



Applied Biosystems
ABI 3730XL
1 Mb / day



Roche / 454
Genome Sequencer FLX
100 Mb / run



Illumina / Solexa
Genetic Analyzer
2000 Mb / run



Applied Biosystems
SOLiD
3000 Mb / run



PACIFIC
BIOSCIENCES®



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Oxford
NANOPORE
Technologies®



illumina inc. (ILMN) - NasdaqGS

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Pacific Biosciences of Califom

■ PACB

Nov 14, 2012



Comparison to other sequencing methods

	Ion Torrent ^{[14][16]}	454 Sequencing ^[17]	Illumina ^[18]	SOLiD ^[19]
Sequencing Chemistry	Ion semiconductor sequencing	Pyrosequencing	Polymerase-based sequence-by-synthesis	Ligation-based sequencing
Amplification approach	Emulsion PCR	Emulsion PCR	Bridge amplification	Emulsion PCR
Mb per run	100	100	600,000	170,000
Time per run	1.5 hours	7 hours	9 days	9 days
Read length	200 bp	400 bp	2x150 bp	35x75 bp
Cost per run	\$ 350 USD	\$ 8,438 USD	\$ 20,000 USD	\$ 4,000 USD
Cost per Mb	\$ 5.00 USD	\$ 84.39 USD	\$ 0.03 USD	\$ 0.04 USD
Cost per instrument	\$ 50,000 USD	\$ 500,000 USD	\$ 600,000 USD	\$ 595,000 USD

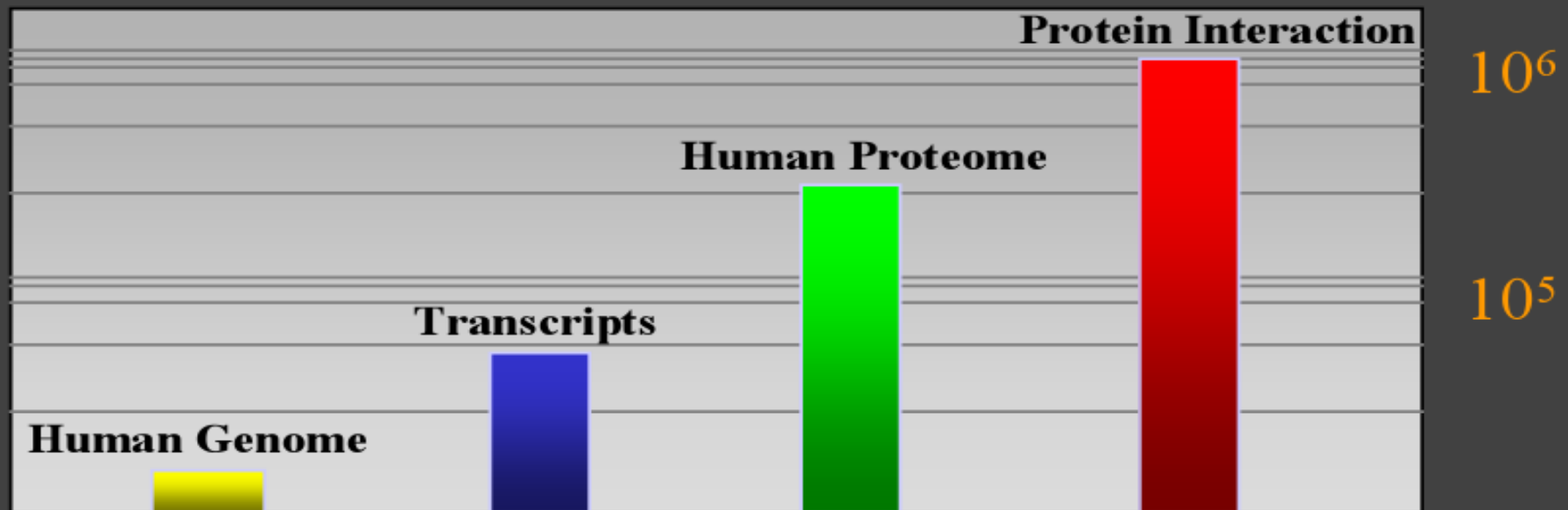
Genome: 30.000 genes



Transcriptome: 40-100.000 mRNAs

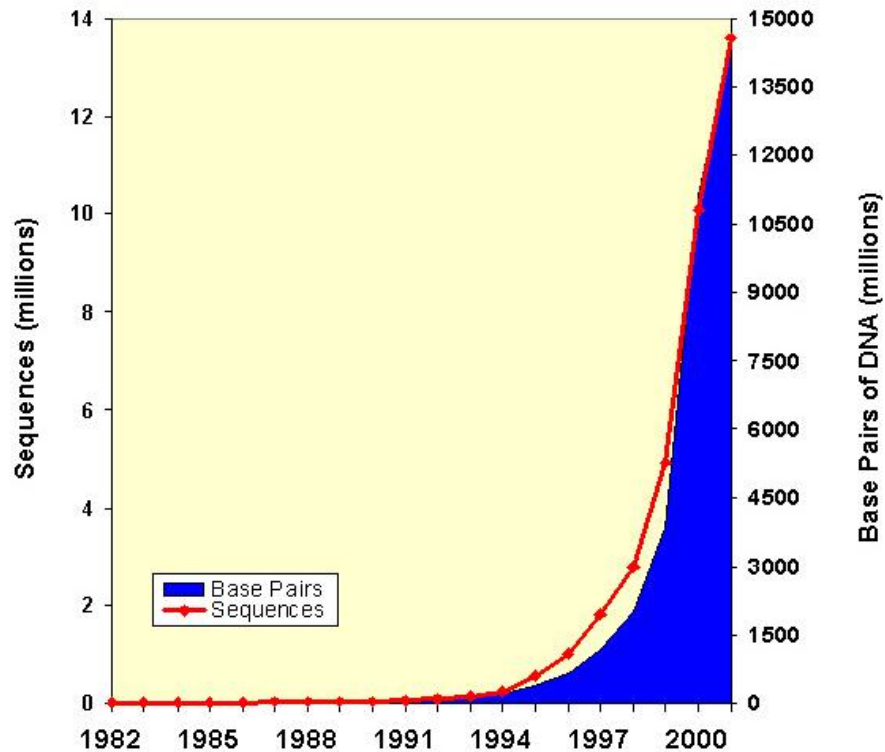


Proteome: 100-400.000 proteins
>1.000.000 interactions



Sekvenování genomů

GenBank vznikla v roce 1982 z Los Alamos Sequence Database



Walter Goad

Proč sekvenovat dál?

- Komparativní genomika
- Biomedicínský výzkum
- Osobní genom

Frederick Sanger

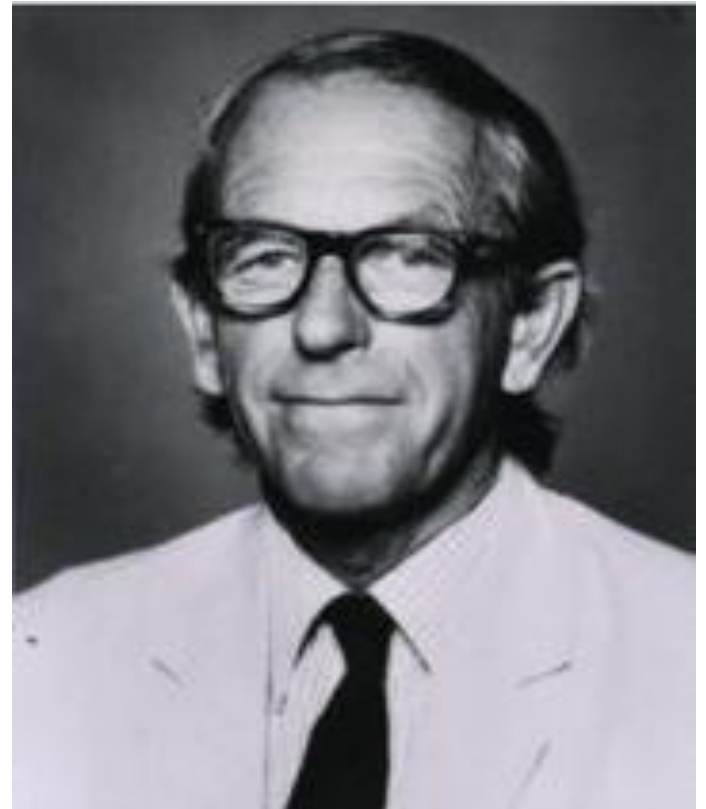
**1958 – Nobelova cena za určení
struktury inzulínu**

1975 - Dideoxy sekvenační metoda

1977 – osekvenoval Φ -X174 (5,368 bp)

**1980 – dostal druhou Nobelovu cenu
za chemii**

**Později (polovina 80-tých let)
osekvenoval bakteriofága λ pomocí
shotgun metody (48,502 bp)**



Sekvenování genomů

- **1986** Leroy Hood: první automatický sekvenátor
- **1986** Human Genome Initiative
- **1990** započat projekt sekvenování lidského genomu (předpokládaná doba 15 let)



Leroy Hood



Sekvenování genomů

- **1995** John Craig Venter sekvenoval první bakteriální genom
- **1996** první eukaryotický genom (kvasinka) sekvenován



John Craig Venter

Sekvenování genomů

- **1997** sekvence *E. coli*
- **1998** *Caenorhabditis elegans* genom (první multicekulární genom)
- **1999** lidský chromozom 22 sekvenován

Sekvenování genomů

- **2000** *Drosophila melanogaster* genom
- **2001** Human Genome Sequencing:
předběžná sekvence lidského genomu



Sekvenování genomů

- **duben 2003** Lidský genom.
Sekvence myšího genomu.
- **duben 2004**
Sekvence krysího genomu

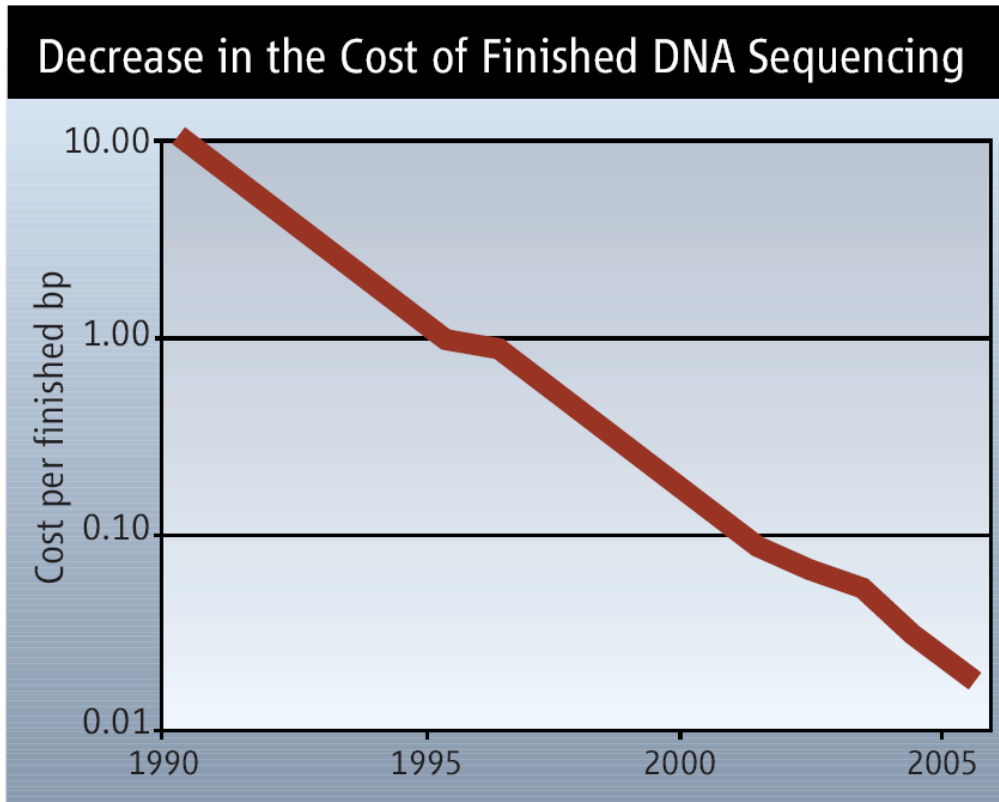


2010 Ideální lidský genom sekvenován

2010 Ideální lidský genom sekvenován



Honba za sekvencemi



Ø Human genome (first draft) –
\$300 million (2001)

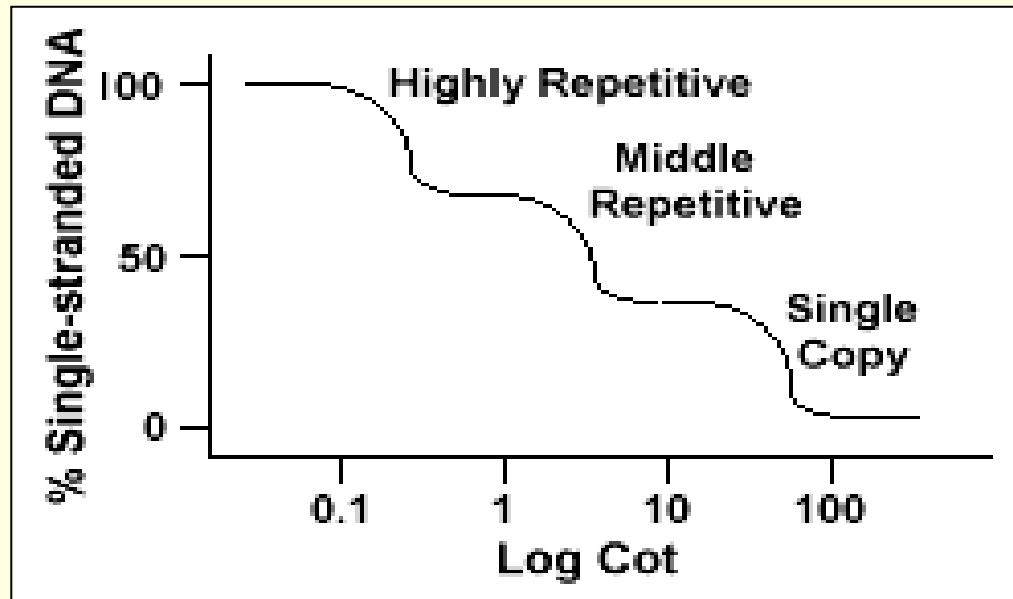
Ø Rhesus macaque –
\$22 million (2006)

Free fall. As with computer technology, the plunging cost of DNA sequencing has opened new applications in science and medicine.

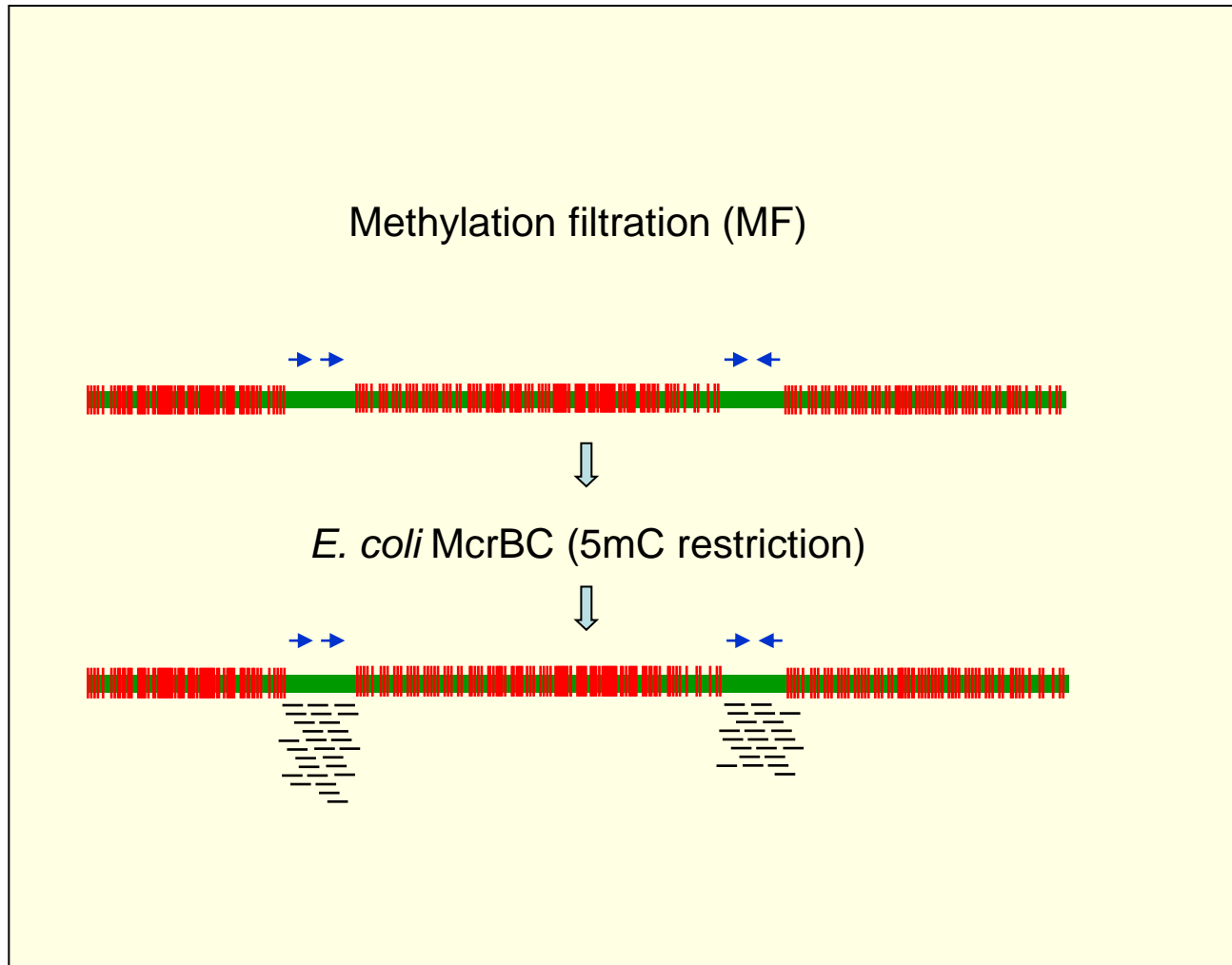
The Race for the \$1000 Genome. *Science* 311: 1544 – 1546, 2006

Redukce kopmlexity

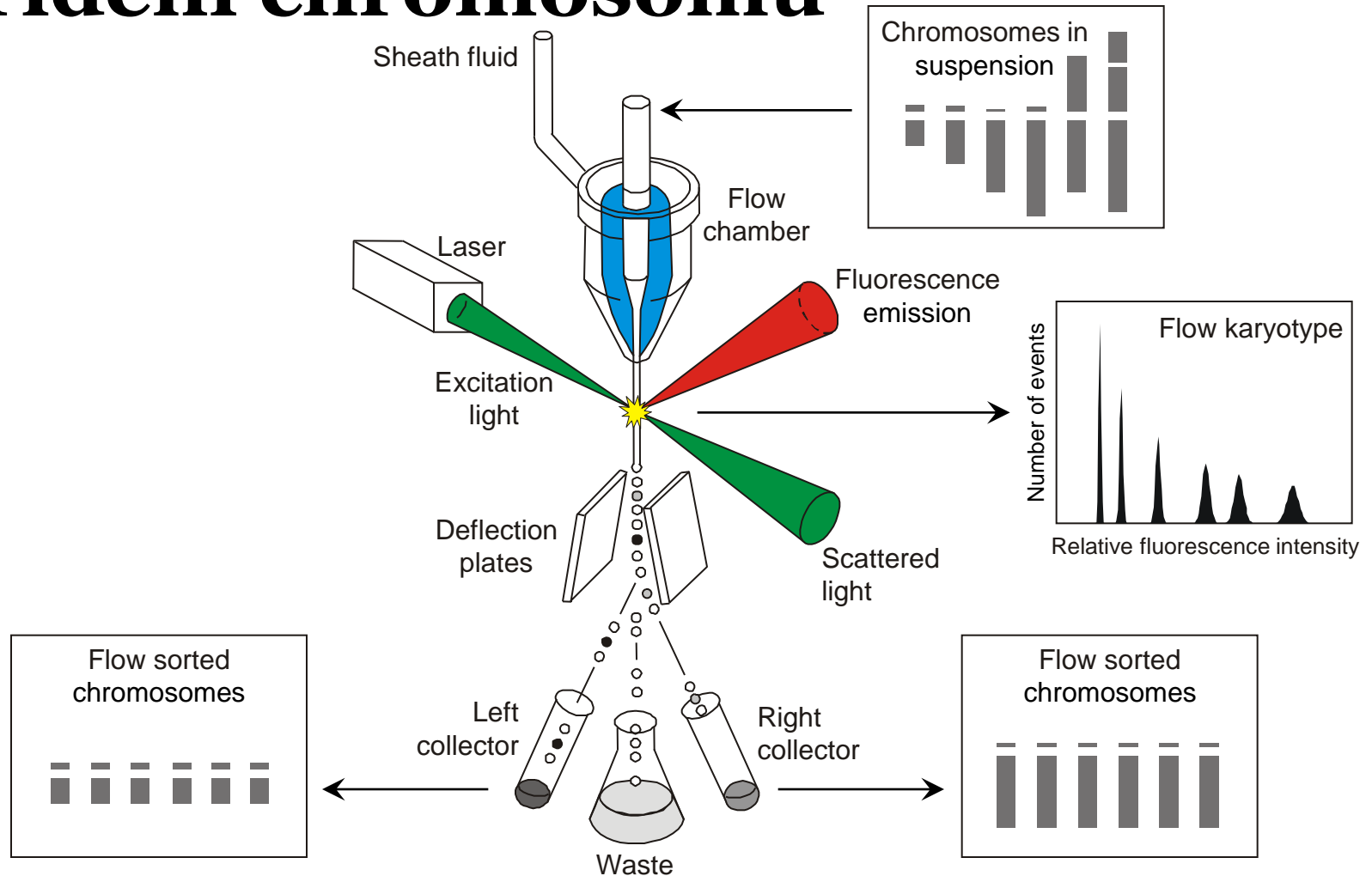
Hi-Cot selection



Redukce kopmlexity



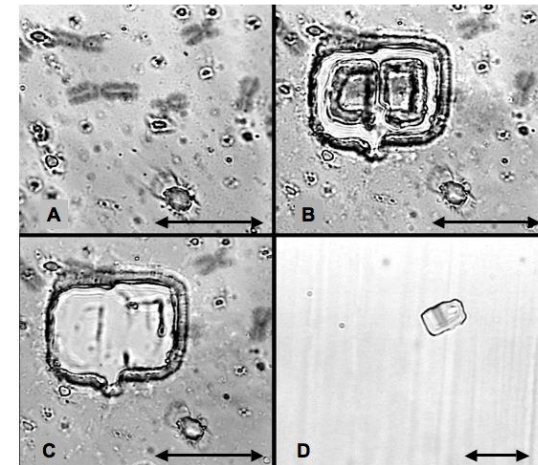
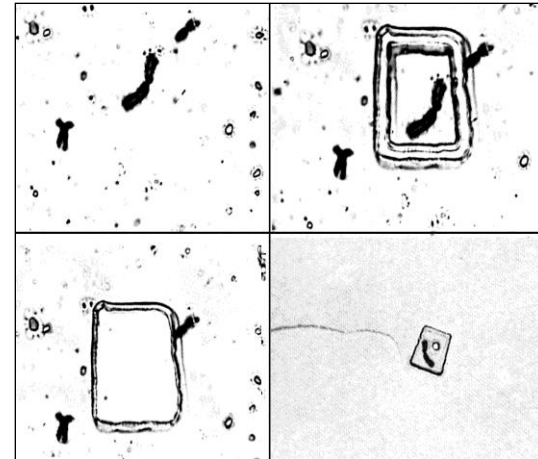
Redukce kopmlexity – třídění chromosomů



