

Experimental DNA Storage Platform

dnarXiv project

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Agenda

1. dnarXiv project

Aims to investigate the storage of information on DNA

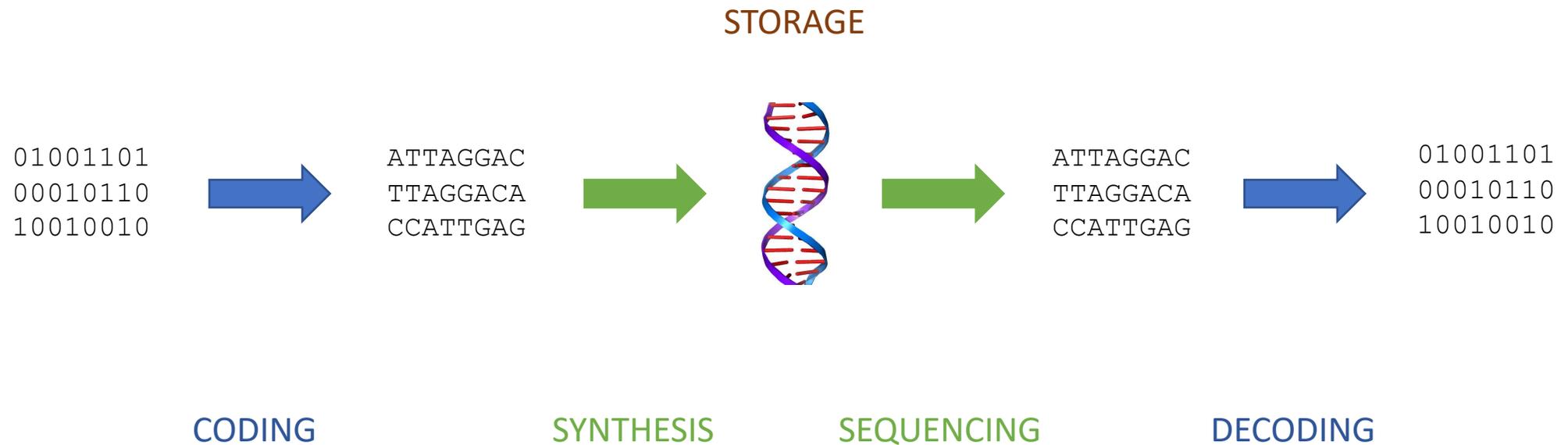
2. dnarXiv platform

Description of the platform features

3. example

To illustrate the way it can be used

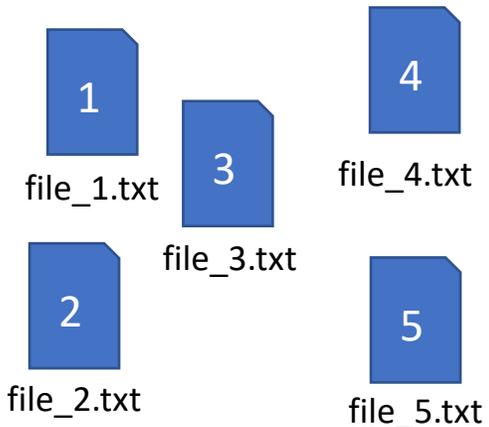
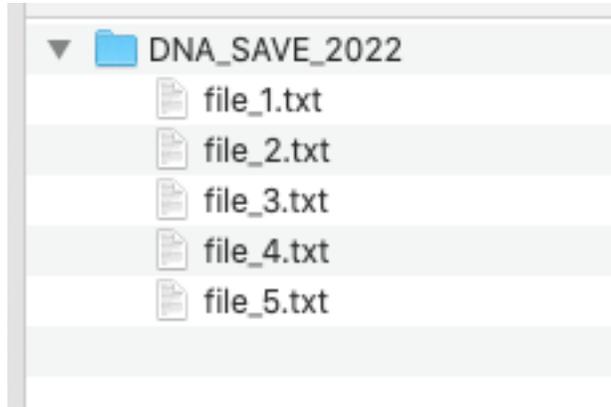
Principle of DNA data storage



dnarXiv approach

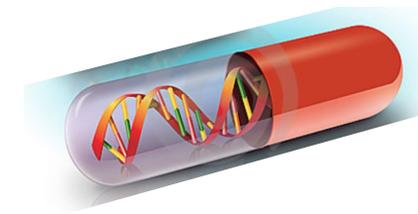
Files that will be archived are copied into a directory

