



BIOMEMORY
Sustainable Storage Solutions

2023 BIOMEMORY

Making DNA Data Storage a Reality

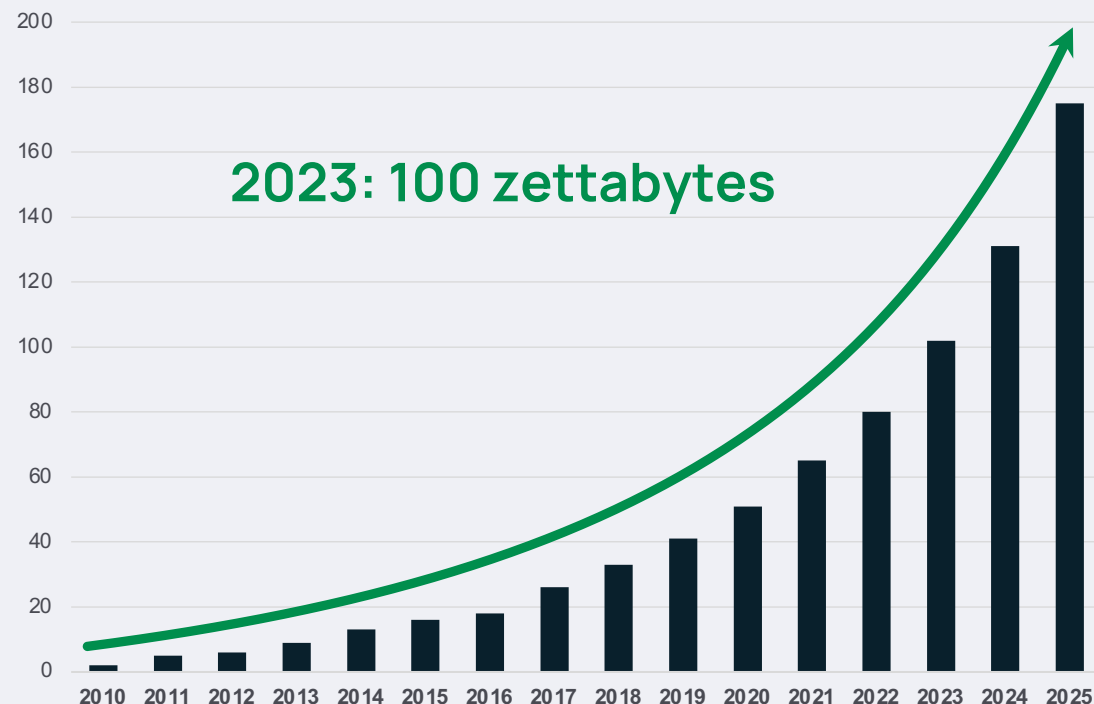


Erfane ARWANI, CEO and Co-founder - erfane@biomemory.com

Current digital media are limited and **storage** needs will **explode**

We produce twice as much data every 3 years

Zettabytes



We are less and less able to store the huge amounts of data we produce



“If today we are capable of storing about 30% of the information we generate, by 2030 we’ll be able to store about 3%”

Dr Karin STRAUSS,
Microsoft Research



Problems with current digital **media**

Bulky

200 km²
of data centers
(2x Paris)



