



EDMI Microsystems and Microelectronics

MICRO-614: Electrochemical Nano-Bio-Sensing
and Bio/CMOS interfaces

Lecture #1 - Introduction

Human Metabolism Monitoring by Electrochemical Sensing: Present & Future!

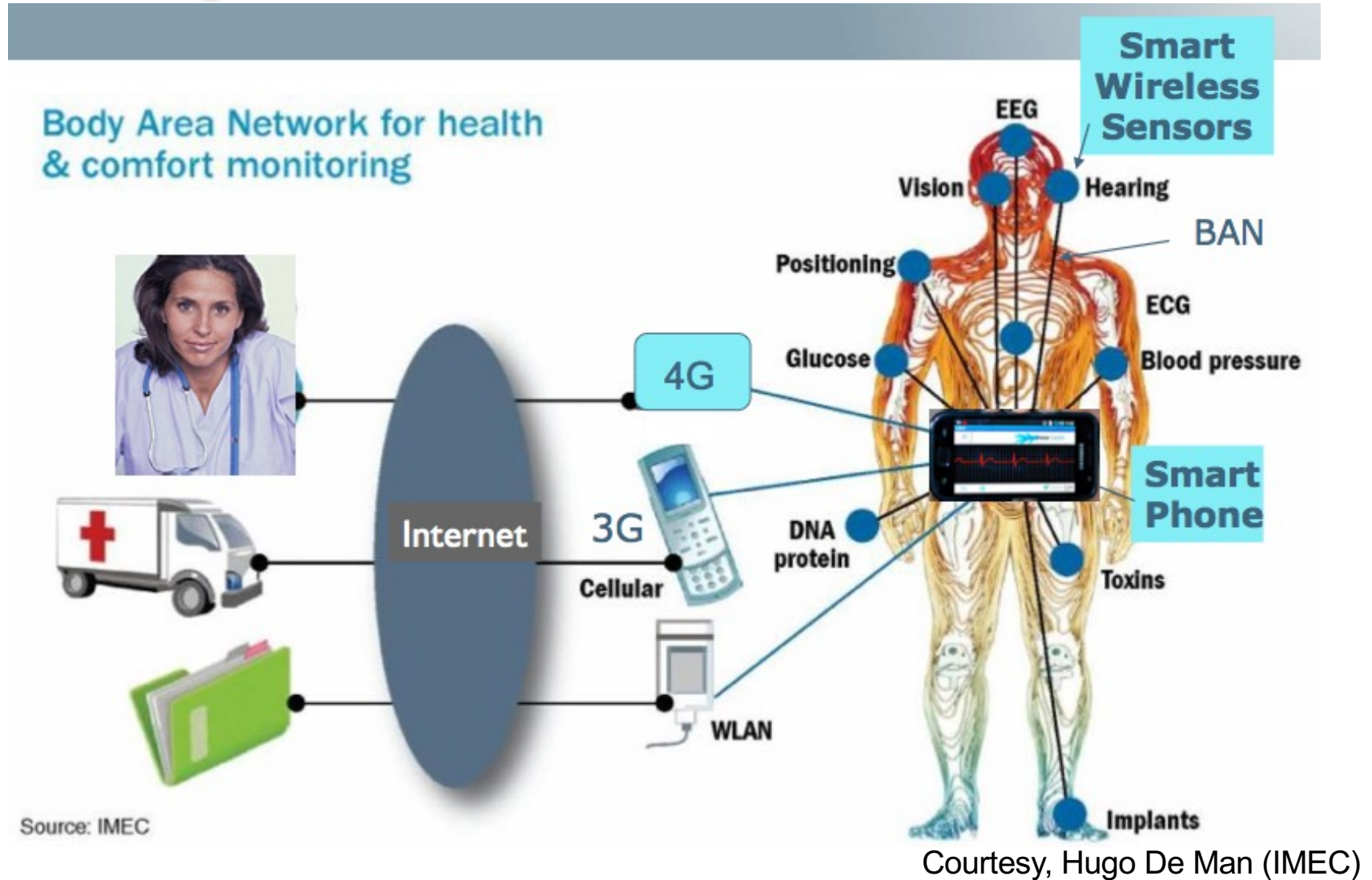
The Time' forecast on Human++



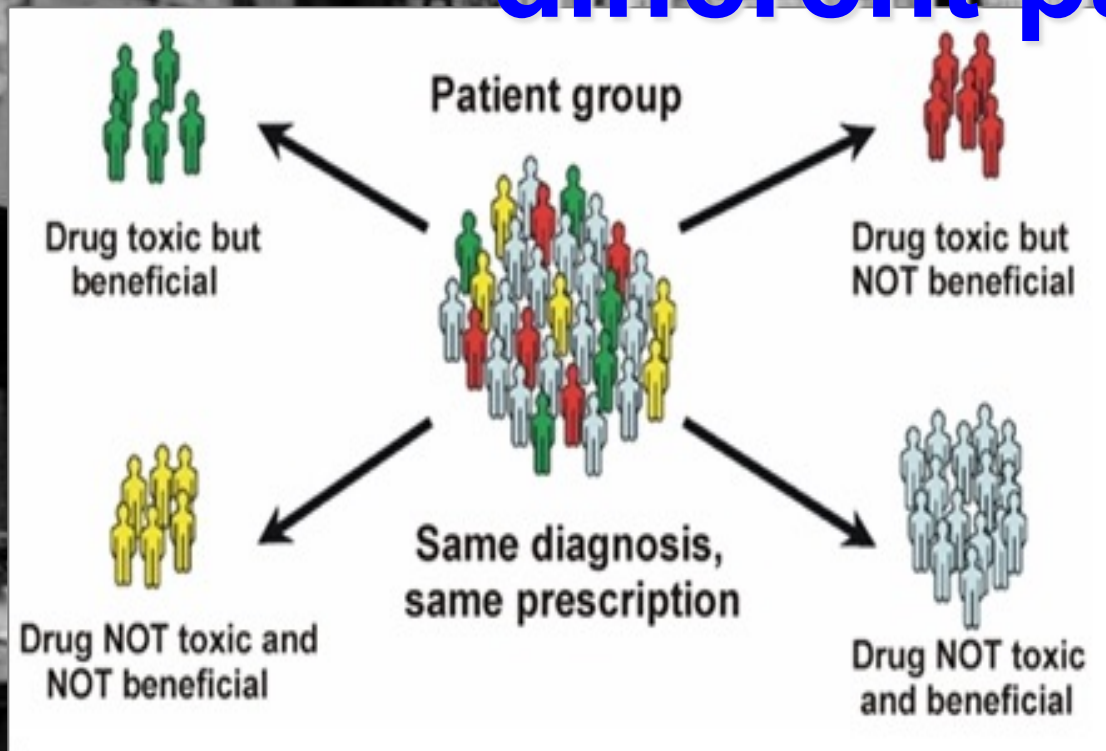
[TIME, February 2011]

