STIKES NOTOKUSUMO
YOGYAKARTA

BIOTEKNOLOGI

KONTRAK PERKULIAHAN

Semester Gasal 2025 - 2026

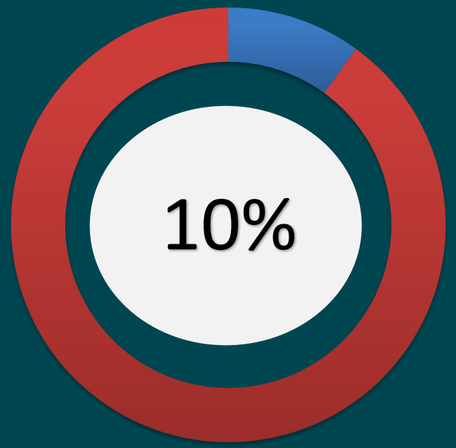
BIOTEKNOLOGI

Deskripsi Mata Kuliah

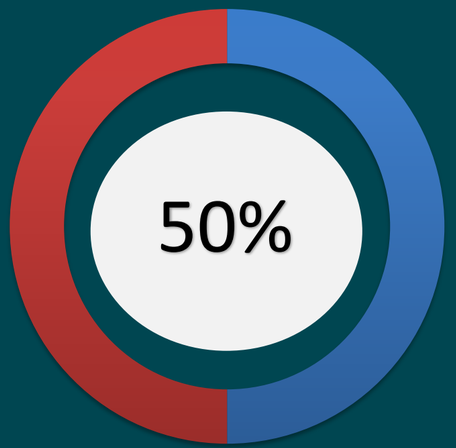
Matakuliah bioteknologi menyajikan gambaran perkembangan bioteknologi yang digunakan sebagai pendekatan pengatasan permasalahan kesehatan, perkembangan bidang farmasi dan perkembangan metode penelitian. Materi yang dicakup dalam mata kuliah bioteknologi meliputi gambaran umum bioteknologi kultur jaringan tanaman, bioteknologi fermentasi, bioteknologi rekayasa genetika, rekayasa protein, rekayasa jaringan, bioteknologi dalam analisis, diagnostik dan penelitian, teknologi antibodi monoklonal, transgenik, dan bioteknologi dalam metode pengujian pra klinis (in vitro).

Ketentuan Perkuliahan

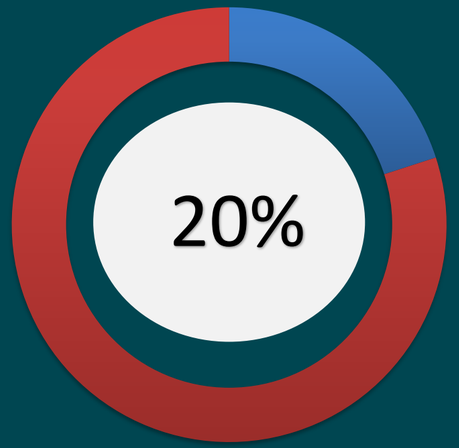
- Hadir tepat waktu. Toleransi keterlambatan 20 menit.
- Jumlah kehadiran 75% dalam 16x pertemuan, termasuk UTS dan UAS.
  → maksimal 4x absen, 2x sebelum UTS dan 2x setelah UTS
  → Melanggar = **NILAI DEFAULT E** (TIDAK LULUS)
- Kuliah : tatap muka, *jika tidak ada kendala*



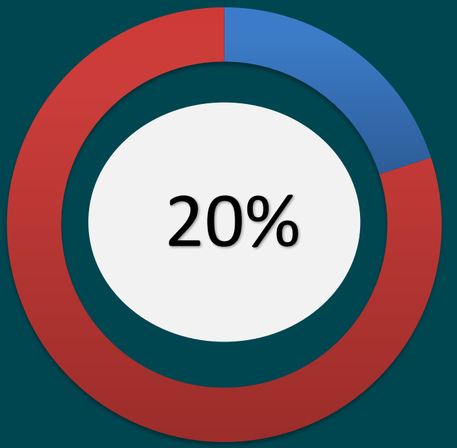
Kehadiran



Tugas



UTS



UAS

RENCANA PEMBELAJARAN SEMESTER

Jadwal Kuliah
Jumat :
08.00 – 09.40 WIB

Dosen Pengampu

- **Koordinator : apt. Trifonia Rosa K, M.Biotech (7x)**
- **Mohamad Ikram, M.Farm (7x)**

Rencana Pembelajaran Semester

Materi UTS	Peran bioteknologi dalam dunia farmasi
	Pendekatan bioteknologi kultur jaringan tanaman
	Pendekatan bioteknologi fermentasi
	Pendekatan bioteknologi rekayasa Genetik dan protein
Materi UAS	Bioteknologi untuk analisis, diagnostik dan penelitian
	bioteknologi antibodi monoklonal.
	bioteknologi transgenic dan biofarmasetikal
	bioteknologi rekayasa jaringan
	Aplikasi Bioteknologi dalam farmasi

Rencana Tugas Mahasiswa

Sebelum UTS

Case-based learning: Mini paper

- Pertemuan 3 : Kultur jaringan
- Pertemuan 5 : Fermentasi
- Pertemuan 7 : Rekayasa genetik dan protein

Setelah UTS

Project-based learning: Makalah dan presentasi

- Pertemuan 13 – 15 : aplikasi bioteknologi

Referensi

- Glick, BR and JJ Pasternak, 2003, Molecular Biotechnology: Principles and Applications of Recombinant DNA, ASM Press, Washington DC
- Groves MJ, 2006, Pharmaceutical Biotechnology, 2nd ed., CRC, Taylor & Francis.
- Brown TA, 2006, Gene Cloning & DNA analysis, Blackwell Publ. Oxford
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- Saltzman W. M, Tissue engineering: engineering principles for the design of replacement organs dan tissues, Oxford university press, 2004
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STIKES NOTOKUSUMO
YOGYAKARTA
PERTEMUAN 1
apt. Trifonia Rosa K, M.Biotech
BIOTECHNOLOGY

TOPIK BAHASAN

Peran bioteknologi dalam dunia farmasi

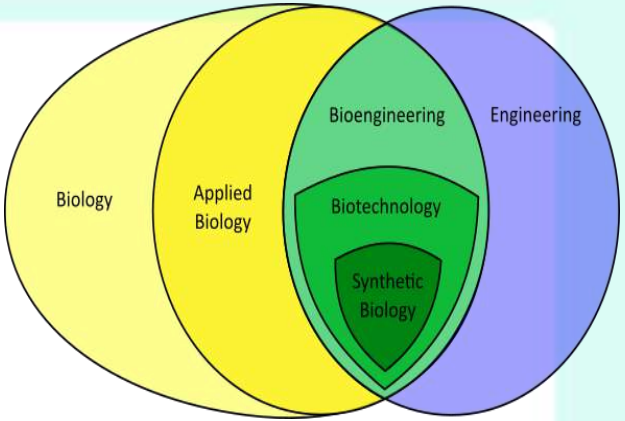
01 Pendahuluan

02 Ruang lingkup

03 Produk farmasi berdasar bioteknologi

P E N D A H U L U A N

Peran bioteknologi dalam dunia farmasi



Bioteknologi merupakan gabungan dua kata yaitu bio dan teknologi.

→ Bio berarti makhluk hidup dan teknologi adalah cara untuk memproduksi barang atau jasa

Bioteknologi adalah cabang ilmu yang mempelajari **pemanfaatan makhluk hidup** (bakteri, fungi, virus, dan lain-lain) maupun **produk dari makhluk hidup** (enzim, alkohol) dalam proses produksi untuk menghasilkan barang dan jasa

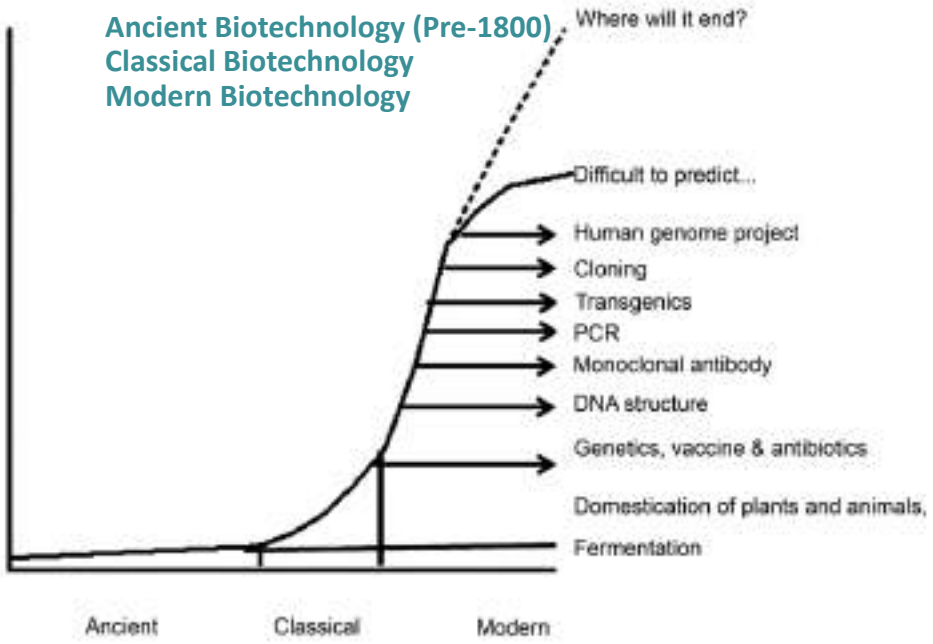
- European Federation of Biotechnology (1989) mendefinisikan bioteknologi sebagai perpaduan ilmu pengetahuan dan ilmu rekayasa yang bertujuan untuk meningkatkan **aplikasi organisme** hidup, sel, bagian dari organisme hidup dan analog molekular untuk menghasilkan produk dan jasa.
- Menurut Louchli (1987) bioteknologi didefinisikan sebagai segala teknik yang **menggunakan organisme** hidup atau bagian dari organisme untuk : (a) memperbaiki sifat tanaman atau hewan ; (b) mengembangkan mikroba untuk tujuan khusus atau ; (c) membuat / memodifikasi produk tanaman.

P E N D A H U L U A N

Peran bioteknologi dalam dunia farmasi

History of the development of biotechnology

Ancient Biotechnology (Pre-1800)
Classical Biotechnology
Modern Biotechnology

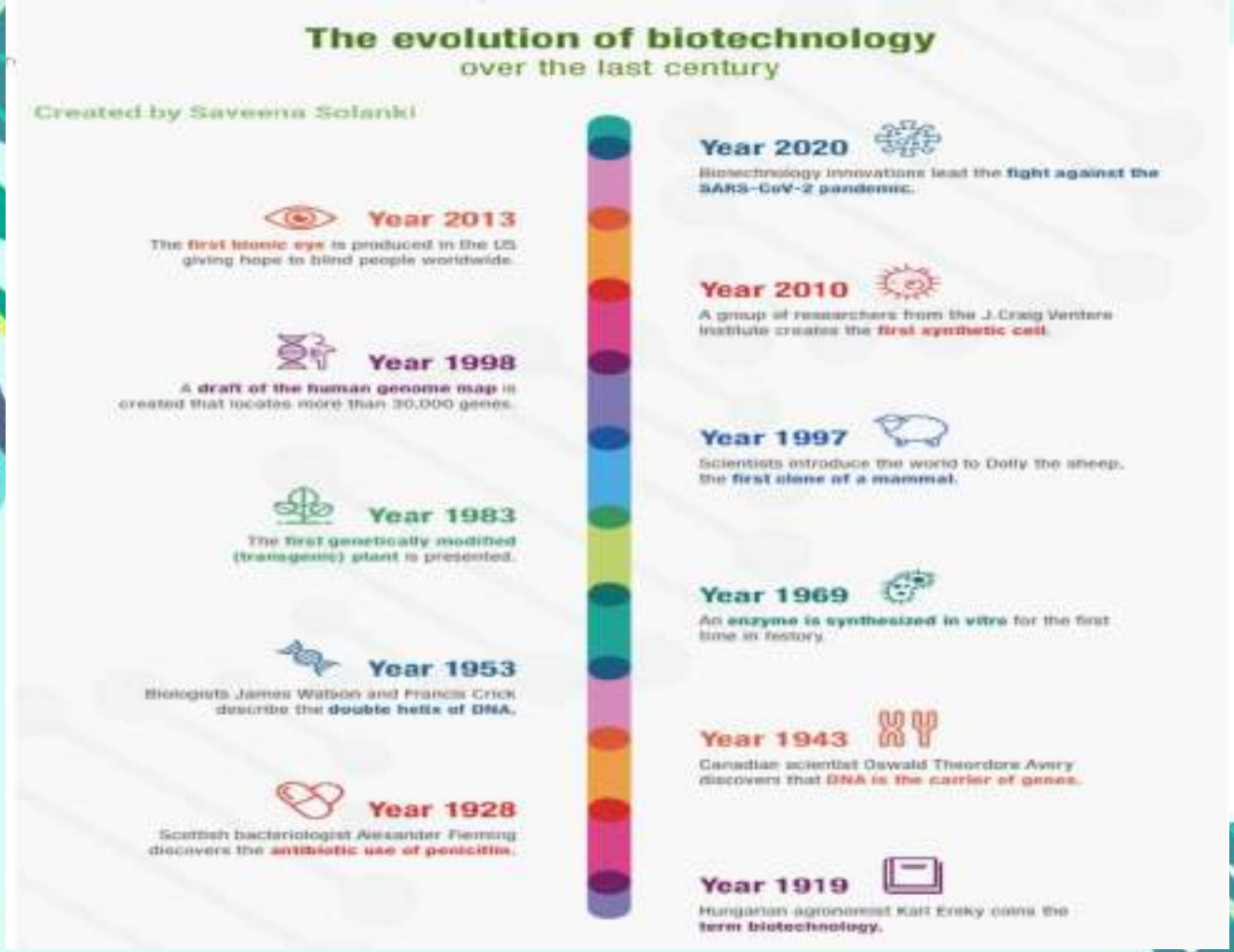


Traditional Biotechnology

Traditional biotechnology includes tissue culture, mutagenesis.

Modern Biotechnology

Modern biotechnology includes DNA profiling, genome analysis, transgenesis, DNA cloning.

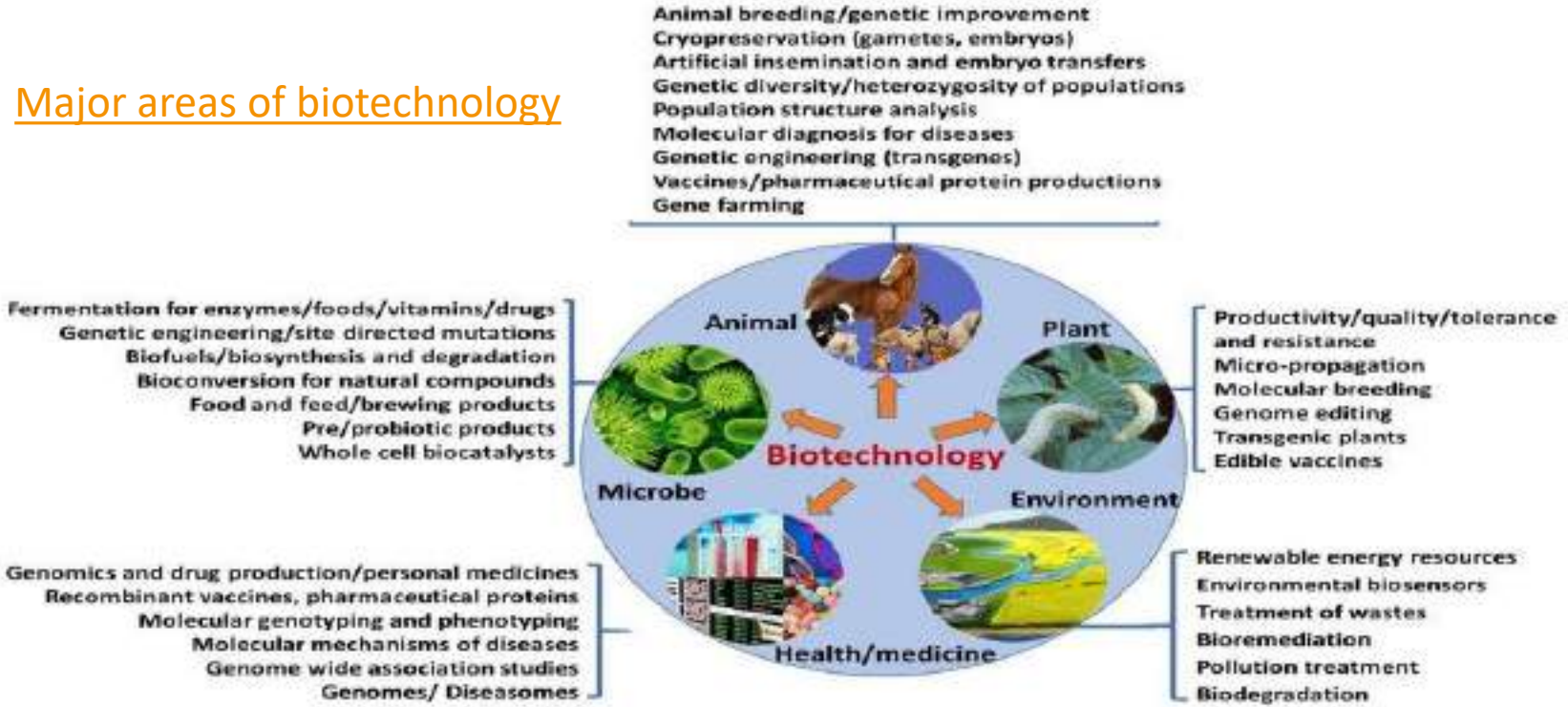


History of the development of biotechnology

RUANG LINGKUP BIOTEKNOLOGI

Peran bioteknologi dalam dunia farmasi

Major areas of biotechnology



Interdisciplinarity Fields of Biotechnology

Biotechnology is one of the most important applied interdisciplinary sciences of the **21st century**. It is the trusted area that enables us to find the beneficial way of life. Biotechnology has wide applications in various sectors like agriculture, medicine, environment and commercial industries.

