Sensorización en aplicaciones alimentarias: el futuro empezó ayer

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1. **¿Qué es un sensor?**
2. ¿Dónde se usan los sensores en la industria/cadena alimentaria?
3. ¿Qué sensores se usarán en el futuro?

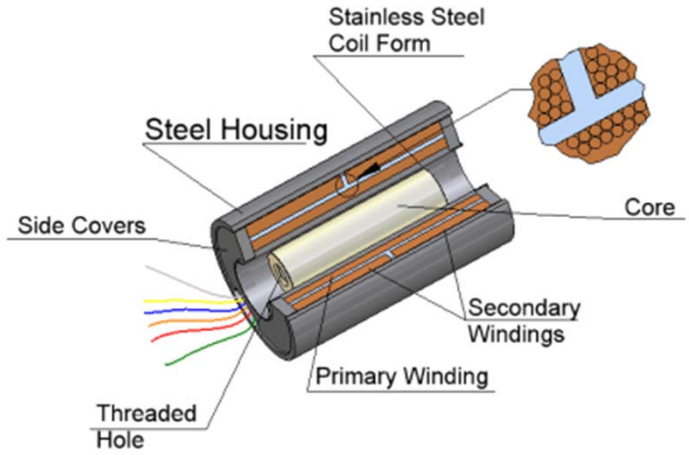
¿Qué es un sensor?

- Sensory → (To) sense→ Sensor (1958)

  Dispositivo que detecta una determinada acción externa y la transmite adecuadamente (DRAE)
- Sensor: superar la capacidad de detección (¡y percepción!) de nuestros sentidos
- Sensor **electrónico**: procesamiento de la información
- Sensor - "Transductor" de entrada

  Dispositivo que transforma el efecto de una causa física en otro tipo de señal, normalmente eléctrica (DRAE)

Evolución de los sensores: de artilugios robustos…



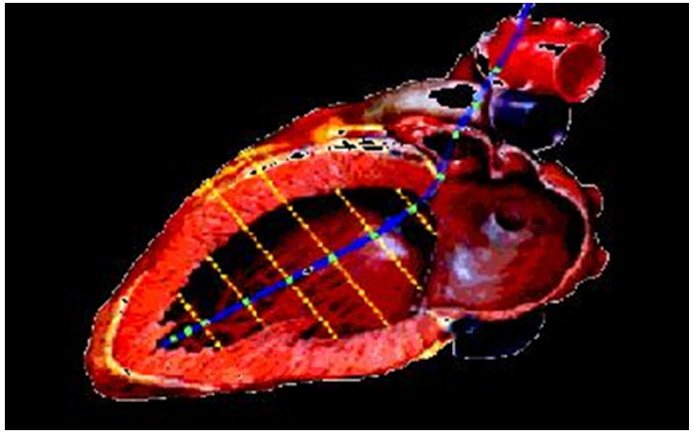
- Fabricación laboriosa
- Voluminosos
- Pesados
- Instalación y mantenimiento caros

…para el control de procesos

…a sensores para **aplicaciones específicas**…

- Industriales

- Médicas



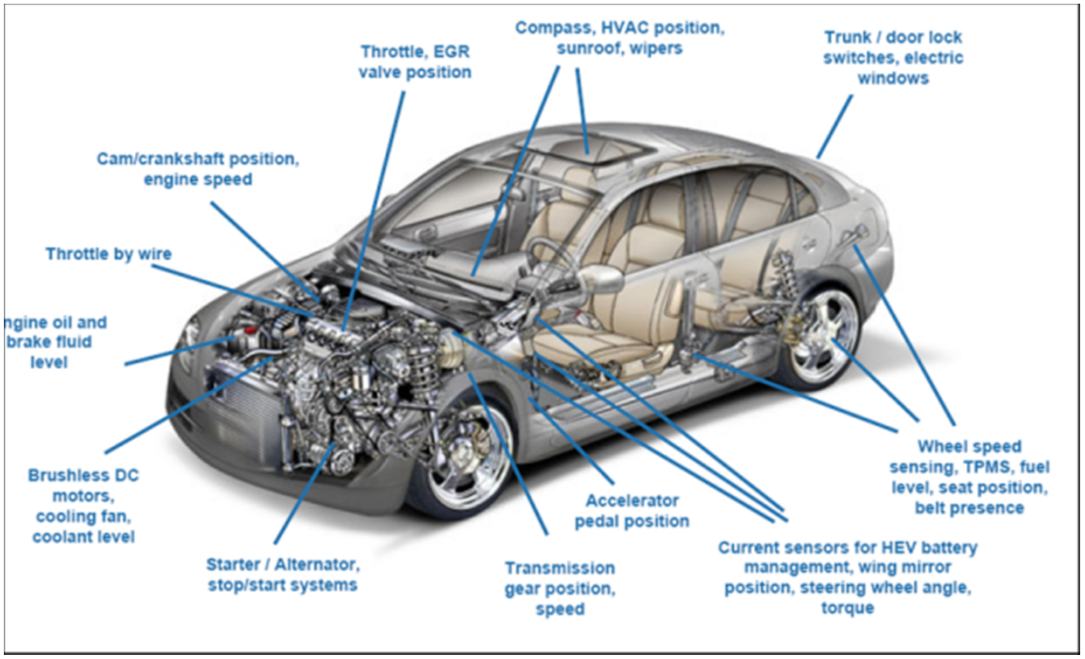
...y sensores **instalados** en <u>productos</u> y <u>embalajes</u>

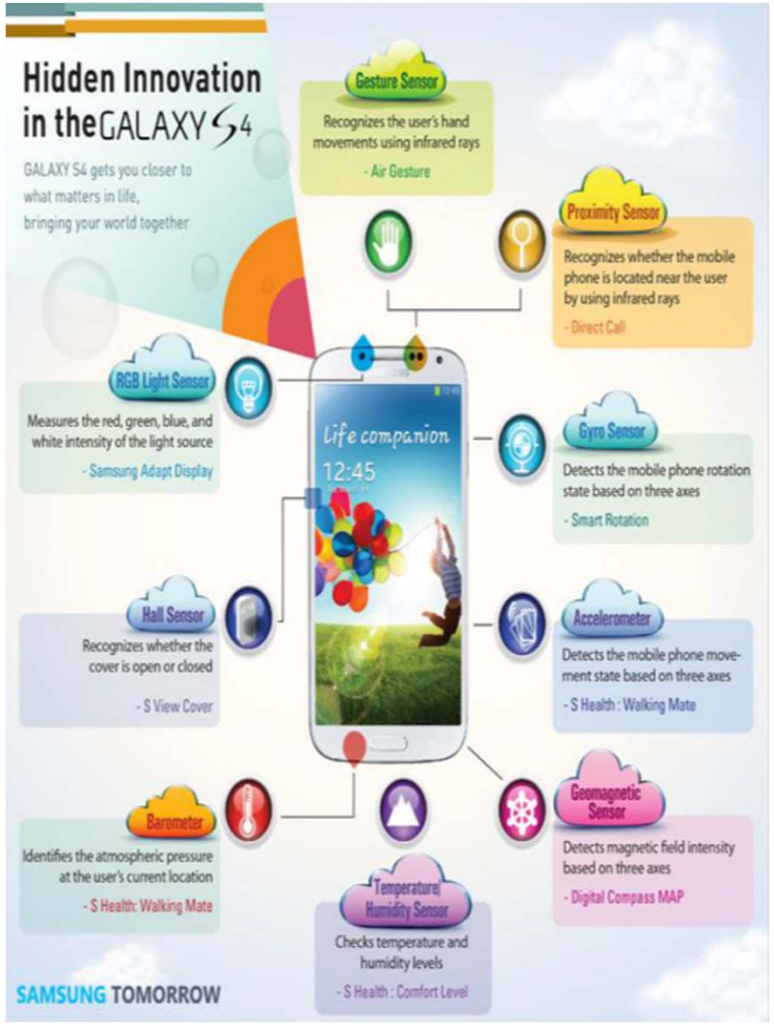
60 ~ 100

15 ~ 20

¡Hay sensores por doquier!

Sensors in cars & mobile phones





¿Cómo funcionan los sensores?

1. **Sensores basados en materiales**: conductores, semiconductores, aislantes, dieléctricos, magnéticos, **biológicos**
2. **Sensores basados en cambios de geometría/posición** (Desplazamientos lineales o angulares)
3. **Sensores basados en radiaciones** (emisión, absorción, reflexión)

¿Qué incluye un "sensor"/sonda?

1. Dispositivo **sensor** → exactitud, sensibilidad, especificidad
2. **Encapsulado**: acceso a la magnitud y protección → ensamblado, factor de forma: Protección IP, CIP, SIP, higiene
3. **Interfaz** física/química → fiabilidad, usabilidad
4. Interfaz **electrónica** → coste, restricciones

+ Instalación, mantenimiento, sustitución…

Example: organic polymer sensors

PVdF (1969)

- Hydrophones
- Tactile sensors
- Switches
- Infrared detectors

Conductive force sensor:

FlexiForce®

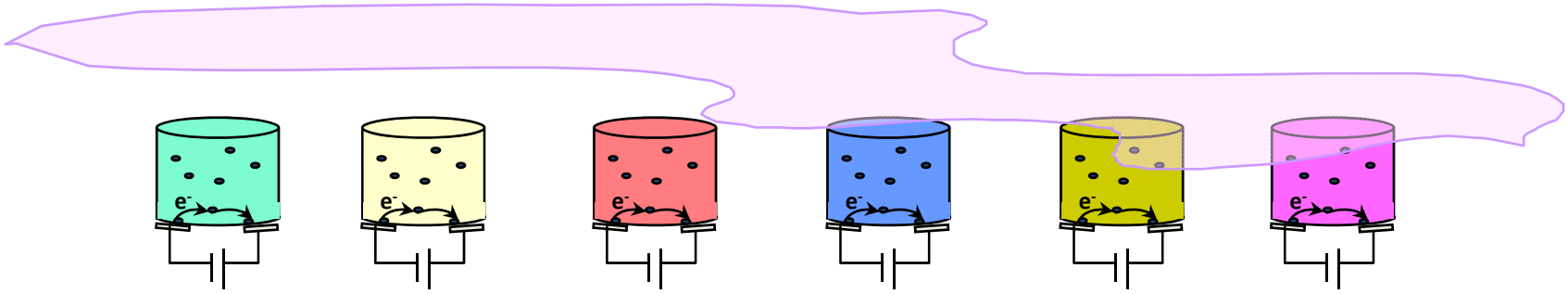
Circular touchpad
(iPod®, 2003)

