

Andrew Hessel

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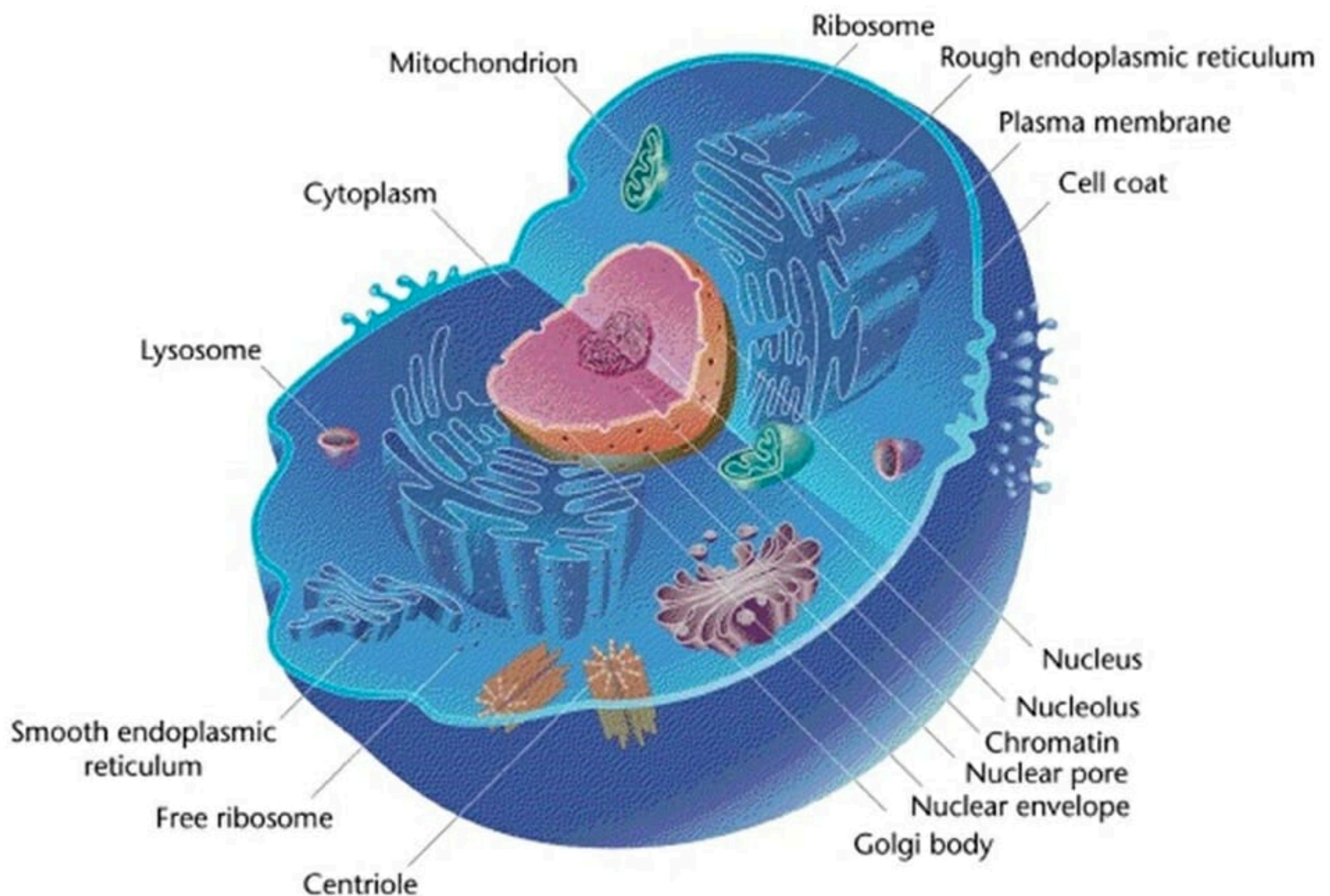
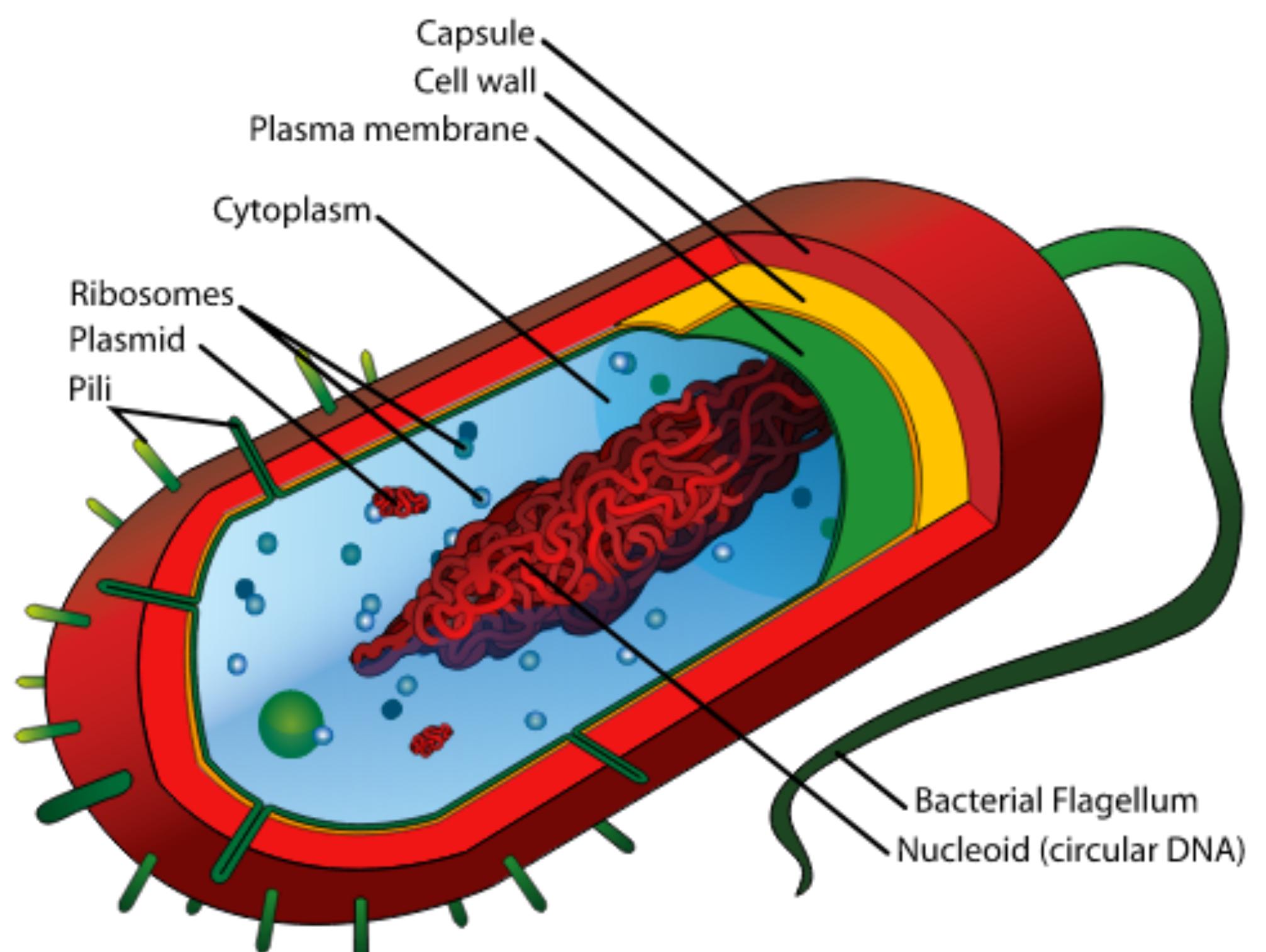
**2020 Innovations Dialogue
Life Sciences, International Security and Disarmament**