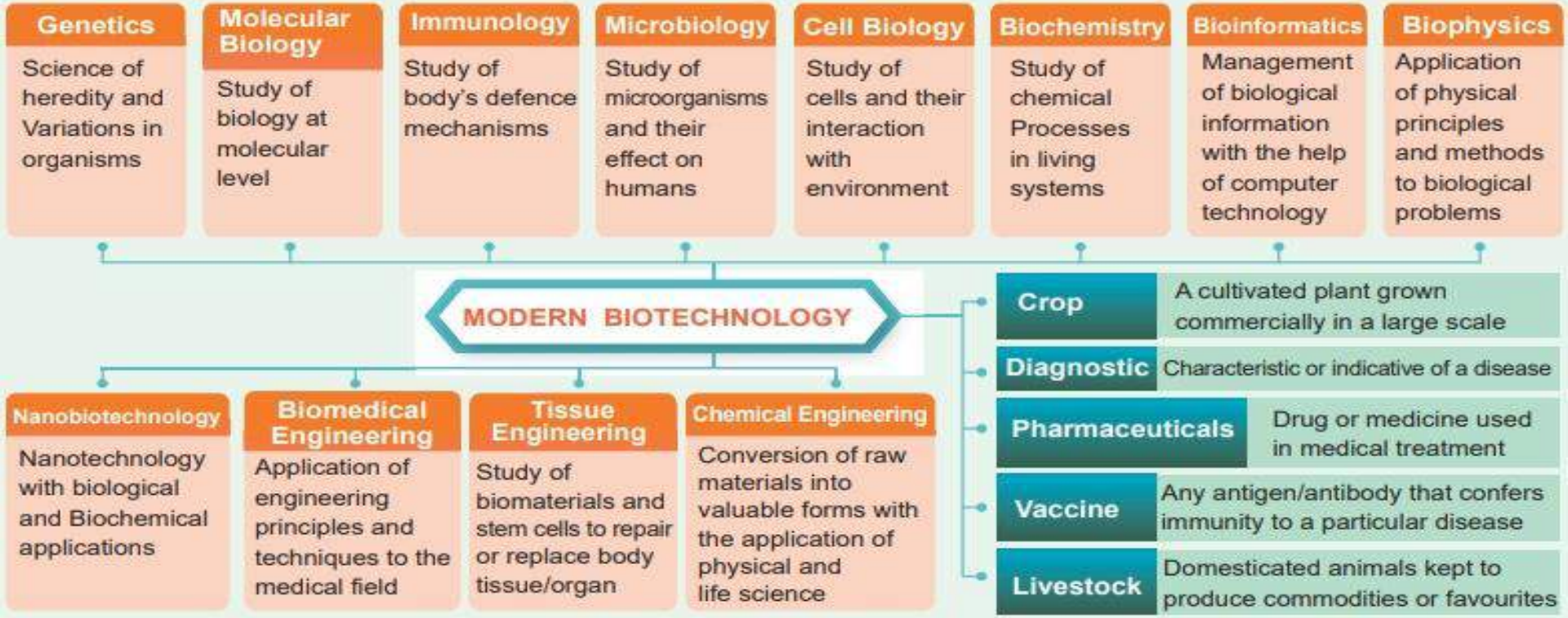
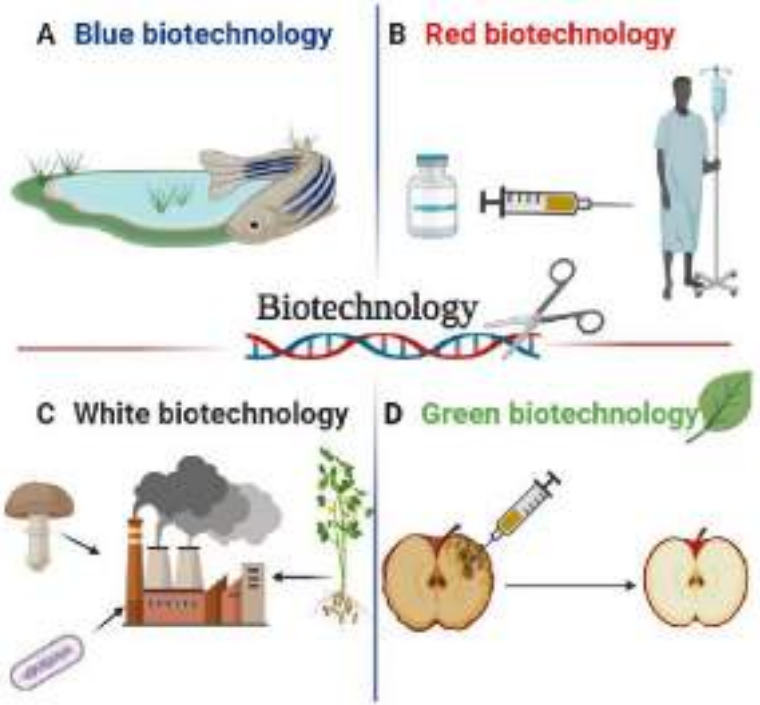


Figure 4.1: Interdisciplinarity Fields of Biotechnology

RUANG LINGKUP BIOTEKNOLOGI

Peran bioteknologi dalam dunia farmasi

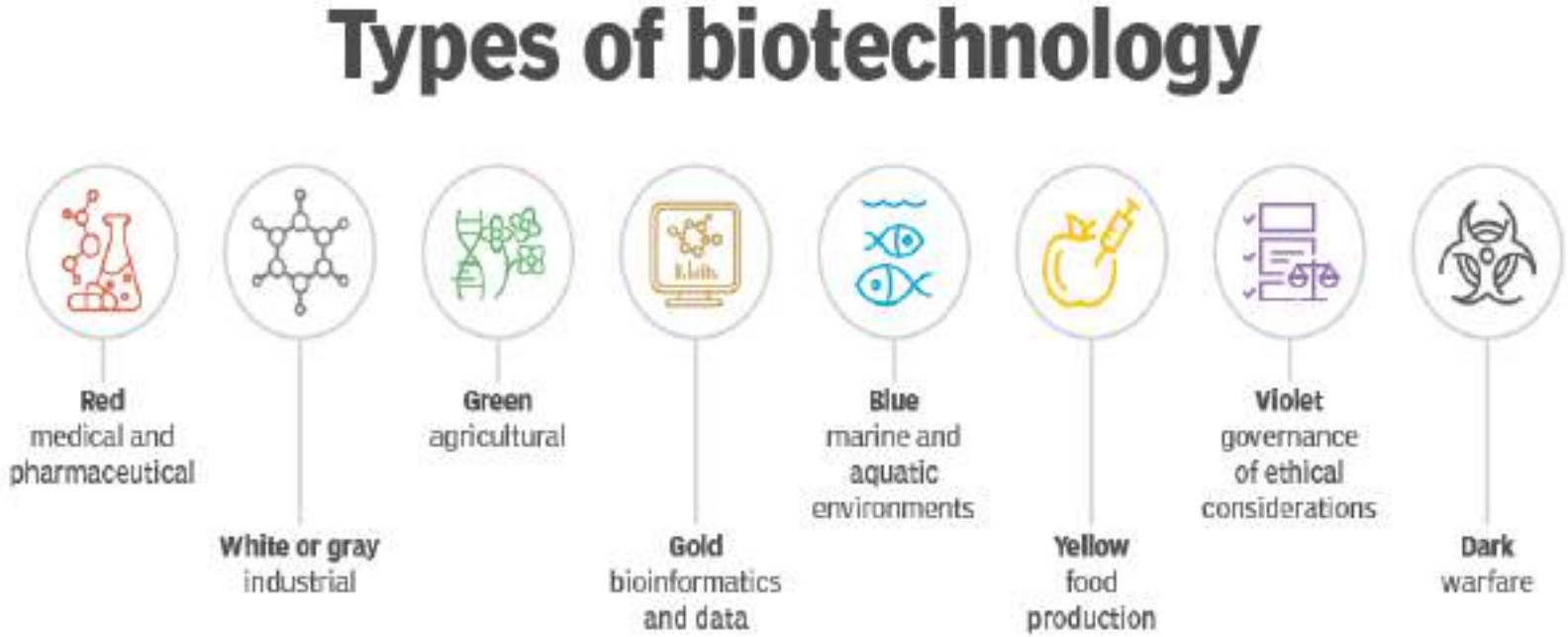


Type of Biotechnology

1. Blue biotechnology : Marine and aquatic applications of biotechnology
2. Red biotechnology : Medical applications
3. White biotechnology : Industrial applications
4. Green biotechnology : Agricultural applications

RUANG LINGKUP BIOTEKNOLOGI

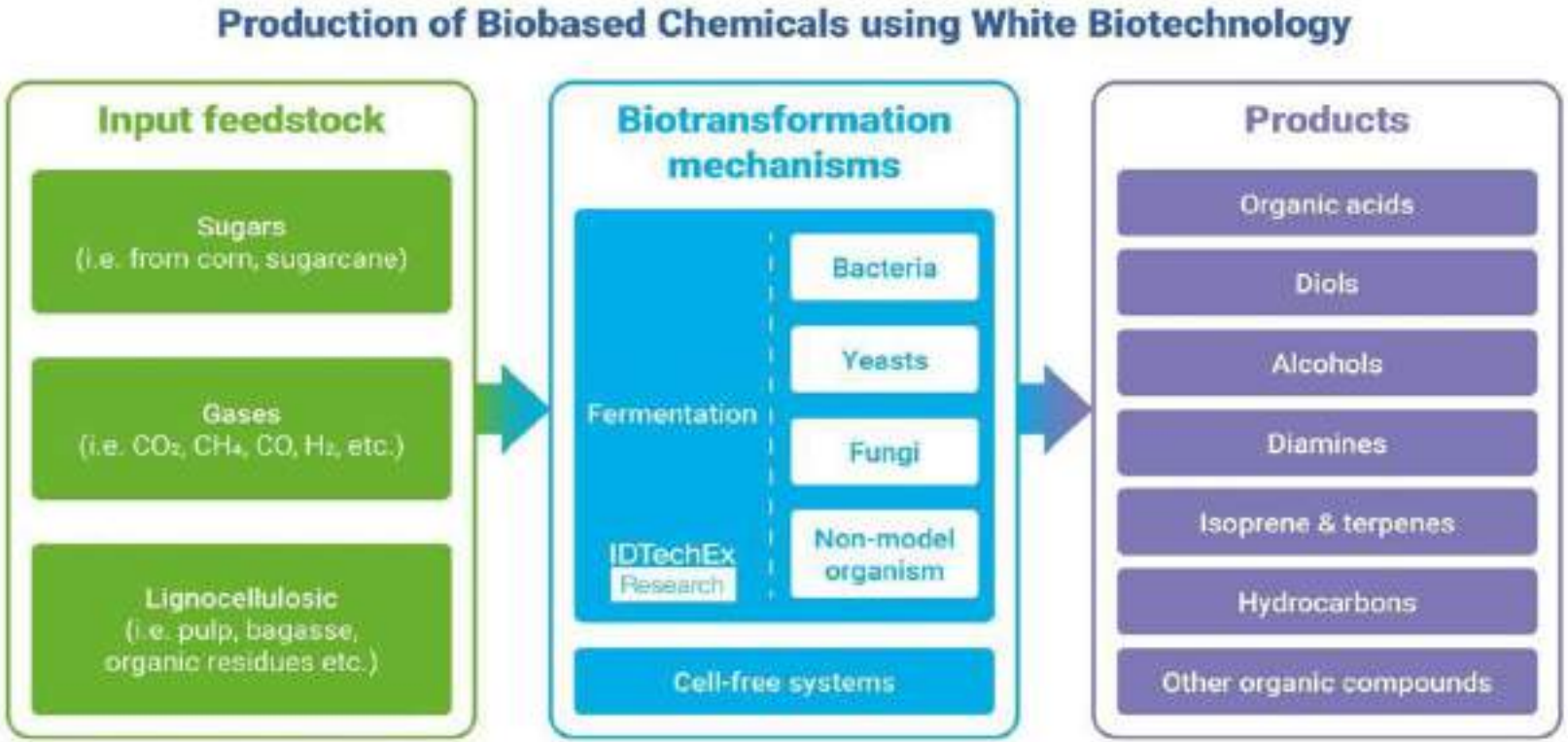
Peran bioteknologi dalam dunia farmasi



https://www.techtarget.com/whatis/definition/biotechnology

RUANG LINGKUP BIOTEKNOLOGI

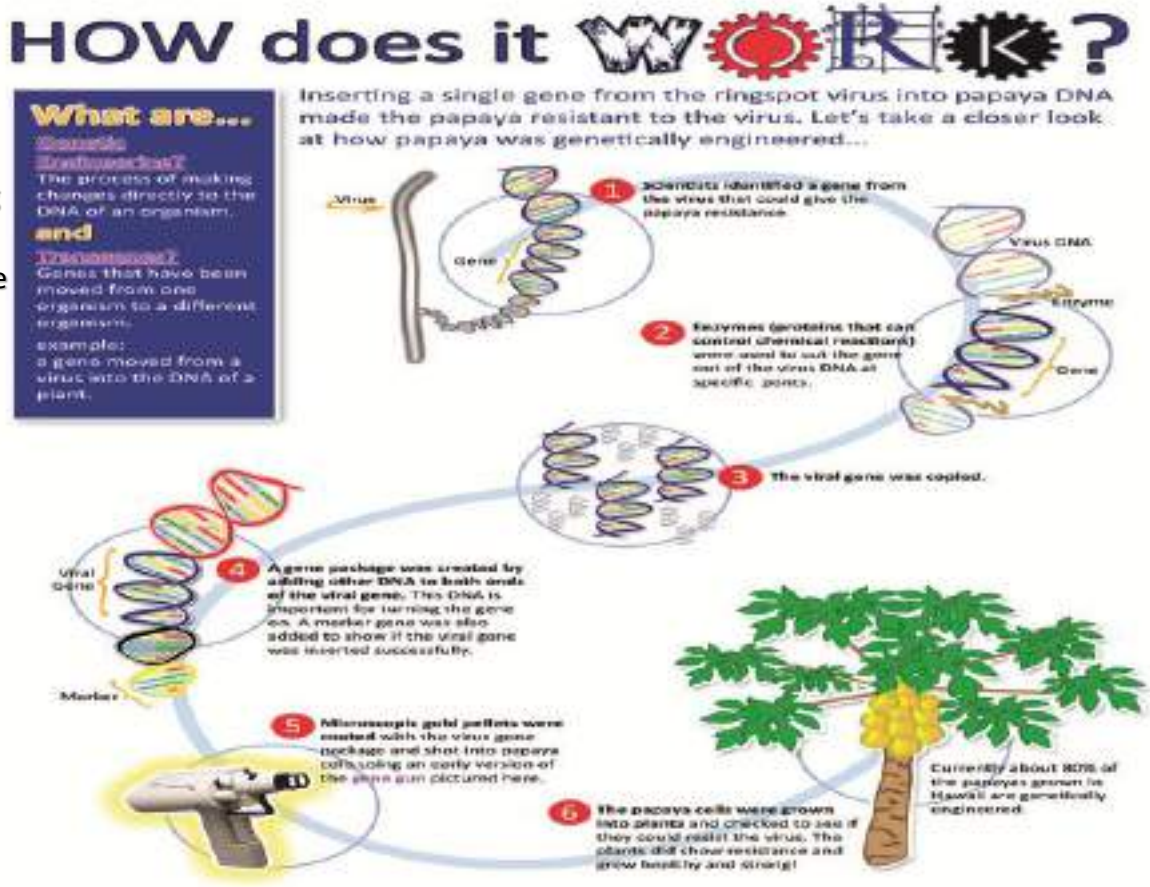
Peran bioteknologi dalam dunia farmasi



https://www.idtechex.com/en/research-report/white-biotechnology-2024-2034/959

genetic engineering

transgene



The process of genetic engineering in papaya.

