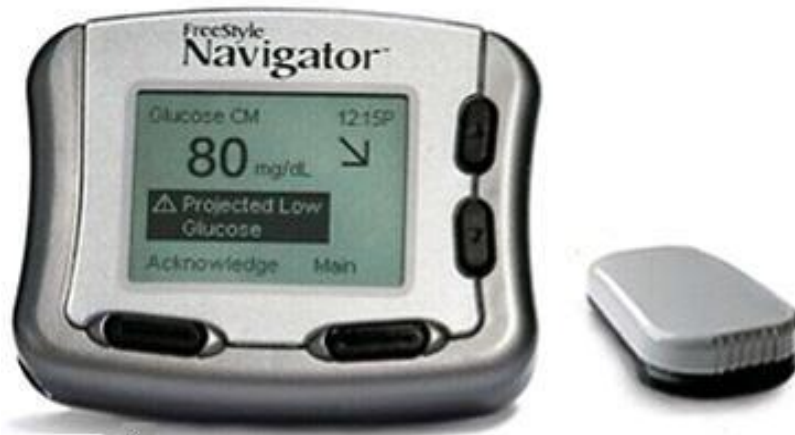
Glucowatch Biographer  
FDA approval 2001 -2007  
Reverse iontophoresis  
Cyngnus/Animas



CGM Gold  
Enzyme tipped catheter  
1999



Freestyle navigator  
2008 -2011



Medtronic Guardian  
Real time  
2004



Dexcom STS 2006



Dexcom STS 7 Continuous Glucose Monitor Sensor and Receiver.  
Courtesy of Dexcom.



# Availability of various CGMS



Welcome, Bill Davis.  
There is new data and reports for you.  
[Add a new logbook entry](#)  
07/25/2013 - 07/31/2013

Dave, 6ft  
Your last visit was on 07/01/2013  
21:00  
Last updated data on 07/31/2013 20:33



Hypo

**2** 14% of your blood glucose values are below hypo limit.  
Target bar for all BG values.

Before meal BG

**2** above target. 22% of your before meal blood glucose values are above target.

After meal BG

**3** above target. 80% of your after meal blood glucose values are above target.

# Glucose Sensors & Blue-tooth communications



# Glucose Sensors & Blue-tooth communications

- Receiver s could share blue-tooth capability built-in so no need to have a cable and phone attached to receiver
- Must have iPhone, iPod touch, or iPad with internet connection close to receiver





### Trend Graphs

Shows the effect of diet, exercise, medication and lifestyle on glucose levels.

### Alarms

Protect patients by warning of low and high glucose levels.

### Continuous Readings

Help patients take action sooner  
Up to 288 glucose readings per day, every 5 minutes, 24 hours a day

### Trend Arrows

Point up or down to show the direction and rate of change in glucose levels

### Glucose Sensor

Up to 3-day of continuous use.

### Wireless Transmitter

Small, discreet and waterproof



# Guardian Connect (Stand-alone CGM system) Medtronic

- No receiver; display device is iOS phone
- Predictive Alert Schedules
- 10-60 minute prediction of hypo-/ hyperglycemia based on threshold settings
- Calibration at least once every 12 hours (4x/day recommended)
- 7 day sensor use
- Acetaminophen sensitive
- Approved for 18 and older



# Dexcom G5 CGM System: Sensor and Transmitter

- Stand alone CGM system
- Display devices = Receiver and/or Android or iOS smart devices
- Calibration once every 12 hours
- Confirmatory finger sticks when:
  - Symptoms do not match
  - No CGM number and arrow
  - Taking acetaminophen
  - More than 2 mg/dL/min ROC
- Remote monitoring
- 7 day wear
- Approved for 2 years and older

# Dexcom Share and Dexcom G5



The Dexcom G4 PLATINUM System with Share and the  
Dexcom G5 are available in the US only

- Dexcom receiver that has Share blue-tooth capability built-in so you will not have to have a cable and phone attached to receiver
- Must have iPhone, iPod touch, or iPad with internet connection close to Dexcom receiver
- Dexcom Share app
- Real-time data available to 5 users on their iPhone, iPad or iPod touch



# Dexcom G6 system

- No Calibration Required
- 10 Day Session Duration
- Cannot Restart Sensor Session
- Acetaminophen blocking Intended For Use for Ages 2 and Older
- Applicator: Less Painful, Simple, Push Button Sensor Applicator Tiny Insertion Needle (26G)
- Transmitter: 30% Thinner
- Direct Transmission of CGM data to Receiver & Mobile Device
- Receiver: Touch screen
- Apps : New Dexcom G6 App