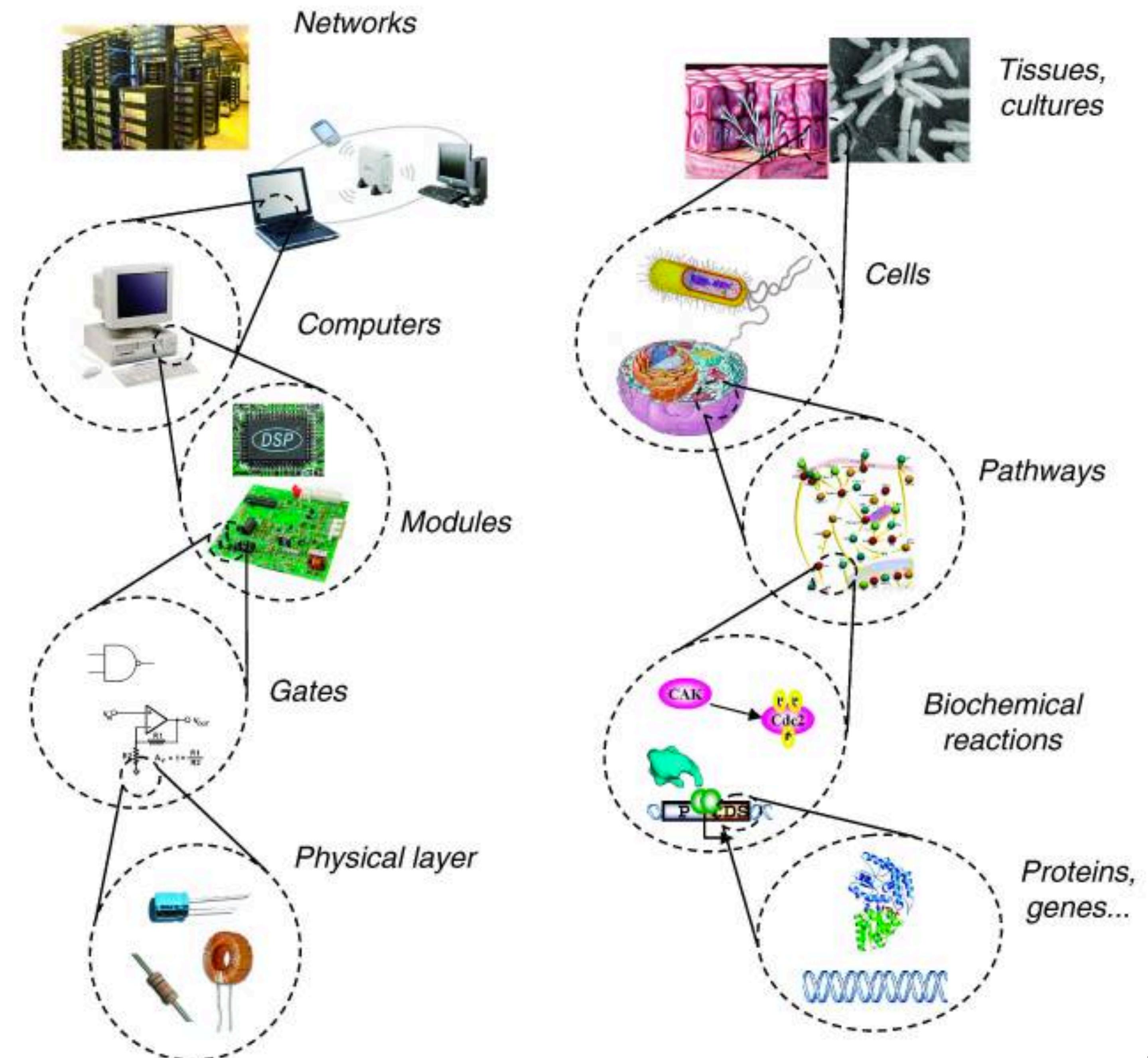
August 20-21, 2020

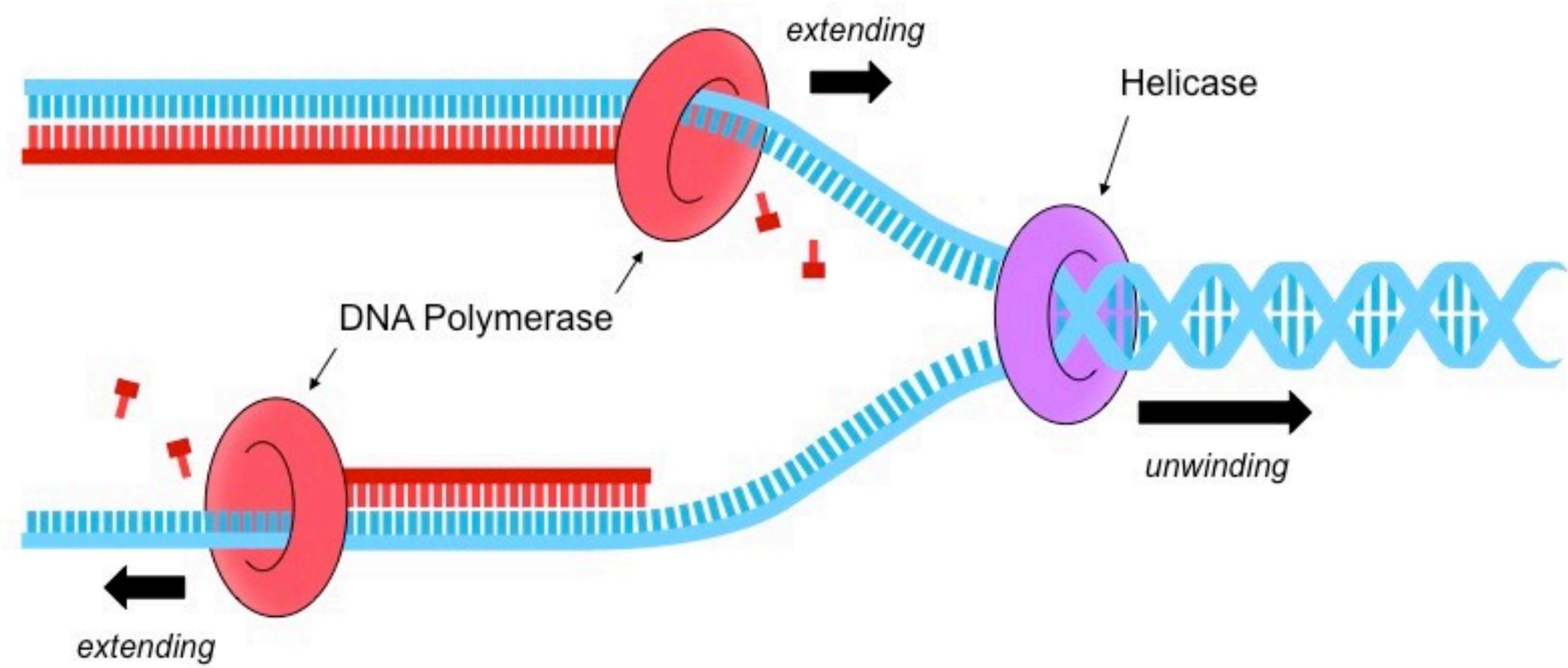
Mitigating Risks, Harnessing Benefits and Demystifying Myths of Innovation in the Life Sciences