- This is the first fruit tree ever genetically engineered (**for resistance to a virus that kills papaya plants**), conducted by Land Grant Universities (University of Hawaii and Cornell University) in the USA

https://www.nature.com/scitable/knowledge/library/history-of-agricultural-biotechnology-how-crop-development-25885295/

B I O P H A R M A C E U T I C A L

Peran bioteknologi dalam dunia farmasi

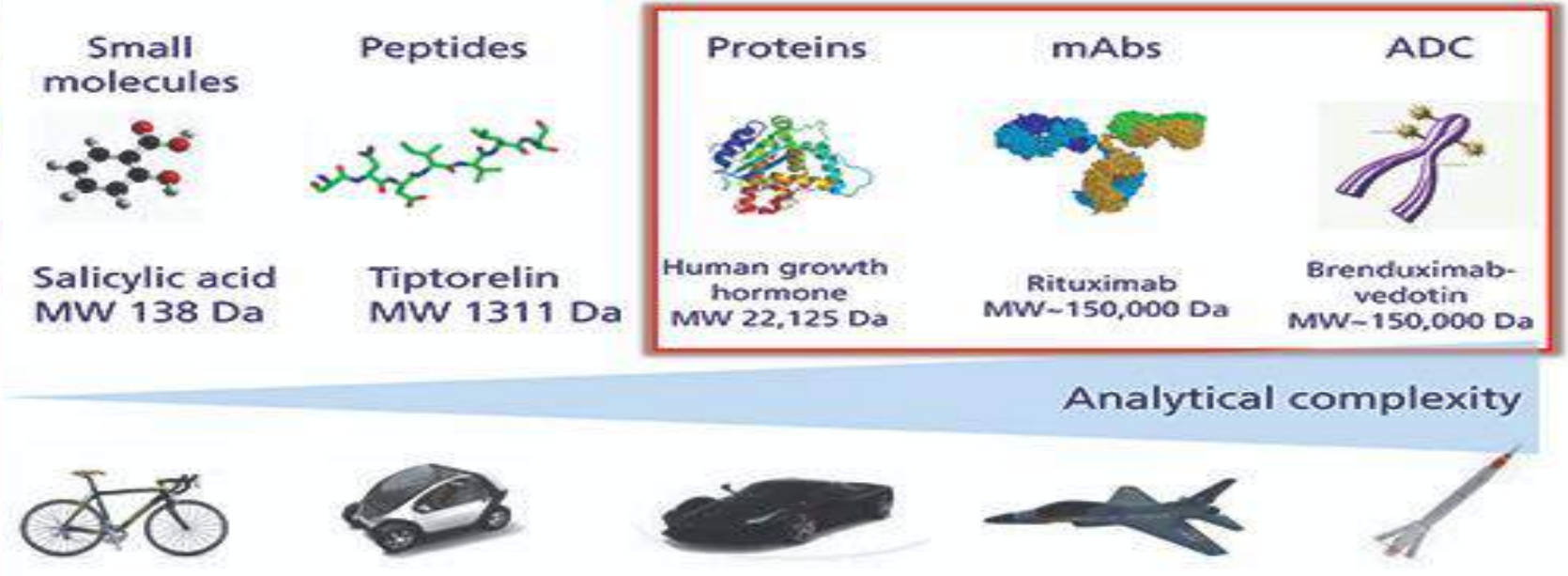
BIOPHARMACEUTICAL

PHARMACEUTICAL BIOTECHNOLOGY

- **Bioteknologi farmasi** adalah bidang yang berkembang di mana prinsip-prinsip bioteknologi diterapkan pada pengembangan obat-obatan.
- Istilah "biofarmasi" diciptakan pada 1980-an dan mengacu pada **obat-obatan yang diproduksi dalam proses bioteknologi** menggunakan metode biologi molekuler.
- Mayoritas obat terapeutik di pasar saat ini adalah bioformulasi, seperti antibodi, produk asam nukleat, dan vaksin.

B I O P H A R M A C E U T I C A L

Peran bioteknologi dalam dunia farmasi

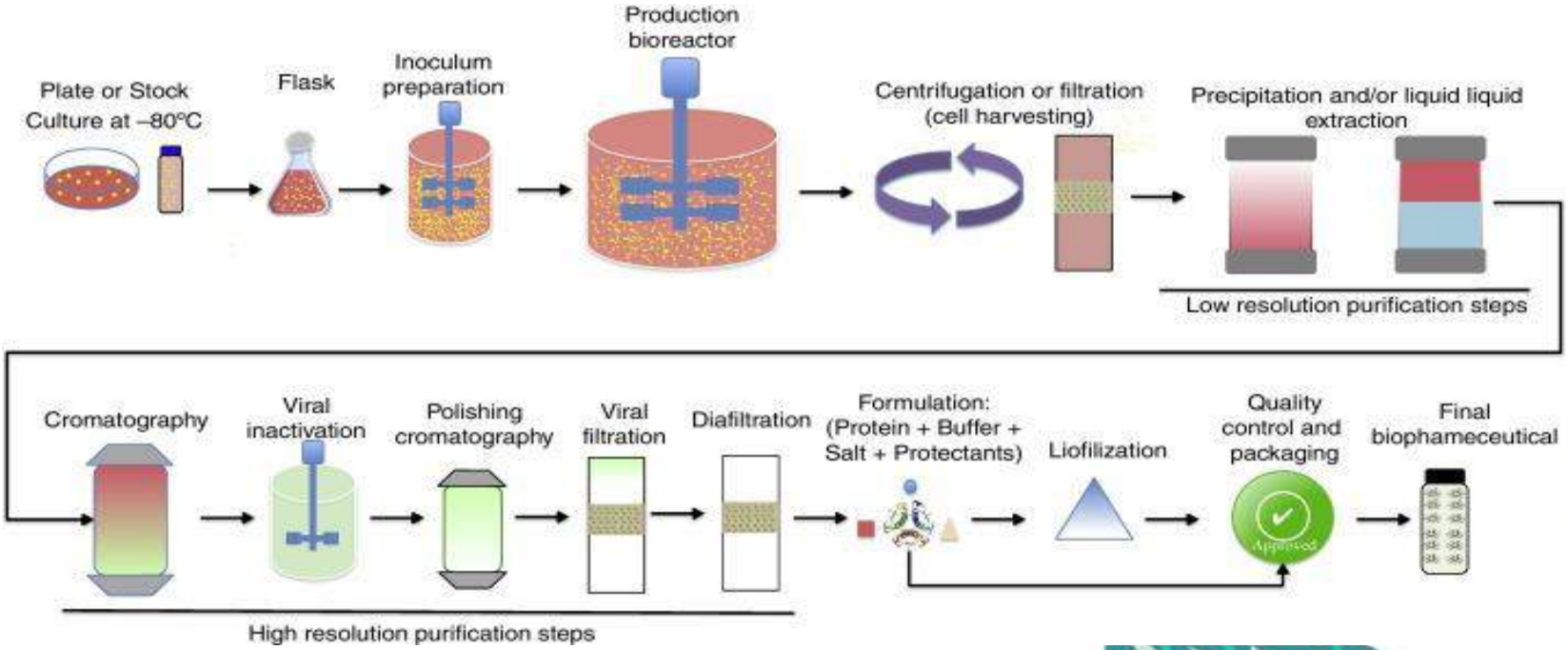


As illustrated, proteins, mAbs, and ADCs produced from living organisms have a complexity far exceeding that of small molecules and peptides produced from chemical synthesis.

B I O P H A R M A C E U T I C A L

Peran bioteknologi dalam dunia farmasi

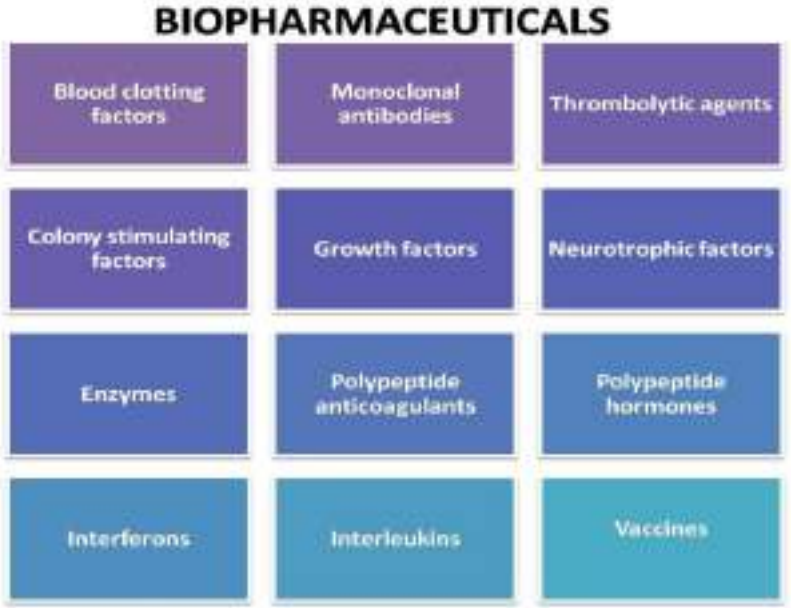
Biopharmaceuticals from microorganisms: from production to purification



The biopharmaceutical manufacturing technology flowchart exemplifying the upstream and the downstream bioprocess.

BIOPHARMACEUTICAL

Peran bioteknologi dalam dunia farmasi



Biopharmaceutical class	Example
Blood factors	Factor VIII
	Factor IX
Thrombolytic agents	Tissue plasminogen activator
Hormones	Insulin
	Growth hormone
	Gonadotropins
Haematopoietic growth factors	Erythropoietin
	Colony stimulating factors
IFNs	IFN-alpha, -beta, -gamma
Interleukin-based products	Interleukin-2
Vaccines	Hepatitis B surface antigen

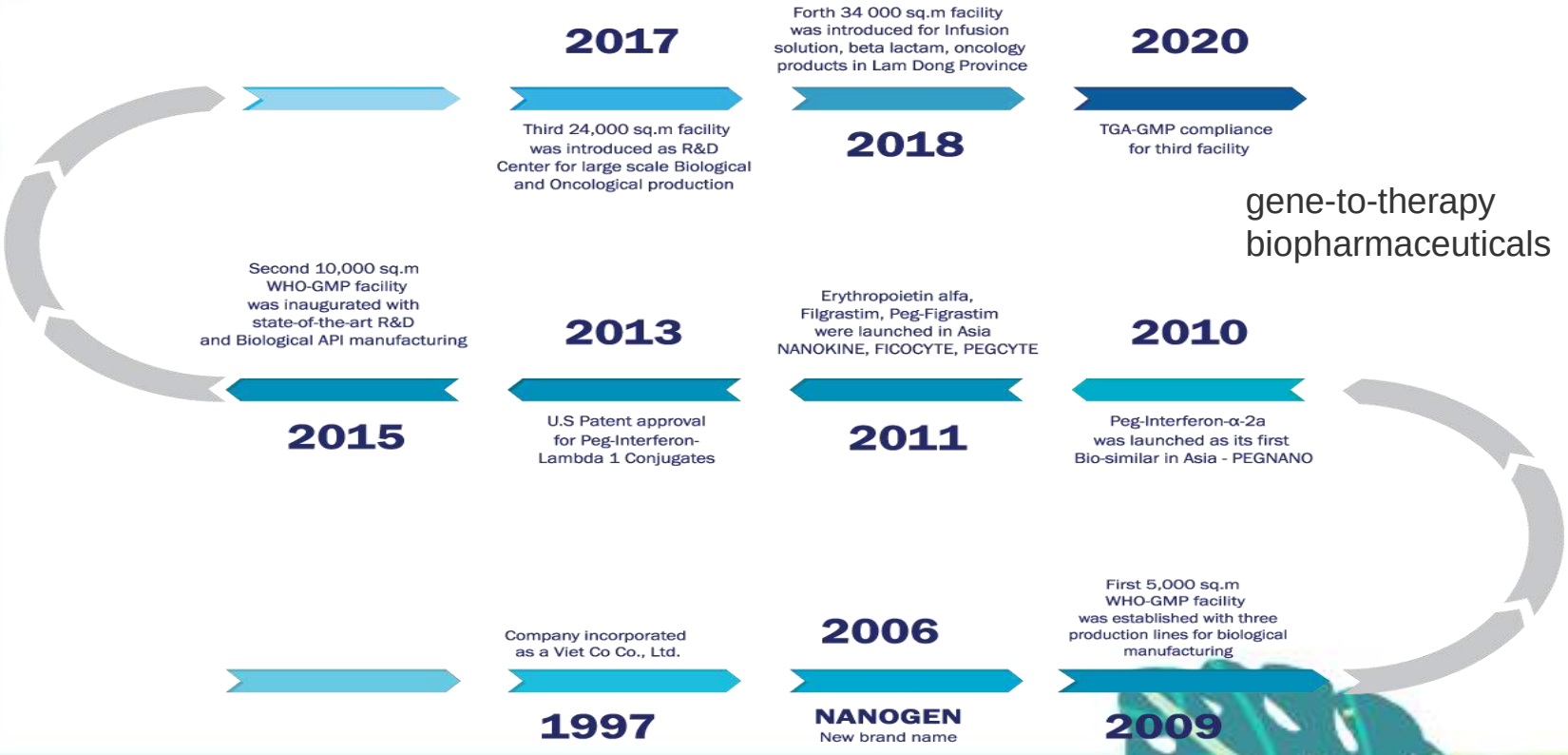
B I O P H A R M A C E U T I C A L

Peran bioteknologi dalam dunia farmasi

Biopharma product	*Application*	*Companies*
Insulin	Diabetes	Eli Lily, Novo Nordisk
Erythropoietin	Anemia	Amgen, Johnson & Johnson
Human growth hormone	Growth deficiency	Genetech, Pharmacia
Interferon α	Hepatitis	Schering, Roche
Interferon β	Multiple sclerosis	Chiron, Biogen
Factor VIII	Hemophilia	Bayer
Tissue plasminogen activator	Bloot clot	Genentech
Glucocerebroidase	Gaucher's disease	Genzyme
Therapeutic antibodies	Cancer	Glaxo, Amgen, Genentech
GCSF	White blood cell	Amgen, Sankyo

