Introduction to Synthetic Biology/21IMBT703
Module01

Program: Int.M.Tech in Bioengineering
Academic Year: 2025-2026

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Disclaimer:

The content delivered here should be considered of utmost importance. However, it is to be noted that, this material is not Stand-alone material for the fulfilment of the course syllabus. The content in this presentation should only be used as an aid to learning.

Books and other resources provided are suggested to be referred for exhaustive understanding.

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Syllabus:

Introduction to logic gates, analog and digital systems, historical perspective of synthetic biology. Current status and future of synthetic biology.

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Objective/Learning Outcome:

CO1. Understand fundamental engineering concepts applicable to biological engineering

CO2. Recognize key research work from academia & industry towards practical applications

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WHY?

- To familiarize students with the data that arises from studies in molecular biology.
- To describe the application of engineering principles to the engineering of biological systems.
- To educate students about the different stages of the synthetic biology life cycle.
- To introduce and demonstrate the basic theory underlying the concepts and techniques of synthetic biology.

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WHAT?

Basic concepts of molecular biology: genomes, transcriptomes, proteomes.
Basic and advanced techniques in genetic engineering.
Engineering biological systems.
Ethical, legal and social implications of synthetic biology.
An introduction to the synthetic biology life cycle:

- Systems requirements, specification
- Computational design
- Strategies for part, device, system and genome implementation.
- Strategies for part, device and system characterisation.
- Learning strategies for iterative design

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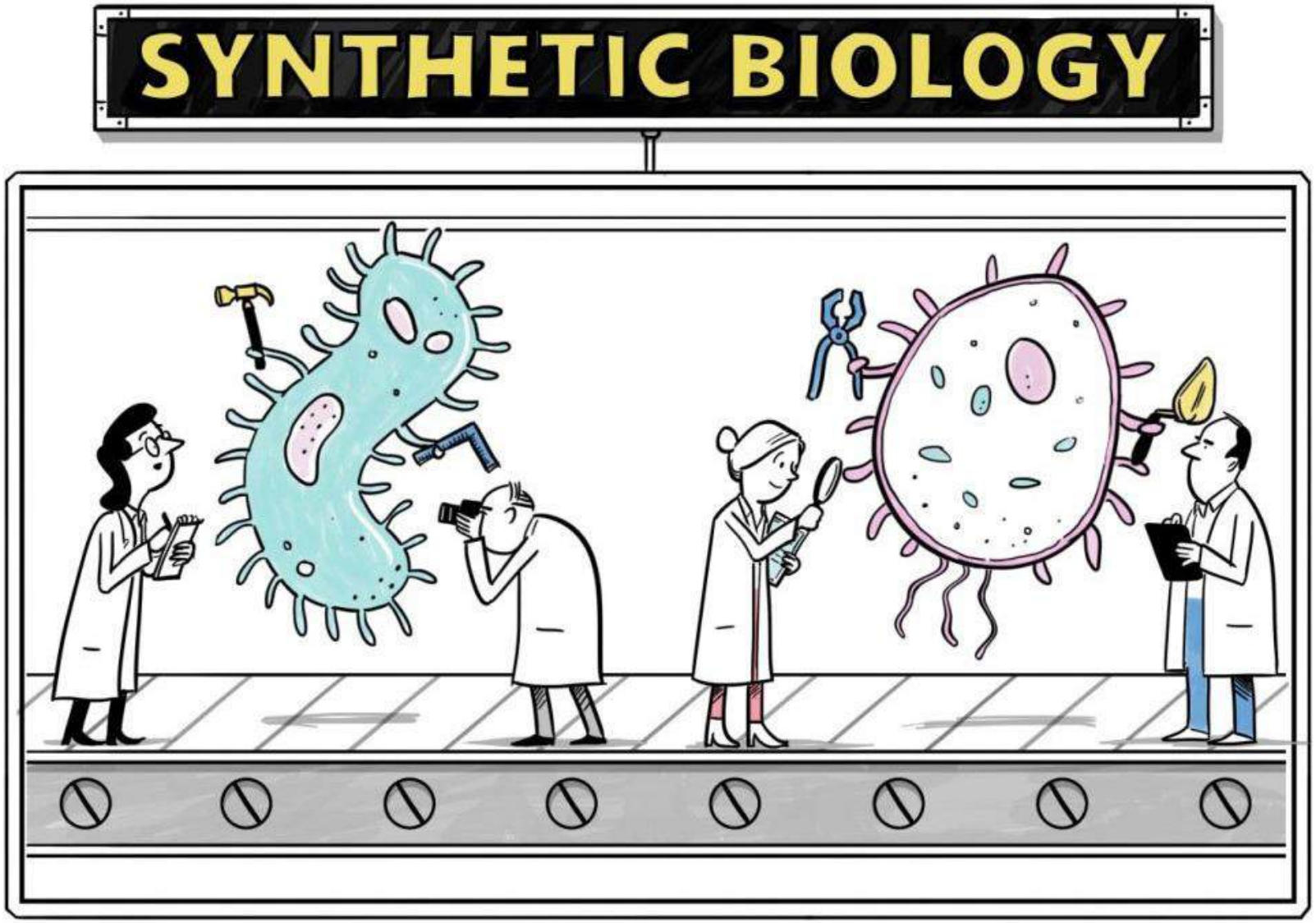
Syn•thet•ic Bi•ol•o•gy
noun
The application of engineering principles in biology to (re-)design and fabricate biological components and systems that do not already exist in the natural world.