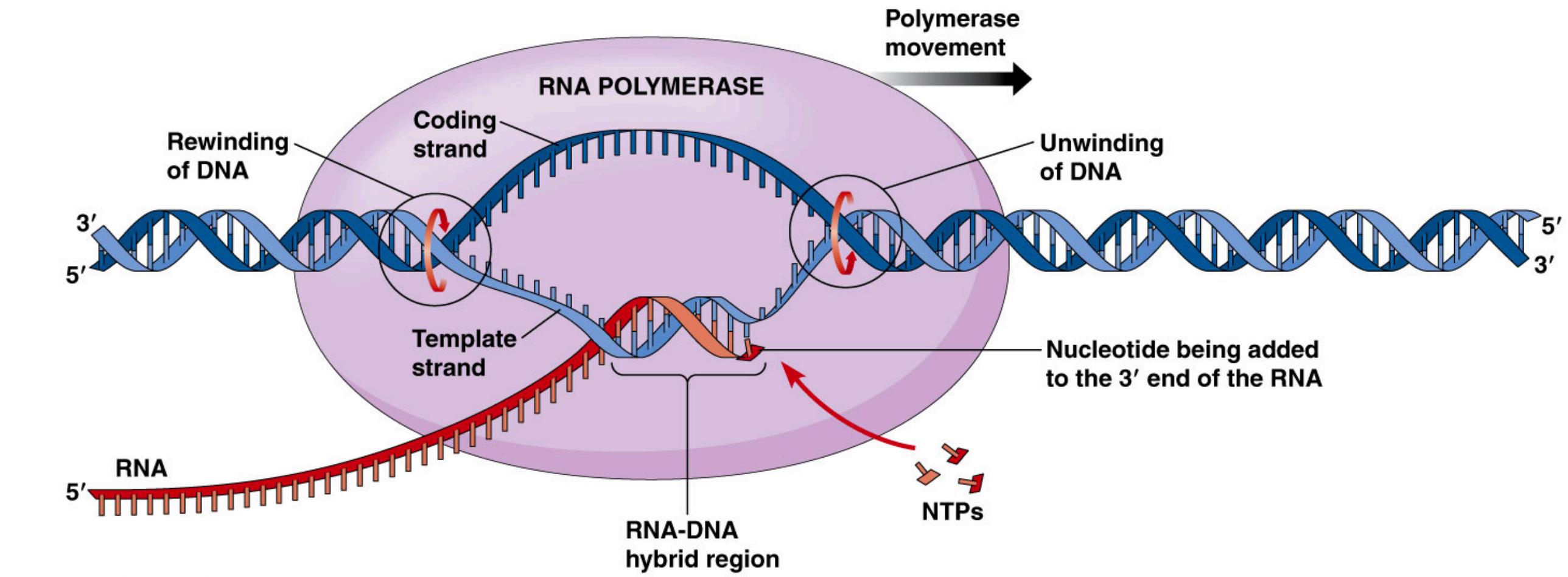




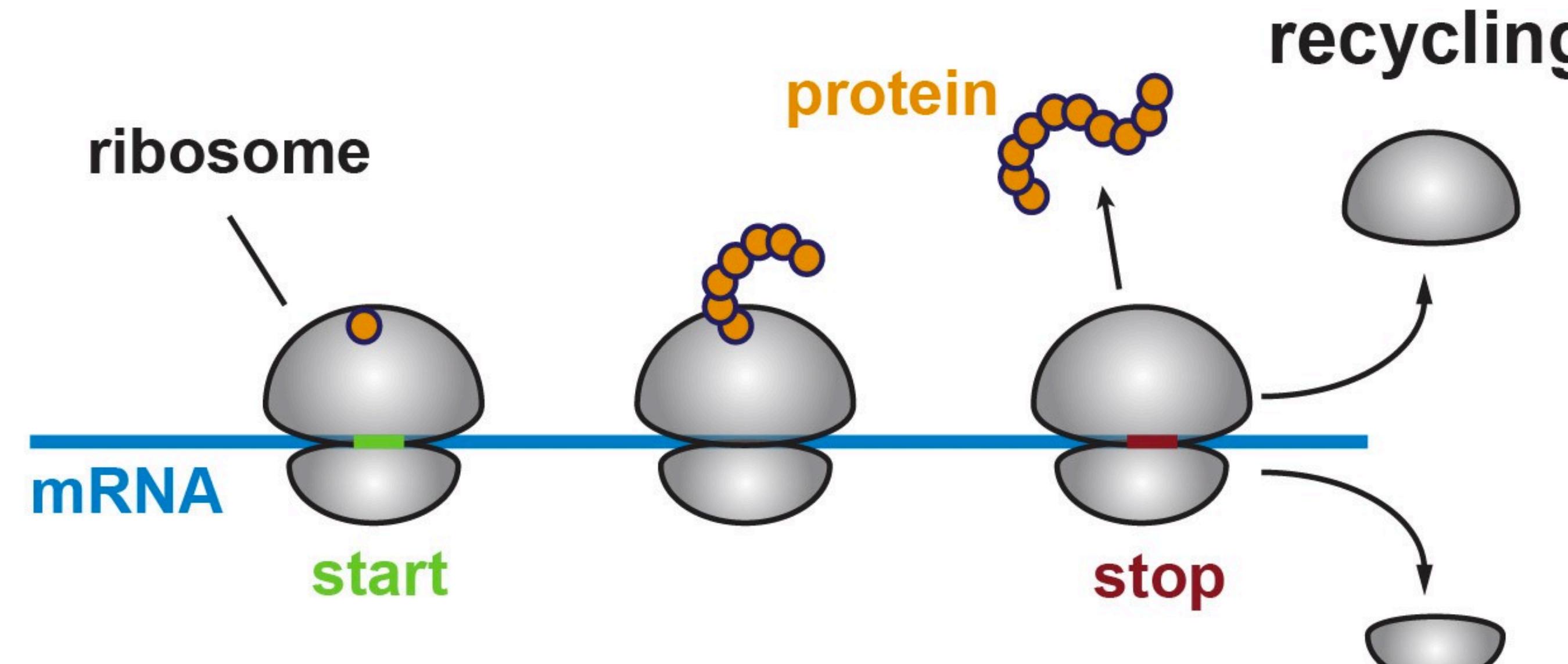




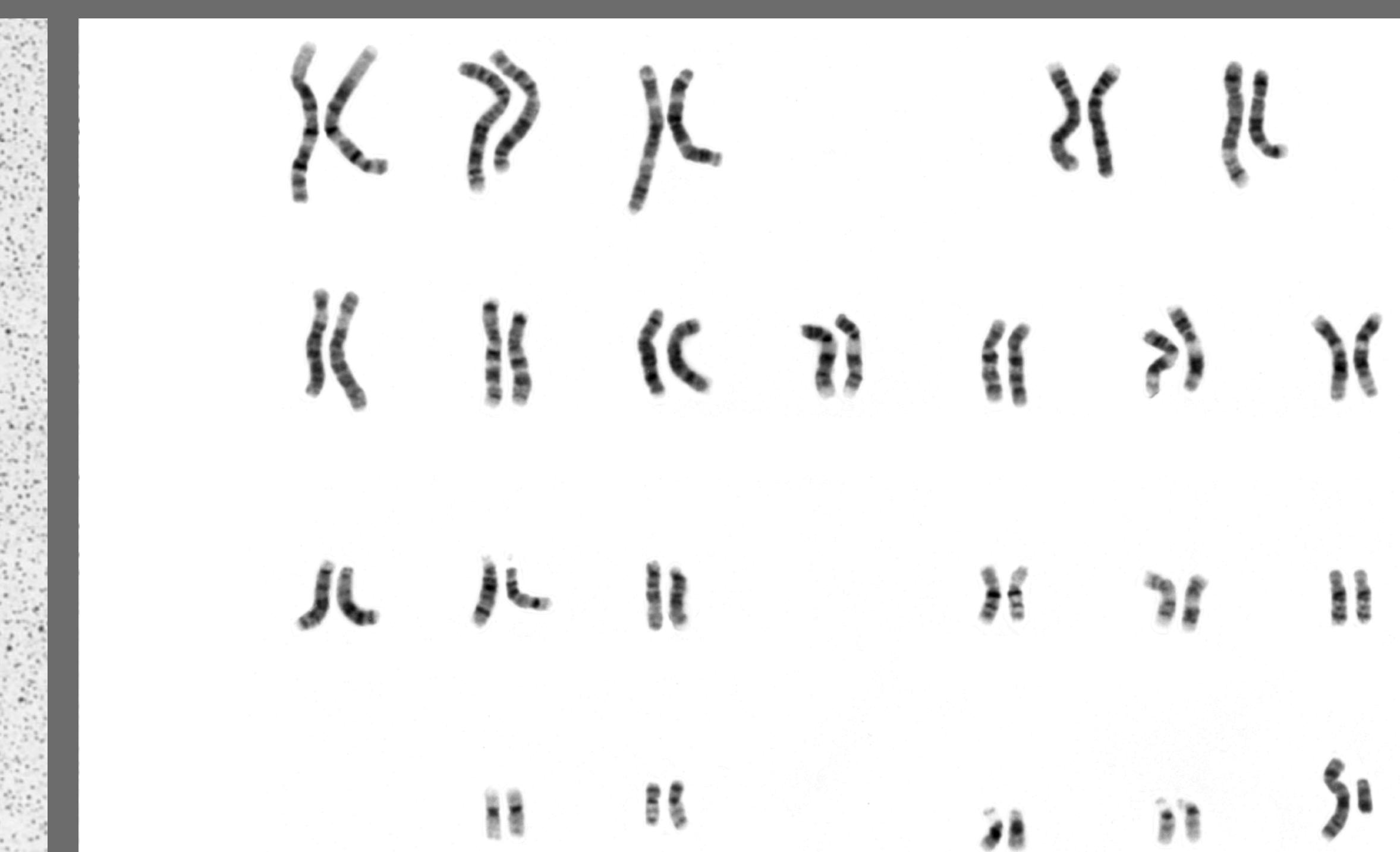
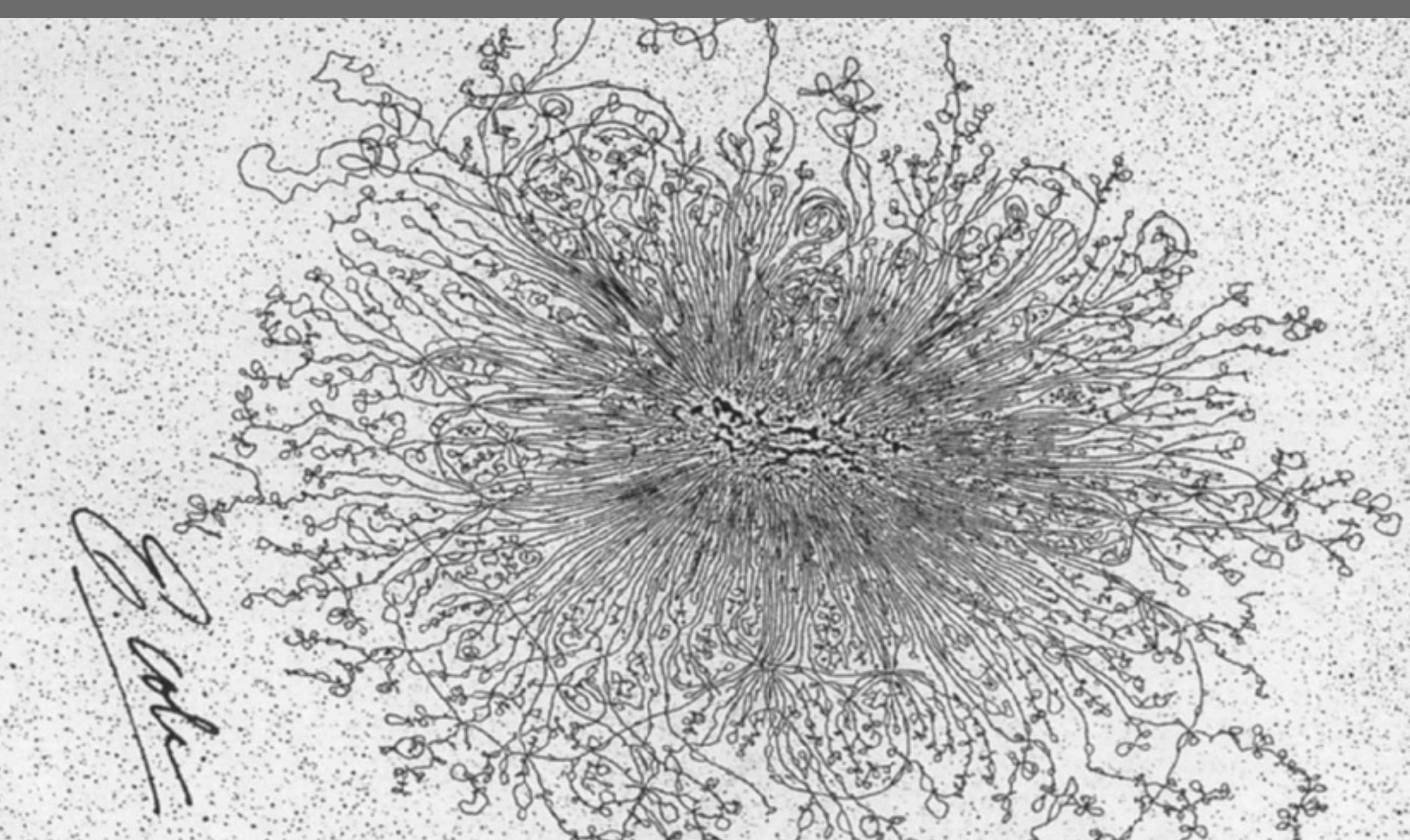
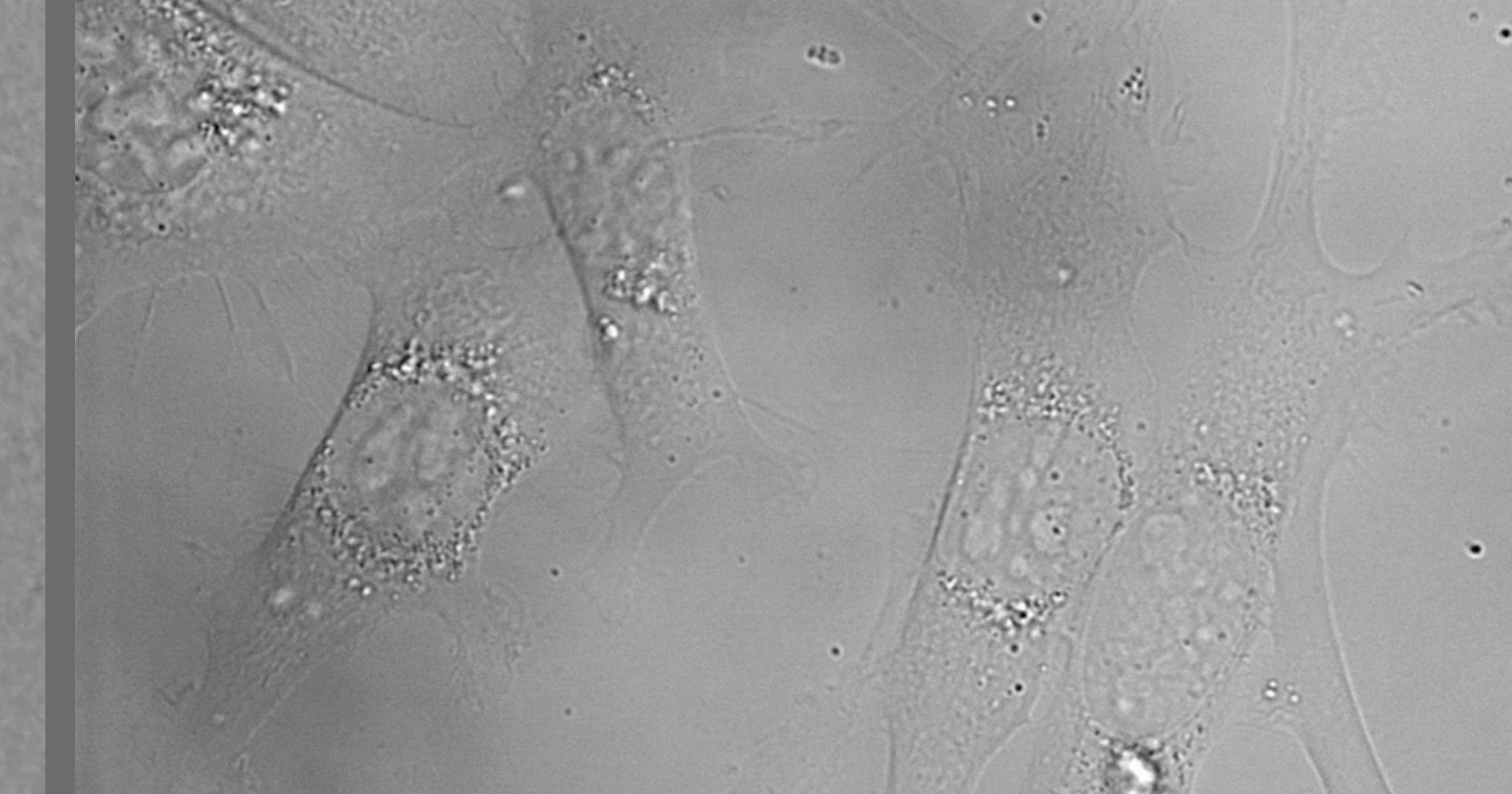
DNA polymerase

