EE-526:
Introduction to Bioengineering

Prof. Sebastian Maerkl

Purpose of the course:

- Introduce engineers to basic concepts in biology, biological engineering, biotechnology, and synthetic biology

- No prior knowledge in biology is required…

People

- Prof. Sebastian Maerkl
  - Institute of Bioengineering, School of Engineering
  - Laboratory of Biological Network Characterization (LBNC)
  - Background: Biology / Chemistry

- TAs:
  - Amogh Baranwal

Contact

- Prof. Sebastian Maerkl
  - sebastian.maerkl@epfl.ch

- Office hours:
  - By appointment (Zoom)

Grading

- Final Exam
  - Multiple choice questions
  - A few math problems

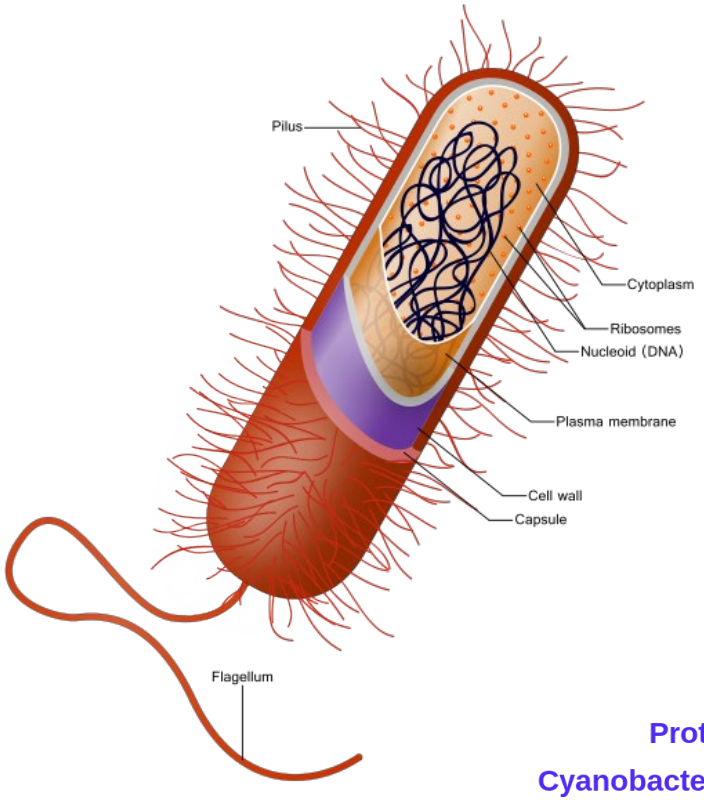
- Regular practice ”tests” during the semester (not graded, self-corrected)

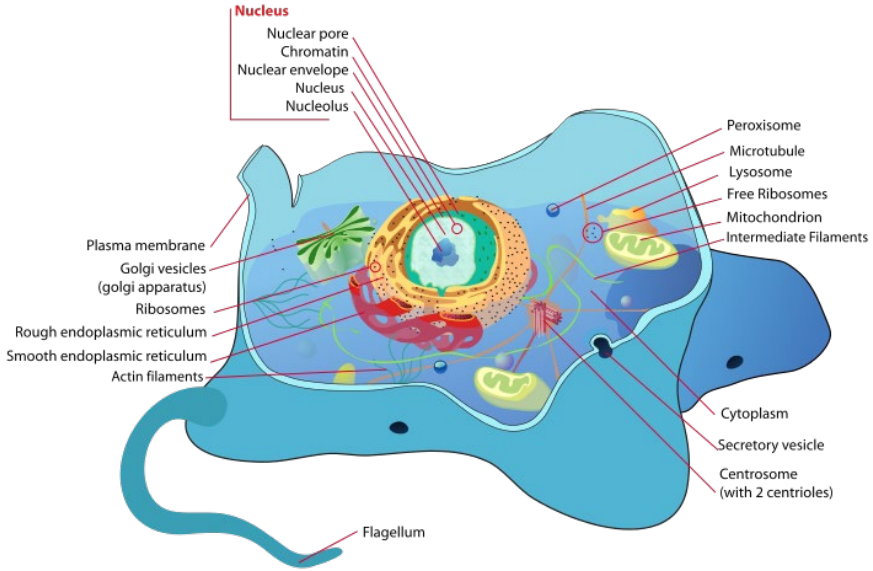
Syllabus (subject to change)

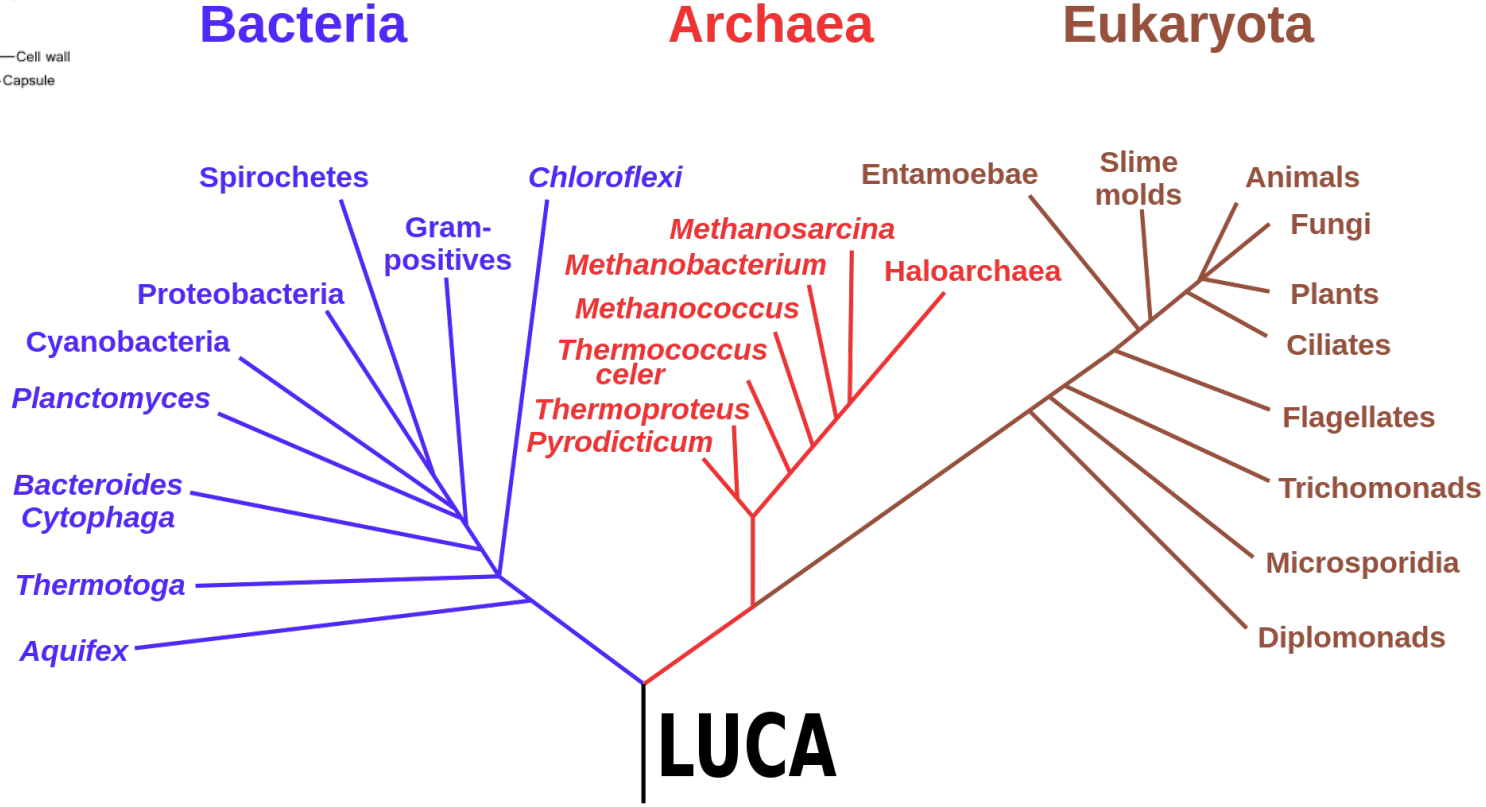
Week	Topic
1	General Introduction
2	Cell Biology
3	DNA and RNA
4	Proteins
5	Biochemistry
6	Thermodynamics 1
7	Thermodynamics 2
8	Techniques and Methods 1
9	Techniques and Methods 2
10	Microfluidics
11	Synthetic Biology
12	Cellular Biotech
13	TBD