dna_copy



Binary files are transformed into long DNA molecules

dna_store



DNA container

dna_read

Molecules corresponding to one file are extracted and converted to a binary file



dnarXiv aims to store long molecules

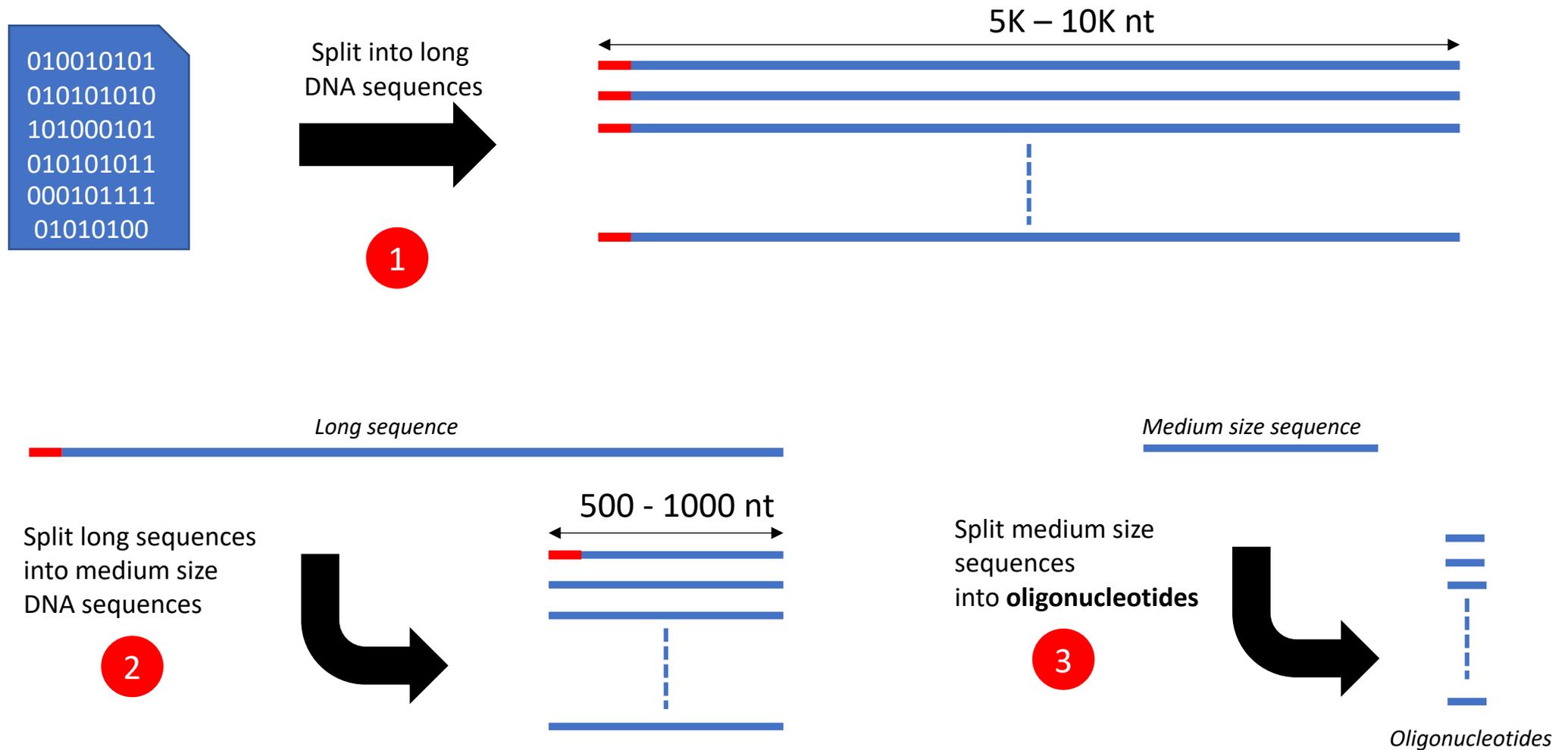
Advantages

- Optimization of the indexing
- Use of 3rd generation sequencing technology

Drawbacks

- Add a bio-tech step : short oligonucleotides → long DNA molecules
- Noisy sequencing step

Long molecules → oligonucleotides

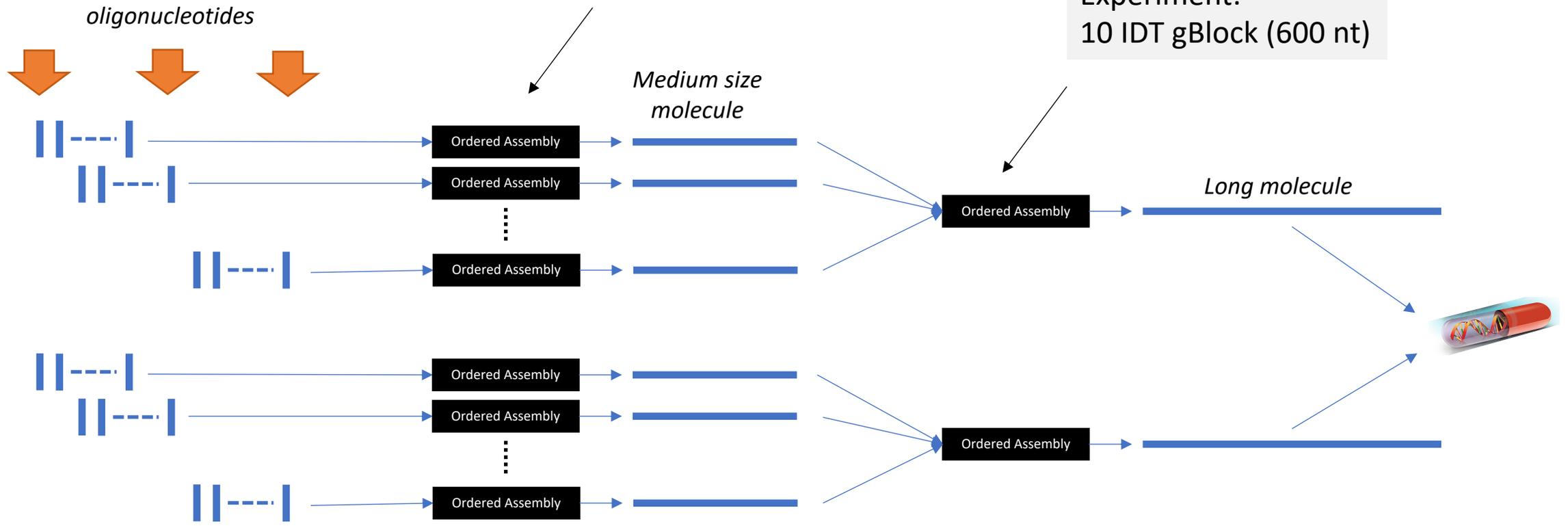


Oligonucleotides → Long molecules



Experiment:
10 oligonucleotides (60 nt)

Experiment:
10 IDT gBlock (600 nt)



Document retrieval

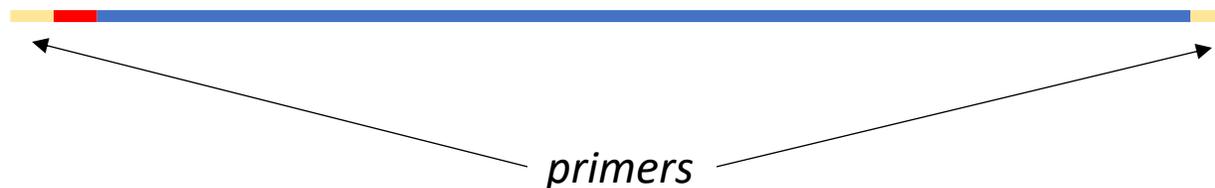
A container contains many documents

How to recover a specific document without sequencing all the molecules of the container ?

