Schedule

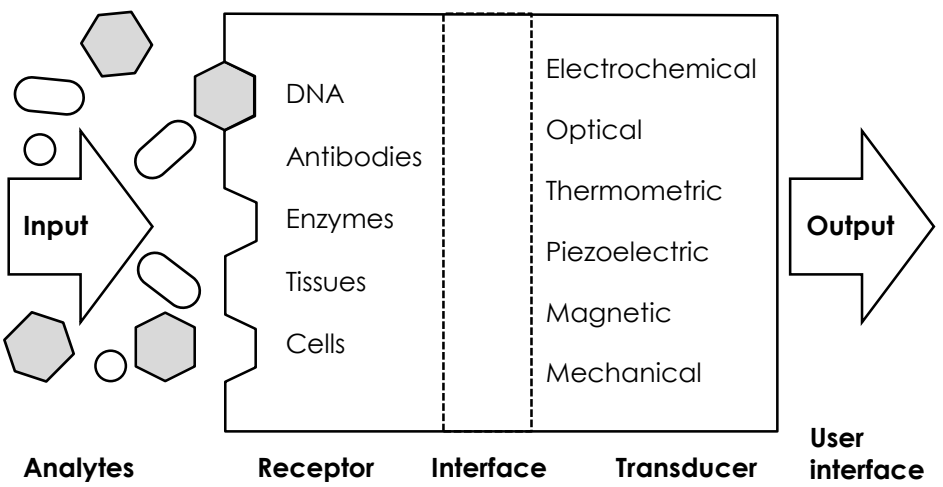
[Fundamentals]

1. 4/15 Basic chemical and biochemical concepts
2. 4/22 Basic biophysical concepts
3. 4/29 Basic bioelectrochemical concepts1
4. 5/13 Basic bioelectrochemical concepts2

[Applications]

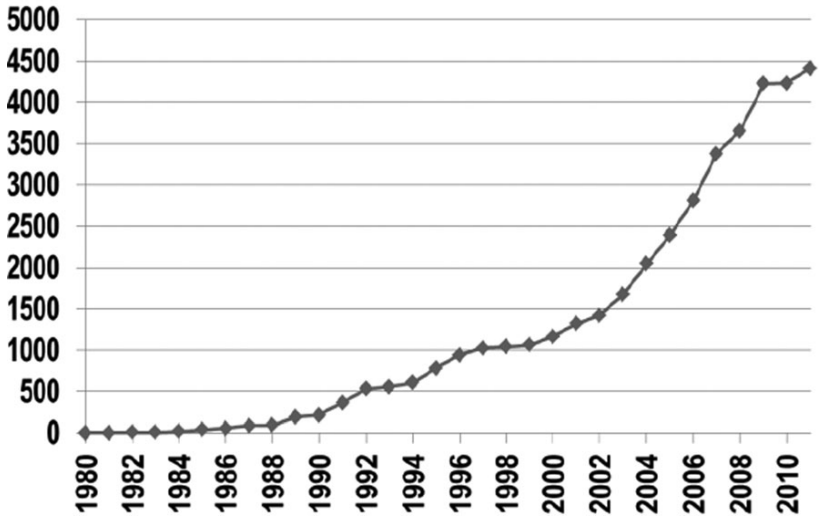
5. 5/20 Cancel (Homework1 and 2)
6. 5/27 Biosensors and bioelectronics1
7. 6/03 Cancel (Homework3 and 4)
8. 6/10 Student seminar
9. 6/17 Biosensors and bioelectronics2
10. 6/24 From bioelectronics (electron) to iontronics (ion)1
11. 7/01 From bioelectronics (electron) to iontronics (ion)2
12. 7/ 8 Wearable applications1
13. 7/15 Wearable applications2
14. 7/22 Student seminar

Biosensor



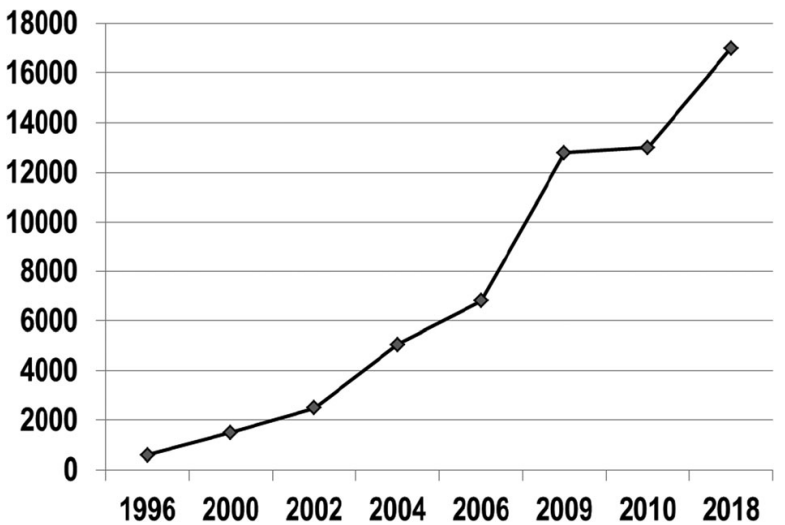
Biosensor publication

Web of knowledge "biosensor"



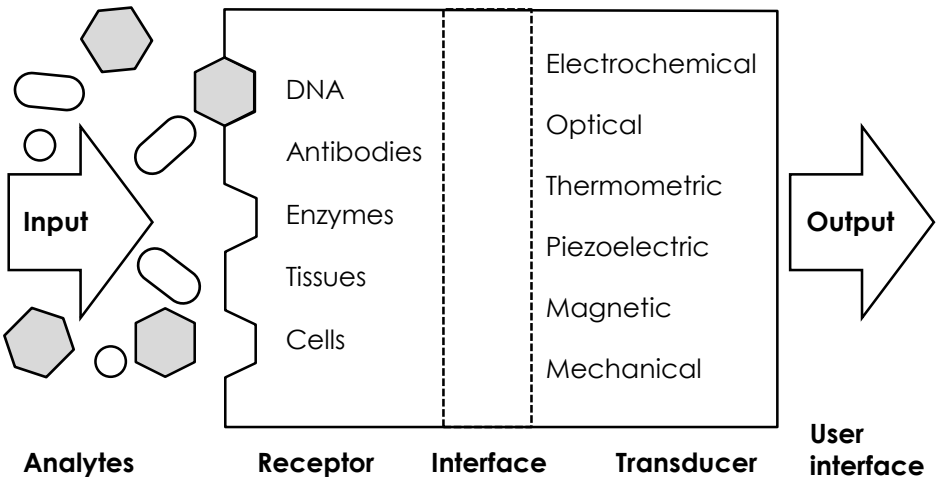
Chem. Soc. Rev., 2013, **42**, 3184--3196

World Market for Biosensor (US$ millions)