A brief introduction to biology

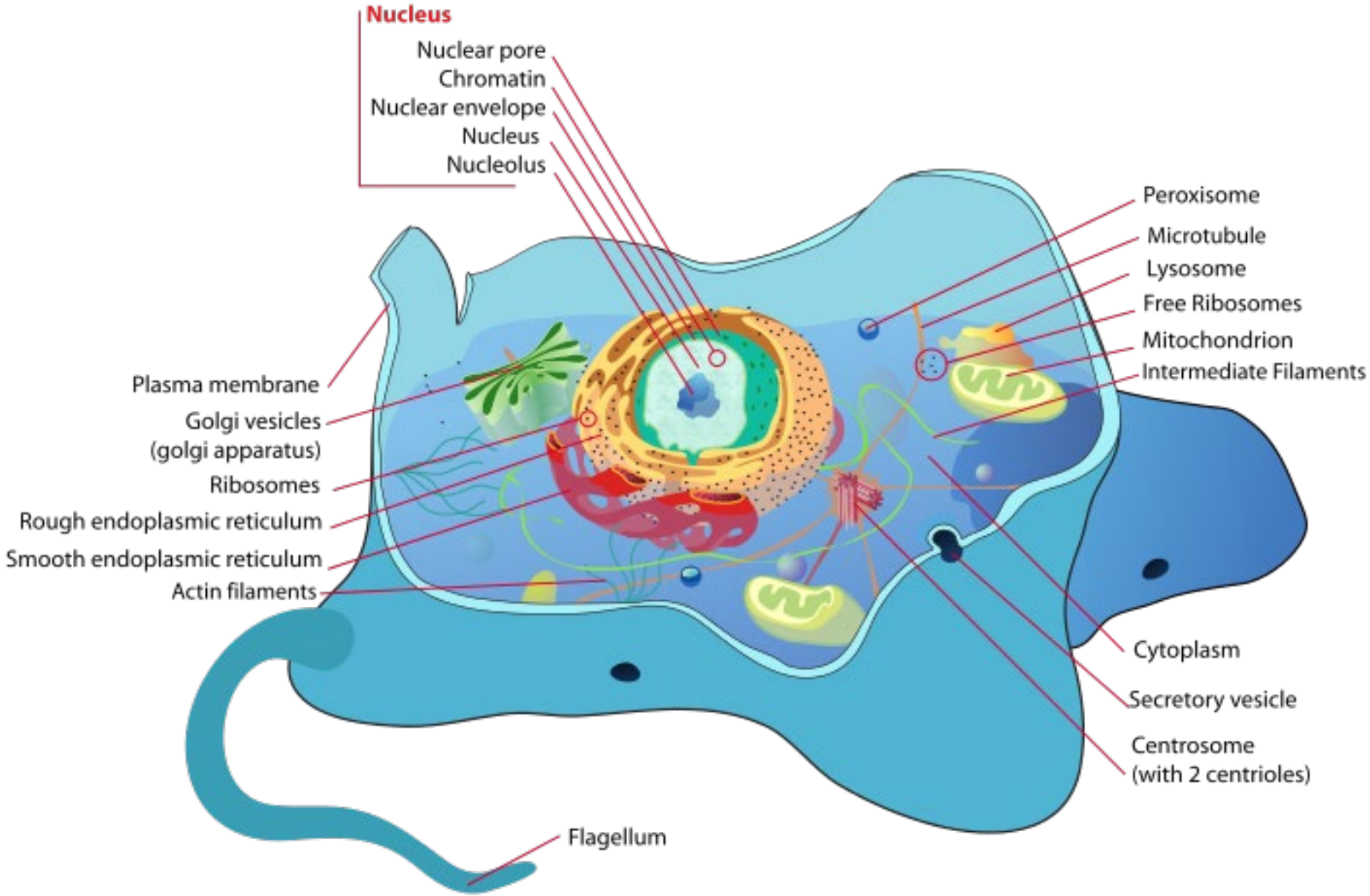
The tree of life



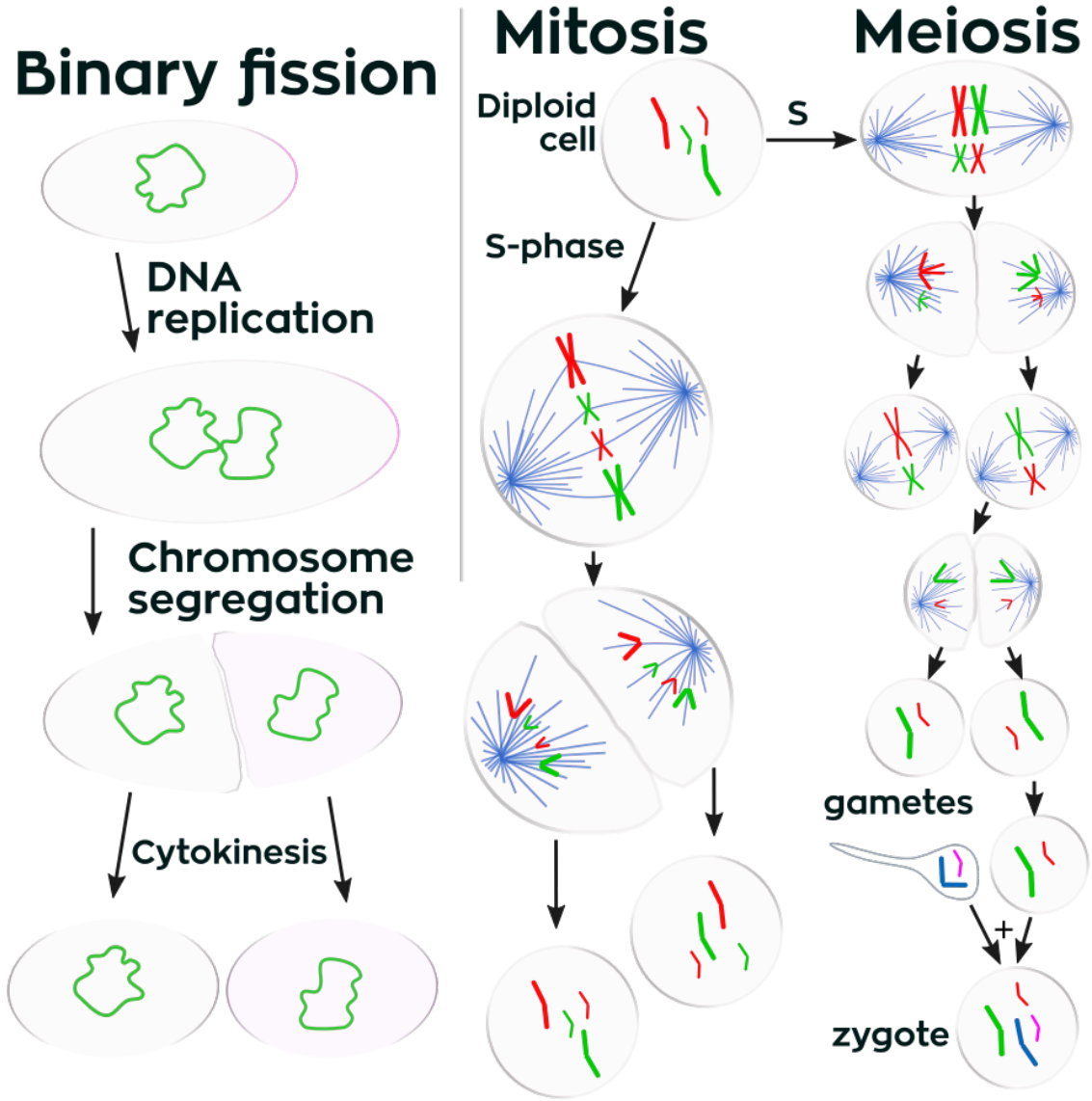




Cell Biology

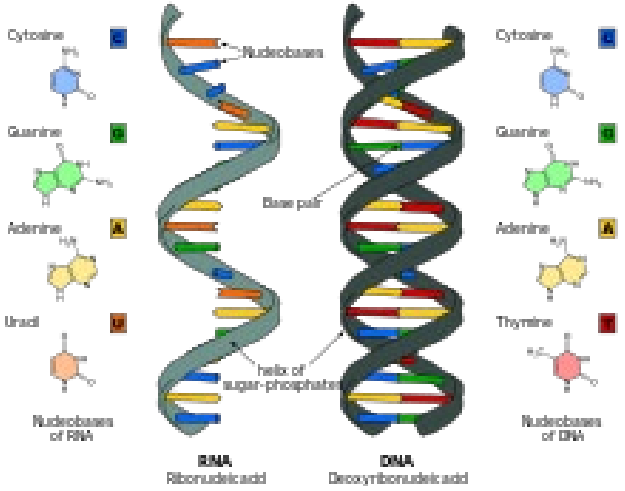


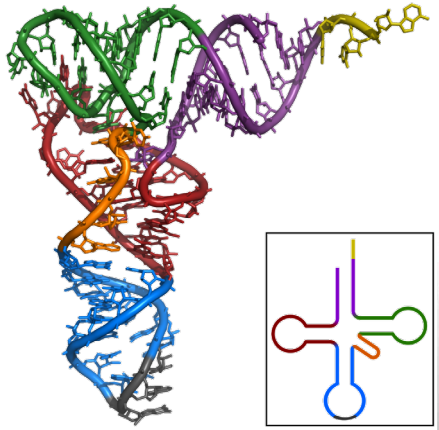
Cell Division

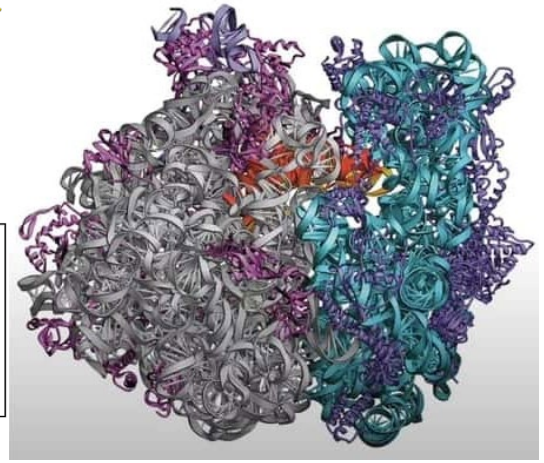


Macromolecular Building Blocks

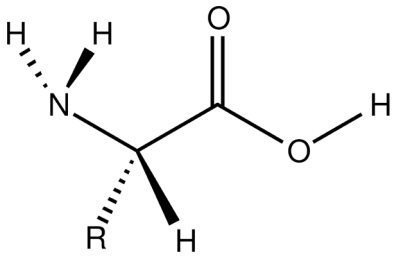
Nucleic Acids



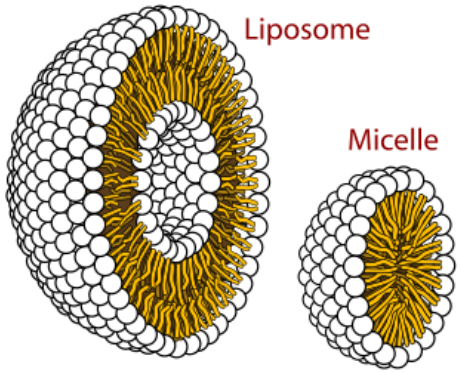


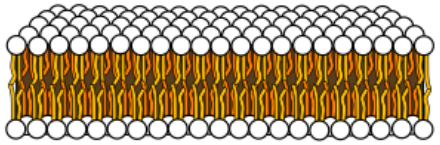


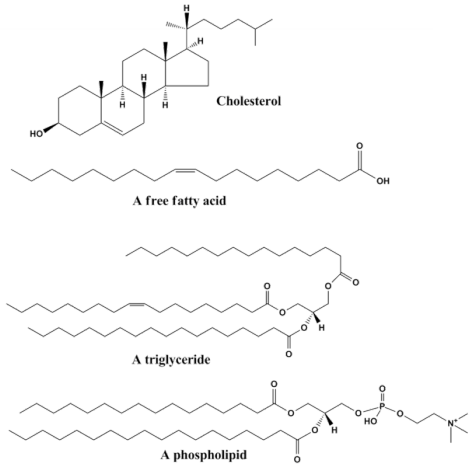
Proteins



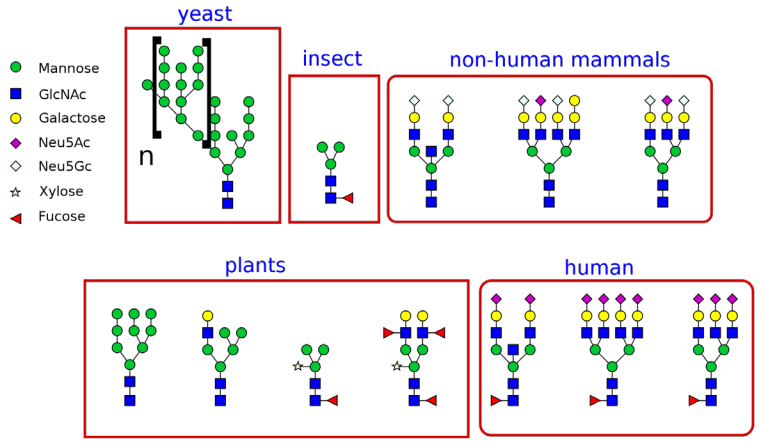
Lipids

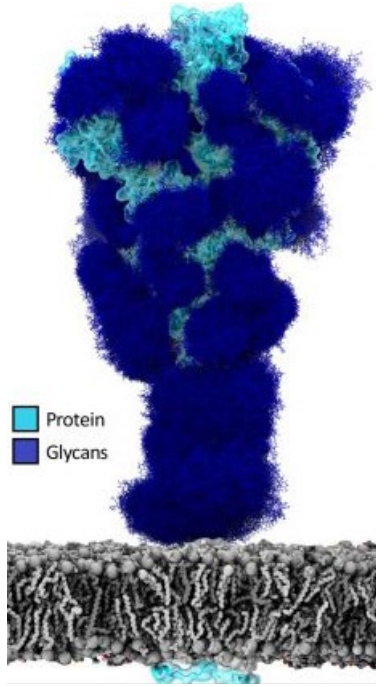