(c) S.Carrara

Fully-Connected Human++



Different outcomes for different patients

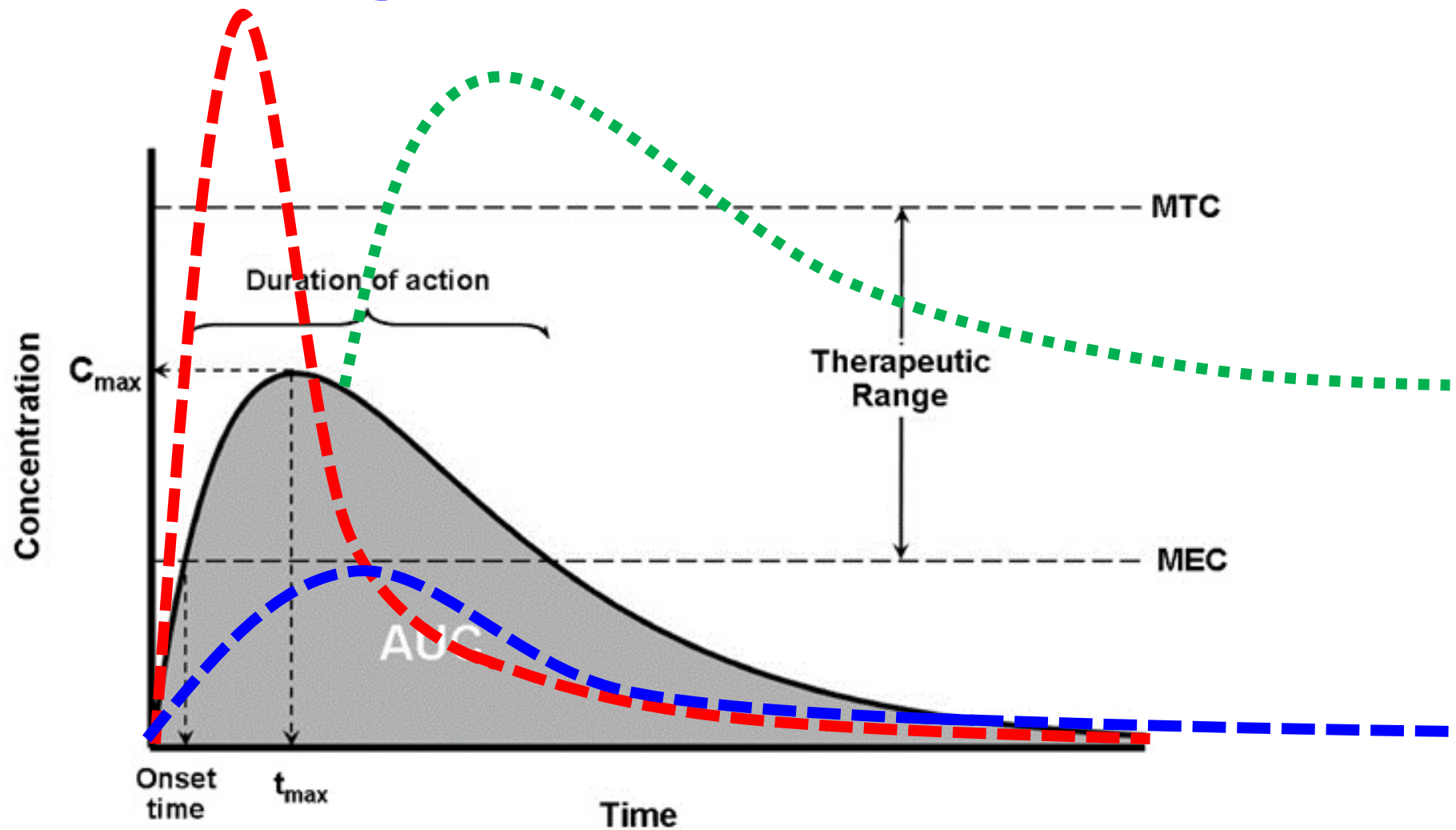


Therapeutic area	Rate of efficacy with standard drug treatment
Cancer (all types)	25%
Alzheimer's disease	30%
Incontinence	40%
Hepatitis C	47%
Osteoporosis	48%
Rheumatoid arthritis	50%
Migraine (prophylaxis)	50%
Migraine (acute)	52%
Diabetes	57%
Asthma	60%
Cardiac arrhythmias	60%
Schizophrenia	60%
Depression	62%

For depression, the data apply specifically to the drug class known as selective serotonin reuptake inhibitors.

Source: Brian B. Spear, Margo Heath-Chiozzi, and Jeffrey Huff, "Clinical Application of Pharmacogenetics," *Trends in Molecular Medicine* (May 2001).

Patients' metabolism drive the Drugs effect in time!