Example: e-nose

BASELINE RESISTANCE

All polymer films on a set of electrodes (sensors) start out at their *baseline resistance* R_0

No change in the air composition → the films stay at R_0



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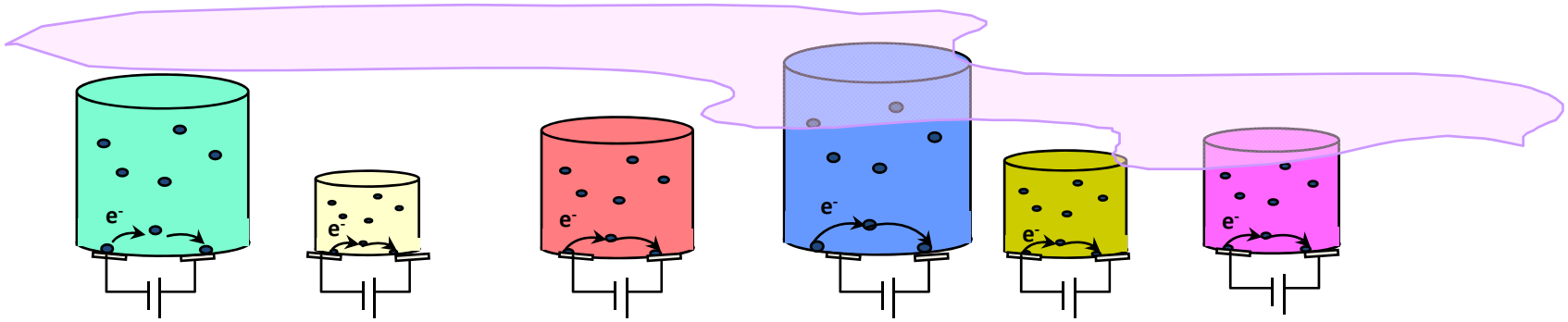
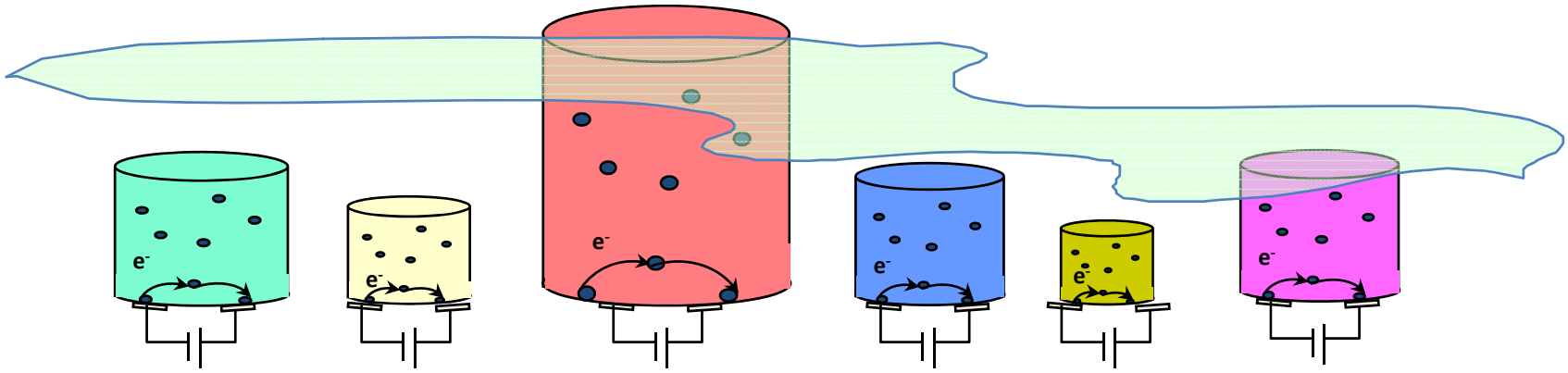
THE ELECTRONIC NOSE SMELLS SOMETHING

Each polymer changes its size hence its resistance by a different amount, making a **pattern** of the change



If a different compound had caused the air to change, the **pattern** of the polymer films' change would have been different:



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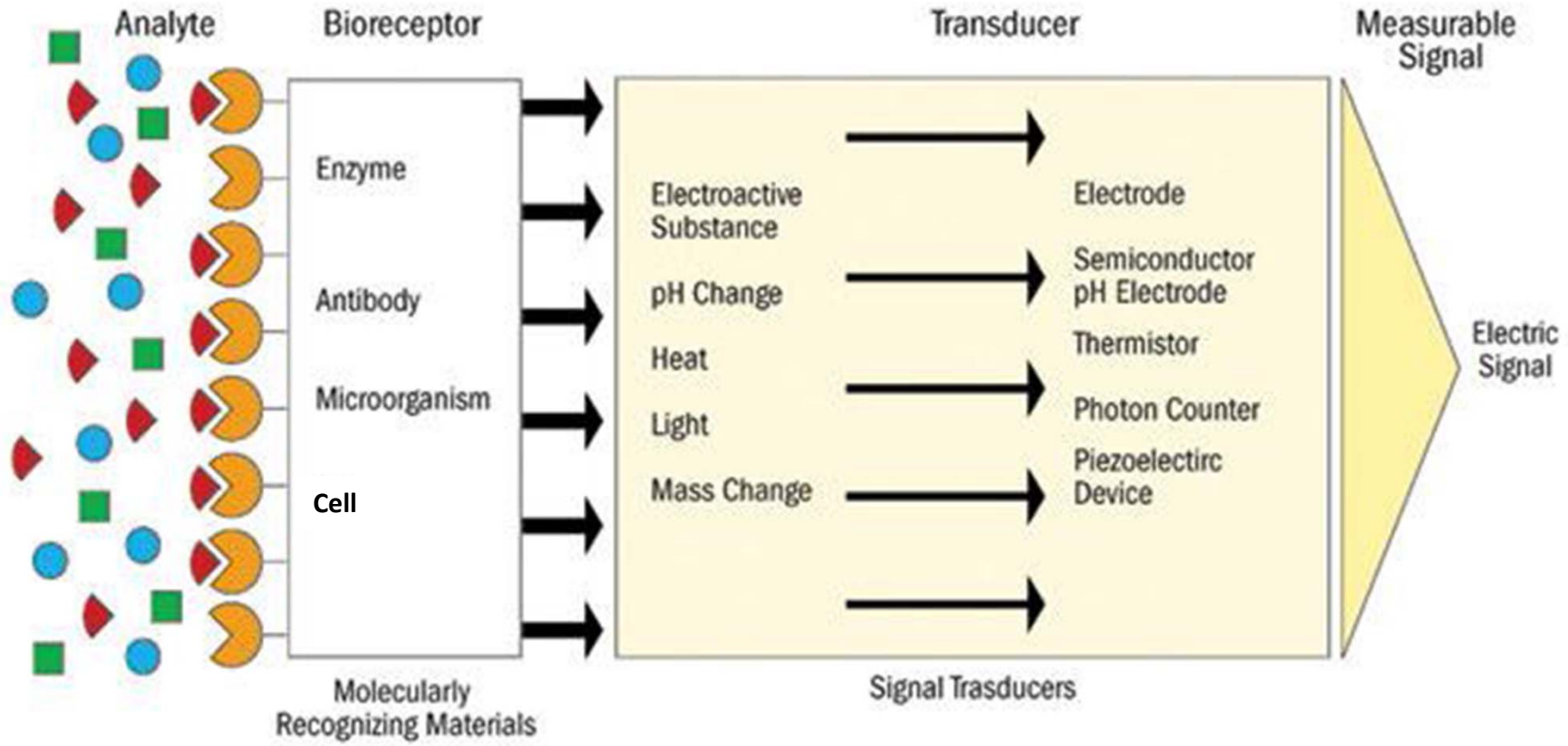
Example: Biosensors



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Measurement aims

1. **Monitoring**
   - Ambient temperature
2. **Control**: keep one or more parameters inside a given range → measurement + action
   - Temperature in a freezer
   - Process management: productivity (waste!), condition monitoring
   - Consumer expectations: nutritive, safe, pleasant
   - Legal requirements: traceability, safety, hygiene
3. **Experimental engineering**
   - Temperature distribution inside heterogeneous mass