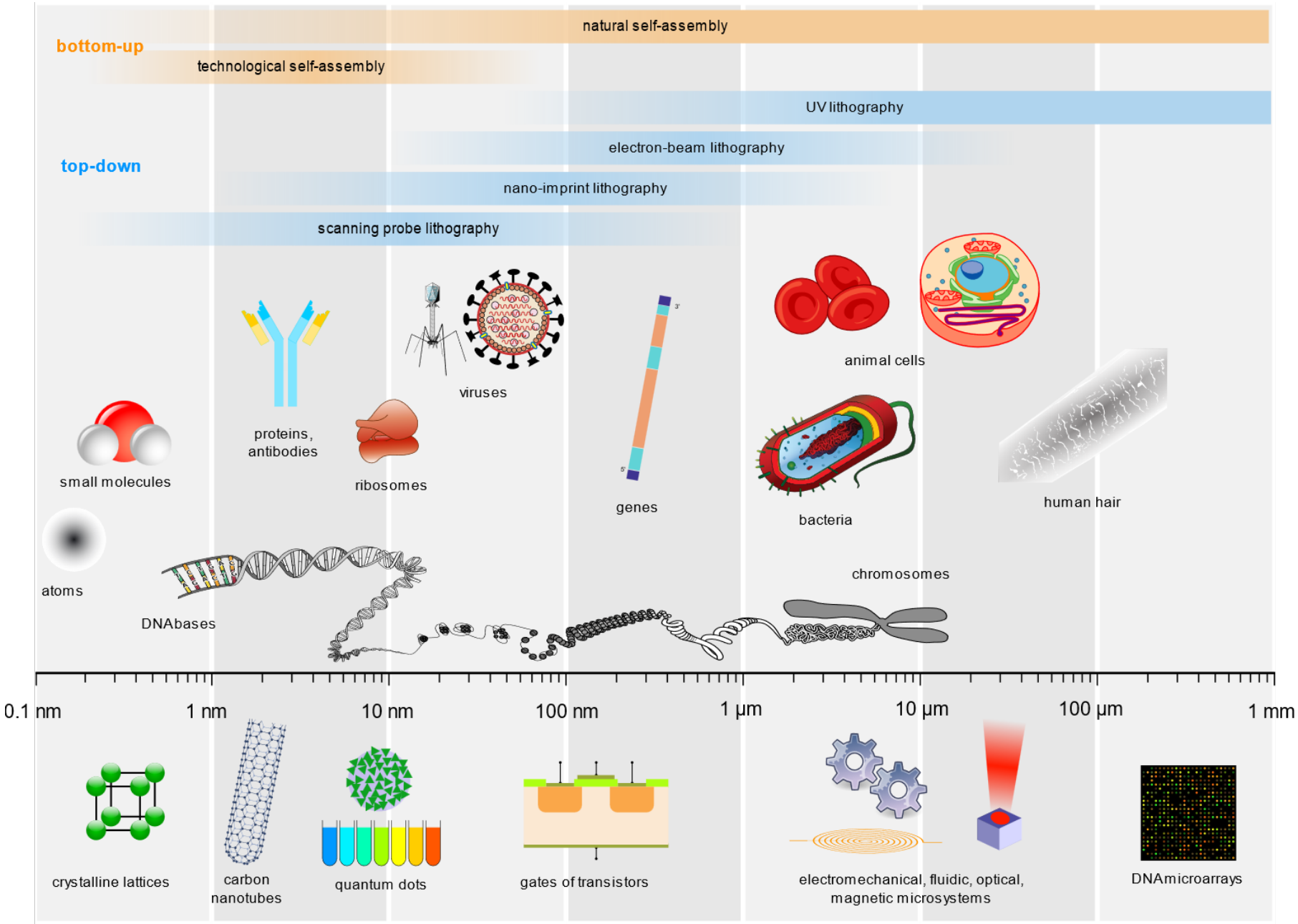


Glycans

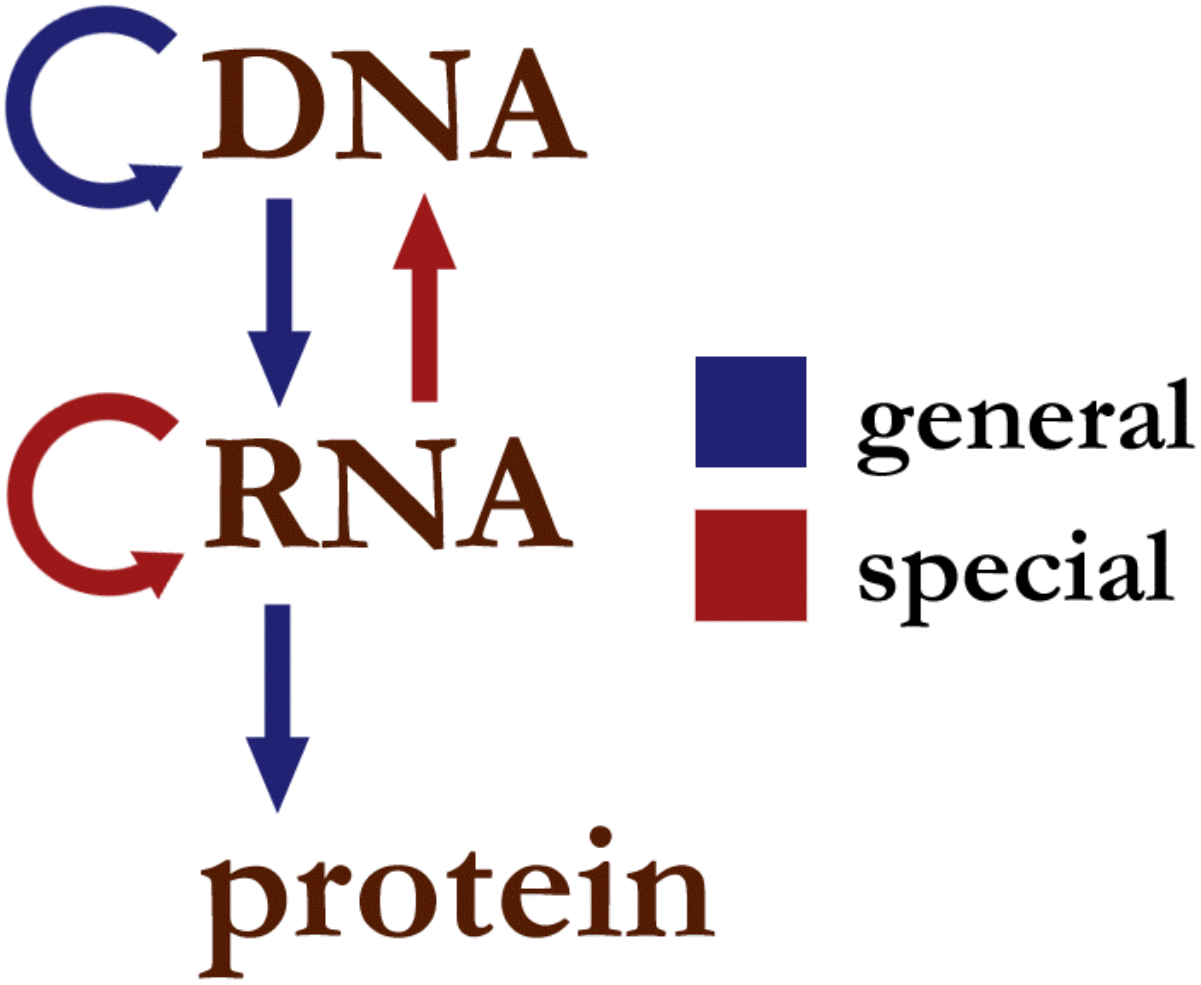


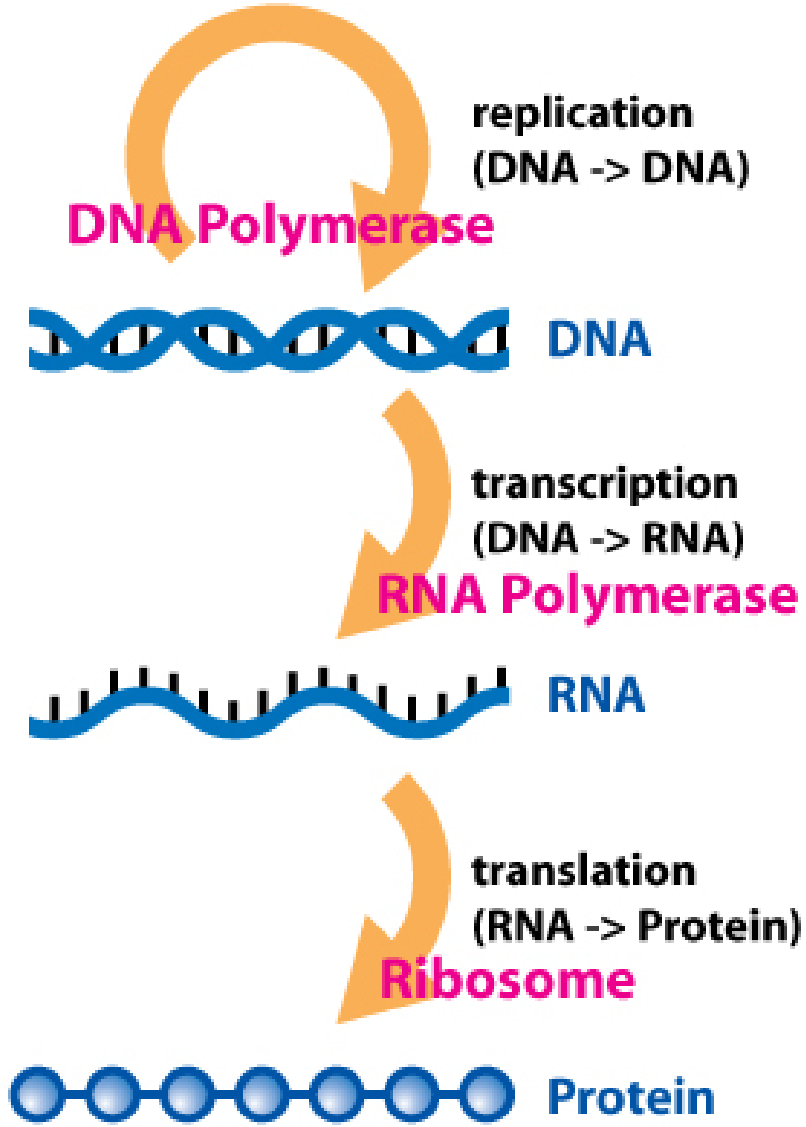


Biological Length Scales

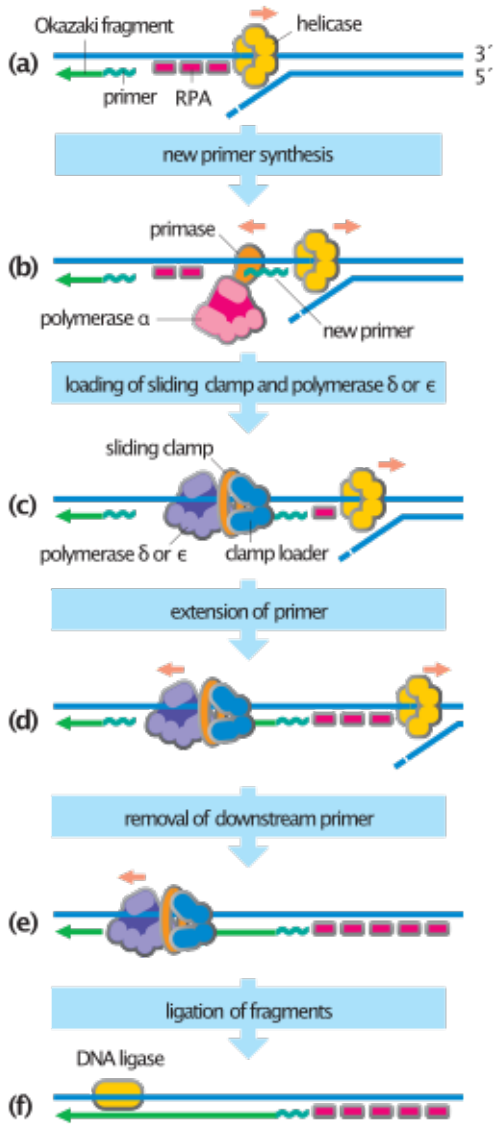


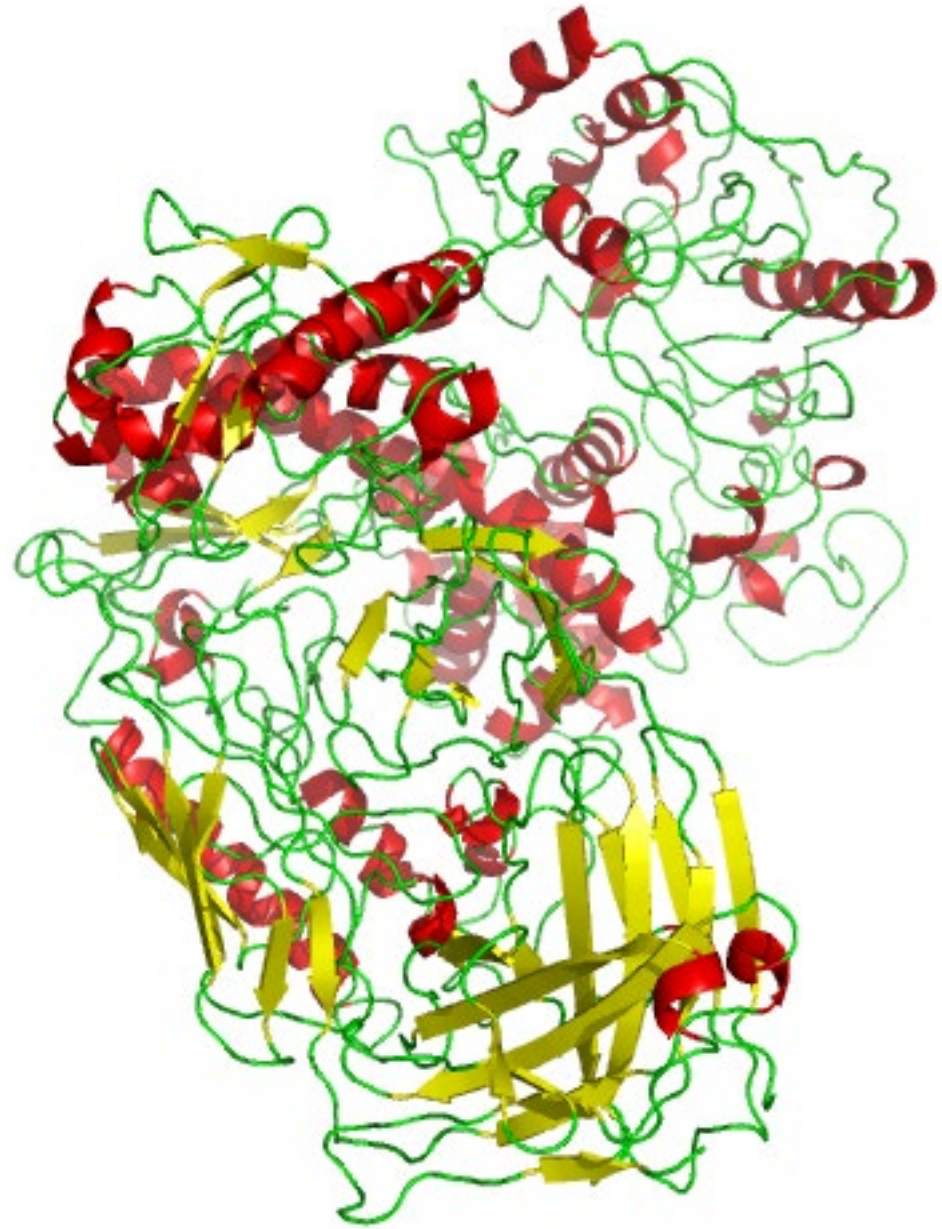
Central Dogma



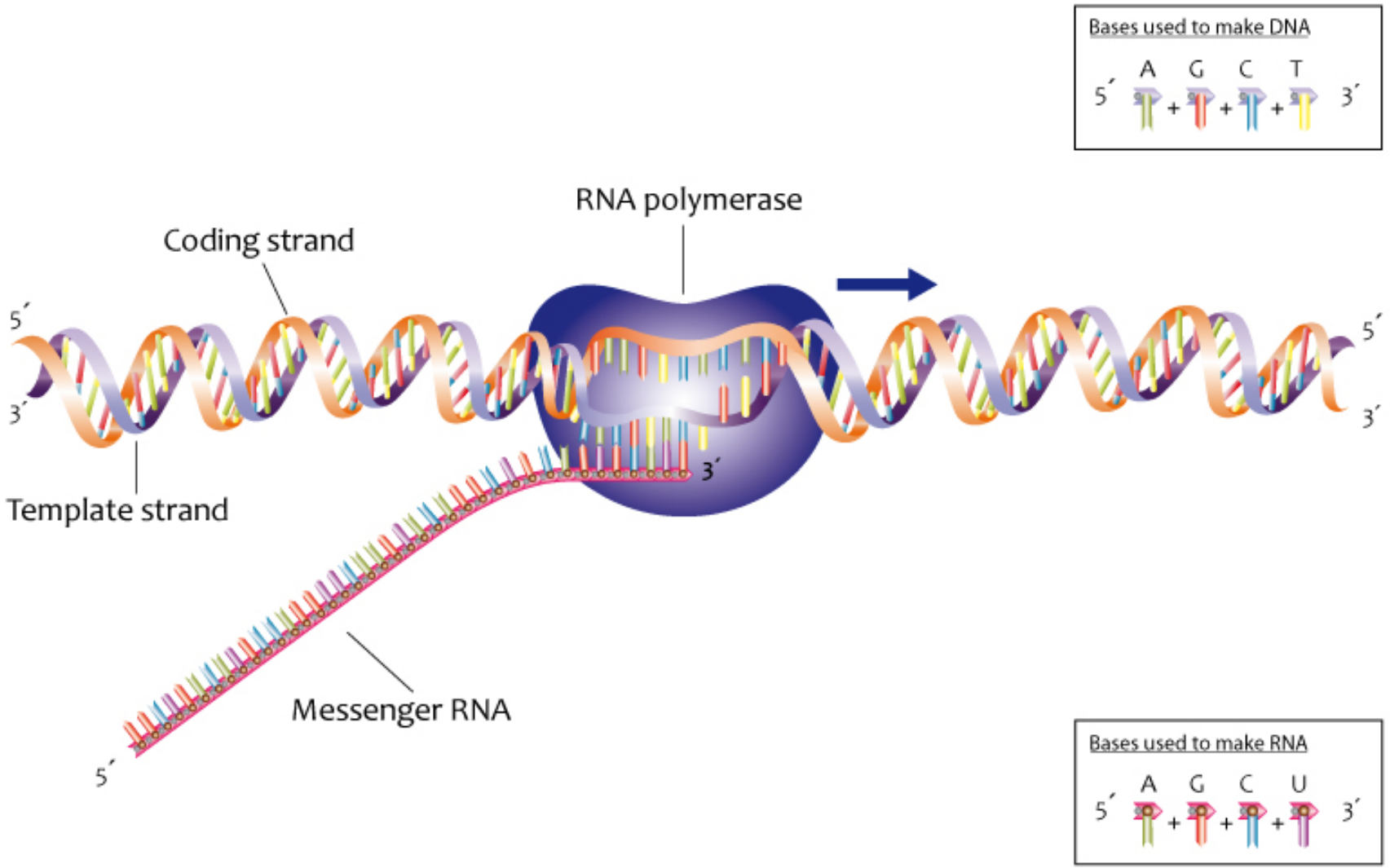


DNA Replication

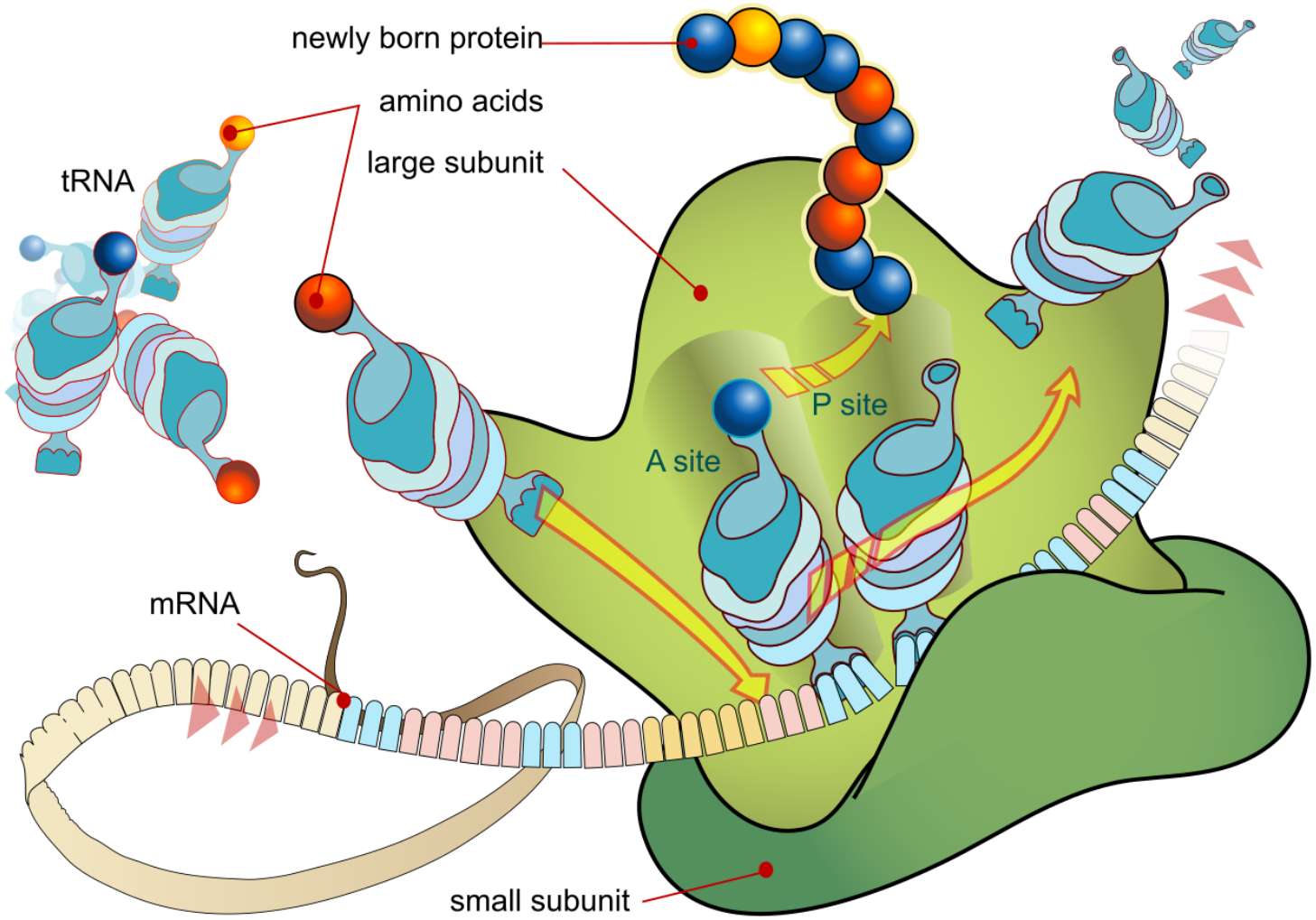


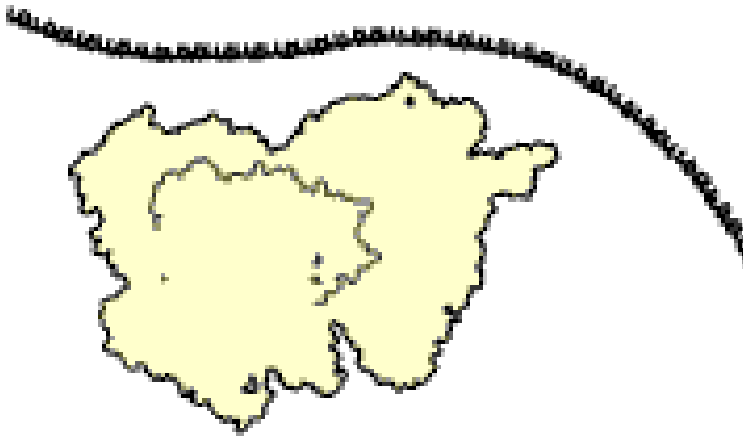


Transcription (make mRNA from DNA)

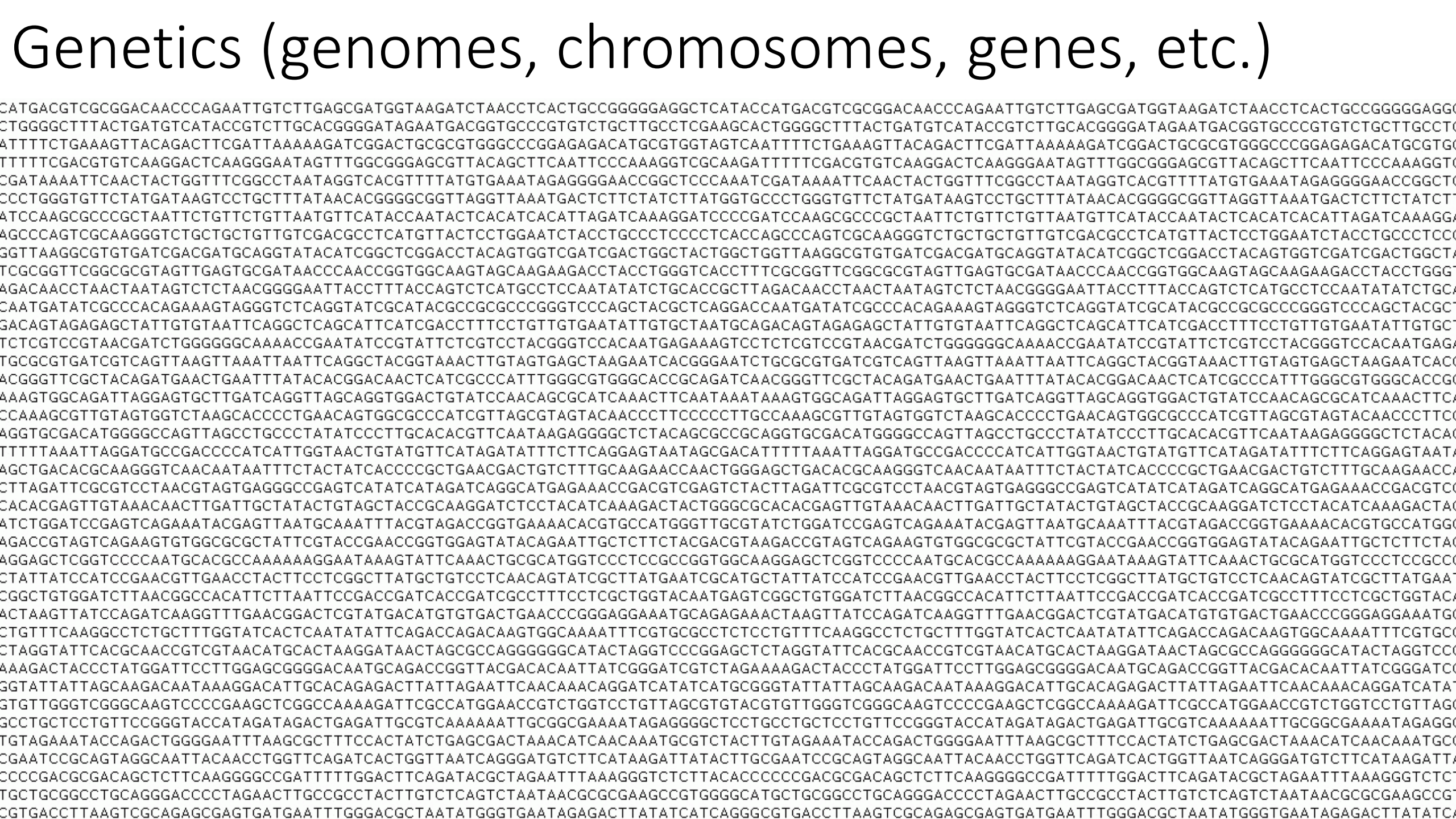


Translation (make protein from mRNA)

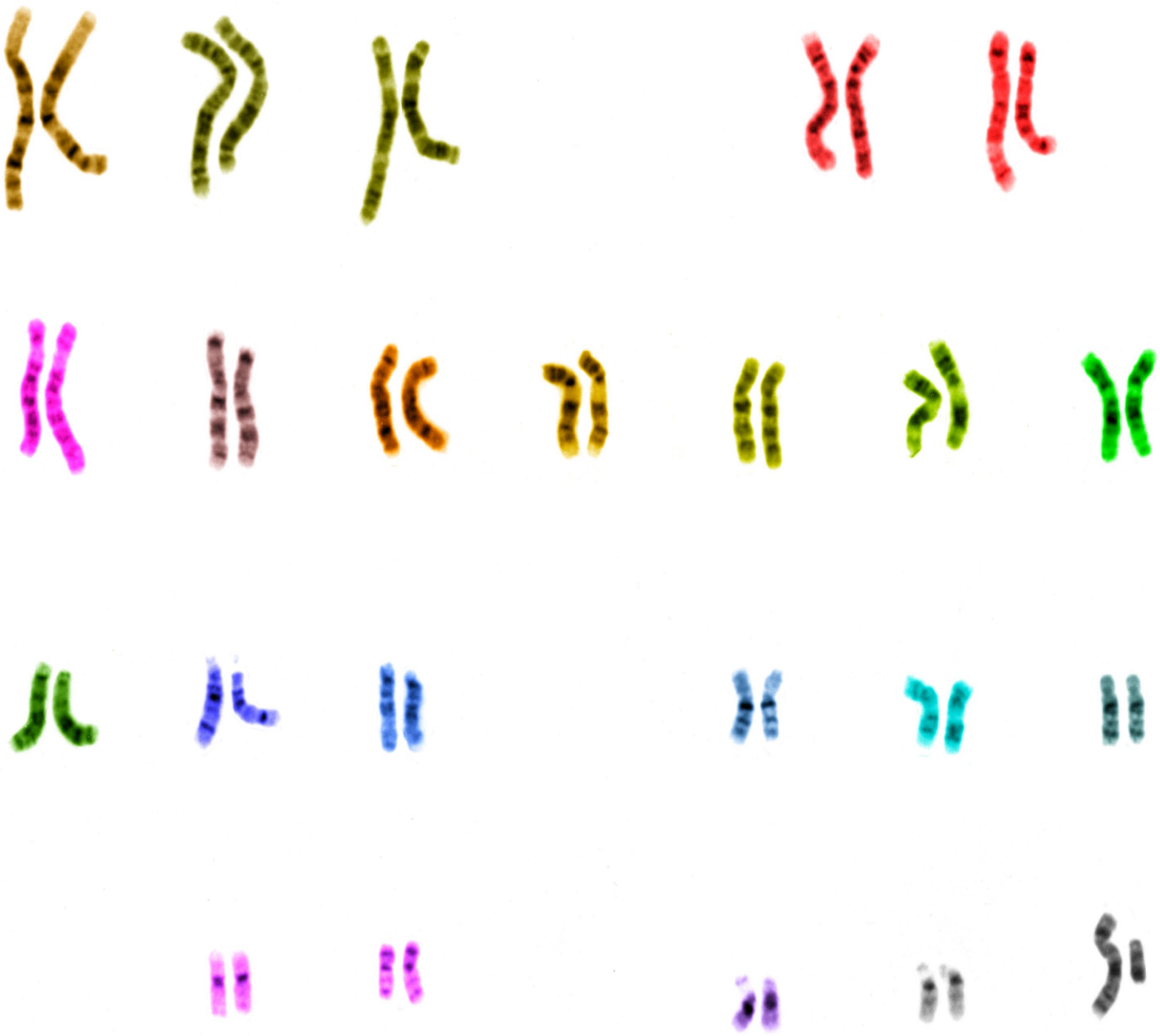


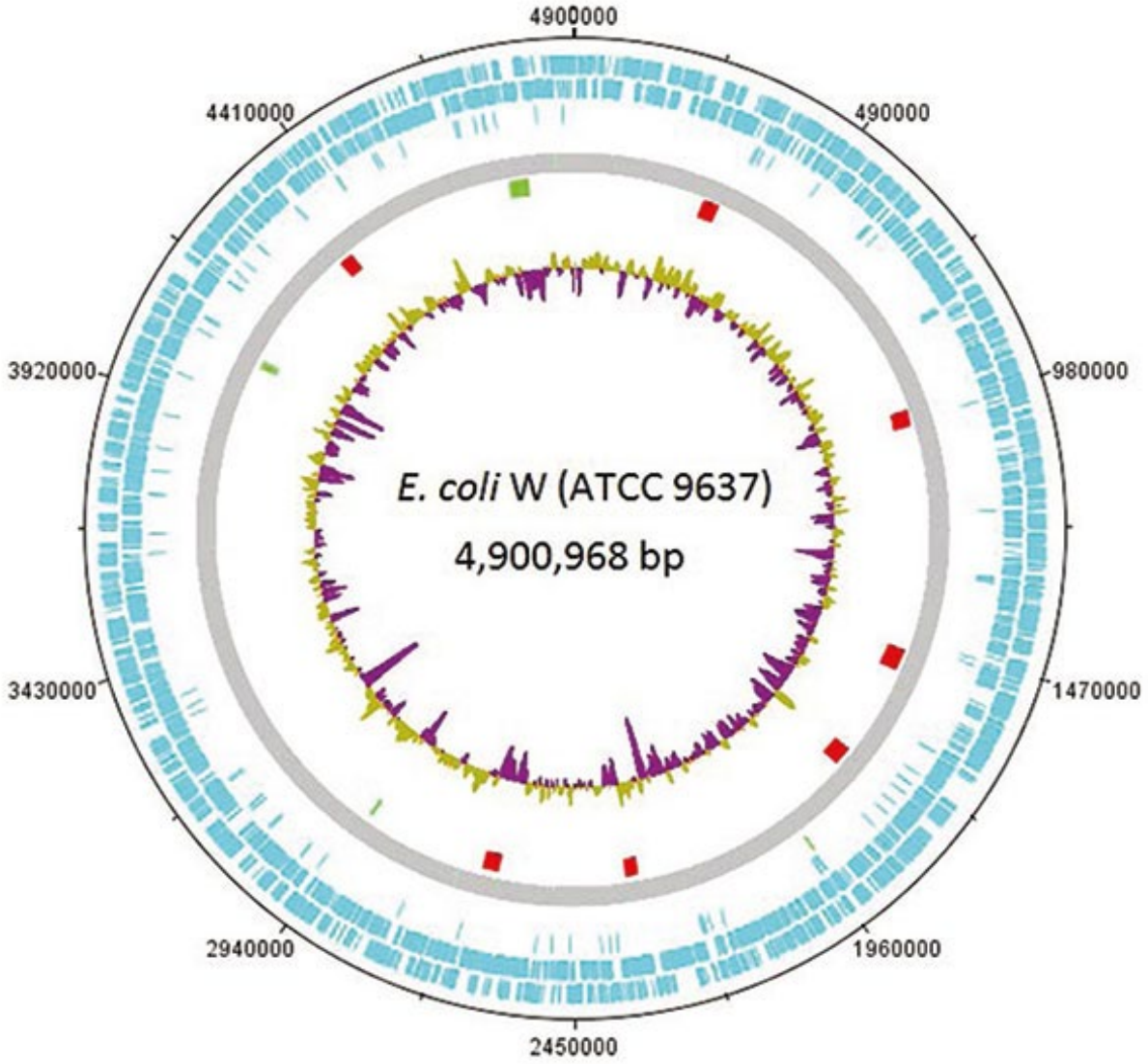


Genetics (genomes, chromosomes, genes, etc.)