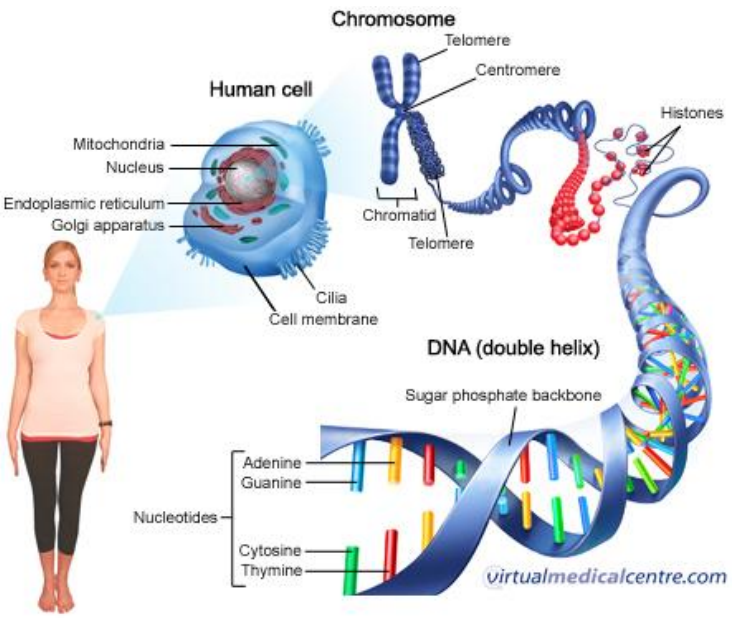


Chem. Soc. Rev., 2013, **42**, 3184--3196

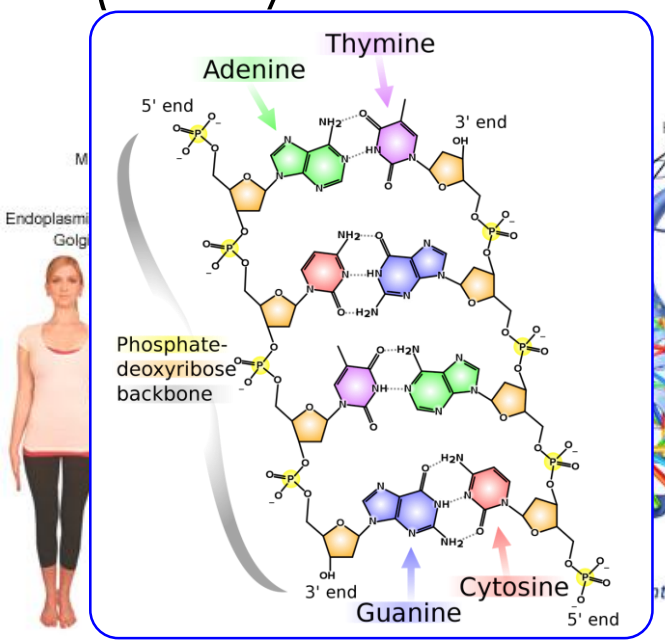
Biosensor



DNA(Deoxyribonucleic Acid)



DNA(Deoxyribonucleic Acid)



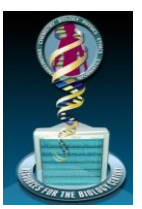
1953
Molecular structure is identified
by James Watson, Francis Crick
(USA) *(UK)*

1962
The Nobel Prize
in Physiology or Medicine

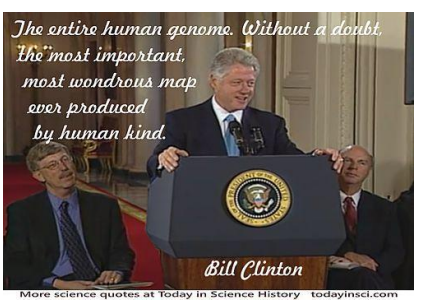
1984-2003
The Human Genome Project

A human Genome
for $100

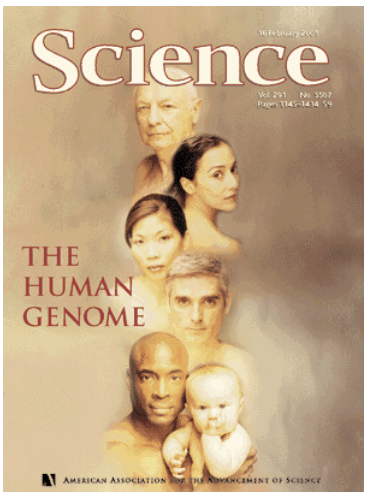
3.3 billion base-pairs



2000

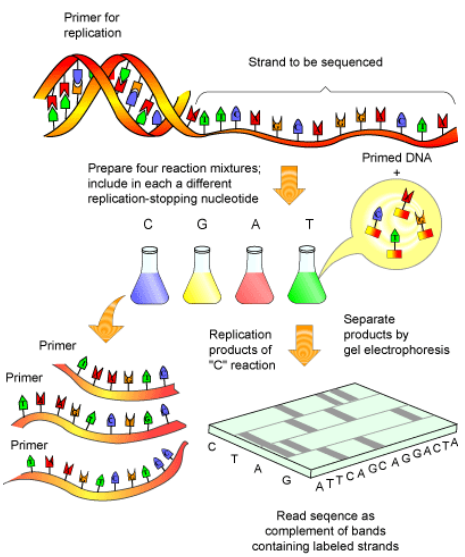


Nature 409, 860-921
(15 February 2001)



Science 291, 1304-1351
(16 February 2001)