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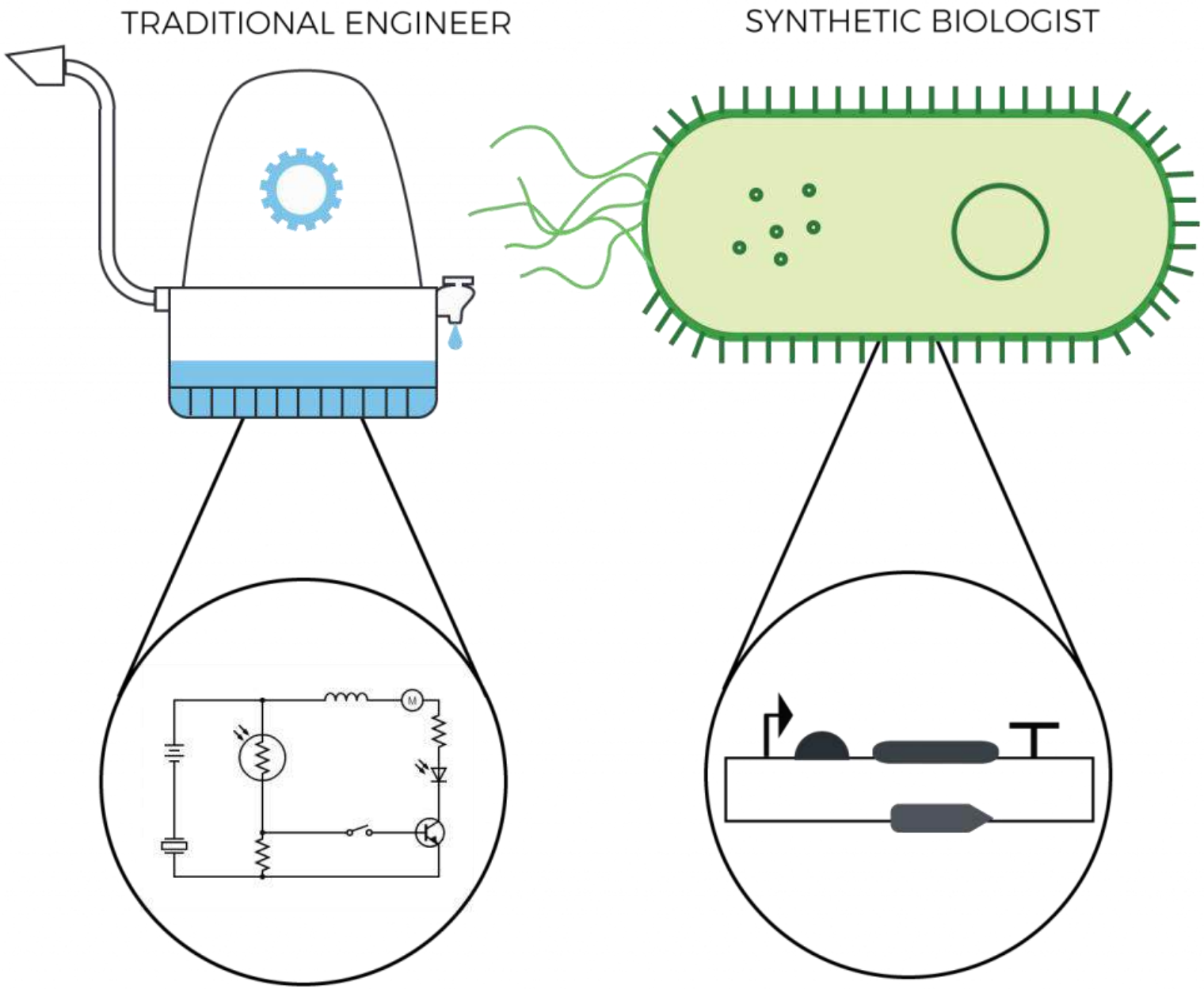

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“Using synthetic DNA”

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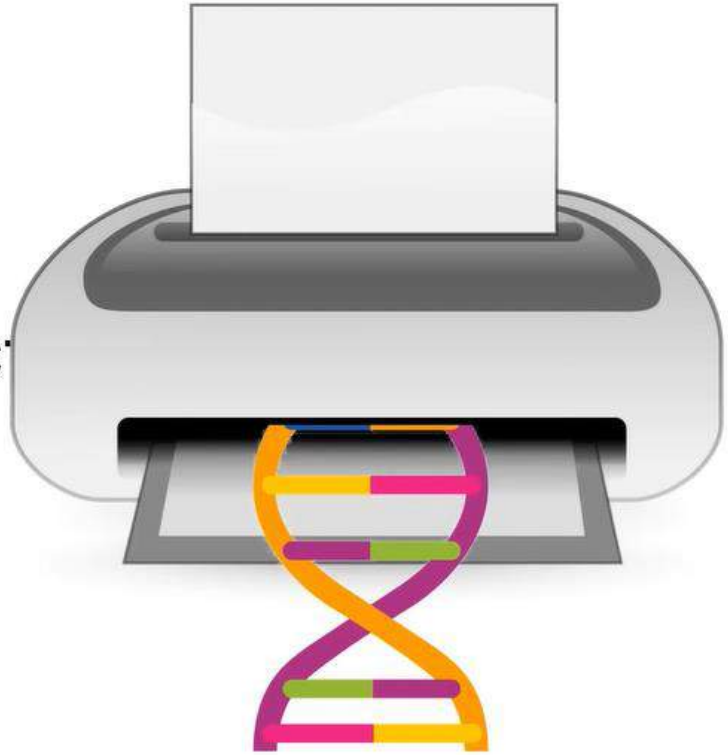