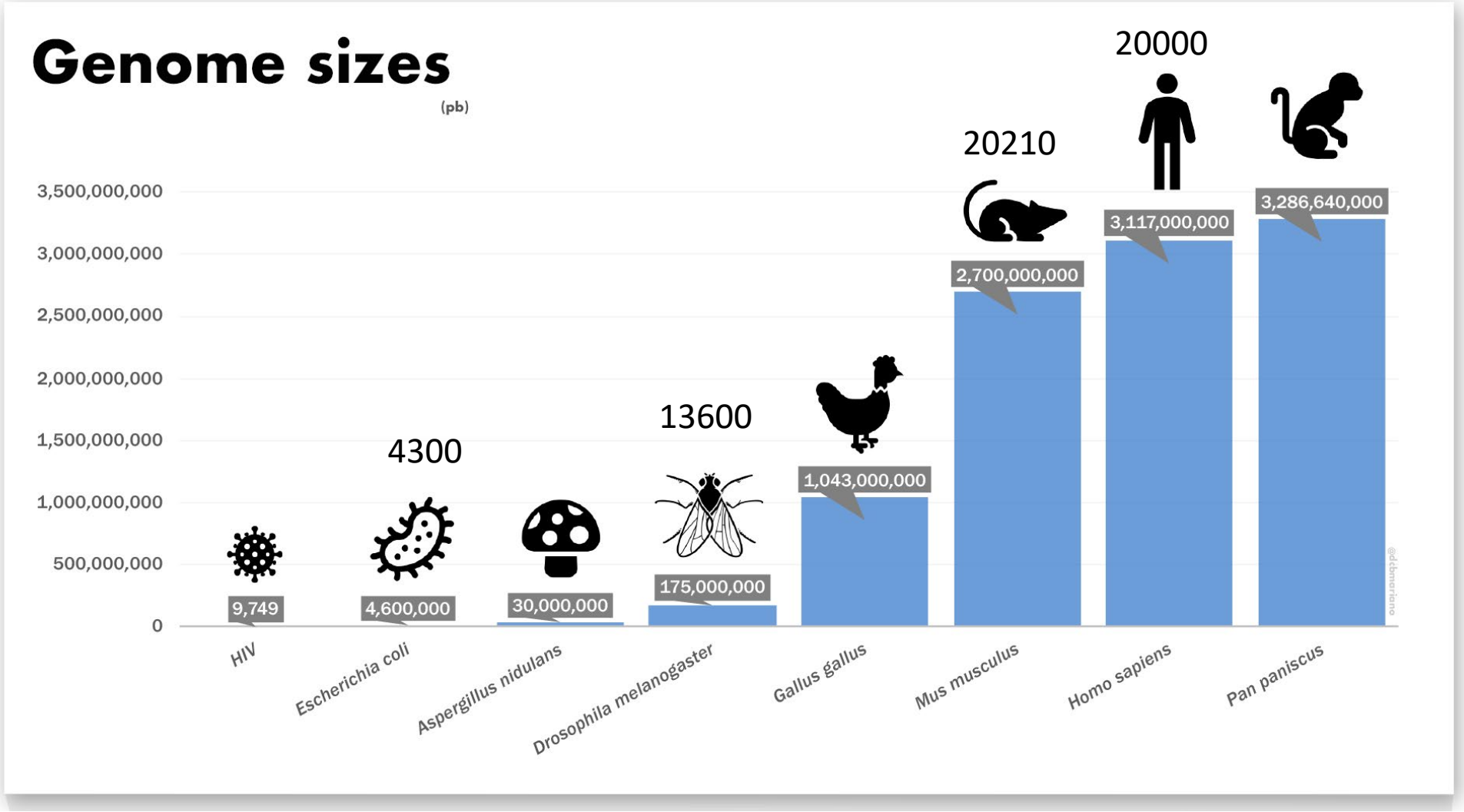


Genomes and Chromosomes

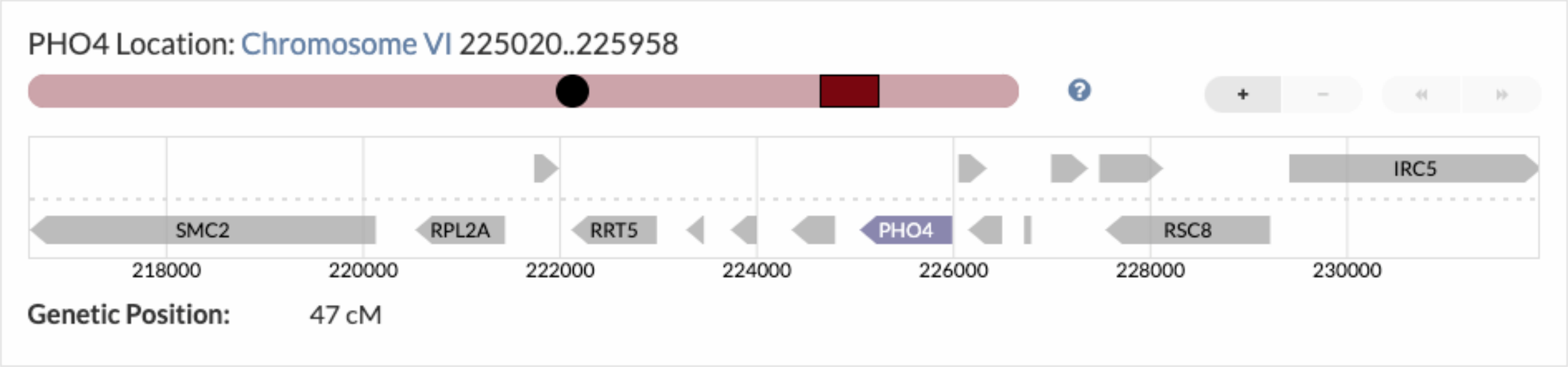




Genome sizes



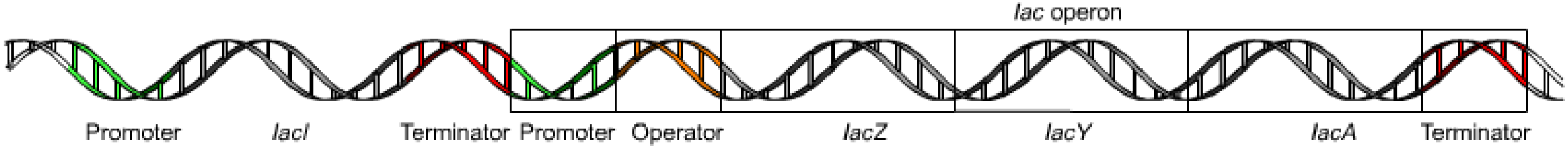
Genes, Promoters, Terminators, Gene regulation

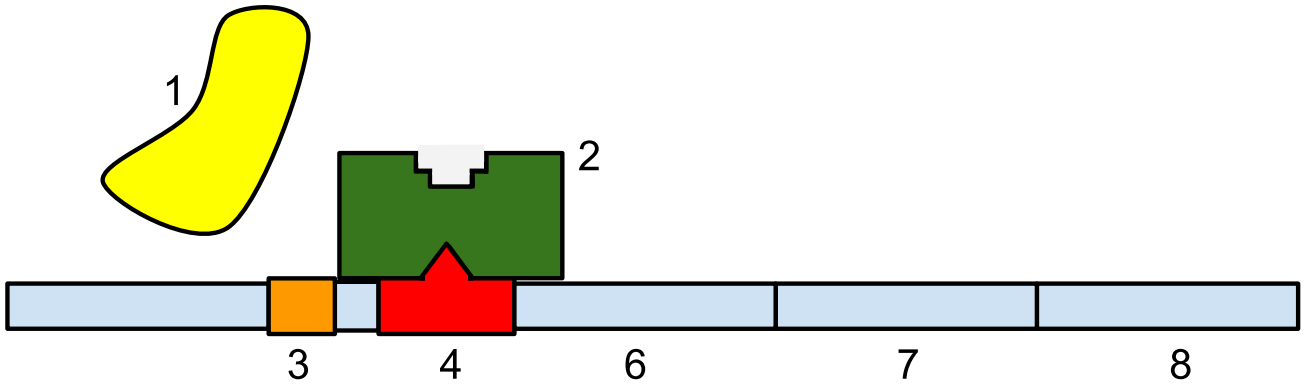


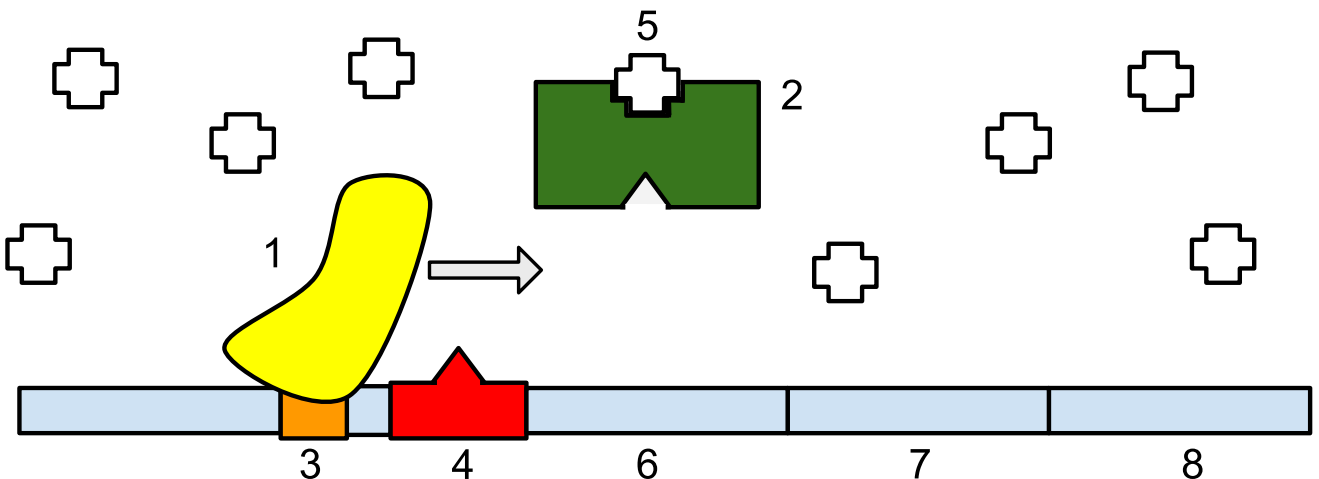
"A gene is a DNA sequence that codes for a diffusible product. This product may be protein (as is the case in the majority of genes) or may be RNA (as is the case of genes that code for tRNA and rRNA). The crucial feature is that the product diffuses away from its site of synthesis to act elsewhere."

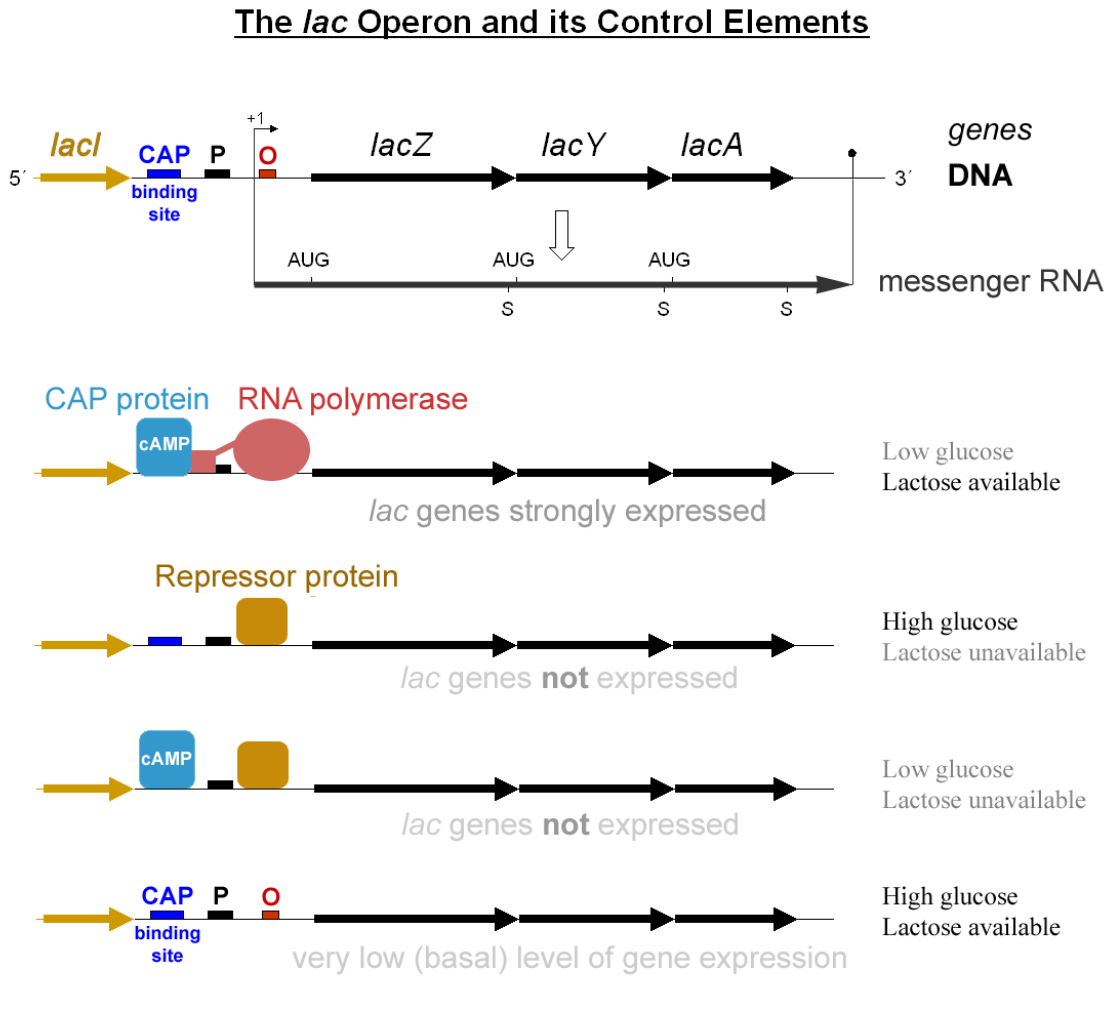
Lewin B (2004). *Genes VIII*. Upper Saddle River, NJ, USA: Pearson/Prentice Hall.

Genes, Promoters, Terminators, Gene regulation

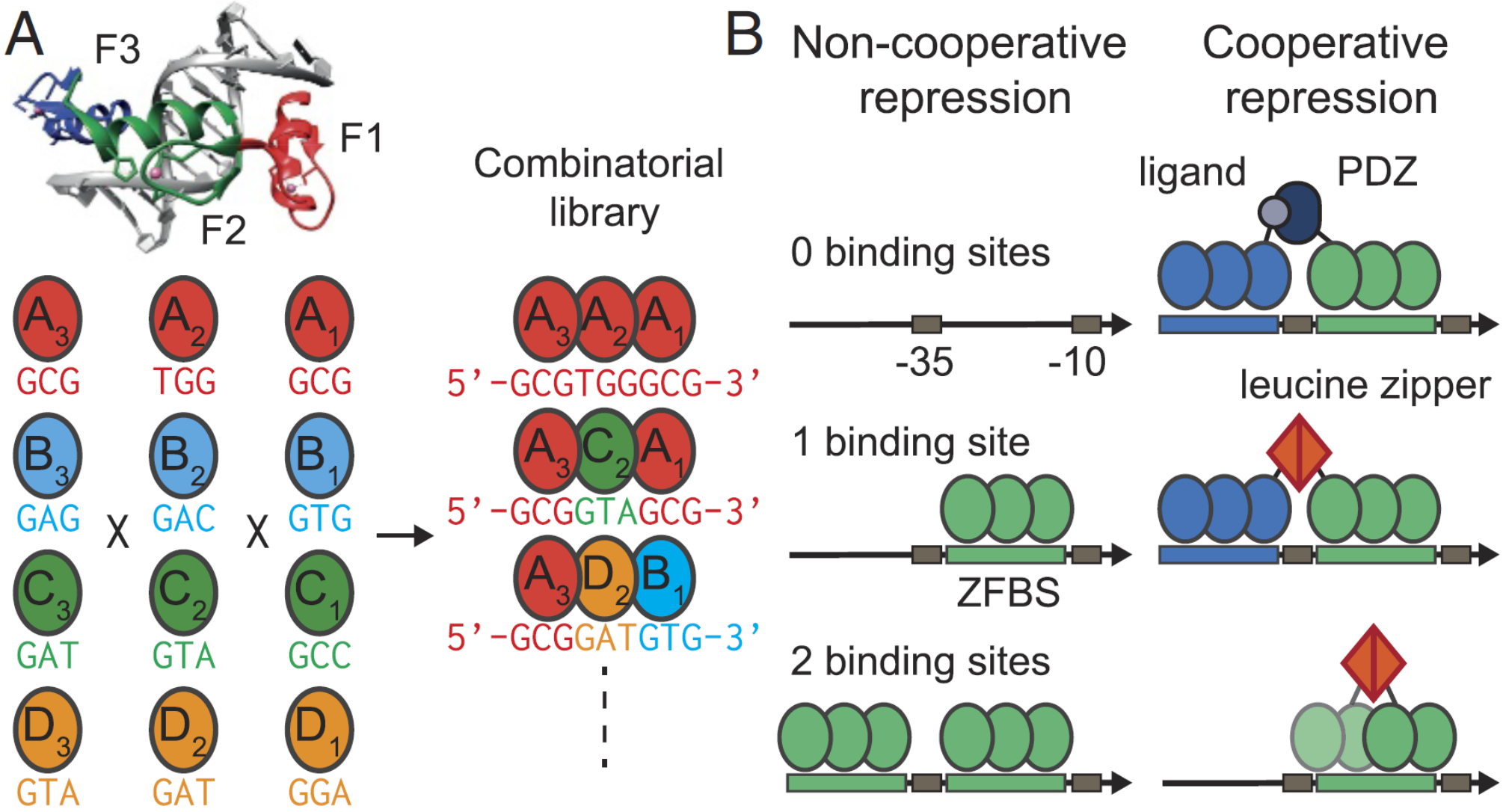








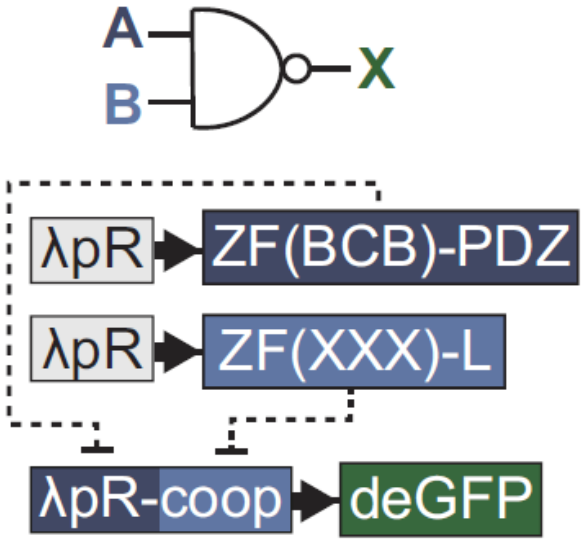
Genes, Promoters, Terminators, Gene regulation