Temperature in wine fermentation

Experimental tank 2000 L

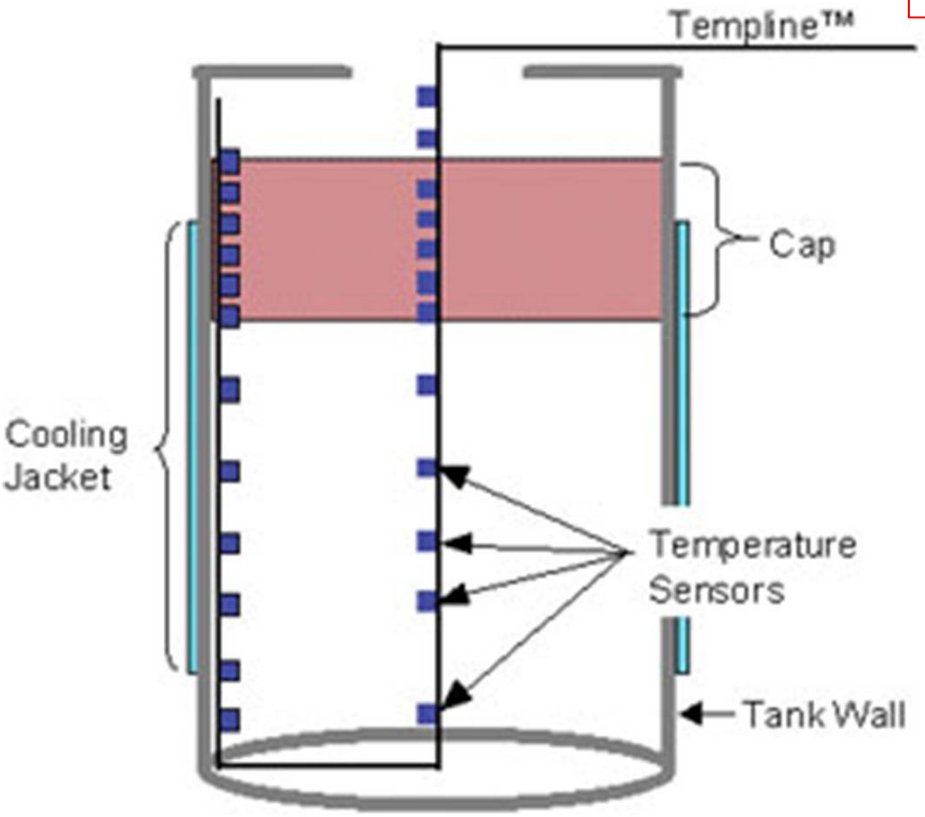
24 sensors

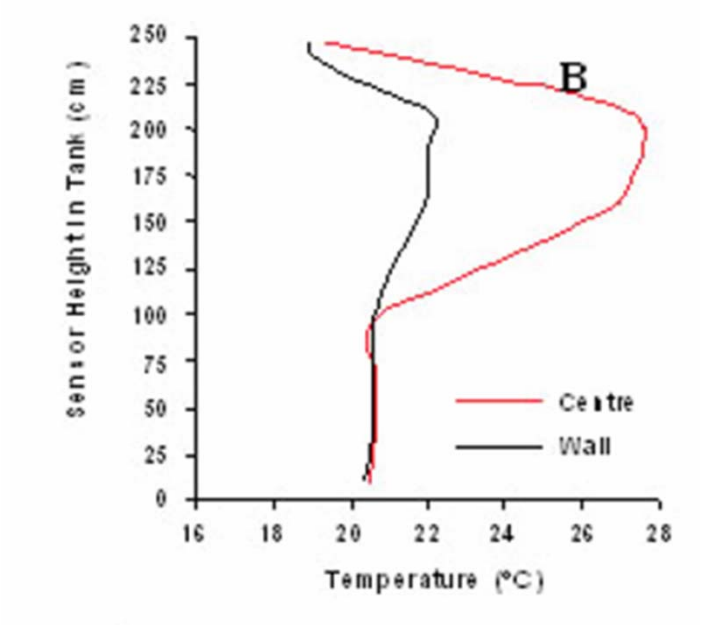
T measured each minute

ΔT = 9 °C $\Rightarrow$ t_{ferm} reduced by 2

But: *T* > 30-35 °C stops fermentation

T > 24 °C aroma molecules evaporate

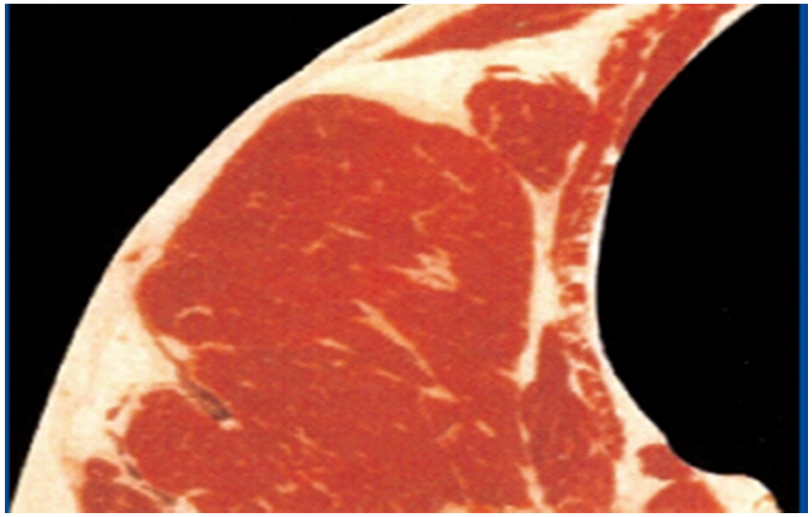




"Continuous temperature monitoring during red wine fermentation," *Australian and New Zealand Wine Industry Journal*, May-June 2006, Vol. 21 No. 3, pp. 26-30.