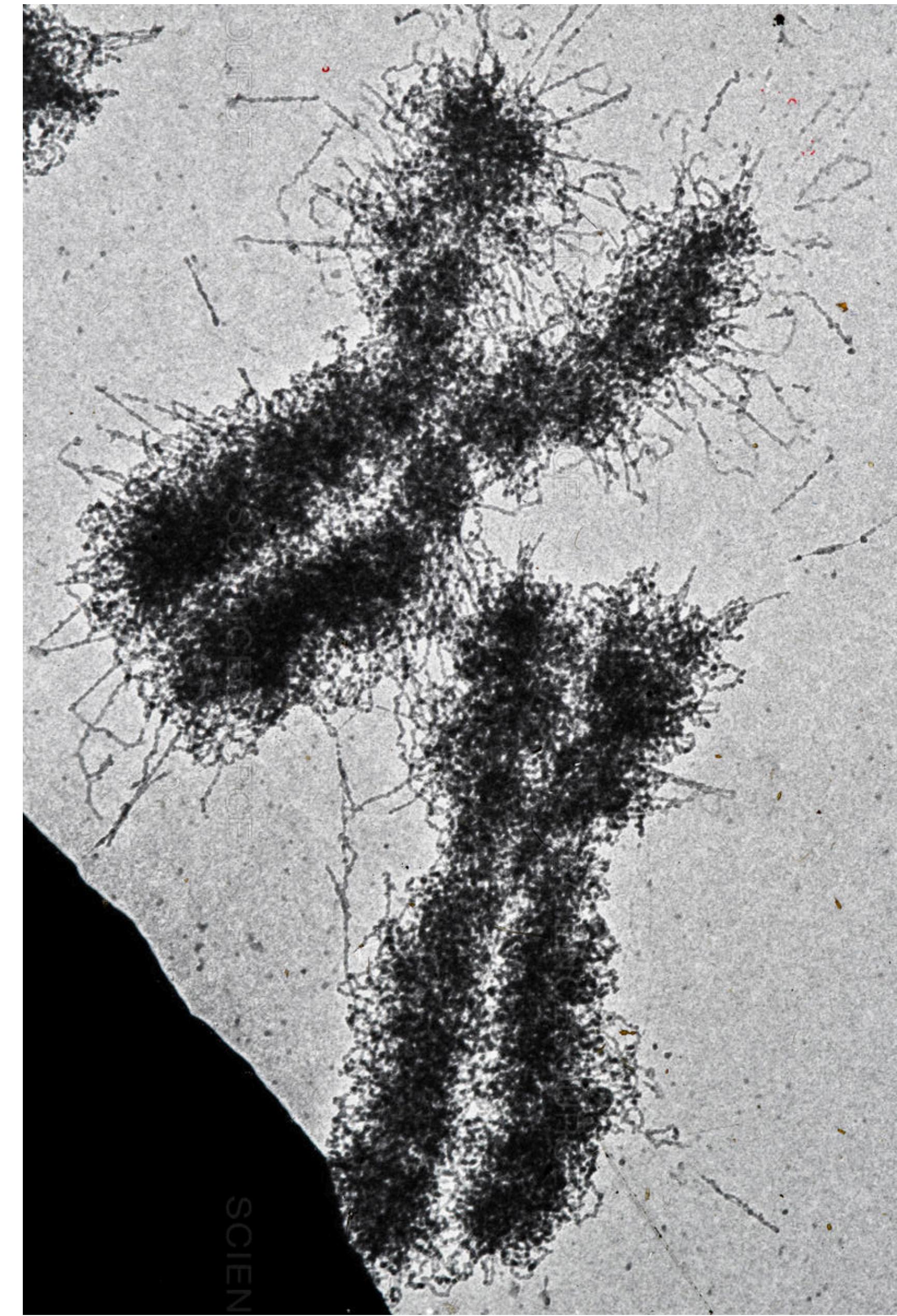
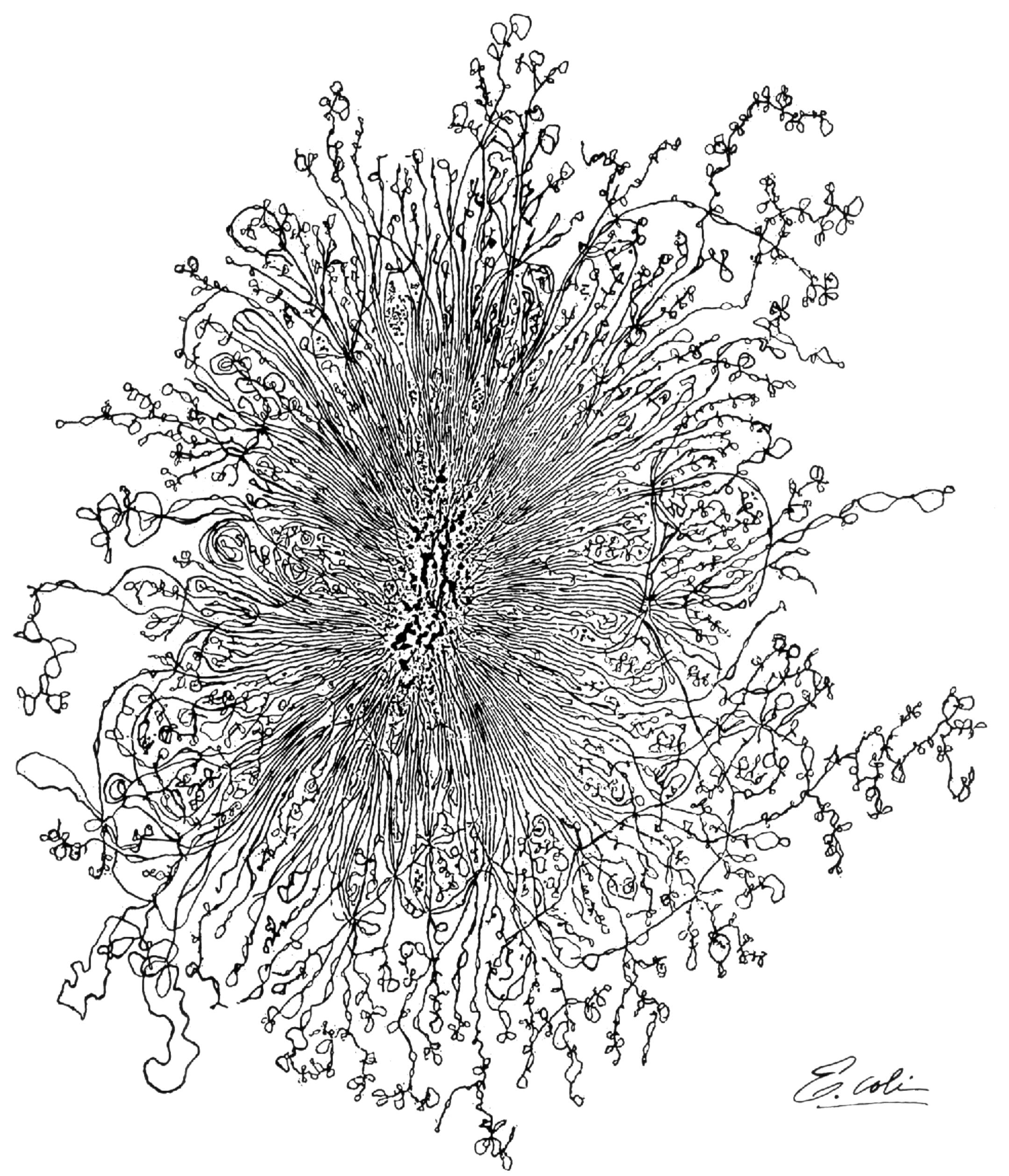


RNA polymerase



cellular machinery







Biggest difference between computers and cells:



DNA is a digital programming language
that directs cell form and function

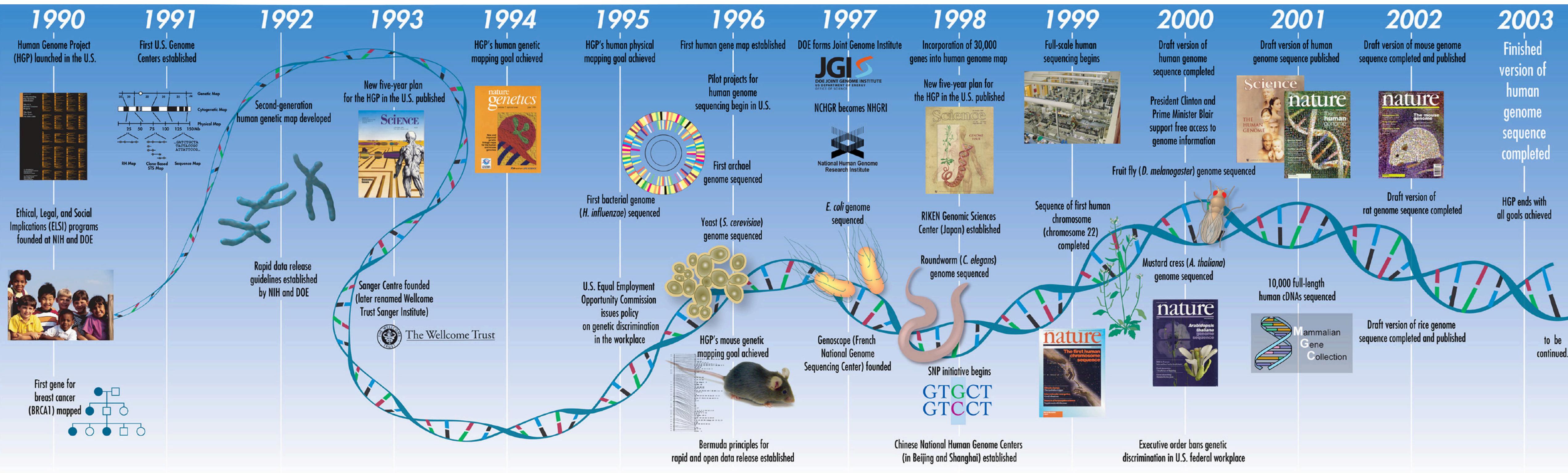
This digital code is written in physical
atoms and executed by universal
molecular machinery

The diversity that we see in nature results
from different genetic software

The world is undergoing unprecedented technological, economic, and social change because of digitization