Genes, Promoters, Terminators, Gene regulation

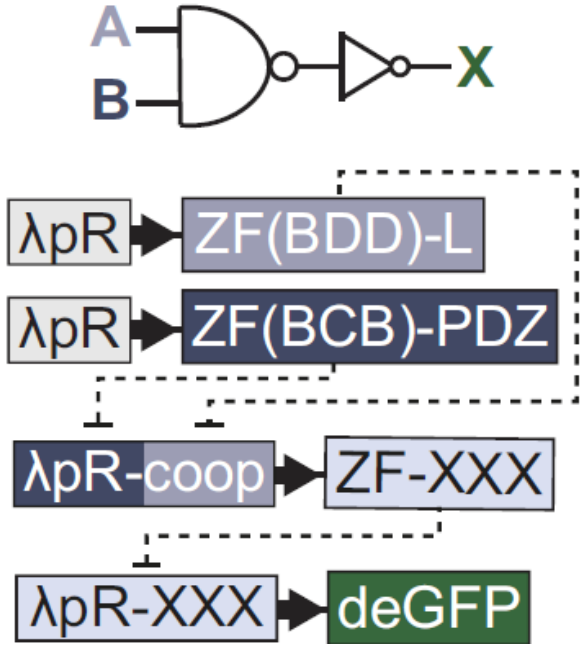
A **NAND**

Inputs		Output
ZF-BCB	ZF-XXX	deGFP
0	0	1
0	1	1
1	0	1
1	1	0

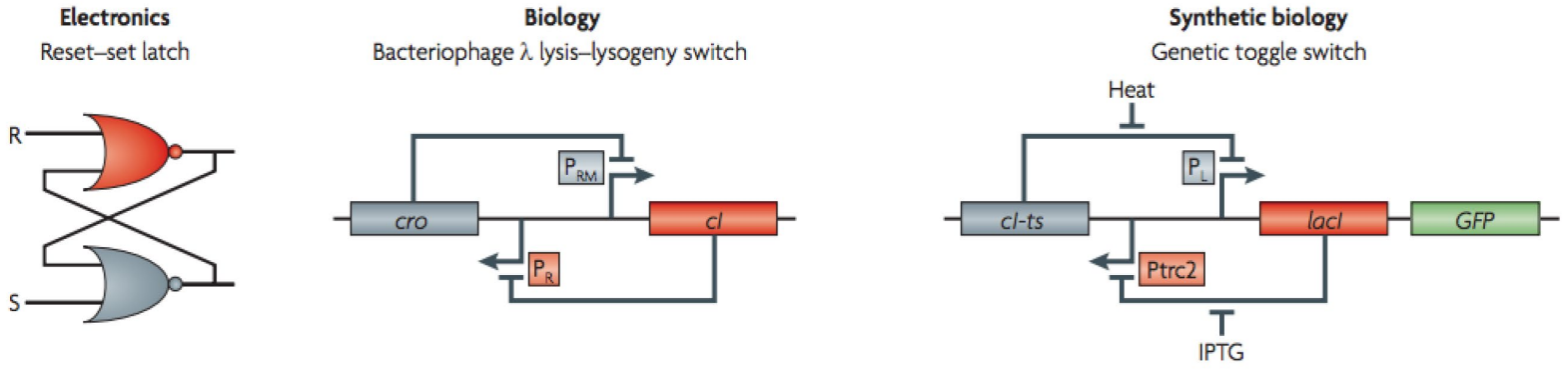


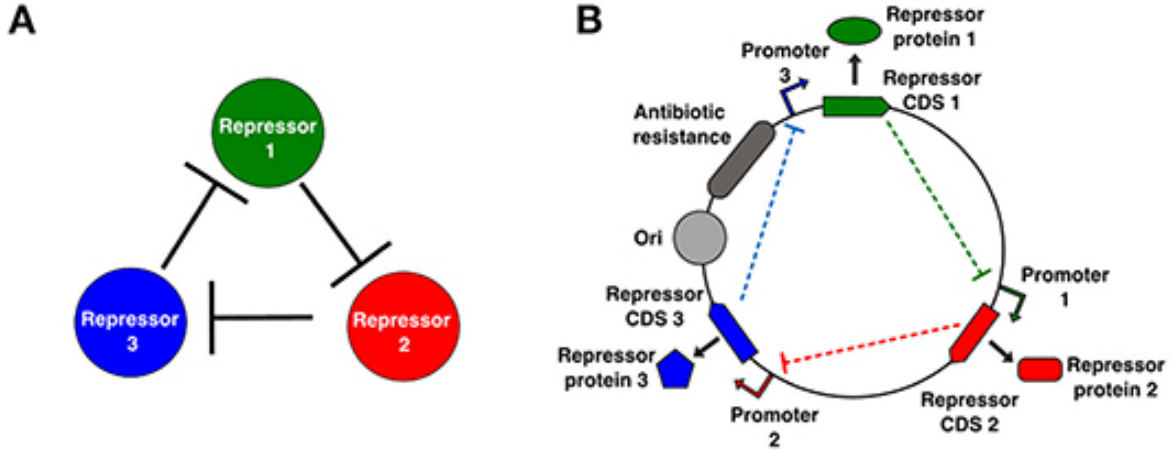
D **AND**

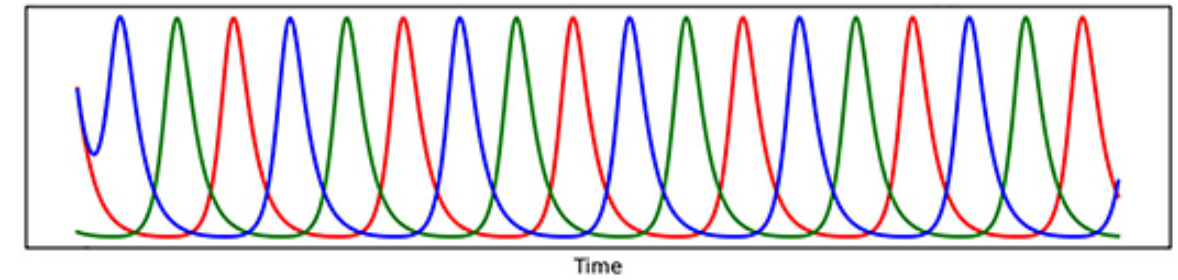
Inputs		Output
ZF-L	ZF-PDZ	deGFP
0	0	0
0	1	0
1	0	0
1	1	1

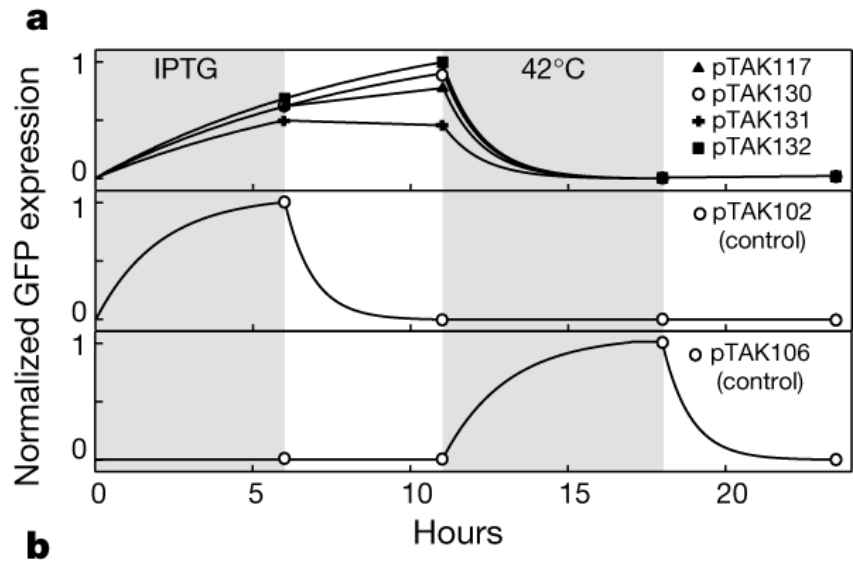


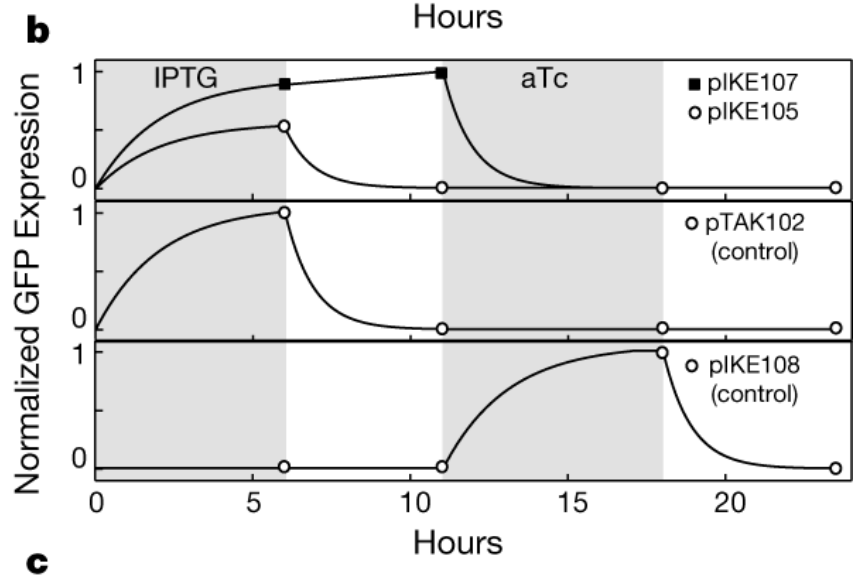
Synthetic Biology

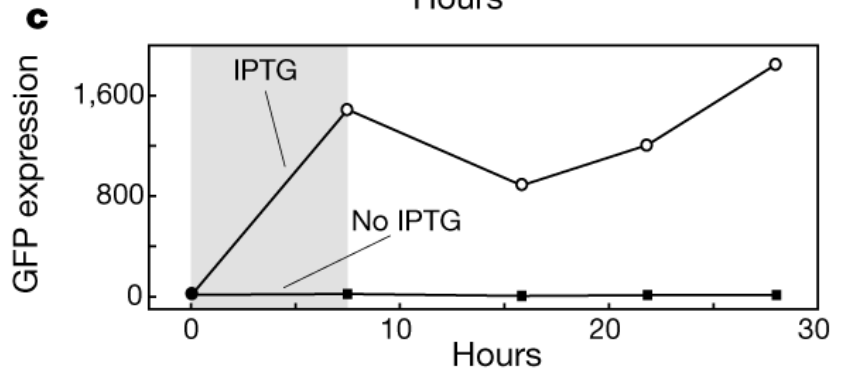




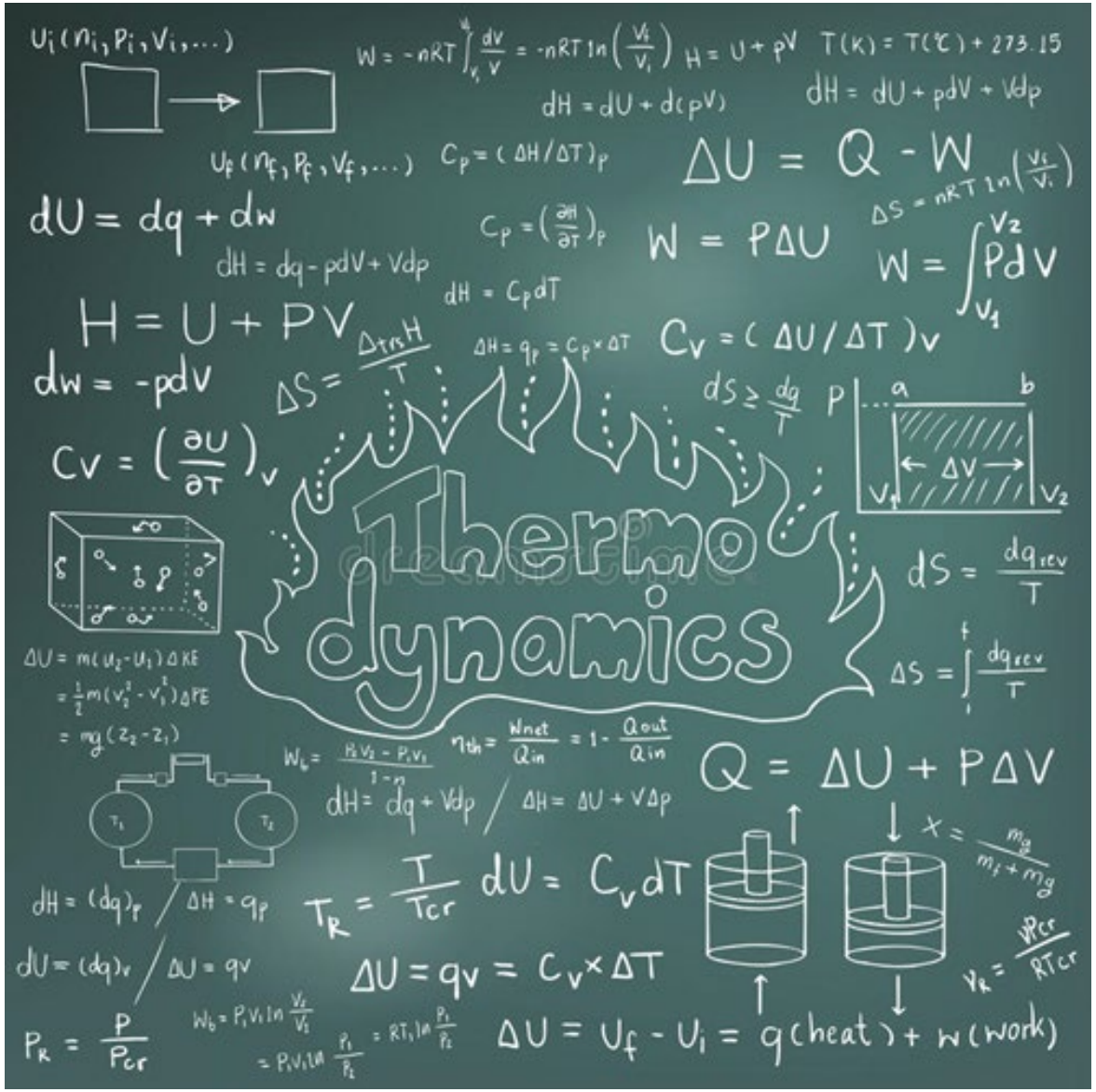


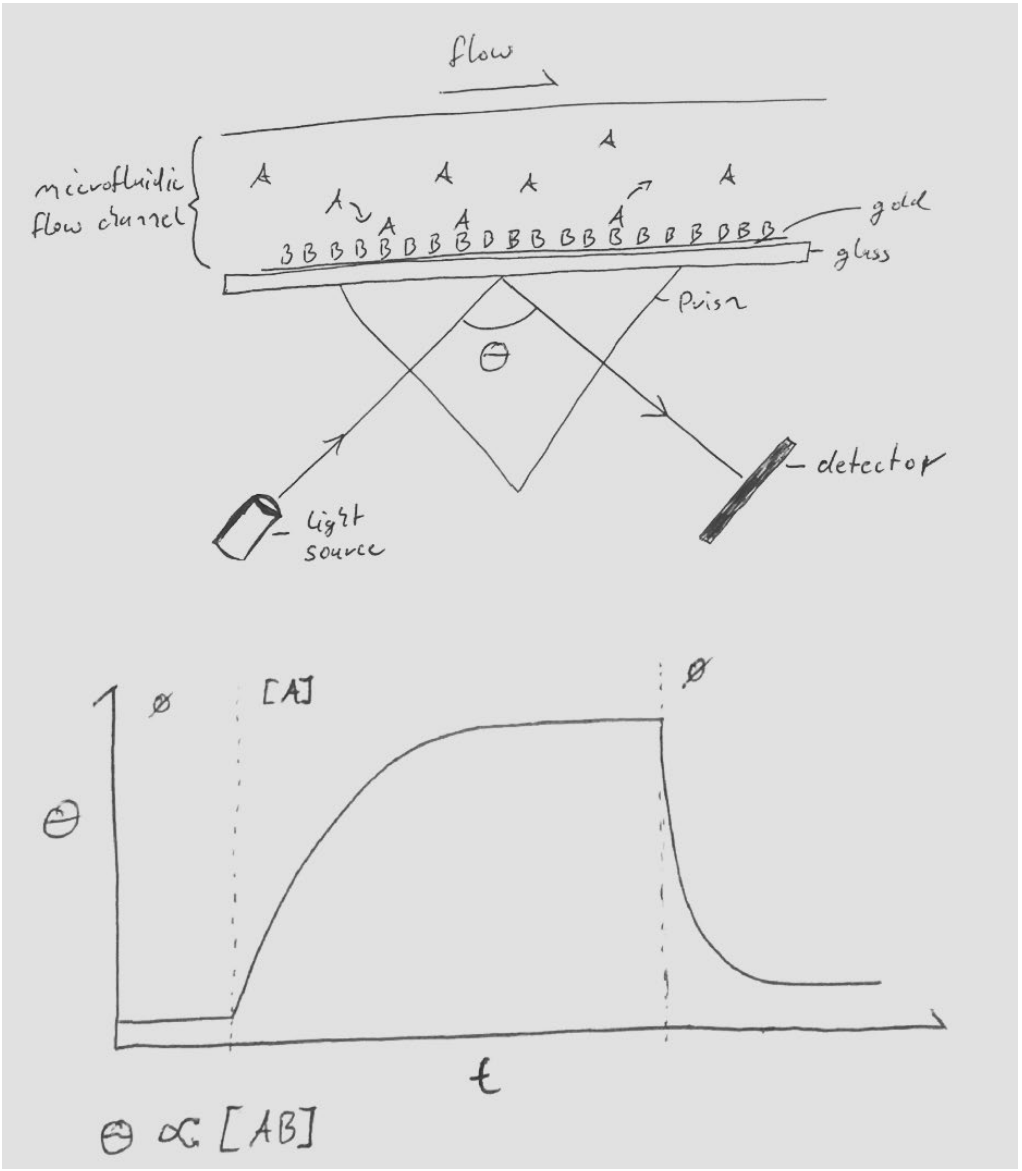






Molecular Interactions / Thermodynamics





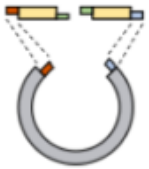
Techniques and Methods

- Cell culturing
- Growth rate measurements
- Methods for cellular characterization
- PCR
- Cloning
- Sequencing
- Protein Expression Purification

How do biological engineers make things?