# Abbott Freestyle Navigator®



# Freestyle Libre Pro

- Professional CGM
- No calibration
- Reasonable price in comparison to other sensors
- 14 days of data



# Limitations of CGMS

- Interference with glucose readings by sensor can occur with certain substances
  - i.e. glutathione, ascorbic acid, uric acid, salicylates
- Lag-time for up to 15 minutes when glucose changes rapidly
- **(MARD = mean average reading deviations)**
  - Overall percentage of error – near 15%
  - Guardian REAL-Time – 17%
  - DexCom - 11-16%
  - Navigator 12-14%



# Sensor Glucose vs. Meter Glucose mean absolute relative difference (MARD)

- **Meter MARD**

- FreeStyle Lite 4.9%
- FreeStyle Freedom Lite 5.5%
- Accu-Chek Aviva 6.8%
- Contour 9.0%
- OneTouch UltraEasy 9.7%

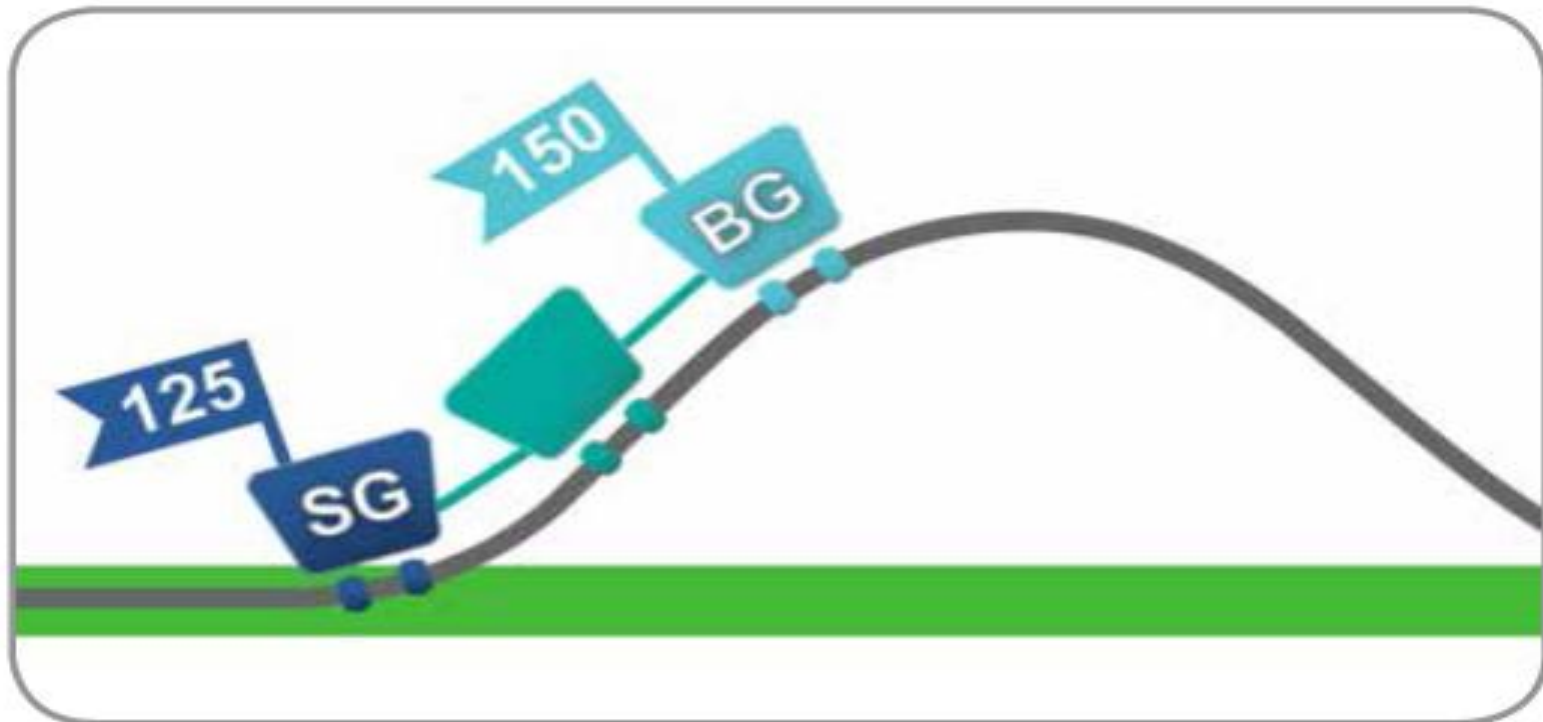
- **Sensor MARD**

- Dexcom <10%
- Enlite 2 13-17%

J Diabetes Sci Technol. A comparative effectiveness analysis of three continuous glucose monitors: the Navigator, G4 Platinum, and Enlite. 2014 Jul;8(4):699-708  
Accuracy Evaluation of Five Blood Glucose Monitoring Systems Obtained from the Pharmacy: A European Multicenter Study with 453 Subjects. 2012 Apr; 14(4): 330–337

# Limitations of CGMS

- During rapid states of change, SG and BG may differ more than 20%
- The CGM needs calibrations a minimum of twice a day (once every 12 hours)



**Sensor Glucose (SG) vs. Blood Glucose(BG)**

# EVOLUTION OF INSULIN PUMP THERAPY

- The idea of continuous insulin delivery first emerged in the **early 1960s** when Dr Arnold Kadish from Los Angeles fashioned a device that would permit such insulin delivery
- This device was the **size of an army backpack** making it impractical for everyday use
- First pump employed continuous **intravenous insulin delivery**, and then by the more practical means of continuous subcutaneous insulin infusion (CSII)

# Insulin Pump Therapy: Past



# Insulin Pump Therapy: Present



Model 515



Model 715



# Patch Pumps

Cellnovo  
France & UK



(FDA approved in Jan. 2010)

Launch in 2016

200 units of insulin

Bolus only pump 1-2 units of Insulin / 0.5-5 unit boluses



Medingo Solo Roche  
(FDA approved in July 2009)



Valeritas V-Go

(FDA approved in Dec. 2010)

Preset basal rate to deliver 20, 30, or 40  
Bolus dosing in 2 Unit increments up to  
36 Units