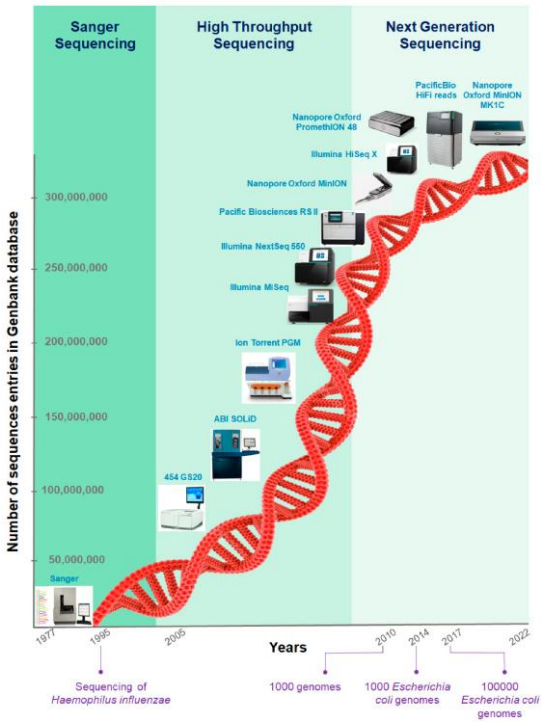
DNA sequencing



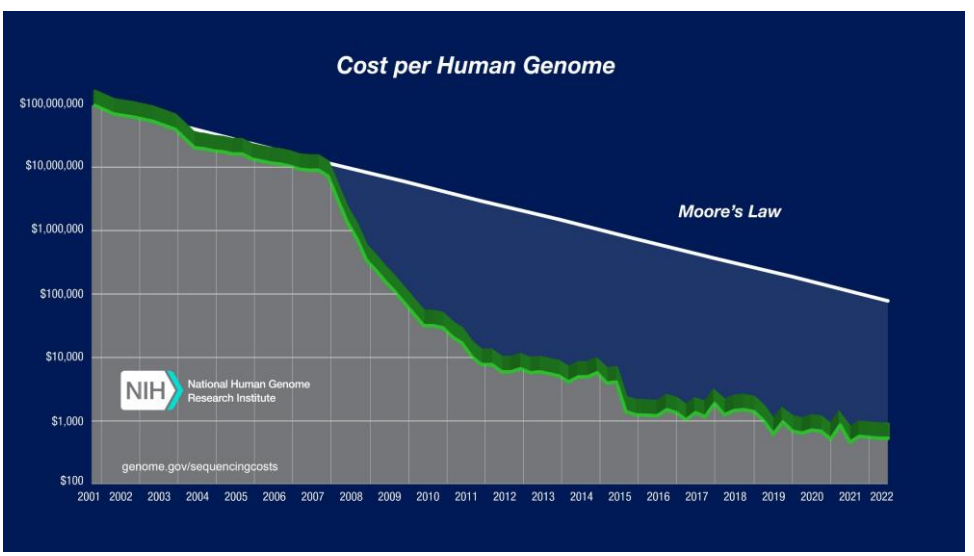
例: 元の配列 GTCTGAAACATGATT

- アデニン(A)で切断した場合
  - [06] GTCTG**A** <-> AACATGATT
  - [07] GTCTGA**A** <-> ACATGATT
  - [08] GTCTGAA**A** <-> CATGATT
  - [10] GTCTGAAACA <-> TGATT
  - [13] GTCTGAAACATG**A** <-> TT
- グアニン(G)で切断した場合
  - [01] **G** <-> TCTGAAACATGATT
  - [05] GTCT**G** <-> AAACATGATT
  - [12] GTCTGAAACATG <-> ATT
- シトシン(C)で切断した場合
  - [03] GT**C** <-> TGAAACATGATT
  - [09] GTCTGAAA**C** <-> ATGATT
- チミン(T)で切断した場合
  - [02] G**T** <-> CTGAAACATGATT
  - [04] GTC**T** <-> GAAACATGATT
  - [11] GTCTGAAACA**T** <-> GATT
  - [14] GTCTGAAACATGA**T** <-> T
  - [15] GTCTGAAACATGATT

[01] **G**
[02] G**T**
[03] GT**C**
[04] GTC**T**
[05] GTCT**G**
[06] GTCTG**A**
[07] GTCTGA**A**
[08] GTCTGAA**A**
[09] GTCTGAAA**C**
[10] GTCTGAAAC**A**
[11] GTCTGAAACA**T**
[12] GTCTGAAACAT**G**
[13] GTCTGAAACATG**A**
[14] GTCTGAAACATGA**T**
[15] GTCTGAAACATGATT



DNA sequencer

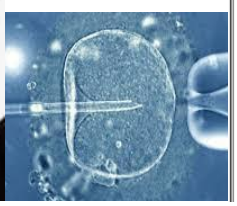


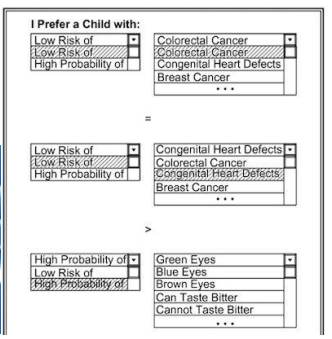
Designer baby

23andMe *In California*

Patent

"Gamete donor selection based on genetic calculations"

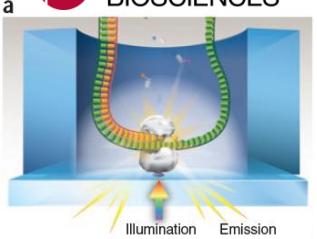




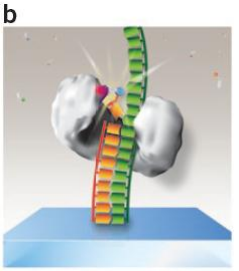
Next generation sequencer

Nature Biotechnology, **28**, 426–428 (2010)