Programable nucleic acid interactions

Professional DNA part libraries



Golden Gate cloning toolkits

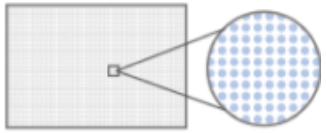
Cheap synthetic genes

Computer aided design

addgene

Accelerated plasmid sharing

CRISPR, CRISPRi and base editing



Pooled oligo synthesis

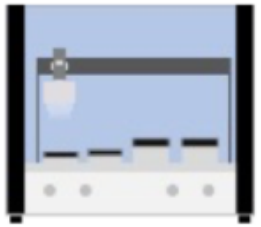
bioRχiv

Manuscript preprinting

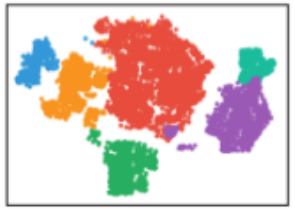
iGEM

Widened education

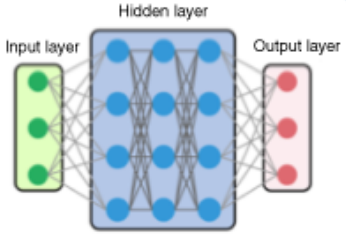
NGS-based measurement



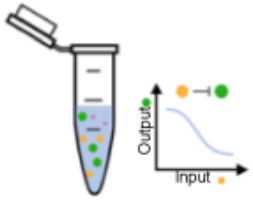
Acoustic liquid handling



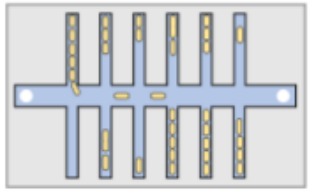
Dimension reduction



Machine learning

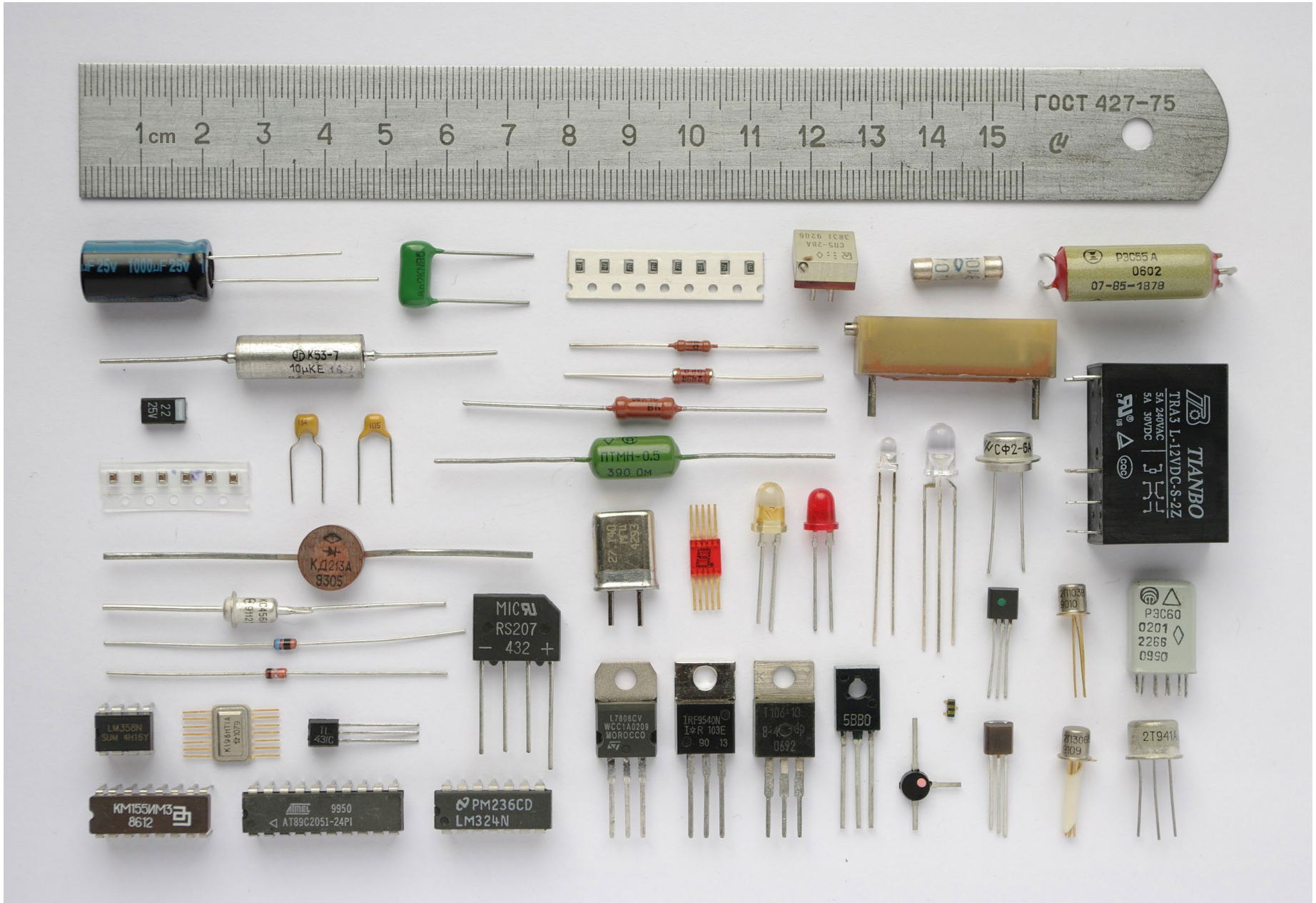


Cell-free systems

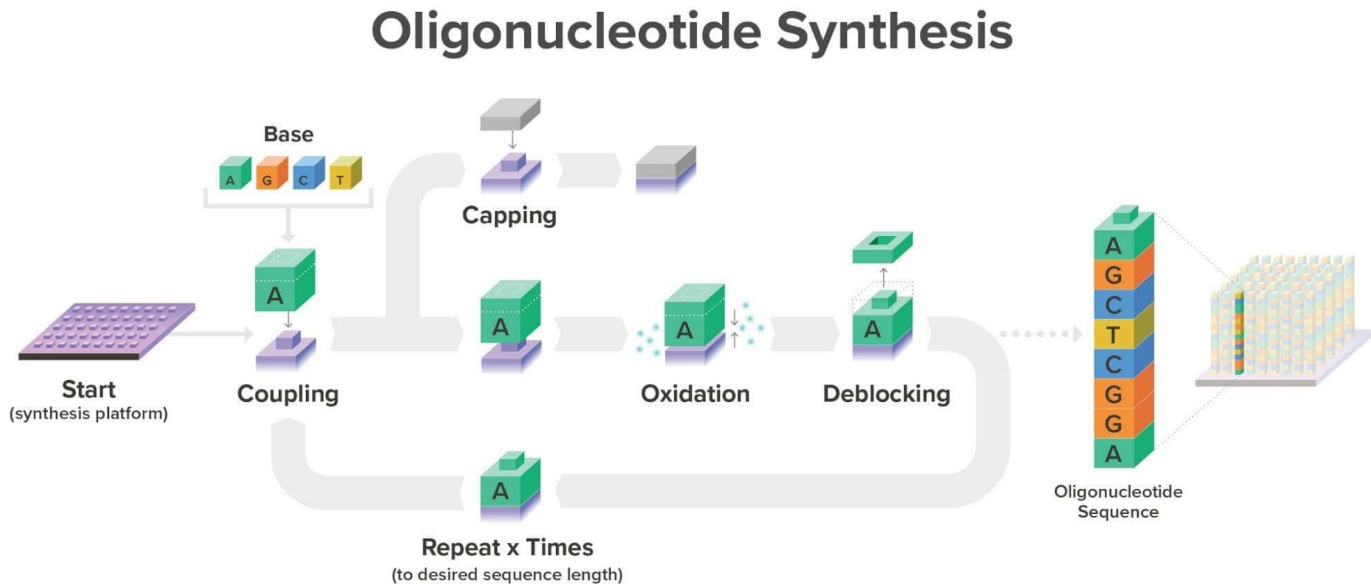


Microfluidic devices

One needs parts to build things…



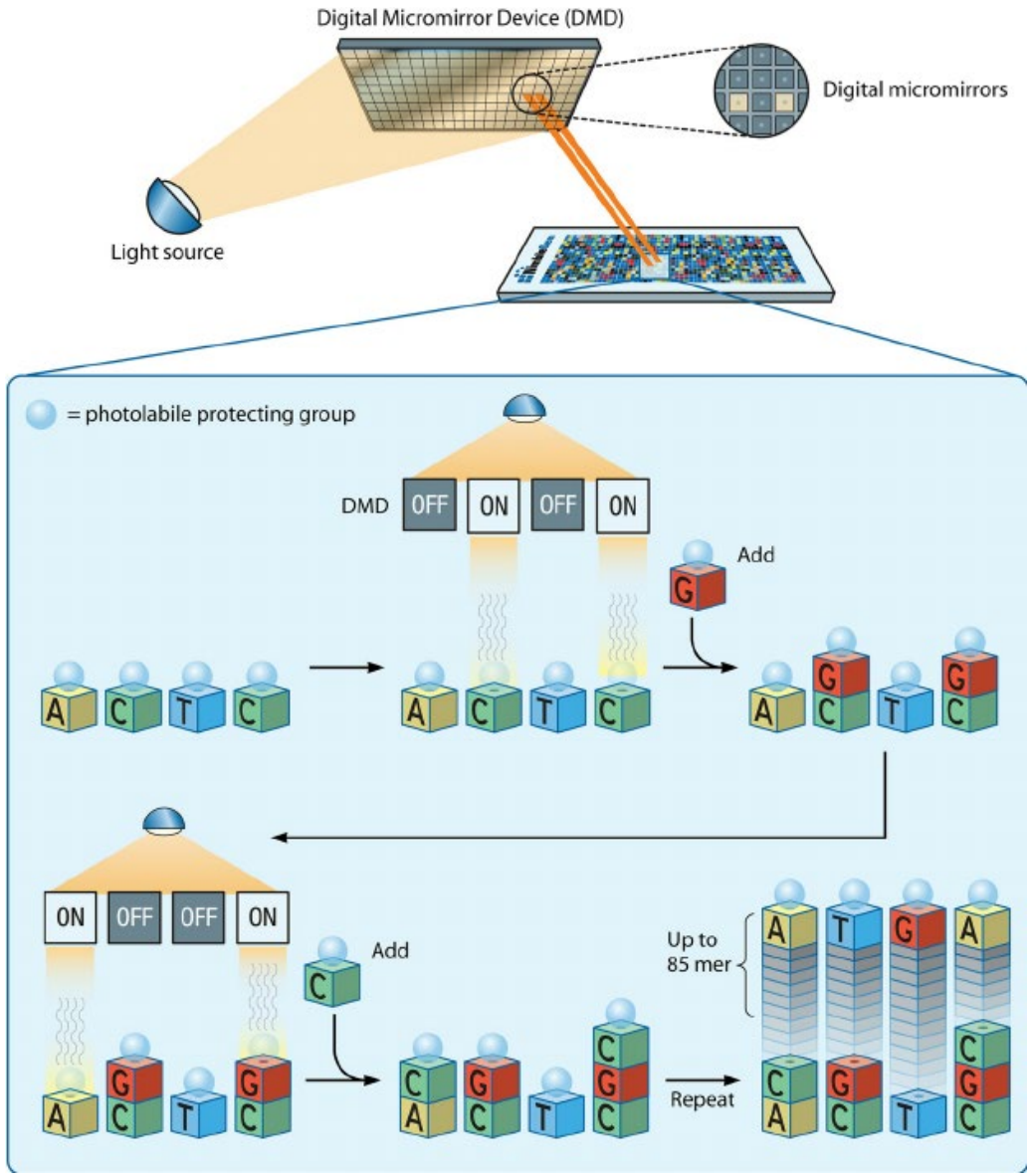
Oligos, Synthetic DNA, PCR



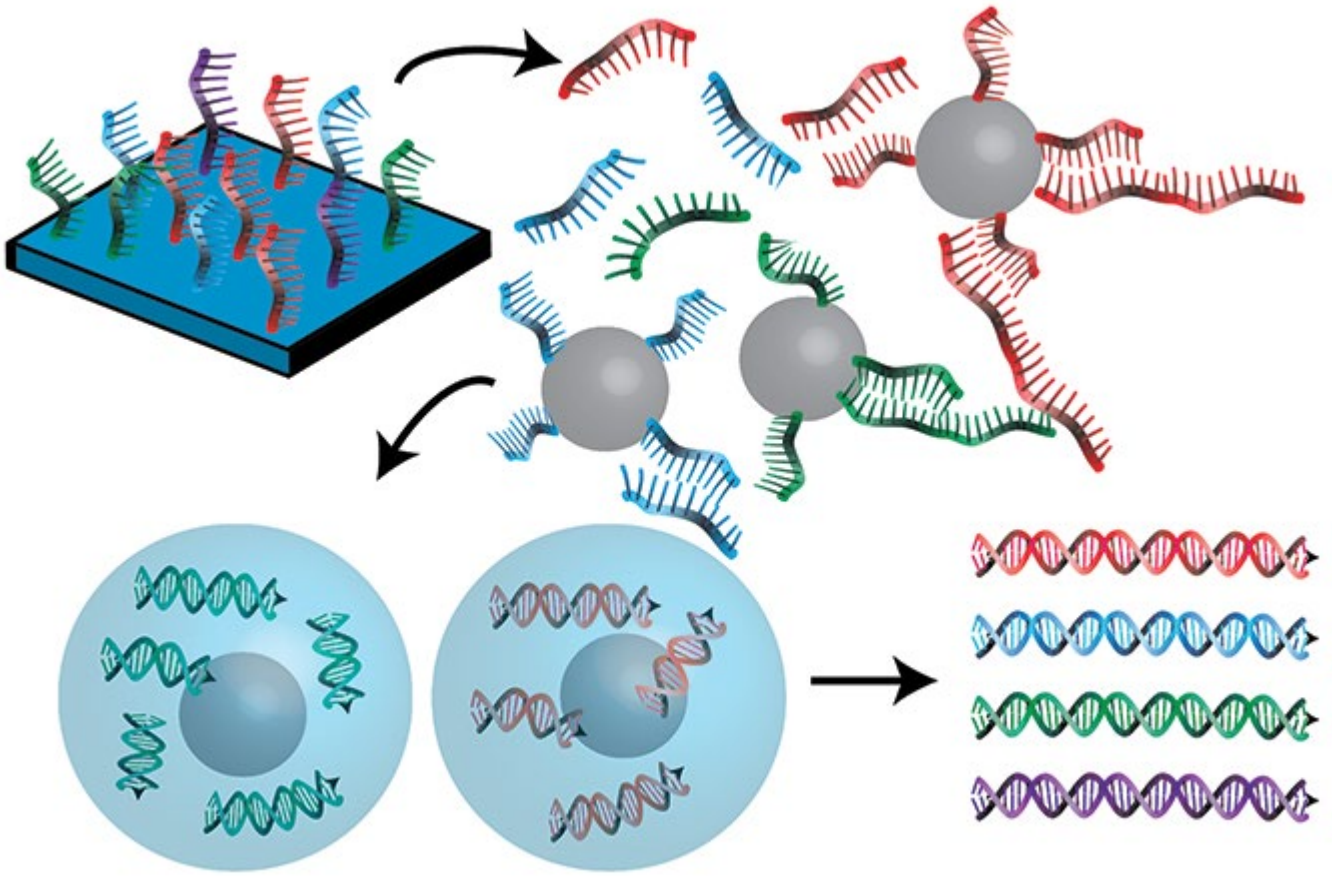
Oligonucleotides:

- Single stranded DNA
- Up to 200 bases in length
- Made by chemical synthesis
- Custom sequences can be ordered
- Oligos can be used in PCR and assembled into longer double stranded DNA

Oligos, Synthetic DNA, PCR



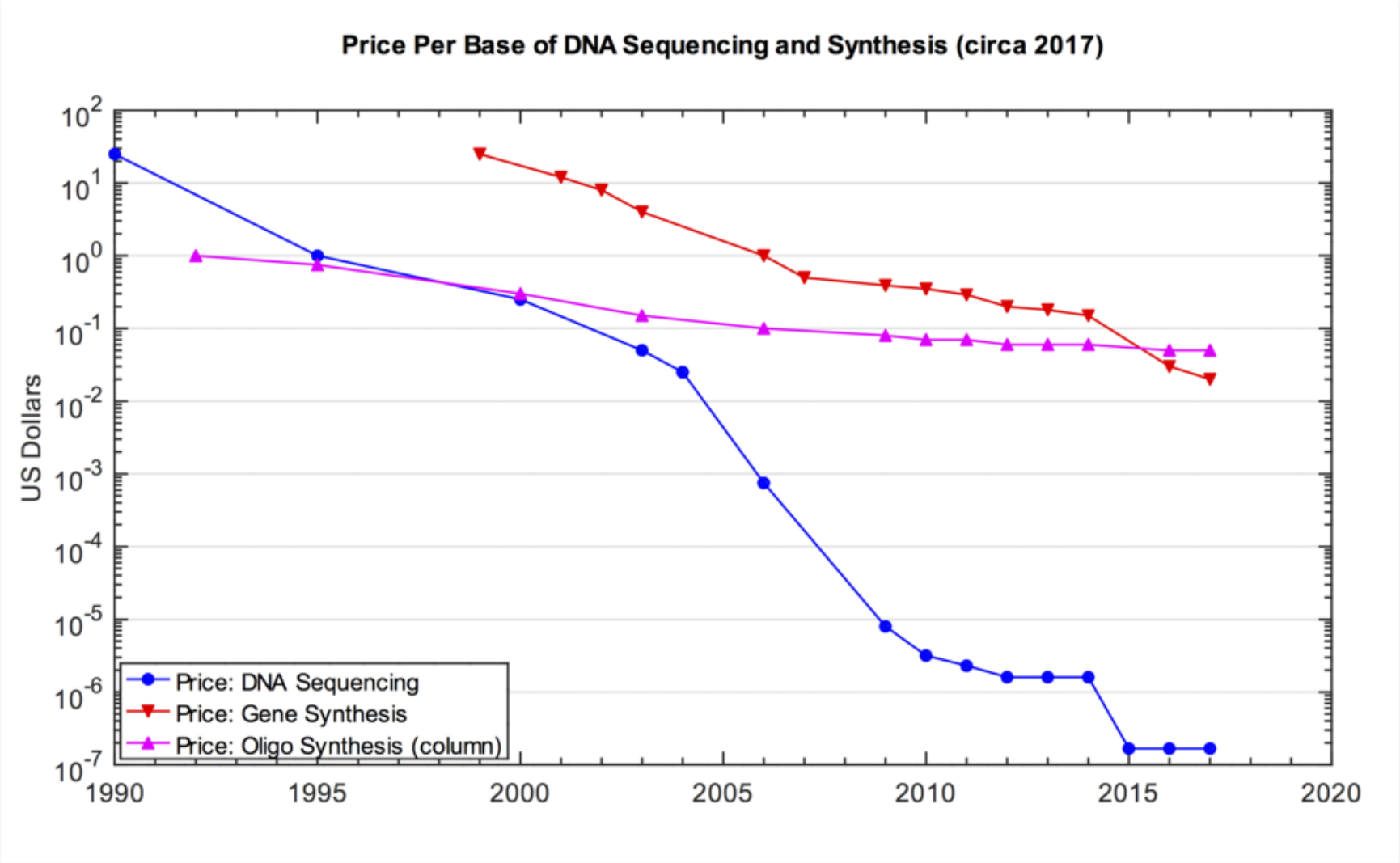
Oligos, **Synthetic DNA**, PCR



Oligonucleotides:

- Double stranded DNA up to ~5kb in length
- Available as linear templates or cloned into a plasmid