# Current insulin pumps

## OmniPod

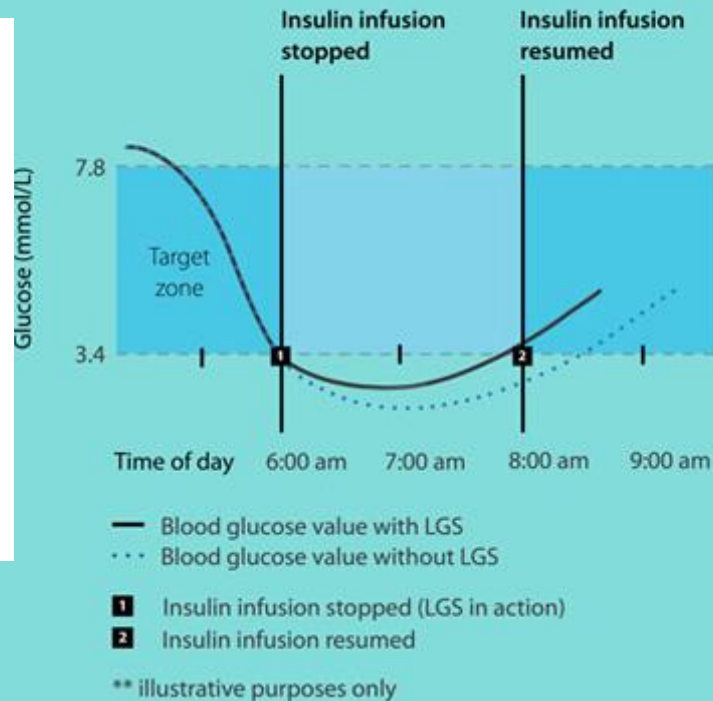


# Sensor Augmented Insulin Pumps (SAP)



Medtronic MiniMed 530G system

## The Low Glucose Suspend in Focus™

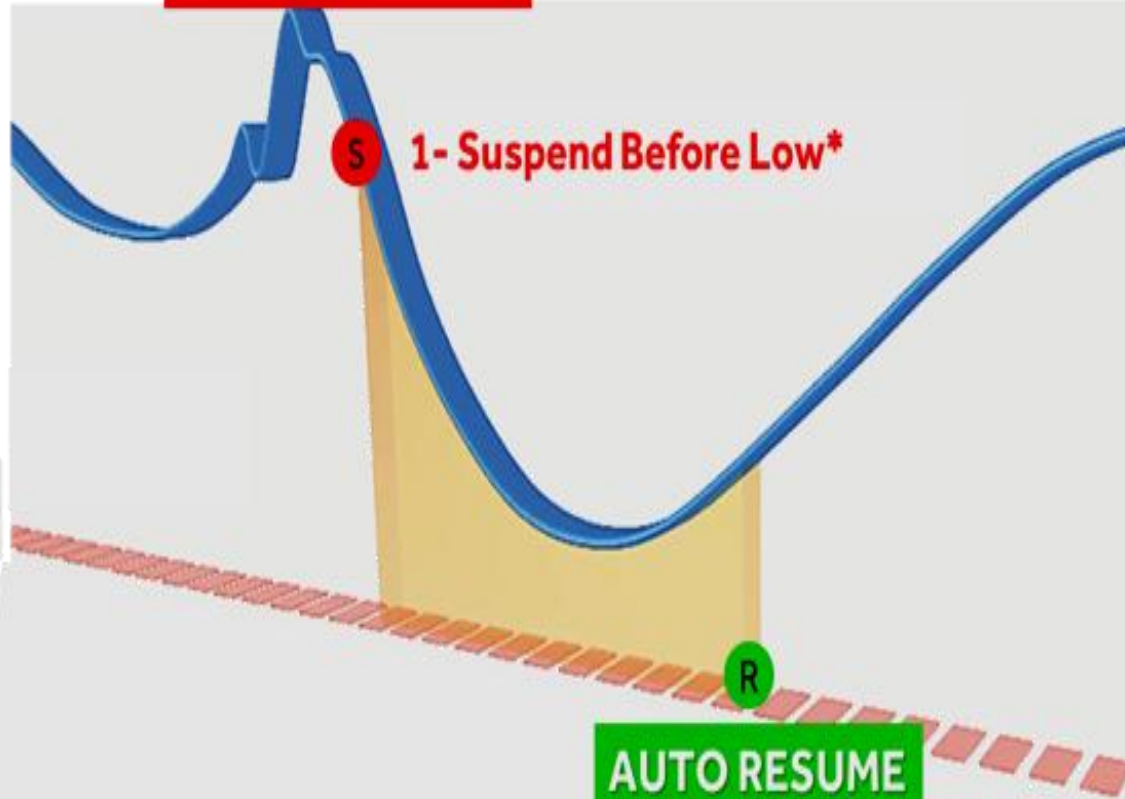


Animas Vibe system



# 'SMARTGUARD™ TECHNOLOGY PROVIDES ADVANCED PROTECTION AGAINST HYPOGLYCEMIA (AUTO SUSPENSION & AUTO-RESUME OF INSULIN)

## AUTO SUSPEND



- ✓ Auto based on SG value
- ✓ Auto based on 2 hour max