Course Motivation: From Labs to Hands



- 100.000 \$ (machinery)
- 1.000 \$ the single μ -array

Labeled



Label-Free

- 50 \$ (machinery)
- 0.05 \$ the single strip

Next step: the future already begun



Glucose Personal Diagnostics on our iPhones

(c) S.Carrara

Next step: the future already begun

How to use the FreeStyle Libre System



The image shows a woman in a white t-shirt applying a small, round, white sensor to her upper arm. She is holding a black handheld device (the reader) against the sensor. The background is a light blue gradient.

1. **Apply sensor**
with applicator
2. **Scan sensor**
using FreeStyle Libre Reader
3. **Get reading**
on the reader

FOR FULL INSTRUCTIONS
www.freestylelibre.co.uk >

OVERVIEW
HOW TO USE
FIND OUT MORE

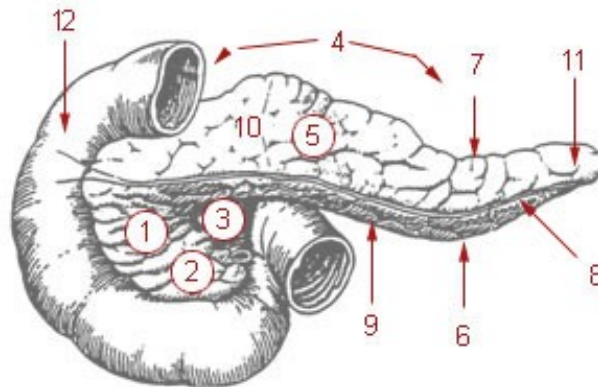
Glucose Personal Diagnostics on our Skin

(c) S.Carrara

The Pancreas Functions

IN-put Signals

Bile acids →
pH →
Syrinic proteases →
Glucose →
Glycagone pancreatic →
.....



OUT-put Signals

insulin
Lipase
Fospholipase A
Cholesterol esterase
Endopeptidase
Esopeptidase
Elastase
Ribonuclease
Enterochinase
.....

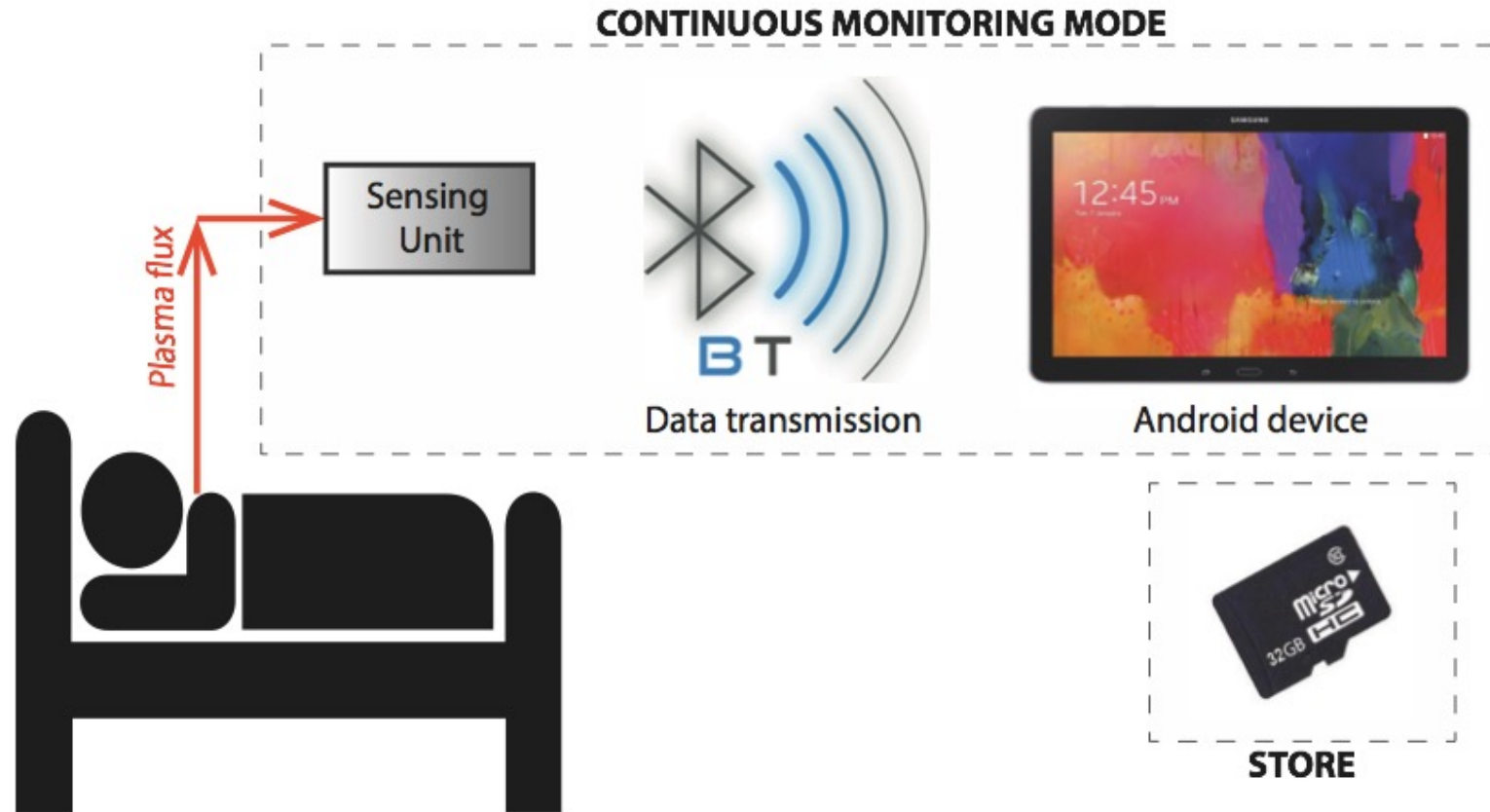
Intensive-Care-Units (ICU) Monitoring



The present monitoring scenario foresees lot of independent devices and input/output interfaces