Different pairs of primer are added at the beginning and at the end of the molecules.

A pair of primers can be seen as a document identifier inside the container.

Document extraction performed by PCR



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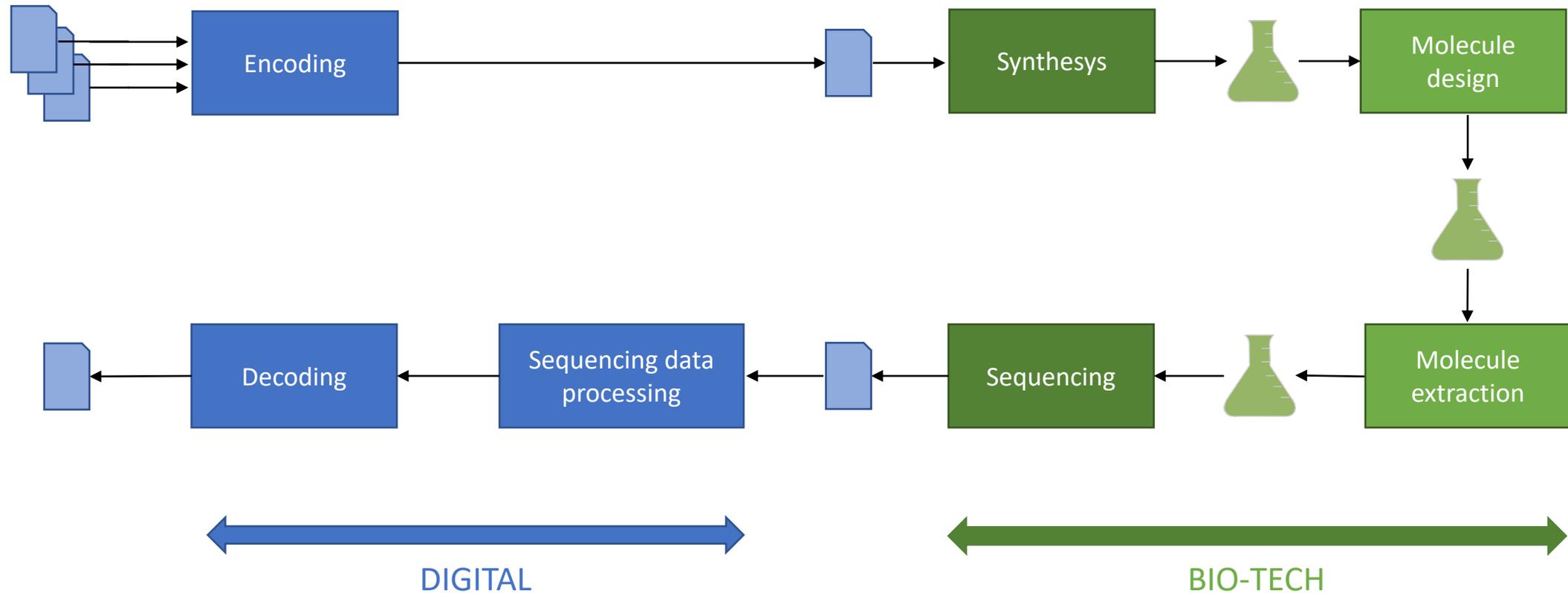
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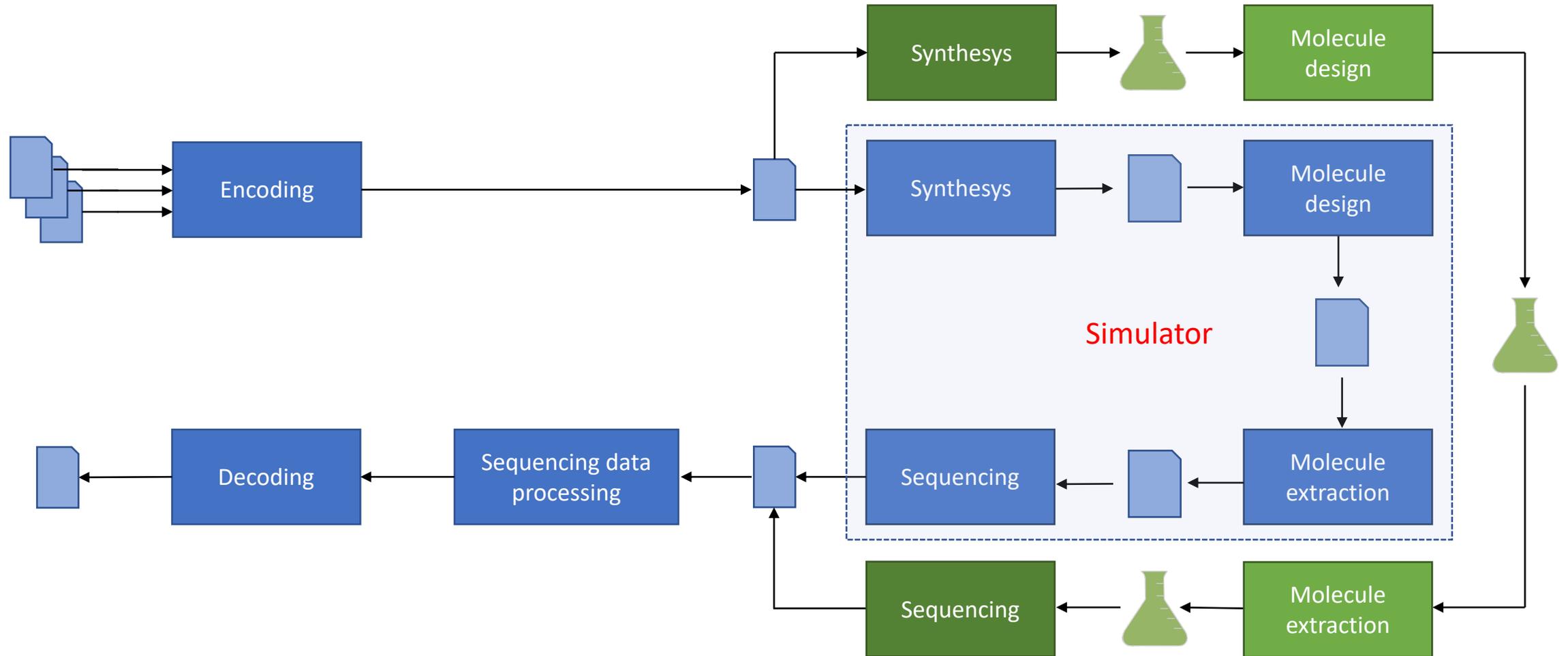
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To illustrate the way it can be used