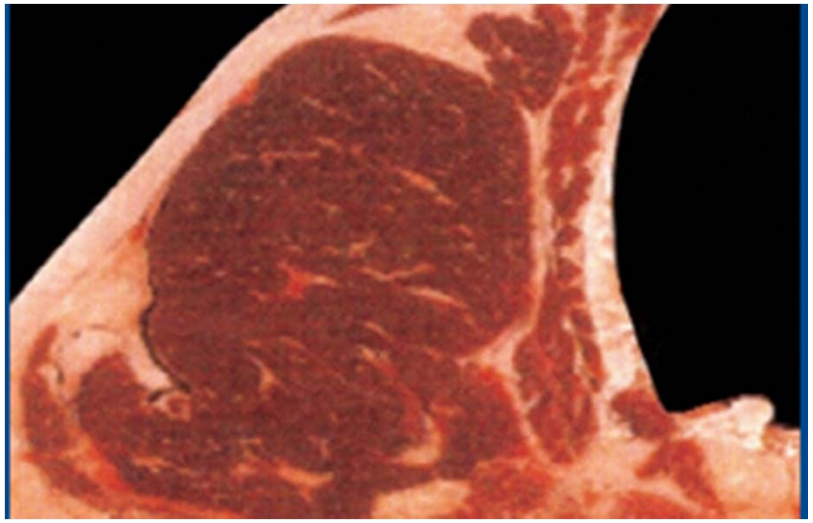
Meat quality

Normal beef lean color

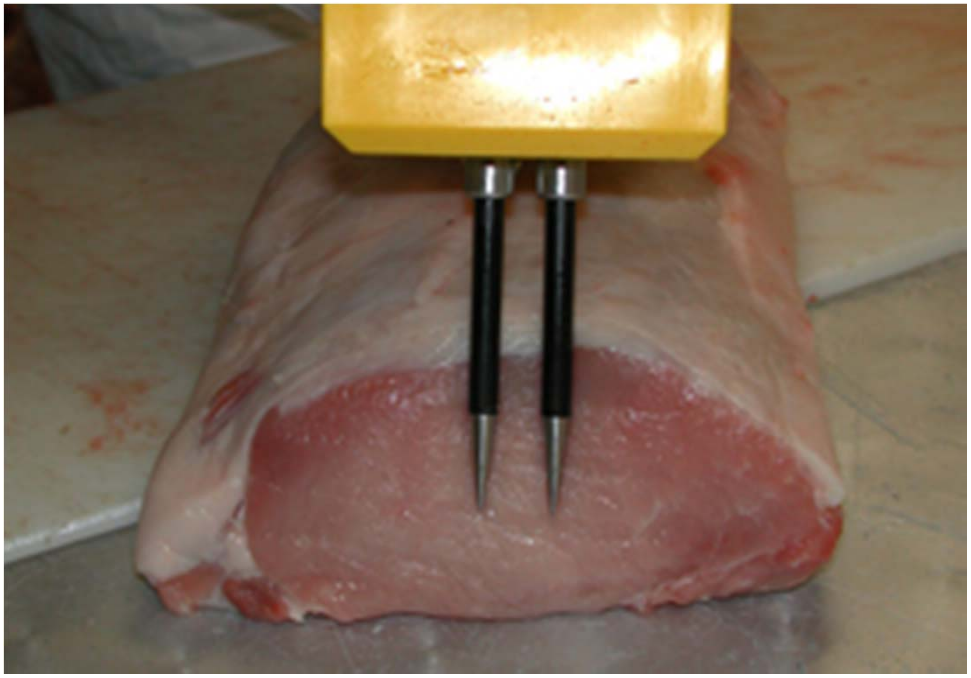


DFD beef lean color

DFD: Dark, Firm and Dry



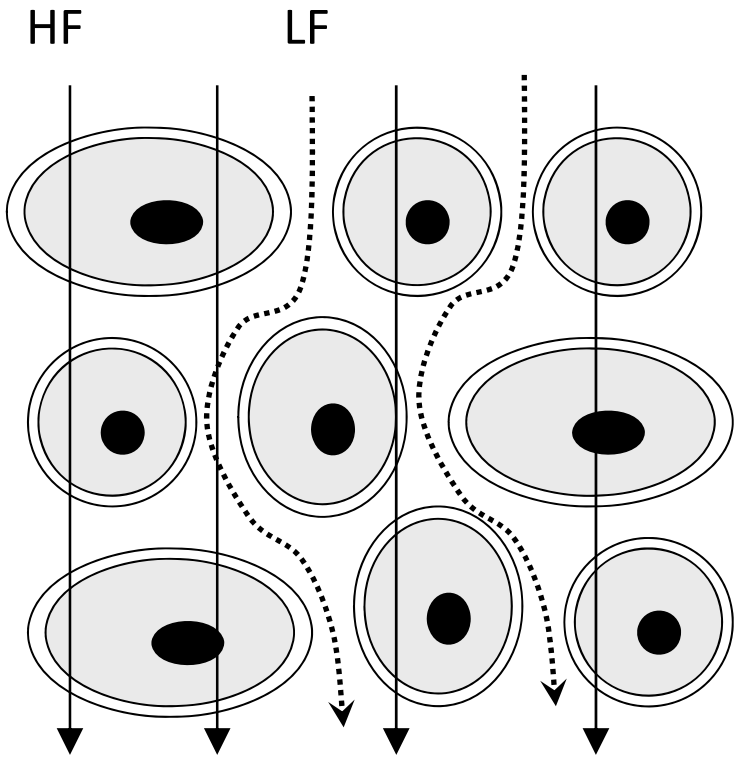
PSE meat vs. DFD meat

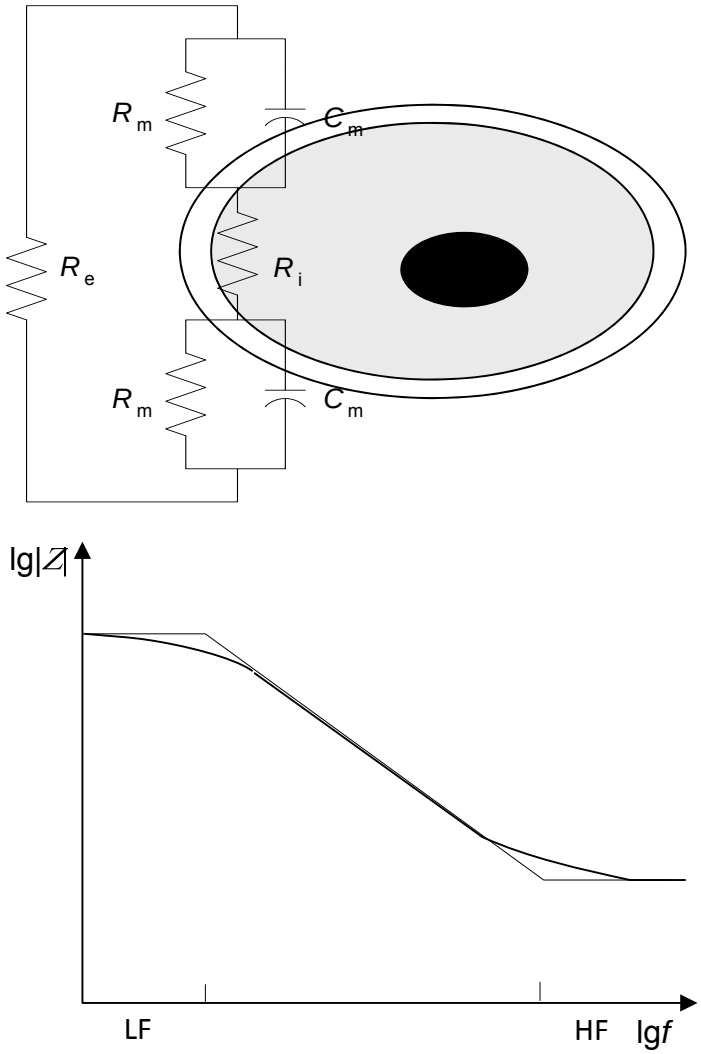


LF-STAR (Mathaus):