# Bionic Pancreas – the iLet Dual Chamber pump (Glucagon and Insulin Reservoir)

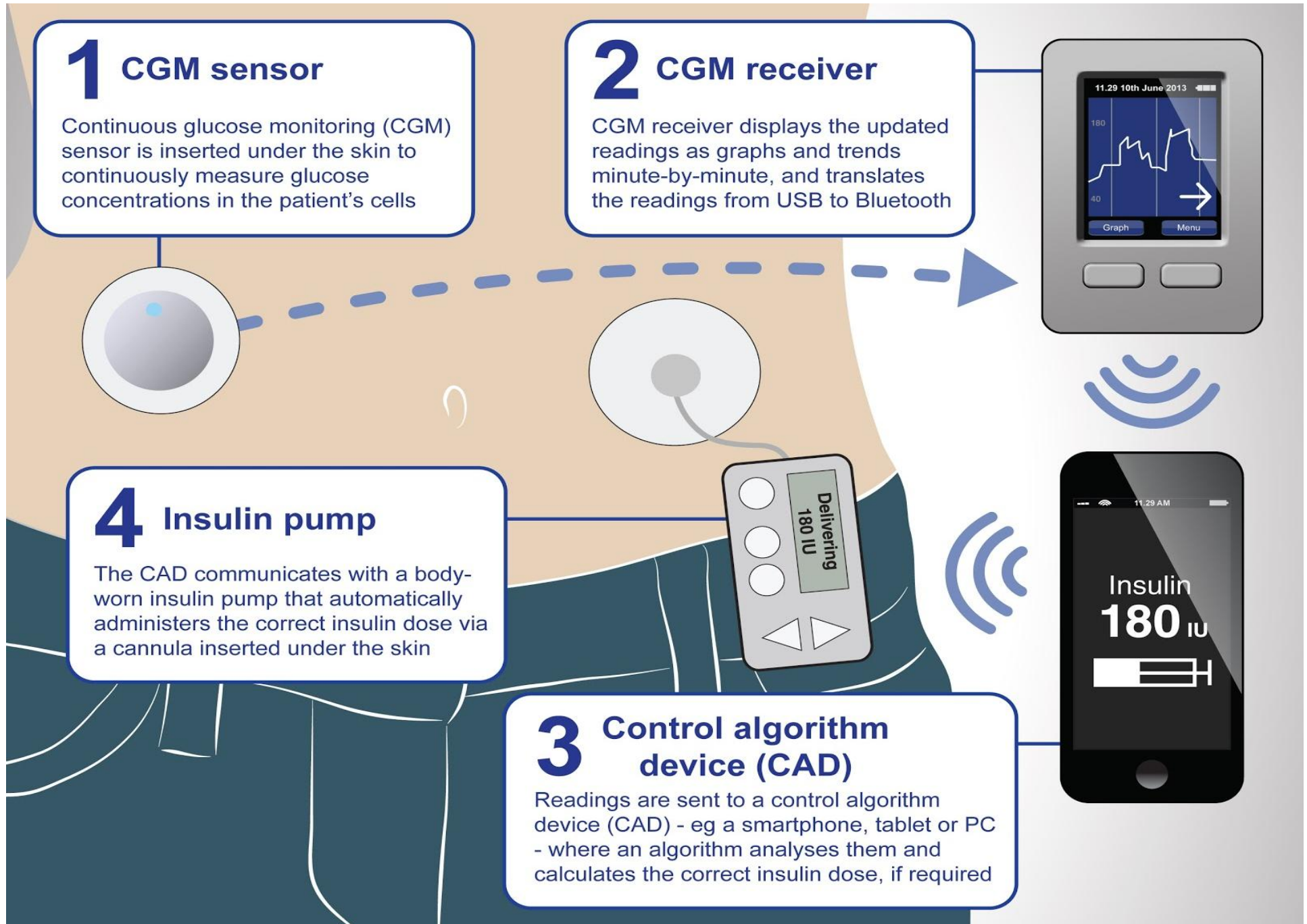


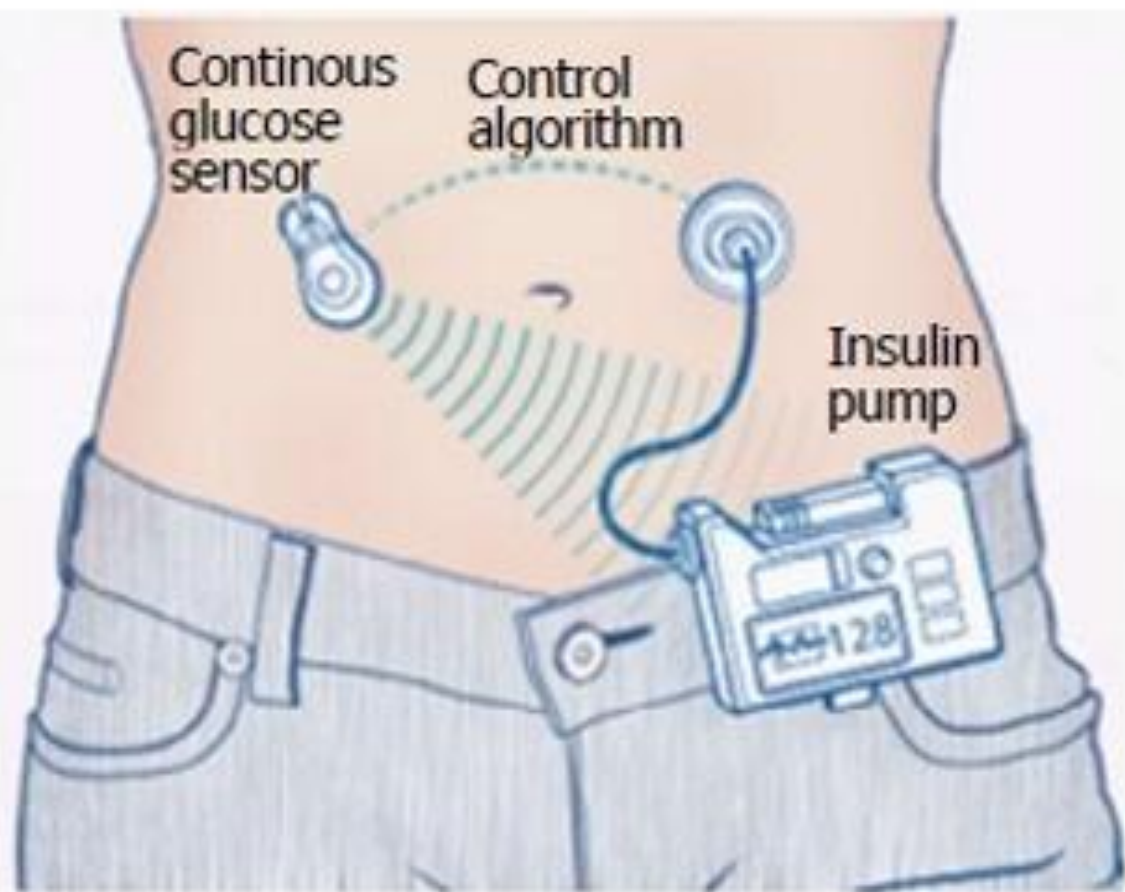
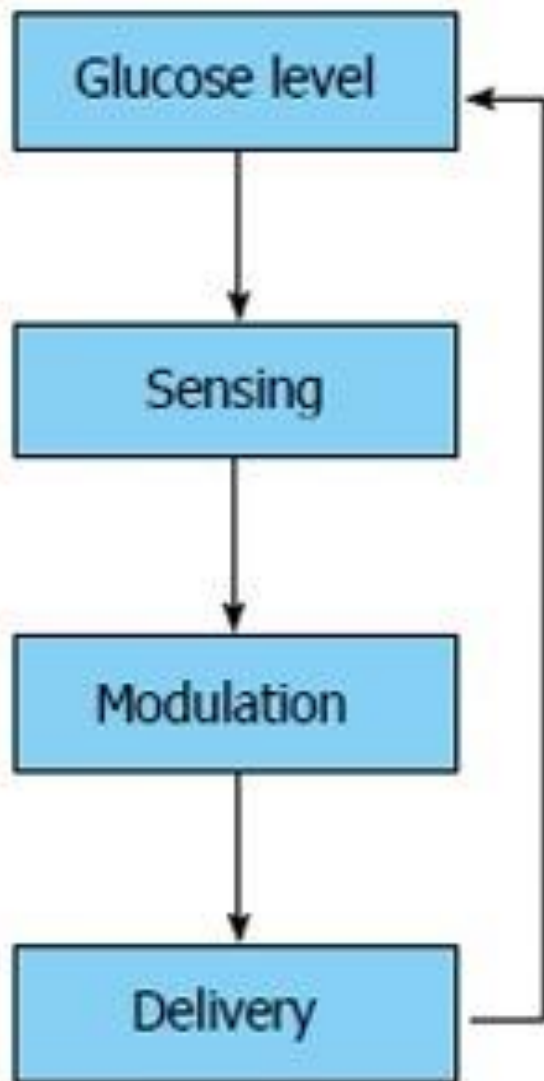


# Ilet – “Bionic Pancreas”



# Components of artificial pancreas







Breaking News: FDA Approves the MiniMed **670G**  
System, World's First Hybrid Closed Loop System  
*September 28, 2016*



# Medtronic's 670G



- “hybrid-closed loop” system with Enlite 3 CGM sensor
- Software automatically increases/decreases insulin delivery to target a blood glucose of 120 mg/dl
- Give bolus for meals
- Notify - exercise

# Medtronic's 670G

- Medtronic CGM Medtronic 670G
- Hybrid closed loop system
- Modulates insulin delivery based on sensor glucose information
- Predictive Low Glucose Suspend and Low Glucose Suspend
- Calibration at least once every 12 hours (4x/day recommended)
- 7 day sensor use
- Acetaminophen sensitive
- Approved for 14 years of age and older



# Conclusions

- Non – invasive glucose monitoring is helping all patients to monitor their glucose variability continuously and adjusting their insulin doses much better than SMBG
- SmartGuard™ Technology provides advanced protection against Hypoglycemia (Auto Suspension & auto-resume of insulin)
- FDA has Approved MiniMed 670G System, World's First Hybrid Closed Loop System in September 28, 2016 with strong hope that, further artificial pump technology will be advancing gradually to help all people with type 1 diabetes