PACIFIC BIOSCIENCES®



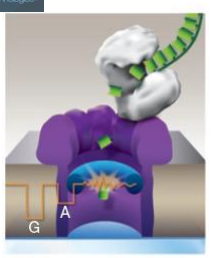
Fluorescence



life technologies™

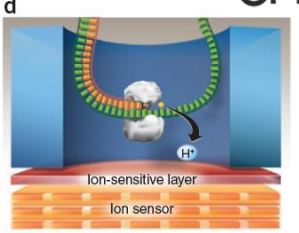
FRET

Oxford NANOPORE Technologies®



Electron

dnae

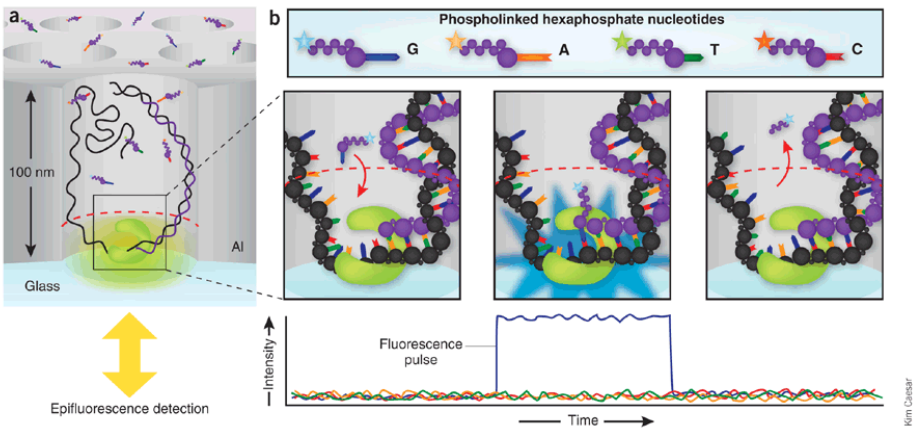


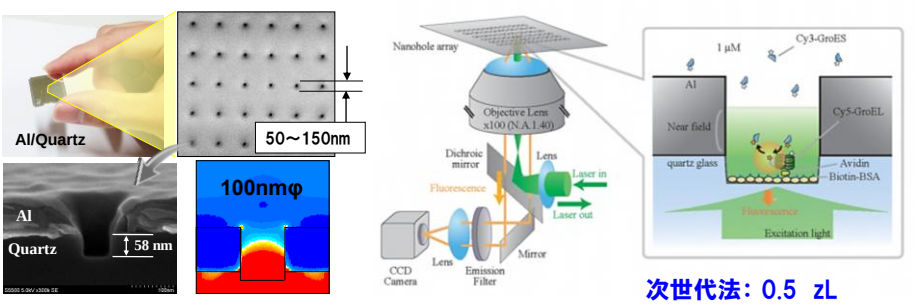
Next generation sequencer

PACIFIC BIOSCIENCES®

Zero-mode waveguide

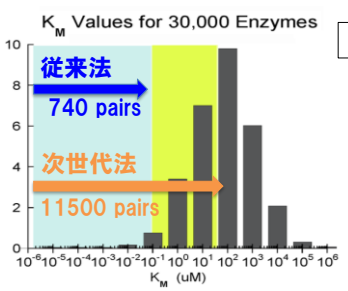
Movie

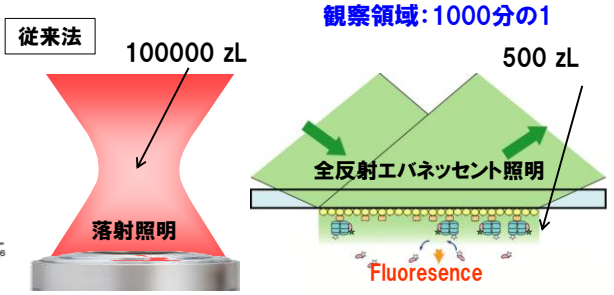


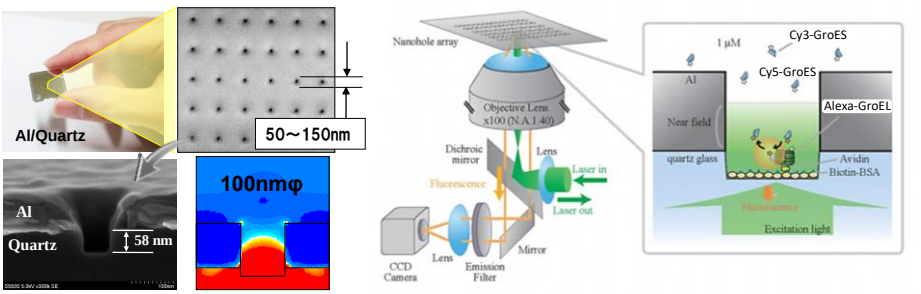


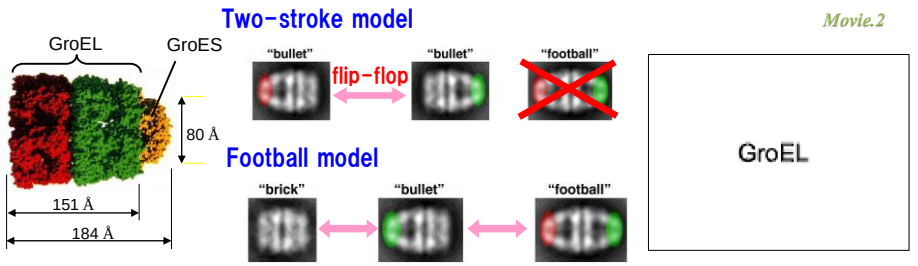
次世代法：0.5 zL

観察領域：1000分の1



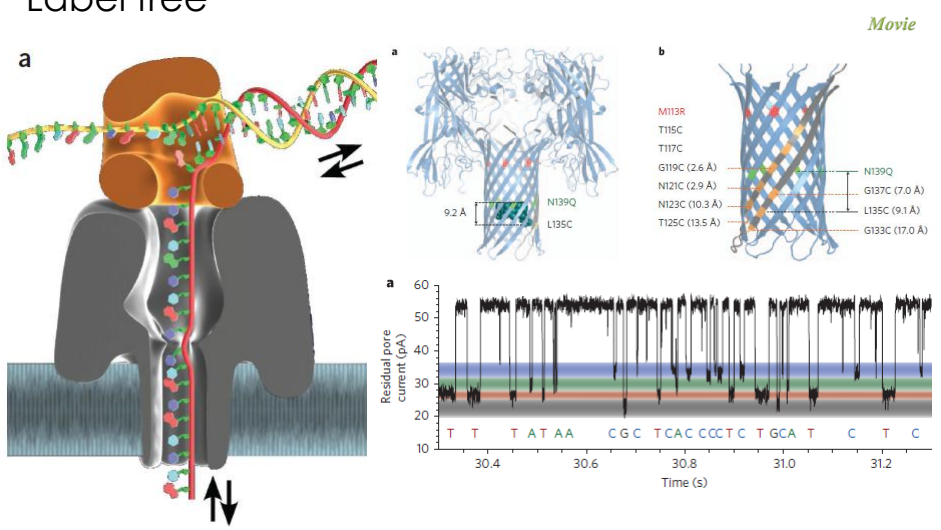


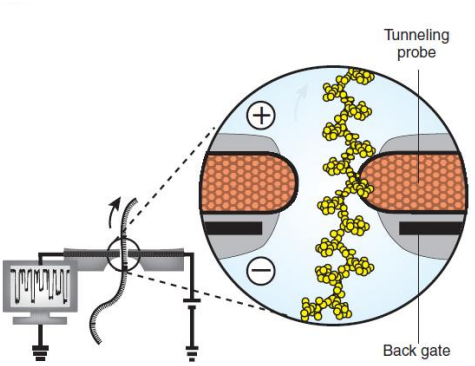




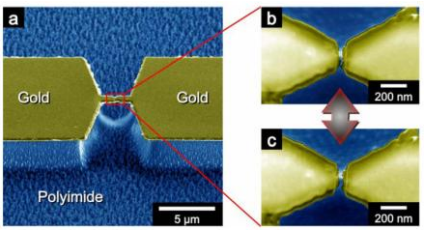
Oxford nanopore sequencing

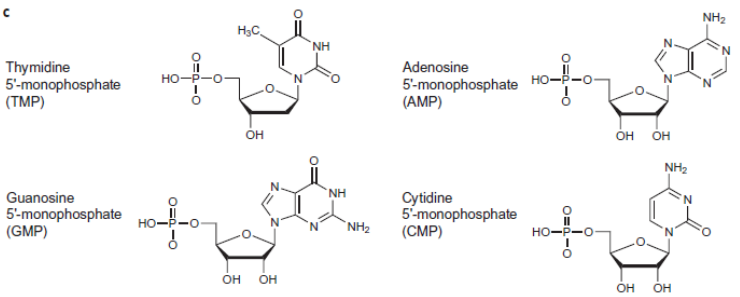
Label free





Tomoji Kawai
Masateru Taniguchi
Osaka University



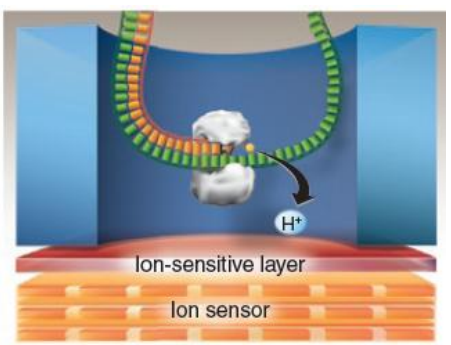


Next generation sequencer

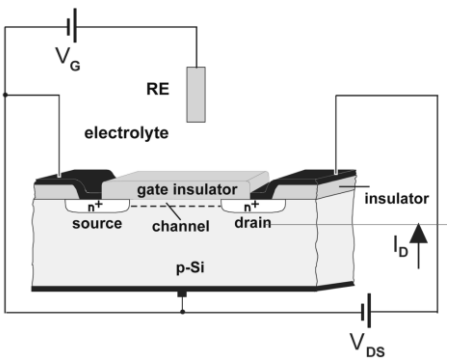
DNA electronics

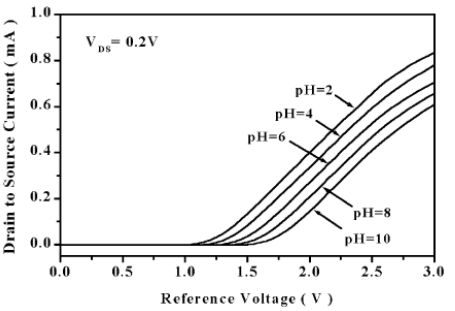
Ion Proton™ System

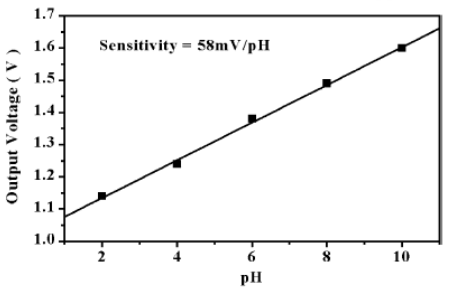
Movie



ISFET: Ion selective FET



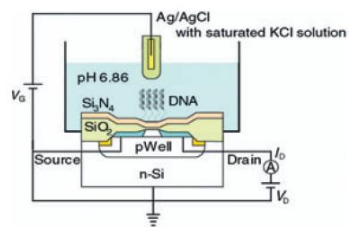


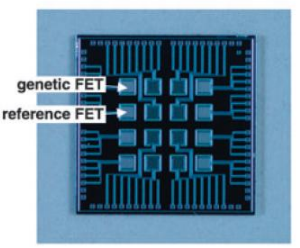


Same value when the pH is changed by 1.0 pH.