MIT School of Bioengineering Sciences & Research

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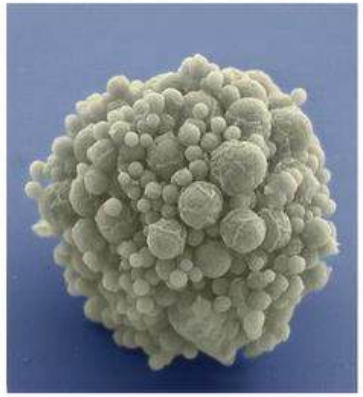
“Creating new organisms/life forms”



Mycoplasma laboratorium

BUILD A CELL

European Synthetic Cell Initiative

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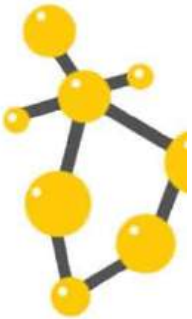
SYNTHETIC BIOLOGY FACTS

Synthetic proteins are the next step after cell transformation.

Biosensors are among the most promising applications of synthetic biology.

Scientists used DNA as a storage medium for synthetic biology.



Biological computers are only one of many applications of synthetic biology.

Synthetic biology redesigns existing cells and lifeforms.

NASA studies synthetic biology for applications in space.

Synthetic life is the ultimate goal of synthetic biology.

Biosafety is a major concern for synthetic biologists.

The creation of synthetic life poses a major ethical dilemma for synthetic biology.

Activists have called for a complete ban on any work on the human genome.

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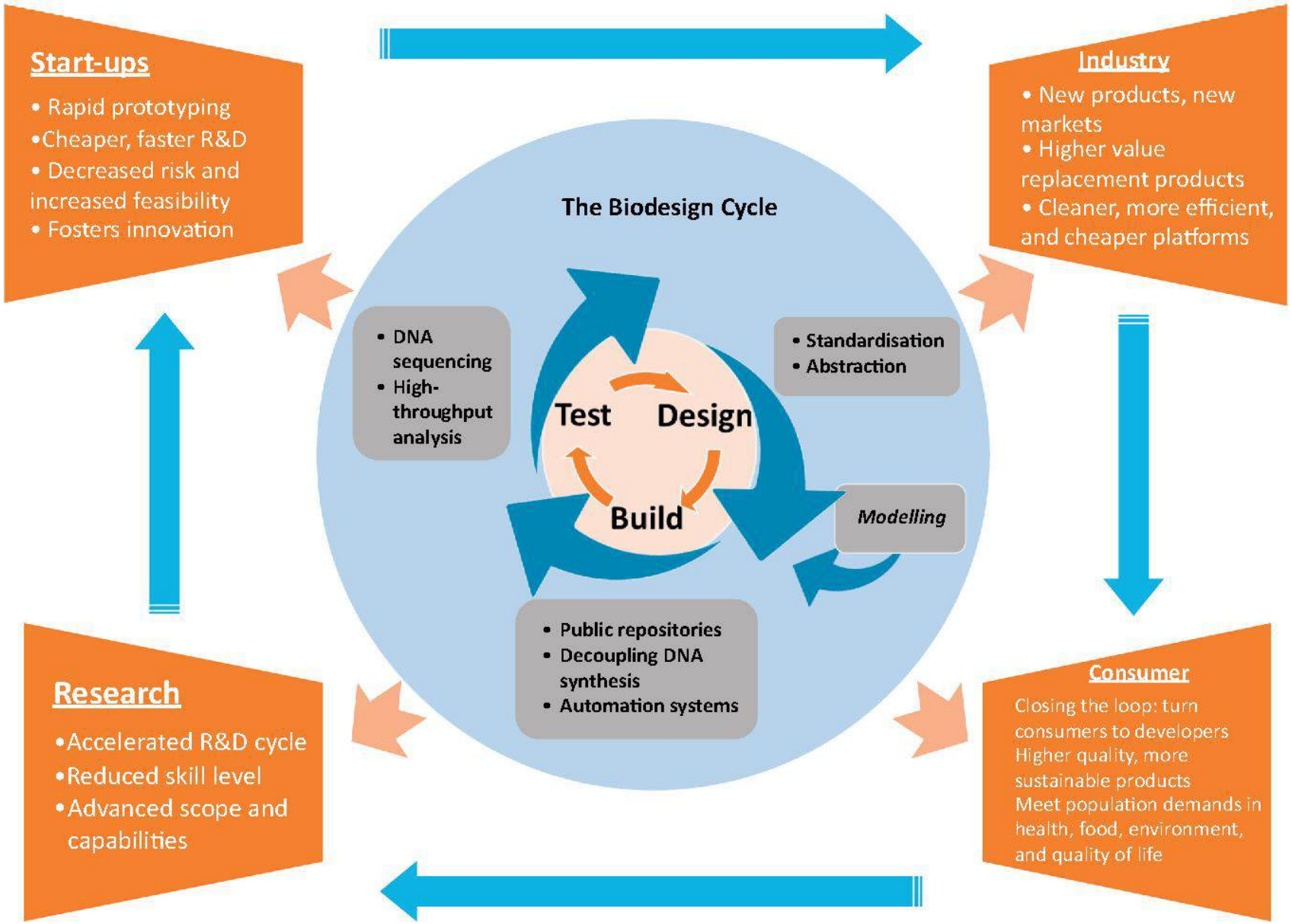
Start-ups
• Rapid prototyping
•Cheaper, faster R&D
• Decreased risk and increased feasibility
• Fosters innovation
Industry
• New products, new markets
• Higher value replacement products
• Cleaner, more efficient, and cheaper platforms
The Biodesign Cycle
• DNA sequencing
• High-throughput analysis
• Standardisation
• Abstraction
Test
Design
Build
Modelling
• Public repositories
• Decoupling DNA synthesis
• Automation systems
Research
•Accelerated R&D cycle
•Reduced skill level
•Advanced scope and capabilities
Consumer
Closing the loop: turn consumers to developers
Higher quality, more sustainable products
Meet population demands in health, food, environment, and quality of life