Laserová mikrodisekce

Výhody: vysoká čistota

Nevýhody: malý počet chromozomů, pracnost

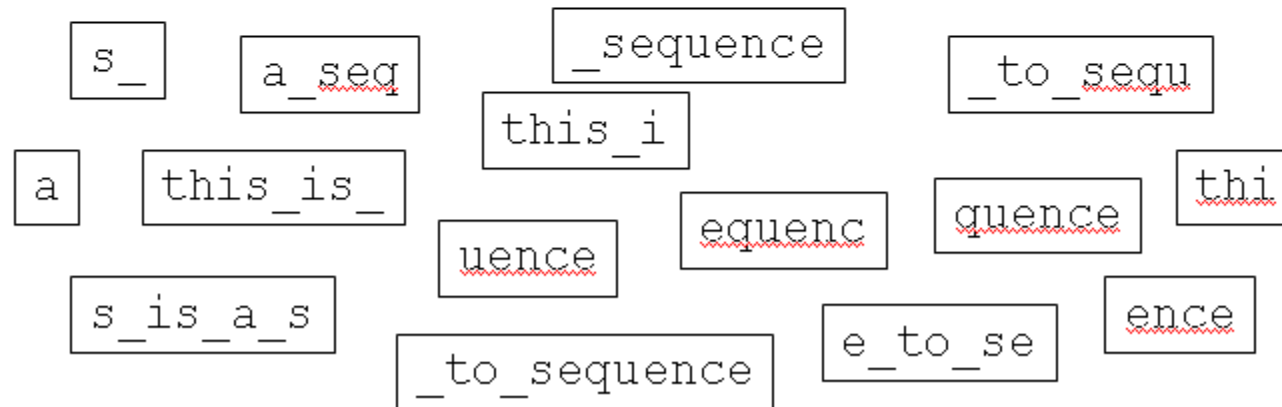


Metody sekvenování

this_is_a_sequence_to_sequence



this_is_a_sequence_to_sequence
this_is_a_sequence_to_sequence
this_is_a_sequence_to_sequence



+ ddGTP:
 _ddG
 _GTACTCTddG
 _GTACTCTGTCAddG
 _GTACTCTGTCAGTATCddG
 _GTACTCTGTCAGTATCGT

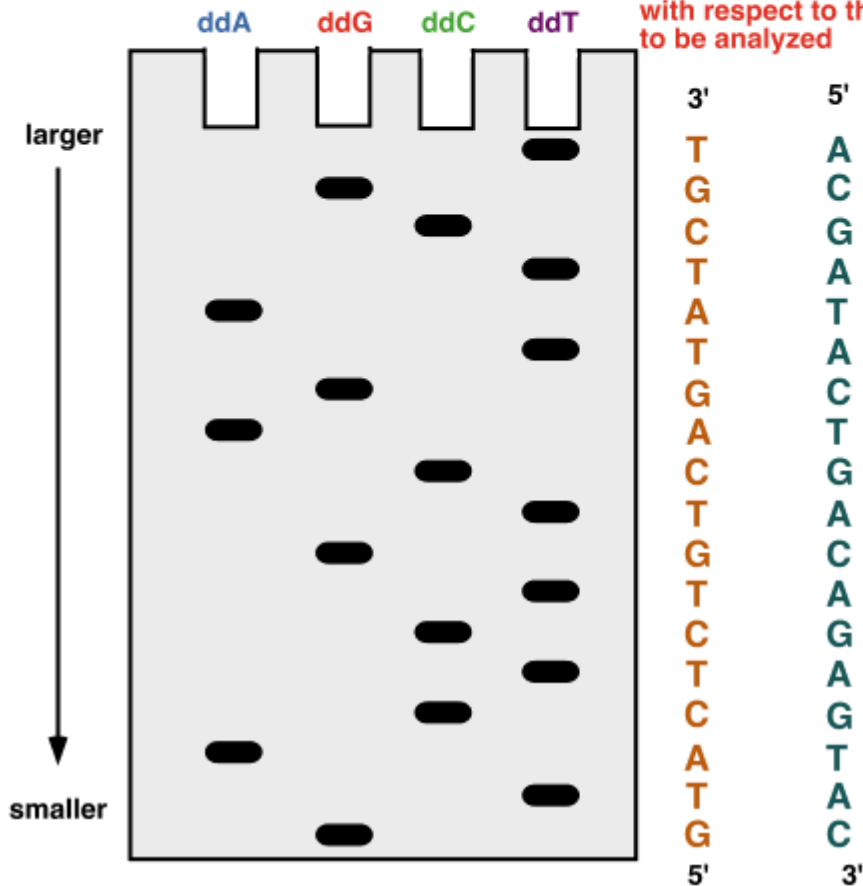
+ ddCTP:
 _GTAddC
 _GTACTddC
 _GTACTCTGTddC
 _GTACTCTGTCAGTATddC
 _GTACTCTGTCAGTATCGT

+ ddATP:
 _GTddA
 _GTACTCTGTCddA
 _GTACTCTGTCAGTddA
 _GTACTCTGTCAGTATCGT

+ ddTTP:
 _GddT
 _GTACddT
 _GTACTCddT
 _GTACTCTGddT
 _GTACTCTGTCAGddT
 _GTACTCTGTCAGTAddT
 _GTACTCTGTCAGTATCGddT
 _GTACTCTGTCAGTATCGT

gel electrophoresis
 autoradiography (if radiolabeled)

sequence read from gel
 is the complementary strand
 with respect to the sequence
 to be analyzed



Genome Sequencer 20 System 454 pyrosequencing (2005)

- <http://www.454.com>



Neanderthal
sequenced *now!*

Max Planck Institut
uses 454 Sequencing™
technology.