Fragile

3/7-year
lifespan



Energy-Consuming

Datacenters represent
**2% of the world's electricity
consumption**



Main storage devices in **datacenters**



Remastering the storage devices

Assess the existing storage infrastructure



Identify the new storage technology



Plan the migration



Data backup and verification



Data migration



Testing and validation



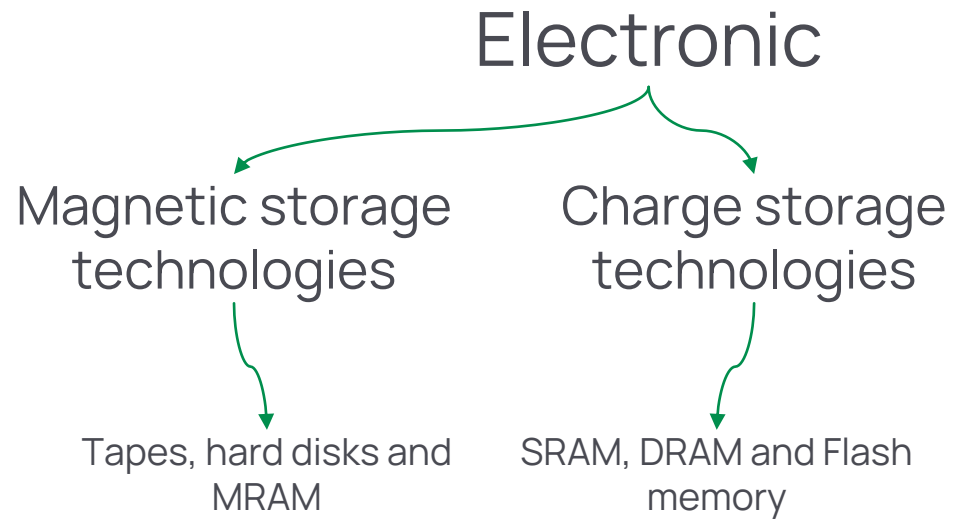
Decommissioning old storage devices



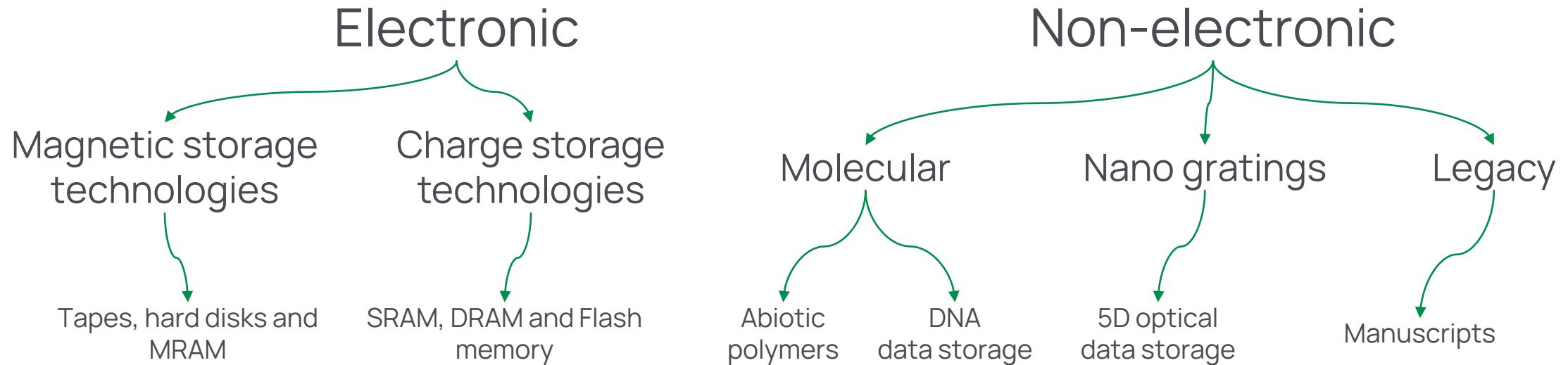
Monitoring and optimization



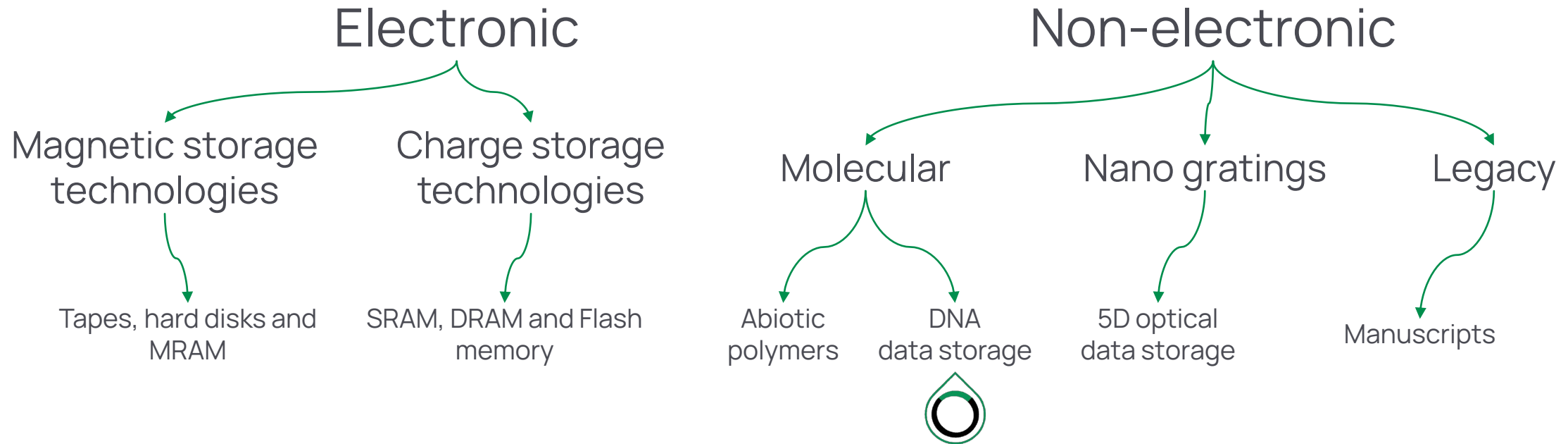
Categories of Data Storage Technologies



Categories of Data Storage Technologies



Categories of Data Storage Technologies





The **DNA** Data Storage

High Storage Density

Complete humanity
data in **100g**
of DNA



Longevity & Stability

Stable
for **millennia**

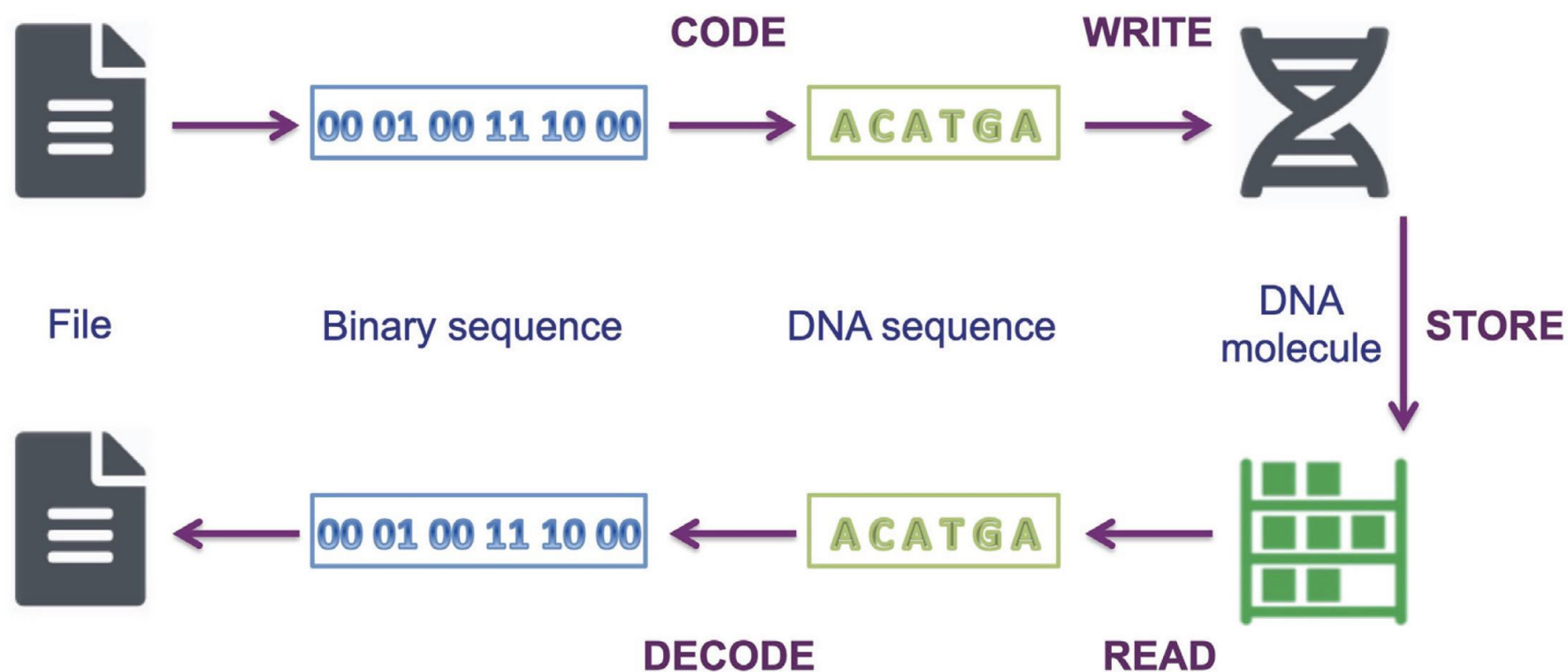


Zero Power Upkeep

Stable at room temperature
without energy input



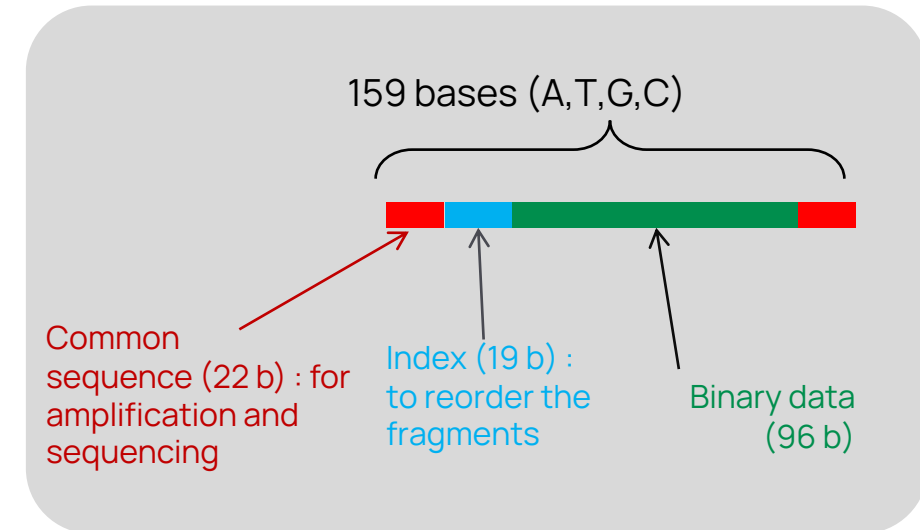
End to end DNA Data Storage



State of the art Storage on **oligonucleotides**

Oligonucleotides = short DNA fragments

- Synthesized chemically
- Maximum 200 bases
- Single strand



2012, **650 kB** = > **54 898** oligonucleotides



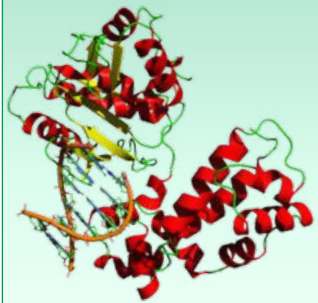
Church *et al.*, 2012 Science

2018, **200 MB** = > **13.4 million** oligonucleotides



Organick *et al.*, 2018 Nature Biotechnol

Need for **more efficient** DNA data storage systems



Our vision

- ✓ Exploiting the potential of Nature
- ✓ Employing biological approaches to overcome DNA storage constraints