dnarXiv platform implementation



in-silico alternative



Why including simulators ?

Bio-tech experimentation are (very) costly

- Especially nucleotide synthesis

This is a way to test how the digital part scale up

- Protocol:
 - Perform wet-lab experimentation on small datasets
 - Extract main features
 - Model them into simulator
 - Run in-silico experimentation on large datasets

dnarXiv: commands & scenarios

commands

dna_create

Create an empty container

dna_copy

Add a file to a container

dna_del

Remove a file from a container

dna_list

List the files of a container

dna_store

Write the container files on DNA

dna_read

Read a DNA file from a container

scenarios

A scenario is associated to:

- ❖ the execution mode: wet-lab or in-silico
- ❖ the nature of the objects to archive
- ❖ the source coding scheme
- ❖ the error corrector code
- ❖ the synthesis technology
- ❖ the structure of the DNA molecules to store
- ❖ the molecule extraction strategy
- ❖ the sequencing technology
- ❖ ...

dnarXiv commands

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dna_list

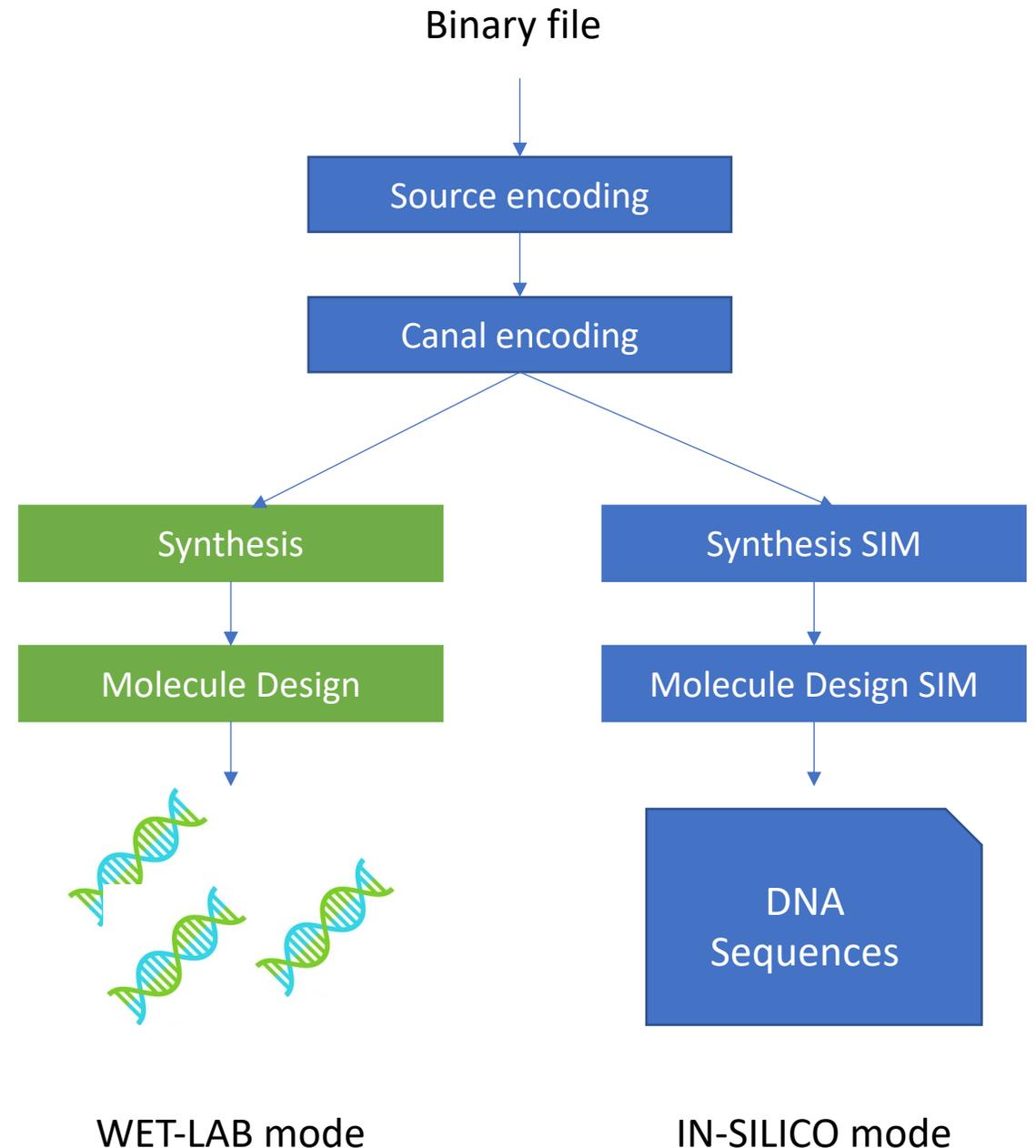
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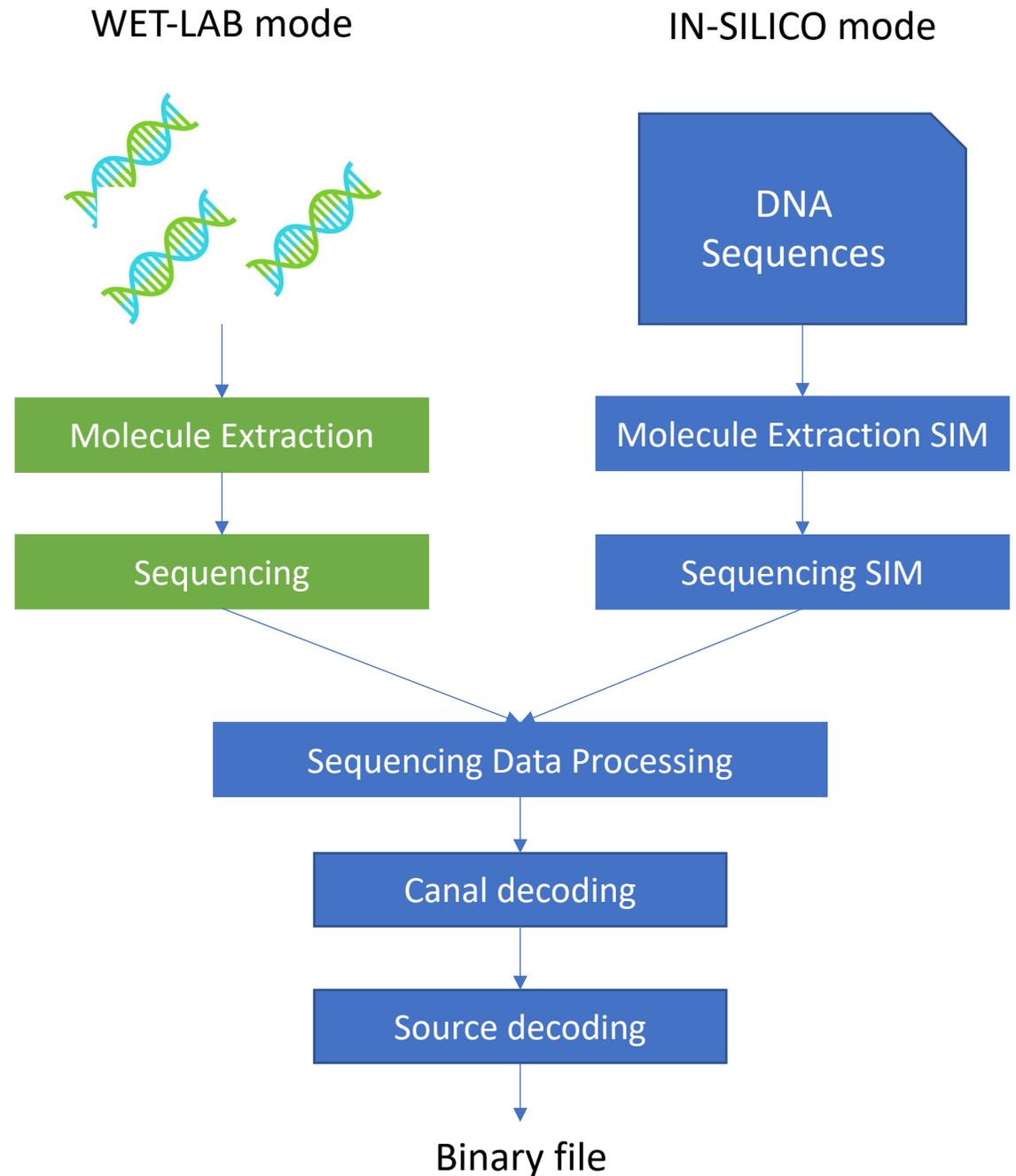
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Write the container files on DNA

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Read a DNA file from a container



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To illustrate the way dnarXiv platform can be used

Scenario example

Investigating encoding efficiency vs oligo size

Study of 3 situations

- **Option A:** channel encoding, oligo size = 200
- **Option B:** **no** channel encoding, oligo size = 200
- **Option C:** **no** channel encoding, oligo size = 100

Document = 1 color image



Encoding

ACGGAT AGGACA CGGATT AGAGAC CAGGGG GATTGG CCGGTA . . .



Pixel scrambling

TGCAAT ACCTGA CTTGGT CAATGA GTAGCA CCAATA TGGACC . . .



Indexing : a few pixels per oligo

ACGTGGCCAT TGCAAT ACCTGA CAATGA

TGCCATATTA GTAGCA CCAATA TGGACC



Channel encoding (LDPC code)

ACGTGGCCAT TGCAAT ACCTGA CAATGA GGTGGACCAGGATTTAGGA

TGCCATATTA GTAGCA CCAATA TGGACC CCATAGGATTGGGACCCAG

Image :