Read about it →

Watch the **CNN** video →

Hear the **NPR** broadcast →

Image credit:
Ken Mowbray and Blaine Maley,
American Museum of Natural History

DNA library preparation

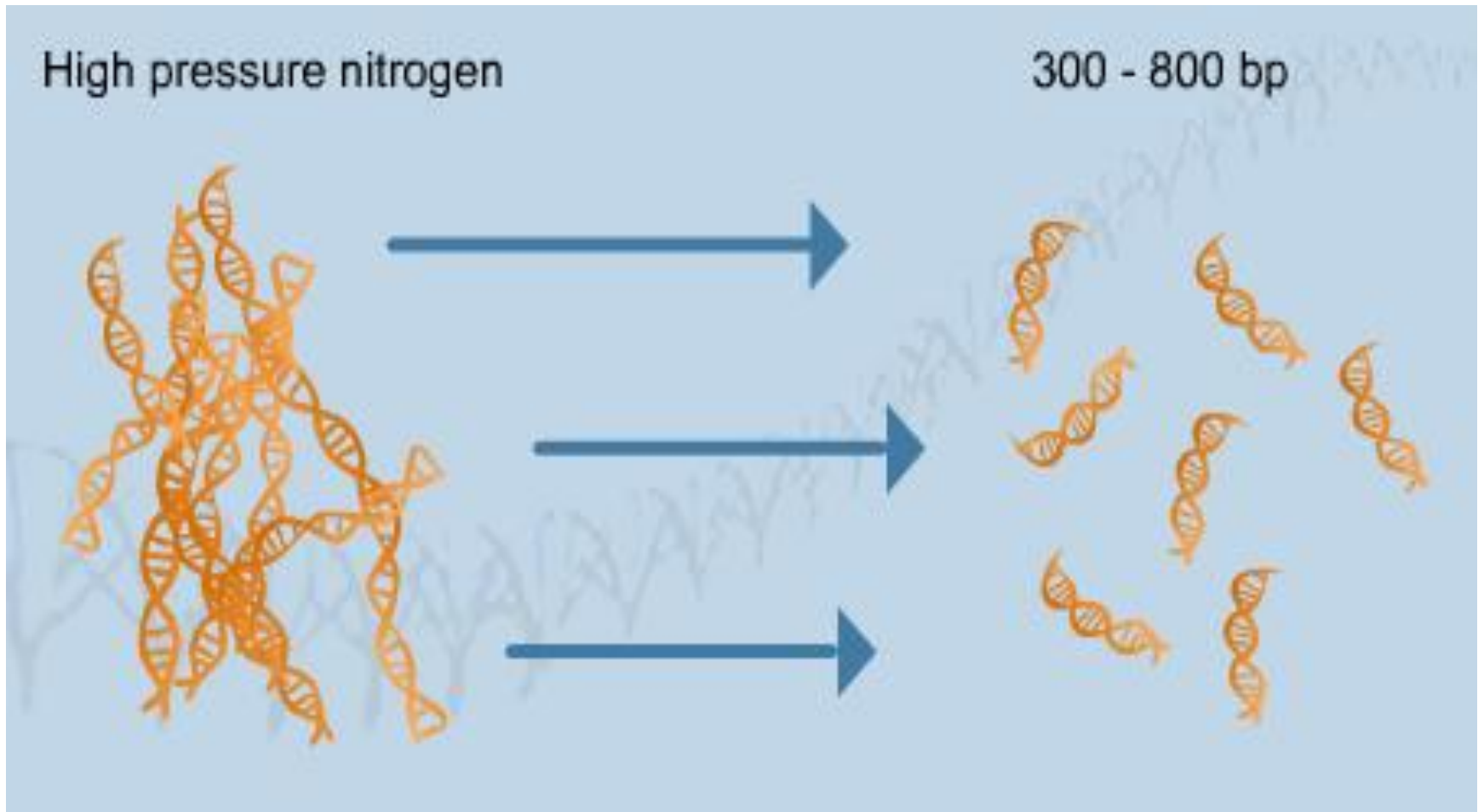
One sample preparation per genome

No Cloning

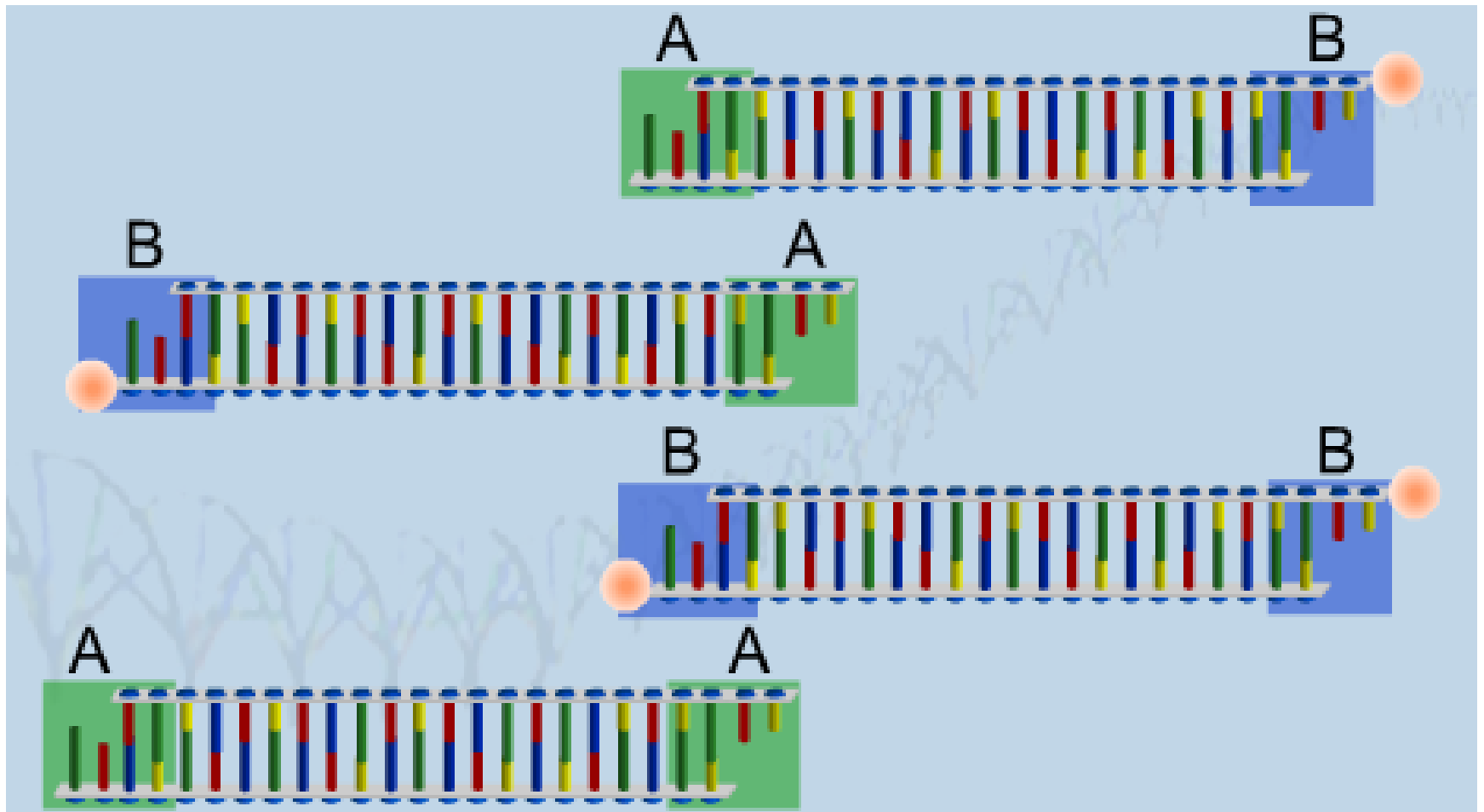
No Colony Picking



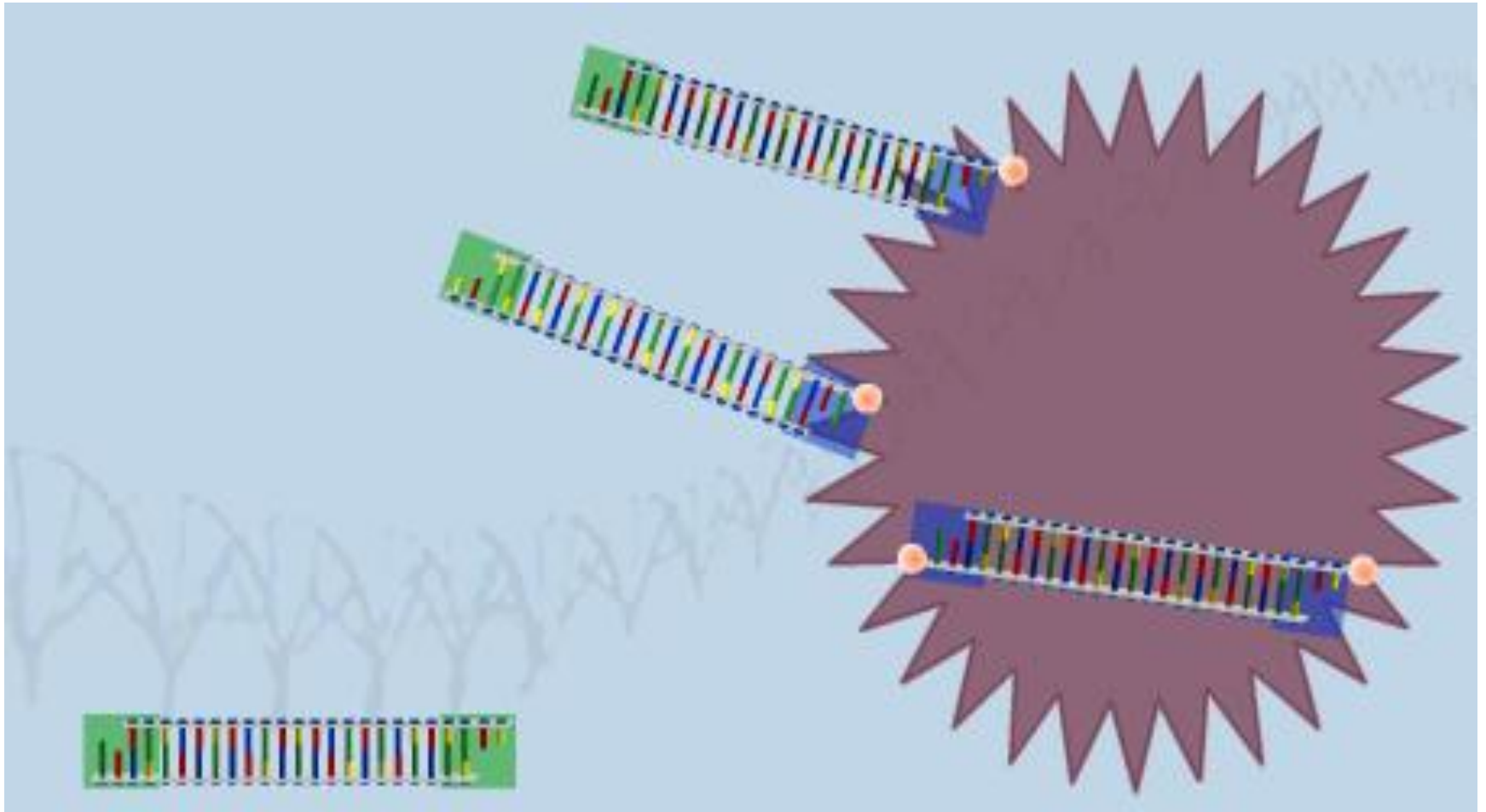
Fragmentace DNA



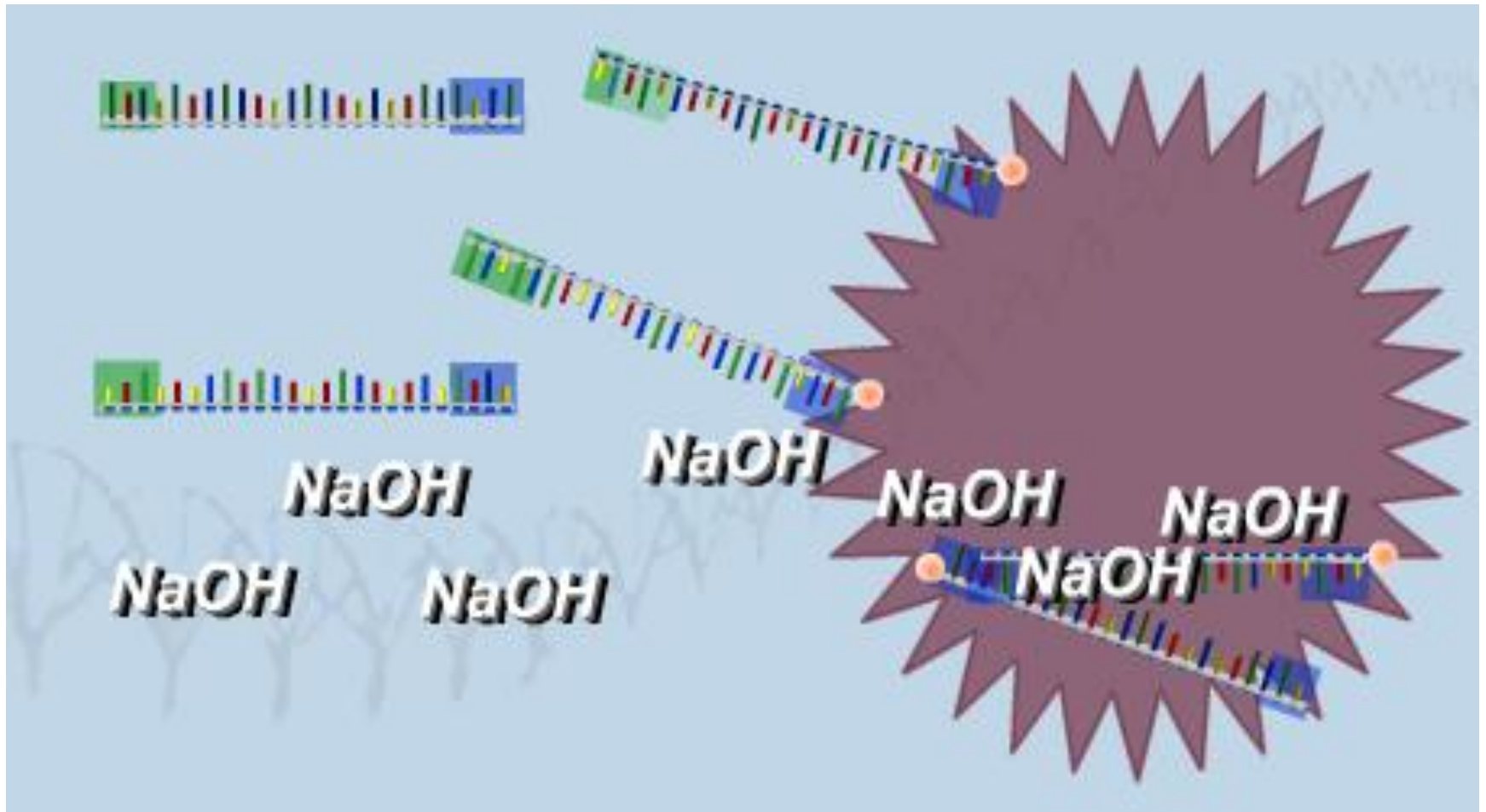
Ligace adaptoru

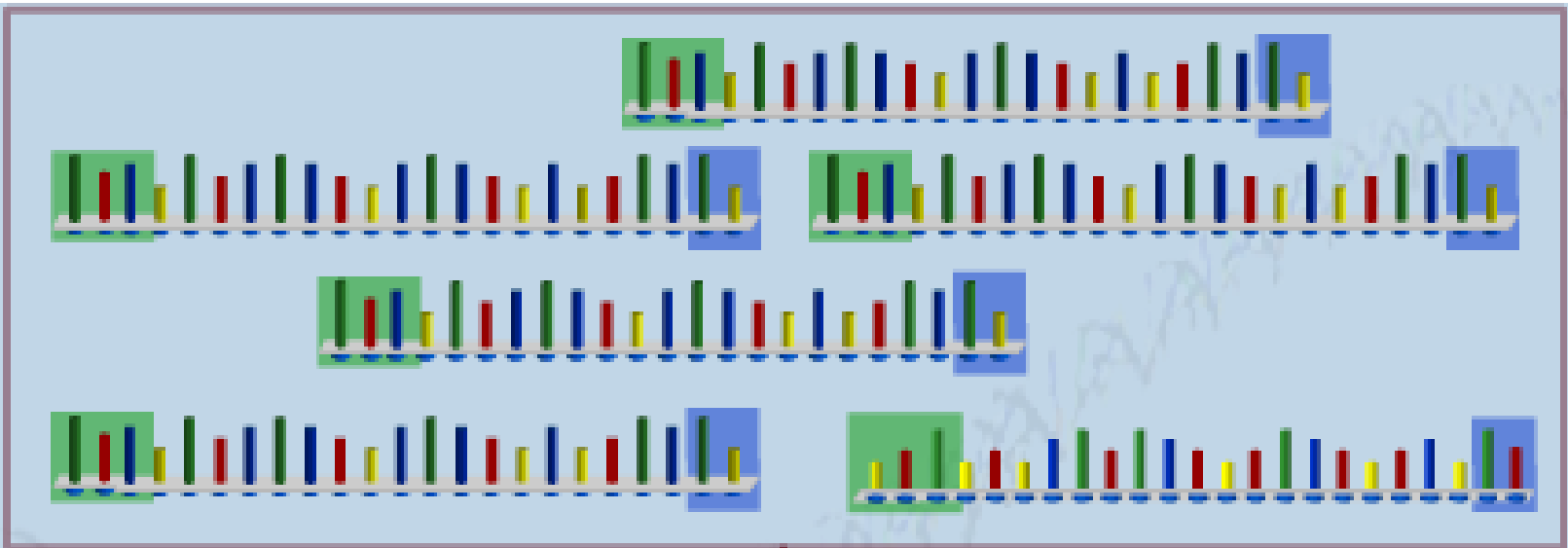


Vychytání DNA molekul



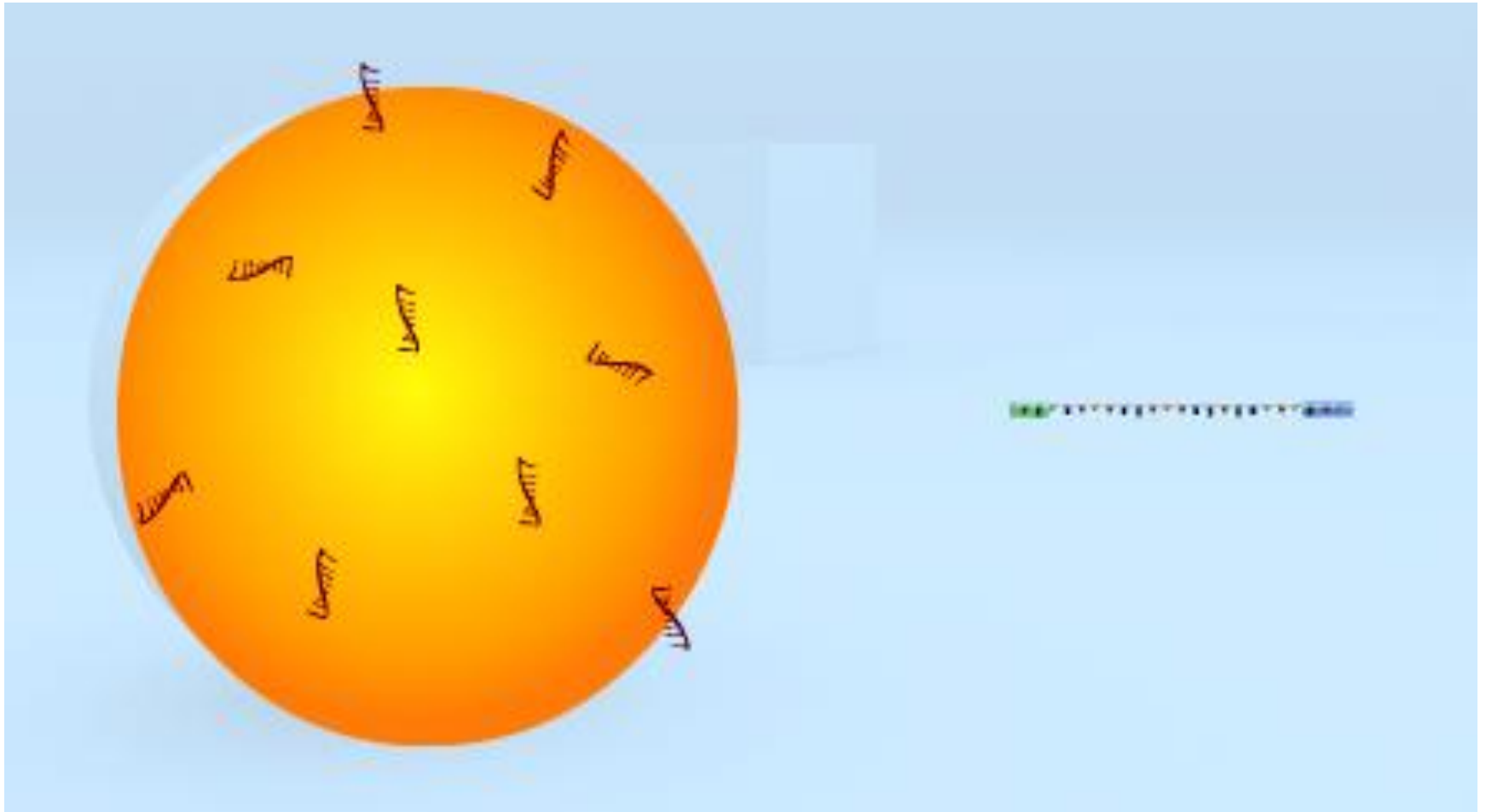
denaturace



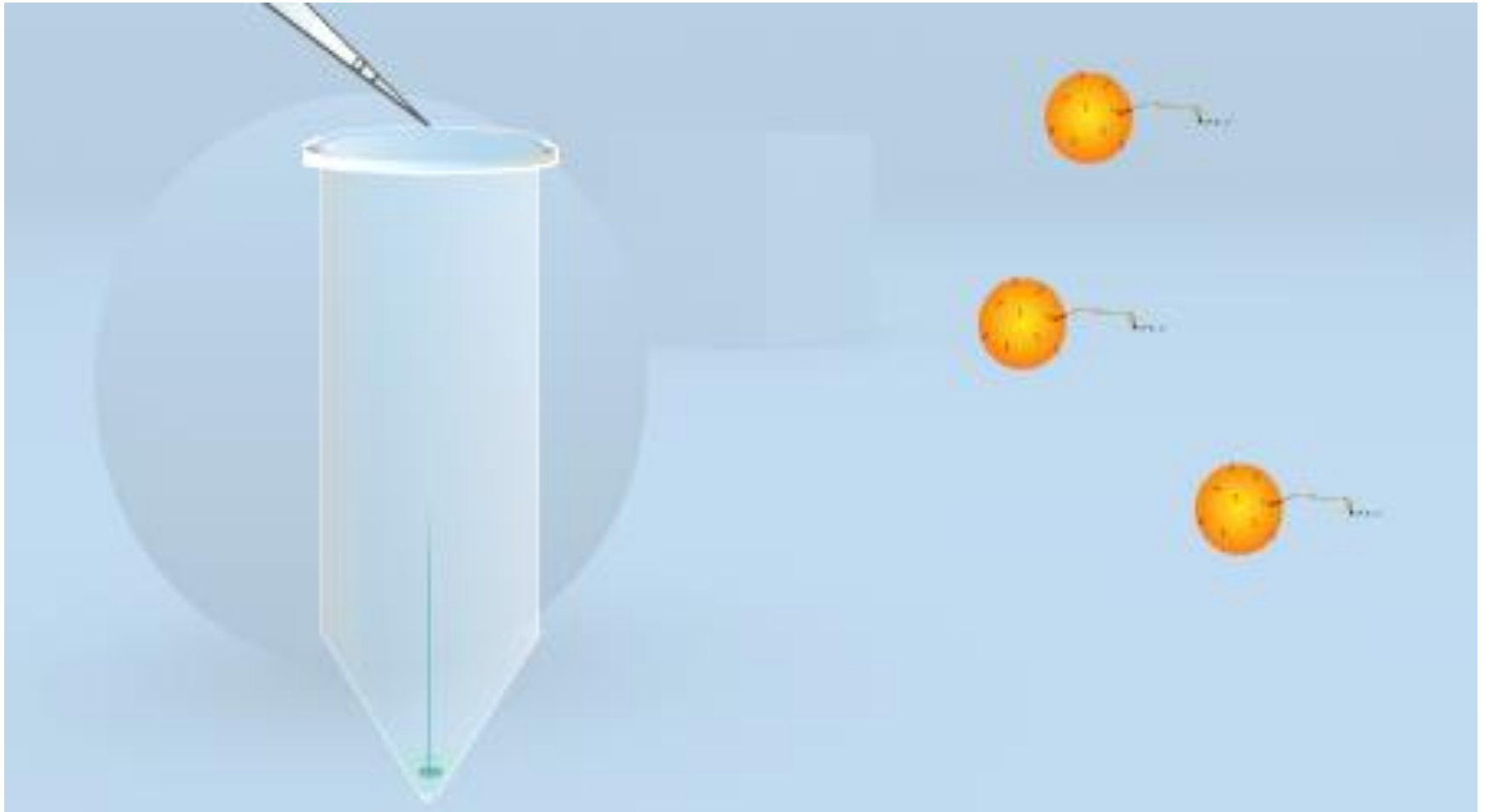


Single-stranded
template DNA
sstDNA

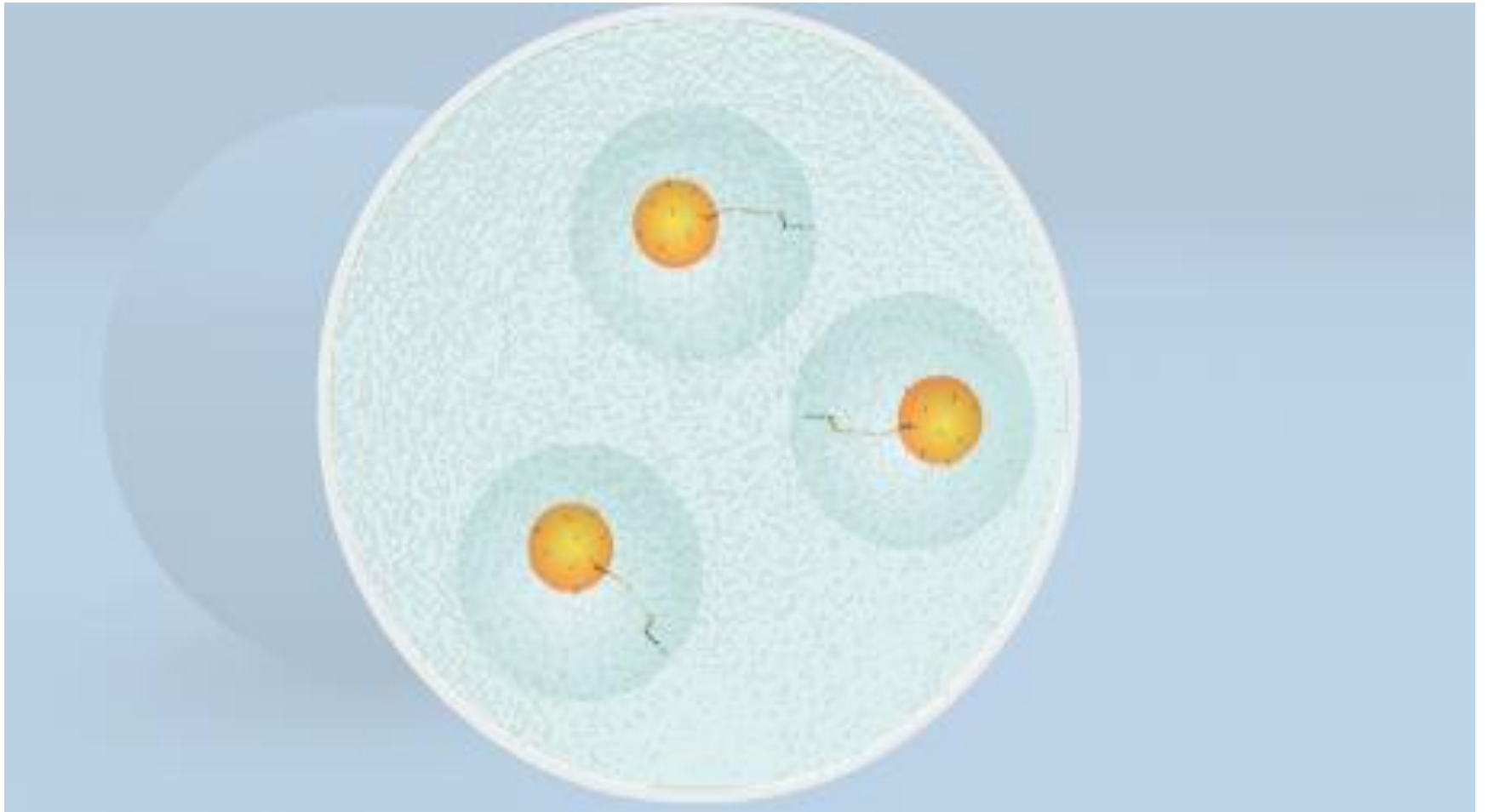
emPCR



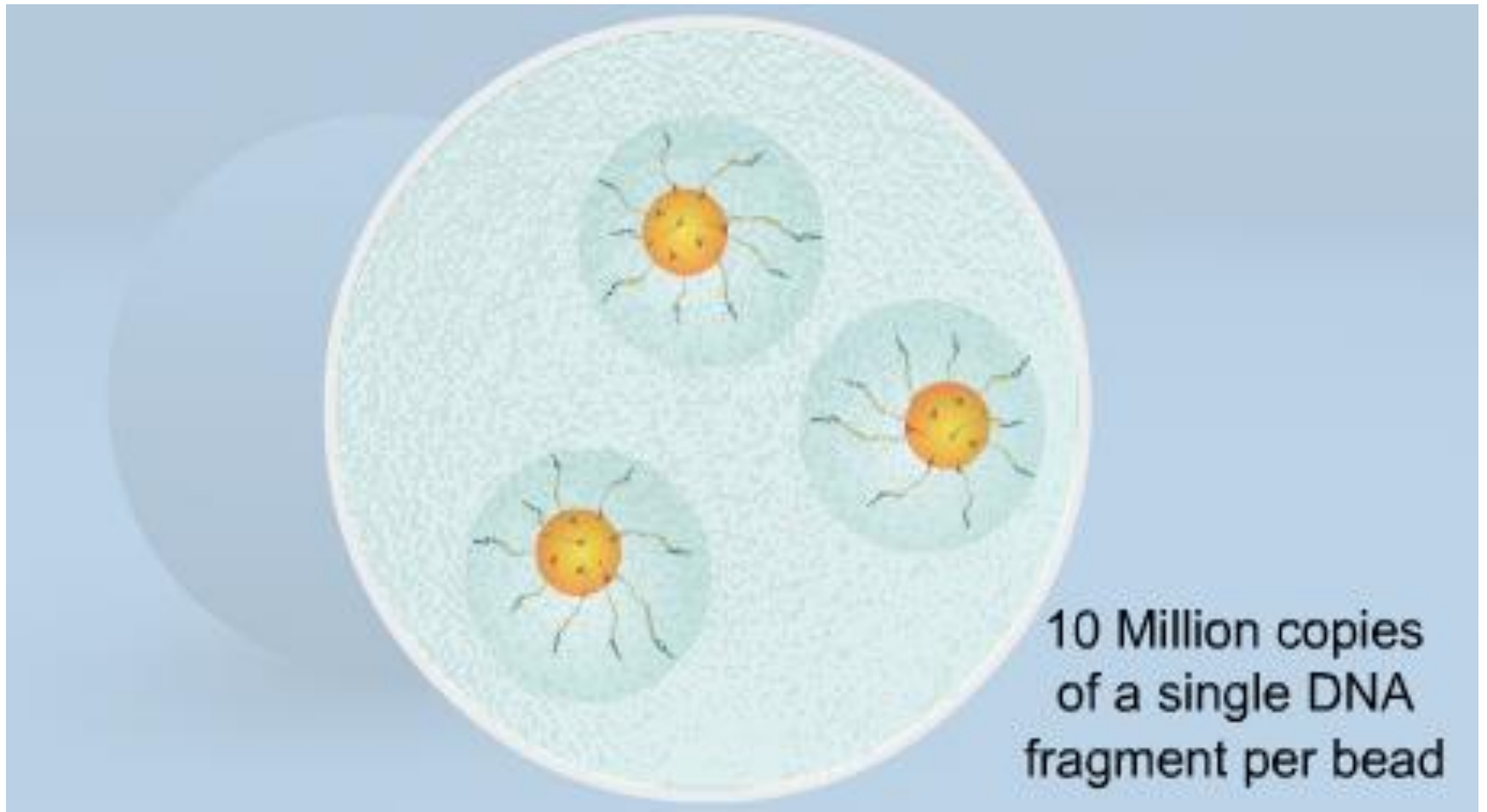
Vznik emulze (olej)