Images: Science et Avenir, Wikipédia

Nature has already
figured it out

DNA copy



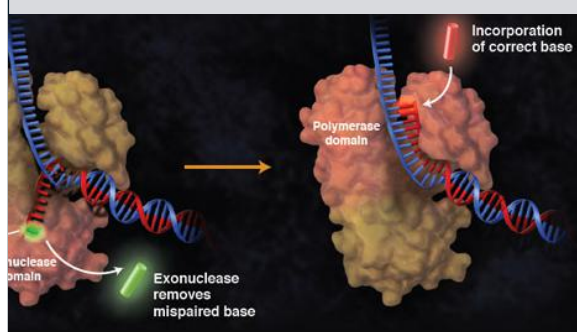
DNA reading



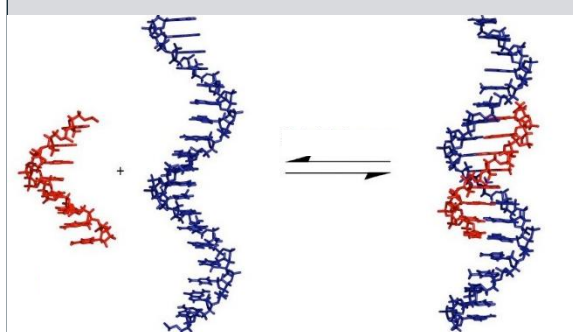
DNA editing



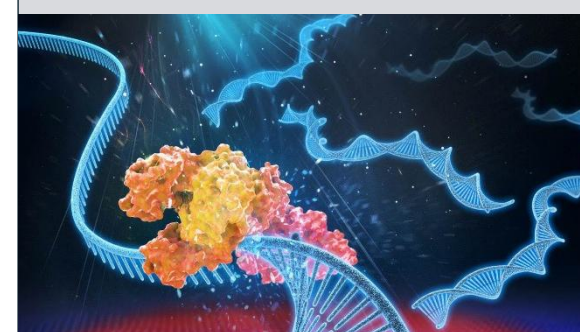
Error correction



Flash random access

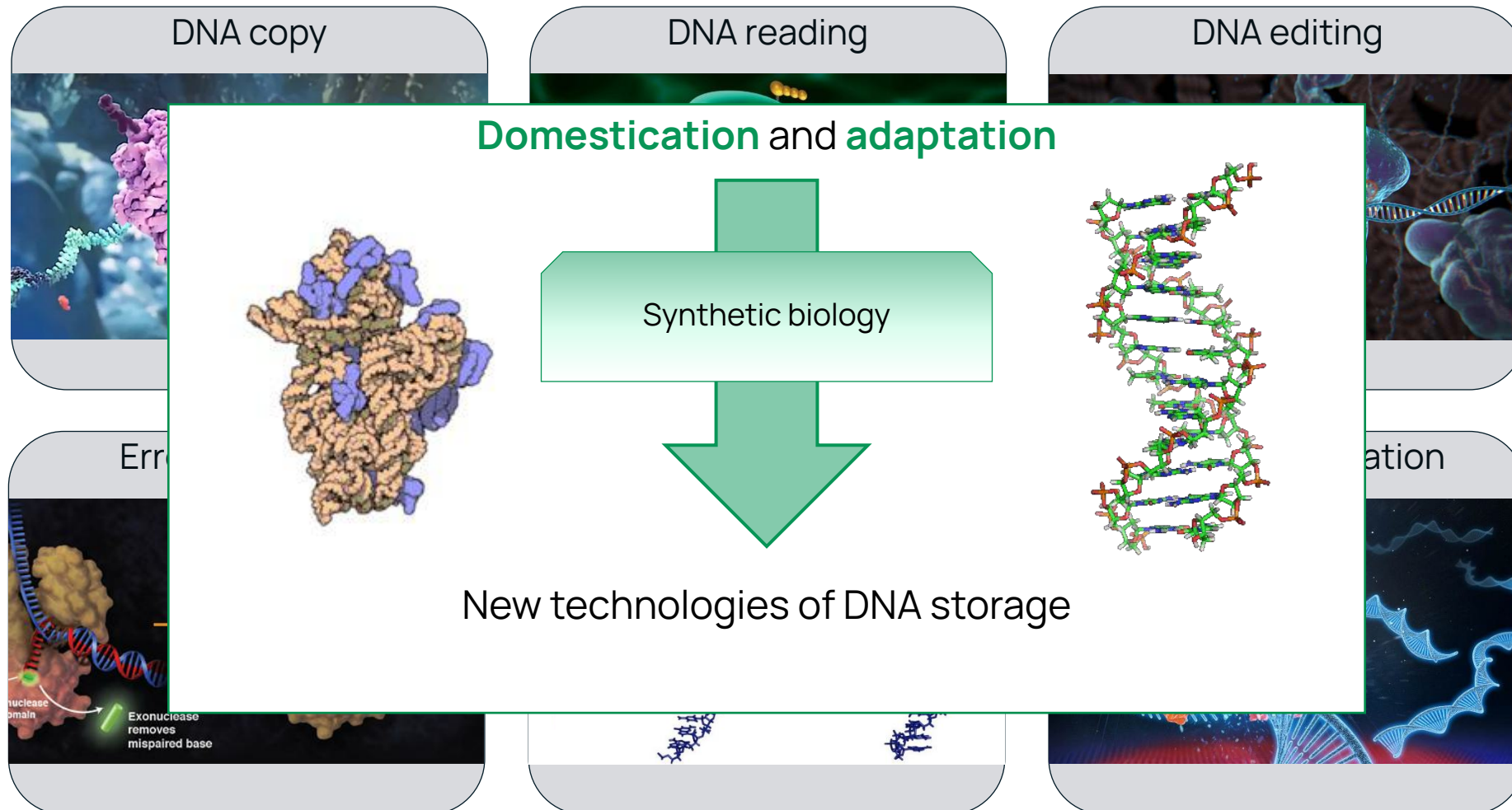


Signal amplification



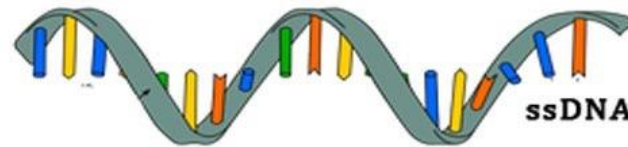
Images : Random42, Neb, Gesundheitsindustrie, Phys

Nature has already
figured it out



Biomemory strategy Biocompatible DNA

The mainstream strategy



Oligonucleotides = single strand

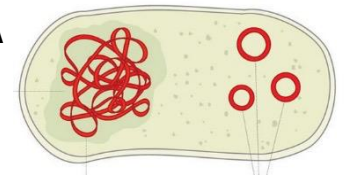
- Short length: ≈ 200 bases
- 70 000 fragments /MB