Now, life itself is being digitized

Human Genome Project



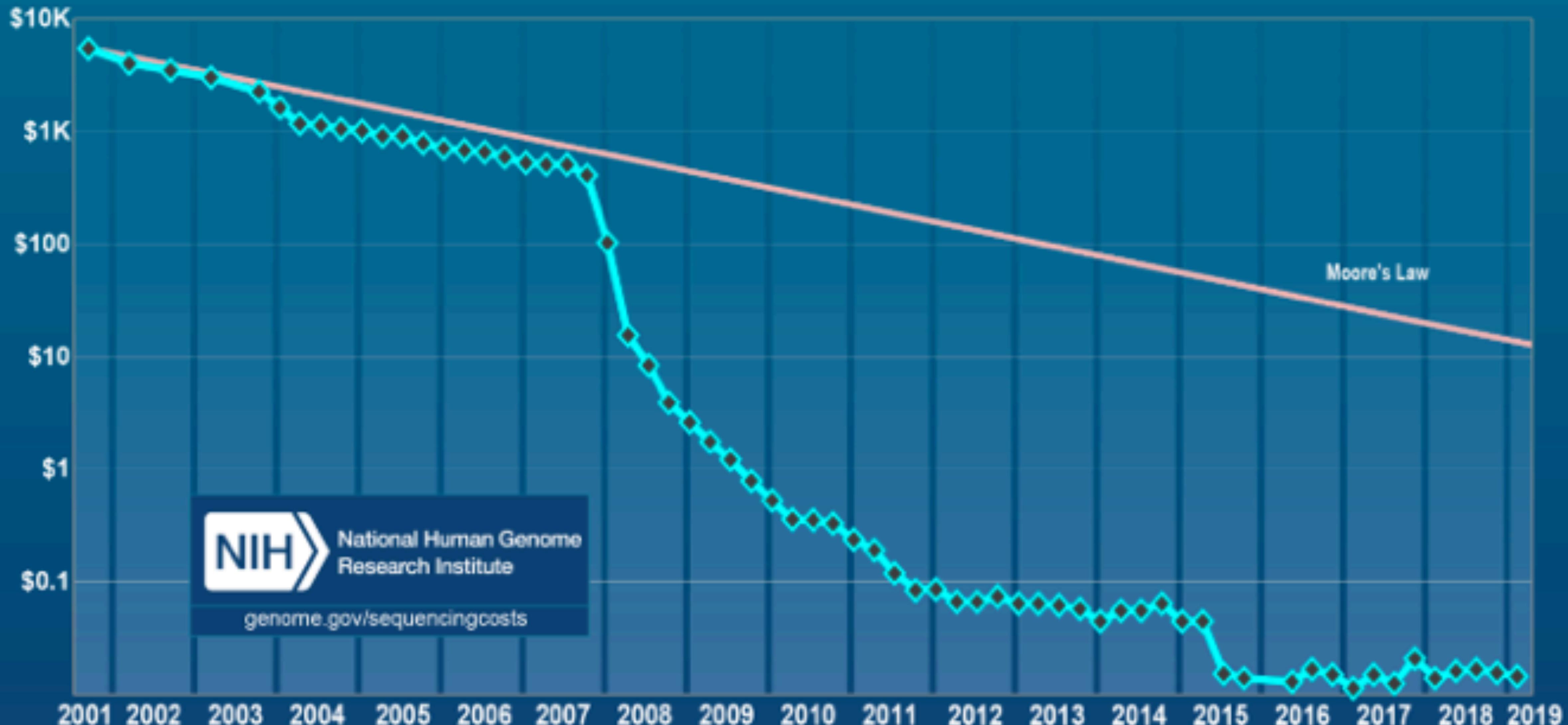


CELERA 1998



BGI 2019

Cost per Raw Megabase of DNA Sequence

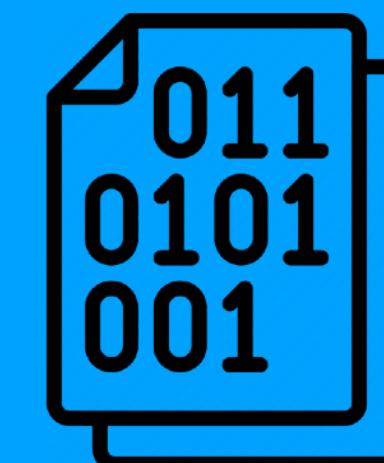


Organism

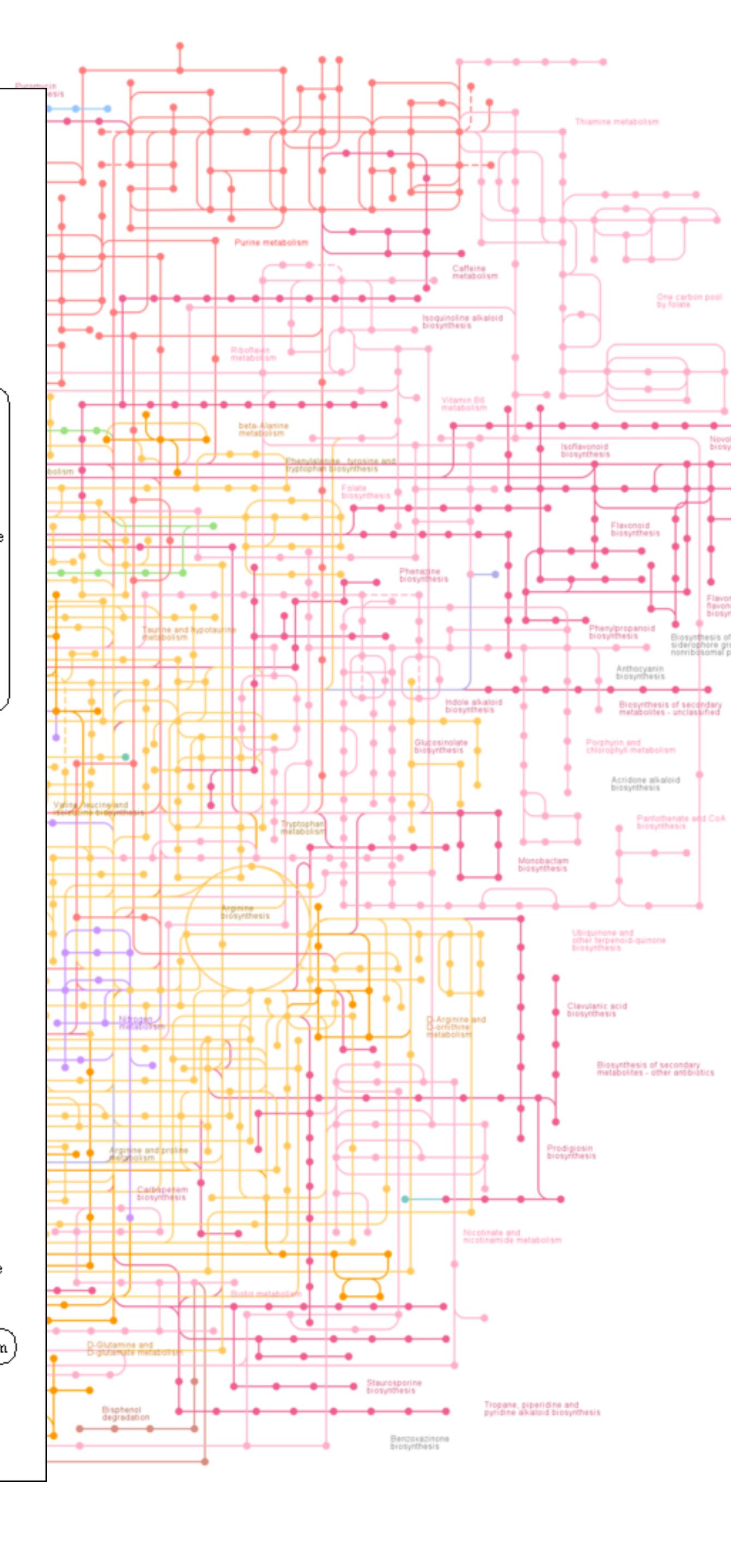
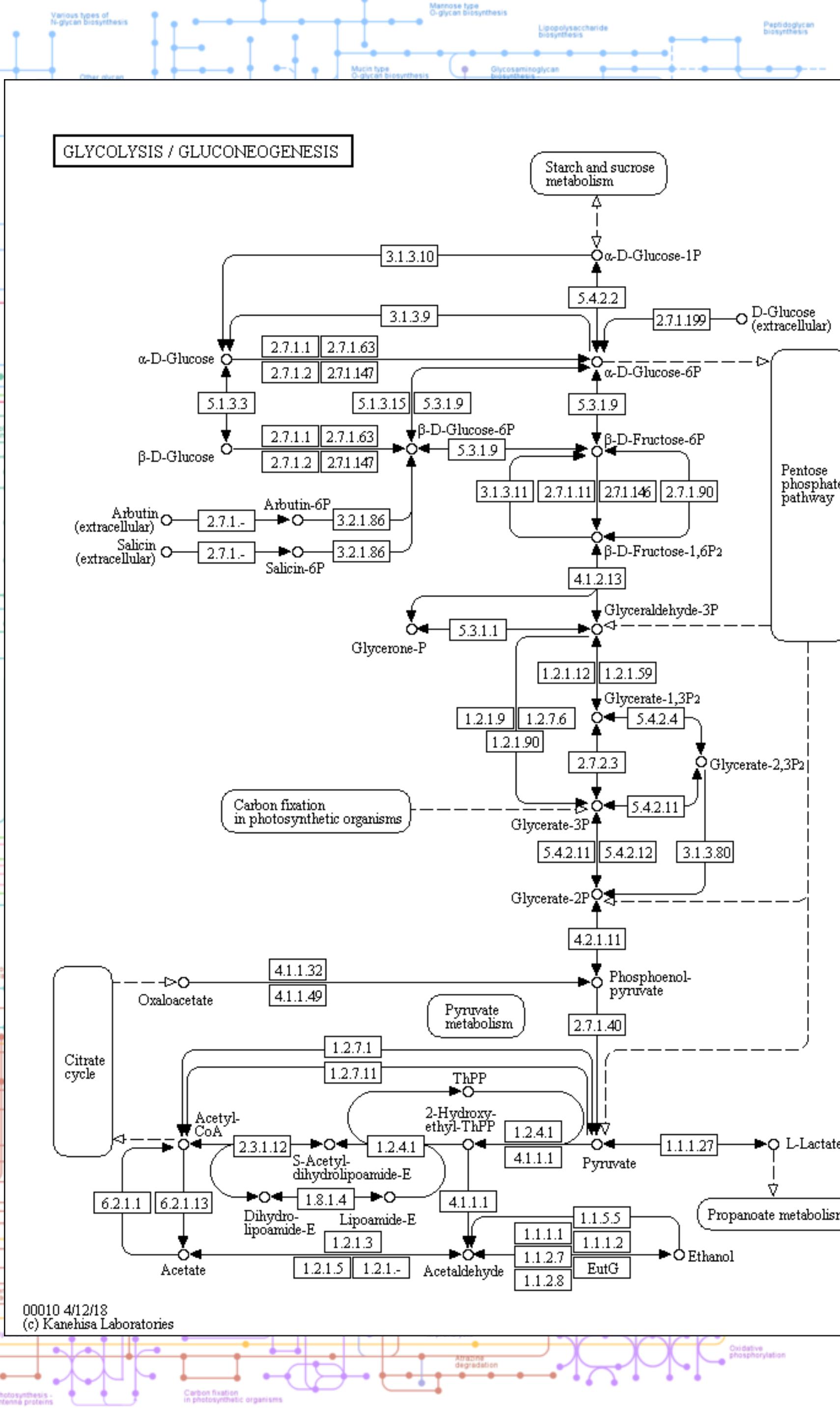
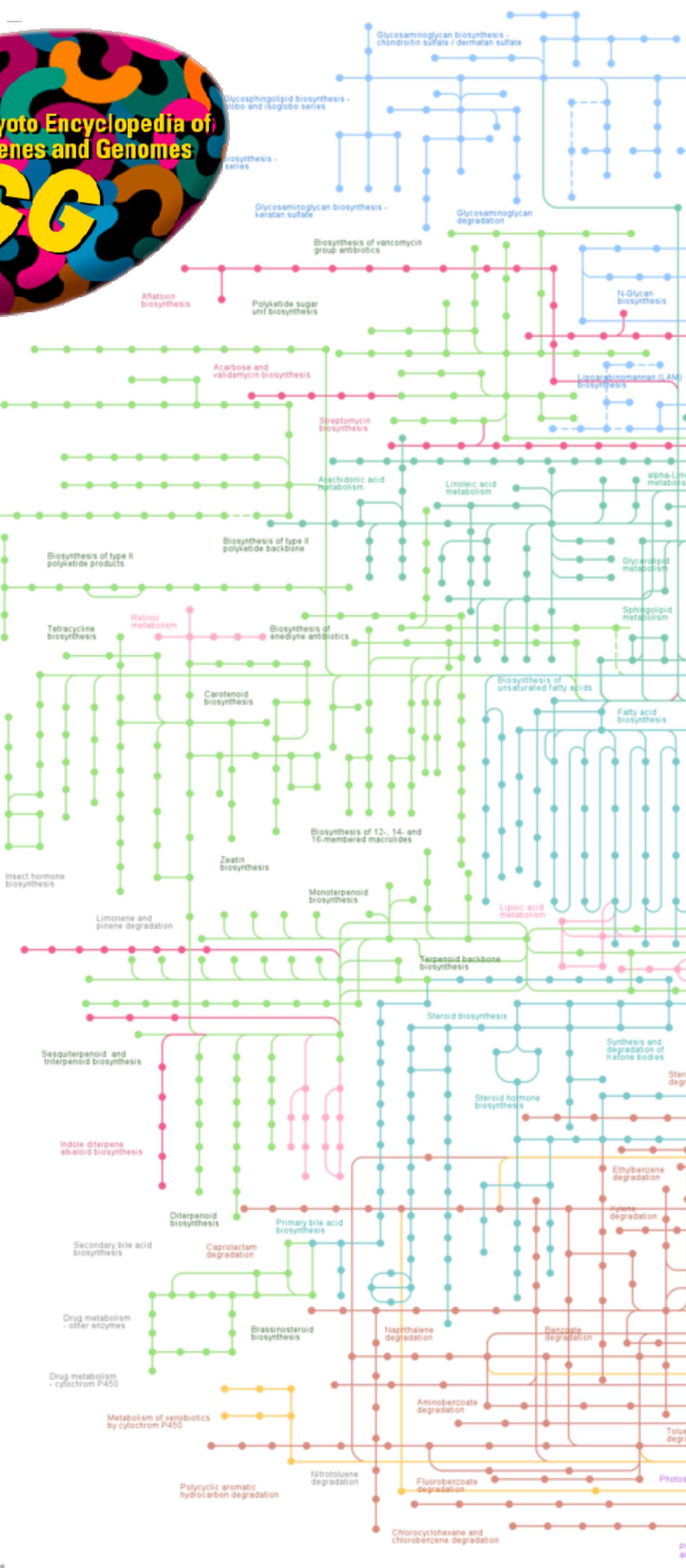
Genome Sequencing