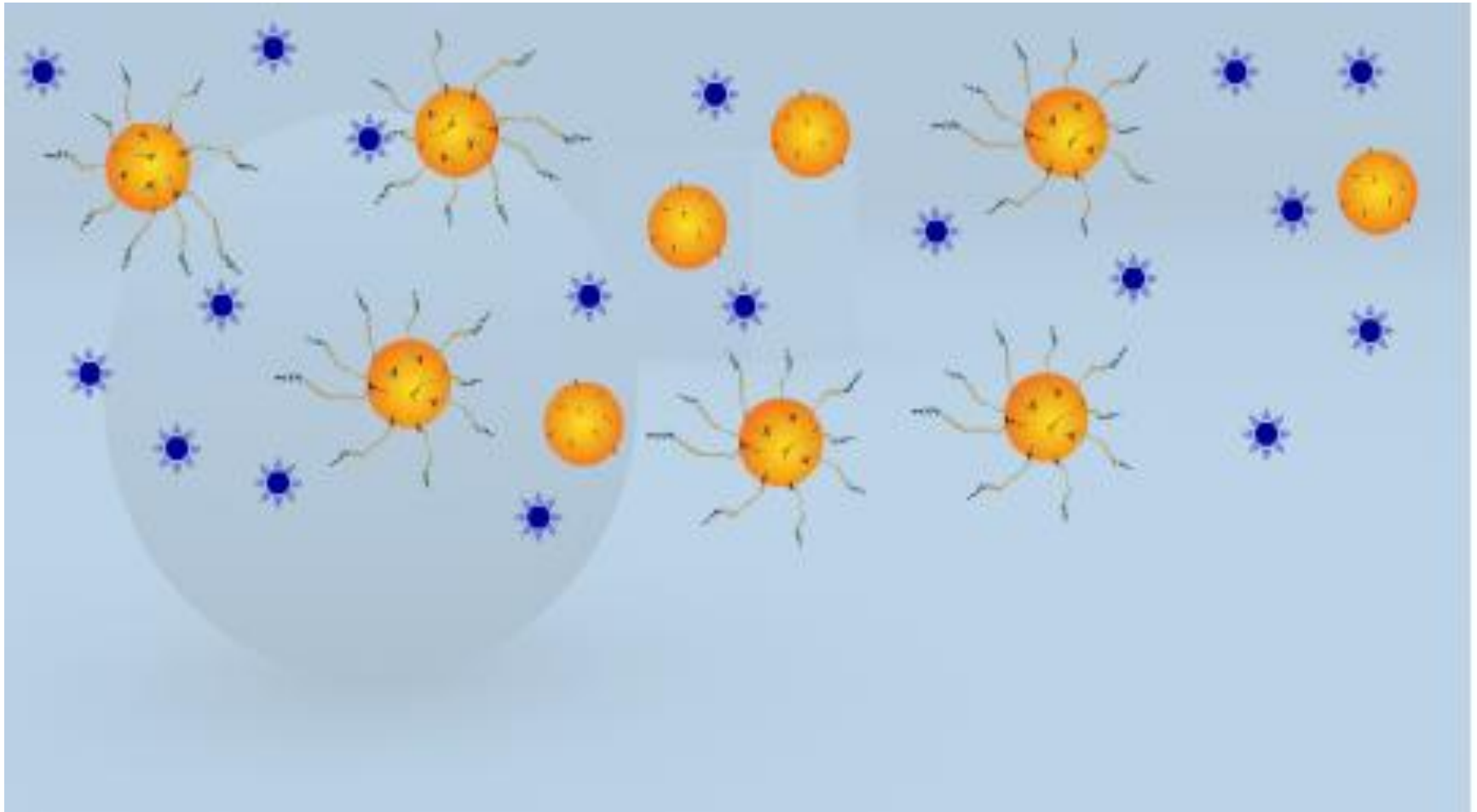
emPCR



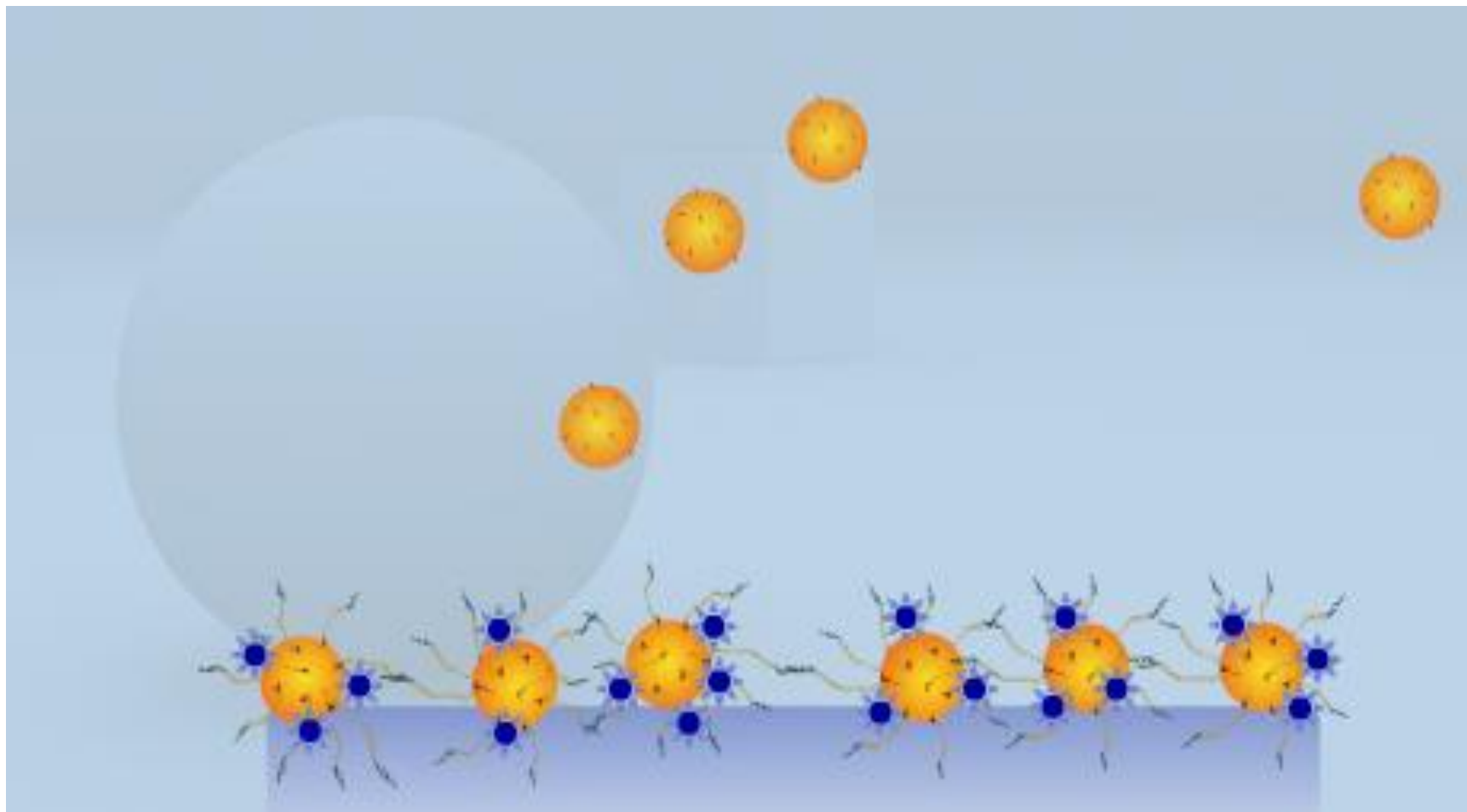
emPCR



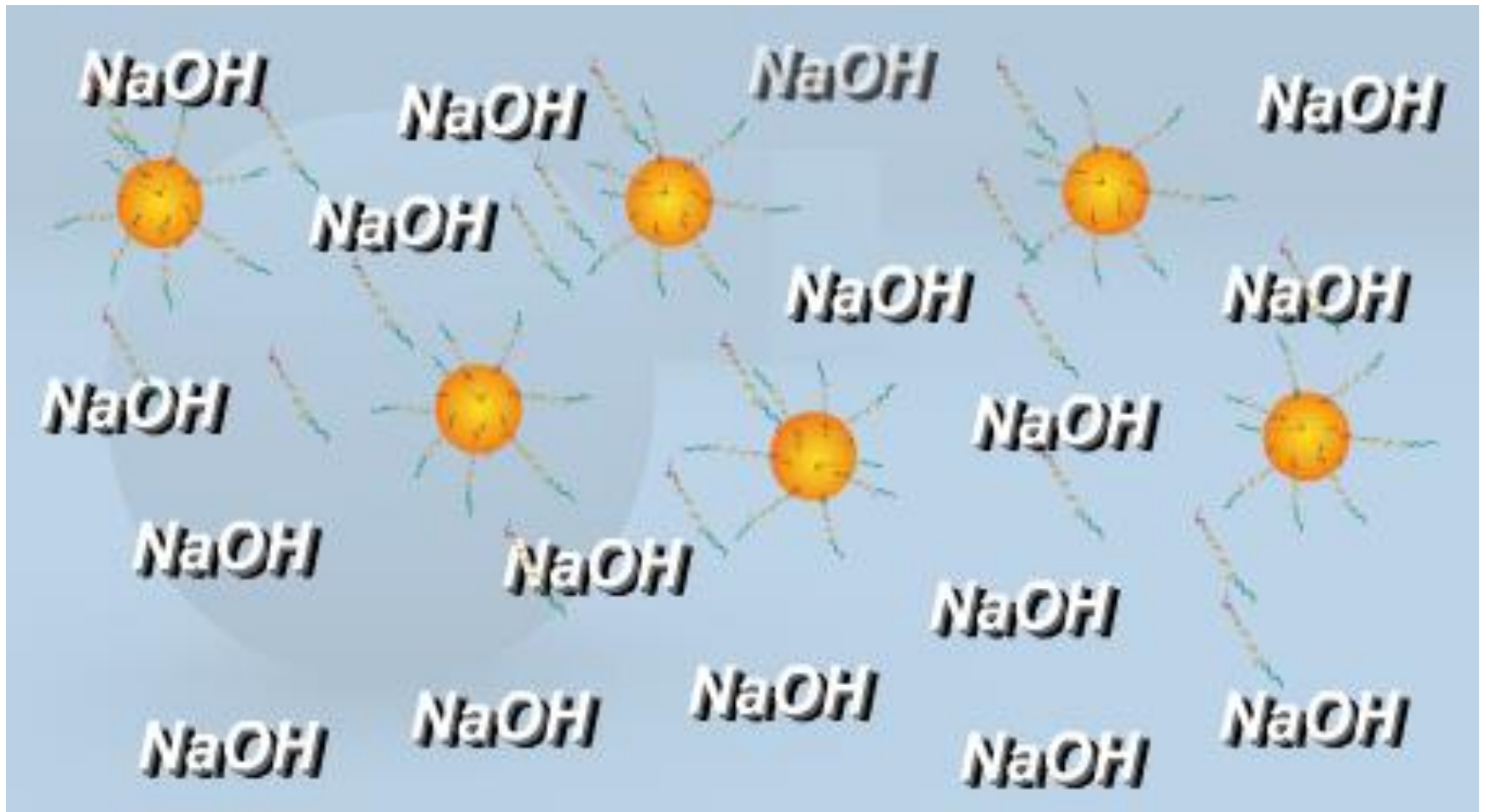
Vychytání kuliček



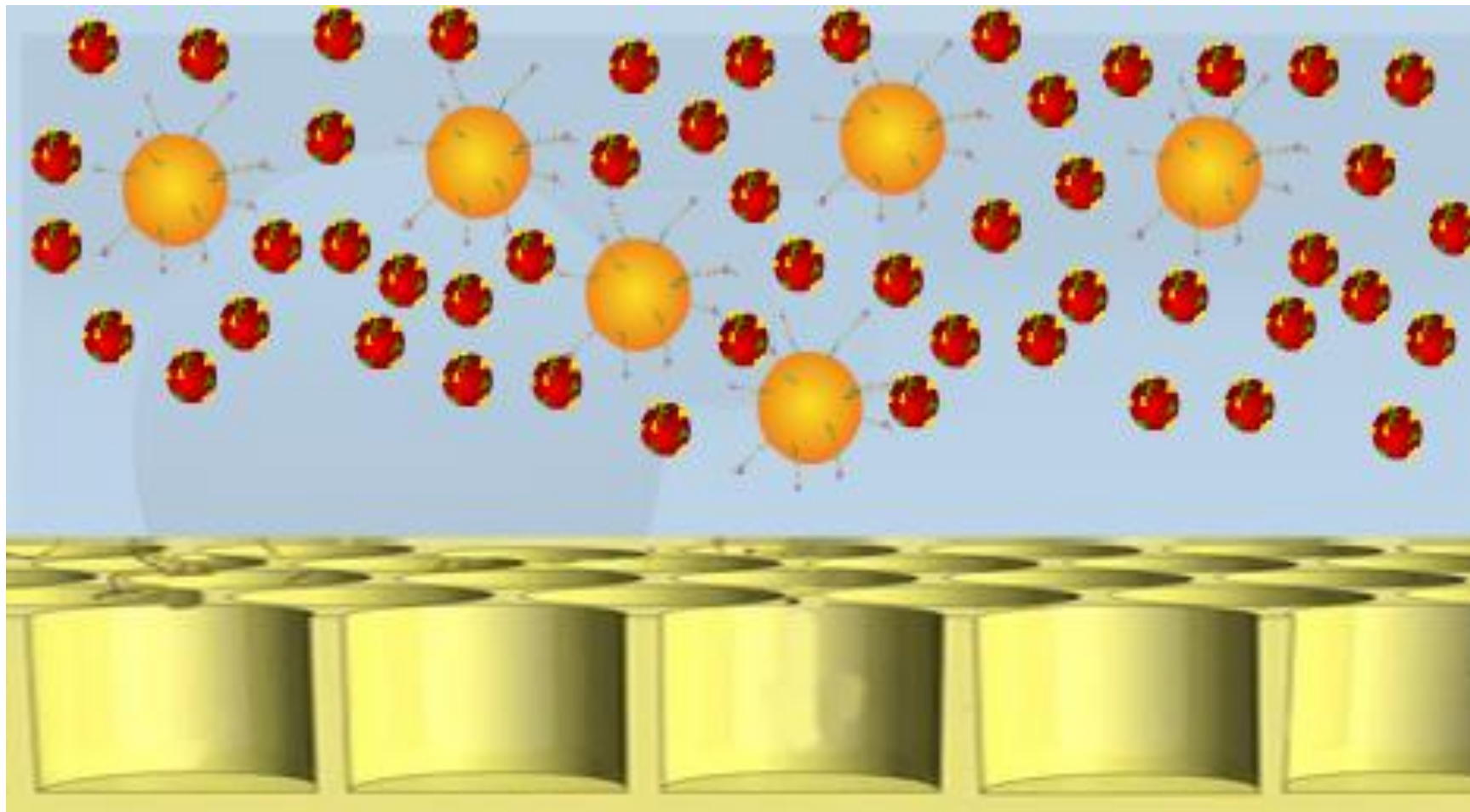
Vychytání kuliček



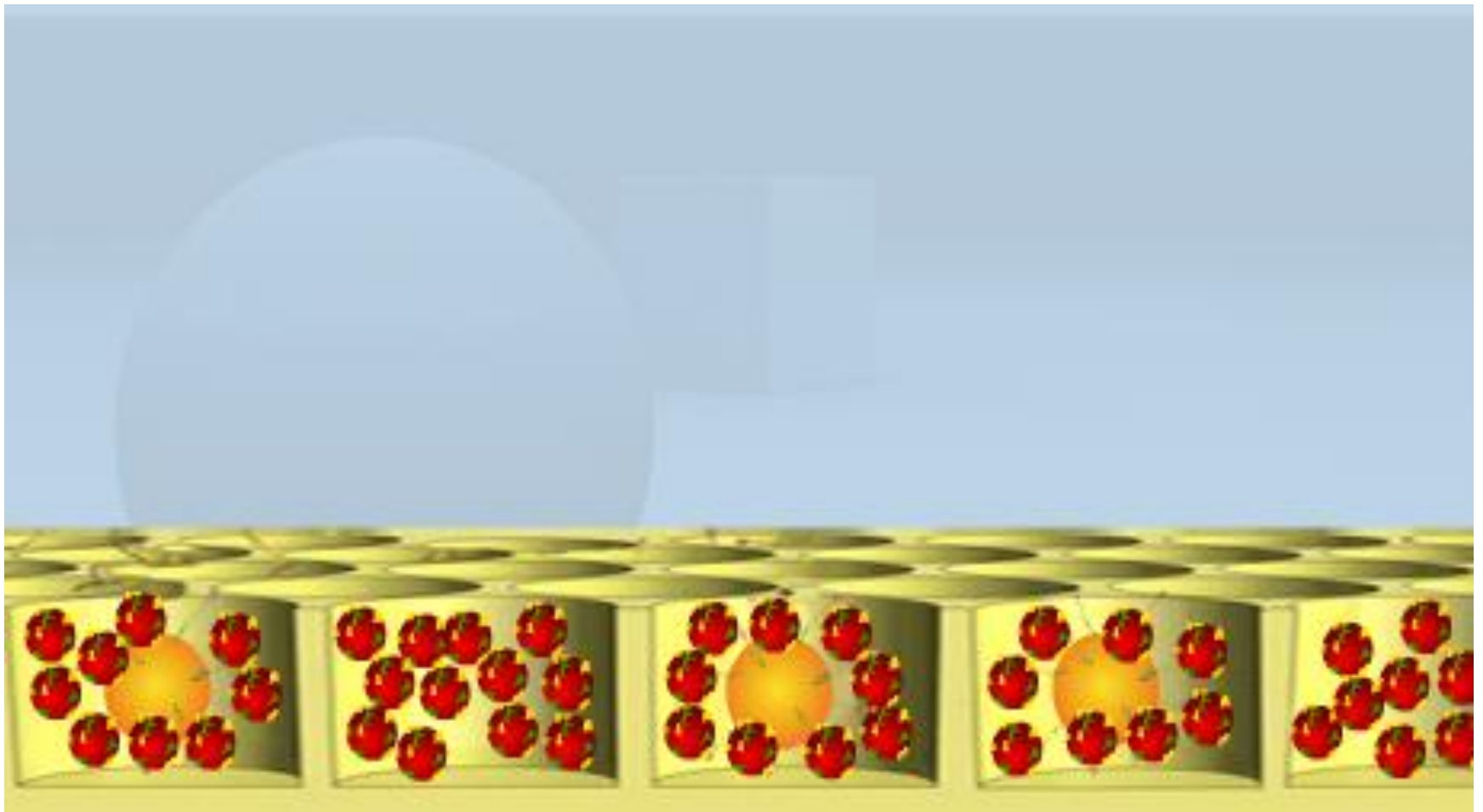
denaturace



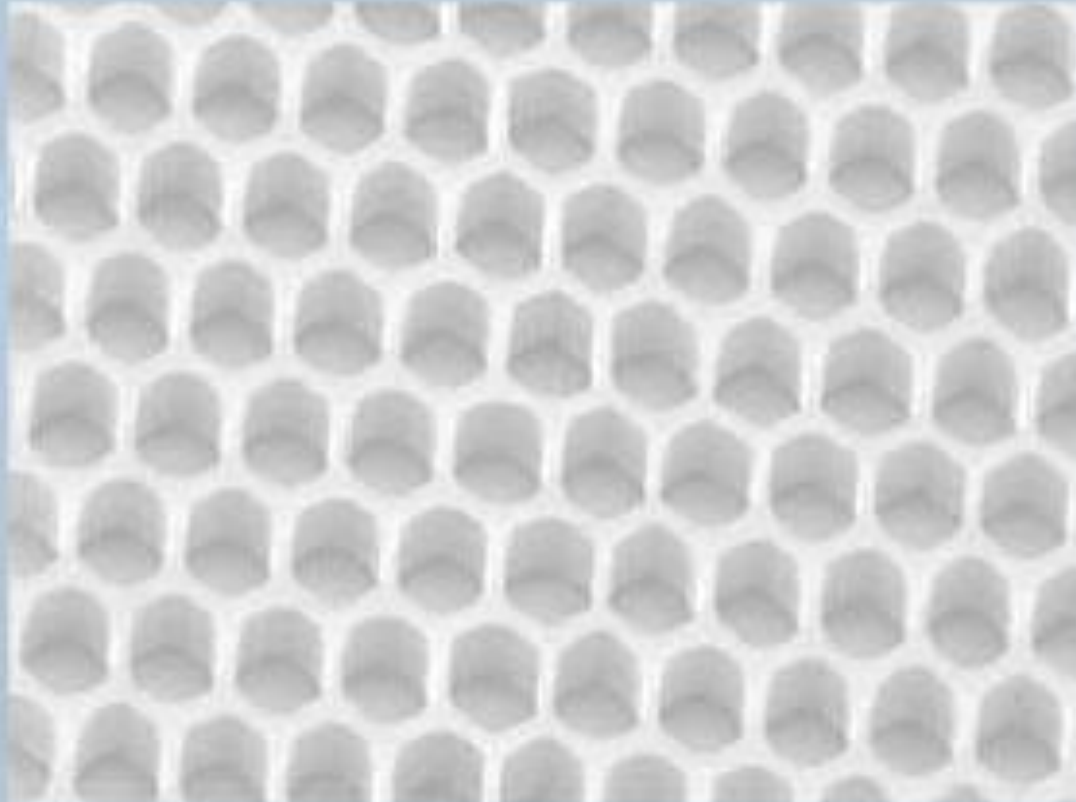
Disperze na sklíčko



Disperze na sklíčko



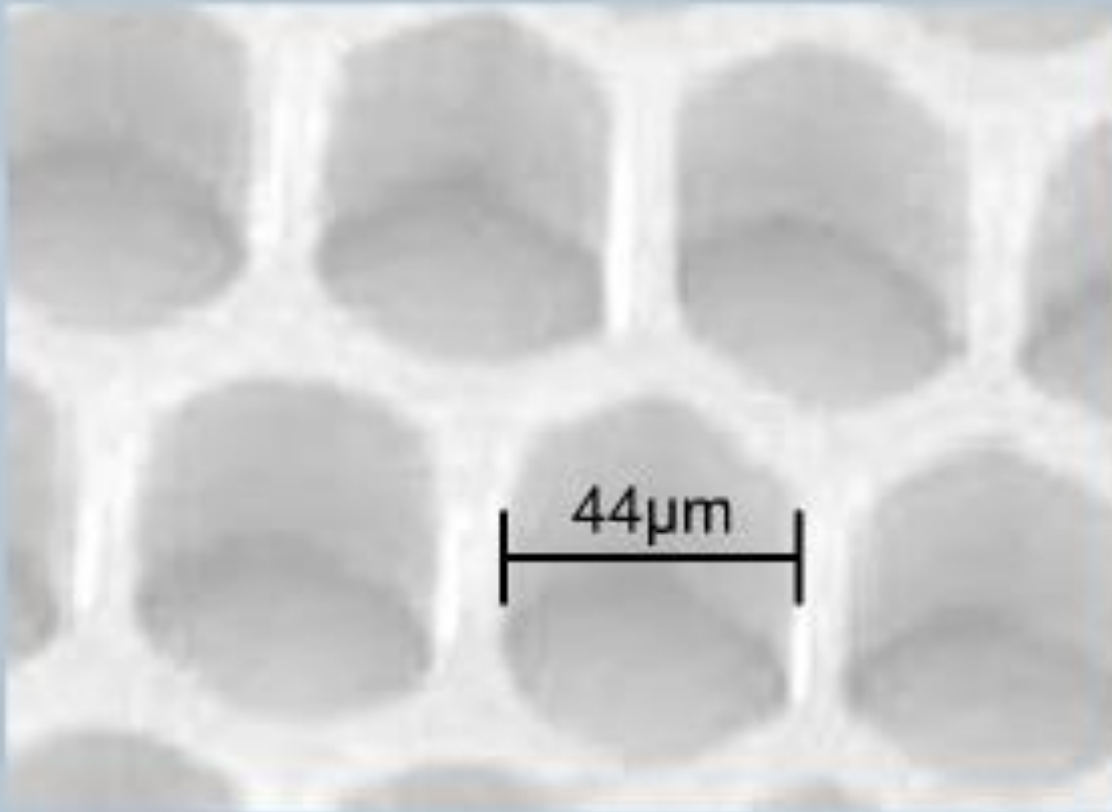
Parametry mikroreaktorů



1.6 million
wells

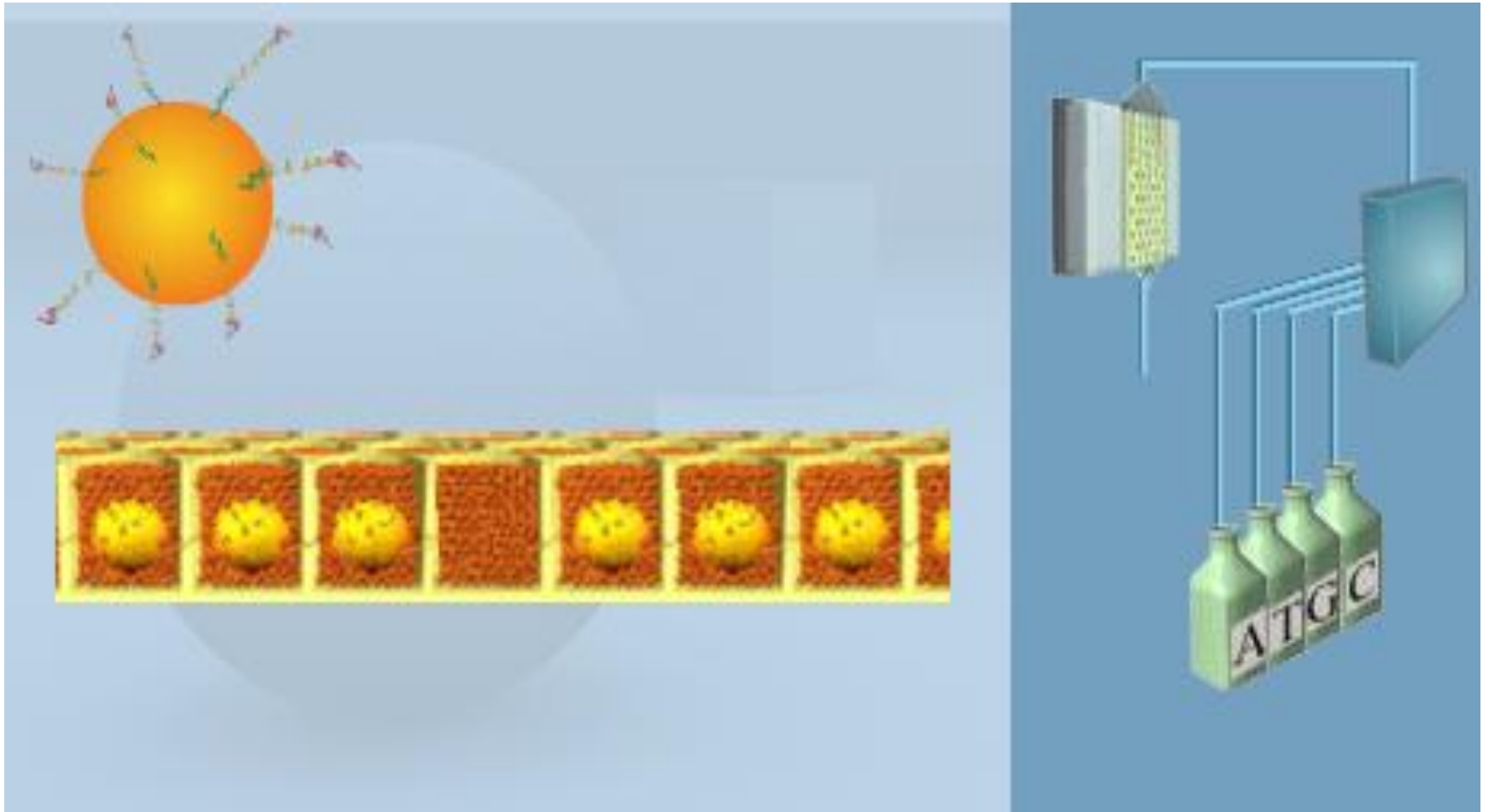
PicoTiterPlate device

Parametry mikroreaktorů

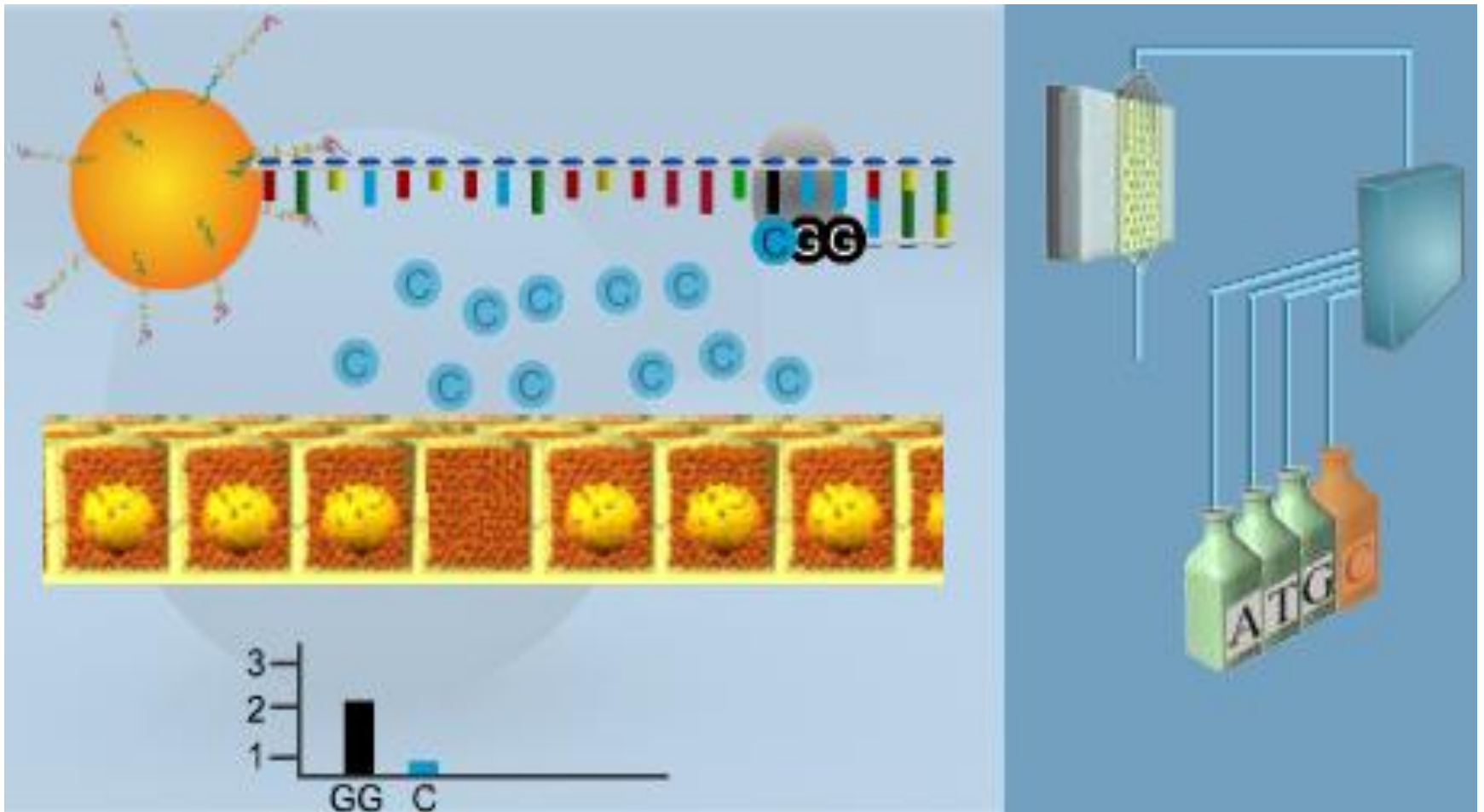


PicoTiterPlate device

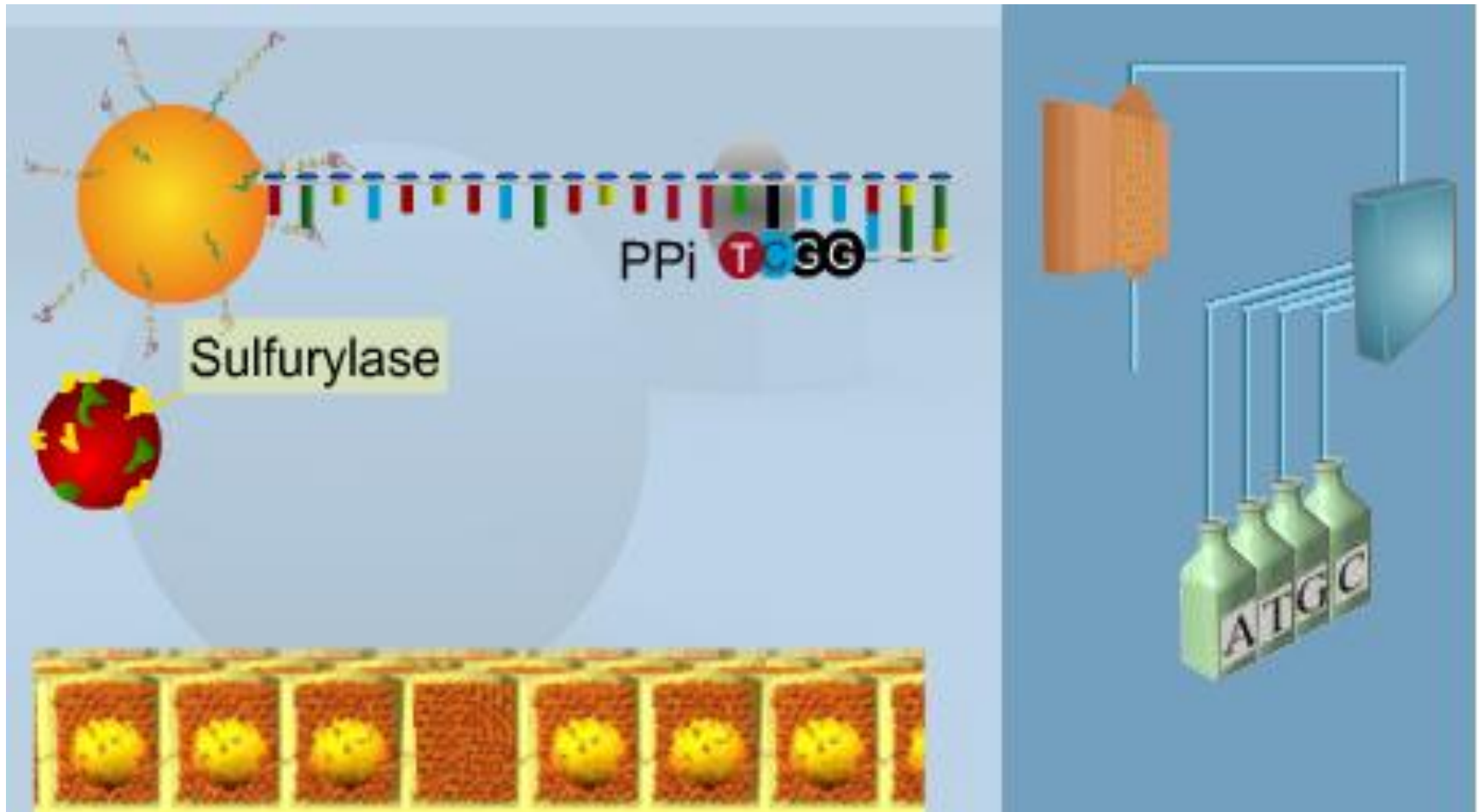
sekvenace