$$\Delta E_p = |E_p{}^a - E_p{}^c| = 2.3\frac{RT}{nF} = \frac{59}{n} mV \ (at\ 289K)$$

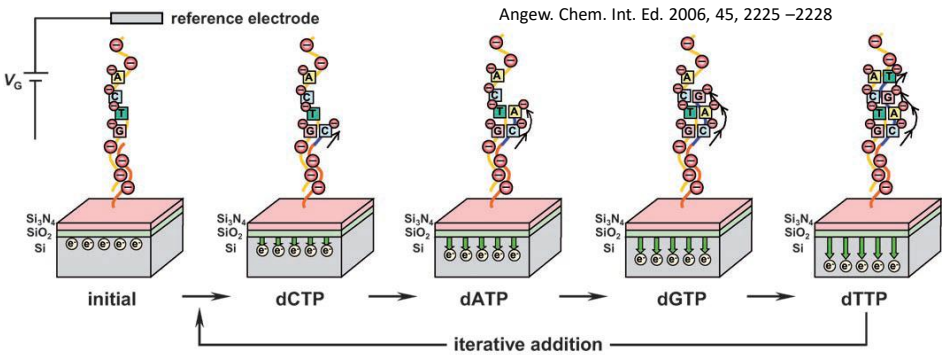
DNA detection with ISFET





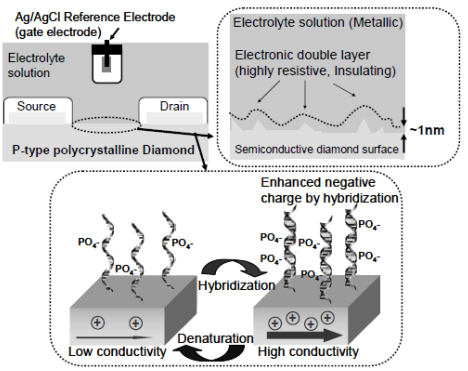
Prof. Yuji Miyahara
Tokyo Medical and Dental University

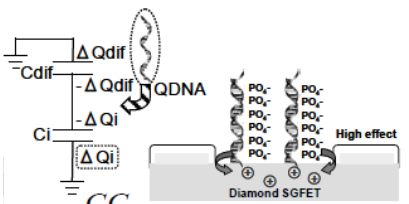
Angew. Chem. Int. Ed. 2006, 45, 2225 –2228



Diamond solution gate FET

Prof. Hiroshi Kawarada
Waseda University



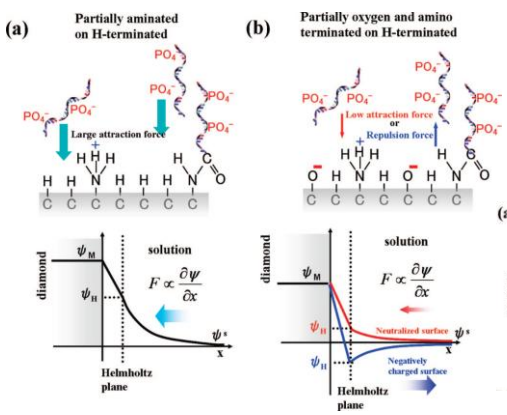


$$C_{Tot} = \frac{C_i C_{dif}}{C_i + C_{dif}}$$

$$\Delta Q_i = \frac{C_i Q_{DNA}}{C_i + C_{dif}}$$

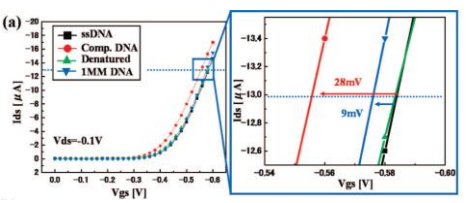
Cdif~10μF/cm²
Ci~10μF/cm²
Large ΔQi and gm

Single-base mismatch detection



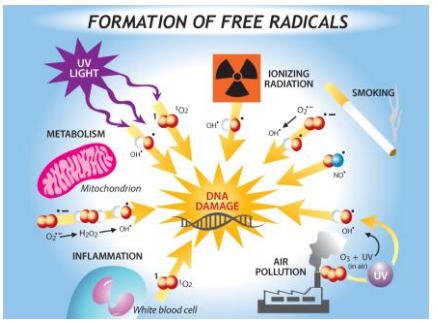
For Potentiometric Detection

Comp. probe DNA	HOOC-5′-CCACGGACTACTTCAAAACTA-3′
Comp. target DNA	3′-GGTGCCTGATGAAGTTTTGAT-5′
1MM target DNA	3′-GGTGCCTGATCAAGTTTTGAT-5′
Noncomp. target DNA	3′-ATGCATGCATGCATGCATGCA-5′



DNA Mismatch and Damage Repair

1 million individual molecular lesions per cell per day



Nobel Prize in Chemistry (2015) "DNA repair"

Photo: Cancer Research UK
Tomas Lindahl

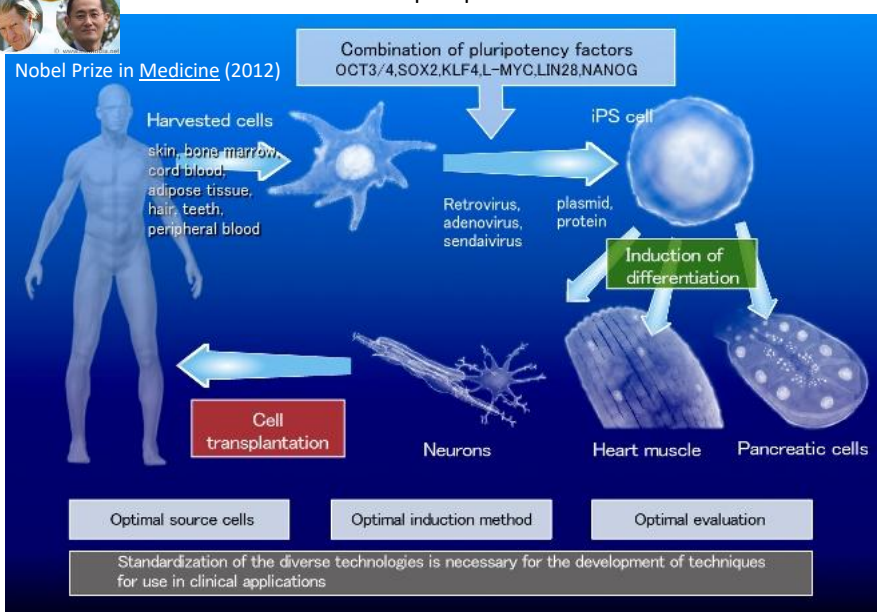
Photo: K. Wolf/AP Images for HHMI
Paul Modrich