Living organisms



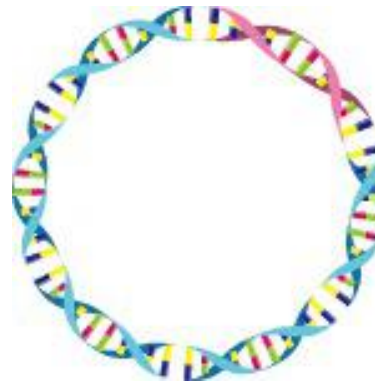
Very Long double-stranded DNA

- Long molecules: kb-MB
- 1 fragment /MB



Chromosome Plasmids

Biomemory



Long circular double-stranded DNA

- Long molecules: 30 kb
- 1000 fragments /MB

➡ Biosafe: no biological code, anti-biohacking

➡ Copy at low cost and ultra-low error rate

DNA DRIVE

A bio-inspired DNA storage strategy

The mainstream strategy
storage on oligonucleotides



Pool 1



Pool 2



Pool 3

DNA DRIVE

A bio-inspired DNA storage strategy

The mainstream strategy
storage on oligonucleotides



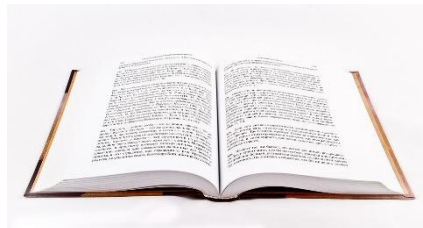
Pool 1



Pool 2



Pool 3



DNA DRIVE

A bio-inspired DNA storage strategy

The mainstream strategy
storage on oligonucleotides



Pool 1



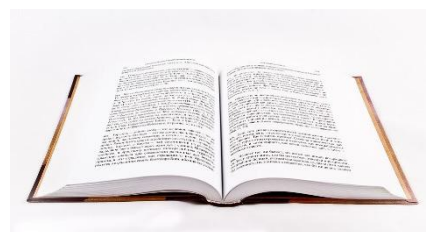
Pool 2



Pool 3



Track



Pool



Array



DNA Drive

DNA DRIVE

A bio-inspired DNA storage strategy