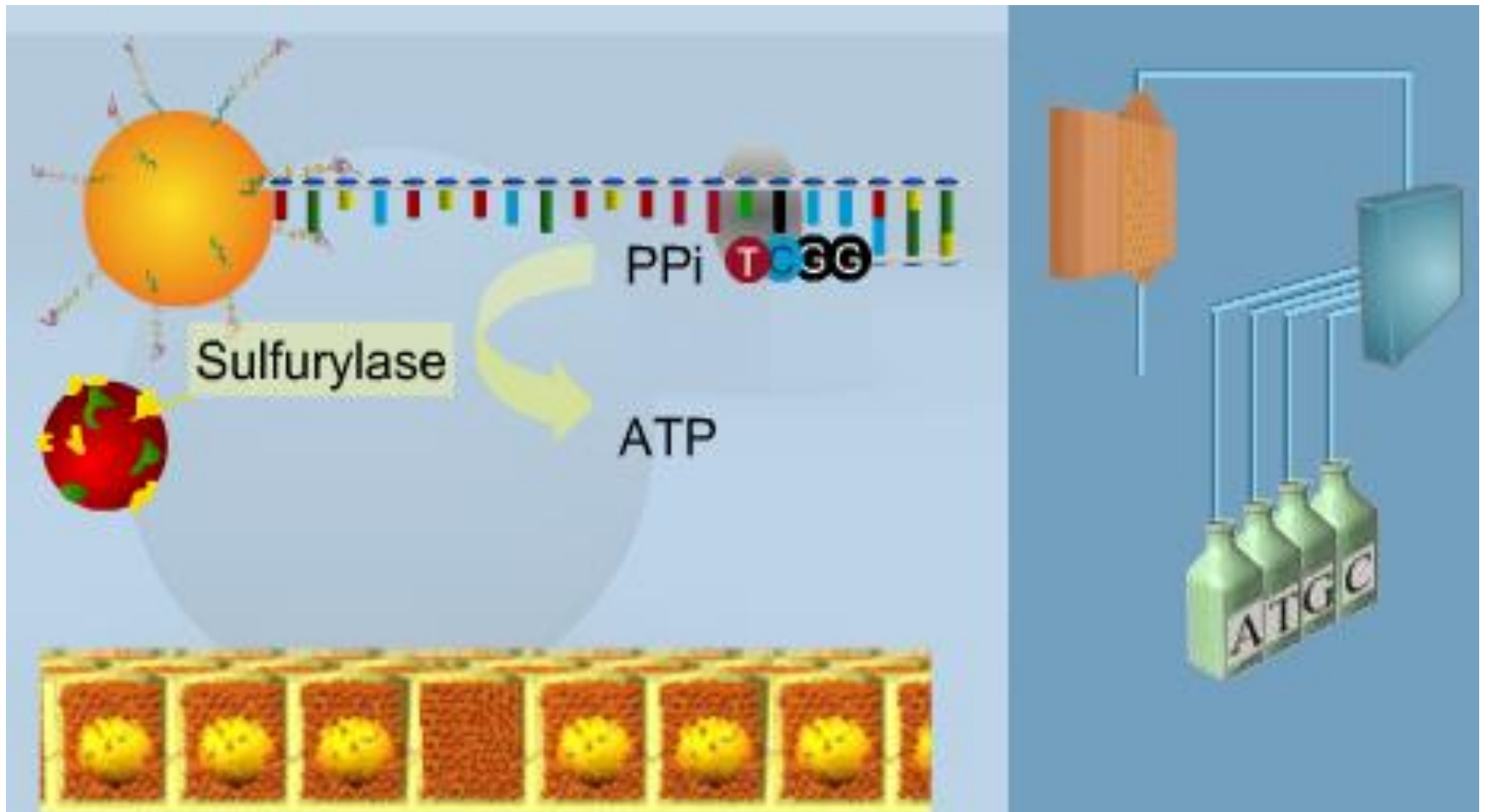
sekvenace



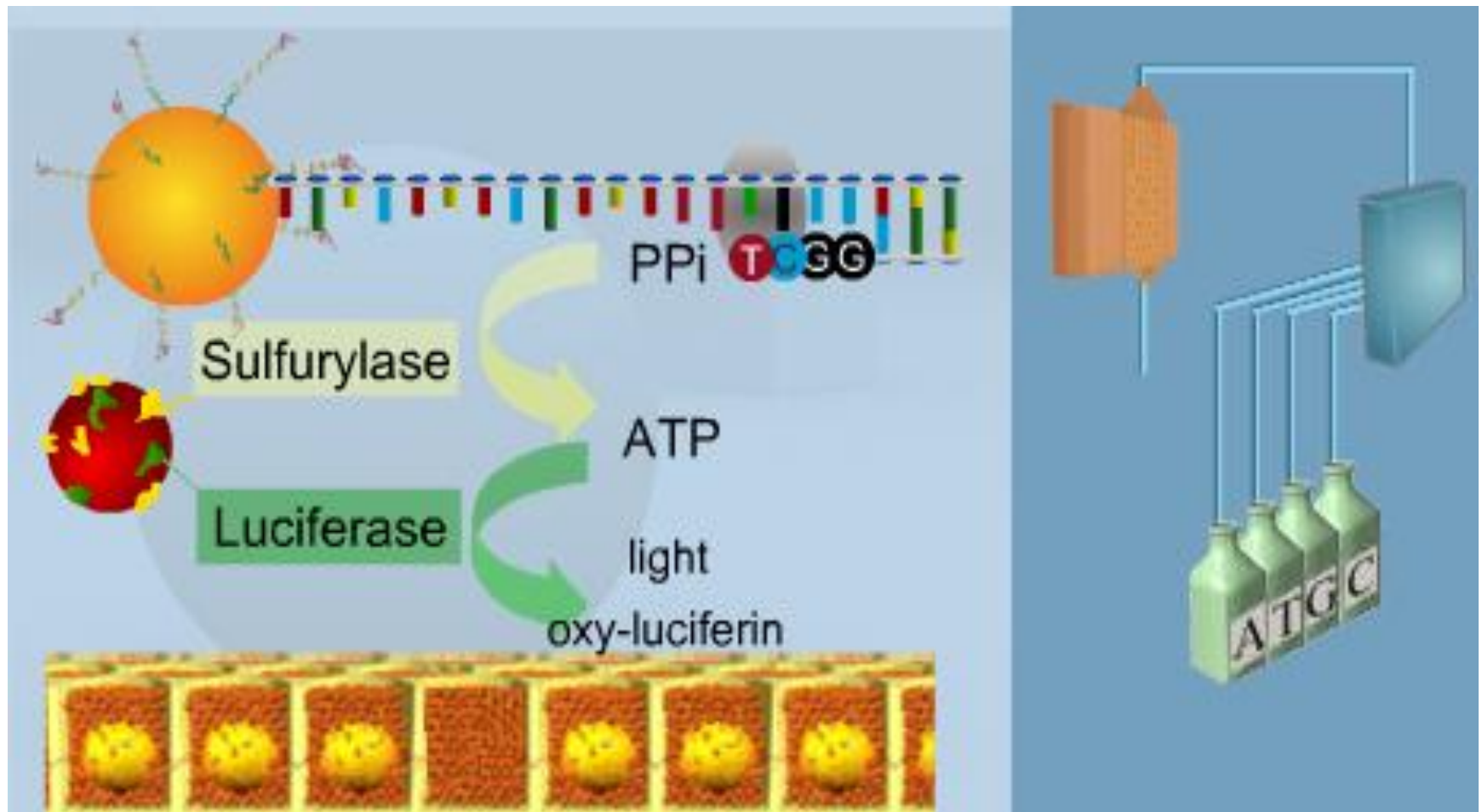
sekvenace



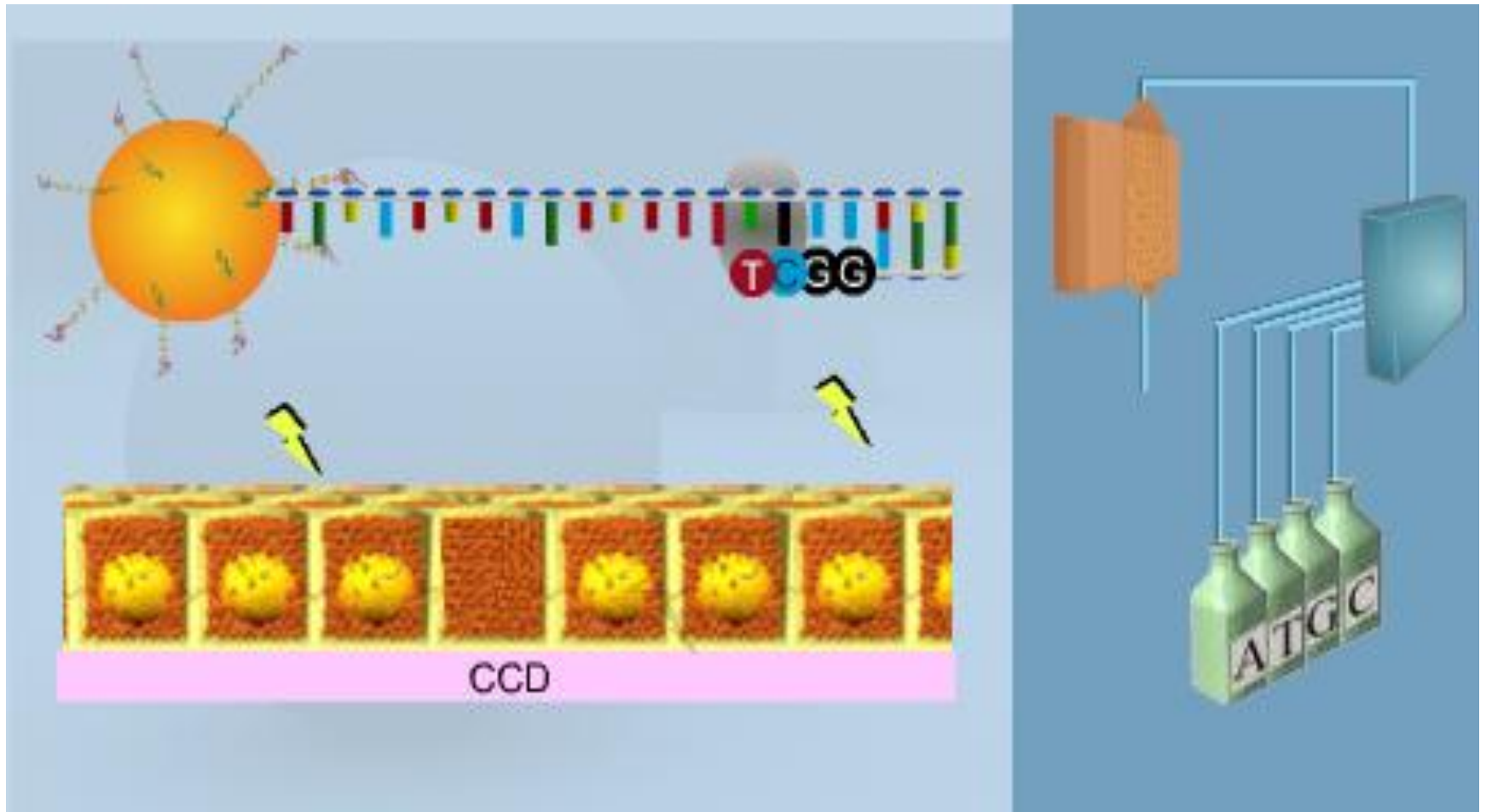
sekvenace



sekvenace



sekvenace



sekvenace



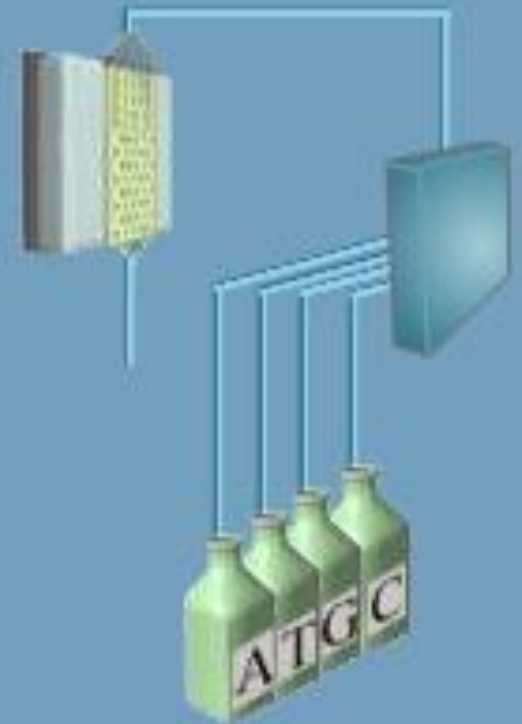
Massive parallelization of sequencing reactions

100 bases read length

X

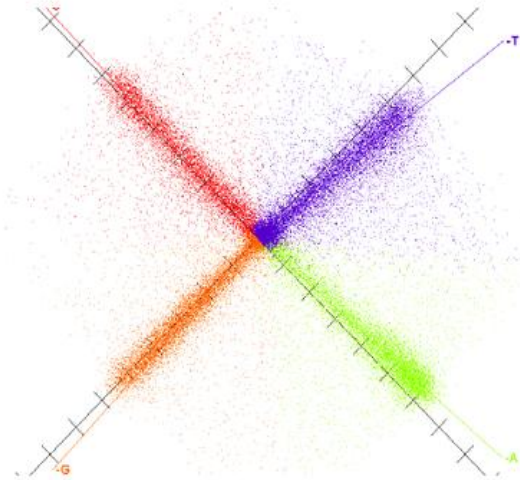
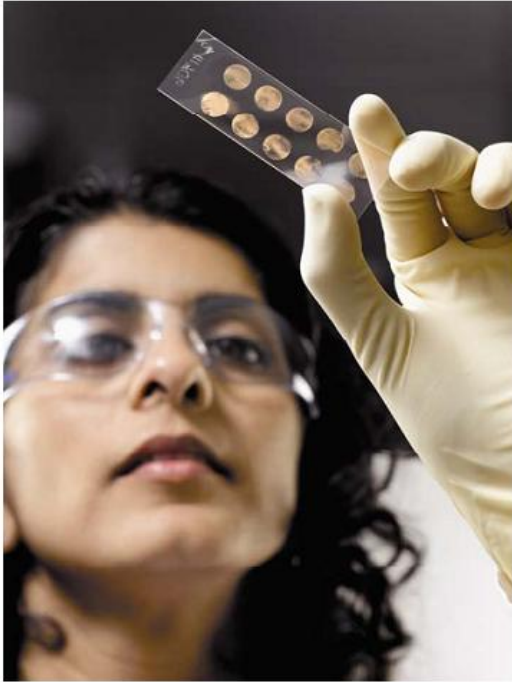
200 000

20 Million Bases



SOLID (Sequencing by Oligonucleotide Ligation and Detection)

2-base encoding sequencing (2007)

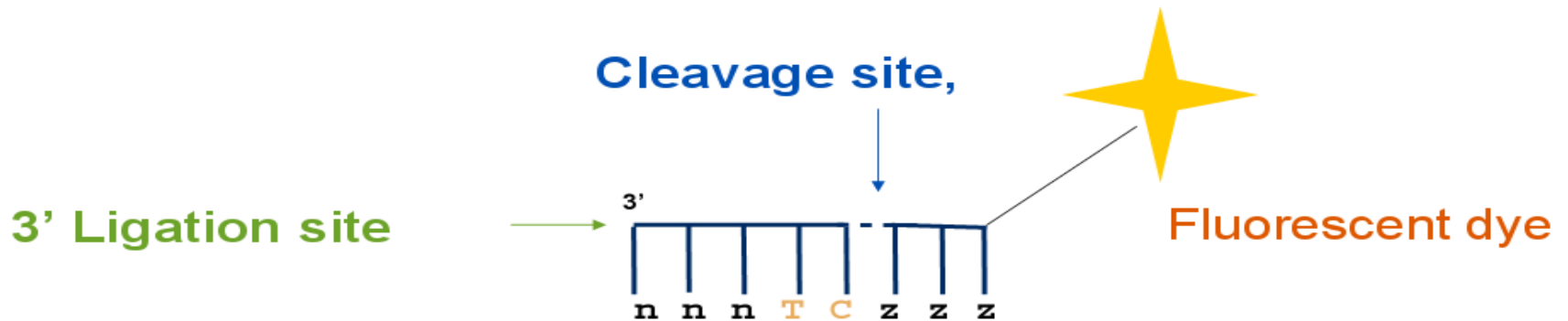


SOLiD™ System

Sequencing by Oligonucleotide Ligation and Detection

Properties of the Probes