Photo: M. Englund, UNC-School of Medicine
Aziz Sancar

DNA Injection into the cell

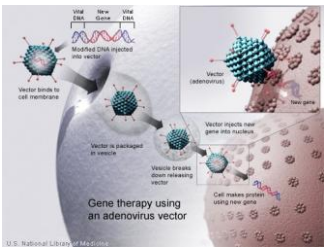
Nobel Prize in Medicine (2012)

iPS cells: induced pluripotent stem cells



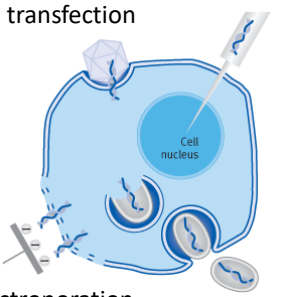
DNA Injection into the cell

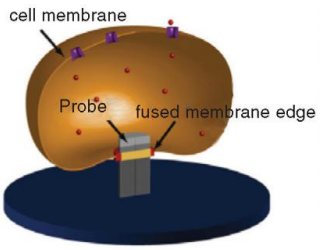
Vector

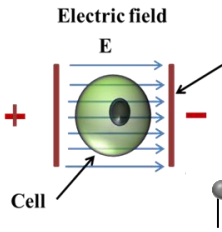


Viral transfection

Tiny needle

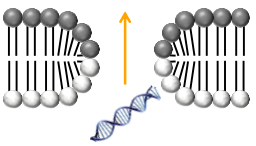






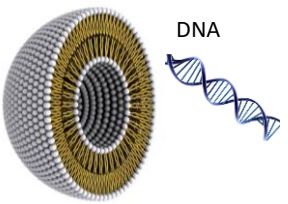
Electroporation

Lipofection



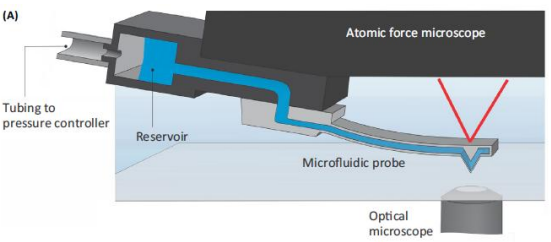
Liposome

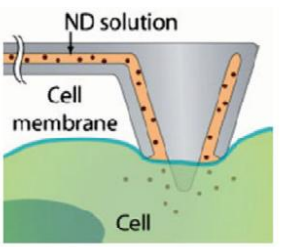
DNA

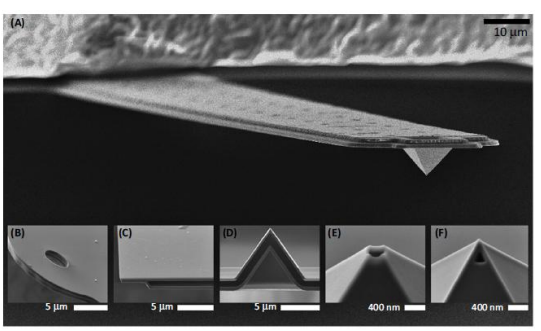


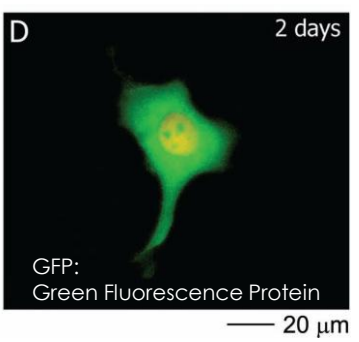
Tiny needle: Microcantilever

Prof. Nicholas A. Melosh
Stanford University

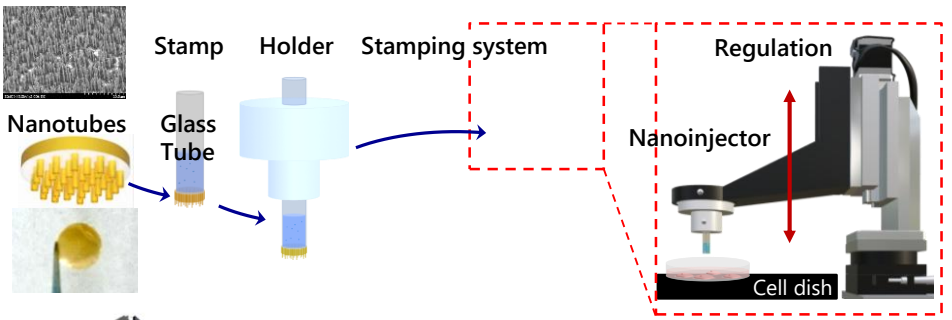