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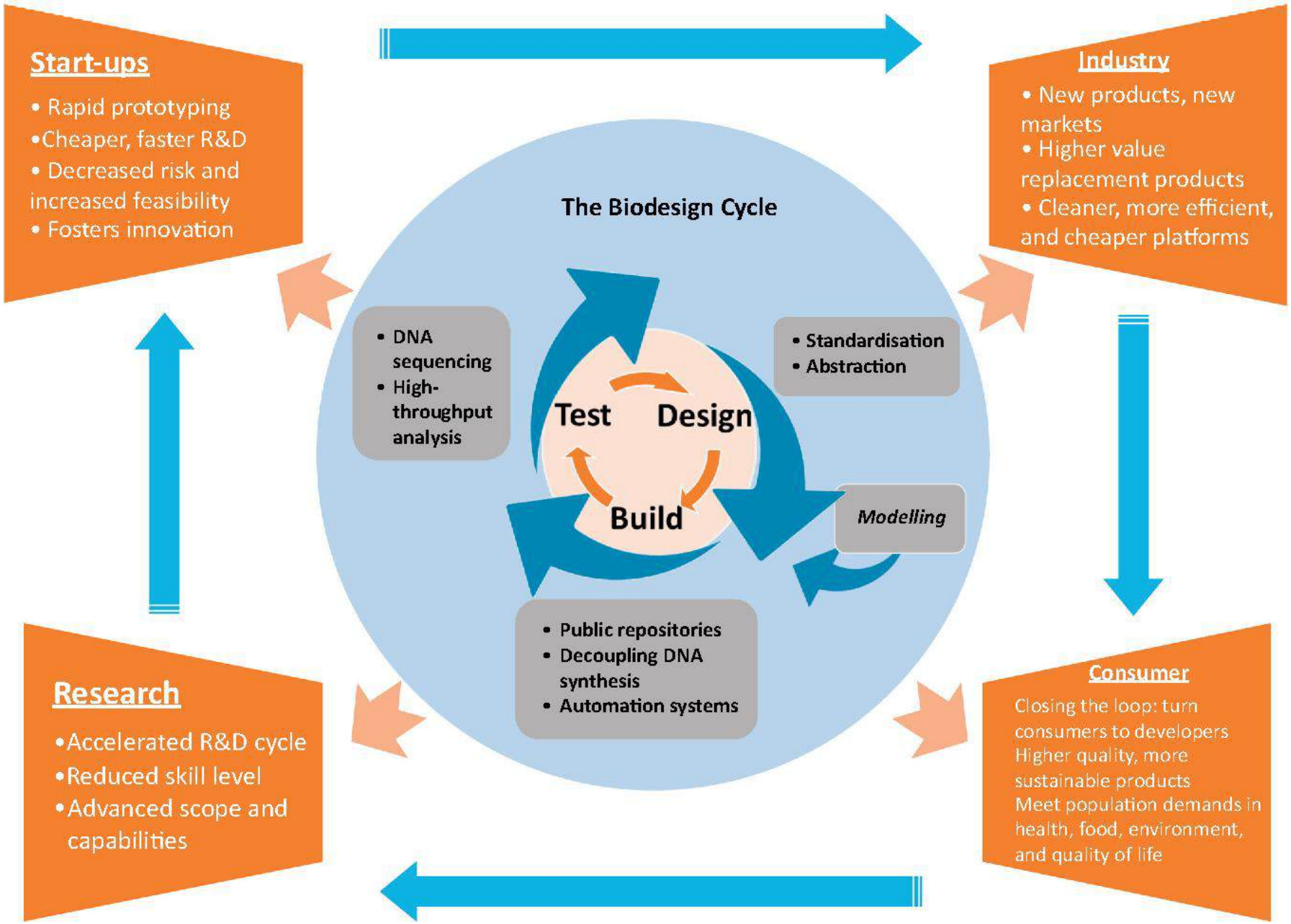
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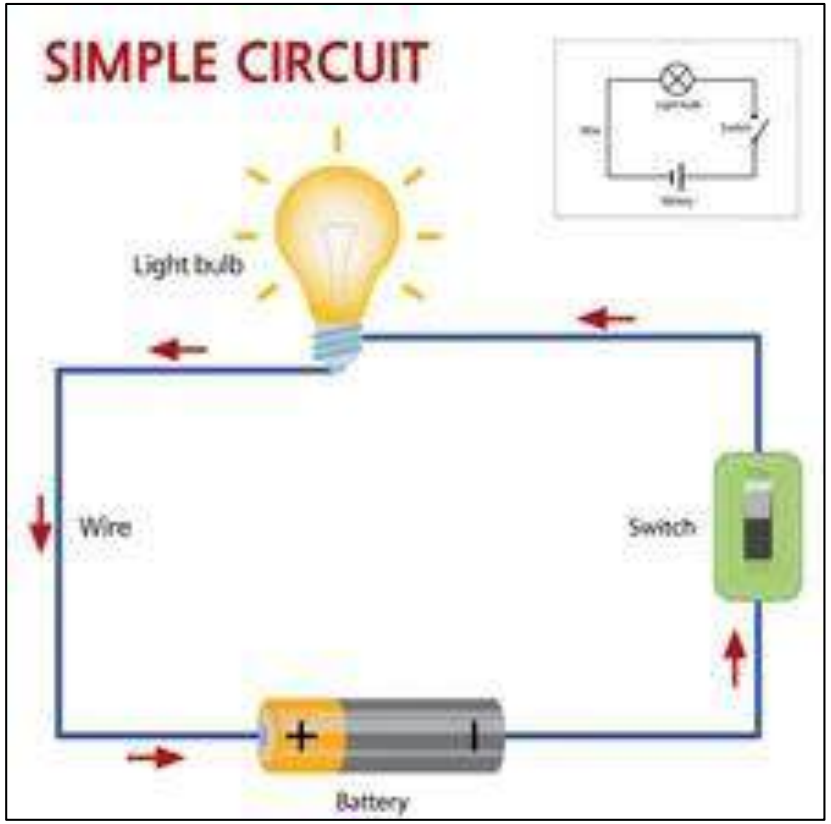