Spatial separation among dye, ligation & cleavage sites



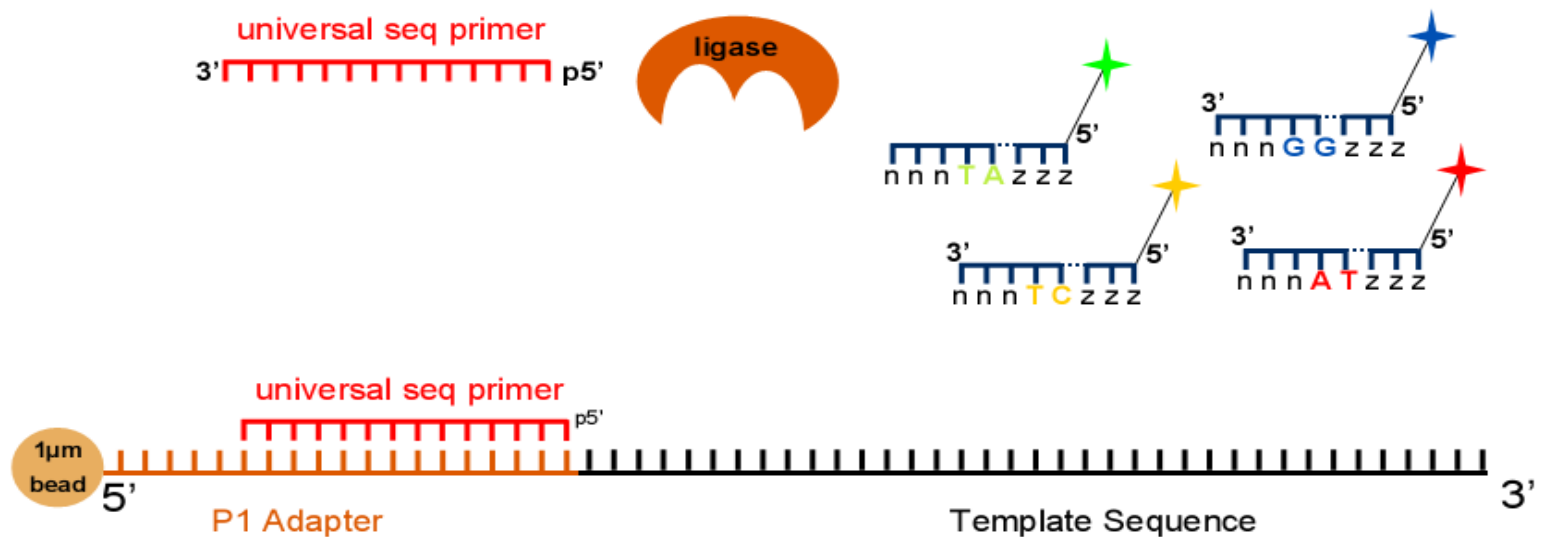
1,024 Octamer Probes (4^5)

4 Dyes, 4 dinucleotides, 256 probes per dye

N= degenerate bases Z= Universal bases

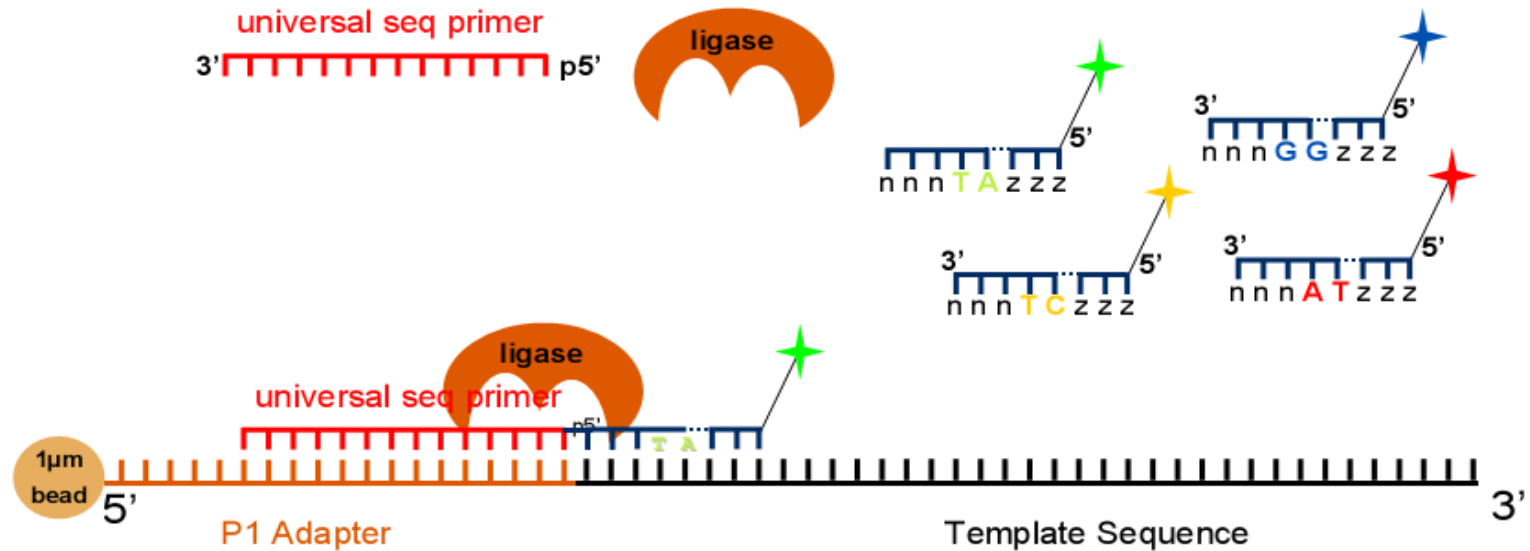
SOLiD Chemistry System 4-color ligation

Ligation reaction



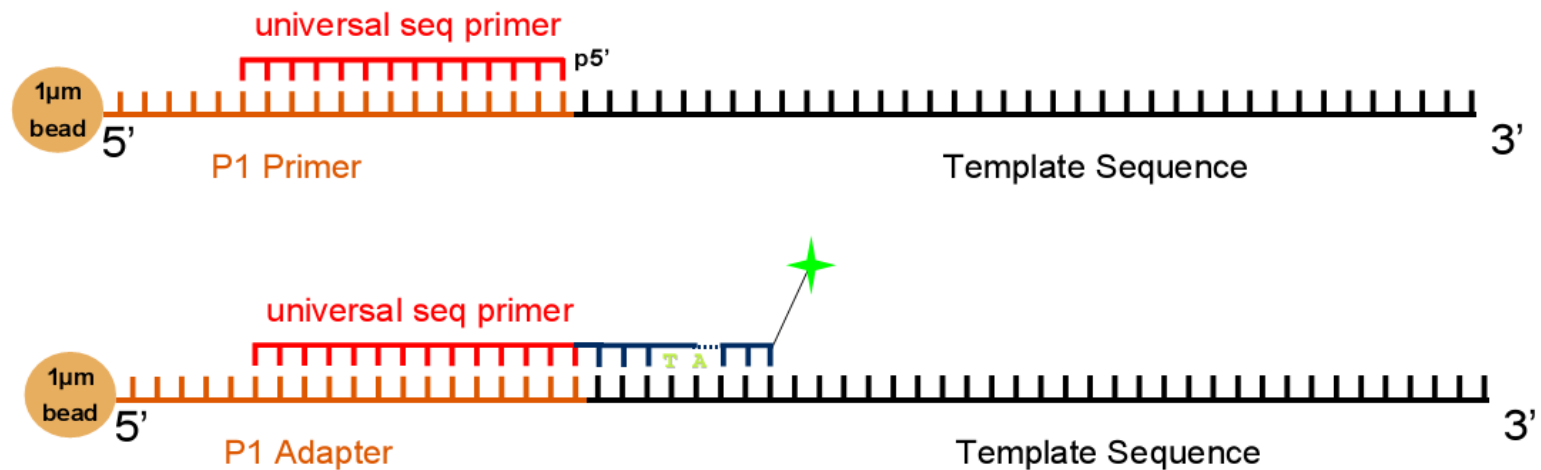
SOLiD Chemistry System 4-color ligation

Ligation reaction

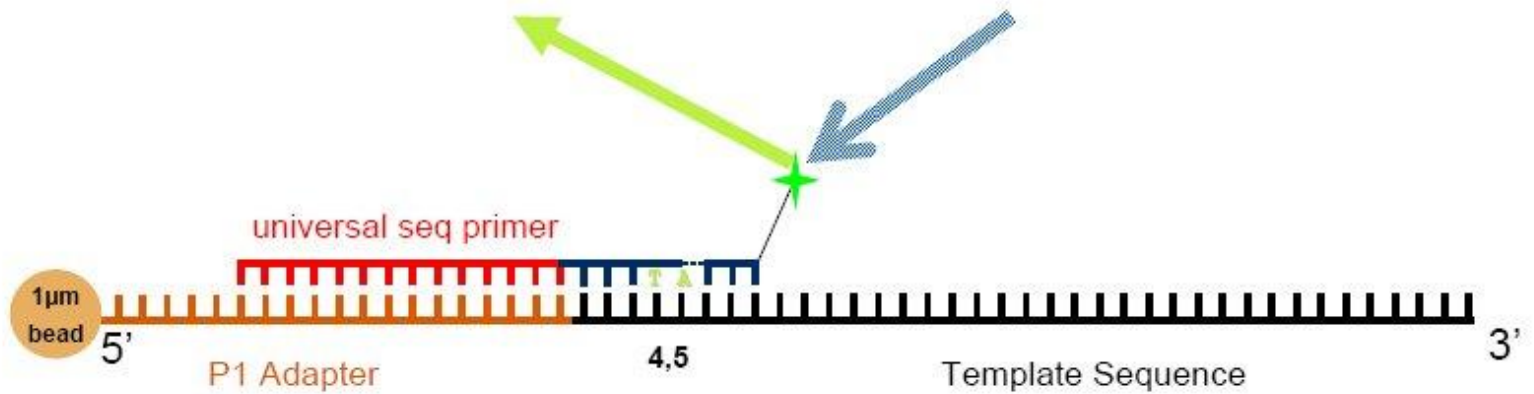


SOLiD Chemistry System 4-color ligation

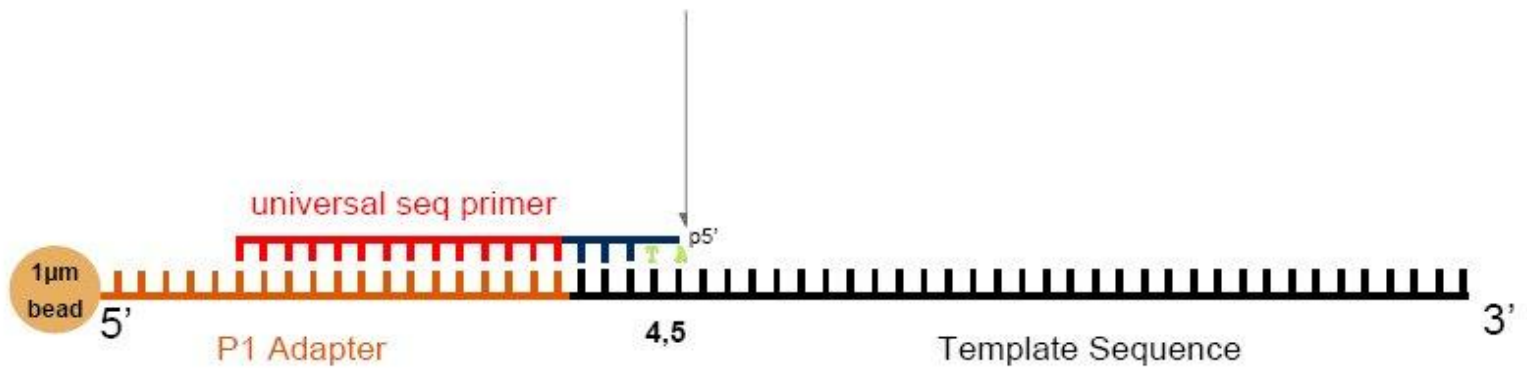
De-Phosphorylation



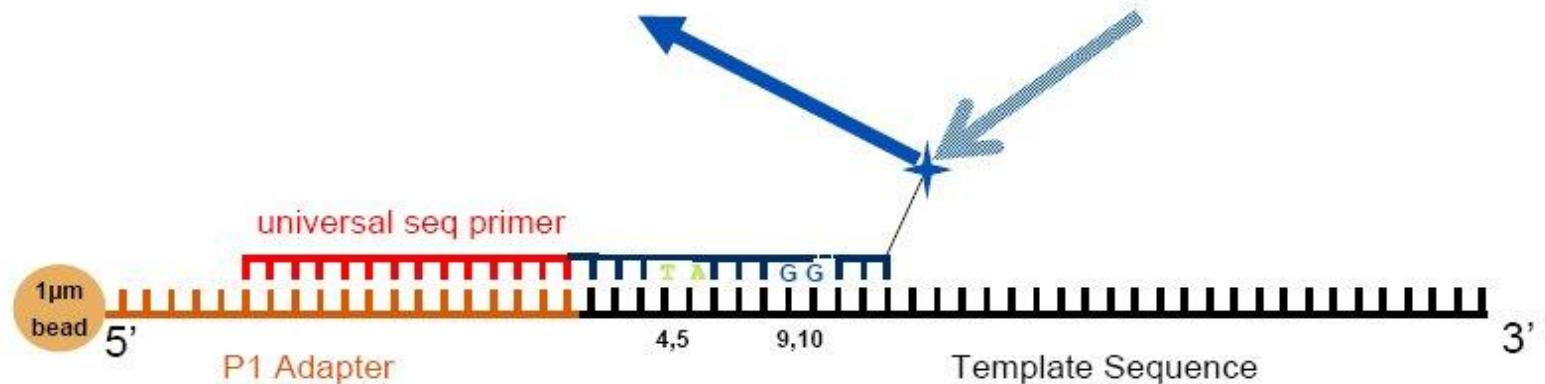
SOLiD Chemistry System 4-color ligation Visualization