The mainstream strategy
storage on oligonucleotides



Pool 1



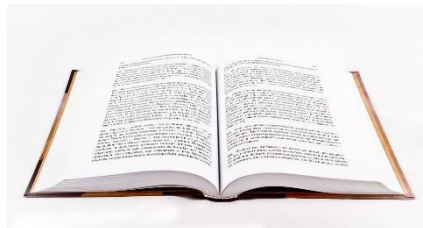
Pool 2



Pool 3



Track



Pool

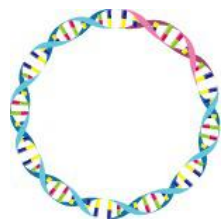


Array

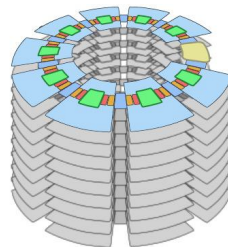


DNA Drive

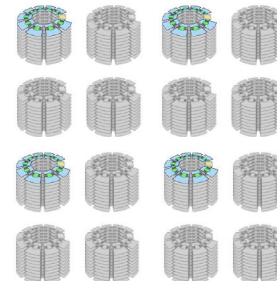
Unlimited number of Arrays



Divided in
sectors



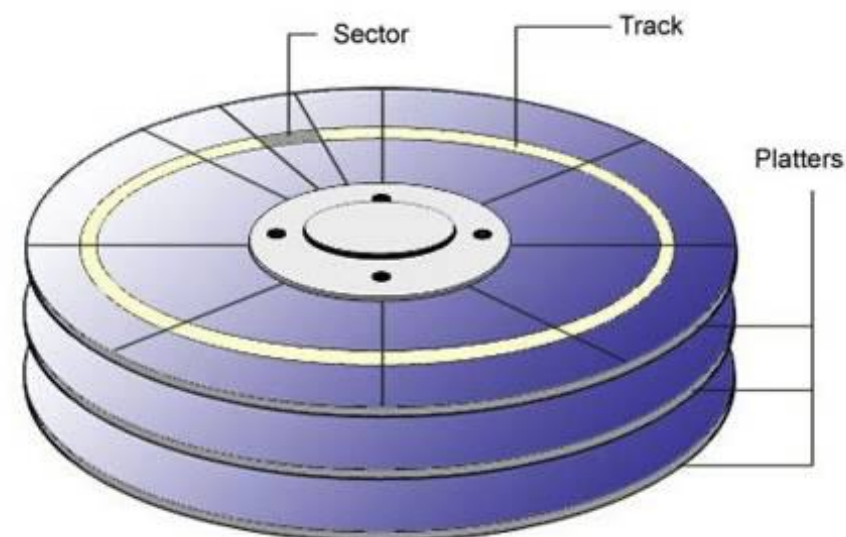
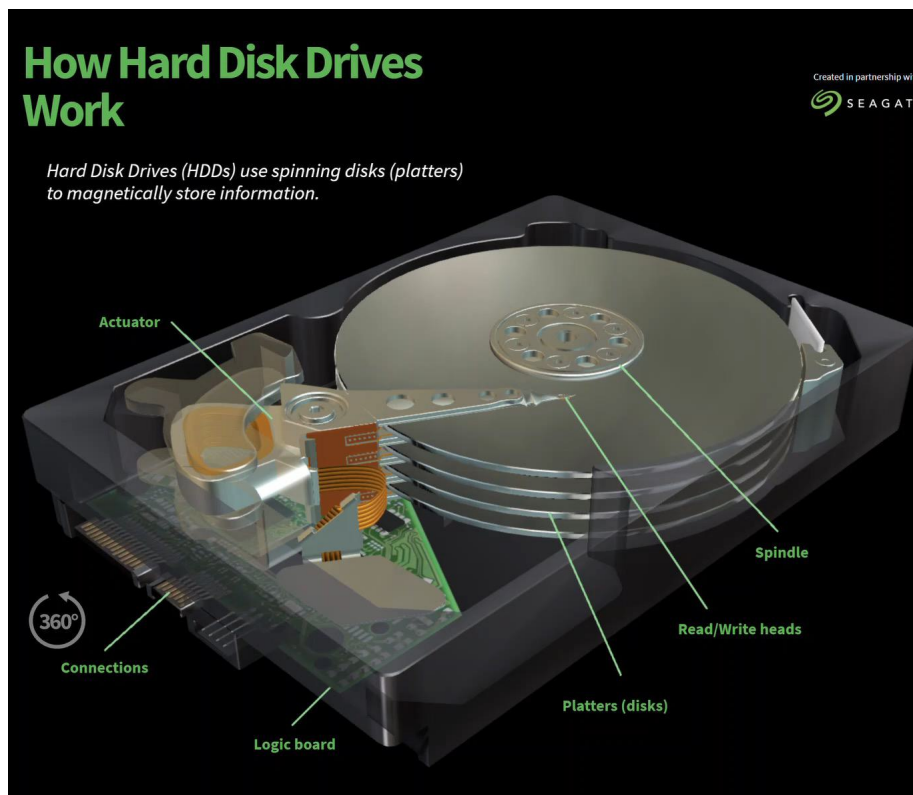
Thousands
of Tracks



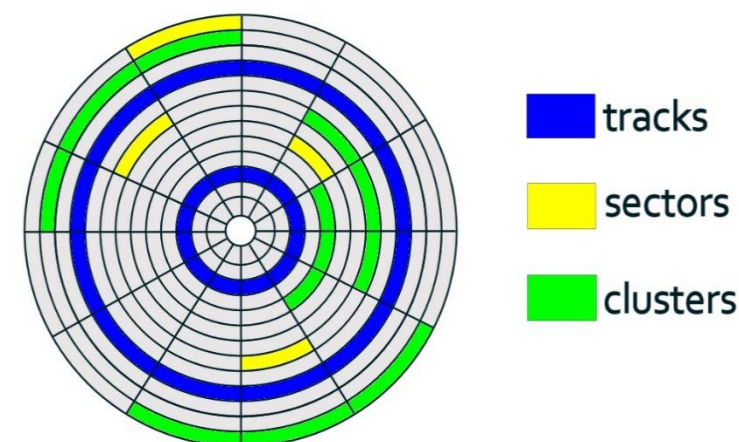
Hundreds of
Pools

Hard disk drive

Physical organization



Hard disk drive structure

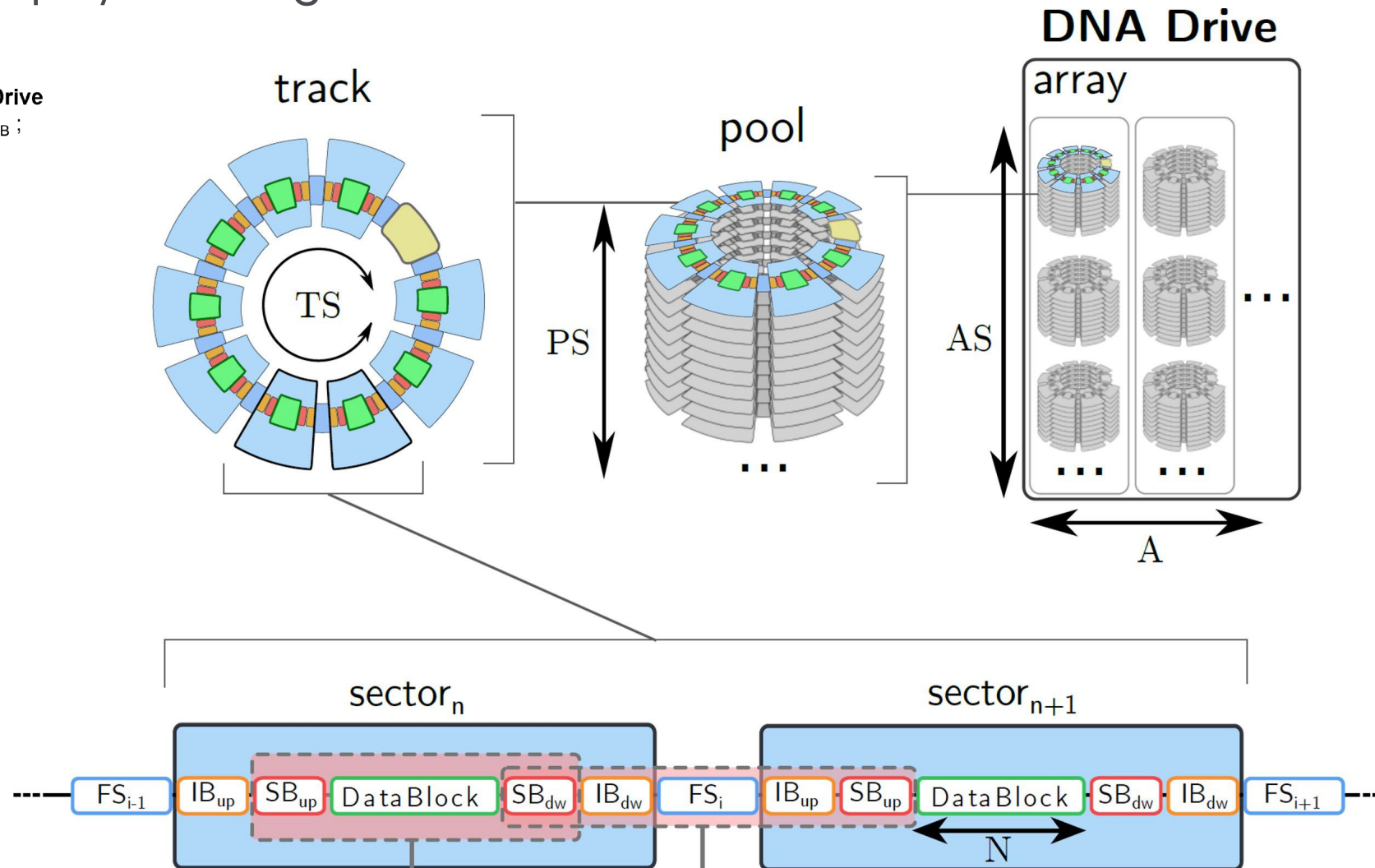


DNA Drive

Multi-scale physical organization

Physical properties of the DNA Drive

- **B** Sector size = $N_{DB} + N_{SB} + N_{IB}$;
- **TS** Sectors/track ;
- **PS** Track /pool ;
- **AS** Pools/array ;
- **P** total pool number ;
- **A** total number of arrays