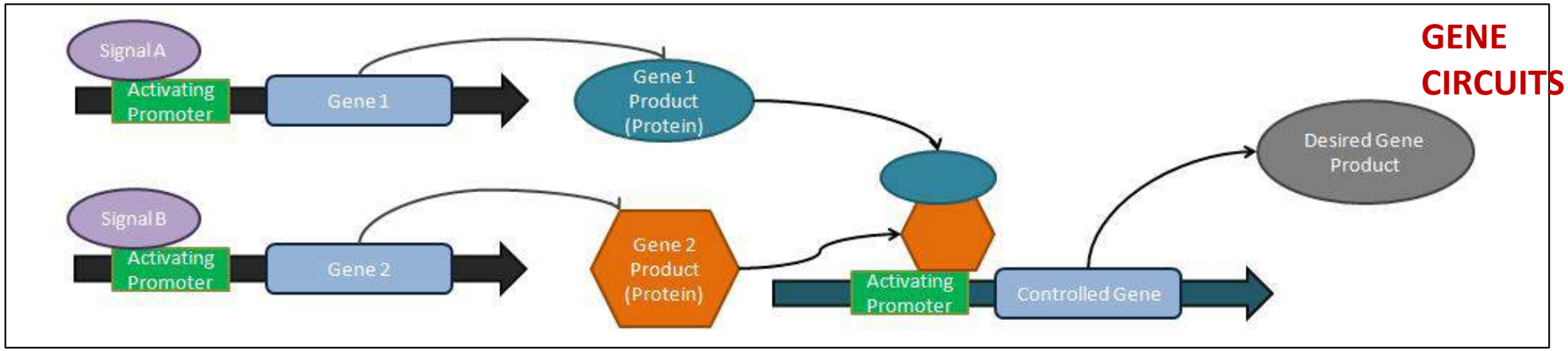

GENE CIRCUITS

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Synthetic Biology
Vs
Genetic Engineering

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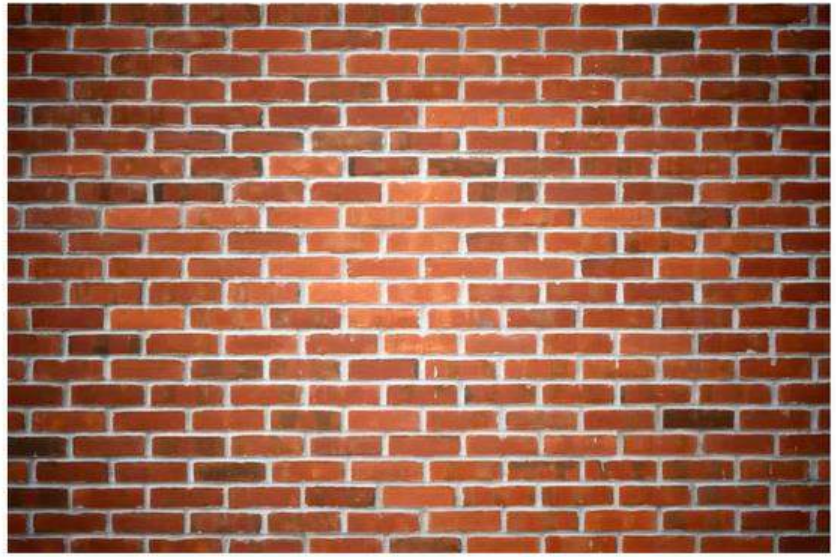
“Combining Biology and Engineering”