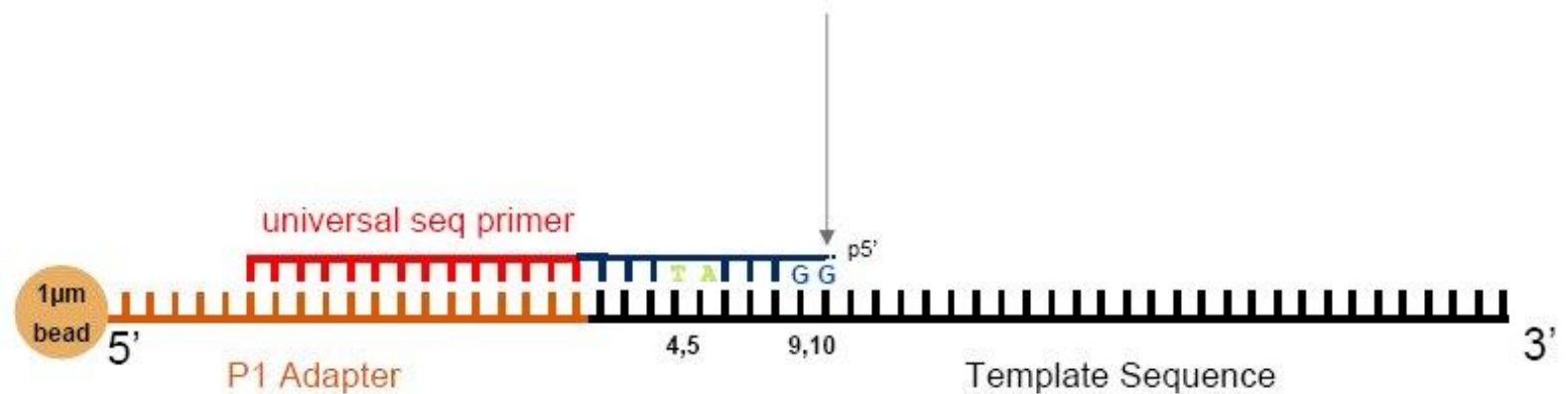
SOLiD Chemistry System 4-color ligation Cleavage



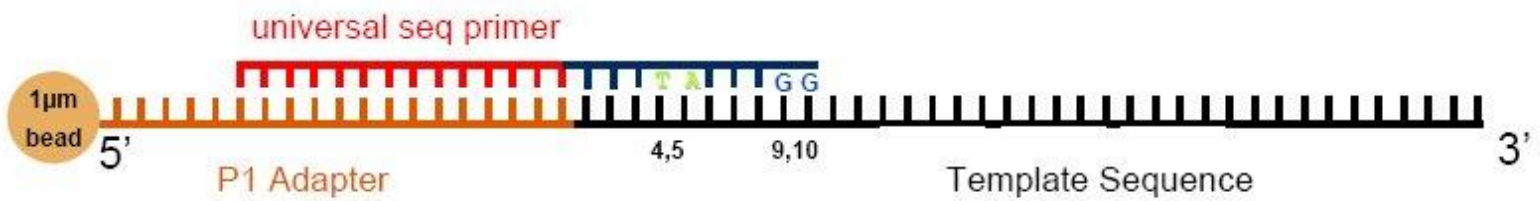
SOLiD Chemistry System 4-color ligation Visualization (2nd cycle)



SOLiD Chemistry System 4-color ligation Cleavage (2nd cycle)



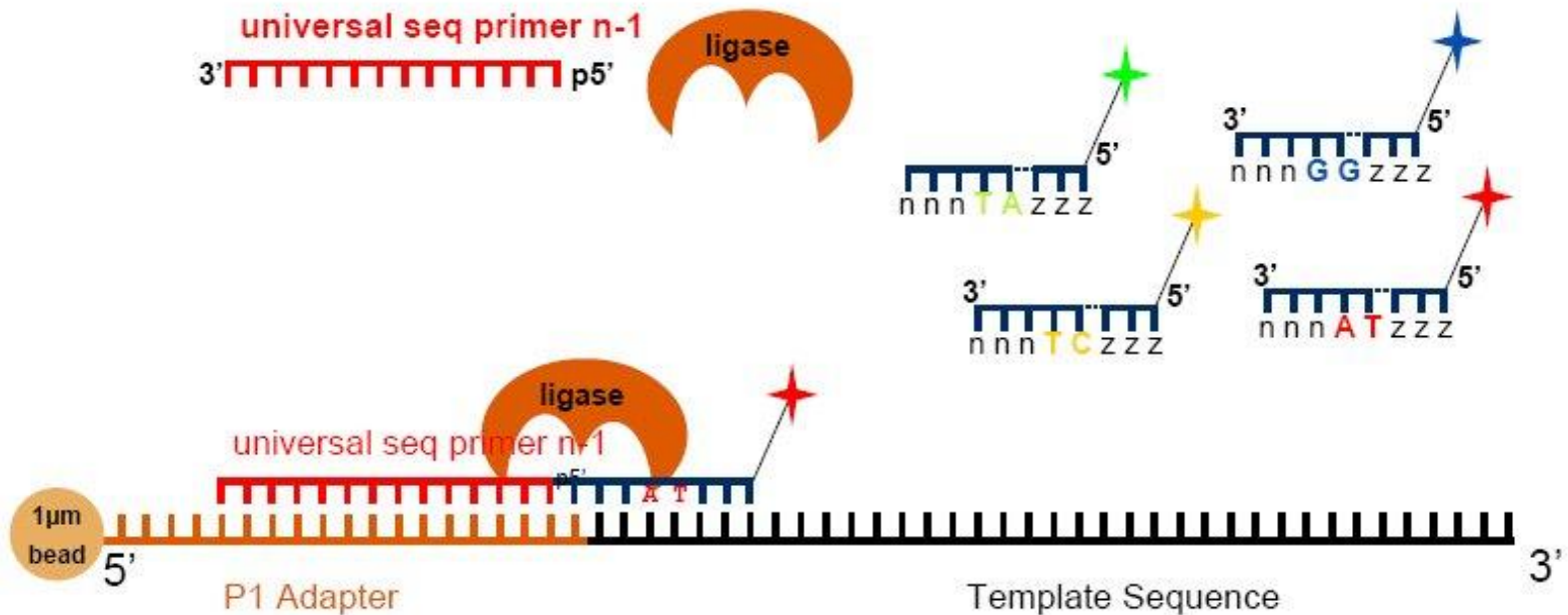
SOLiD Chemistry System 4-color ligation interrogates every 5th base



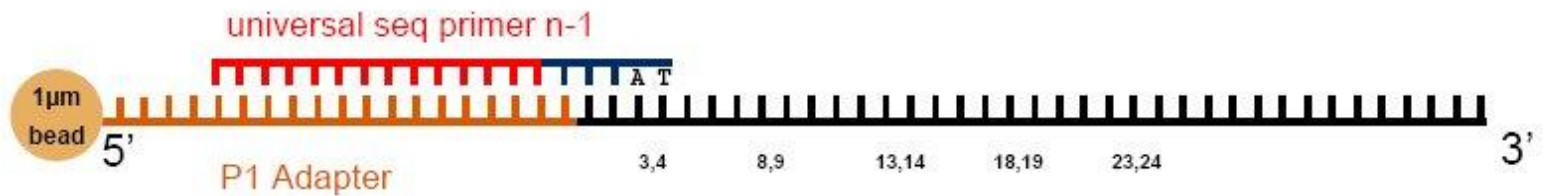
SOLiD Chemistry System 4-color ligation Reset



SOLiD Chemistry System 4-color ligation (1st cycle after reset)

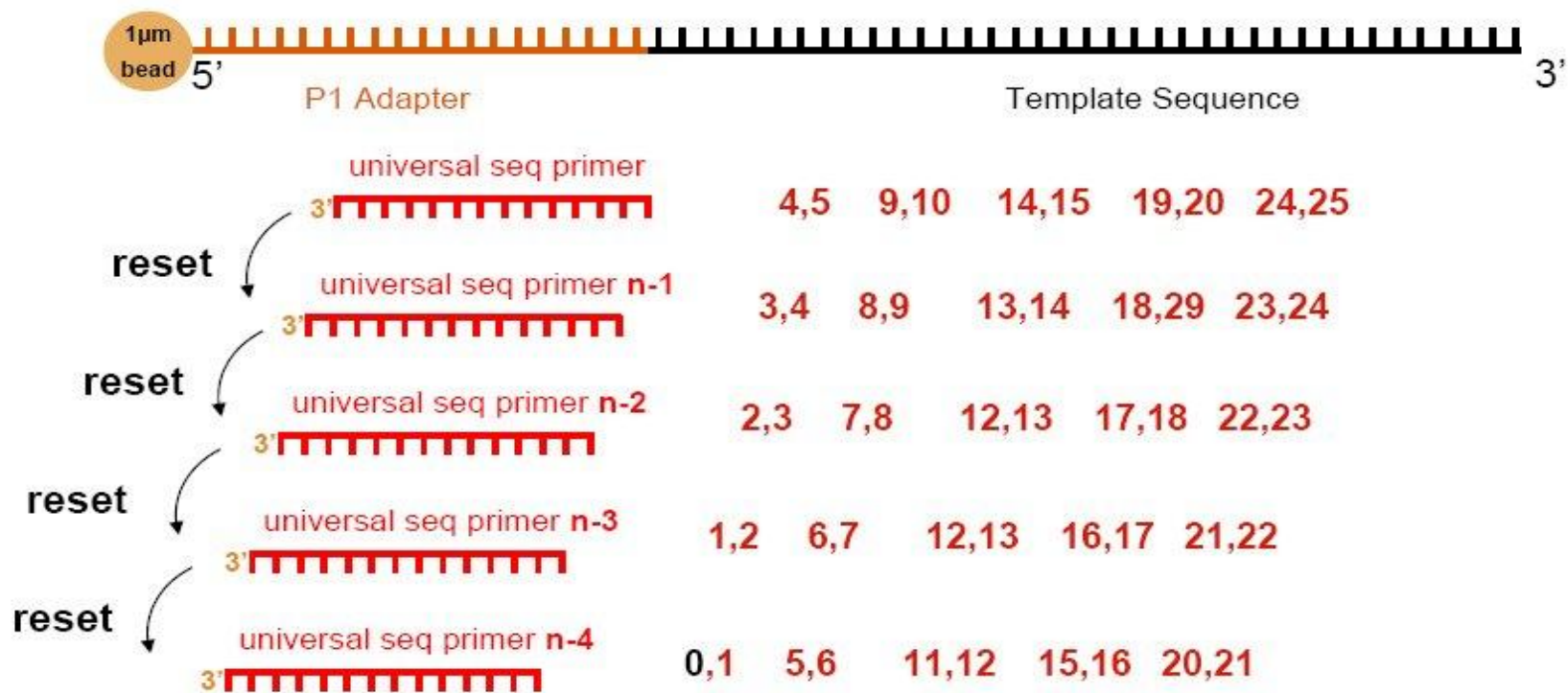


SOLiD Chemistry System 4-color ligation (2nd Round)

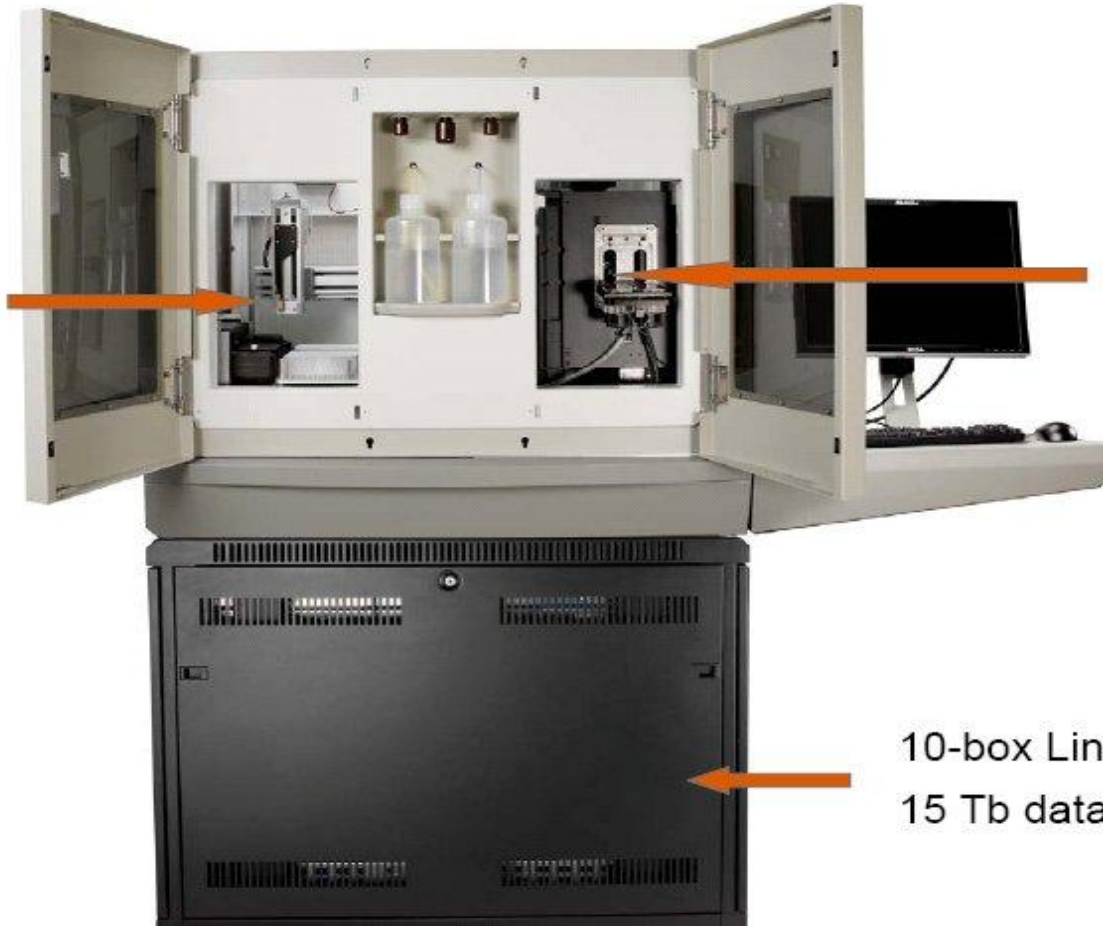


Sequential rounds of sequencing

Multiple cycles per round



Reagent
handling

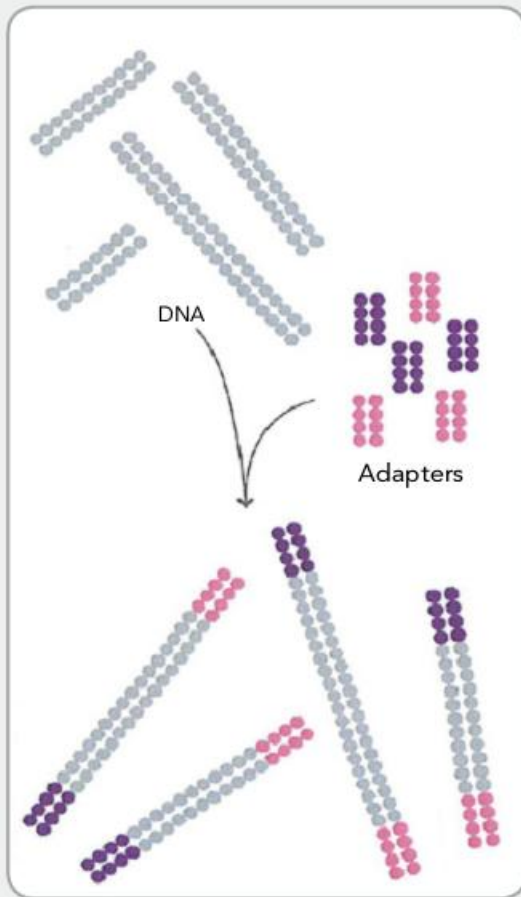


Dual Flow
Cell

10-box Linux Cluster
15 Tb data storage

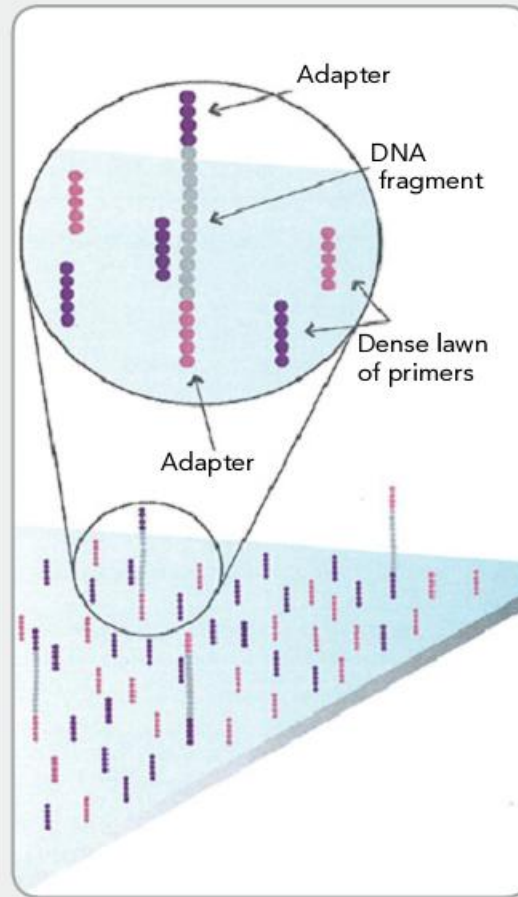
Solexa (2007)

1. PREPARE GENOMIC DNA SAMPLE



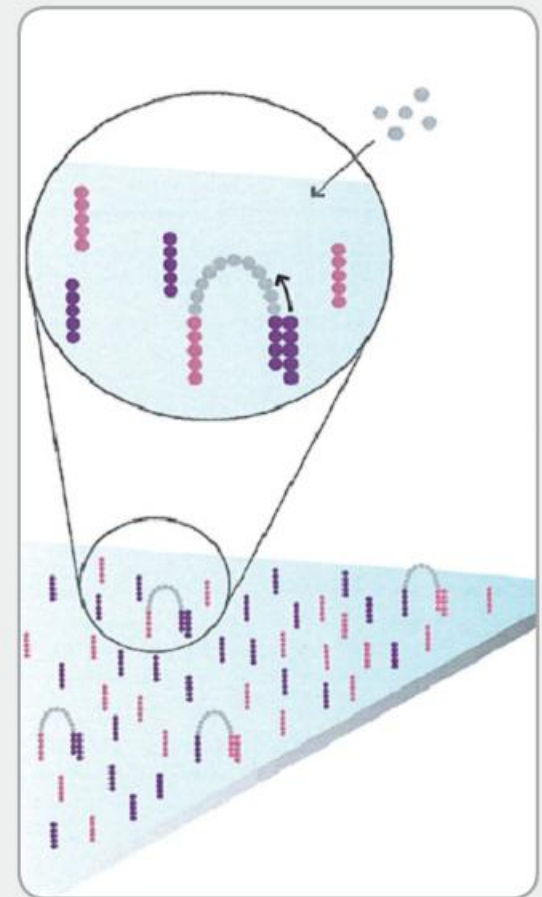
Randomly fragment genomic DNA and ligate adapters to both ends of the fragments.