DNA DRIVE

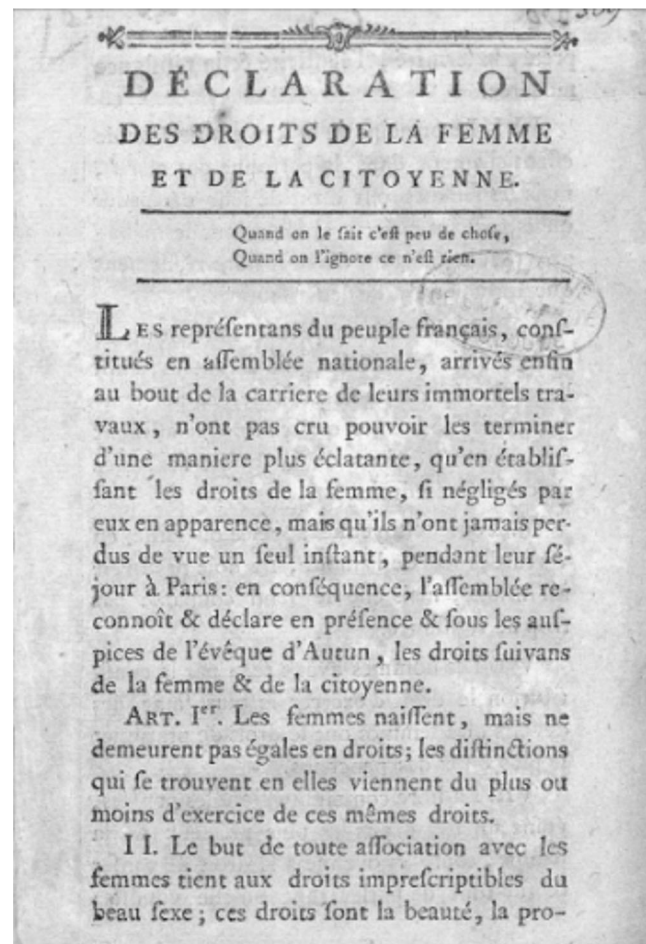
A bio-inspired DNA storage strategy



DNA Drive
The next generation of
cold storage media

- Unlimited total capacity
- Low cost copy
very low copy error rate
- Compatible with all sequencing technologies
- Any binary file system
organized in physical DNA sectors, tracks, arrays..
- Compression, random access
- Powerful error correction code
- Biosafe
Non-biohackable by design
- Fully automatable