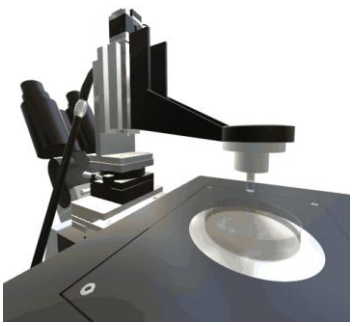


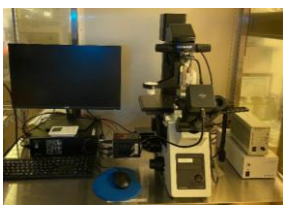


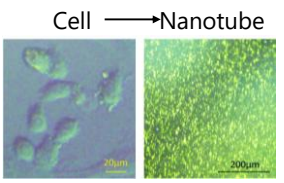


Miyake's group

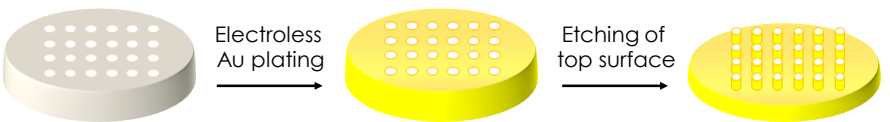


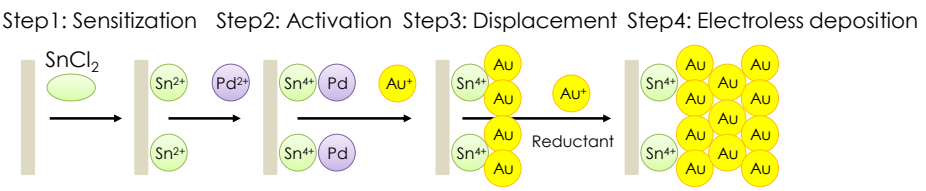


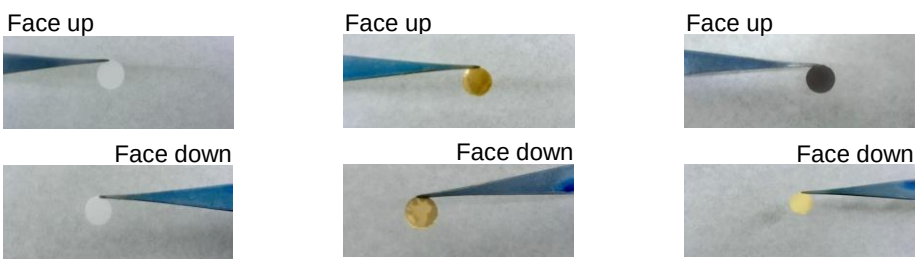


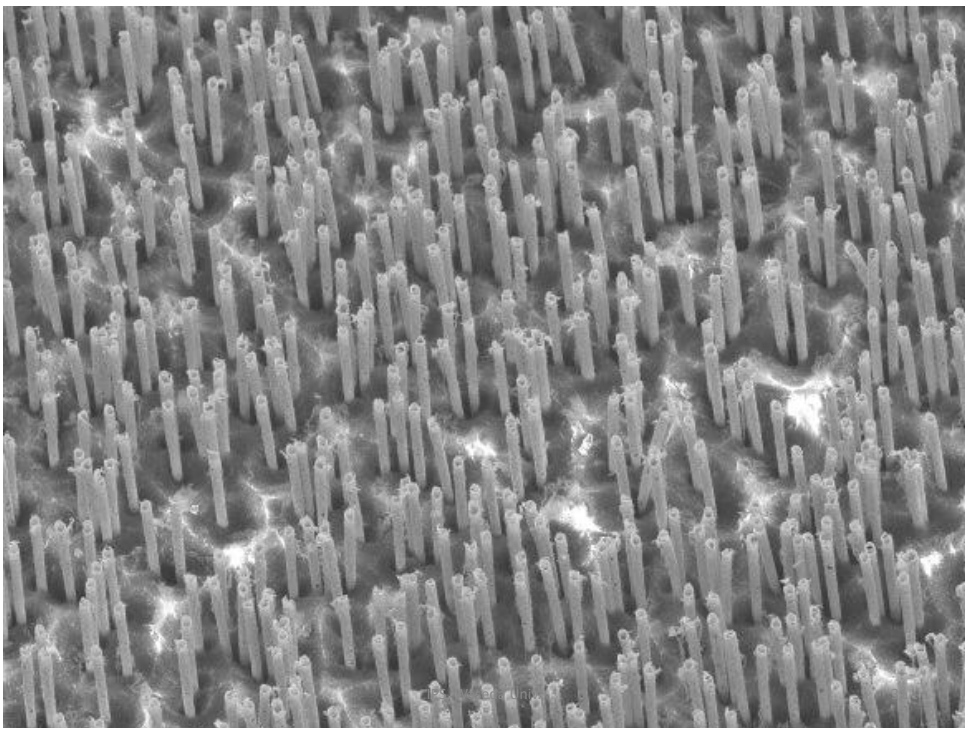


Au-nanostraw membrane

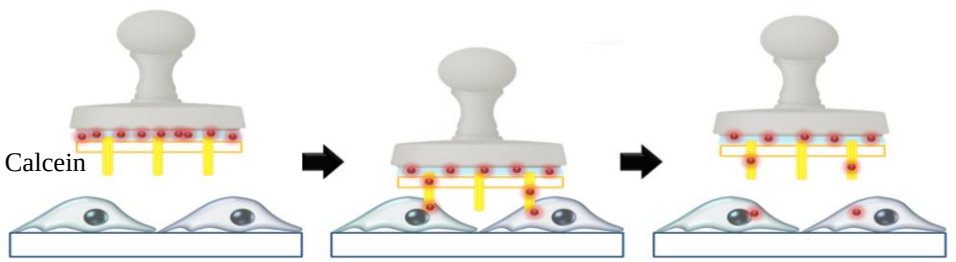






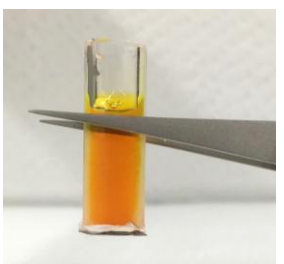


Au-nanostraw stamping

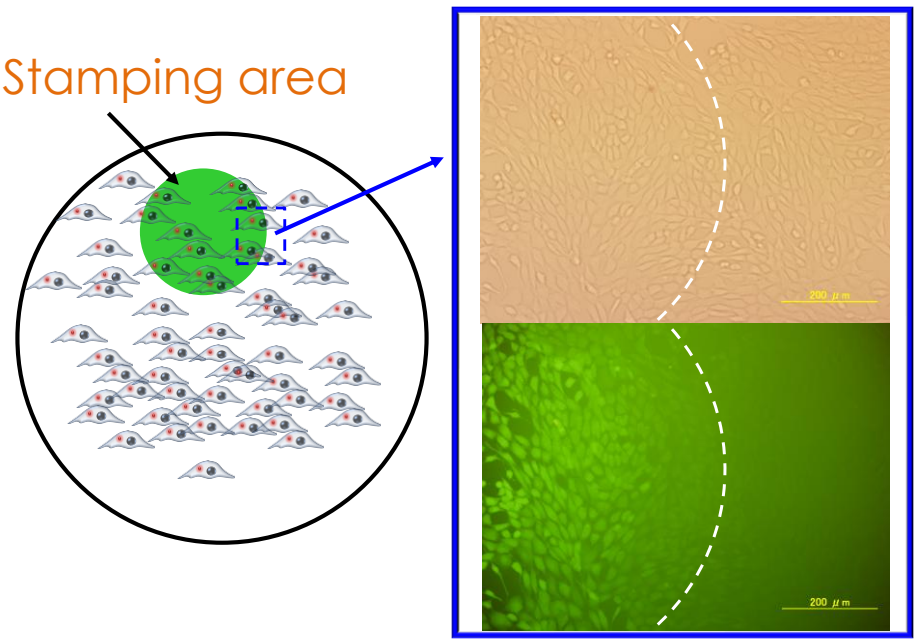


3T3: fibroblast cell

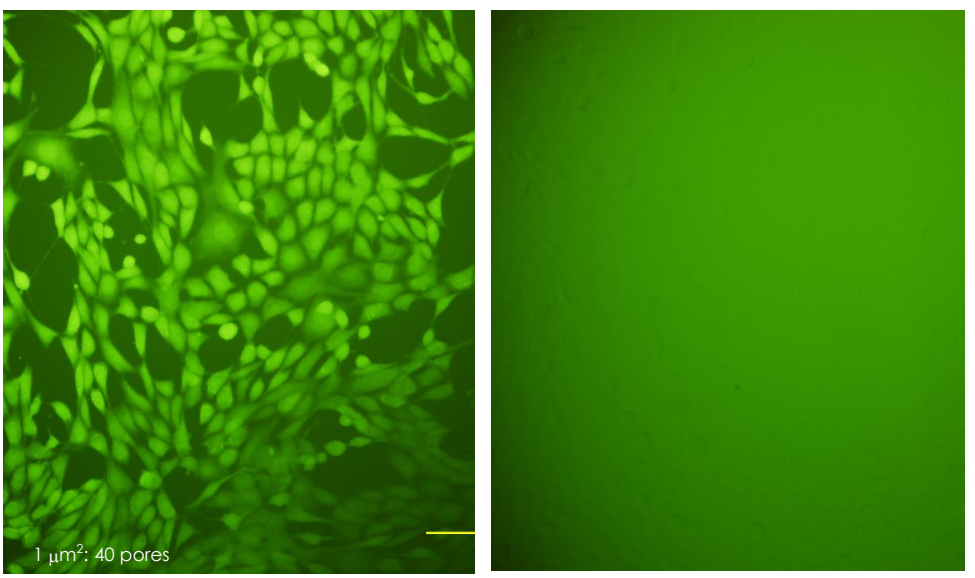
1.6 mM Calcein in PBS



Calcein delivery into the cells



With and without nanoneedles



Calcein色素 622.55 g/mol

Oligo DNA 6603.51 g/mol

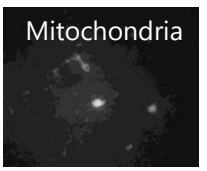
GFP 26.9 kDa

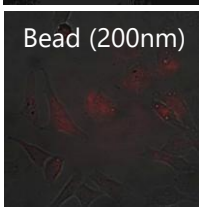
Mitochondria ＞1 MDa

低分子 ⟷ 高分子