BIOPHARMACEUTICAL

Peran bioteknologi dalam dunia farmasi

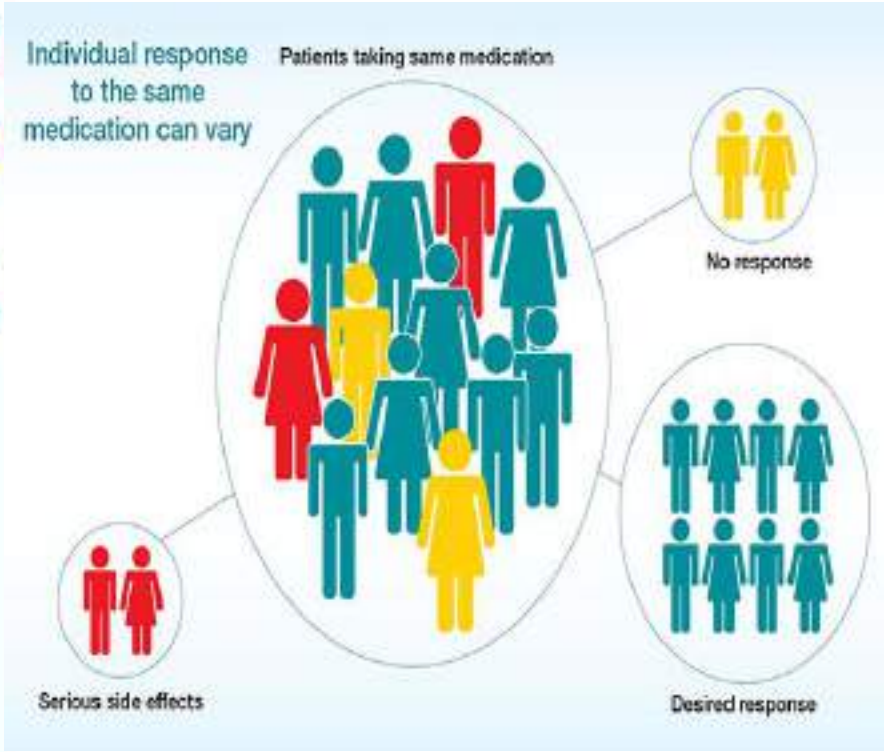


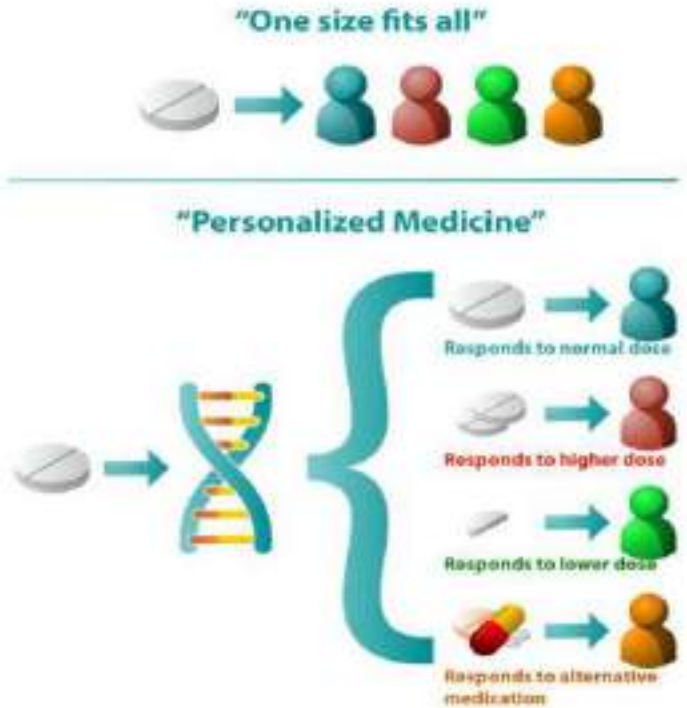
gene-to-therapy biopharmaceuticals

https://nanogenpharma.com/our-journey

B I O P H A R M A C E U T I C A L

Peran bioteknologi dalam dunia farmasi





PHARMACOGENOMICS

B I O P H A R M A C E U T I C A L

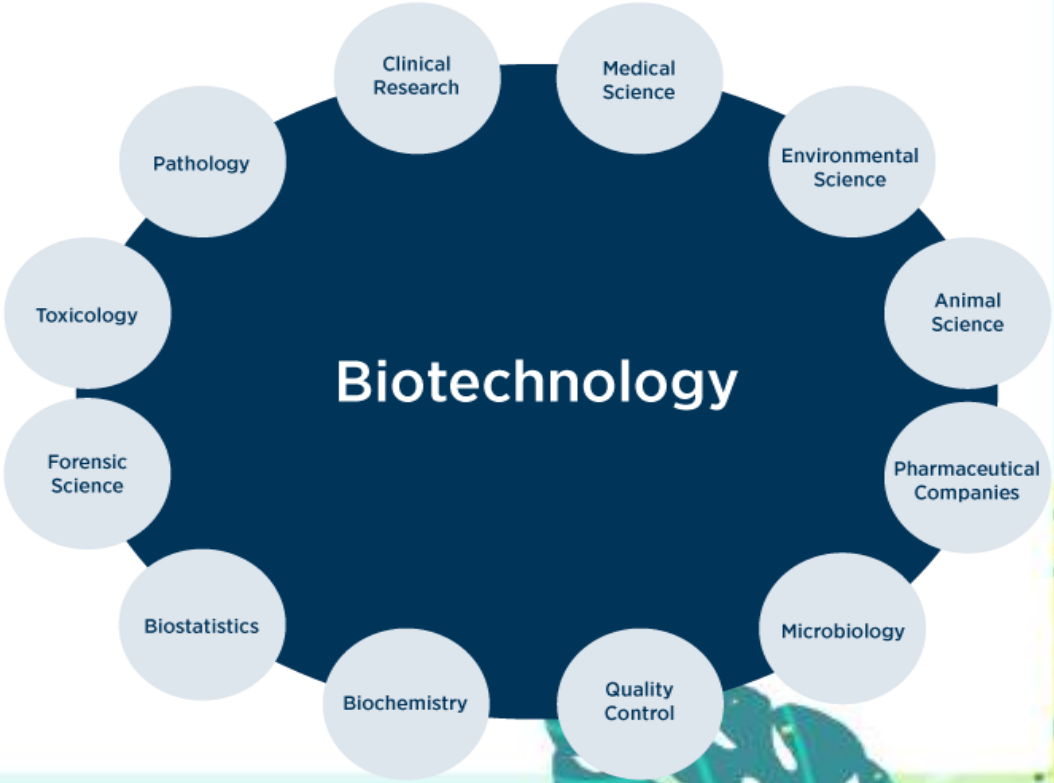
Peran bioteknologi dalam dunia farmasi

Drivers of change	Impact on biopharmaceutical manufacturing
Future proofing	■ **Evolving expectations of the regulators** with regard to sterile manufacturing including emerging critical new technology areas like continuous bioprocessing ■ **Flexible facilities** with greater flexibility, multi-product, hybrid, and completely modular facilities are being developed
Supply chain and quality	■ Switch from **vials to pre-mixed bags** requires machinery and process changes ■ Manufacturing parenteral 'Ready-To-Use' products require manufacturing to be **flexible to switch from one container to another** while maintaining sterility as well as set-up and manage a **manufacturing cold chain**
Data management	■ Body sensors (e.g., wearable, implantable) require new manufacturing c**apability to include chips** and new fill finish configurations to make these products ■ Nano sensors, **regenerative medicines, and nano robotics** are concepts that possess great potential to transform pharmaceutical business in future
Regulatory and compliance	■ **Serialization** and related changes in packaging and labeling are required and this would provide new information ■ The tracking-tracing of internal movement between sites, including **automated handling processes**

Career Opportunities in Biotechnology

Peran bioteknologi dalam dunia farmasi

- Pharmaceutical Biotechnologist
- Molecular Biotechnologist
- Geneticist
- Environmental Biotechnologist
- Forensic Science Technicians



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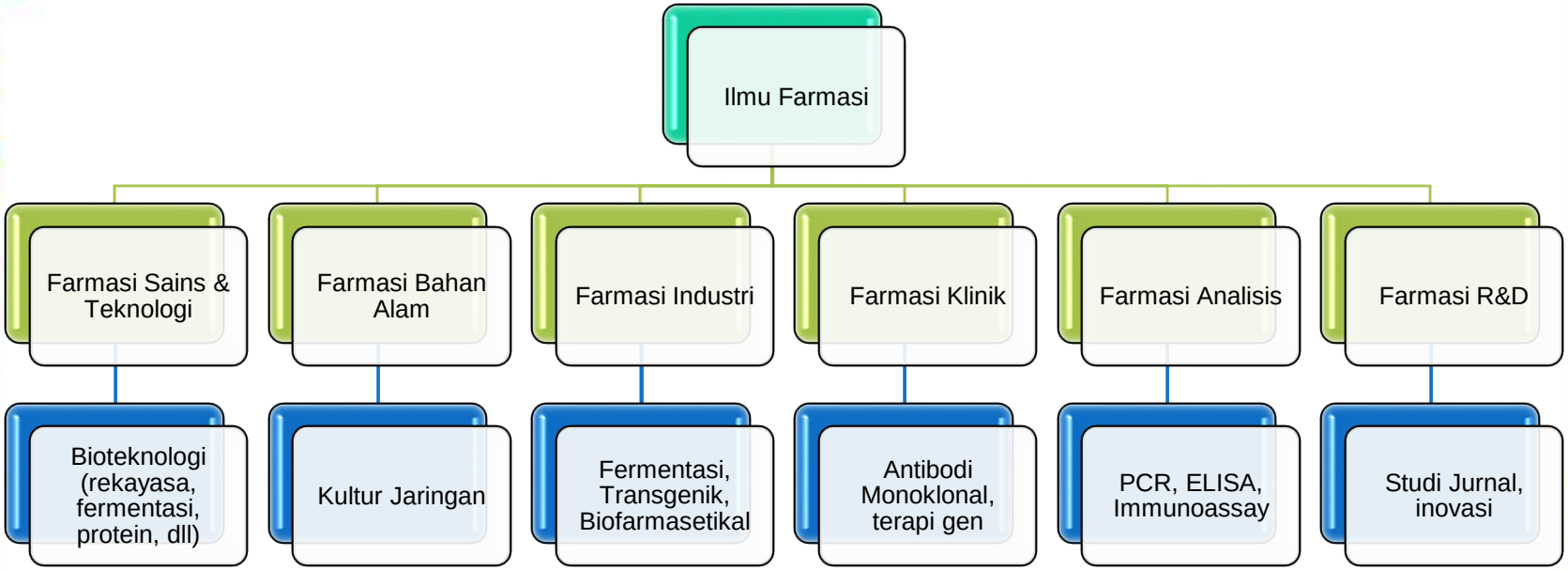

Ilmu Farmasi
Farmasi Sains & Teknologi
Farmasi Bahan Alam
Farmasi Industri
Farmasi Klinik
Farmasi Analisis
Farmasi R&D
Bioteknologi (rekayasa, fermentasi, protein, dll)
Kultur Jaringan
Fermentasi, Transgenik, Biofarmasetikal
Antibodi Monoklonal, terapi gen
PCR, ELISA, Immunoassay
Studi Jurnal, inovasi

THANK YOU

TEMPLATE

BIOTEKNOLOGI

Pertemuan 2

apt. Trifonia Rosa Kurniasih, M.Biotech

STIKES Notokusumo Yogyakarta

TOPIK BAHASAN : KULTUR JARINGAN

- Pendahuluan
- Manfaat
- Faktor - faktor yang menunjang keberhasilan kultur jaringan.
- Macam- macam teknik kultur jaringan

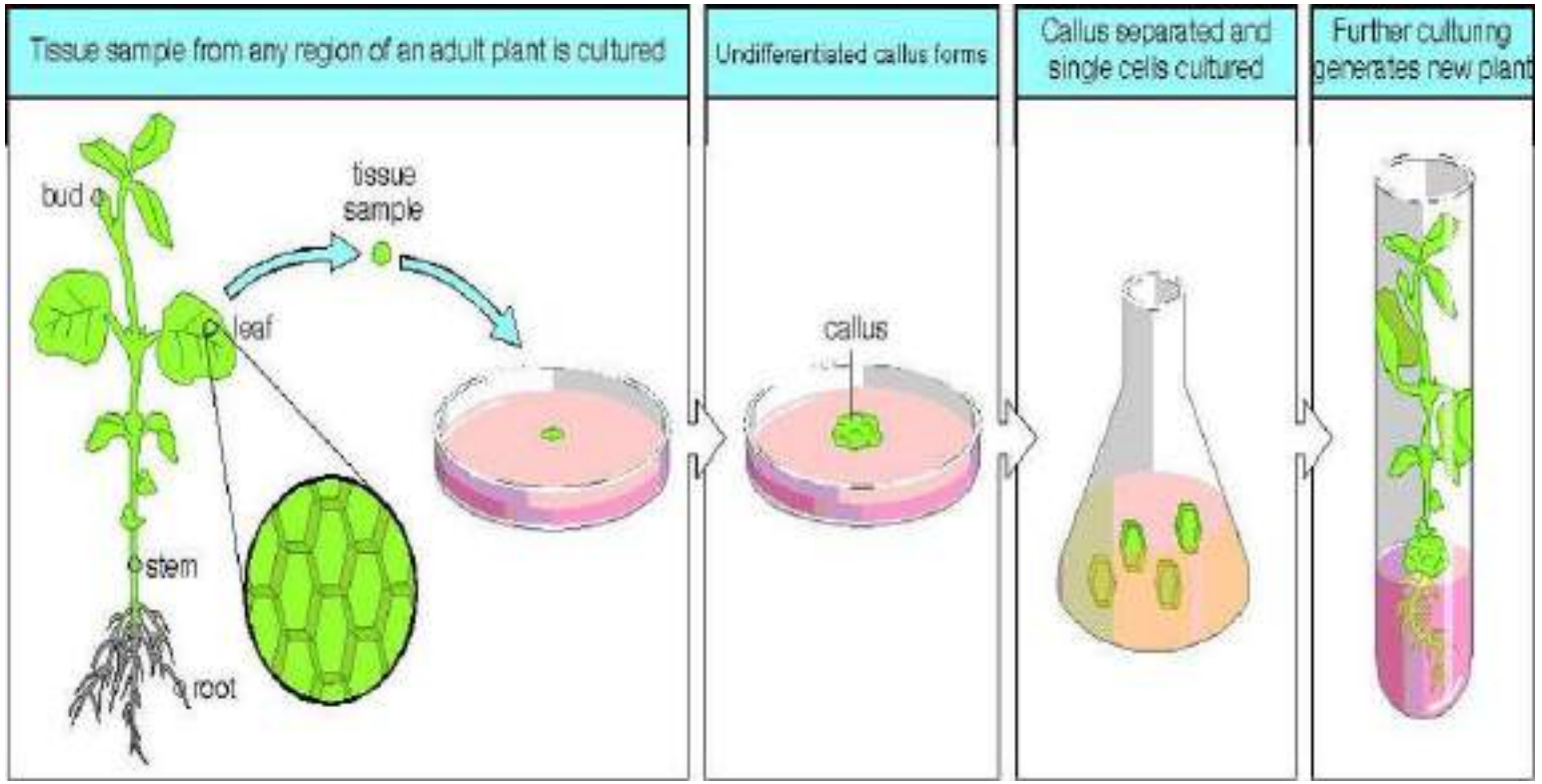
Pendahuluan

Beberapa istilah dalam kultur jaringan

- Subkultur : pemindahan kultur ke media lain
- Passage: masa inkubasi
- Inokulum : bahan yang diambil pada setiap subkultur
- Aseptik : steril
- Asenik: satu macam organisme
- Pucuk Adventif : pucuk yang terbentuk pada tempat selain meristem (bukan jaringan asal), misal dari kalus, kotiledon, dll

- Organogenesis : pembentukan batang, daun, akar
- Embrio somatik : embrio yang bukan dari zigot
- Embriogenesis : pembentukan embrio
- Androgenesis : embrio terbentuk langsung dari kultur anther atau polen
- Gynogenesis: embrio terbentuk dari ovari yang belum dibuahi (fertilisasi)
- Aklimatisasi : masa adaptasi planlet
- Variasi somaklonal : variasi pucuk hasil subkultur
- Hibridisasi genetik : fusi protoplas sel yang berbeda
- Heterokarion : gabungan 2 atau lebih inti sel protoplasma
- Cybrid : gabungan sitoplasma 2 sel atau lebih

Pendahuluan



Kultur jaringan merupakan teknik perbanyakan sel, jaringan atau organ tanaman dengan pada medium buatan (*in vitro*) secara aseptik

Teknologi kultur in vitro dimulai dengan spekulasi ilmuwan dari Jerman bernama Haberlandt pada awal abad ke 20 tentang **teori totipotensi.**

Haberlandt menyatakan bahwa *setiap sel mampu tumbuh dan berkembang menjadi tanaman normal jika dikulturkan pada nutrisi dan lingkungan yang tepat*

Pendahuluan

LANDASAN KULTUR JARINGAN

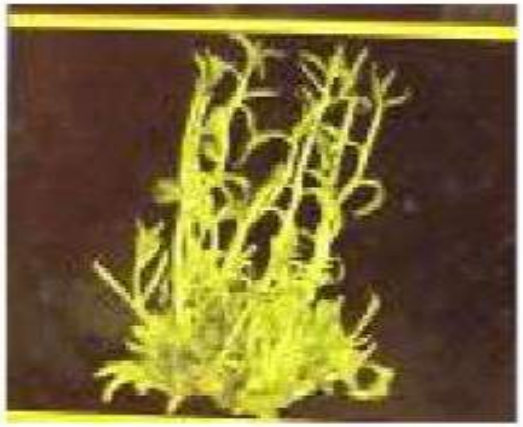
Istilah	Definisi	Contoh dalam Kultur Jaringan	Peran dalam Regenerasi Tanaman
Totipotensi	Kemampuan setiap sel tumbuhan untuk menjadi individu utuh .	Sel parenkim daun → dapat berkembang jadi tanaman lengkap.	Landasan dasar kultur jaringan.
Kompetensi	Kesiapan sel/jaringan untuk merespons rangsangan morfogenetik (hormon).	Sebagian sel kalus mampu membentuk embrio bila diberi ZPT tepat.	Menentukan sel mana yang bisa berkembang.
Rediferensiasi	Proses sel terdiferensiasi kembali ke kondisi meristematik lalu membentuk organ/embrio baru .	Sel daun → kalus → tunas/akar.	Tahap penting organogenesis & embriogenesis.