Proof of concept historical texts saved for eternity



Officially stored
at the [French National Archives](#)
since November 23rd 2021

**ARCHIVES
NATIONALES**
Fontainebleau - Paris - Pierrefitte-sur-Seine

DNA writing mainstream technique

The chemical synthesis

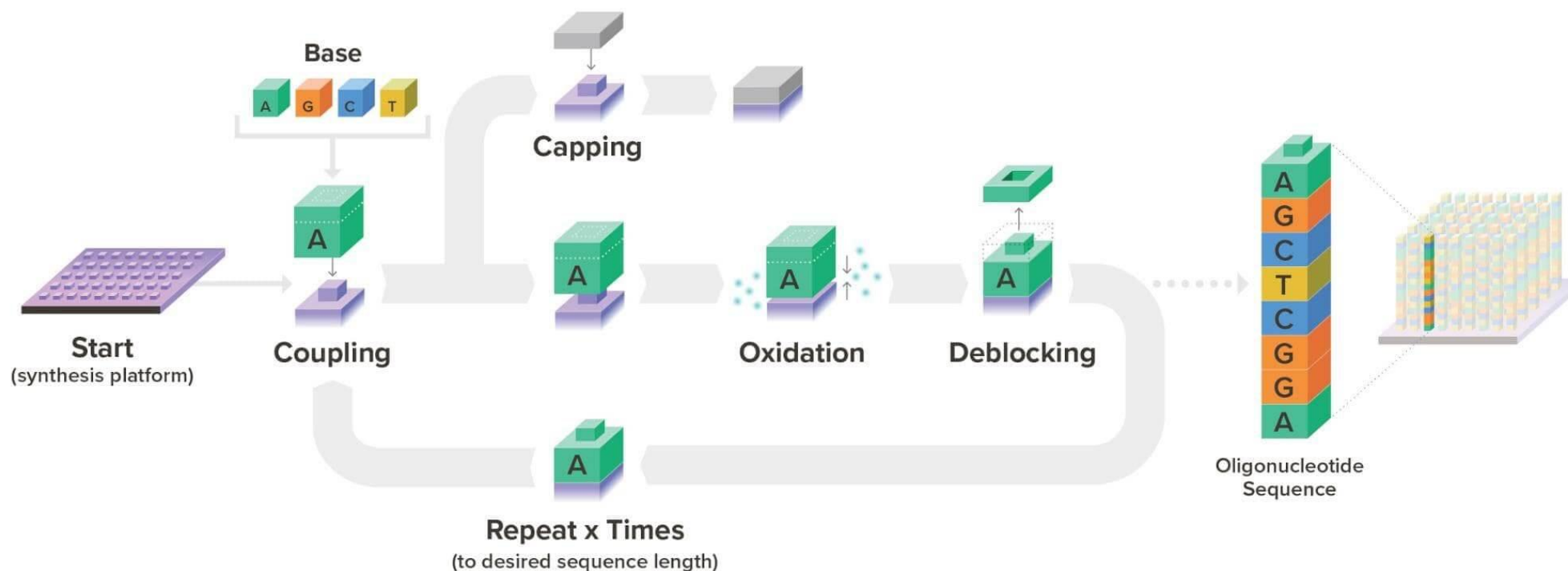


Illustration : Twist Bioscience

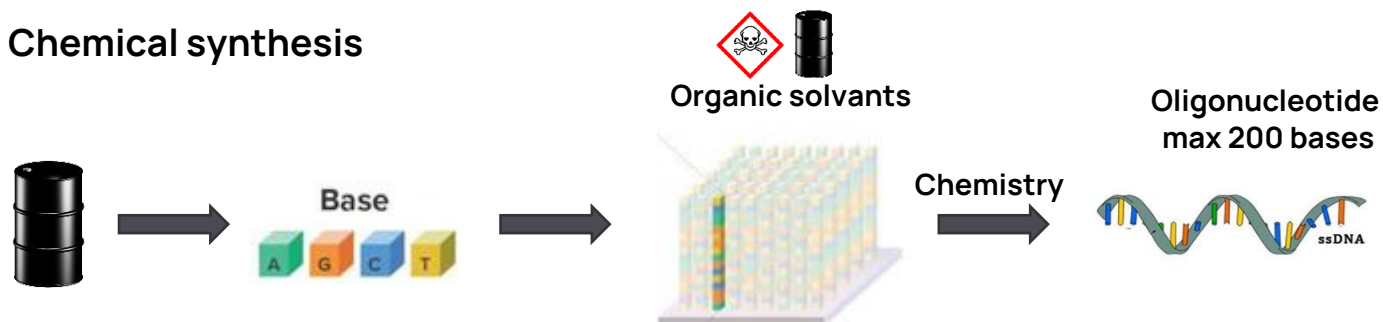
Short fragments (< 200 nt)
Building blocks from petrochemical phosphoramidites
Utilizes hazardous, flammable organic solvents
Expensive DNA data storage: >\$1000/Mo

DNA writing Synthesis

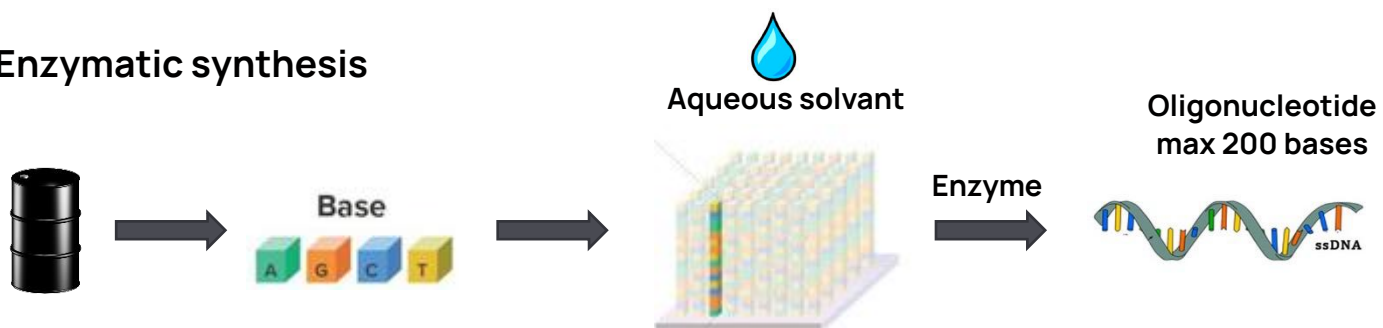
The mainstream strategy
storage on oligonucleotides



Chemical synthesis



Enzymatic synthesis



DNA writing A complexity problem

Biology: you need to be able to synthesize **all** possible DNA sequences

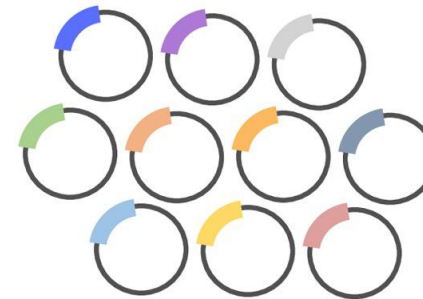
$$8 \text{ nt} \Rightarrow 4^8 = 65,536 \text{ sequences}$$

Digital data: *limited* complexity

$$8 \text{ bits} \Rightarrow 2^8 = 256 \text{ sequences}$$

Biomemory solution:

A collection of 256 bricks
to write any binary file



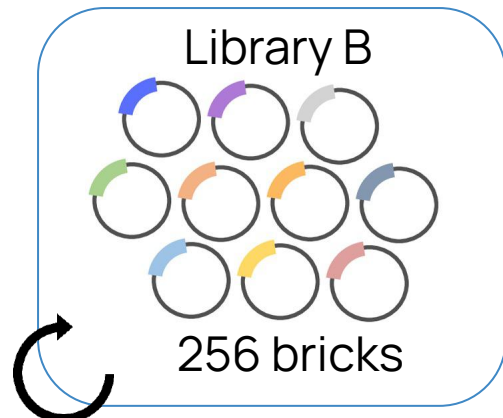
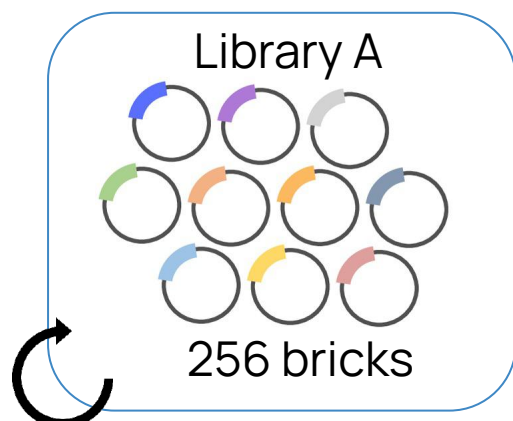
256 Self-replicating
DNA bricks

Production at

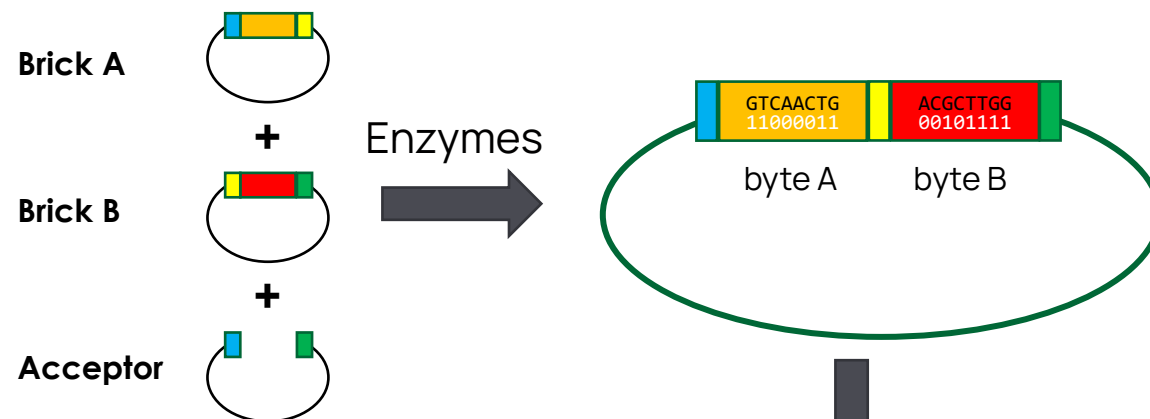
- High volume
- Low cost
- Low error rate