~55,000 Complete Genomes read

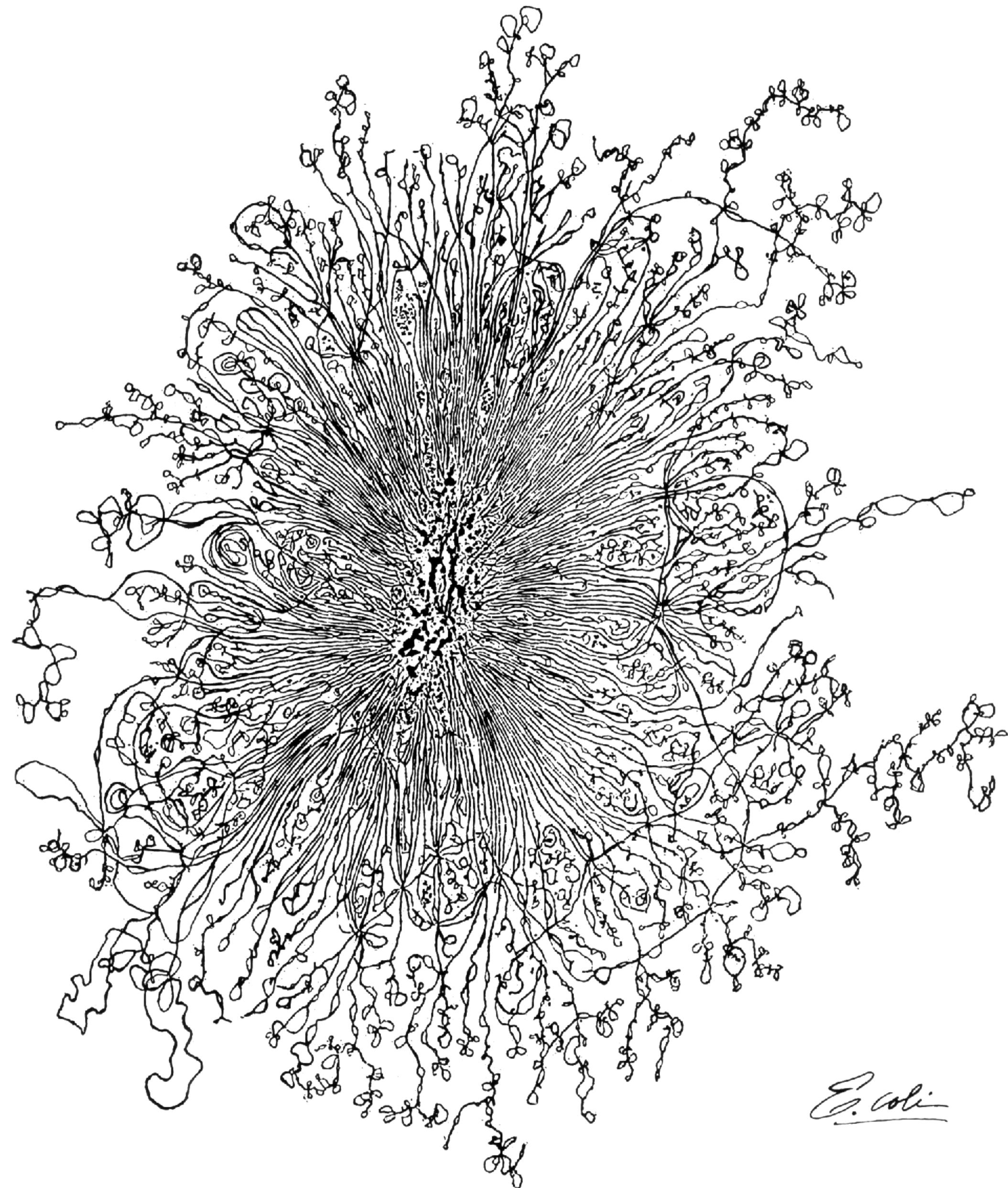
millions of people have been sequenced



DNA sequencing has profound implications
for understanding life at a low level



But we can also write and edit DNA code



dna



restriction enzymes



ligases

if you can write DNA,
you're no longer limited
to "What is" but to what you could make.

Quote by Stanford synthetic biologist Drew Endy



WELCOME TO THE FUTURE

Print DNA faster with the all new BioXp™ 3250 system



Writing the Future



DNA synthesis technology - or DNA molecule “printers”