Pendahuluan

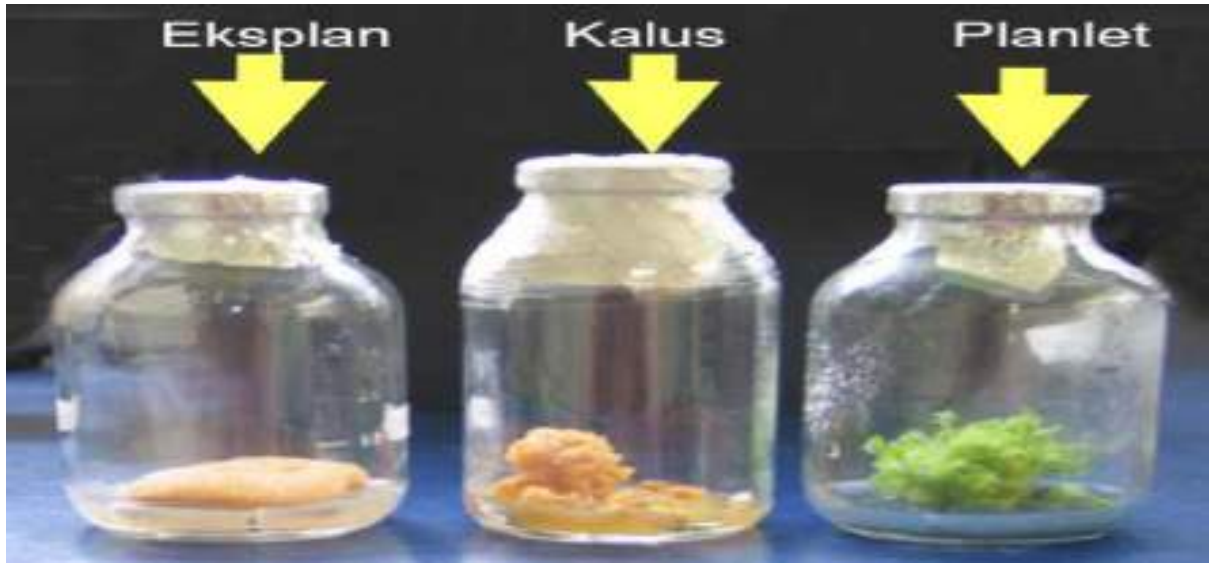
Embriogenesis

- Embriogenesis: produksi embrio
- Embrio somatik: embrio dari somatik atau bukan sel kelamin
- Terjadi setelah pembentukan kalus

Organogenesis

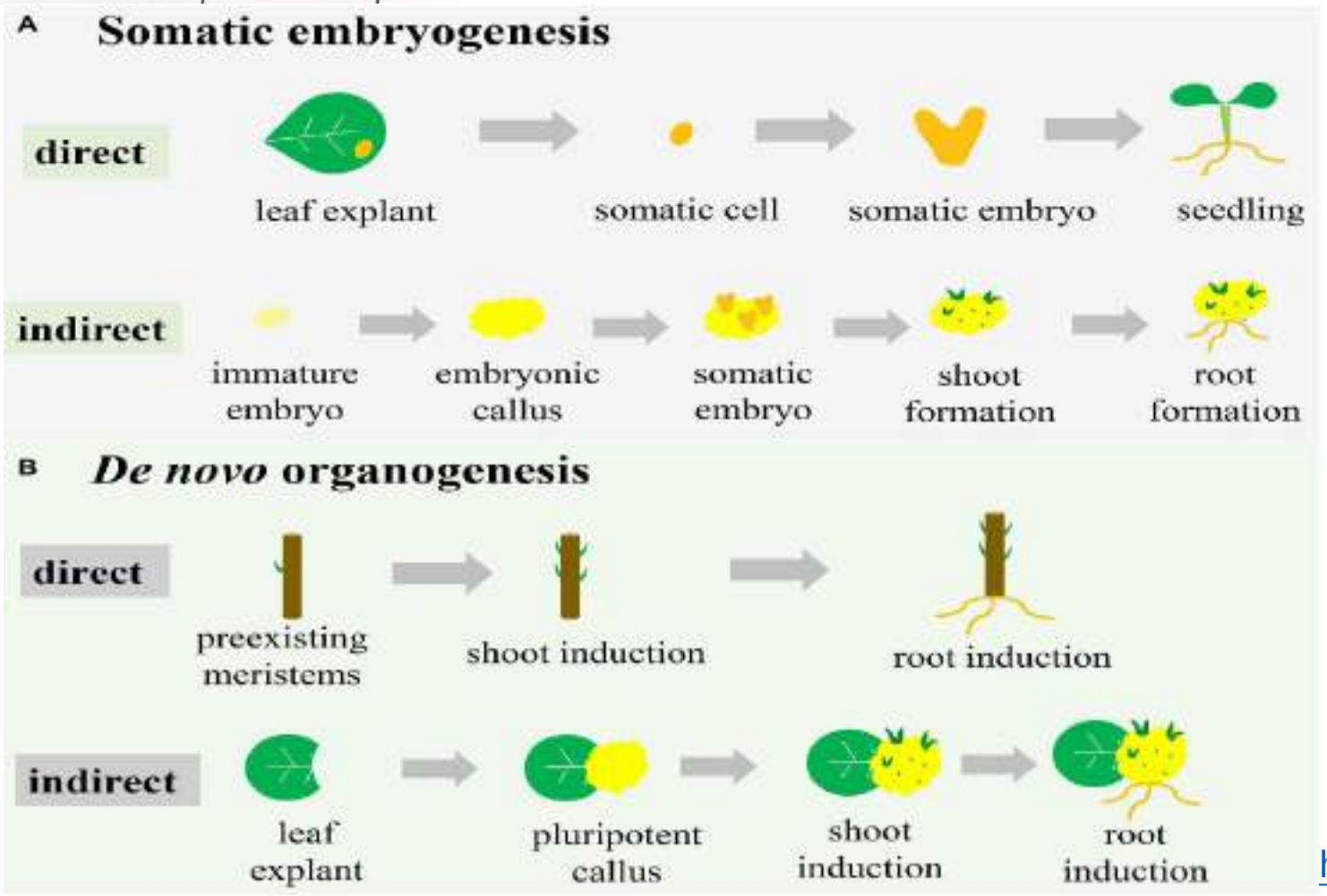


- Produksi akar, batang atau daun
- Organ tumbuh dari perkembangan meristem atau dari diferensiasi jaringan
- Melalui pembentukan kalus tetapi kadang-kadang tanpa kalus



- Eksplan: bagian tanaman untuk bahan awal inisiasi kultur
- Kalus : sekumpulan sel amorf yang terbentuk dari sel yang terus membelah
- Planlet: tanaman lengkap hasil regenerasi kultur jaringan

Pendahuluan



Different pathways of plant regeneration

Somatic embryogenesis.

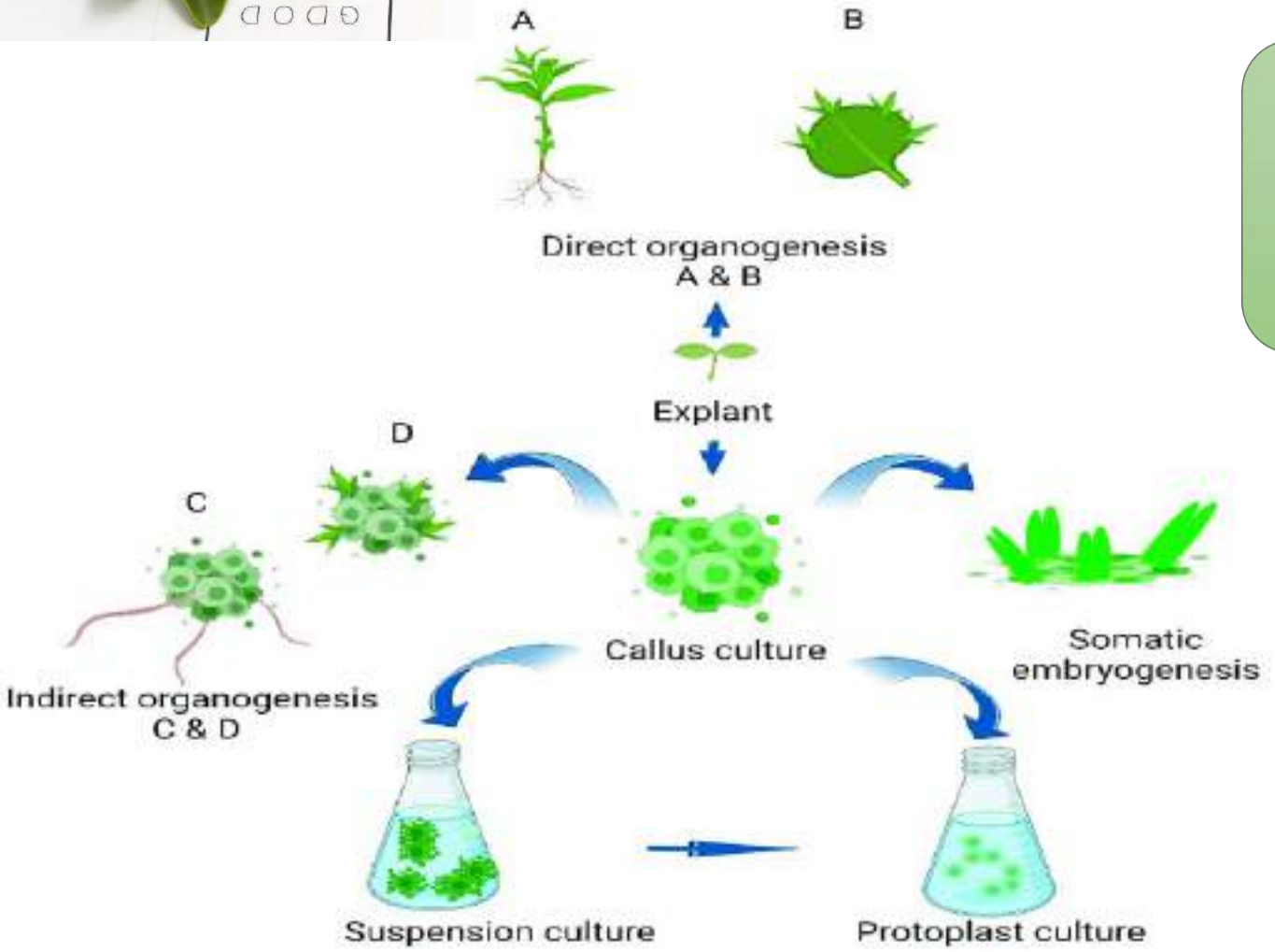
- In the direct pathway , the somatic cell originated from explants (e.g., a leaf) is induced to form the somatic embryo, which subsequently drives the development of the whole plant.
- In the indirect pathway , the explant (e.g., an immature embryo) is induced to initiate the embryonic callus, on which somatic embryos are formed to subsequently develop shoots and roots.

De novo organogenesis.

- In the direct pathway , shoots and roots are induced directly on the stem with pre-existing meristems.
- In the indirect pathway , pluripotent callus is produced around the wound in a leaf explant, with formation of shoots and roots subsequently induced.