Genetic Engineering



Synthetic Biology

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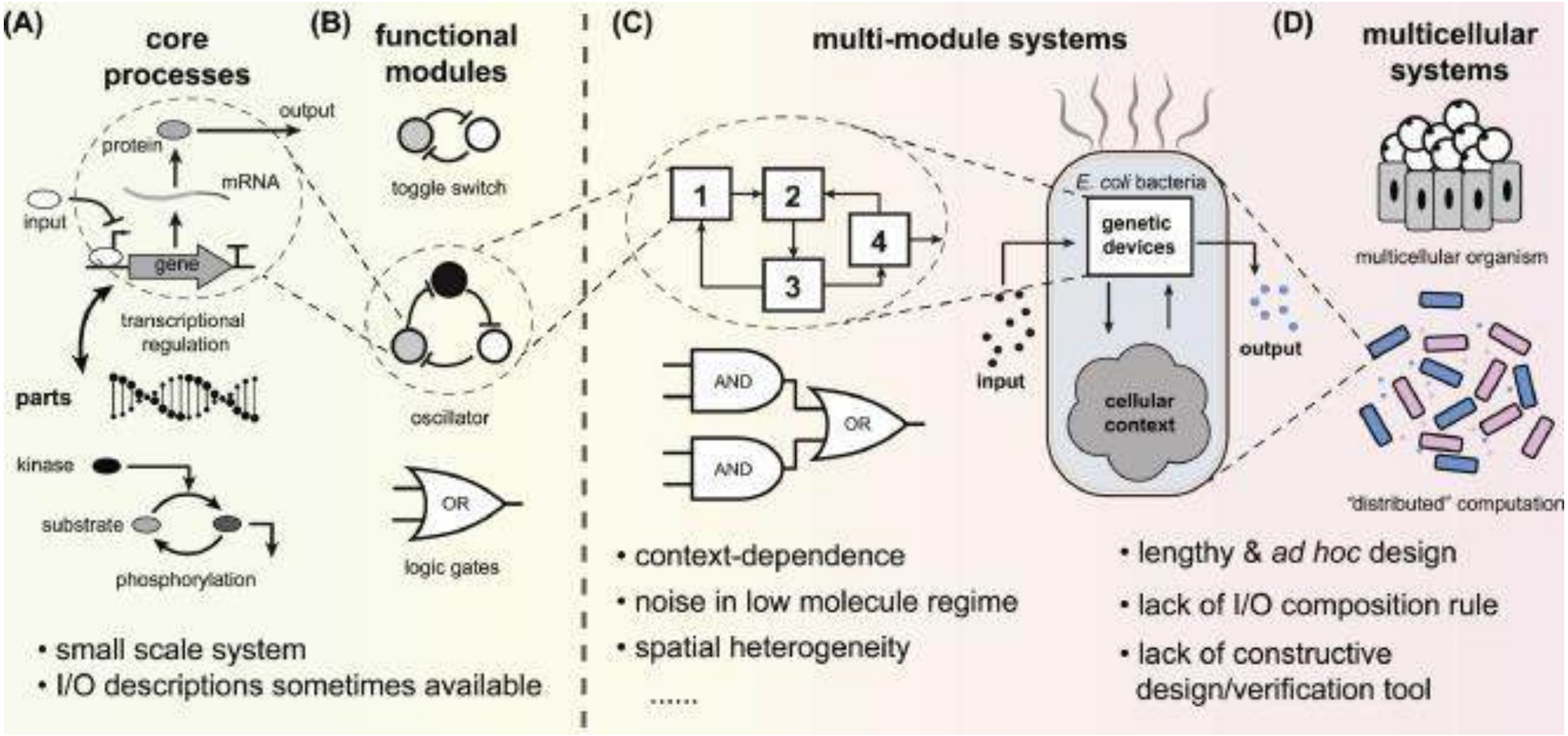
(A)
core processes
output
protein
mRNA
input
gene
transcriptional regulation
parts
kinase
substrate
phosphorylation
(B)
functional modules
toggle switch
oscillator
OR
logic gates
• small scale system
• I/O descriptions sometimes available
(C)
multi-module systems
1
2
3
4
AND
AND
OR
E. coli bacteria
genetic devices
input
output
cellular context
• context-dependence
• noise in low molecule regime
• spatial heterogeneity
.....
(D)
multicellular systems
multicellular organism
"distributed" computation
• lengthy & ad hoc design
• lack of I/O composition rule
• lack of constructive design/verification tool

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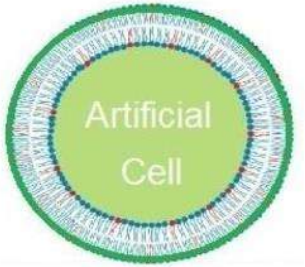
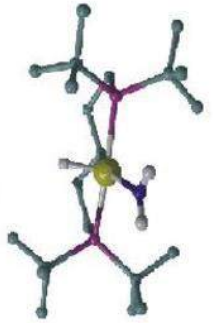
Top Down elimination approach:



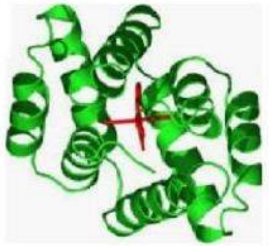
Bottom-up
Synthetic Biology

increasing
complexity

Bottom Up approach:



Abiotic Building Blocks



Is it possible?