- list of pixels

- 1 pixel → 6 nt

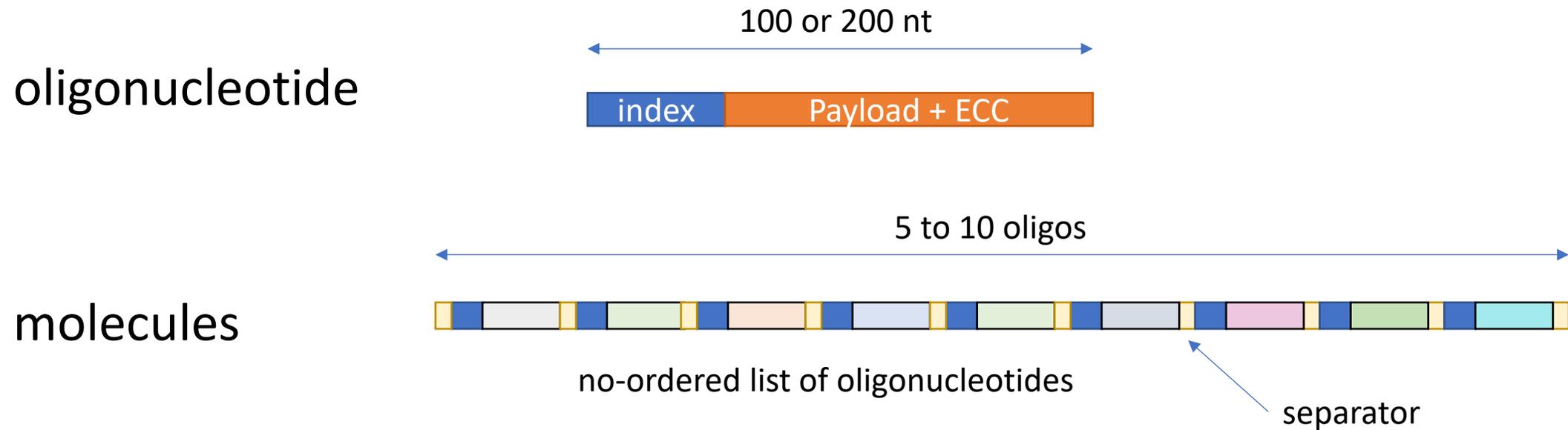
Oligonucleotides



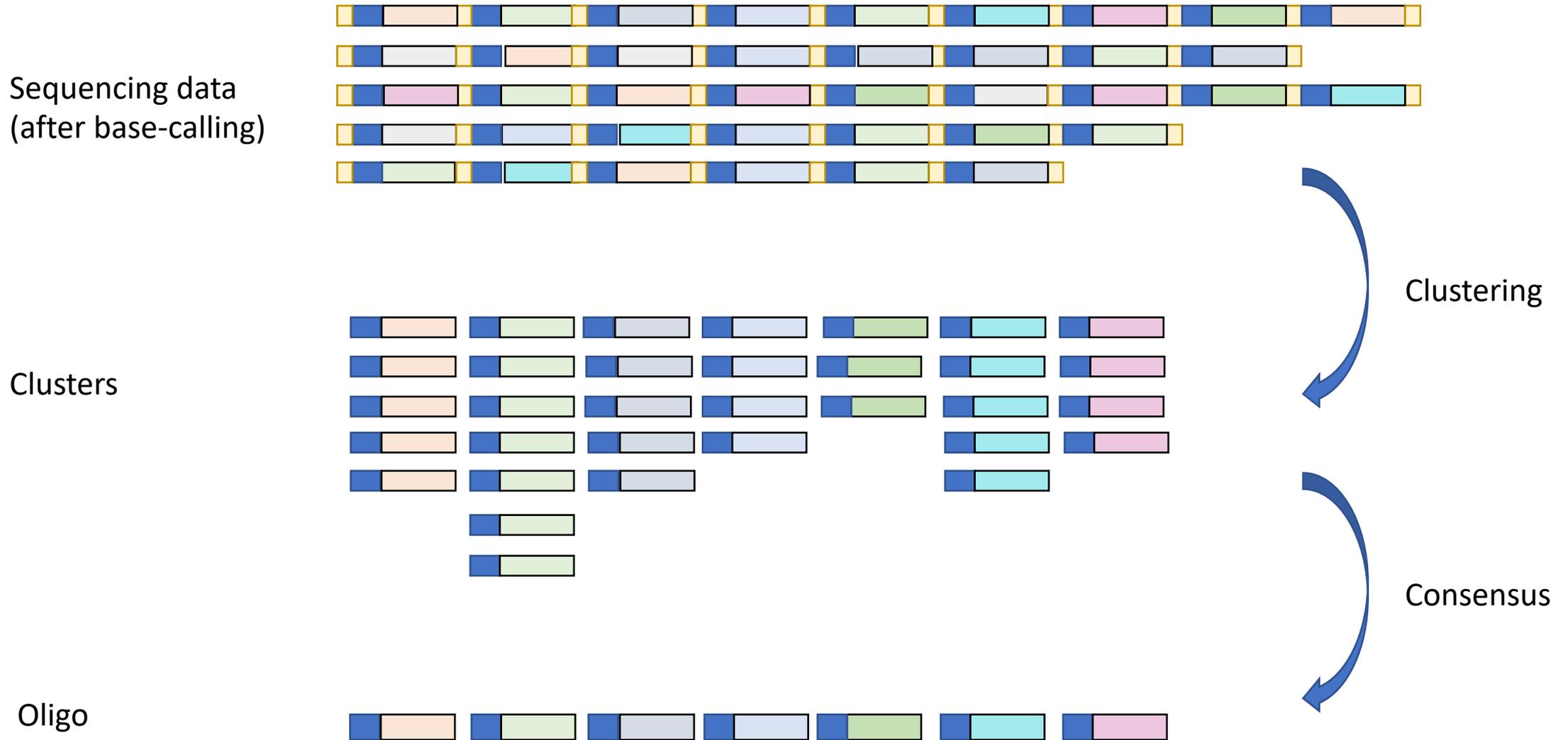
100 or 200 nt

Molecule Design

Oligonucleotides  Sequences



Sequencing data processing



Pipeline

IN-SILICO Experimentation

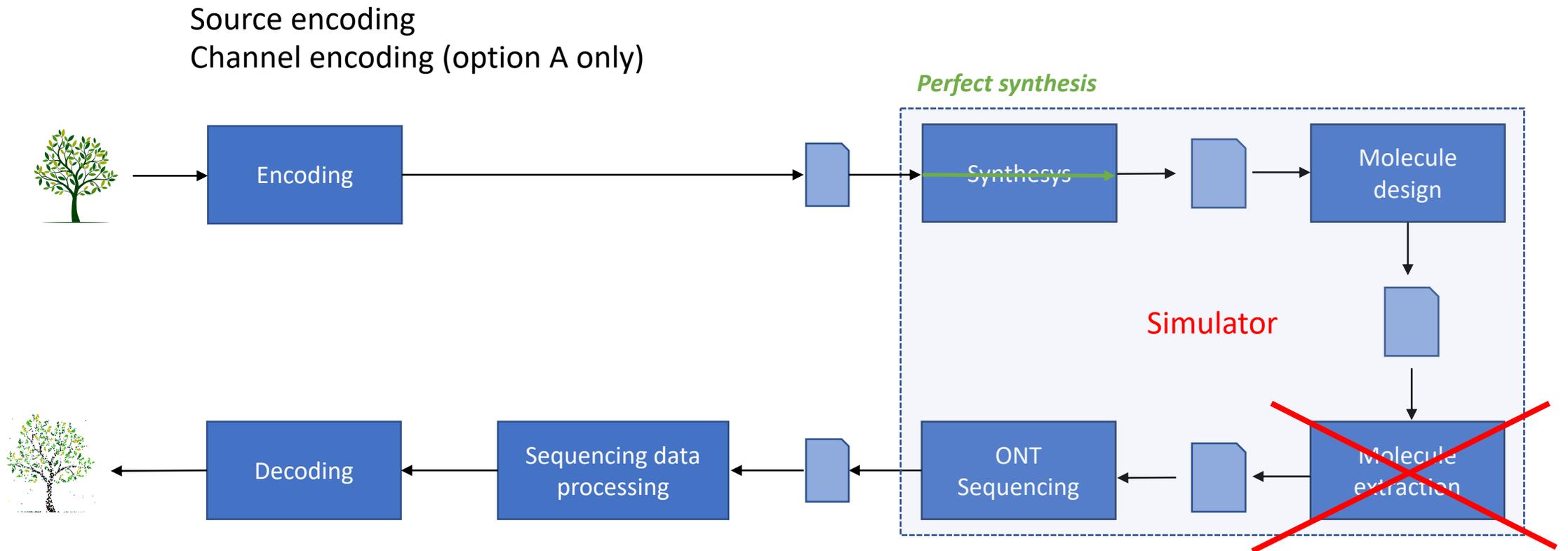


Image reconstruction

How many DNA sequences do we need to reconstruct the image ?

→ 4000 molecules (coverage ~ 10)

image size : 213 X 237