- PSE meat: high σ
- DFD meat: low σ

Electrical impedance spectroscopy

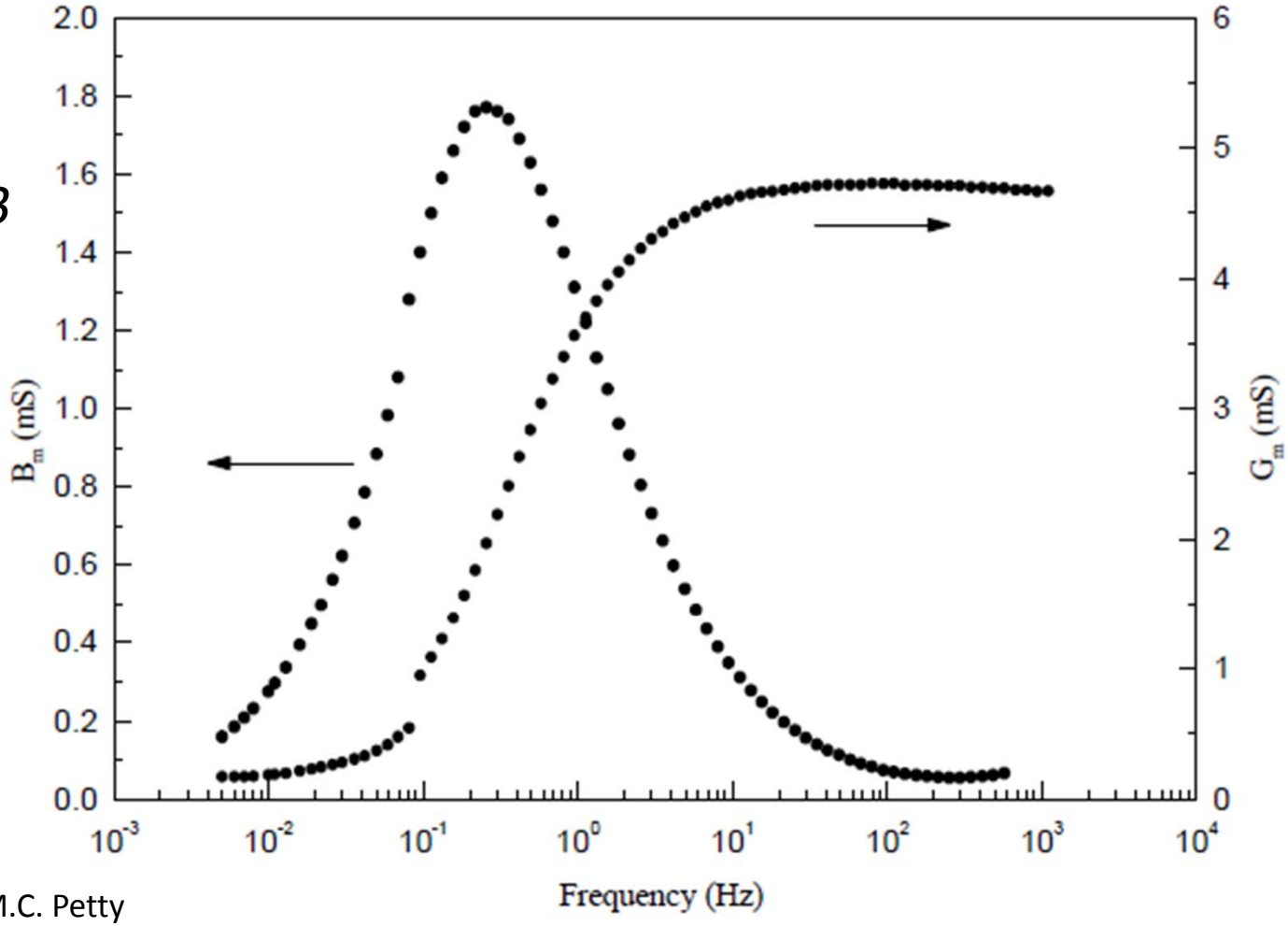




Milk conductance

$Z = R + jX$

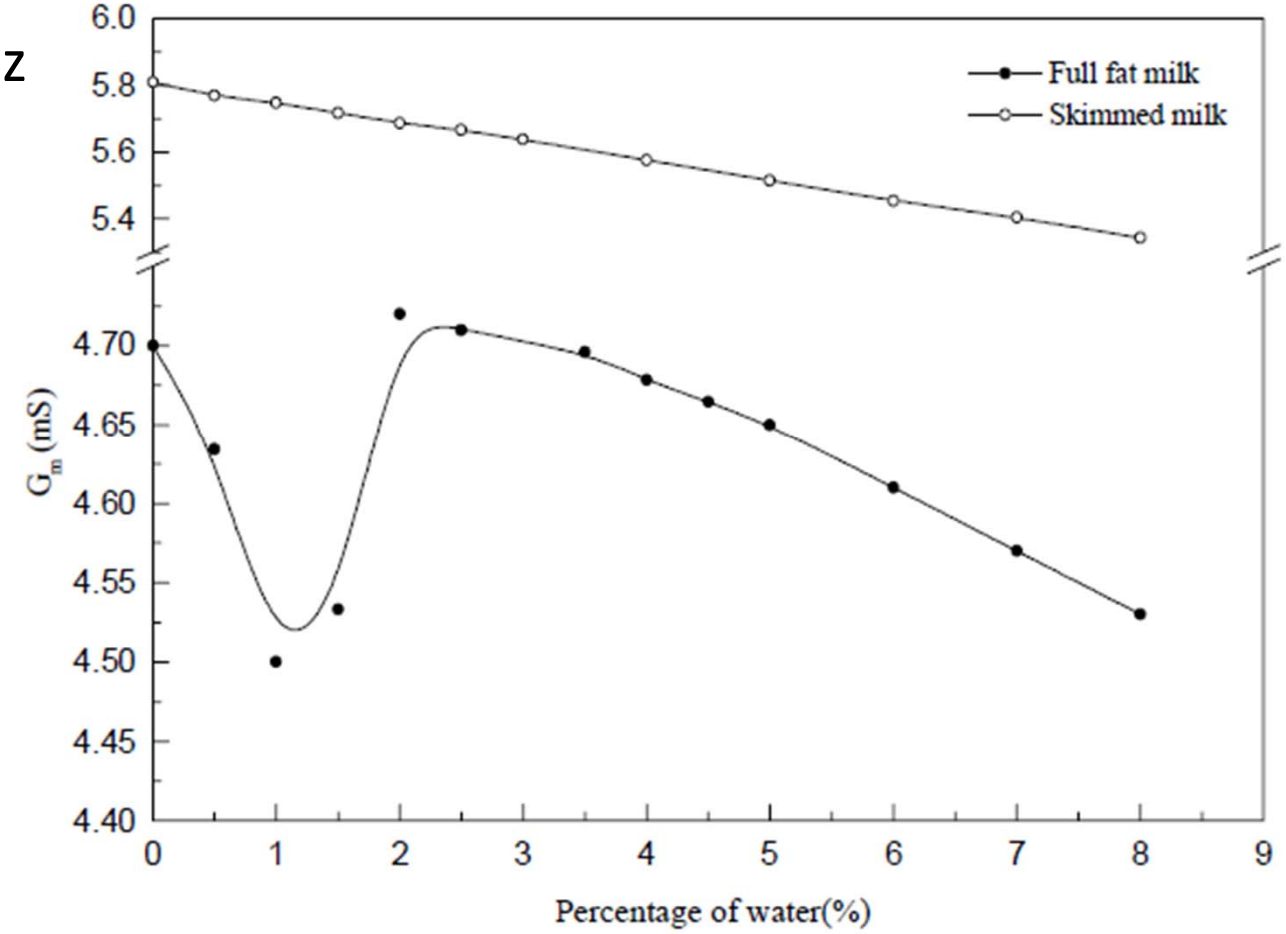
$Y = Z^{-1} = G + jB$



M.F. Mabrook, M.C. Petty
Sensors and Actuators B 96 (2003) 215–218

Detecting water in milk

f = 100 kHz
T = 8 °C



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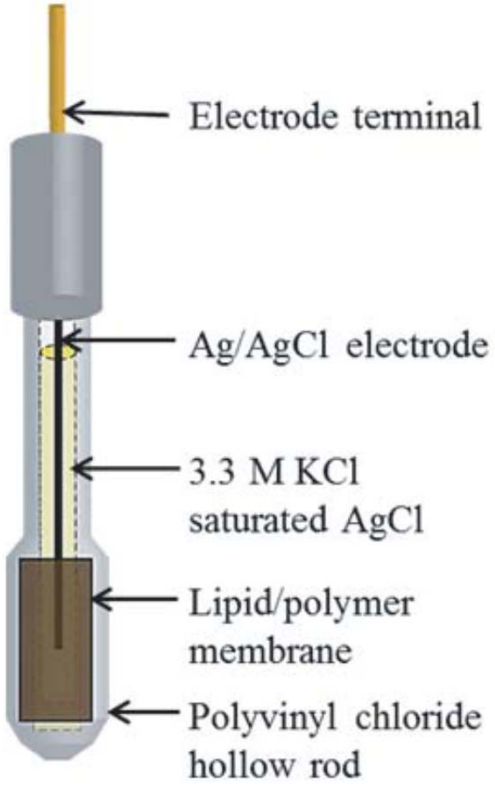
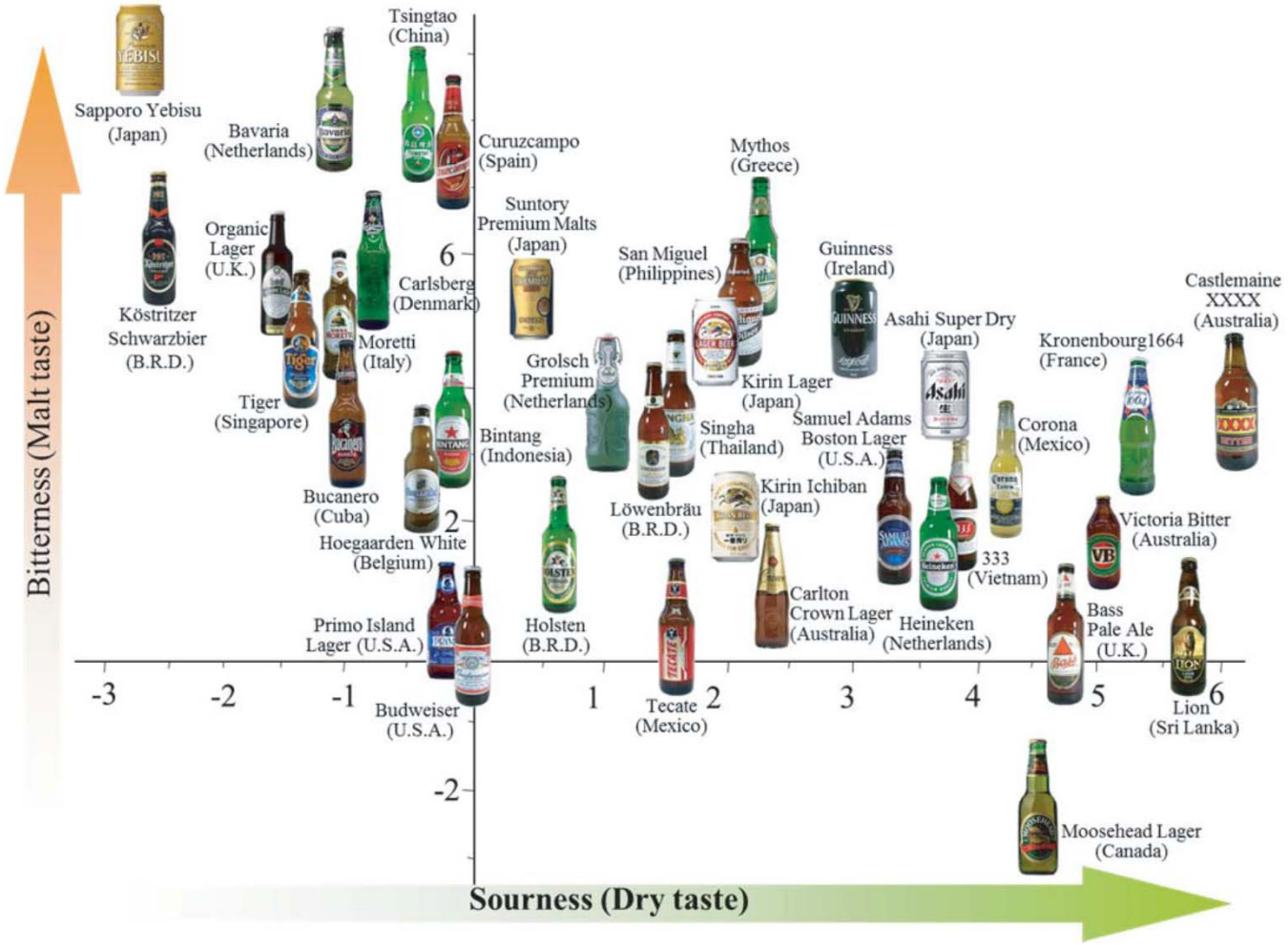
e-taste



TS-5000Z taste sensing system (Intelligent Sensor Technology, Inc.)