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Industrial SynBio: Fabricating At Scale With Biology

Renewable Chemicals

genomatica
greenlight
Arzeda.
LYGOS
INDUSTRIAL MICROBES
SYNTHETIC GENOMICS

Multi-Product

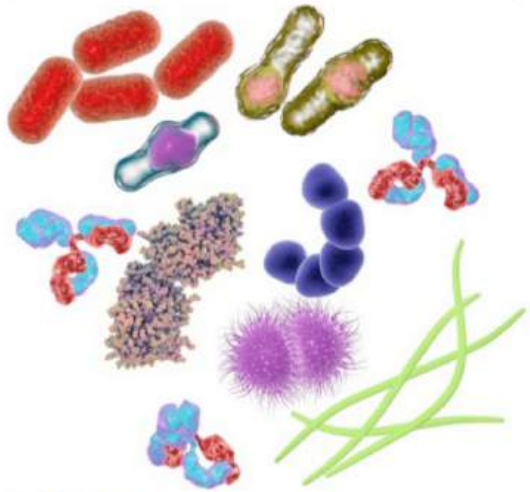
zymergen
GINKGO BIOWORKS™ THE ORGANISM COMPANY
SYNTHACE
CARIBOU BIOSCIENCES

Materials, Fabrics, & Fibers

Bolt Threads
BENTHIC LABS
Modern Meadow
glowee enlightened by the sea

Biofuels & Oils

LanzaTech
novvi
C16 BIO
JOULE



Alternative Plastics

AMBERCYCLE
BioCellection

Fertilizer

PIVOT BIO
Plant Sensory Systems

Protein & Feed

GELTOR
CALYSTA
TRITON
NOBLEGEN
GEA enzymes

Lab Ops

ELEMENTAL MACHINES
CYRUS BIOTECHNOLOGY
iXpressGenes
SYNVIVIA

Cannabinoids & Alternative Pharma

DEEP CELL
hyasynth
TEEWINOT LIFE SCIENCES
CB Therapeutics

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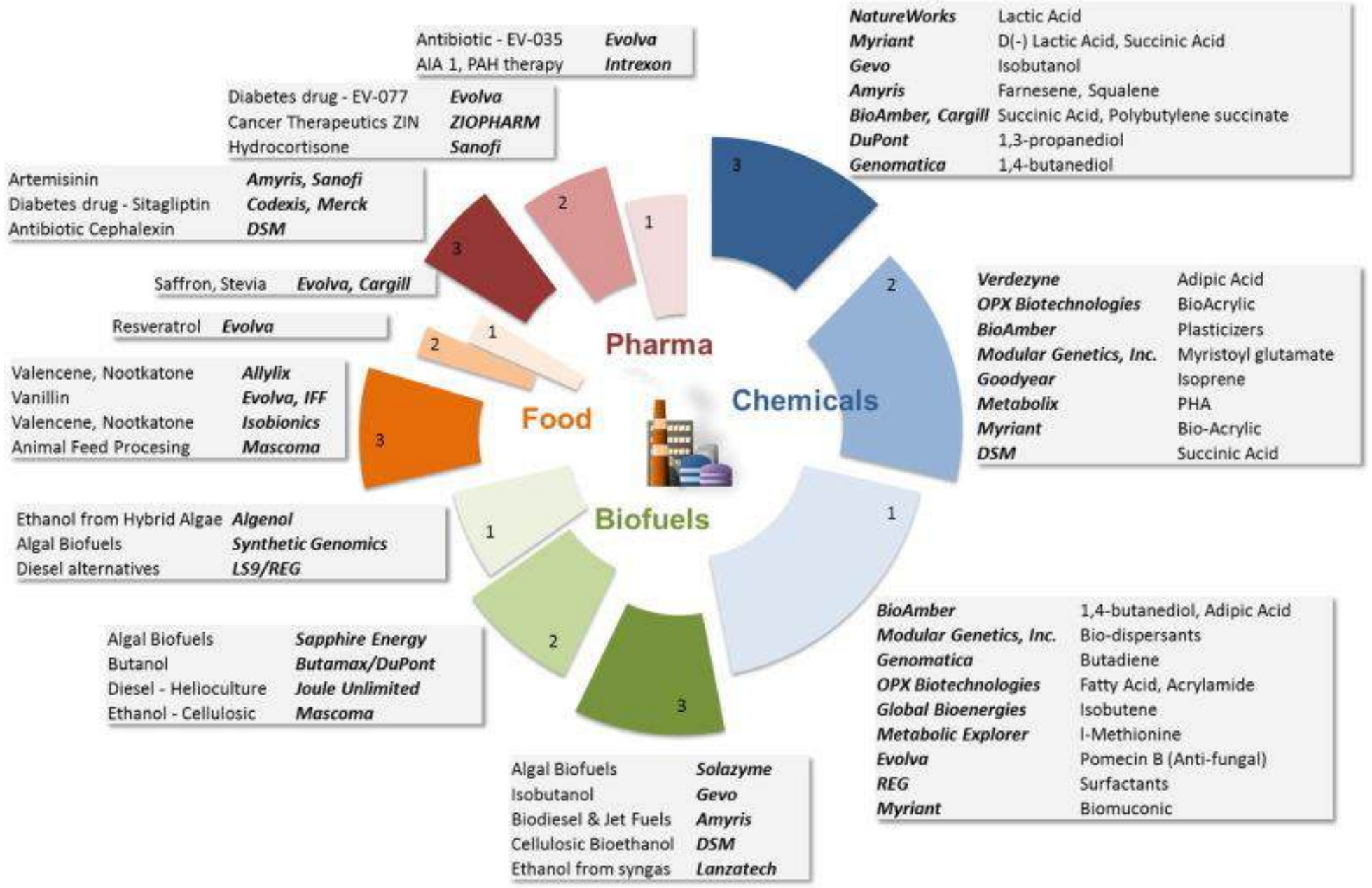
Antibiotic - EV-035 Evolva
AIA 1, PAH therapy Intrexon
Diabetes drug - EV-077 Evolva
Cancer Therapeutics ZIN ZIOPHARM
Hydrocortisone Sanofi
Artemisinin Amyris, Sanofi
Diabetes drug - Sitagliptin Codexis, Merck
Antibiotic Cephalexin DSM
Saffron, Stevia Evolva, Cargill
Resveratrol Evolva
Pharma
NatureWorks Lactic Acid
Myriant D(-) Lactic Acid, Succinic Acid
Gevo Isobutanol
Amyris Farnesene, Squalene
BioAmber, Cargill Succinic Acid, Polybutylene succinate
DuPont 1,3-propanediol
Genomatica 1,4-butanediol
Verdezyne Adipic Acid
OPX Biotechnologies BioAcrylic
BioAmber Plasticizers
Modular Genetics, Inc. Myristoyl glutamate
Goodyear Isoprene
Metabolix PHA
Myriant Bio-Acrylic
DSM Succinic Acid
Chemicals
Valencene, Nootkatone Allylix
Vanillin Evolva, IFF
Valencene, Nootkatone Isobionics
Animal Feed Procesing Mascoma
Food
Ethanol from Hybrid Algae Algenol
Algal Biofuels Synthetic Genomics
Diesel alternatives LS9/REG
Biofuels
BioAmber 1,4-butanediol, Adipic Acid
Modular Genetics, Inc. Bio-dispersants
Genomatica Butadiene
OPX Biotechnologies Fatty Acid, Acrylamide
Global Bioenergies Isobutene
Metabolic Explorer l-Methionine
Evolva Pomecin B (Anti-fungal)
REG Surfactants
Myriant Biomuconic
Algal Biofuels Sapphire Energy
Butanol Butamax/DuPont
Diesel - Helioculture Joule Unlimited
Ethanol - Cellulosic Mascoma
Algal Biofuels Solazyme
Isobutanol Gevo
Biodiesel & Jet Fuels Amyris
Cellulosic Bioethanol DSM
Ethanol from syngas Lanzatech