Biodata Multi-level assembly

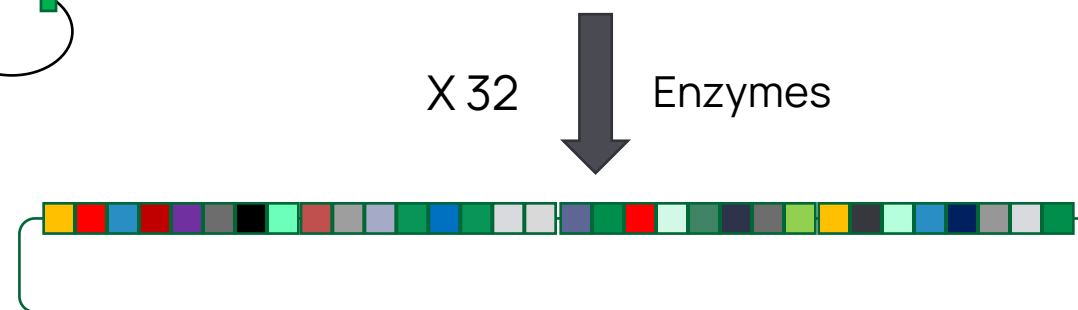
Two self-replicating libraries



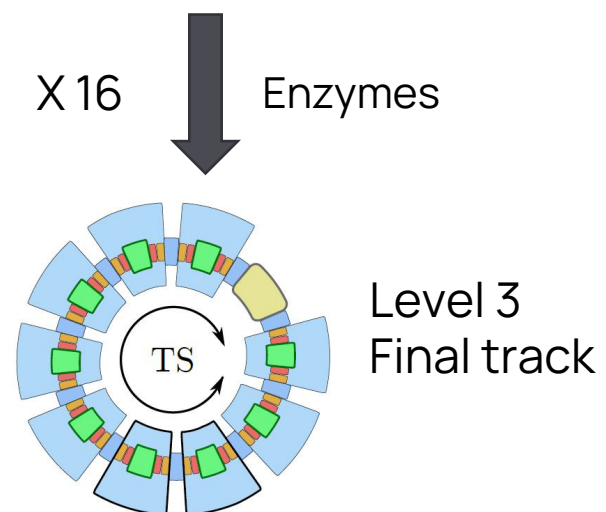
Level 1
2 bytes
Assembly



Level 2
64 bytes
Assembly

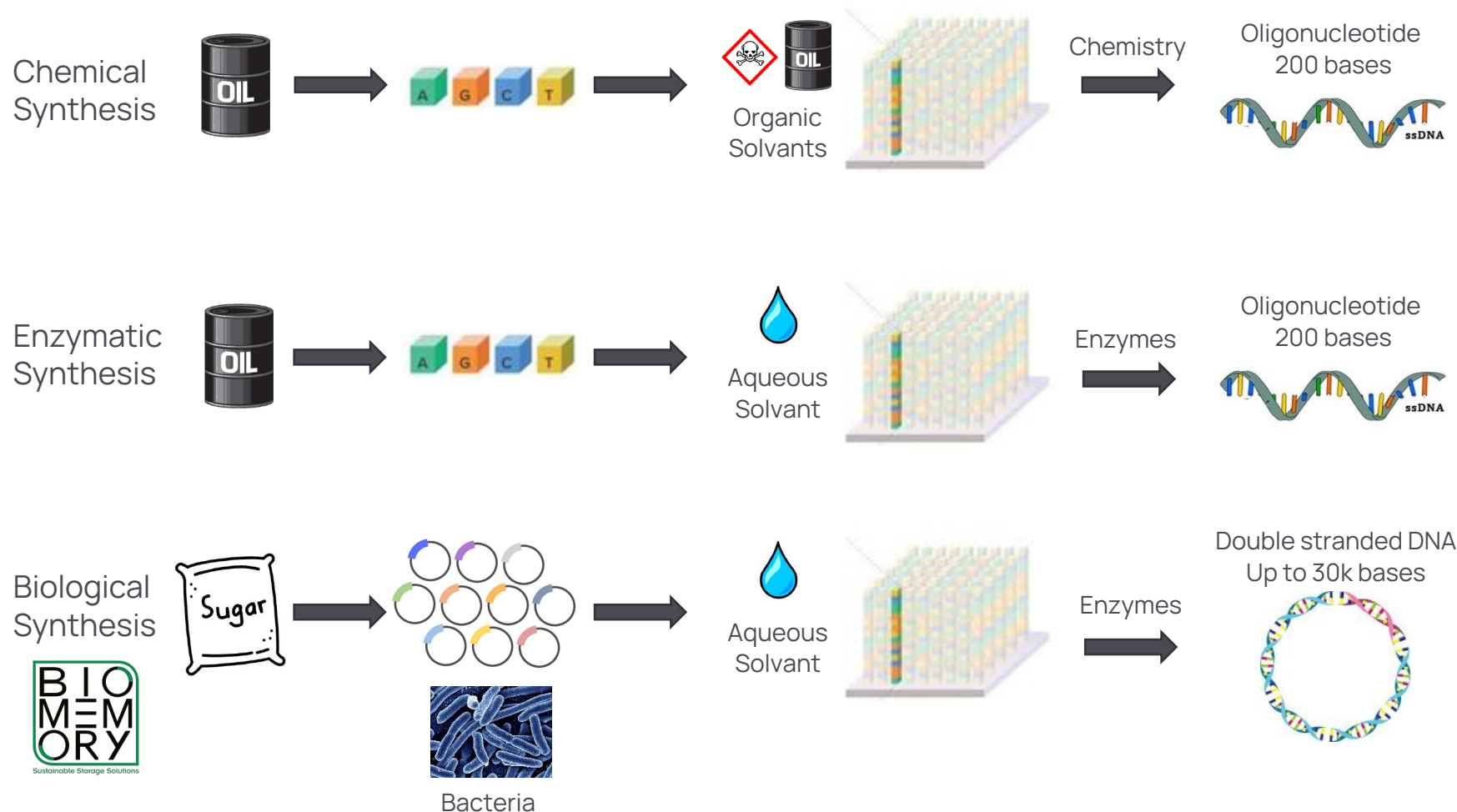


Level 3
1024 bytes
Final assembly



DNA writing

Biomemory's DNA synthesis is radically different



- Potential \$1/MB and beyond
- **Renewable** : 100% biosourced
- **Biosafe** : non-biohackable by design

Our **2030** Vision : A rackable DNA Data Storage Server A business model similar to printers



- ✓ Autonomous
- ✓ Read/Write
- ✓ Exabyte scale
- ✓ \$1/terabyte
- ✓ Removable DNA Drive cartridges
- ✓ Removable DNA ink cartridges
- ✓ 4U rackable server for existing DCs
- ✓ No biological expert on site

BIOMEMORY

Sustainable Storage Solutions



Pure Player of
DNA Data Storage



Bio-based
DNA Storage

**Let's build the first
sustainable data storage solution!**

Twitter @BIOMEMORYLABS

Erfane ARWANI, CEO and Co-founder - erfane@biomemory.com