Taste map of beer

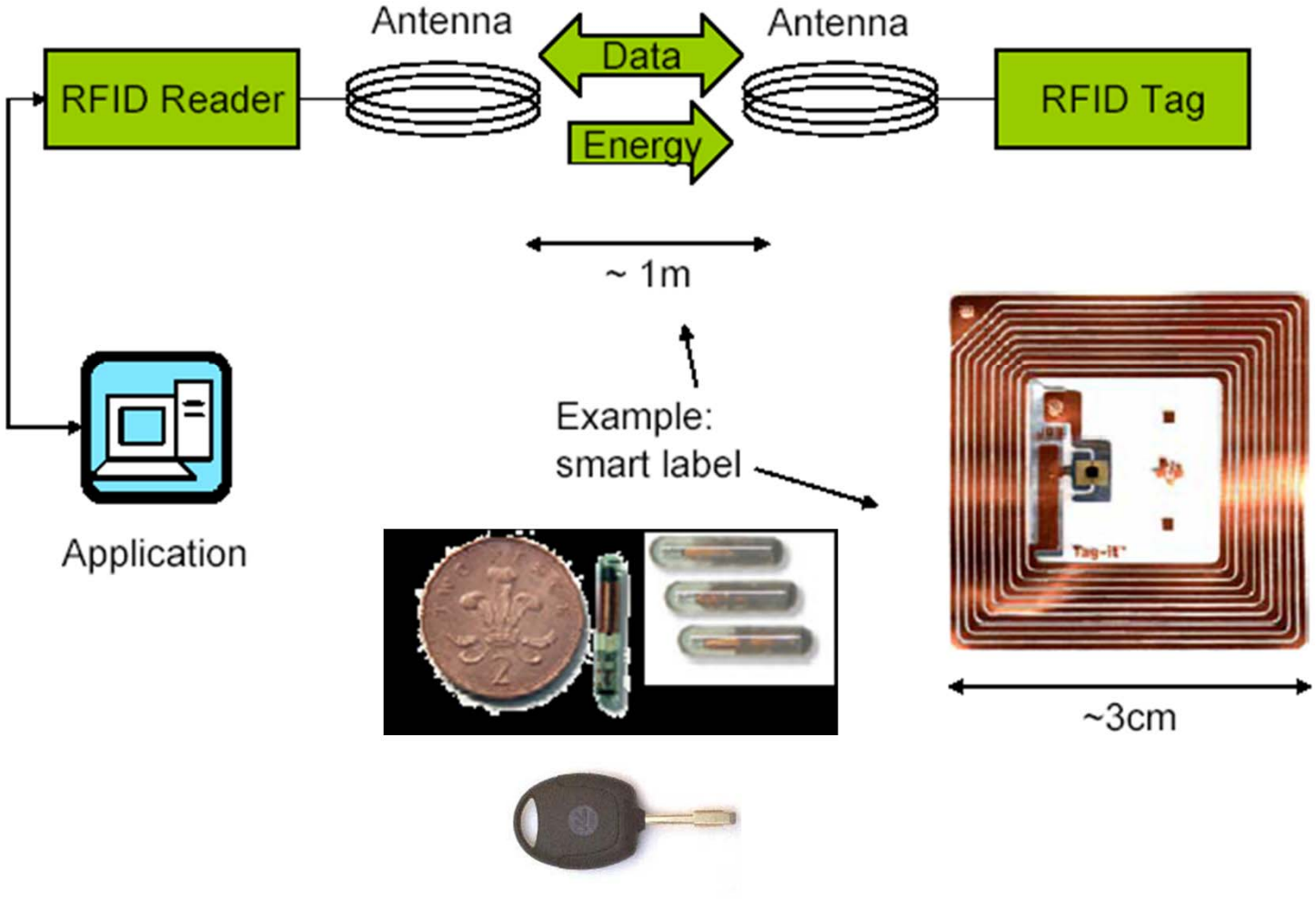


Source: IEEE Sensors Journal, 2013

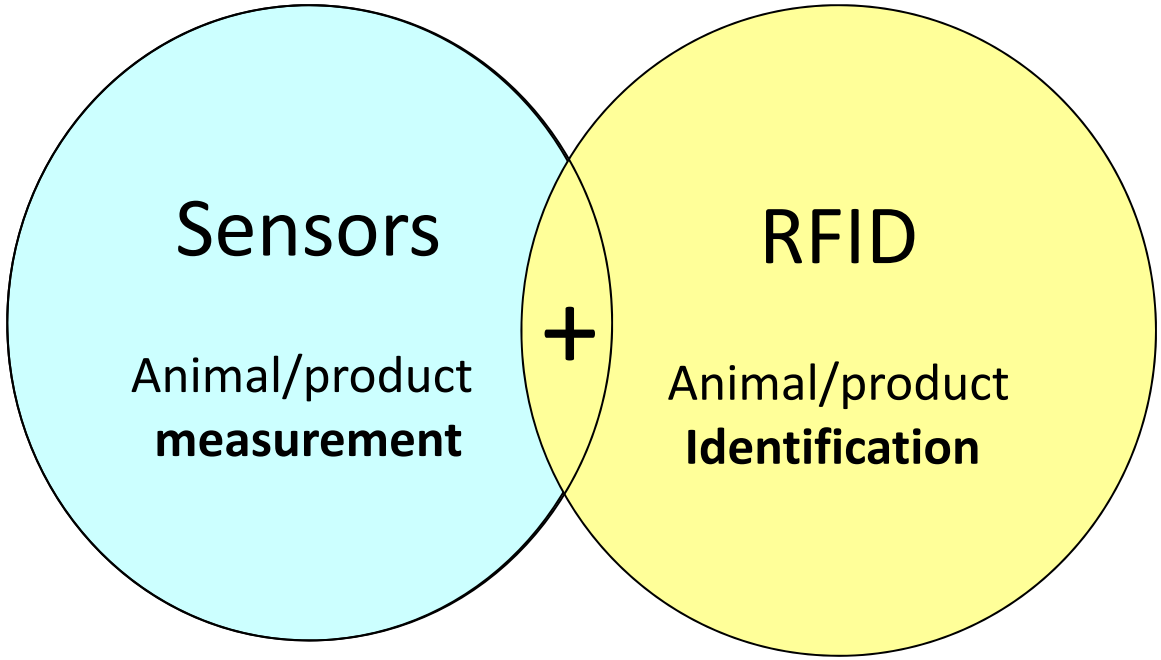
RFID

Reader

Transponder

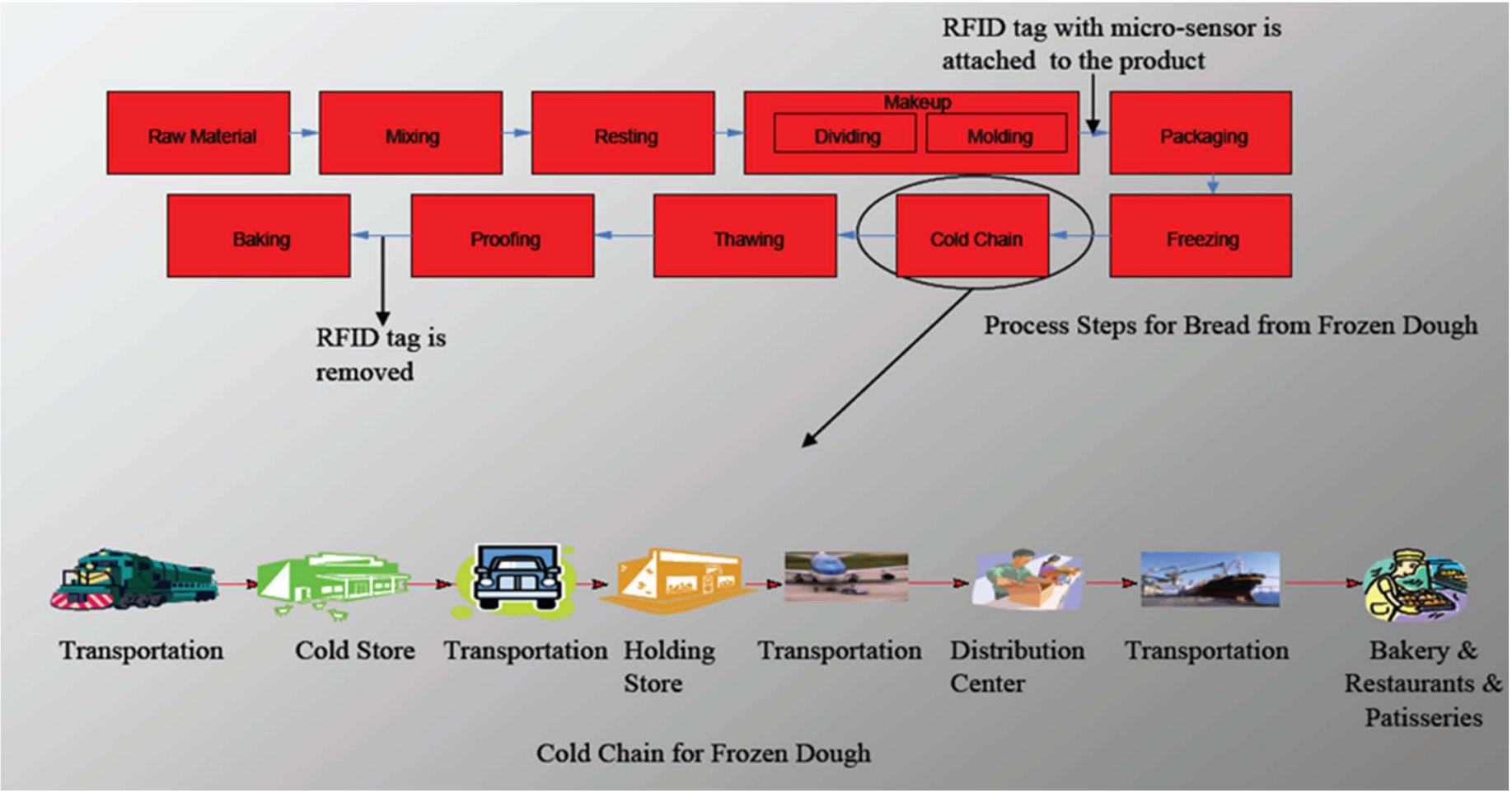


RFID in F&B industry



- Animal and disease monitoring
- Smart packages:
  - Color change according to state/caducity date
  - Control of food transportation
- Smart labels: *T*, RH, pH, weight, motion…

Cold chain management



RFID “freshness” sensor

Freshness: time-temperature sensor

Smart bottles

Source: Thinfilm

- Sealed/opened sensing
- Passive
- Non-modifiable memory
- NFC reading

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Who knows?

- "*X*-rays will prove to be a hoax" Lord Kelvin, 1883
- "Everything that can be invented has been invented" Charles H. Duell, 1899
- "There is not the slightest indication that nuclear energy will ever be obtainable"

  Albert Einstein, 1932

❑ "Any sufficiently advanced technology is indistinguishable from magic"

Arthur C. Clarke, 1962

Needs bring solutions

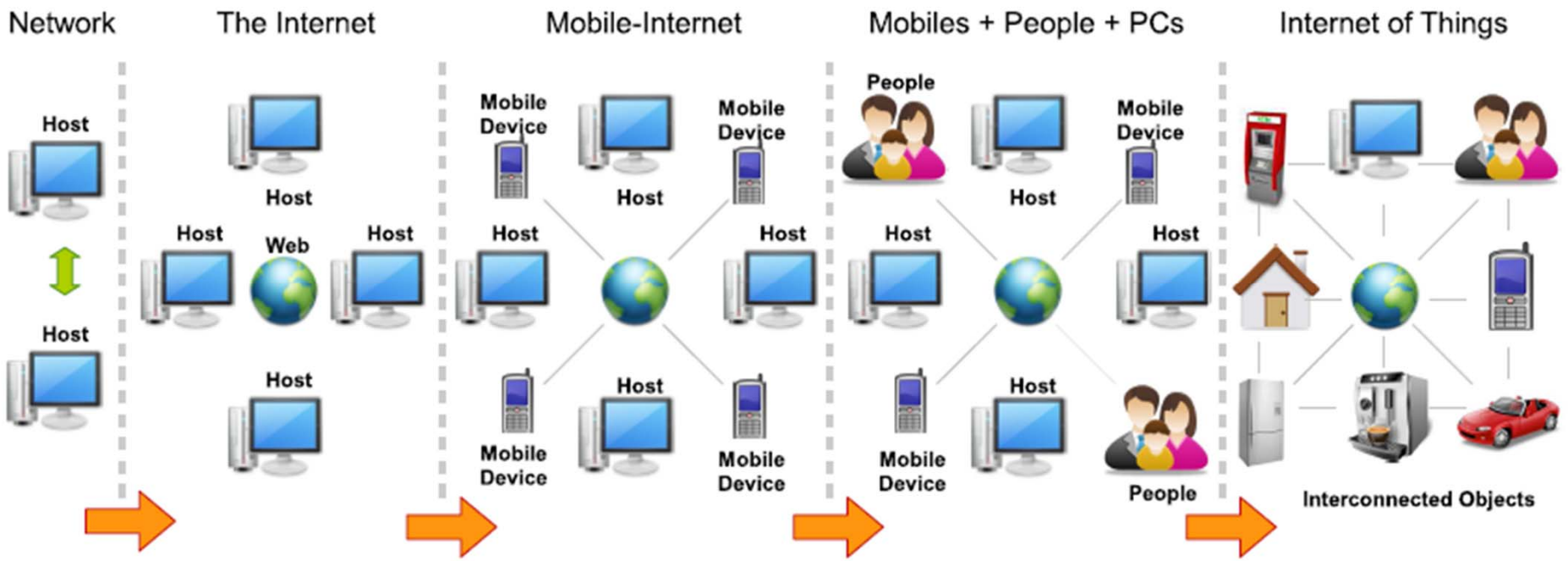
- **WWII**: aviation fuel demand → process control sensors
- **Manhattan project** → nuclear radiation detection
- **Apollo program** → sensors for harsh environments and non-encumbering physiological measurements
- Building **regulations** (and utilities), **security**, **environmental monitoring** → wired + wireless sensor networks
- **Global warming**: car industry regulations → Low cost, reliable sensors

Some trends

1. **IoT** will further reduce the cost of sensors, printed (+organic) electronics and batteries
2. **Wireless technology** will pervade all industrial fields (WSN, RFID, optical)
3. **Biosensors** will expand their role
4. Consumers will be empowered
   - **Smarter packaging**: smartphones as “readers”
   - Food/water/air **sensors in personal electronics**: “appcessories”, chemical sensing displays…