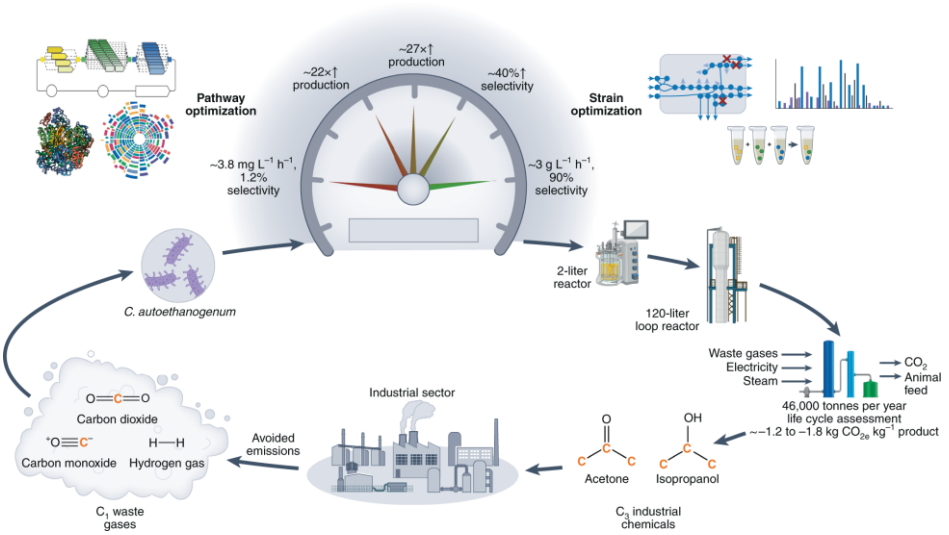
Viability (生存率) [%]		
99.3	99.0	98.5
Delivery rate (導入効率) [%]		
100	90.0	84.0

$$\frac{Stained\ cell\ number\ (●+●)}{Total\ cell\ numbers\ (●)}=\text{Delivery} \qquad \frac{Live\ cell\ number\ (●)}{Stained\ cell\ number\ (●+●)}=\text{Viability}$$





Sustainable manufacturing with synthetic biology



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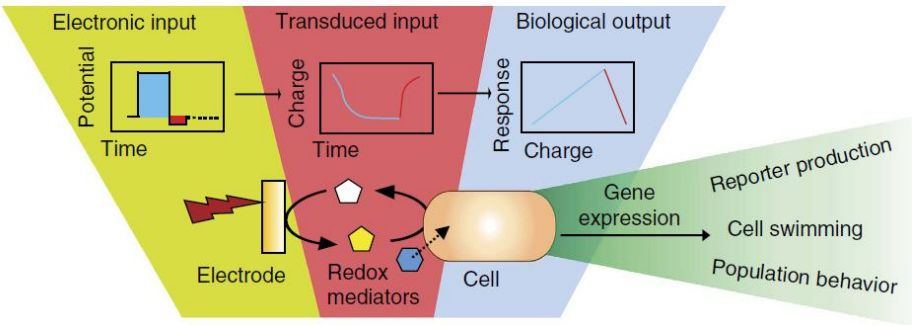
Electrogenetics



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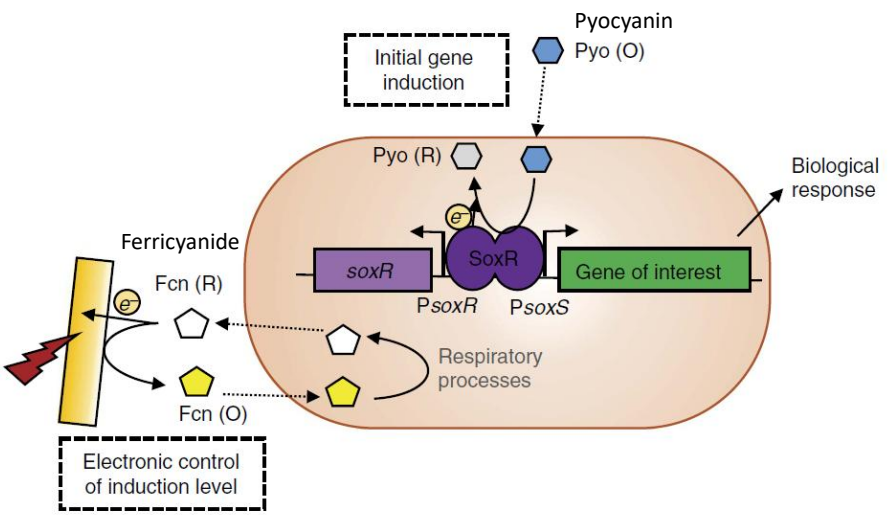
Electrogenetics



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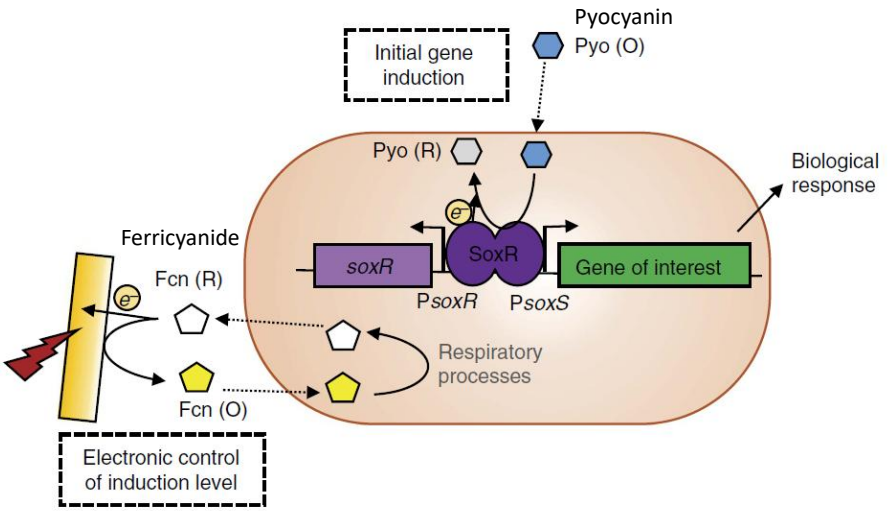
Electrogenetics



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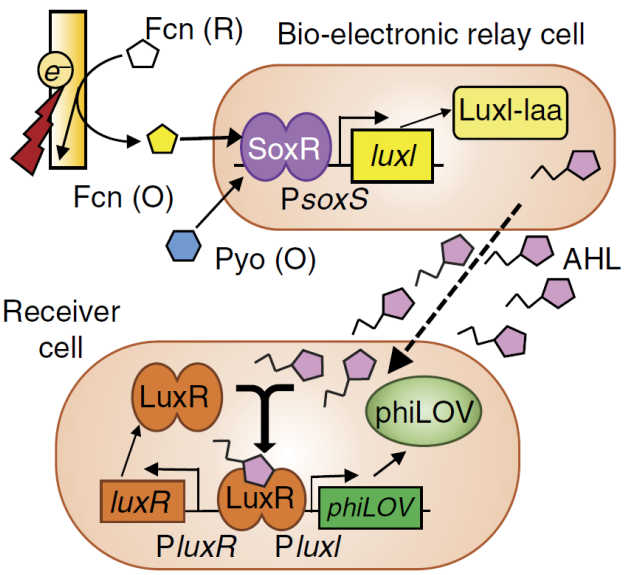
Electrogenetics



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