(c) S.Carrara

Lab-on-a-chip for ICUs



F. Stradolini, *et al.*, *IEEE Sensors Journal* 16(2016) 3163 - 3170

Monitoring scenario where the main parameters of the patient are continuously displayed on an Android mobile device

(c) S.Carrara

The full connected system



The whole system with the Android™ interface that allows connectivity too

One Interface for Remote Monitoring of Patients in Intensive Care Units



Image / *Bam Labs*

The whole system with the Android™ interface that allows connectivity too

S.Carrara (C)

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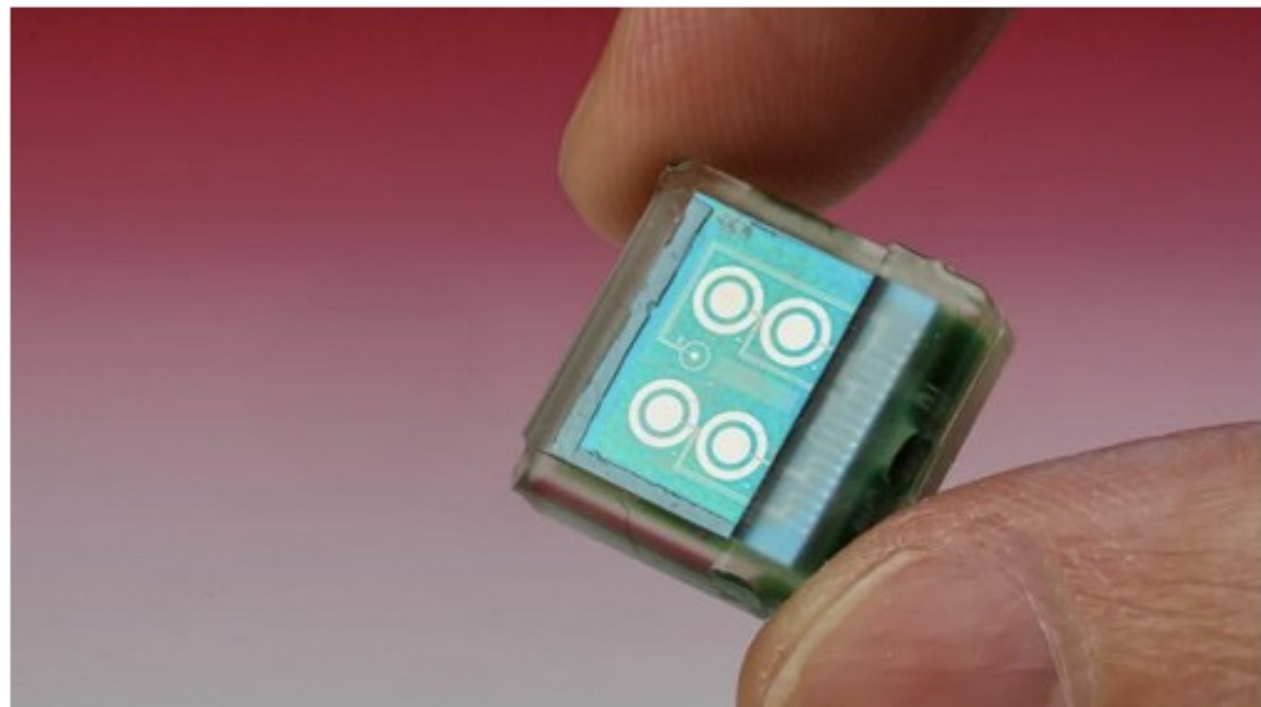
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A subcutaneous biosensor chip to revolutionize tomorrow's medicine

May 29, 2015 9:26 AM

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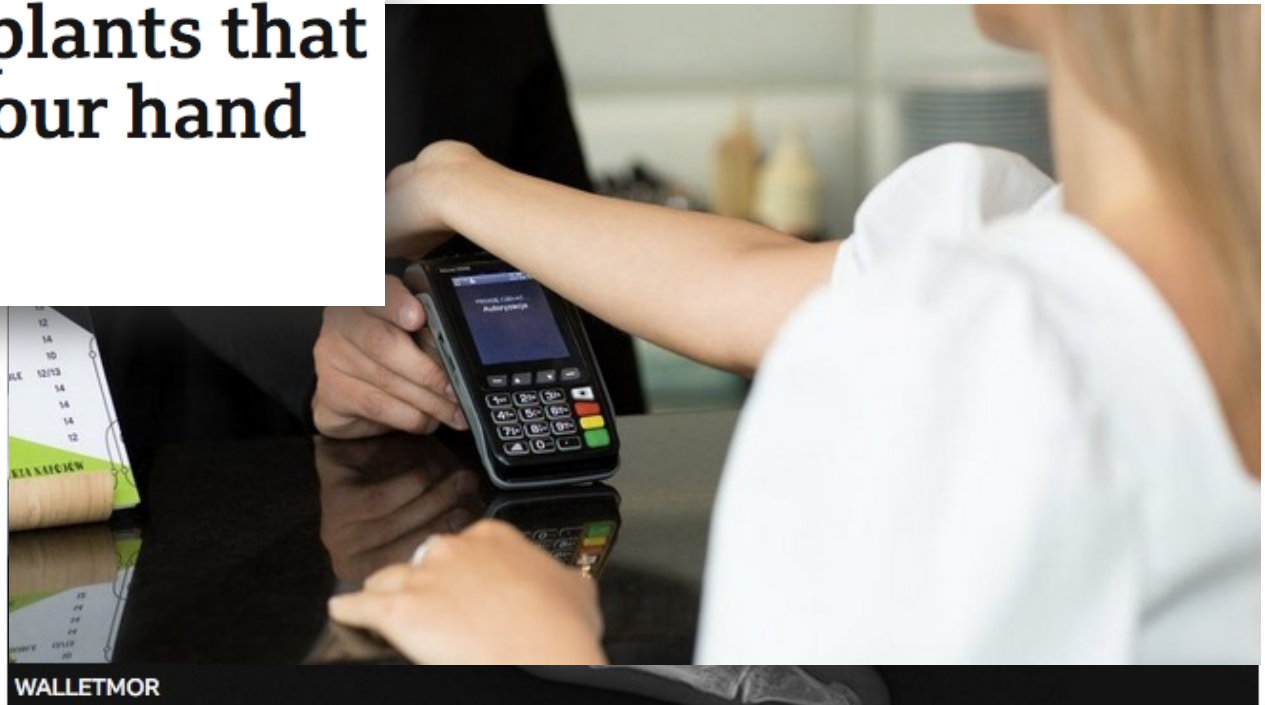
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The microchip implants that let you pay with your hand