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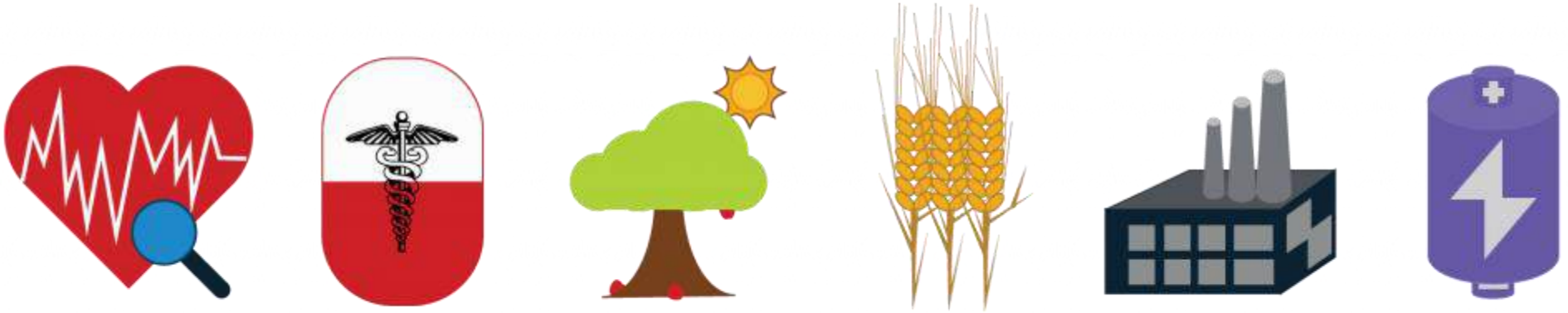
APPLICATIONS OF SYNTHETIC BIOLOGY



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Concerns and challenges

- Public perception of “GMO”
- Replacing current producers, global inequalities
- Intellectual property
- Competition for food production
- Dual-use, biosafety
- Unintended and intentional release

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Summary:

Synthetic biology aims to create customized organisms from a growing catalog of existing molecular parts.

The understanding of living systems in detail allows customization of systems to create desired outcomes

Genome is regarded simply as the sum of its parts or fundamentally modular

Modularity: Genome parts are modular, and retain their integrity and function independance

Biological engineers can select desired genes, assemble them into a genome and give rise to an organism that might never have evolved on its own.

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