https://doi.org/10.3389/fpls.2022.926752

Pendahuluan

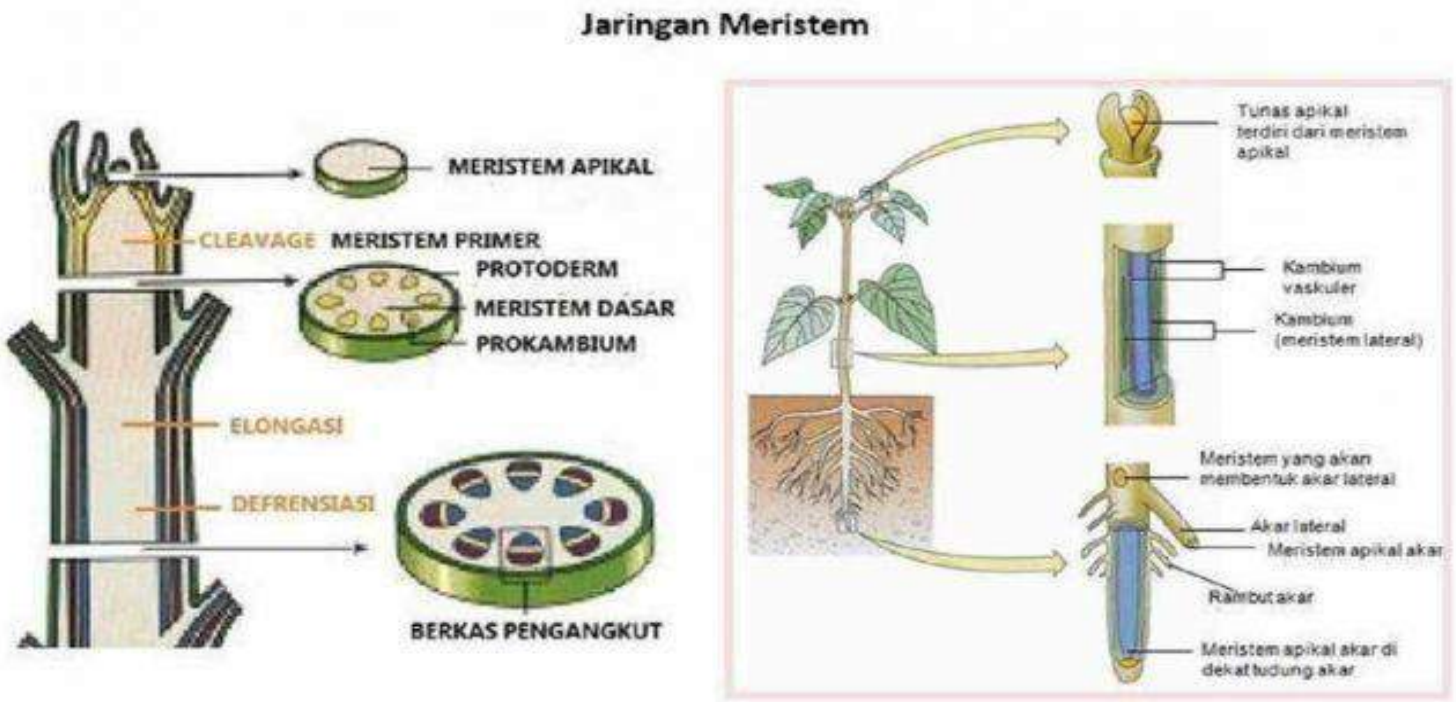


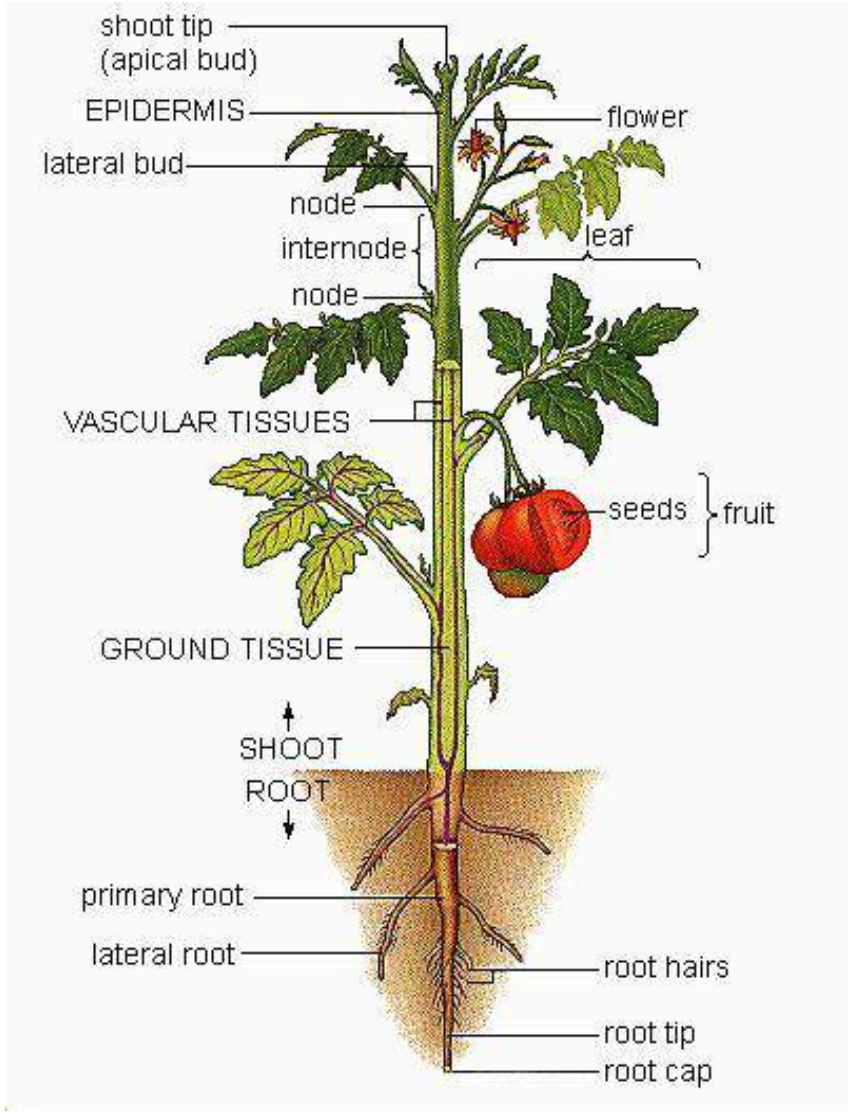
Different techniques in tissue culture for plant regeneration can be utilized for the selection and genetic transformation of plants.

- Starting from explants under selection mediums, direct organogenesis can be achieved (A and B) or indirect organogenesis (C and D) through an intermediate callus phase.
- Further, callus can be used to form intact plantlets through an embryonic pathway or in suspension culture directly or via protoplast culture techniques in genetic transformation attempts

https://doi.org/10.3390/life13030780

Pendahuluan





Jaringan meristem adalah jaringan tanaman yang memungkinkan tanaman untuk tumbuh

Manfaat Kultur Jaringan

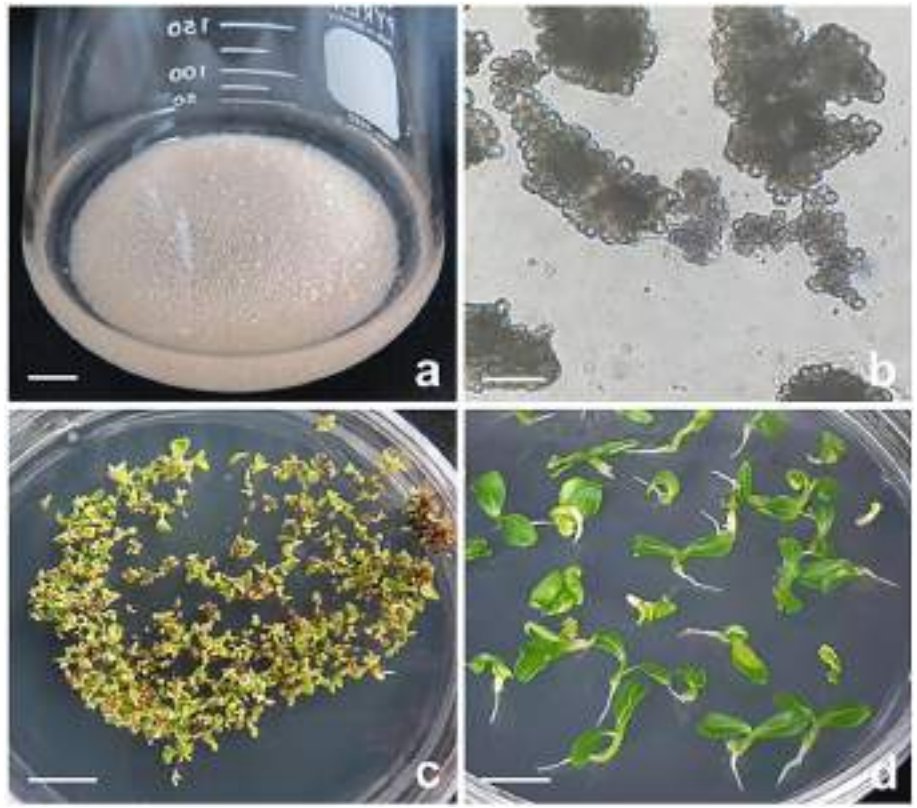
Secara umum

- Perbanyakan tanaman dalam jumlah besar, seragam, dan cepat.
- Menghasilkan bibit bebas penyakit (virus-free plants).
- Pelestarian plasma nutfah (material genetic yang dapat diwariskan secara seksual atau somatik)
- Produksi metabolit sekunder (misalnya alkaloid, flavonoid
- Pemuliaan tanaman (mendapatkan varietas unggul).

Manfaat Kultur Jaringan

PemuliaanIn Vitro: perbaikan dan pengembangan varietas tanaman

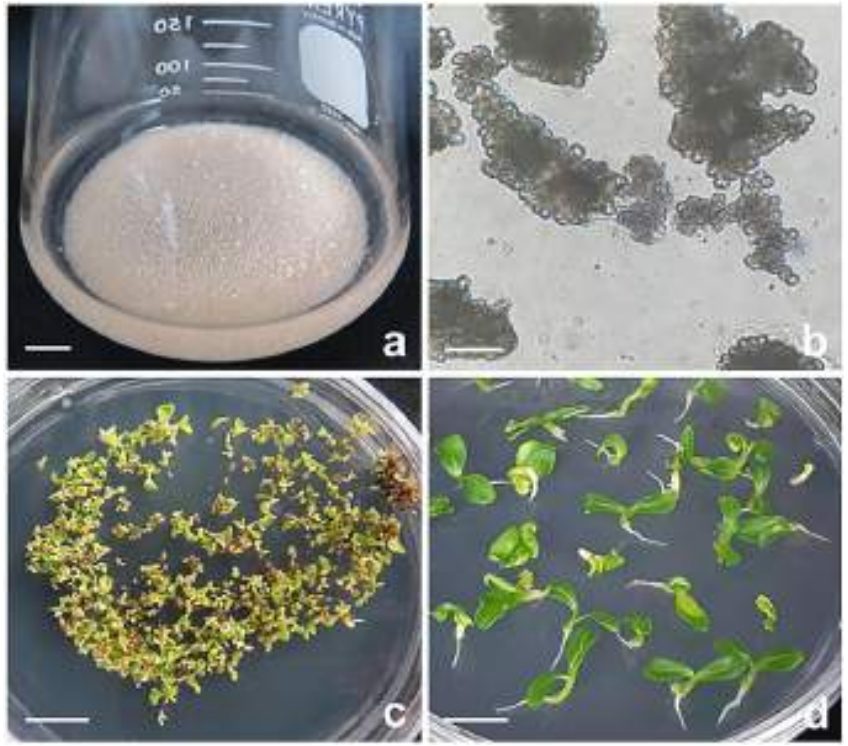
- Produksitanaman haploid dan double haploid
- Hibridisasisomatik melalui fusi protoplas
- Seleksi keragaman alami
- Mutagenensis in vitro



https://doi.org/10.1038/s41598-021-94597-4

Manfaat Kultur Jaringan

Metode	Prinsip Utama	Contoh Aplikasi
Haploid & Double Haploid Culture	Menghasilkan tanaman haploid dari kultur antera/mikrospora, lalu digandakan kromosomnya (double haploid) → langsung homozigot.	Padi double haploid untuk varietas unggul cepat panen.
Mutasi In Vitro	Induksi mutasi (fisik/kimia) pada kultur jaringan untuk memperoleh sifat baru.	Kentang tahan penyakit melalui mutasi terarah.
Fusi Protoplas	Menggabungkan dua protoplas dari spesies berbeda → hibrid somatik.	Anggrek hibrid dengan warna/bentuk bunga baru.
Seleksi Sel In Vitro	Mengkultur sel/kalus pada media selektif (misal kadar garam tinggi/herbisida) → hanya sel tahan yang tumbuh.	Tanaman toleran salinitas atau herbisida.

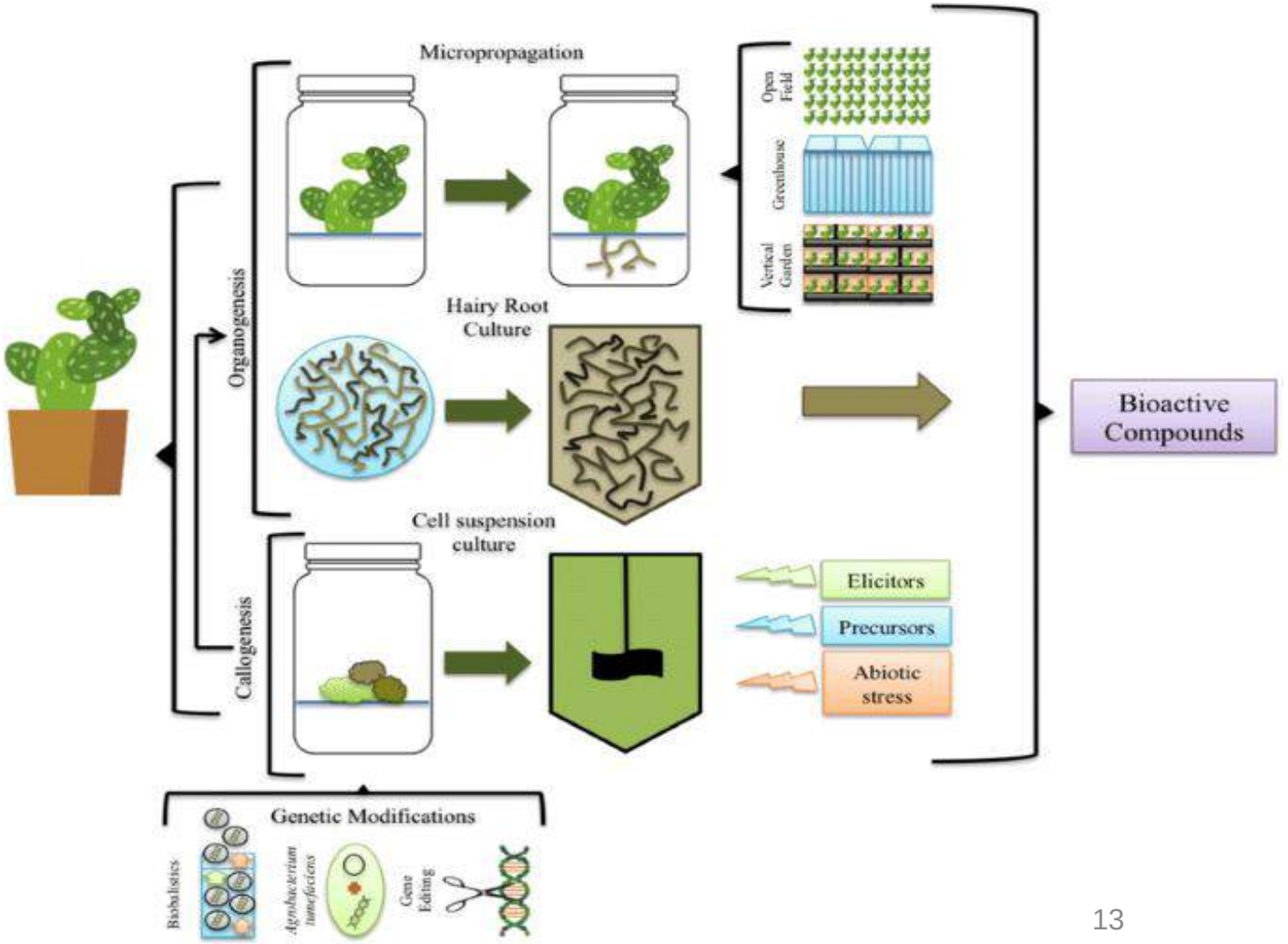


https://doi.org/10.1038/s41598-021-94597-4

Manfaat Kultur Jaringan

Untuk produksi Obat: metode alternatif untuk memperoleh metabolit sekunder

- produksinya dapat diatur,
- kualitas dan hasil produksi lebih konsisten,
- biaya produksi lebih kecil,
- mengurangi penggunaan lahan

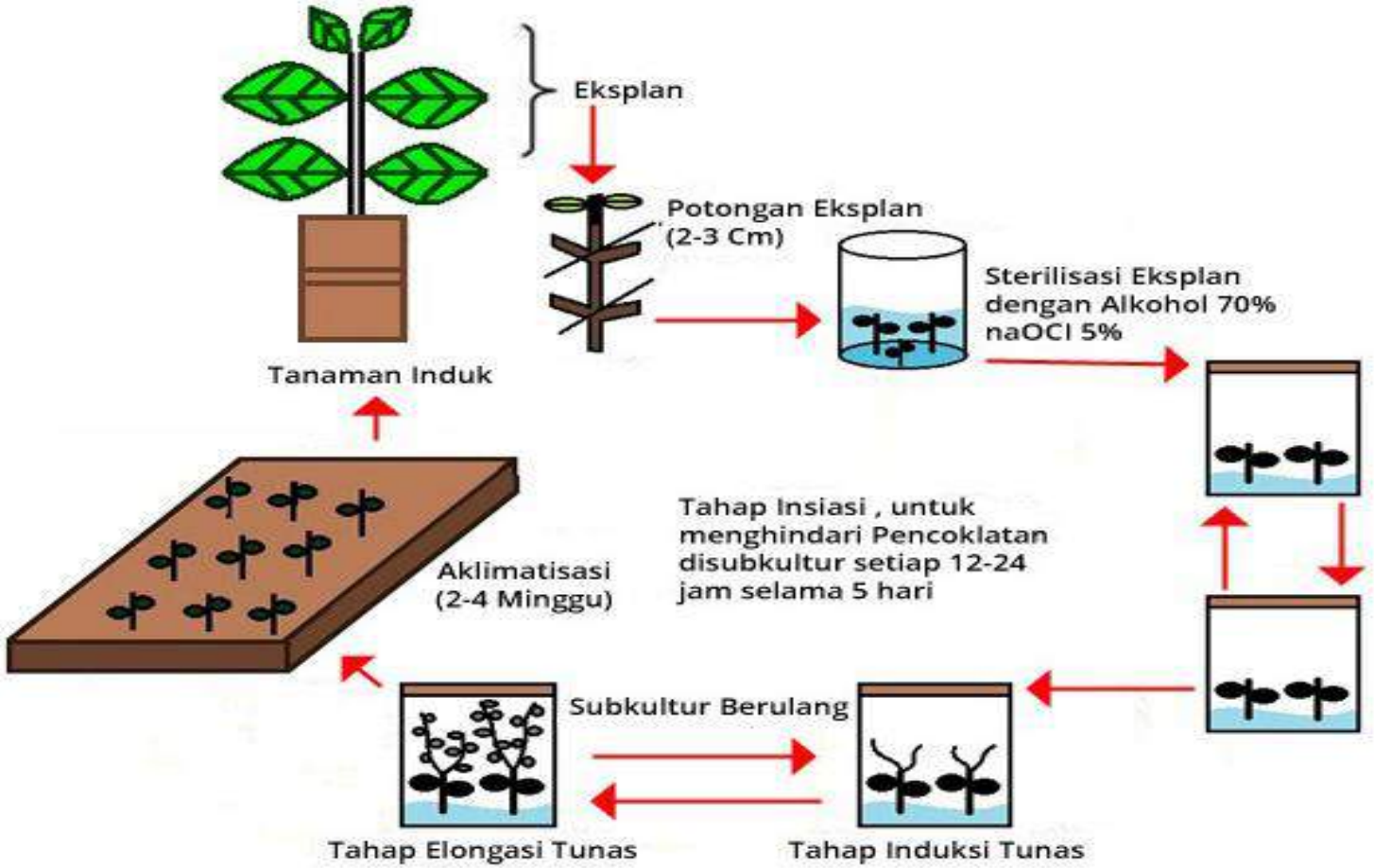


https://doi.org/10.1007/s00425-018-2910-1

Manfaat Kultur Jaringan

Mikropropagasi

- Pengkulturan bagian tanaman yang sangat kecil (eksplan) secara aseptik didalam tabung kultur atau wadah serupa
- Disebut juga perbanyakan klonal cepat karena menghasilkan banyak bibit identik dalam waktu singkat