From computer networks to IoT

Source: IEEE Access, 2015



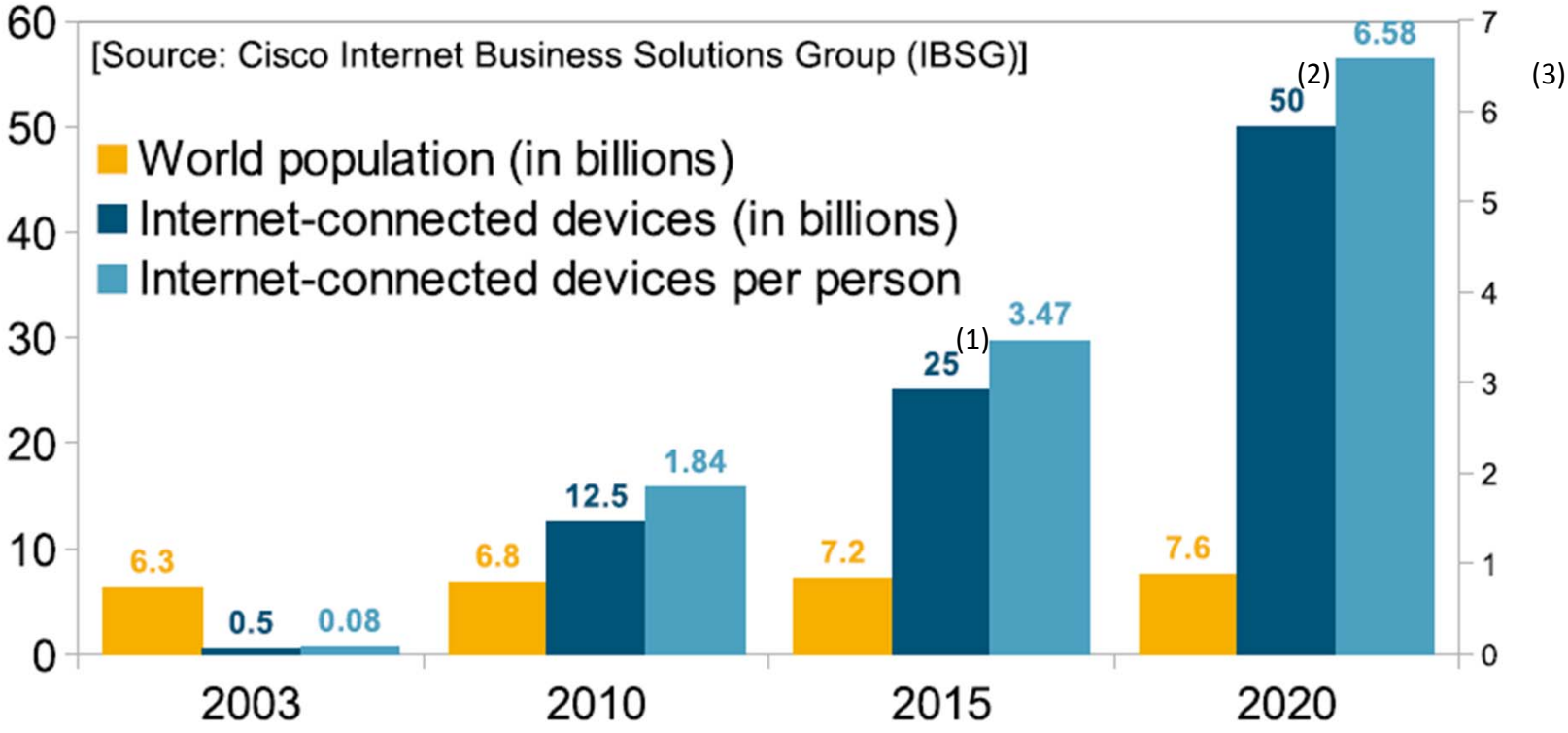
Point to point

www

Social networks

Objects

Internet-Connected devices/objects

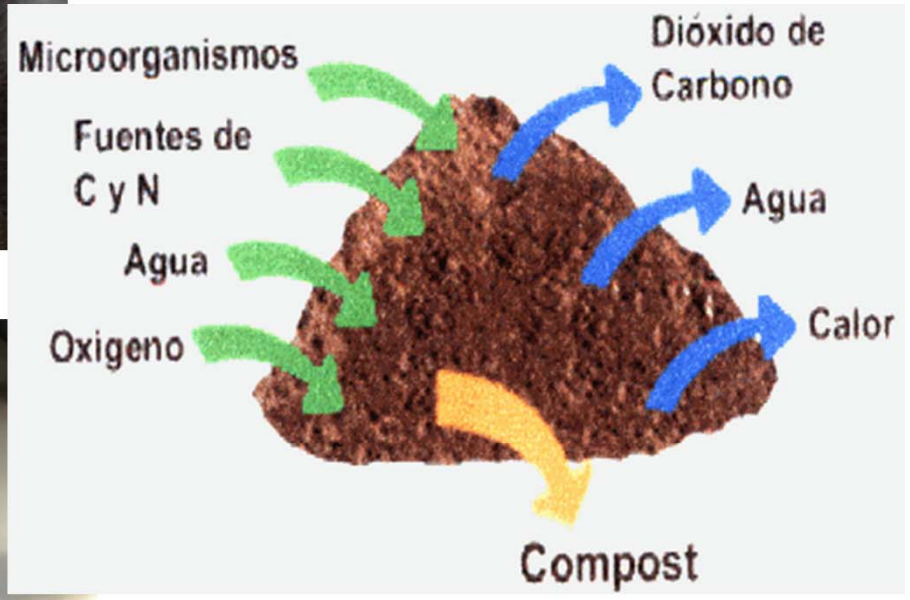


(1) 6 billion according to BCDS

(2) 30 billion according to IDC

(3) 1 trillion by 2022 – Trillion Sensors Summit 2014

Wireless technologies



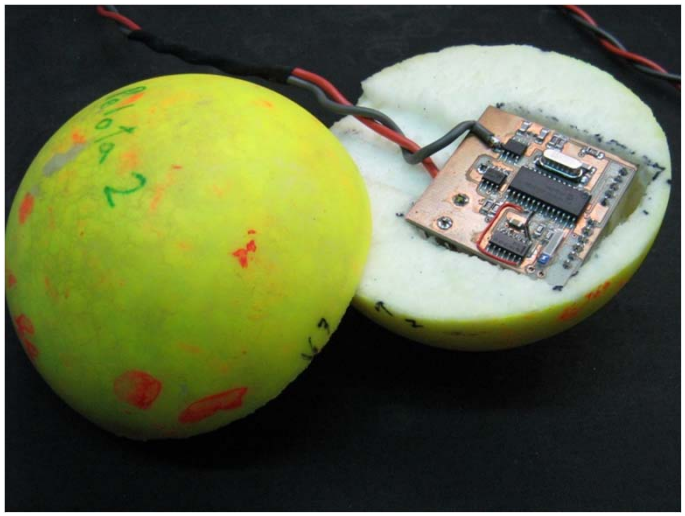
Medir: temperatura, humedad

Ahora: adaptar sensores

Manual

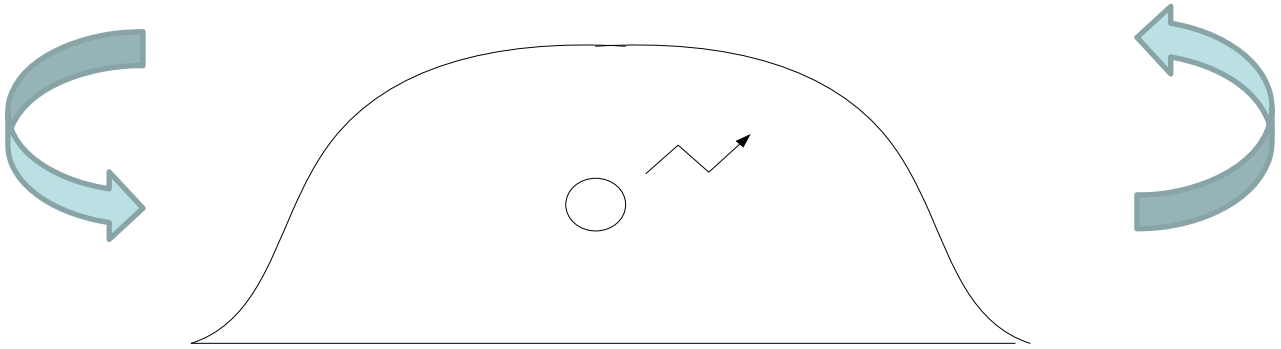
Automático exterior

Alternativa: nuevos sensores

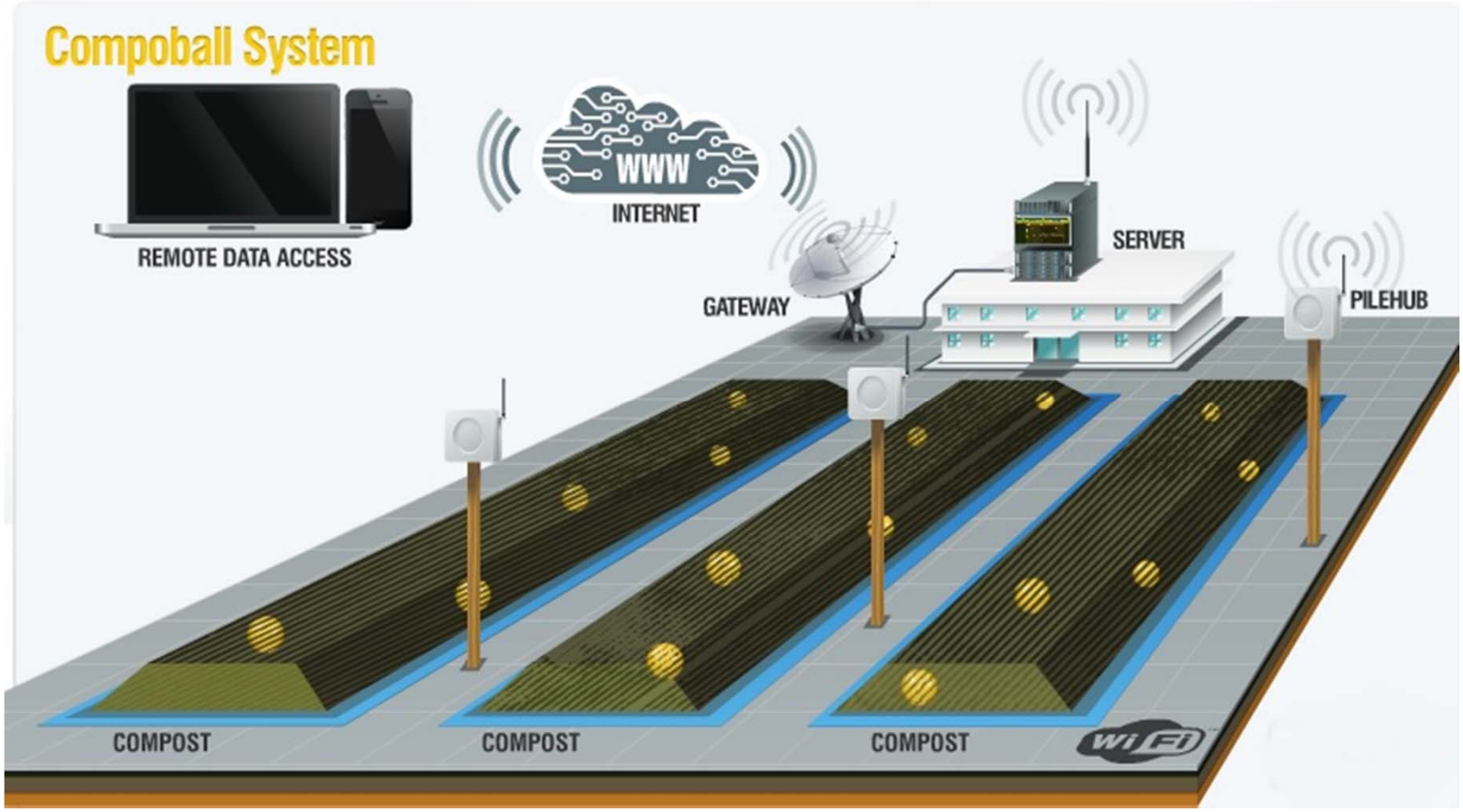


Sensor autónomo: *T*, humedad

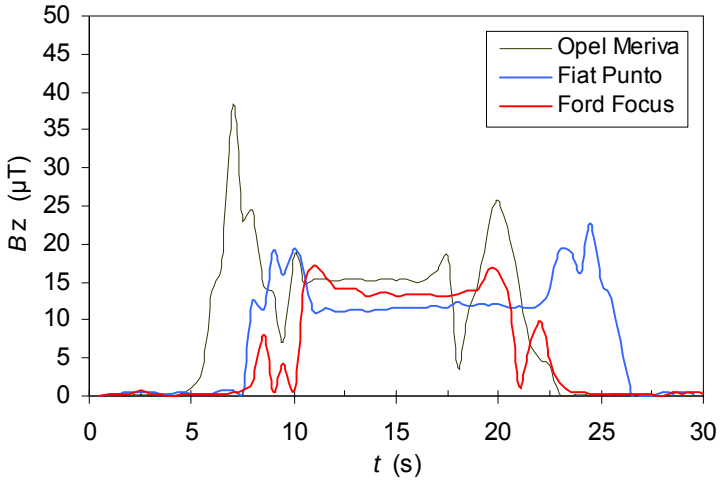
Comunicación: 27 MHz



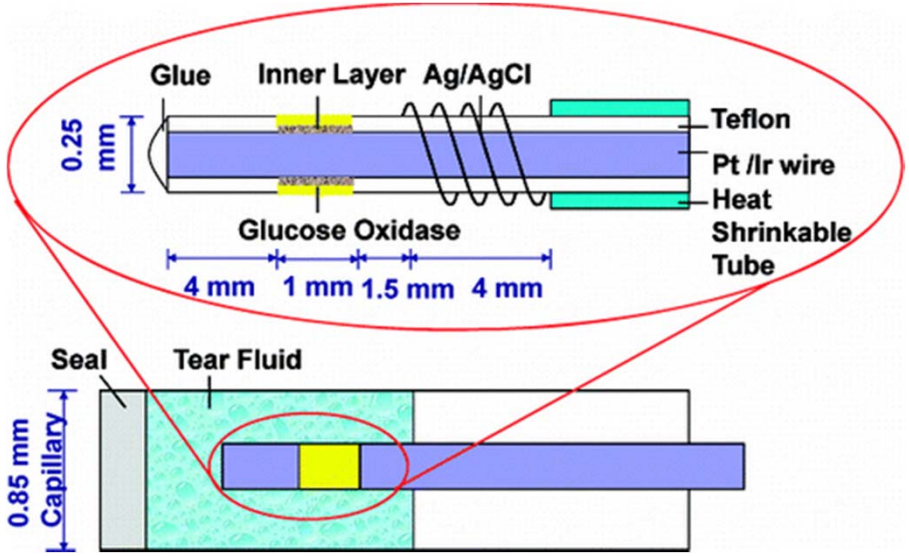
Wireless sensor networks



“Wireless” vehicle detection

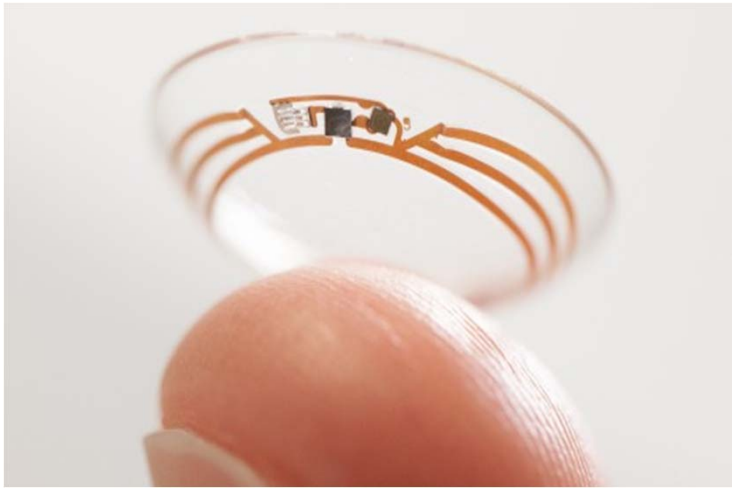


Biosensor-based glucometer



Sample fluid: 4-5 µL of tears

Source: Univ. Michigan, 2011



Contact lens to monitor glucose level

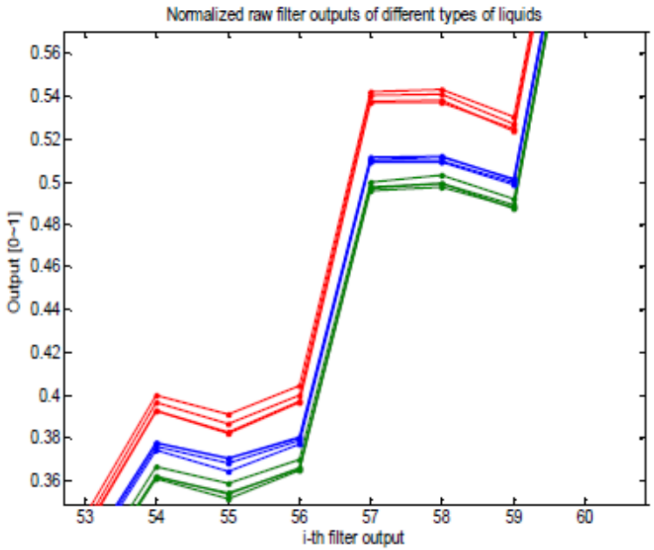