By Katherine Latham
Business reporter

🕒 April, 11th, 2022



An x-ray showing a Walletmor implant, which are injected into a person's hand after a local anaesthetic

For many of us, the idea of having such a chip implanted in our body is an appalling one but a 2021 survey of more than 4,000 people across the UK and the European Union found that 51% would consider it.

Chips under the skin?

See video on Moodle!



[EuroNews, June 2015]

Under the skin for body sculpting

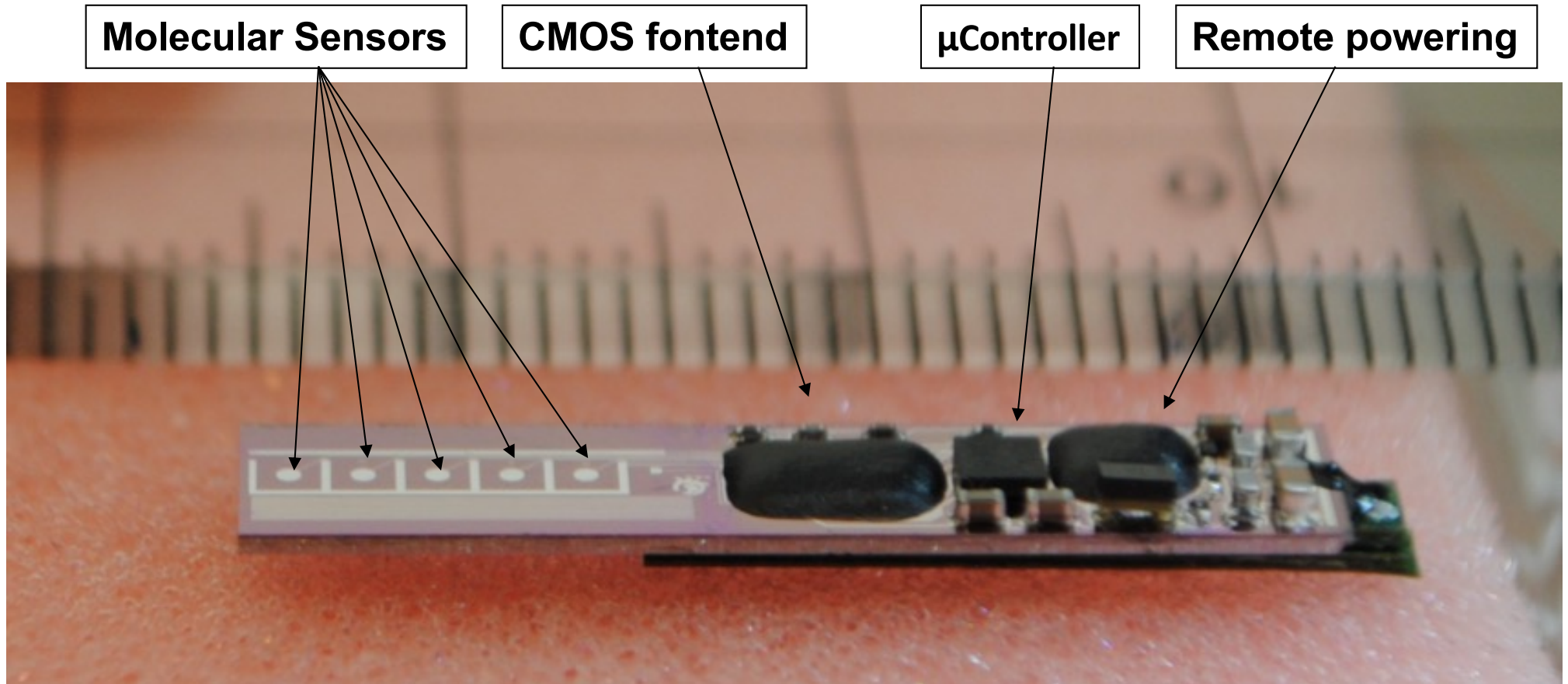


(c) S.Carrara

Enhancing human being



Size and Shape to be injectable as a Needle?



The IC has been fabricated in UMC 0.18 technology and interfaced to the passive multi-panel platform