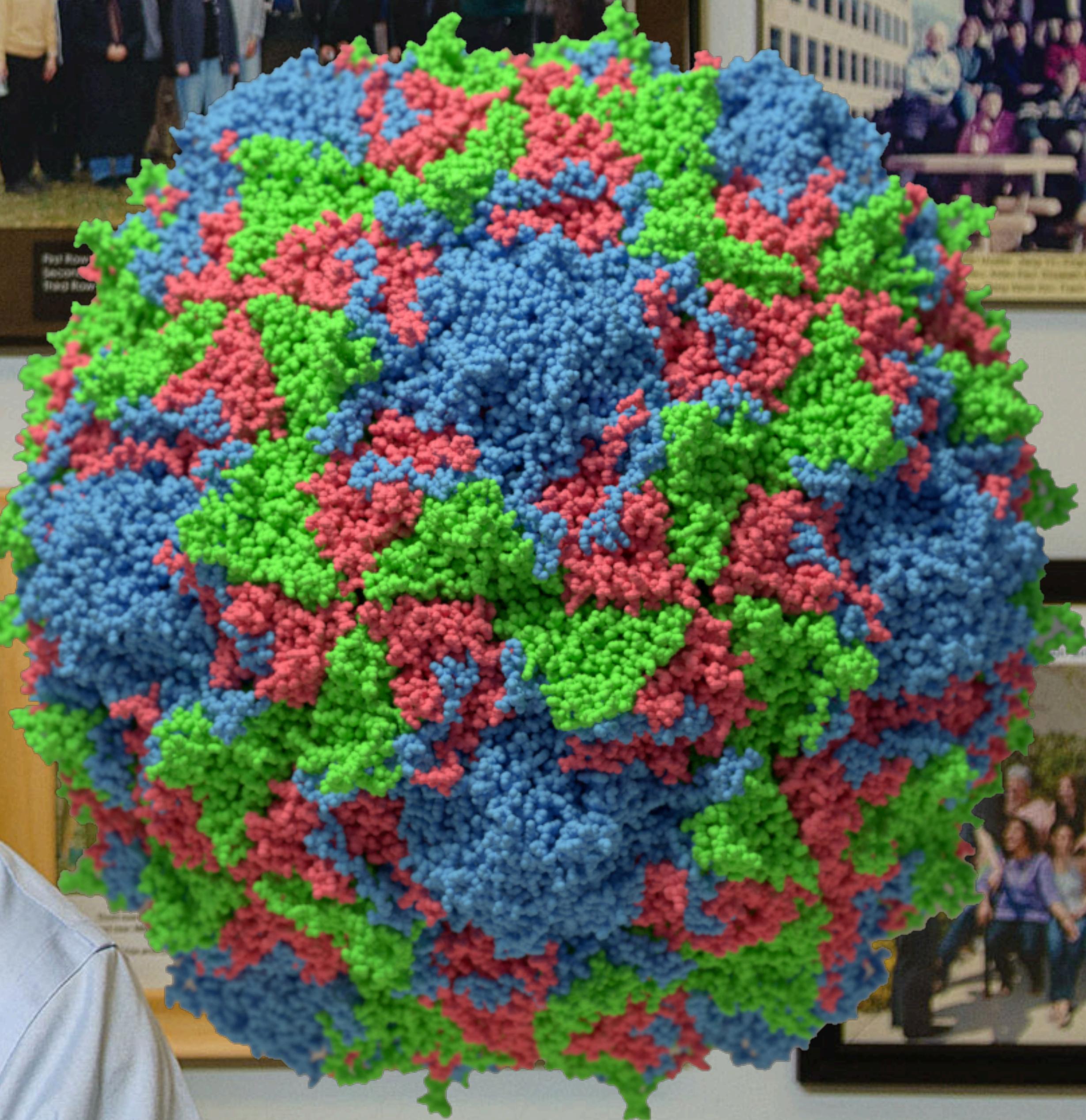
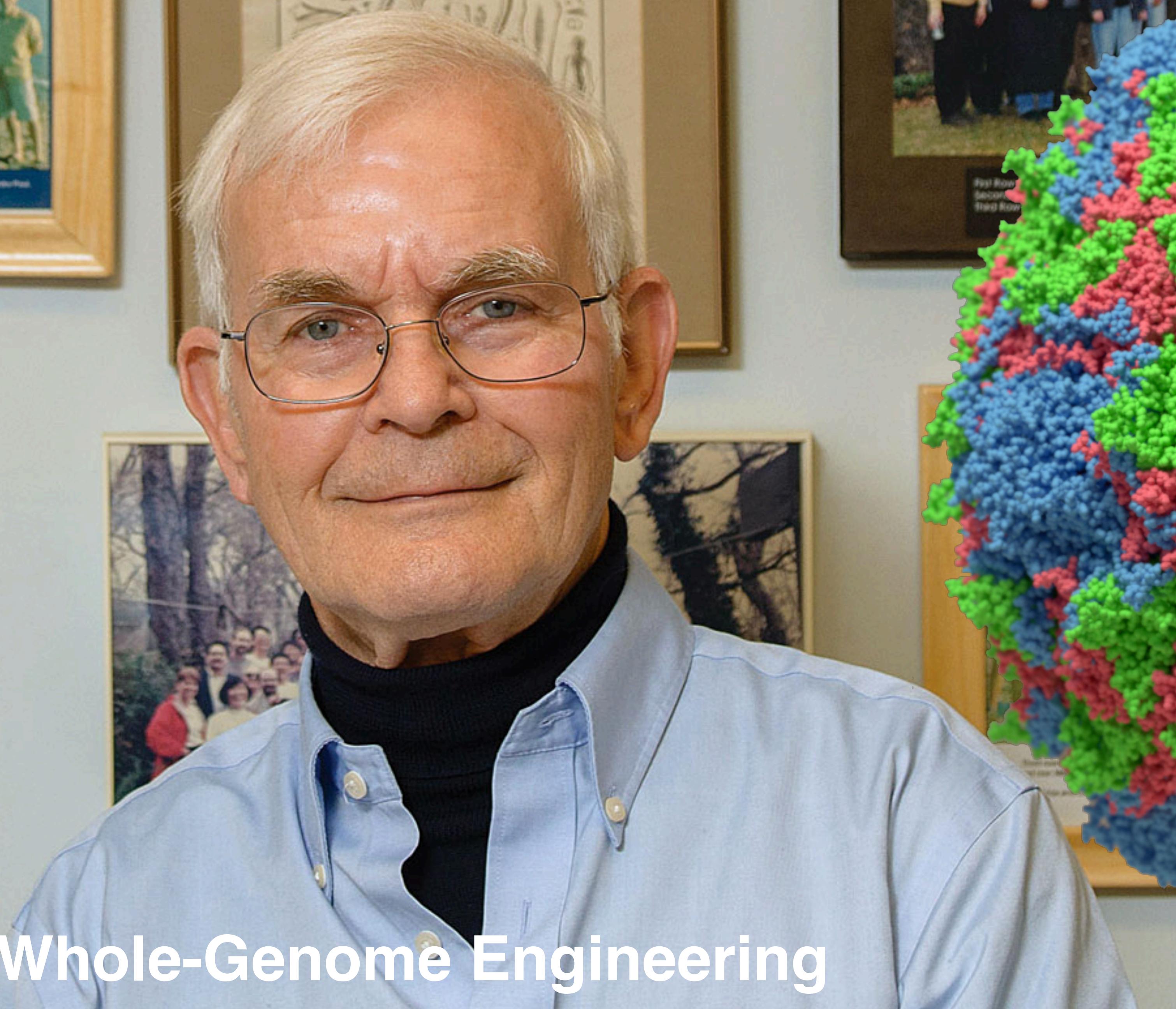
GINKGO BIOWORKS™
THE ORGANISM COMPANY



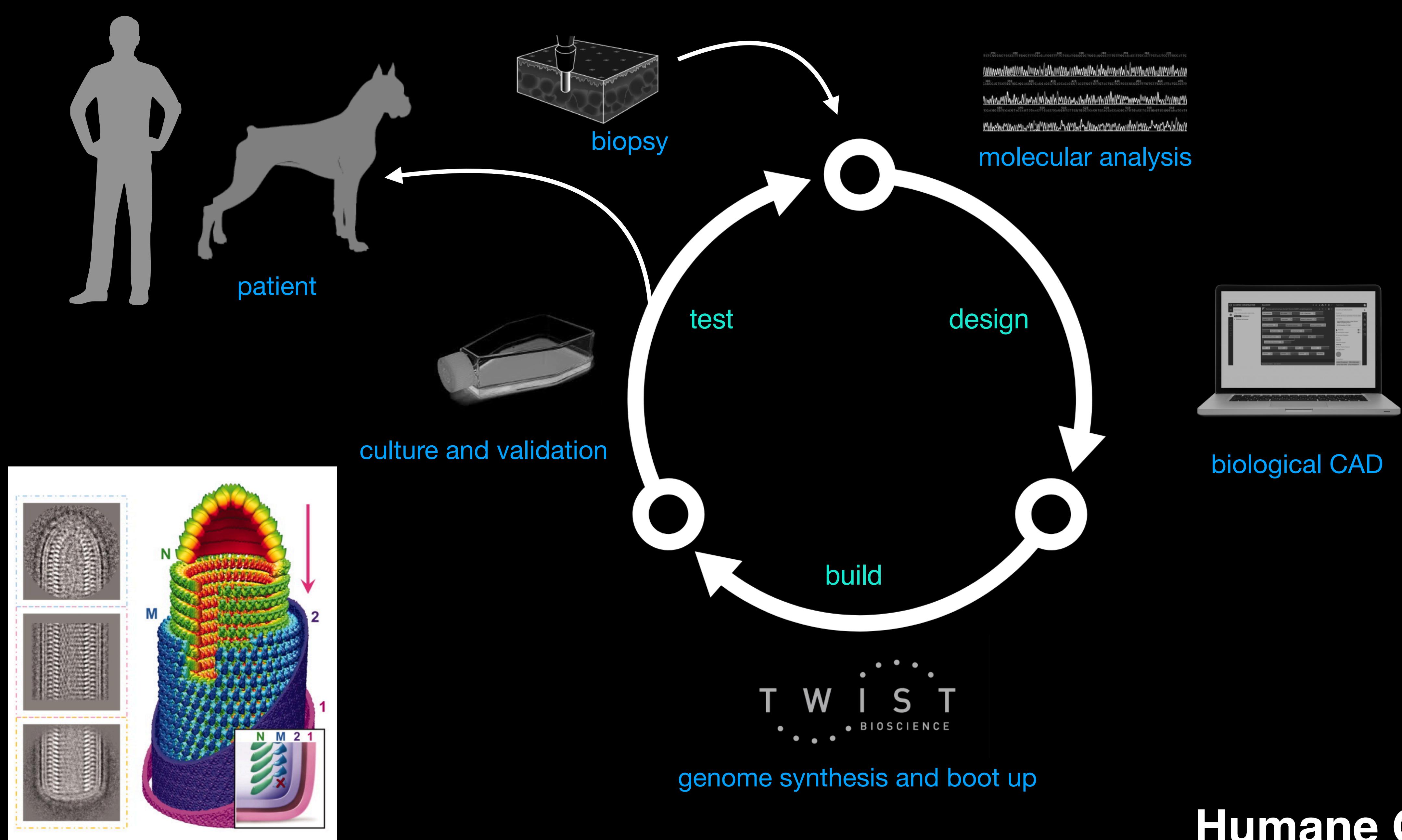
TIM LLEWELLYN/GINKGO BIOWORKS

write the genome = build the organism

Whole-Genome Engineering



Dr. Eckhard Wimmer

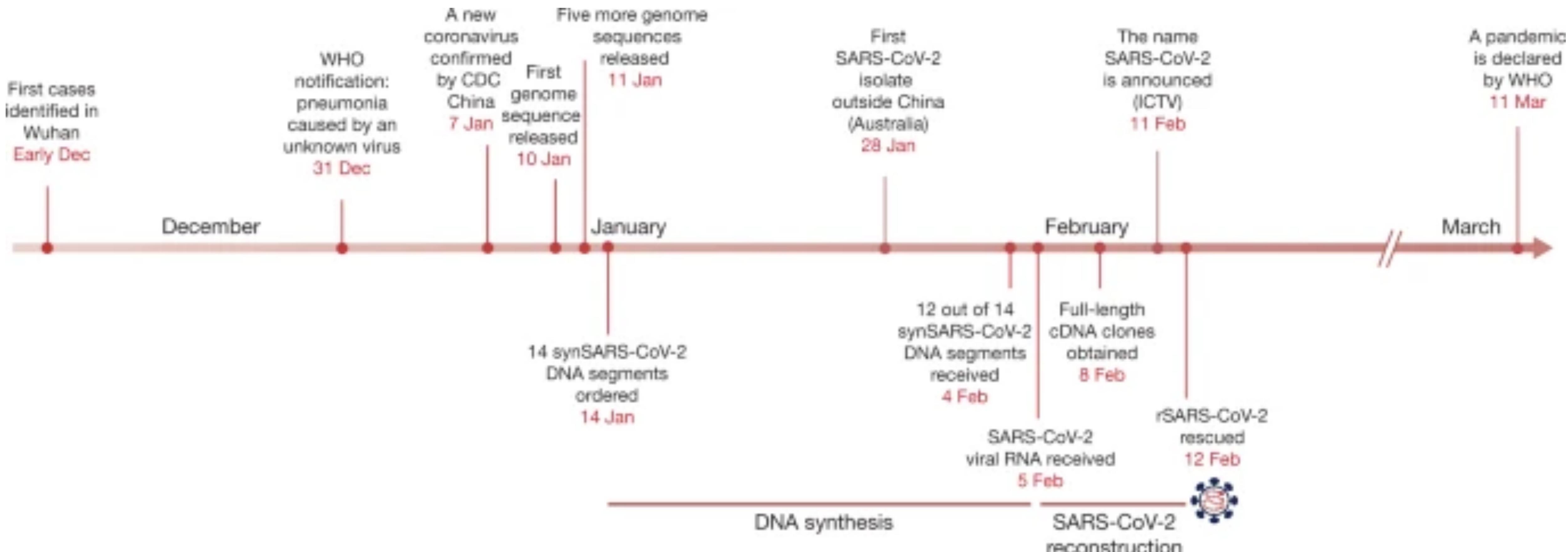


Humane Genomics

Rapid reconstruction of SARS-CoV-2 using a synthetic genomics platform

Tran Thi Nhu Thao, Fabien Labroussaa, [...] Volker Thiel *Nature* 582, 561–565(2020) | Cite this article