Source: Google, 2014

Empowering consumers (1)

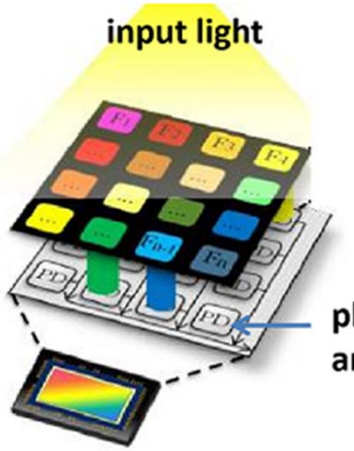
Handheld food scanner: miniature NIR spectrometer

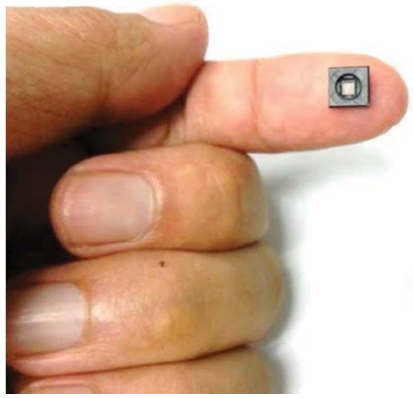
Source: Tellspec

Empowering consumers (2)



$10 spectrometer chip for biochemical analysis
+ Optics + Database of spectral fingerprints





5 mm × 5 mm × 2 mm

Source: NanoLambda, Dec. 2014

Fresh vs. old milk (4, 6 days)

Resumen

1. Hay **sensores** por doquier: desde el control de procesos hasta los **productos electrónicos personales** y embalajes
2. La **sensorización** no es un fin en sí misma sino un **medio** esencial para tomar decisiones inteligentes
3. Puede ser mejor **redefinir un problema** y solucionarlo con los sensores disponibles que inventar un nuevo sensor
4. **Adaptar un sensor** existente puede crear un **problema** peor que el que se pretendía resolver
5. El **Internet de los Objetos** (IoT) será en Tecnología Alimentaria lo que los automóviles fueron para la telefonía móvil

Moltes gràcies per la seva atenció!