Faktor penunjang

01

pemilihan eksplan sebagai bahan dasar untuk pembentukkan kalus

02

penggunaan medium yang cocok

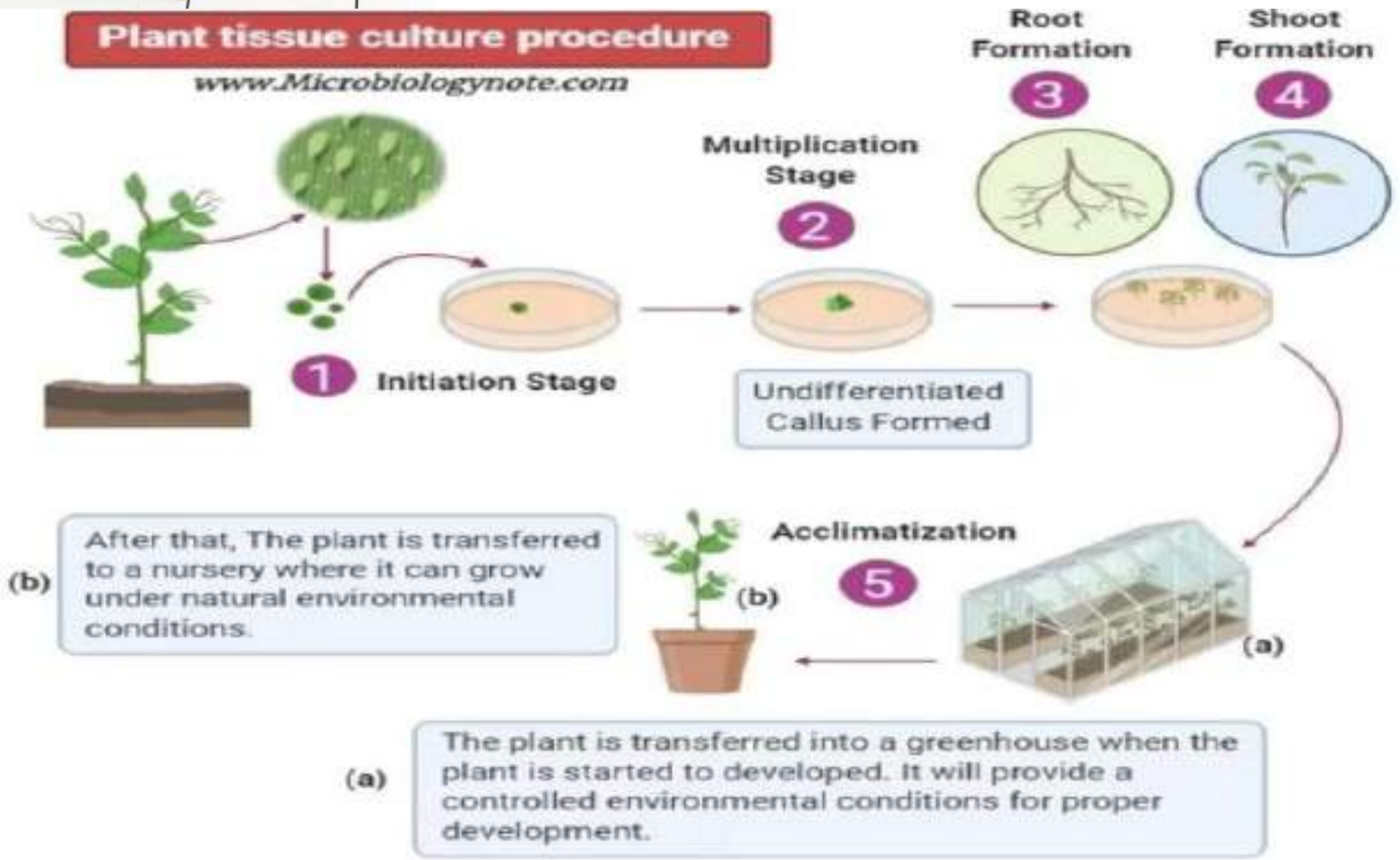
03

keadaan yang aseptik

04

Lingkungan (temperatur, cahaya, pengaturan udara yang baik terutama untuk kultur cair)

Faktor penunjang



Media tanam kultur jaringan merupakan media yang diperlukan agar sel atau jaringan tanaman yang diisolasi dapat tumbuh dan berkembang menjadi tanaman yang lengkap.

Media tersebut mempunyai komposisi nutrien yang dapat mendukung pertumbuhan eksplan sesuai dengan yang diinginkan.

Media tanam pada kultur jaringan berisi kombinasi dari asam amino essensial, garam- garam anorganik, vitamin- vitamin, larutan buffer, dan sumber energi (glukosa)

Contoh Kasus Faktor Penunjang dalam Kultur Jaringan

Faktor yang Bermasalah	Contoh Kondisi	Dampak pada Kultur Jaringan
Jenis Eksplan	Menggunakan jaringan tua/keras	Sel sulit membelah → pertumbuhan lambat/gagal.
Sterilisasi kurang baik	Eksplan tidak steril, alat/media terkontaminasi	Tumbuh jamur/bakteri → kultur mati.
pH Media salah	pH terlalu asam (<5) atau basa (>6)	Nutrisi tidak tersedia optimal → eksplan menguning, mati.
Zat Pengatur Tumbuh tidak seimbang	Auksin terlalu tinggi, sitokinin rendah	Eksplan hanya membentuk akar tanpa tunas.
	Sitokinin terlalu tinggi, auksin rendah	Banyak tunas kecil, tidak membentuk akar.
Suhu tidak stabil	Suhu <20 °C atau >30 °C	Pertumbuhan terhambat, bisa nekrosis (mati jaringan).
Cahaya kurang/berlebihan	Tidak ada cahaya sama sekali	Planlet pucat (etiolasi), tidak kuat tumbuh.
	Cahaya terlalu terang	Daun terbakar/nekrosis.
Kelembaban rendah	Ruang kultur kering	Eksplan cepat layu & mati.
Manusia (teknisi)	Proses pemindahan eksplan tidak hathati	Eksplan rusak, kontaminasi silang.

Teknik kultur jaringan

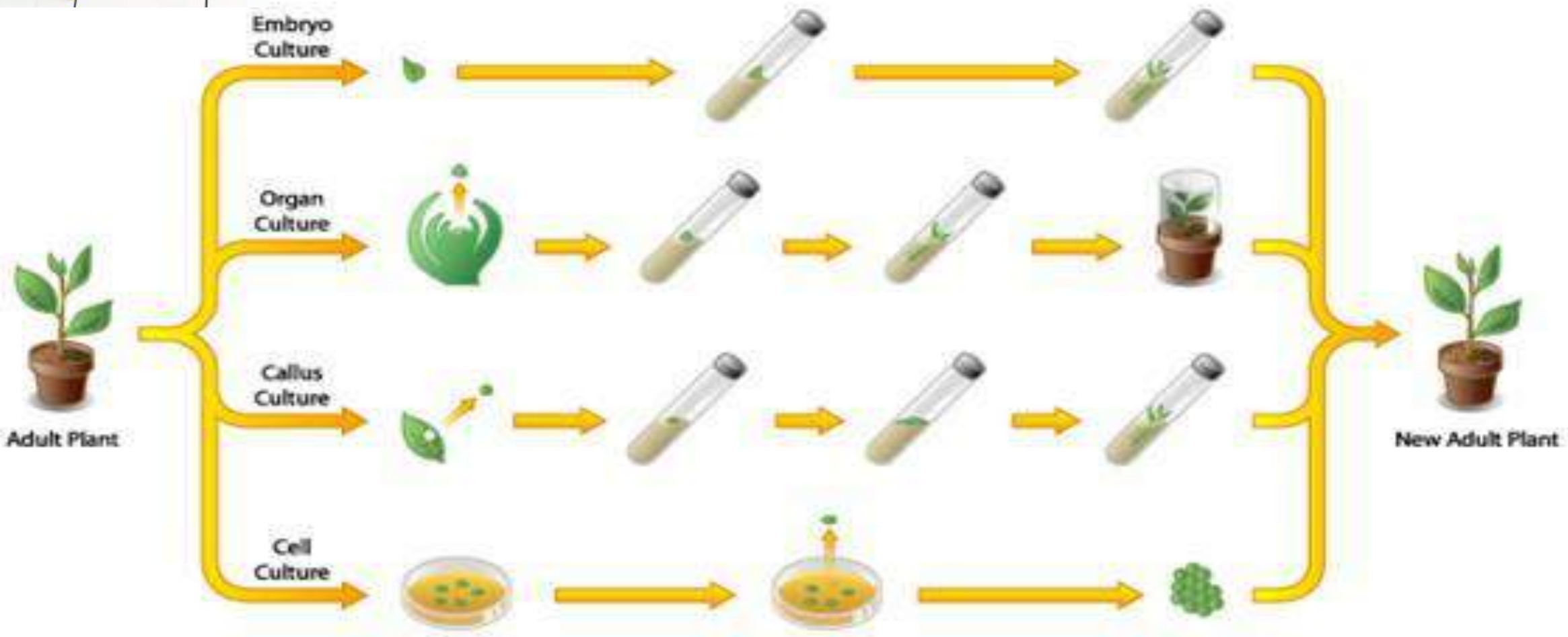
KULTUR JARINGAN BERDASARKAN ASAL EKSPLAN

Kultur Sel	• Dilakukan isolasi sel tunggal yang diambil secara mekanik atau enzimatik atau dari kultur jaringan dipisahkan selnya. Ditujukan untuk seleksi mutan maupun industri (produksi metabolit sekunder atau induksi poliploid)
Kultur Meristem	• (daun, batang, akar , meristem) untuk membentuk tanaman utuh
Kultur Protoplas	• Yaitu sel telanjang yang tidak mempunyai dinding sel atau dinding selnya telah rusak
Proliferasi pucuk aksilar	• Pertumbuhan tunas terminal tertekan, sedangkan pertumbuhan tunas samping mengalami peningkatan
Induksi Tunas Adventif	• Inisisasi tunas adventif baik secara langsung pada permukaan eksplan yang dikulturkan atau secara tidak langsung pada permukaan kalus eksplan yang terbentuk

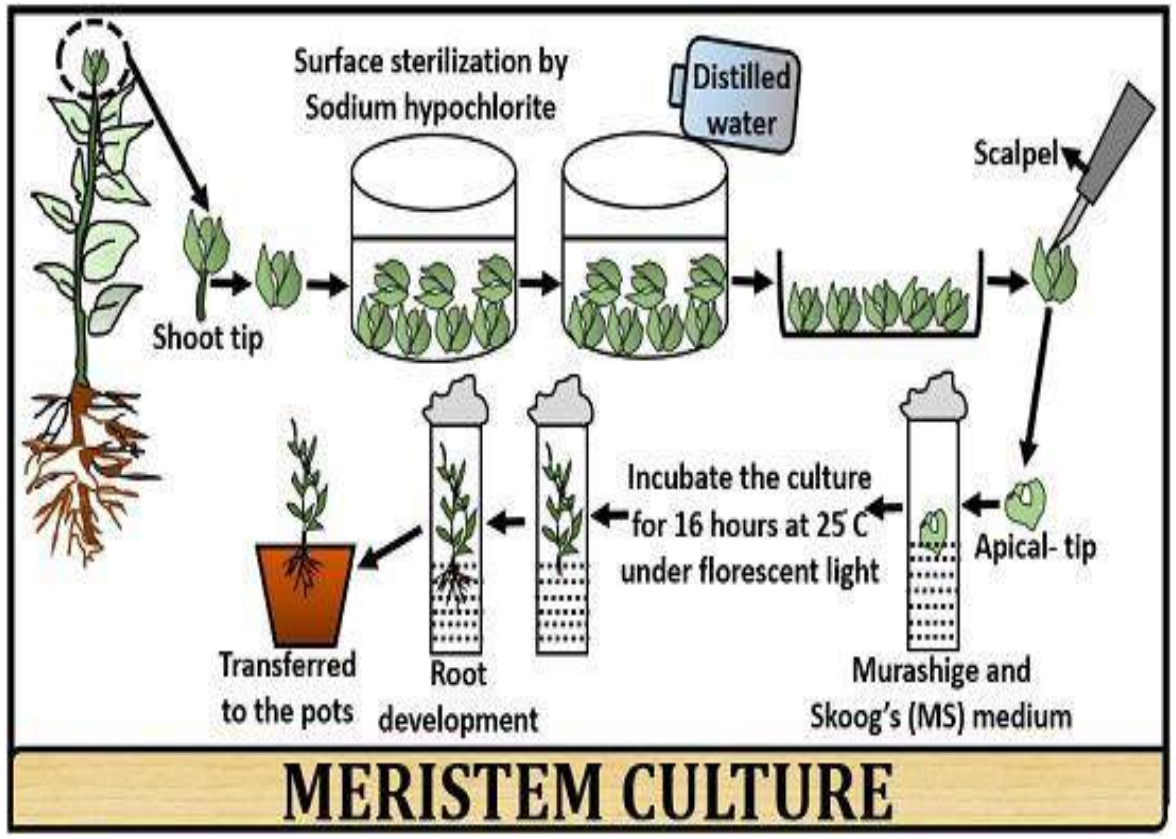
Teknik kultur jaringan

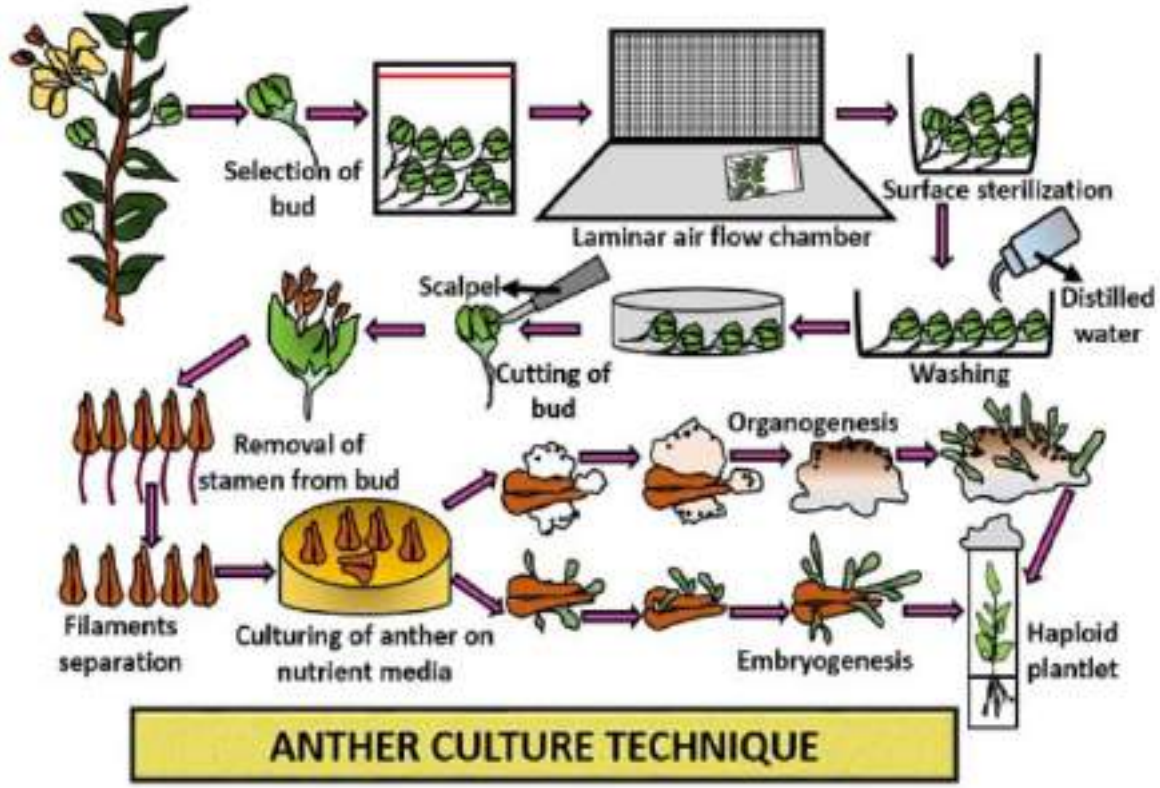
Kultur Organ	• Kultur semua bagian tanaman, untuk perbanyakan secara cepat, bebas penyakit
Kultur Kalus	• Kultur jaringan tanaman menggunakan eksplan jaringan akar
Kultur Suspensi Sel	• Kultur jaringan dengan menggunakan teknik bioreaktor
Kultur Protoplasma	• Shoot tip, tujuanya untuk perbanyakan vegetatif tanaman
Kultur Haploid	• Bertujuan memperoleh kalus dari eksplan yang ditanam