2. ATTACH DNA TO SURFACE



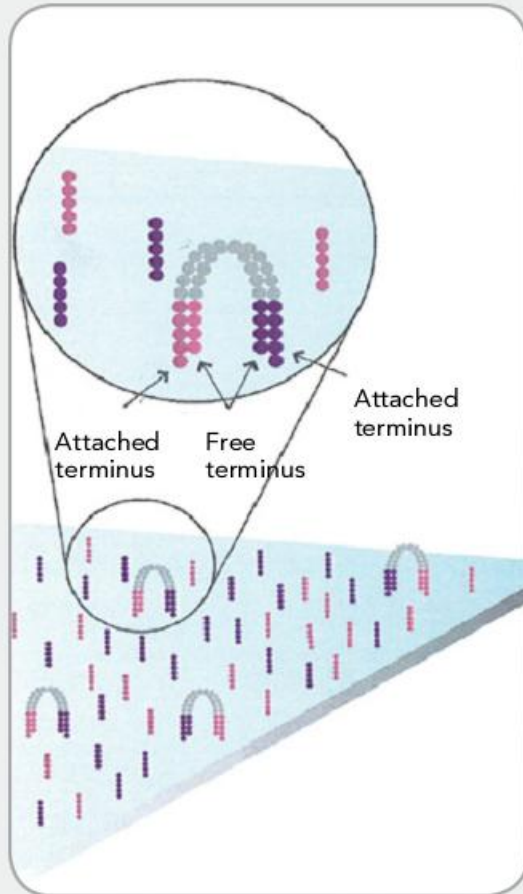
Bind single-stranded fragments randomly to the inside surface of the flow cell channels.

3. BRIDGE AMPLIFICATION



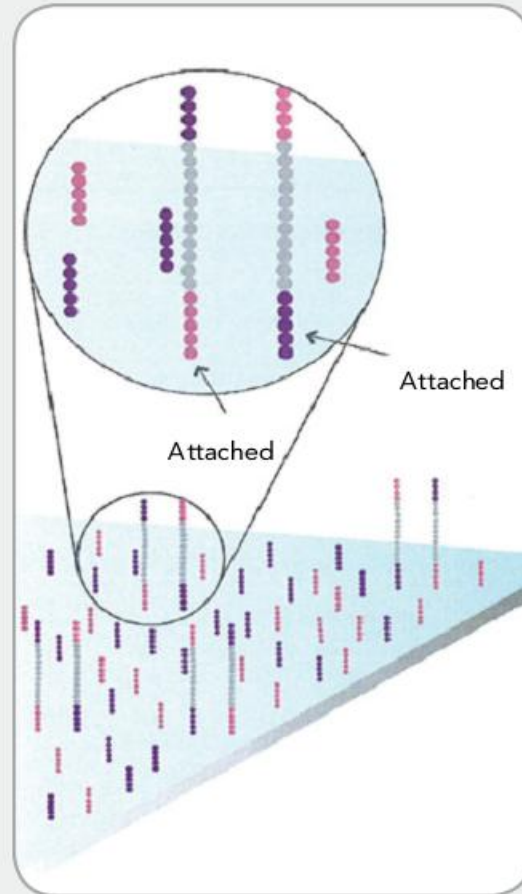
Add unlabeled nucleotides and enzyme to initiate solid-phase bridge amplification.

4. FRAGMENTS BECOME DOUBLE STRANDED



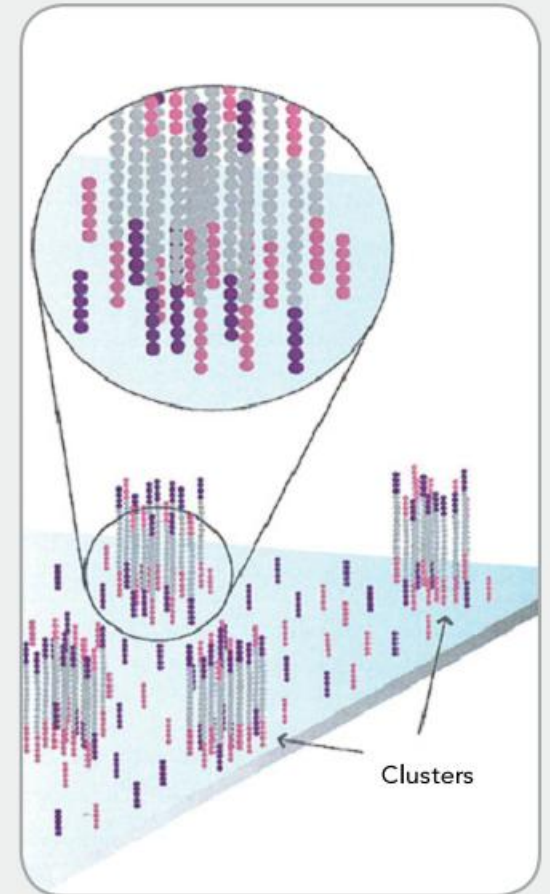
The enzyme incorporates nucleotides to build double-stranded bridges on the solid-phase substrate.

5. DENATURE THE DOUBLE-STRANDED MOLECULES



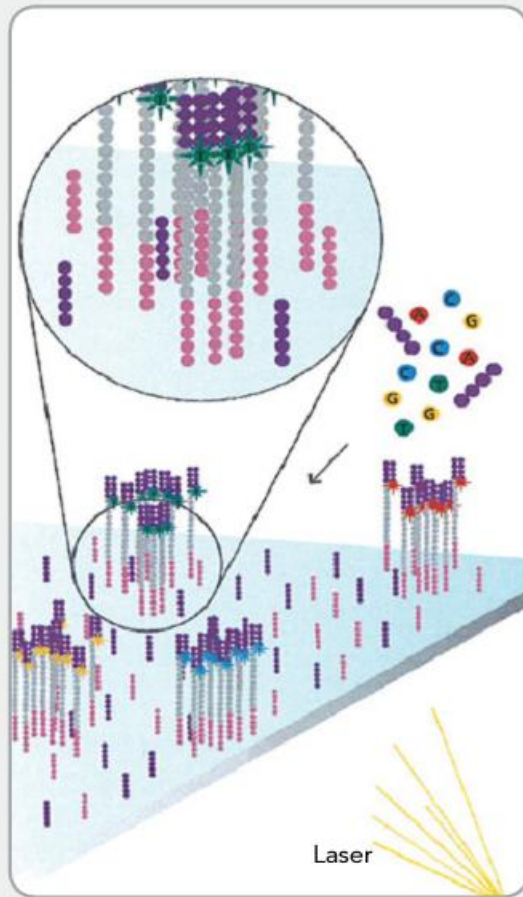
Denaturation leaves single-stranded templates anchored to the substrate.

6. COMPLETE AMPLIFICATION



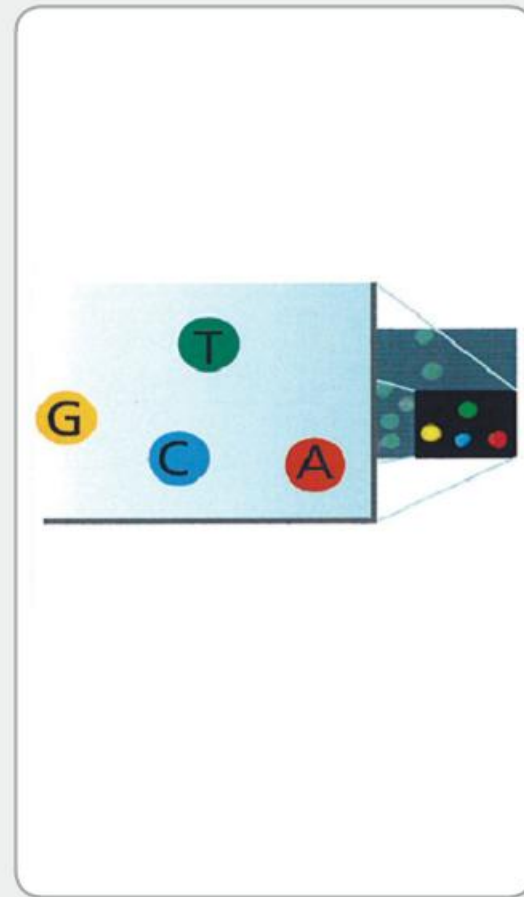
Several million dense clusters of double-stranded DNA are generated in each channel of the flow cell.

7. DETERMINE FIRST BASE



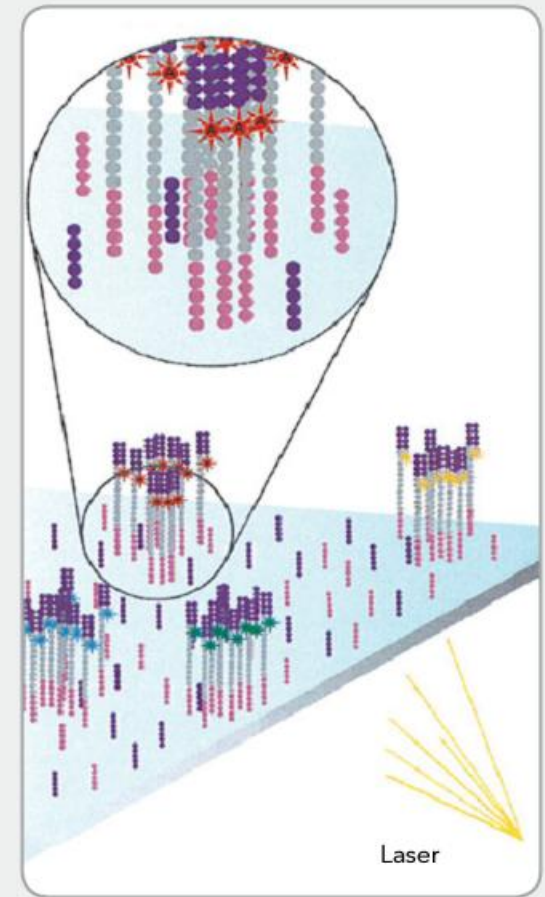
First chemistry cycle: to initiate the first sequencing cycle, add all four labeled reversible terminators, primers and DNA polymerase enzyme to the flow cell.

8. IMAGE FIRST BASE



After laser excitation, capture the image of emitted fluorescence from each cluster on the flow cell. Record the identity of the first base for each cluster.

9. DETERMINE SECOND BASE

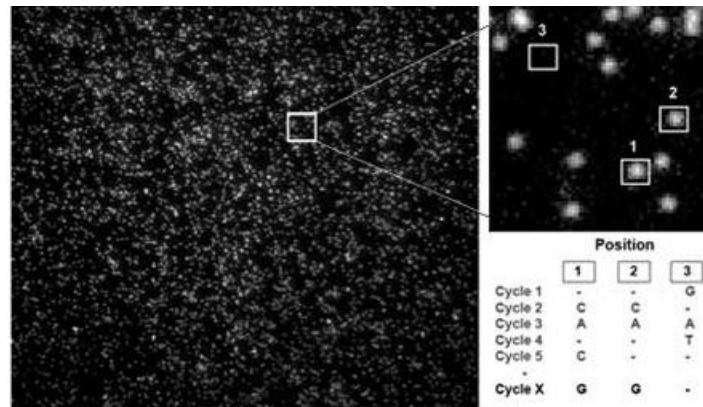
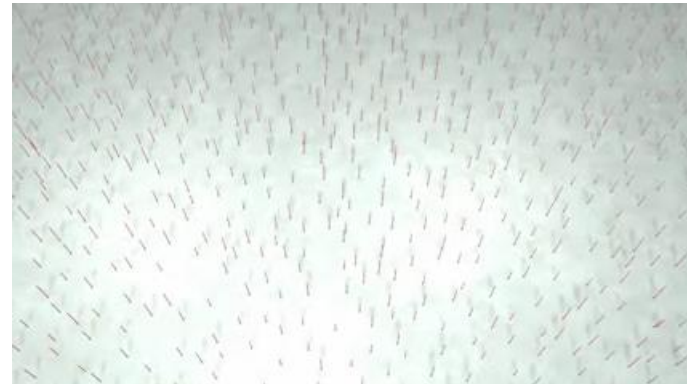
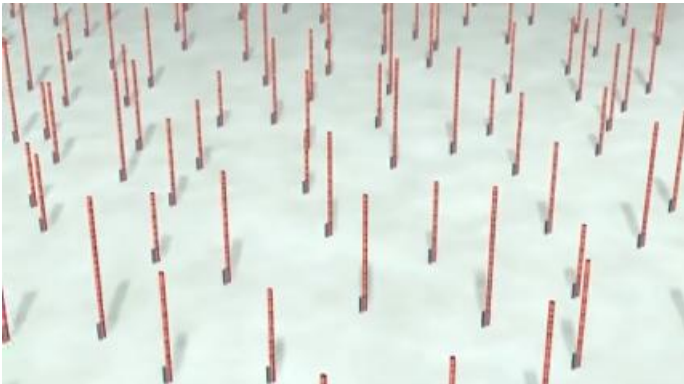


Second chemistry cycle: to initiate the next sequencing cycle, add all four labeled reversible terminators and enzyme to the flow cell.

HELICOS (2008)



True Single Molecule Sequencing (tSMS)

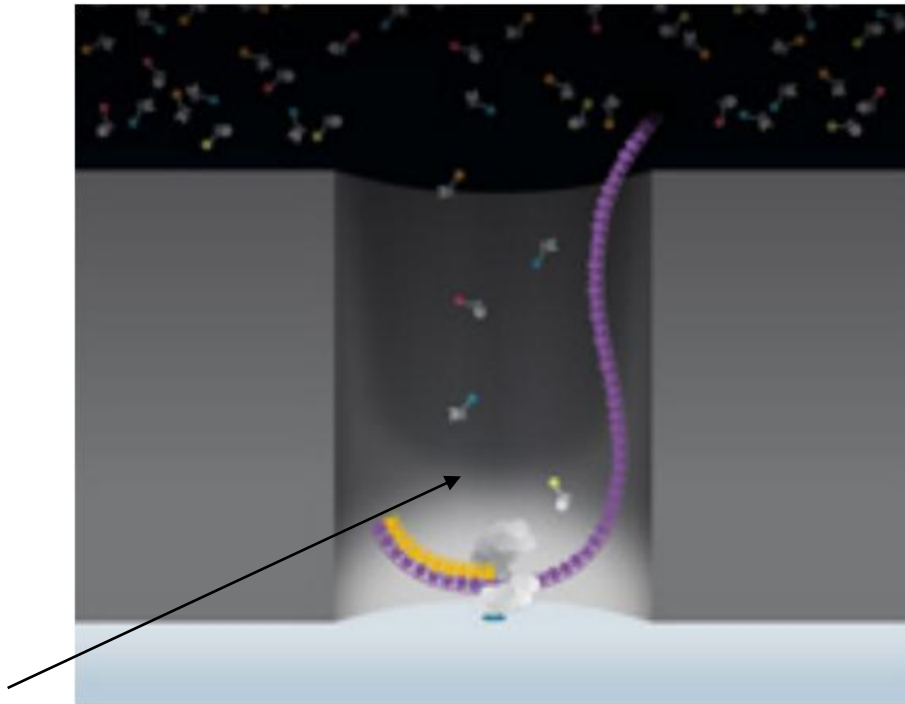


Single Molecule Real-Time (SMRT)

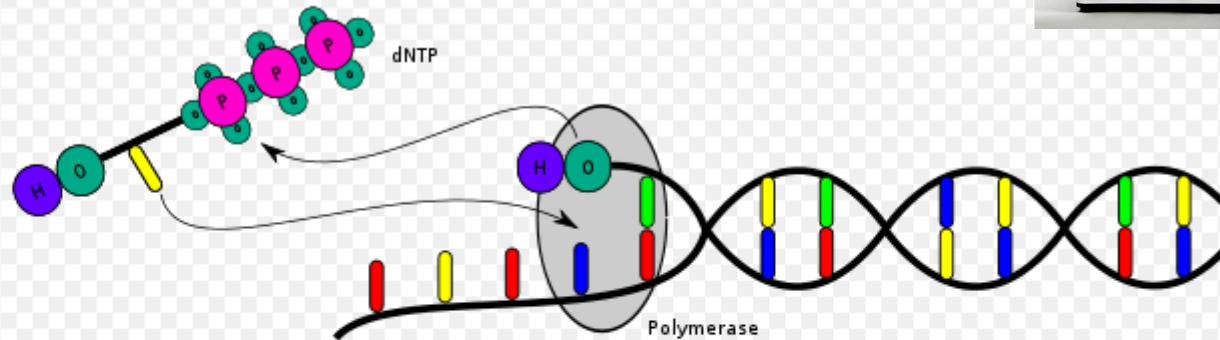
Pacific Biosciences



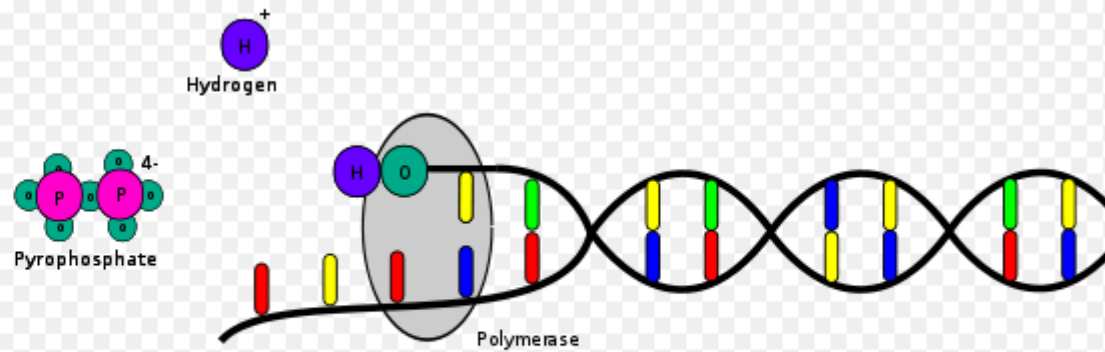
20 zeptolitru



Ion Torrent

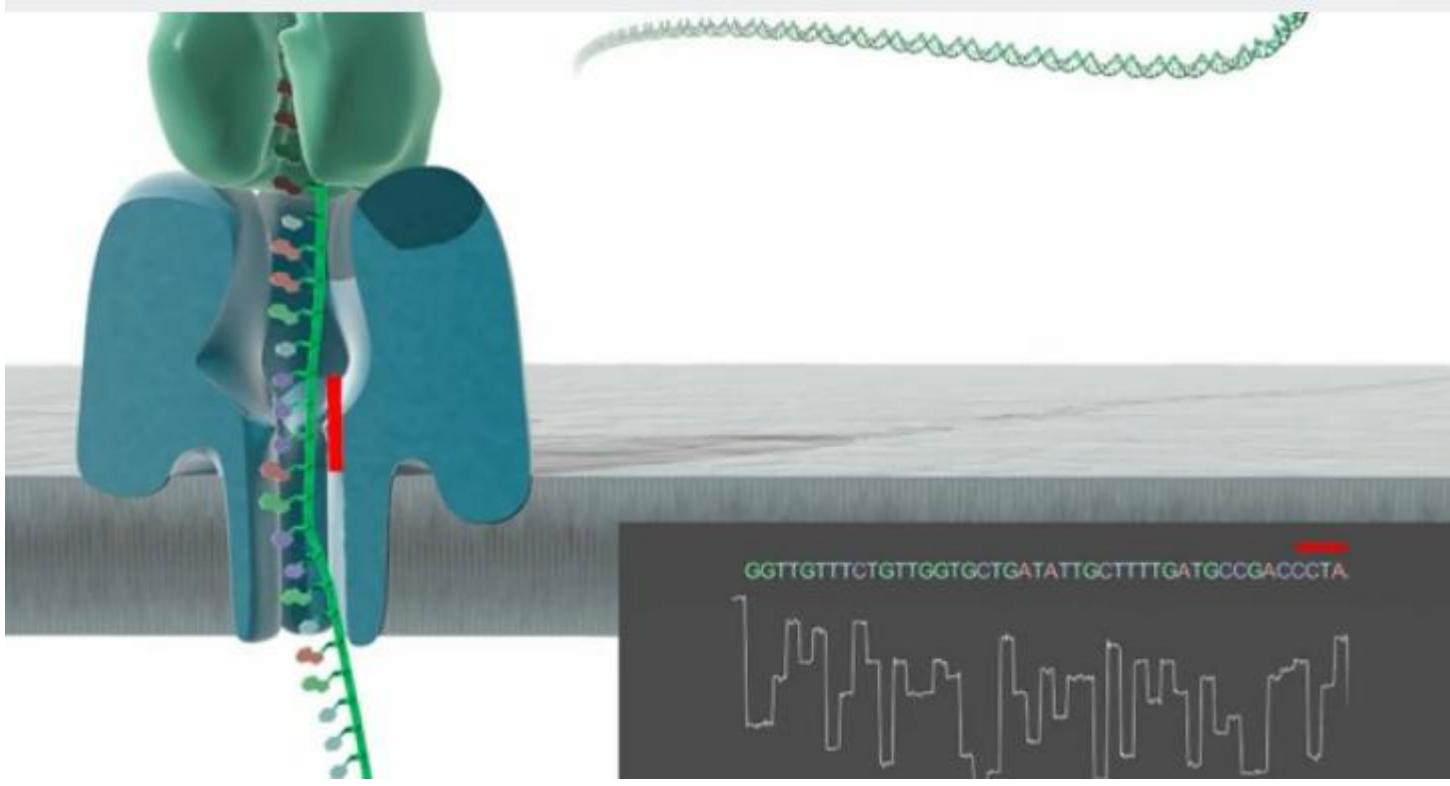


Polymerase integrates a nucleotide.



Hydrogen and pyrophosphate are released.

Oxford nanopore



Další technologie

- Mikroelektroforéza
- Sekvenování na bázi microarray