50 000 pixels

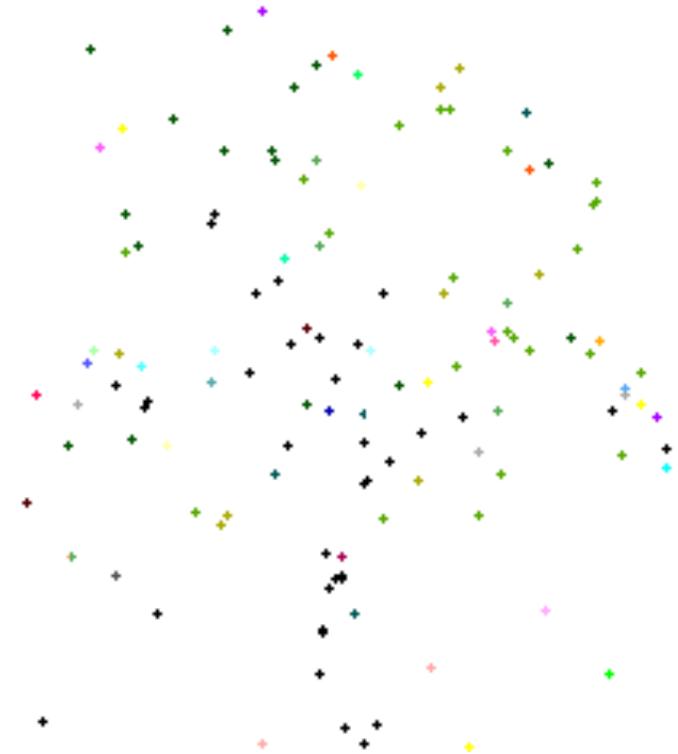


Image reconstruction

How many DNA sequences do we need to reconstruct the image ?

→ 6000 molecules (coverage ~ 15)

image size : 213 X 237
50 000 pixels



Image reconstruction

How many DNA sequences do we need to reconstruct the image ?

→ 10000 molecules (coverage ~ 25)

image size : 213 X 237
50 000 pixels



Image reconstruction

How many DNA sequences do we need to reconstruct the image ?