87k Accesses | 8 Citations | 1052 Altmetric | Metrics

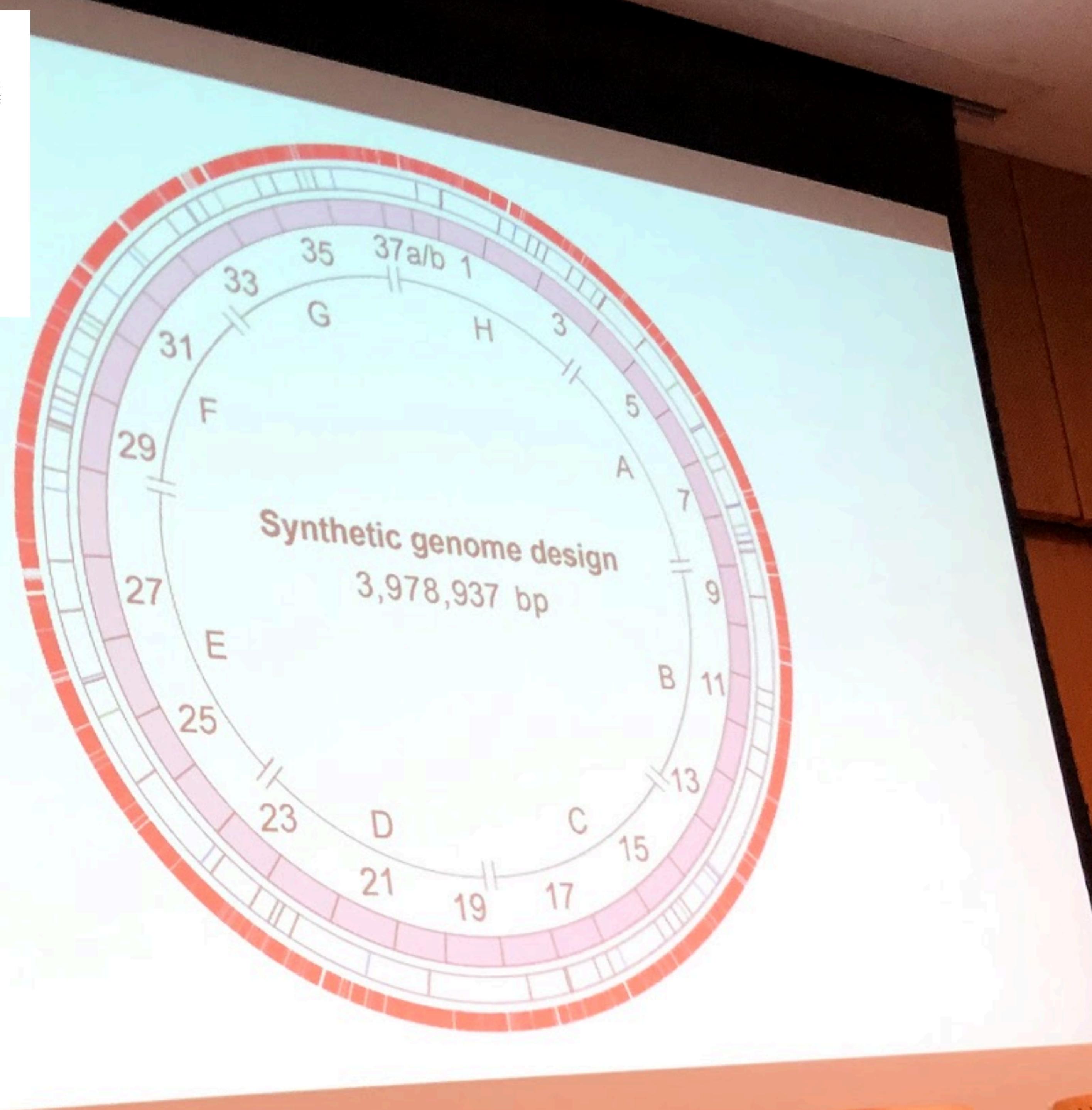


ARTICLE

<https://doi.org/10.1038/s41586-019-1192-5>

Total synthesis of *Escherichia coli* with a recoded genome

Julius Fredens^{1,4}, Kaihang Wang^{1,2,4}, Daniel de la Torre^{1,4}, Louise F. H. Funke^{1,4}, Wesley E. Robertson^{1,4}, Yonka Christova¹, Tiongsun Chia¹, Wolfgang H. Schmied¹, Daniel L. Dunkelmann¹, Václav Beránek¹, Chayasith Uttamapinant^{1,3}, Andres Gonzalez Llamazares¹, Thomas S. Elliott¹ & Jason W. Chin^{1*}



A 35-year romance with
a seafaring microbe *p. 1006*

Social ties and policy reforms in
China's S&T system *pp. 1019 & 1022*

Designing zeolites
to react *pp. 1028 & 1057*

Science

SYNTHETIC CHROMOSOMES

Remodeling the yeast genome
piece by piece *p. 1038*

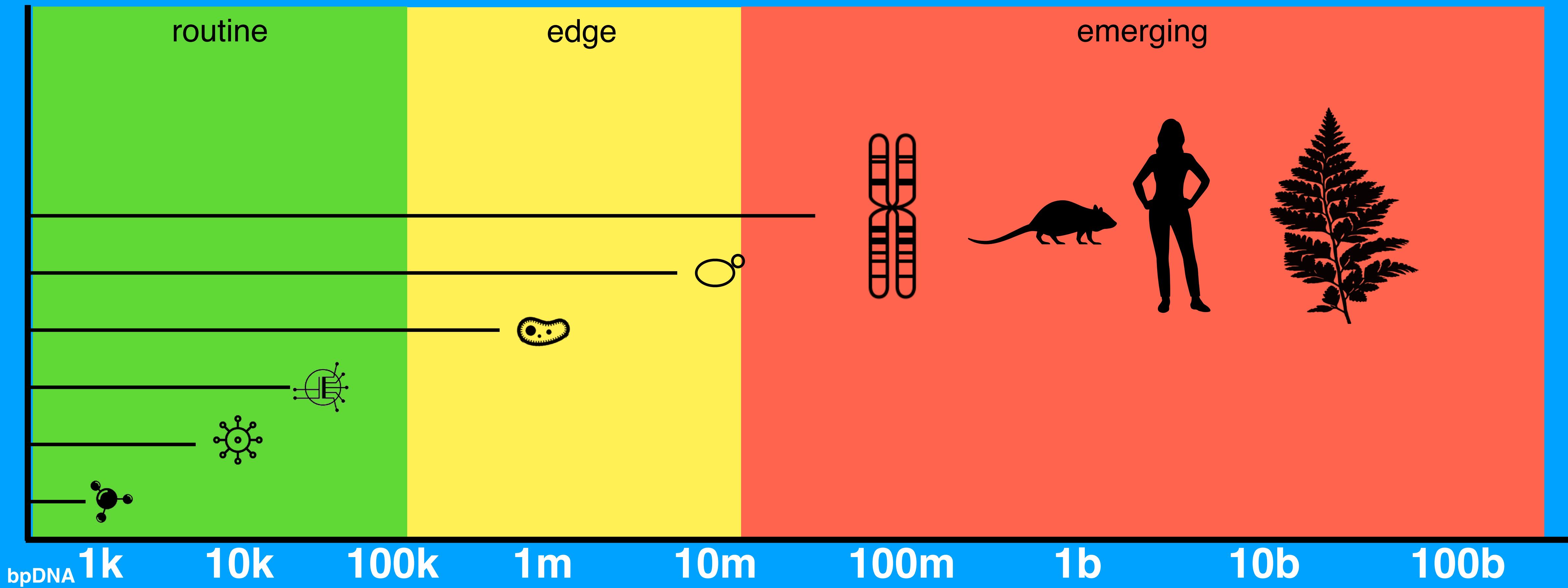


\$15
10 MARCH 2017
sciencemag.org

AAAS



Current DNA synthesis capabilities (2020)



We are entering an era where organisms can be programmed as today we program computers

Why write genomes?

Genome engineering allows atomic control and understanding of an organism's form and function, providing new insights into how life works, accelerating the development of diverse applications, and opening the door to completely novel capabilities.

It's a revolution in evolution.

GP-write

A Grand Challenge Project
to Build and Test New
Genomes



**“What I cannot create,
I do not understand”**

Richard Feynman

While the sequence of the human genome has been known for nearly 20 years, many mysteries in life's recipe book remain to be solved. That's why one group of researchers as well as ethicists and communicators is proposing to move **from passively reading genomes to actively writing them**.

Founded 2016 to explore the science, technology, ethics, standards, and social implications of whole genome engineering.

Engineered
organisms

design/modification

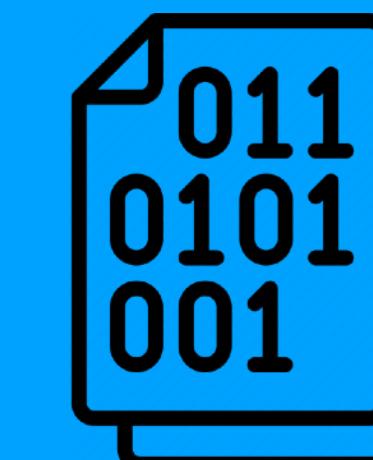
Genome Synthesis

~50 Complete Genomes written

most of them viruses

Organism

synthetic genomics
cycle



conservation
teleportation
de-extinction

Genome Sequencing

~55,000 Complete Genomes read

millions of people have been sequenced

What can we expect?

- Continued advancement of and access to DNA sequencing and data analysis
- DNA synthesis (write) capabilities to quickly equalize with DNA sequencing (read::write) — this is important!
- Improved CAD tools for organism design and engineering
- More automation, miniaturization, and standarization of laboratory systems — particularly test and measurement
- Rapid rise of new companies, applications, and growth of the bioeconomy



Apple 1976



Apple 2020



Photo by National Cancer Institute on Unsplash



Emerald Cloud Lab

Zymergen



How do you harness the benefits?

- Commit, even if there is not full consensus
- Create and implement a vision and strategy
- Develop and implement standards for digitization and automation
- Educate at all levels, starting with K-12
- Invest in biological science, engineering, biomedicine, and entrepreneurship
- Remove regulatory barriers to entry and activity

What are the risks?

- Lack of transparency, oversight, and international cooperation
- Asymmetry between bioengineering and biosecurity, particularly with viruses
- Biological warfare, biological terrorism, bio-error
- Societal resistance because of lack of trust, understanding
- “Missing the boat” – not taking action, not trying new things