ECG monitoring by Medtronic



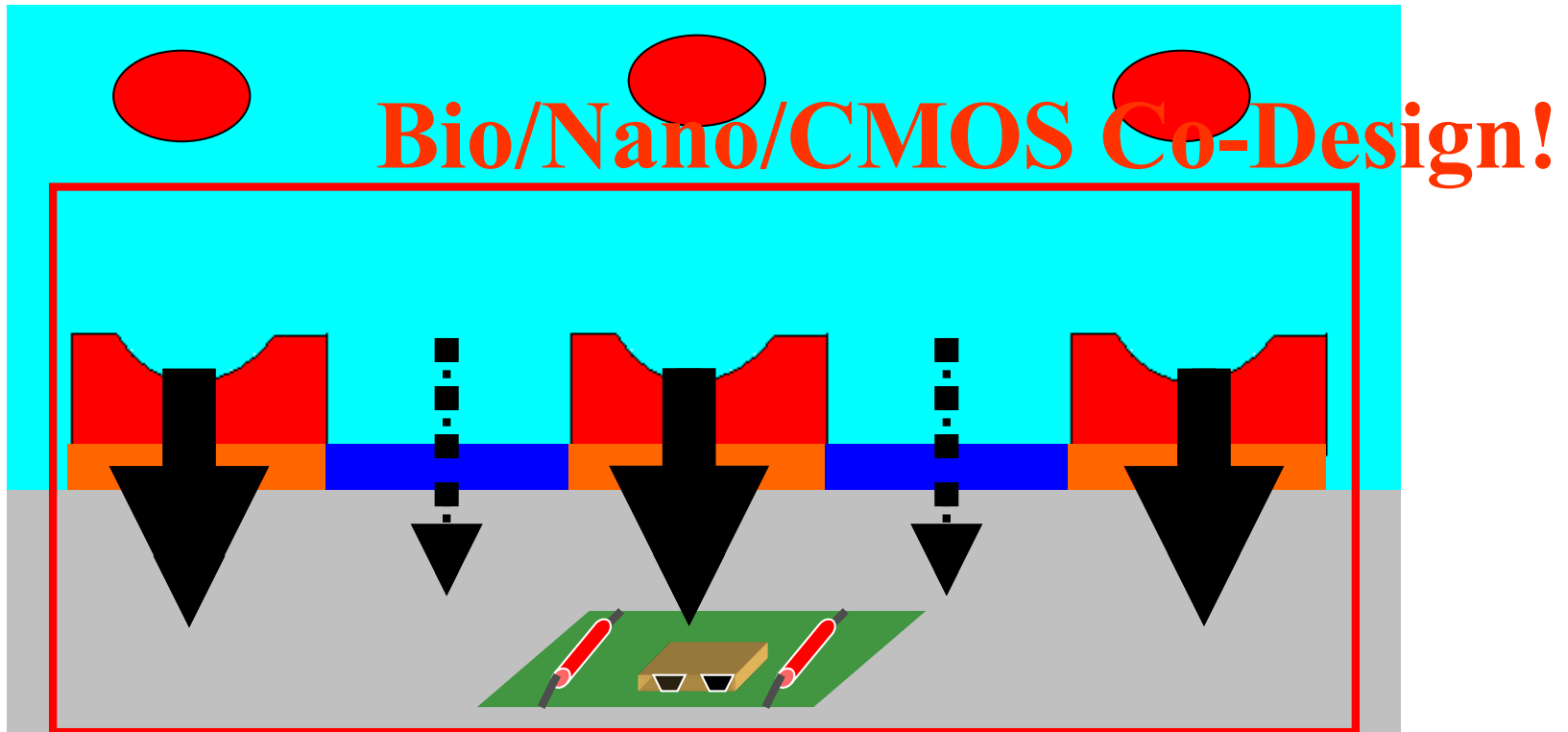
Mark Phelps by Medtronic, and the Reveal LINQ™ system

Toward Ultrasensitive Biosensors:

1. Fully integration of **Bio**molecules to assure specificity
2. Fully integration of **Nano**-structures to assure sensitivity
3. Proper **CMOS** frontends to assure
 - (i) Correct Voltage driving
 - (ii) Precise Current measurements,
 - (iii) Reliability in Temperature and pH

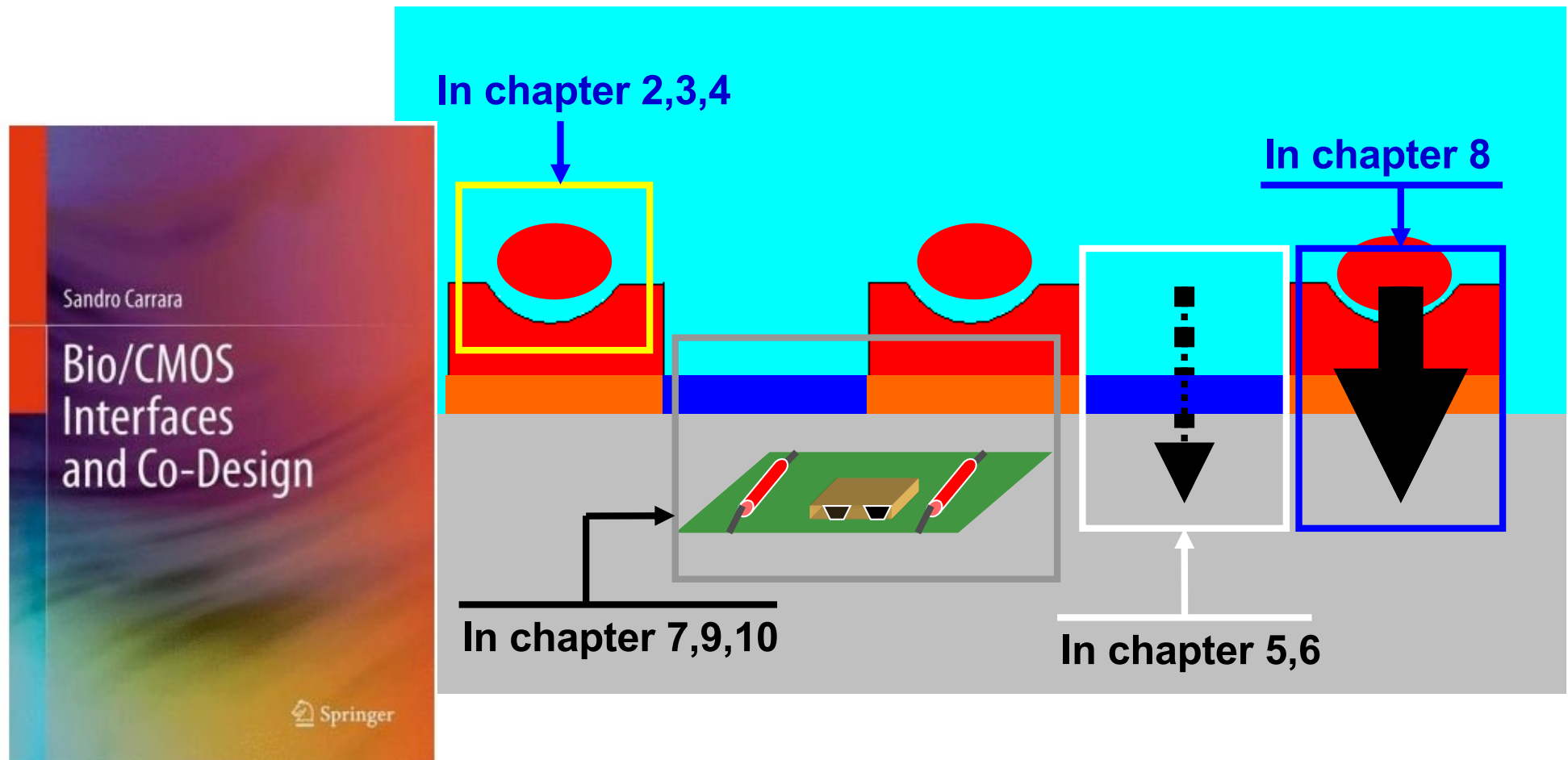
Bio/Nano/CMOS Co-design !