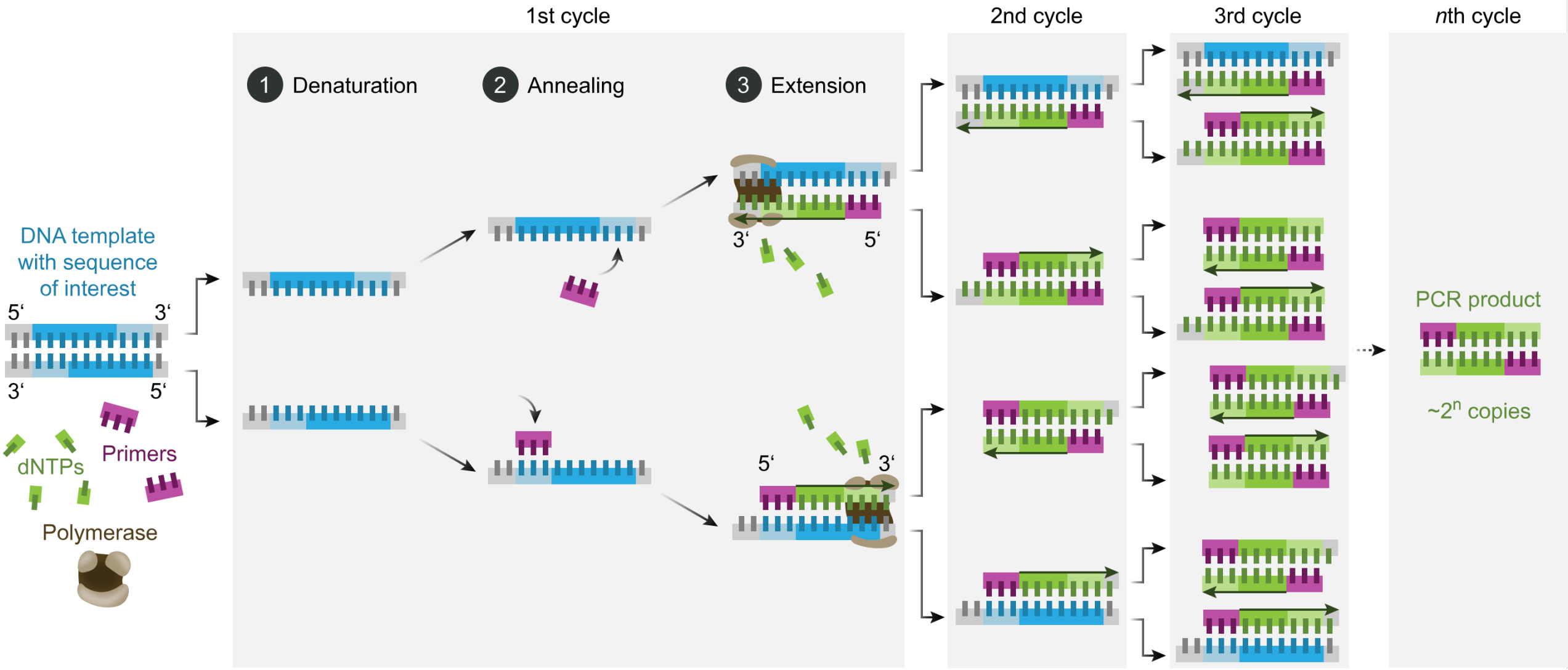
Oligos, **Synthetic DNA**, PCR



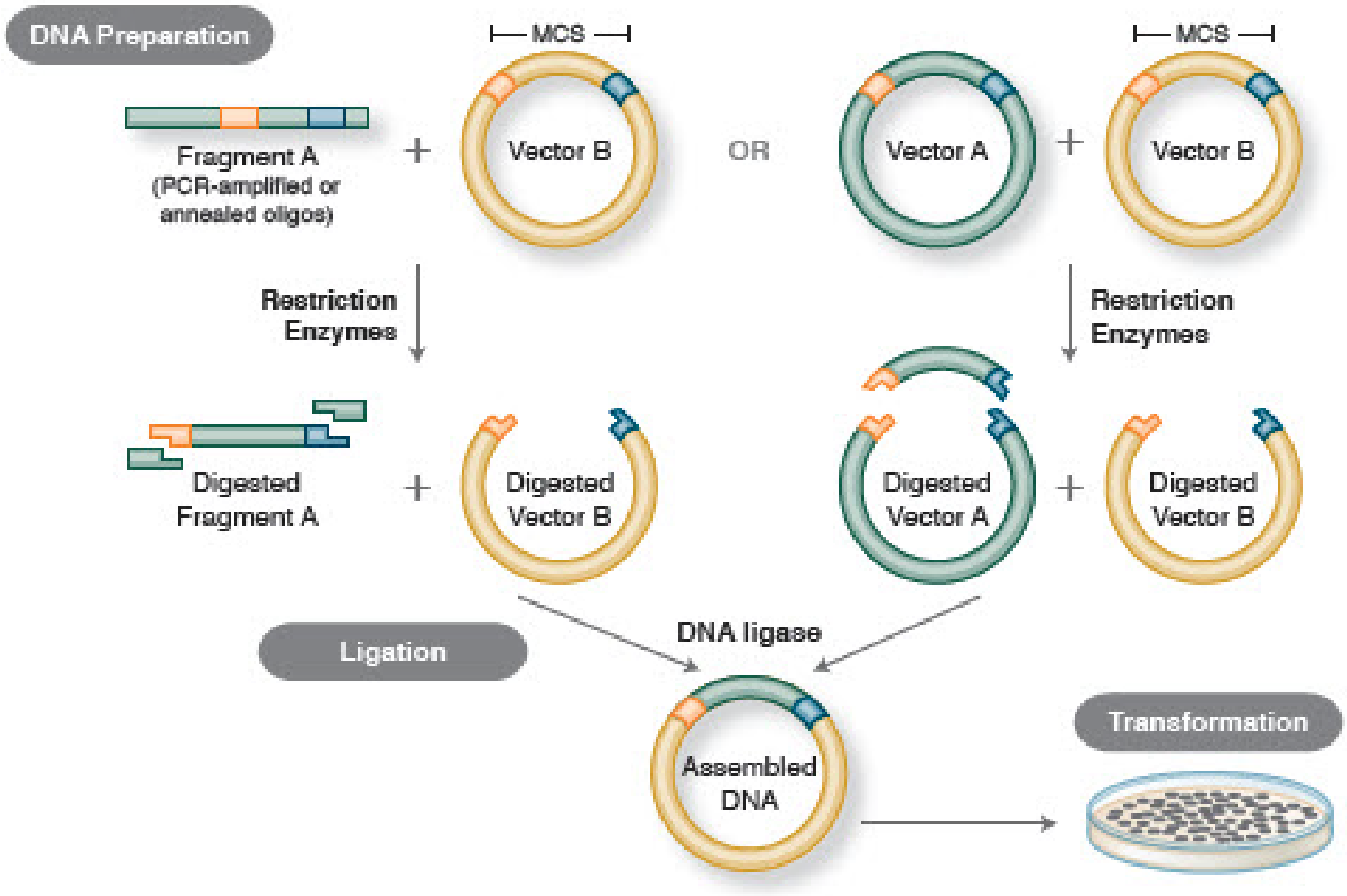
Bioeconomy CAPITAL

20 January, 2018

Oligos, Synthetic DNA, **PCR**



Cloning



Restriction Digest

- Use a restriction enzyme that cuts dsDNA at specific sequences

De-Phosphorylation

- Use a phosphorylase to remove phosphate group from the cut sites, this prevents re-ligation of the cut vector

Ligation

- Use an enzyme called a ligase to link two pieces of DNA to one another

Transformation

- The cloned vector is then put into E. coli cells which amplify the vector

Protein Expression and Purification

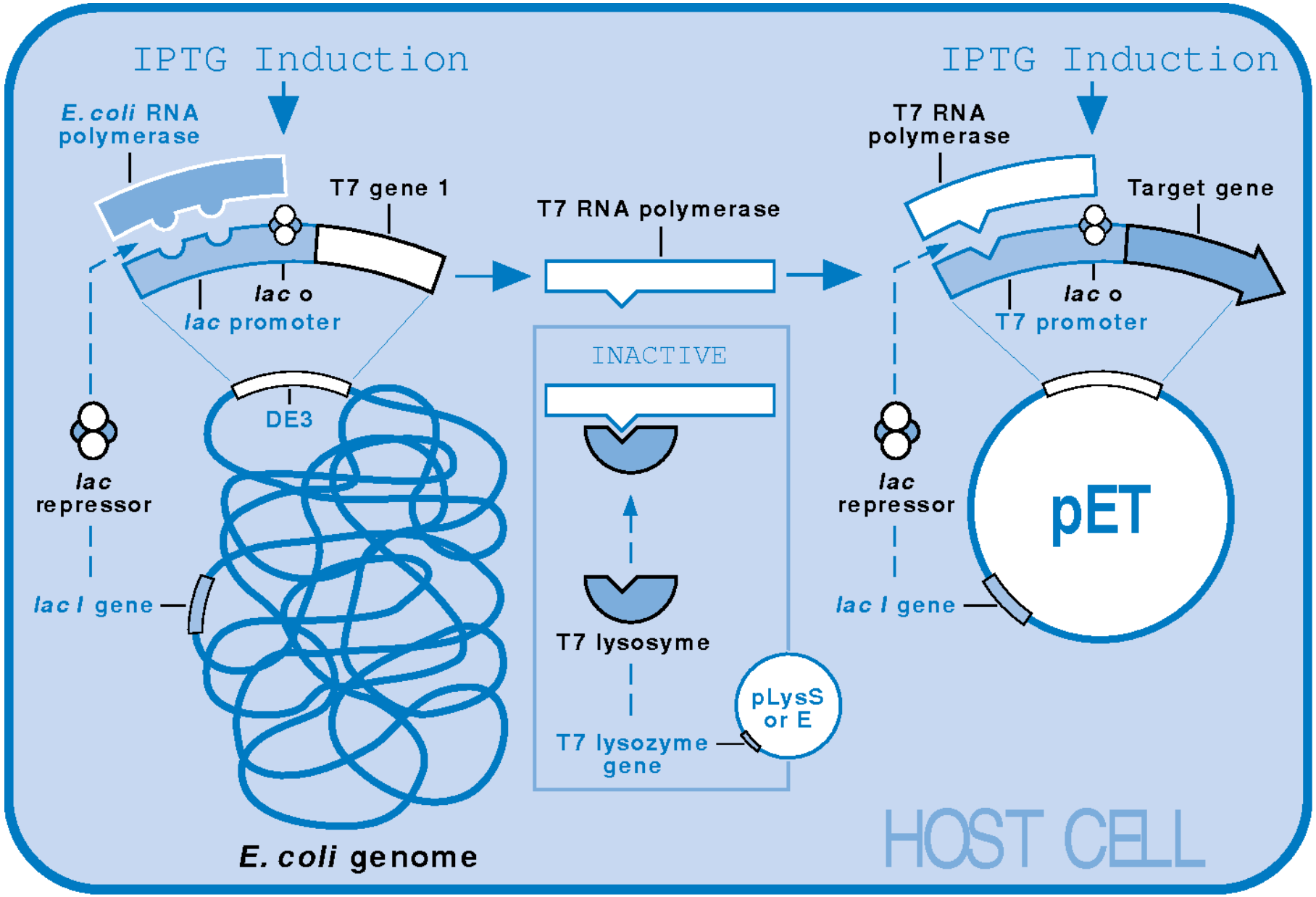
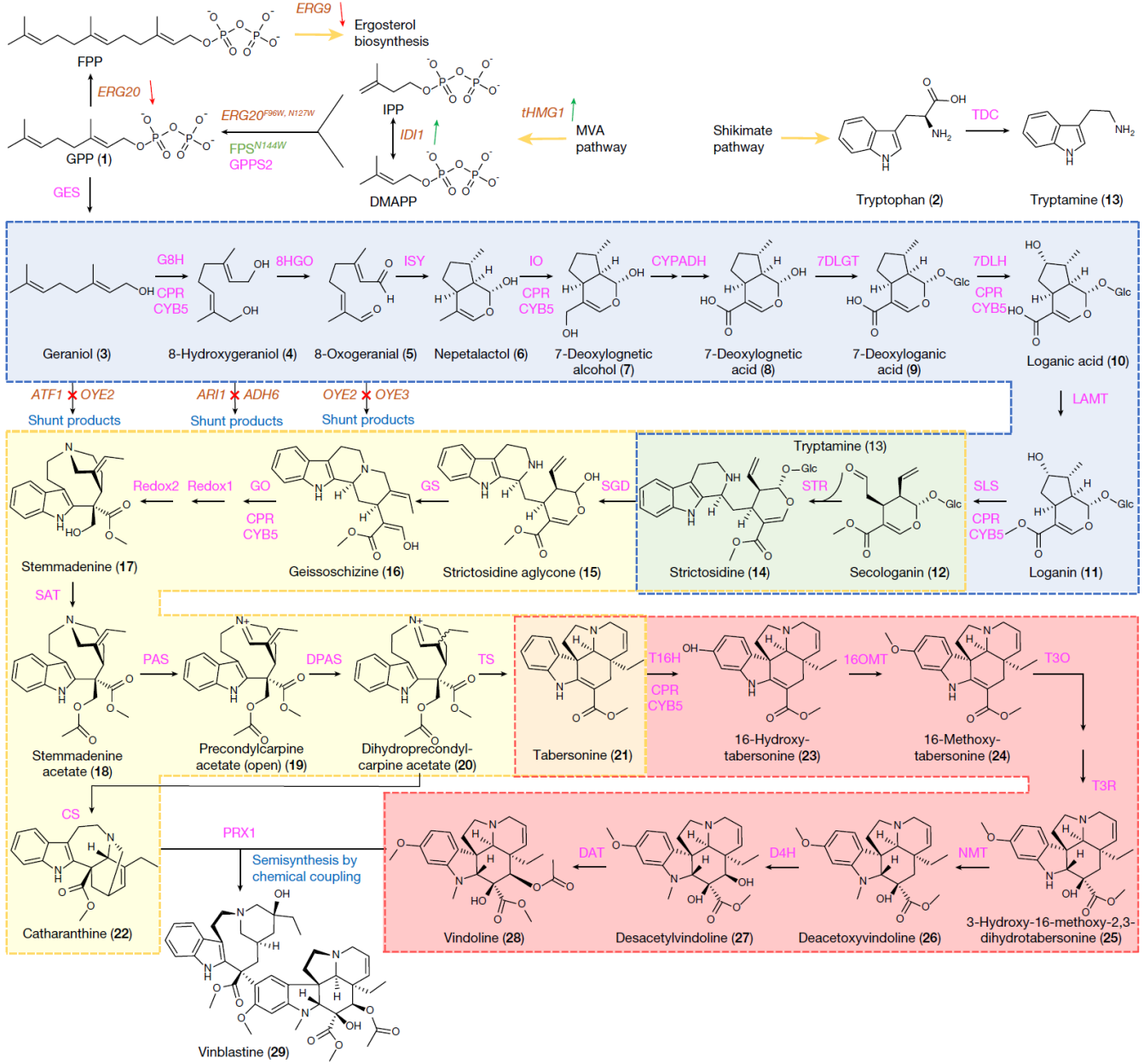
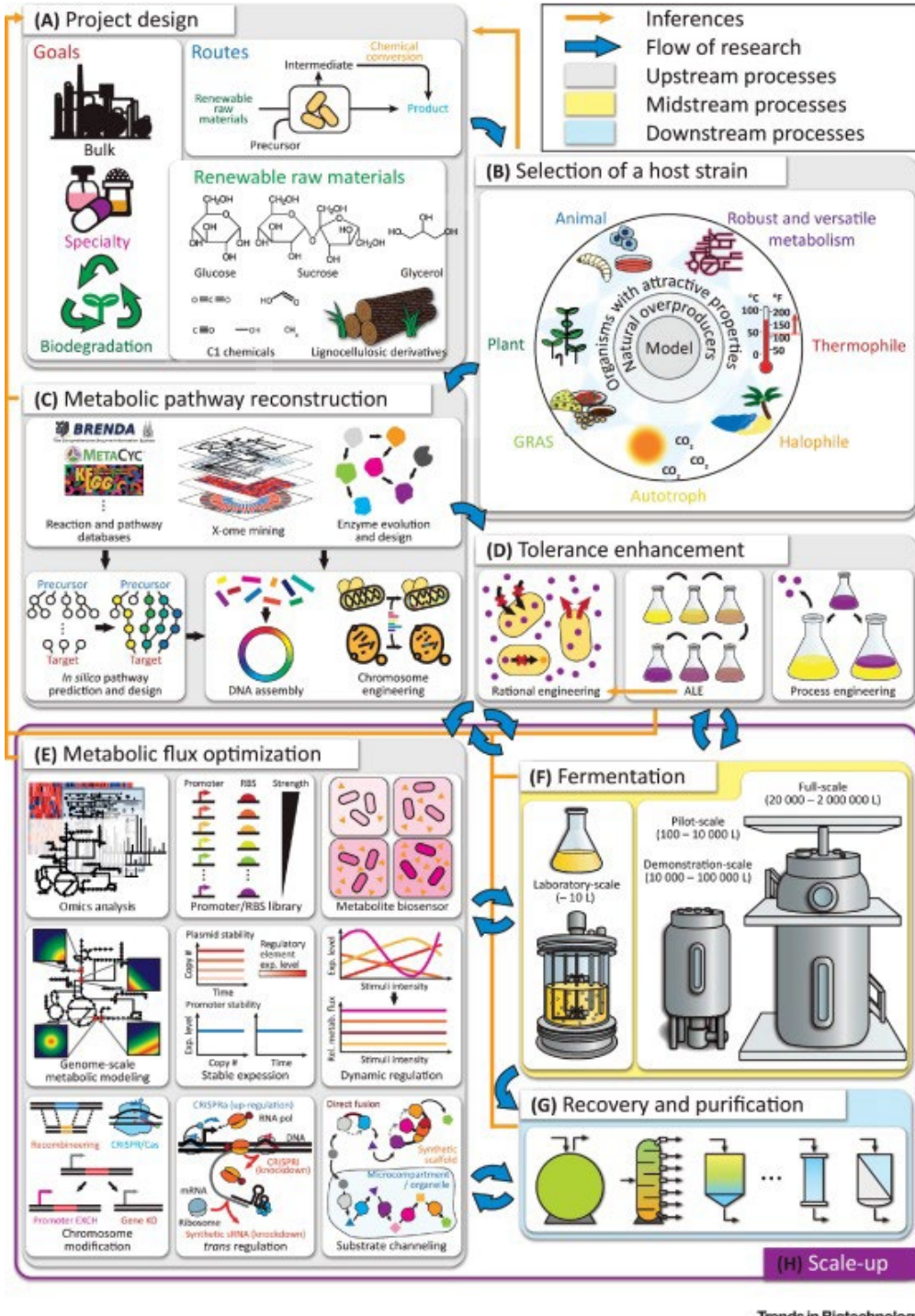


Figure 1. Control elements of the pET System

What is Bioengineering good for?