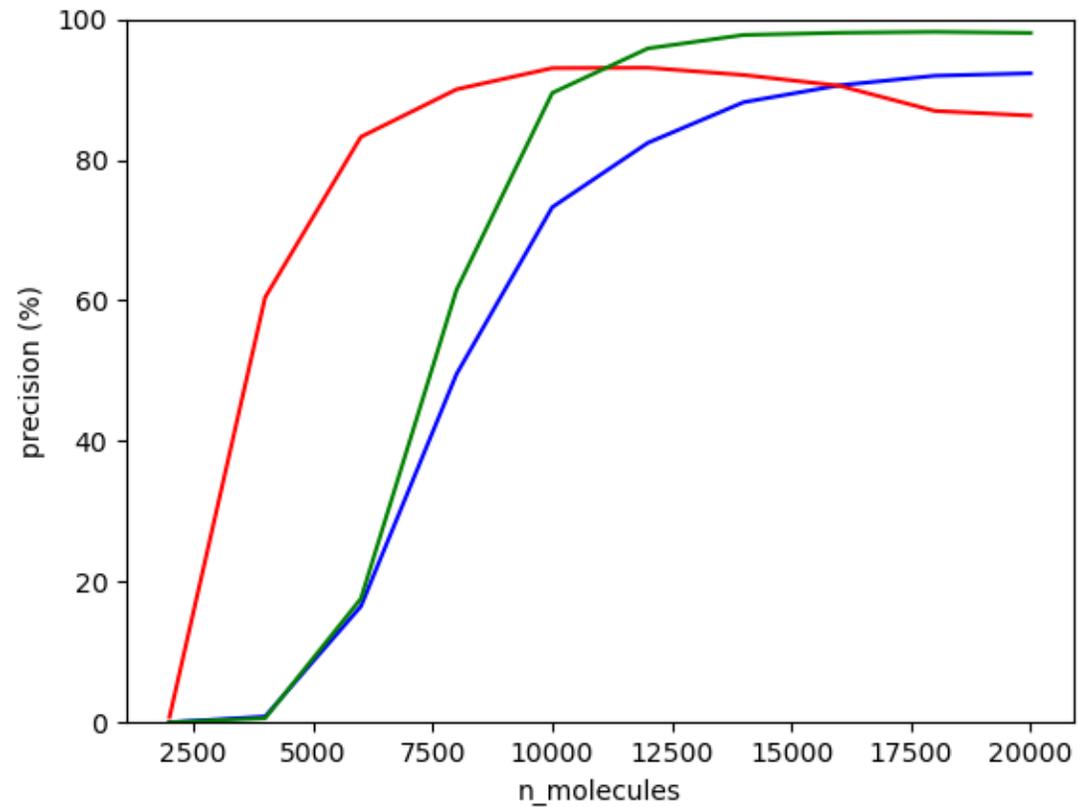
→ 20 000 molecules (Coverage ~ 50)

image size : 213 X 237
50 000 pixels



Image reconstruction

Percentage of oligonucleotides well reconstructed



channel code,
fragment size = 200

no channel code
fragment size = 200

no channel code
fragment size = 100

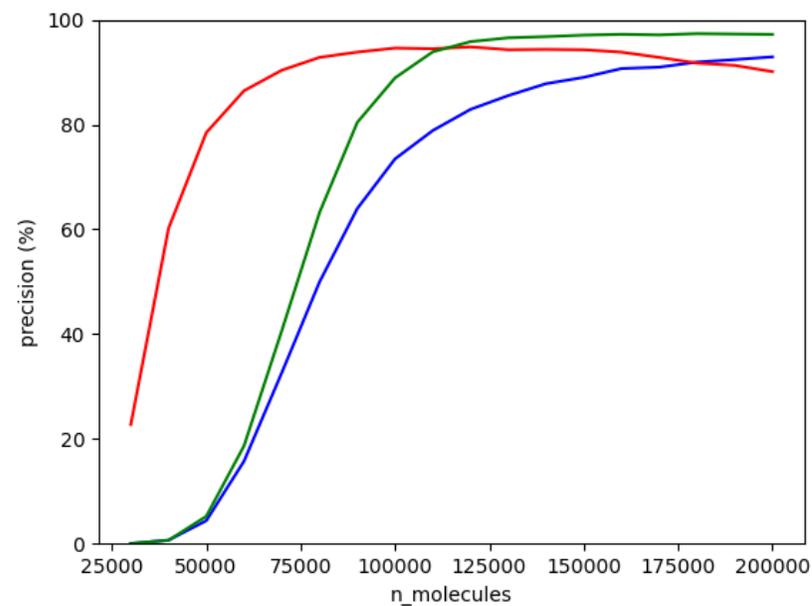
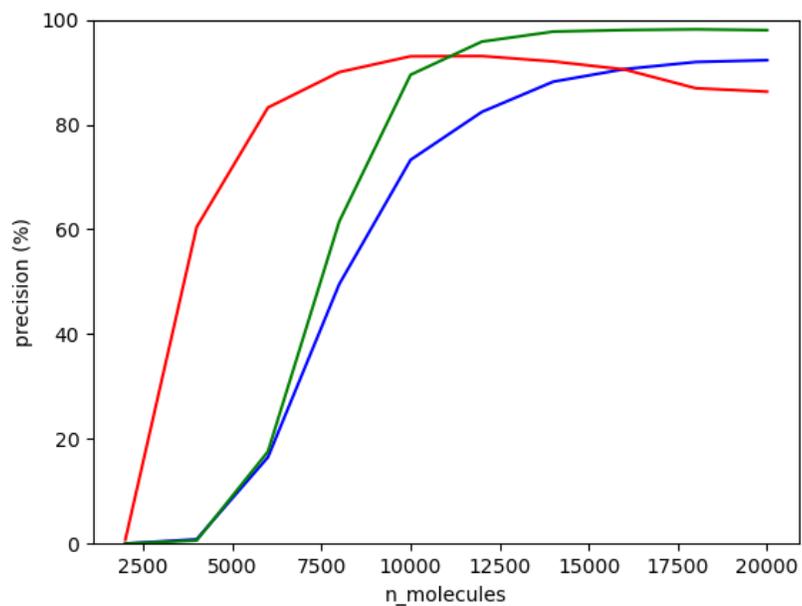
Image reconstruction



213 X 237
50 000 pixels



700 X 700
500 000 pixels



To conclude...

- dnarXiv project
 - Investigate DNA archiving
 - Multidisciplinary project
- dnarXiv platform
 - Allow various DNA storage strategies to be investigated
 - Flexible tool : different modules can easily be plugged
 - Offset the costs of oligo synthesis
 - A way to test the scalability of data processing



Thank you for your attention