CMOS/Sample interface

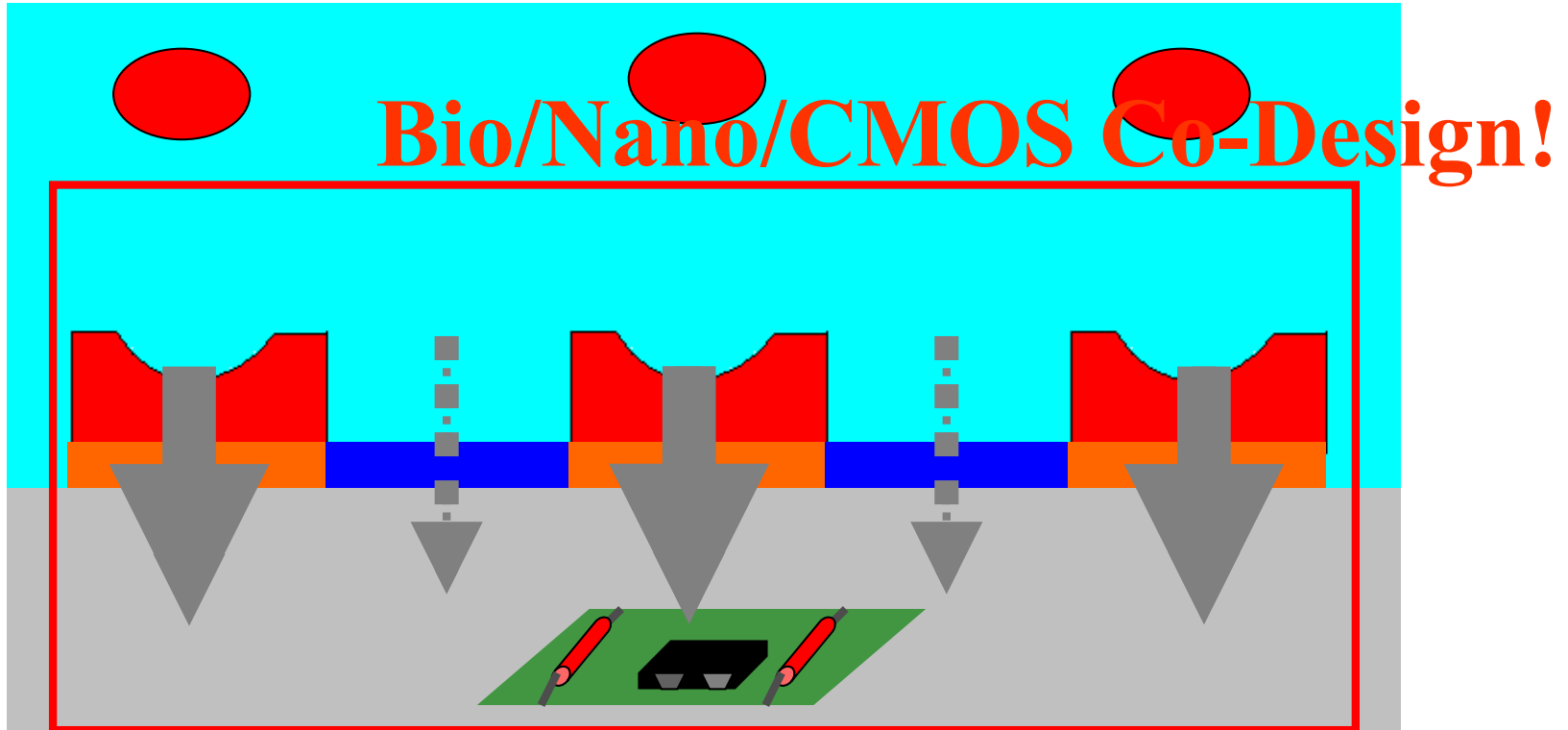


The interface between the CMOS circuit and the bio-sample needs to be deeply investigated and organized