Metabolic Engineering





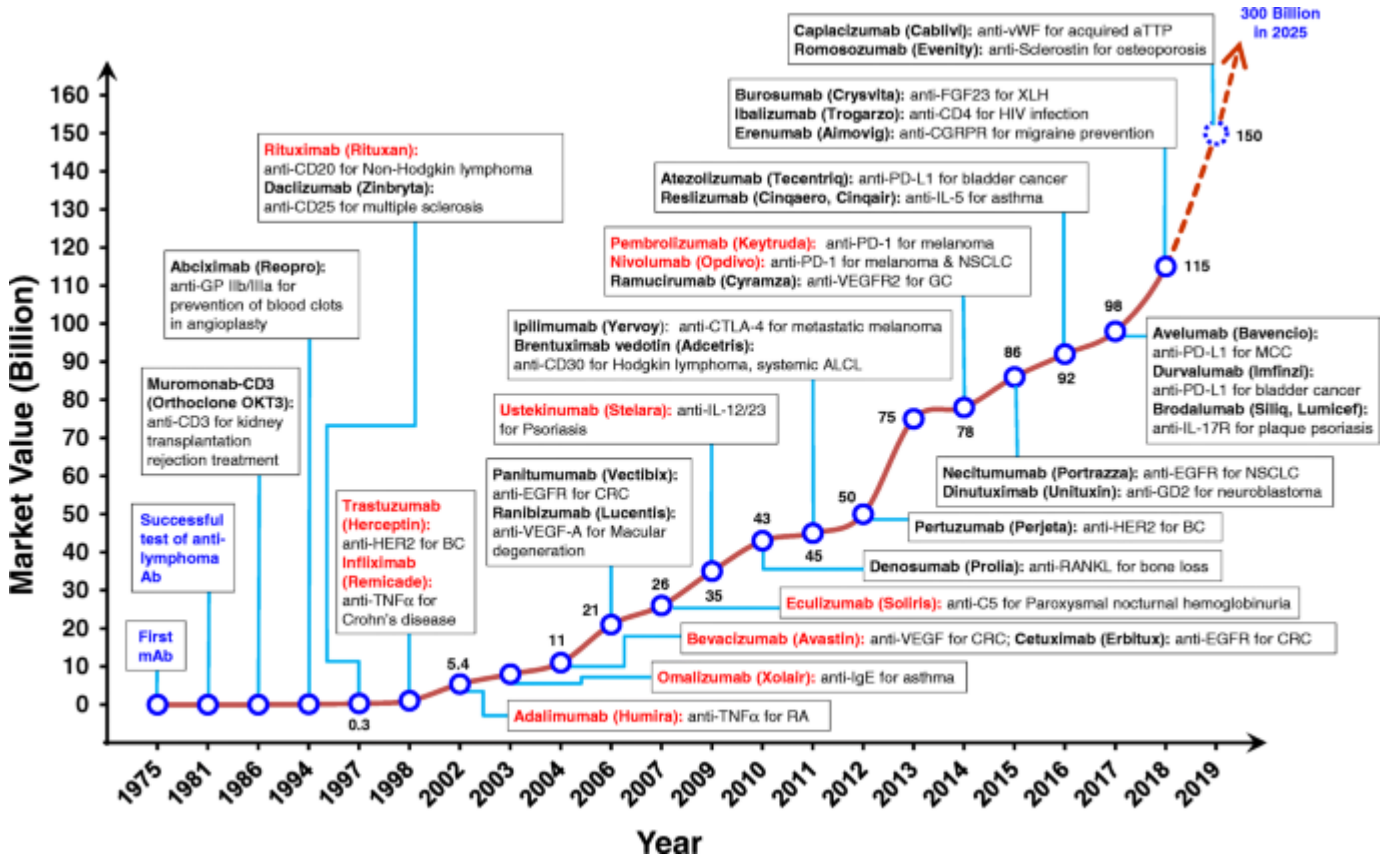
Antibody Therapeutics

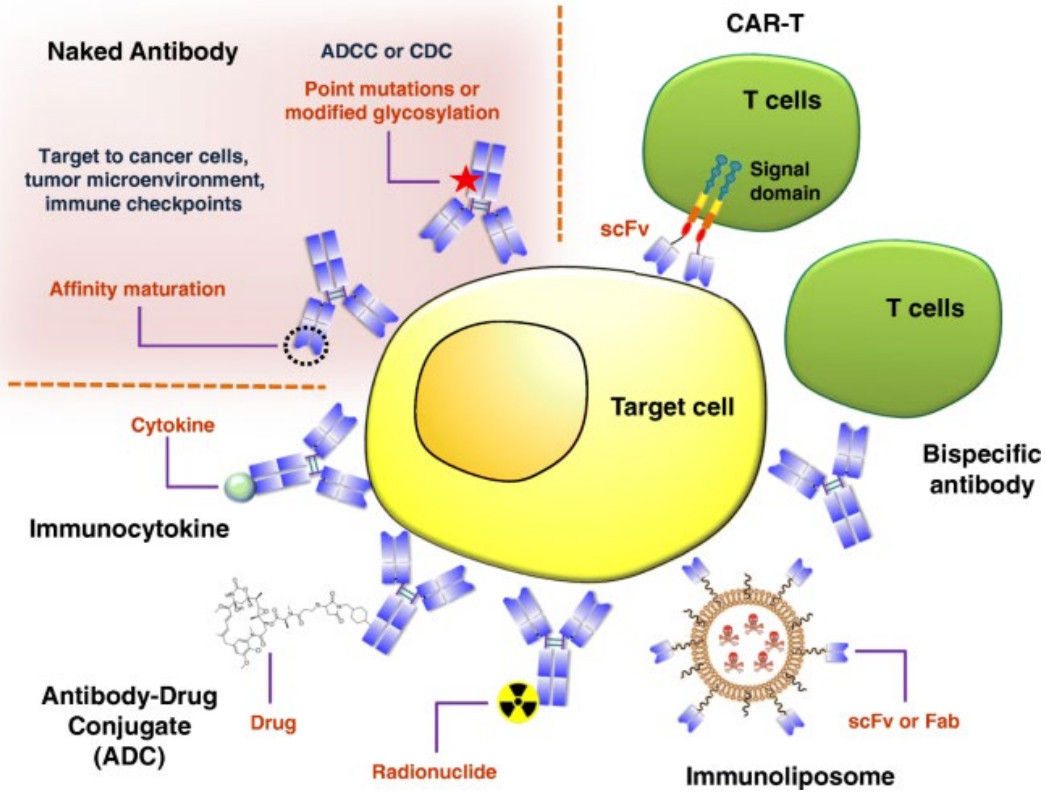
$188.18 billion

The global monoclonal antibodies (MAbs) market size is expected to grow from $168.70 billion in 2021 to **$188.18 billion** in 2022 at a compound annual growth rate (CAGR) of 11.5%.

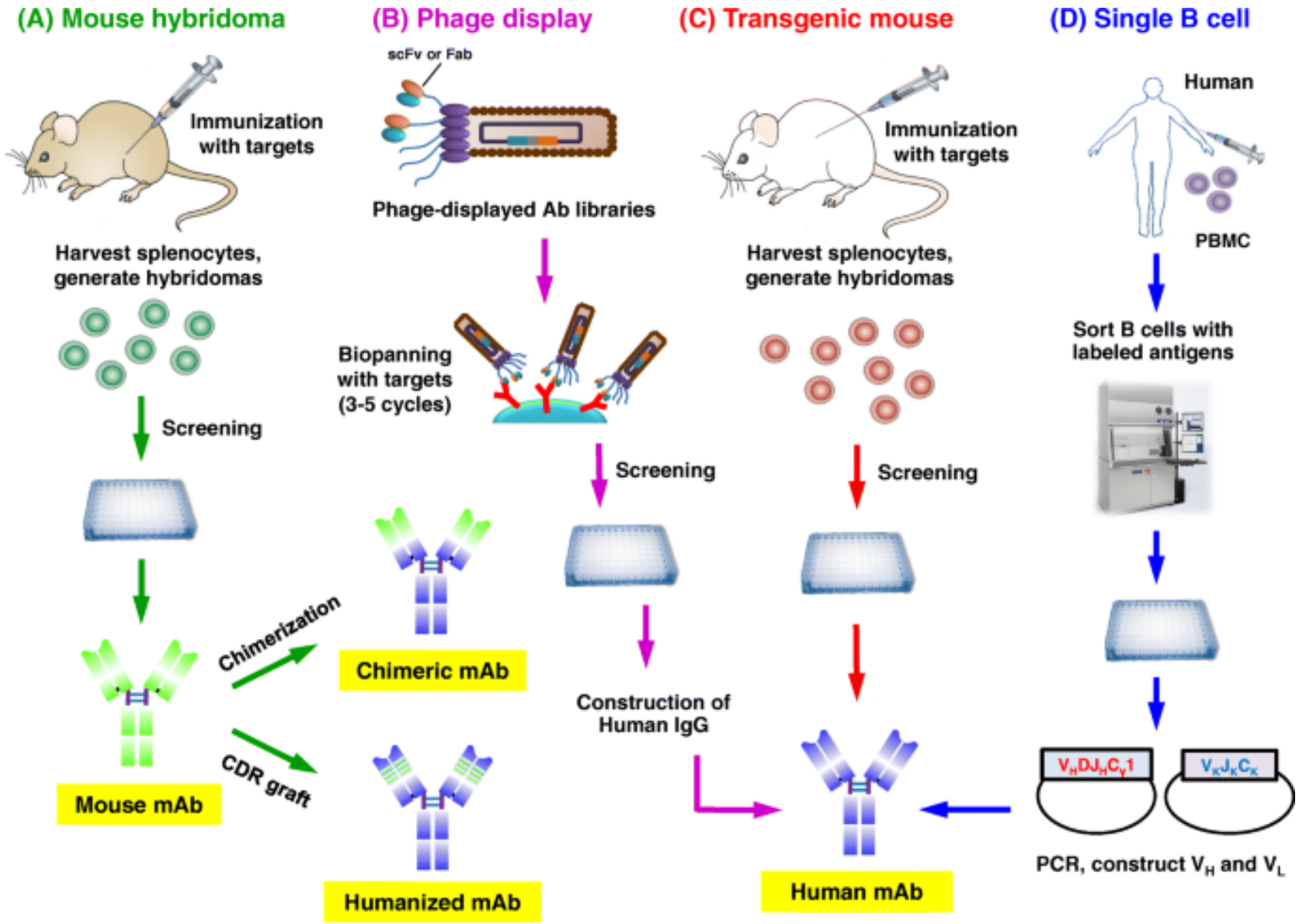
https://www.thebusinessresearchcompany.com › report

Monoclonal Antibodies (MAbs) Global Market Report 2022

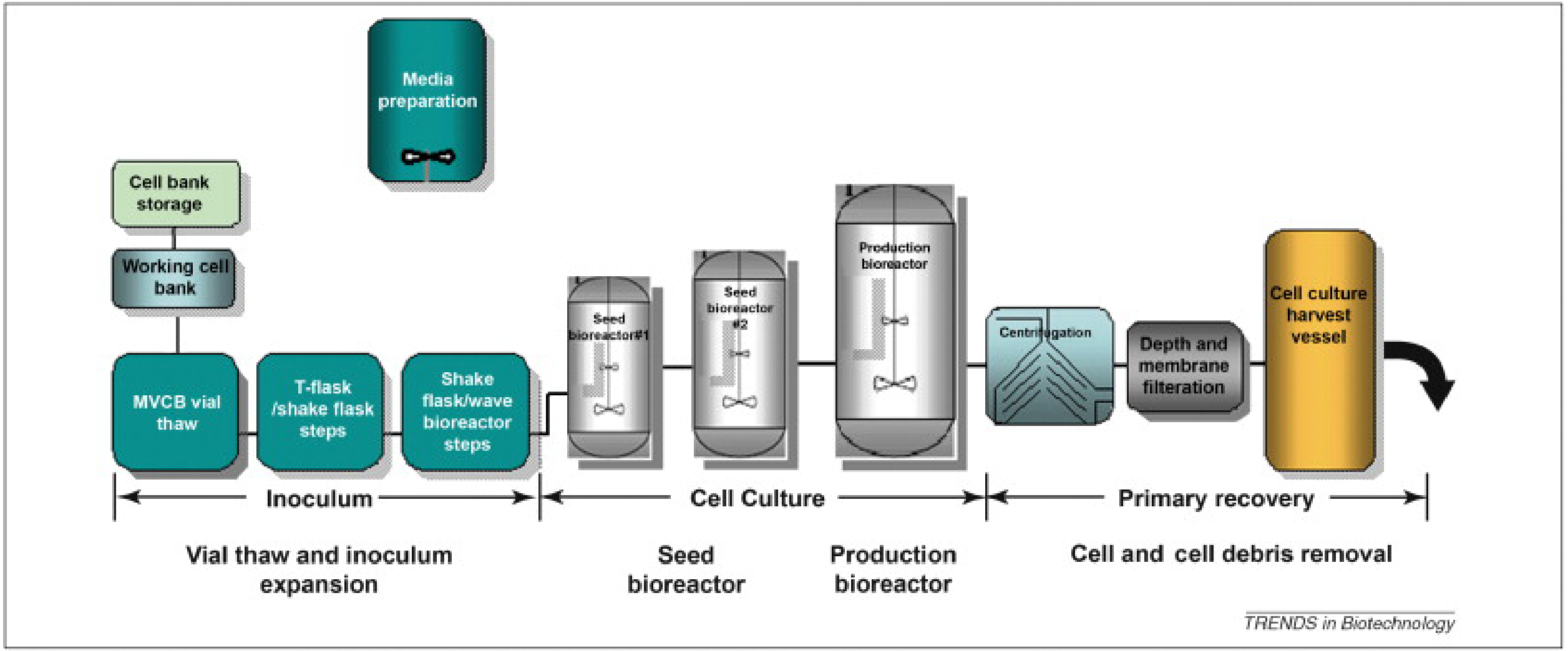




Antibody Discovery

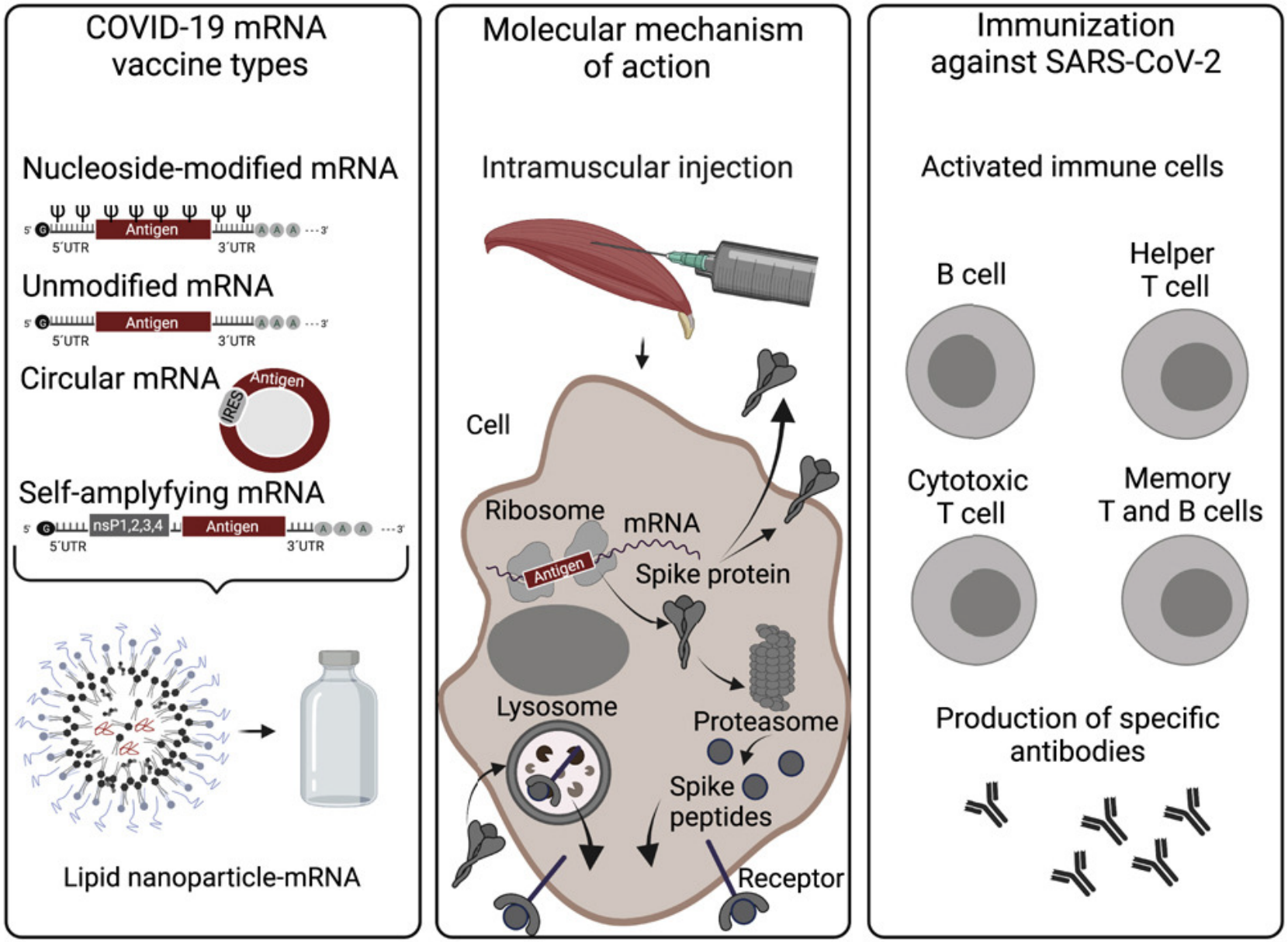


Antibody Production

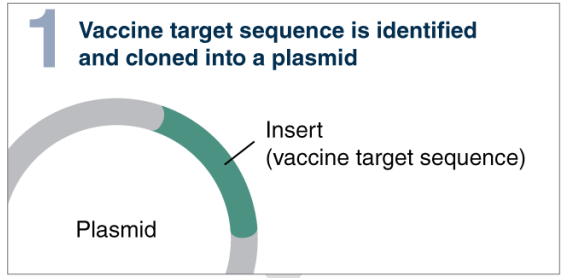


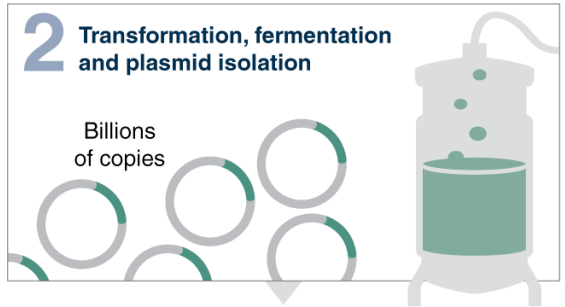
Antibody Production

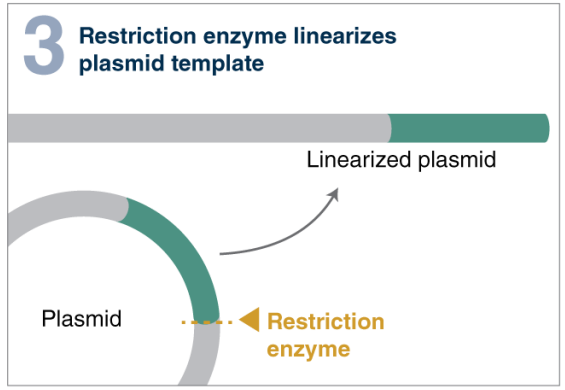
mRNA Vaccines

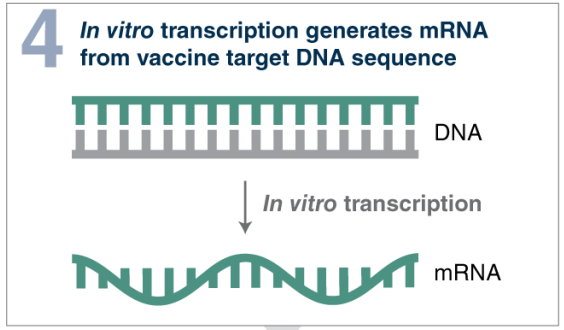


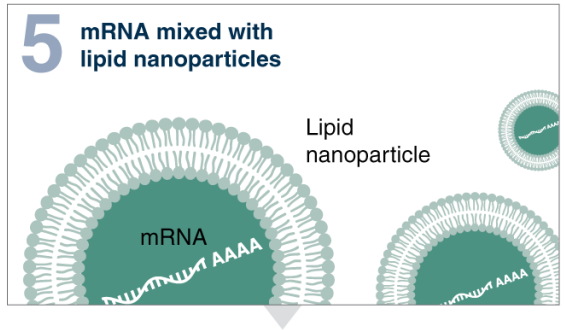
mRNA Vaccines how do you make them?

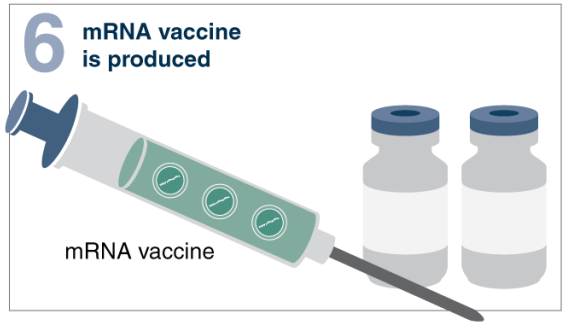












mRNA

LNP-mRNA

Lab-scale
(in microliters
or milliliters)

Scale-up
(in liters)