A book as a reference

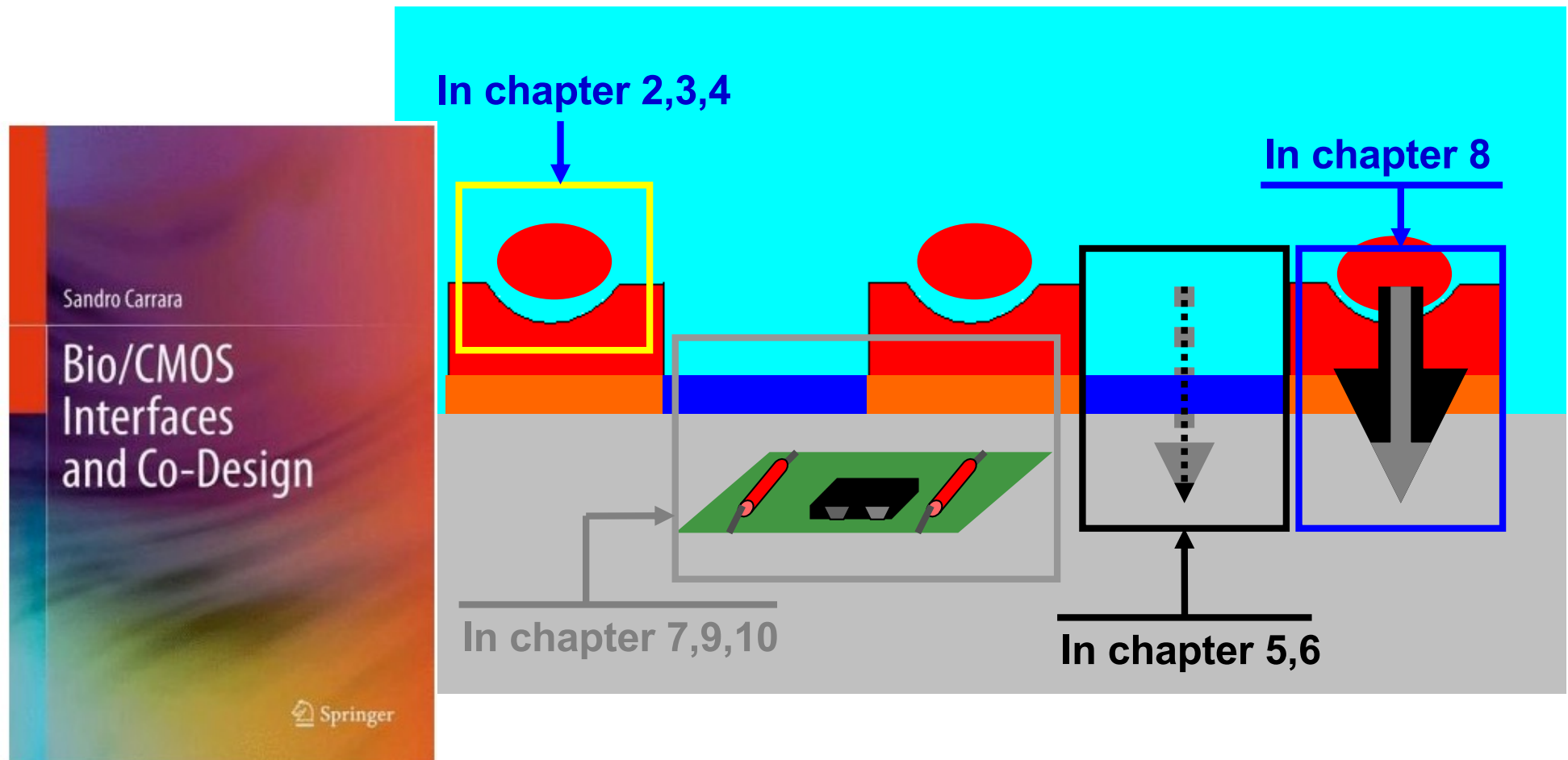


CMOS/Sample interface



The interface between the CMOS circuit and the bio-sample needs to be deeply investigated and organized

The course book



Get you copy of the Textbooks

Bio/CMOS Interfaces and Co-Design – Springer

link.springer.com/book/10.1007/978-1-4614-4690-3

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EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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Sandro Carrara

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Authors: Sandro Carrara

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Introduction

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MICRO-614: Electrochemical Nano-Bio-Sensing
and Bio/CMOS interfaces

Course outline

1. Intro about Metabolism Monitoring
 2. Bio 1 metabolites, Peptides, Proteins & DNA
 3. Bio 2 Probes/targets interaction
 4. Bio 3 Detection principles
 5. Bio 4 Amperometric Biosensors
6. Nano 1 Functionalization: Methods & Models
 7. Nano 2 Characterisation by RM, SPR, SEM, AFM
 8. Nano 3 Preventing ET
 9. Nano 4 Enhancing ET
 10. Nano 5 Memristive Sensing
11. CMOS 1 in Constant Bias
 12. CMOS 2 in Scanning Voltage
 13. CMOS 3 for DNA: Capacitive & Amperometric
 14. CMOS 4 Memristive Sensing
 15. CMOS 5 Beyond implantable & wearable

Bio

Nano

CMOS

To fruitful follow the course

Meeting Information - Zoom | EDOC Teaching | Day-15th-June - Dropbox | Course: Electrochemical nano- | +

https://moodle.epfl.ch/course/view.php?id=14479

Go to main site < EPFL MOODLE FR EN

MICRO-614

- Participants
- Grades
- General
- Day 1 - Bio: Probe/Target Molecular interactions
- Day 2 - Bio: Electrochemical Sensing
- Day 3 - Nano: Probes-layer for Targets Detection
- Day 4 - Nano/CMOS: Memristors and CMOS Analog4Bio

Day 1 - Bio: Probe/Target Molecular interactions

- Bio/CMOS: present & future! (An introduction)
- Probe/Target interactions
- Sensing Principles with biomolecules
- APPENDIX 1: Building Blocks & Protein Structures
- APPENDIX 2: Binding Energy
- Euronews about under-the-skin biochip

Read Chapter 2 in the Book for Conductive Solutions and the concept of pH, and Chapters 3 & 4 for Target/Probe biochemistry & interactions

Read also APPENDIX A in the Book for the concept of Molar Concentration

Solve the Exercise # 1 in page 28 of the Book (show computations)

Solve the Exercise # 9 in page 50 of the Book (justify the answer)

Solve the Exercise # 5 in page 85 of the Book (Solve the exercise by also