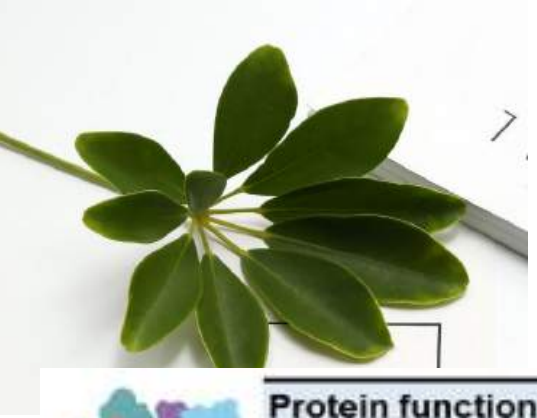
Teknik kultur jaringan



Teknik kultur jaringan

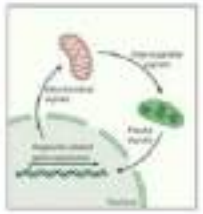




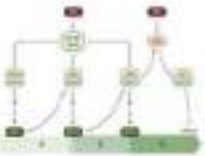


Teknik kultur jaringan

Protein function
Subcellular localization, protein-protein interaction, western blotting, protein secretion and transport, and protein activity analysis.

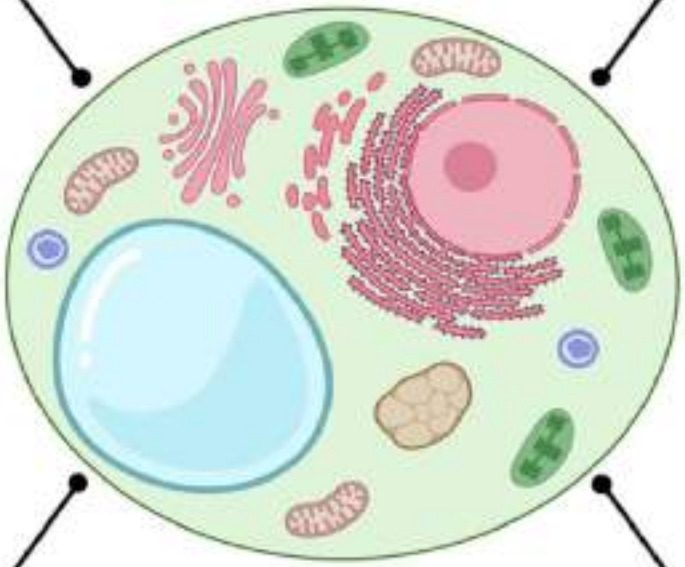


Signal transduction
Elucidating signal transduction pathways involved in plant growth, development, immunity and physiology.



Transcriptional regulation
Investigating gene promoter activity and gene expression level, and constructing transcriptional regulatory network.

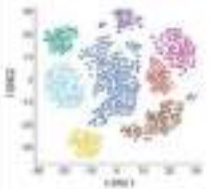
Protoplast



CRISPR/Cas9 editing
Estimating gene-editing efficiency, combining CRISPR/Cas9 with protoplast regeneration to develop plants with desired traits.

Cellular process
Cell wall synthesis, cell division, embryogenesis, cell differentiation and dedifferentiation, somatic hybridization, membrane transport.

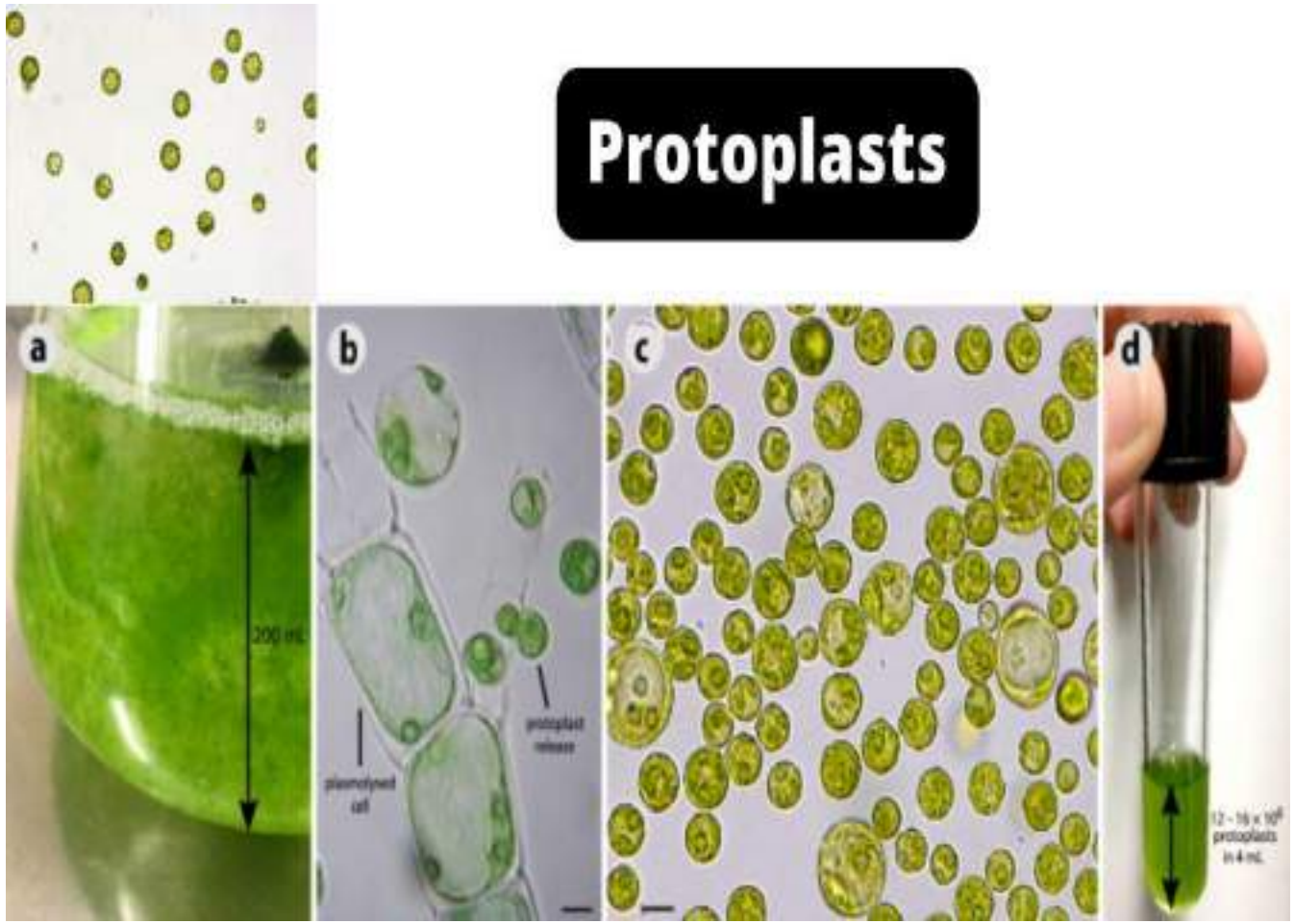
Multi-omics analysis
Protoplast is a single-cell system to investigate genomics, transcriptomics, proteomics, metabolomics and epigenetics.



Protoplast culture refers to the process in which whole plants are developed from the culture of cells without cell wall

Trends in Plant Science

Teknik kultur jaringan



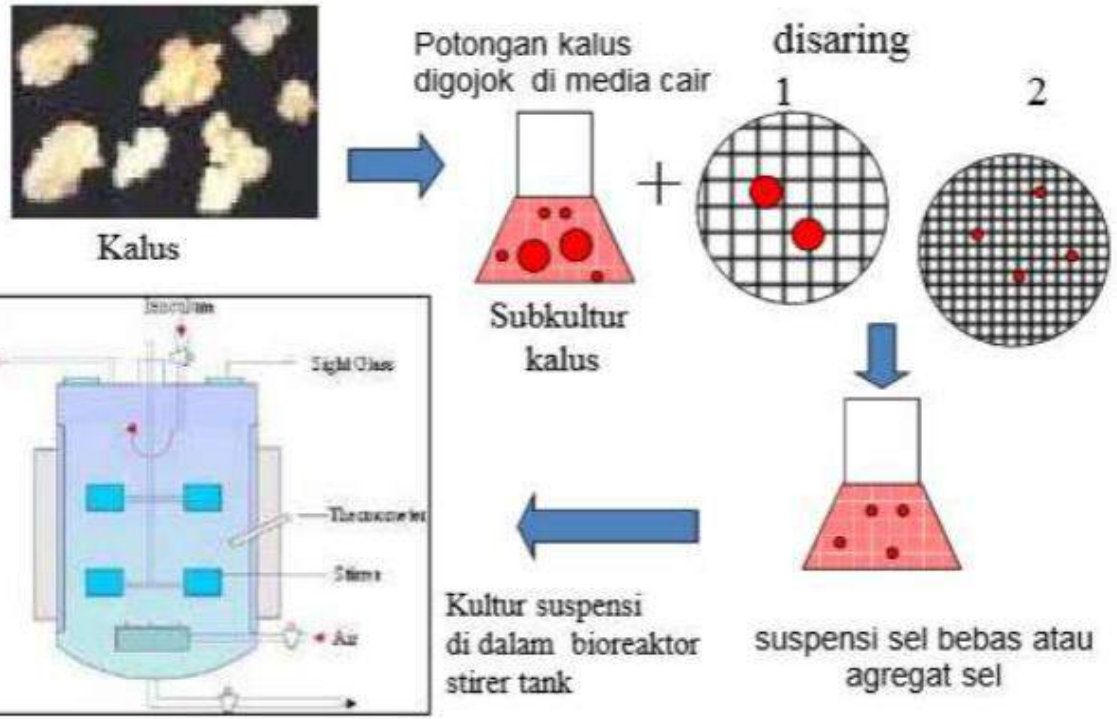
In protoplast culture, protoplasts isolated from any plant part, including root, shoot, leaves, or embryo, is cultured in an artificial media under artificial conditions favoring cell division and plant regeneration

The mechanical method involves placing cells in a hypertonic solution, which induces the separation of the plasma wall, leading to the exudation of cellular material and the subsequent division of plant tissue, resulting in the release of protoplasts

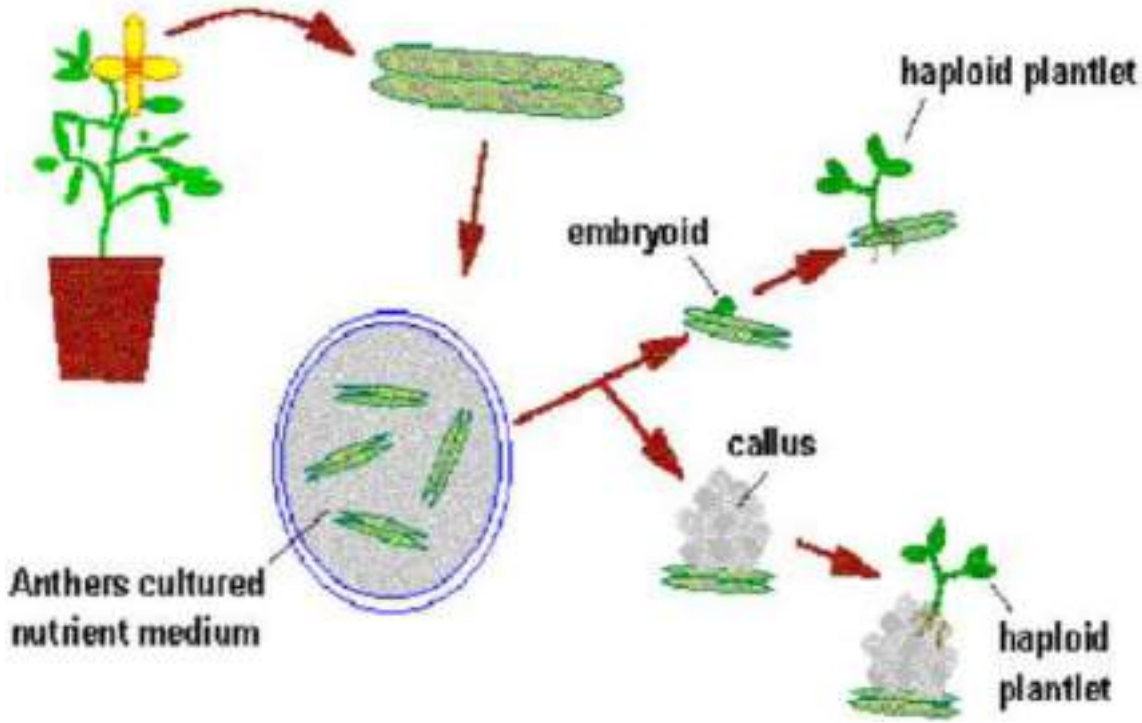
The enzymatic isolation of protoplasts represents a widely employed technique in protoplast extraction. It operates on the principle of employing enzymes, including cellulase, hemicellulose, dissociative enzymes, and pectinase, to facilitate the degradation of the plant cell wall, leading to the acquisition of protoplasts

Teknik kultur jaringan

Kultur suspensi sel



Kultur Haploid (Anther/Mikrospora)



Kelebihan & Kekurangan

Kelebihan

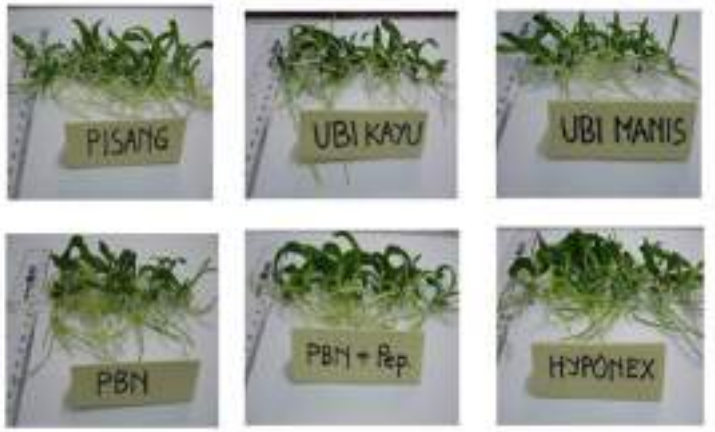
- Jumlah bibit yang diproduksi bisa banyak
- Sehat, bebas dari virus dan penyakit lain
- Relatif cepat (rate 45 perbulan)
- Seragam
- Memudahkan dalam transportasi

Kekurangan

- Biaya lebih mahal
- Butuh skill/keahlian khusus
- Mutasi /off type akibat sub kultur berlebih variasi somaklonal

APLIKASI KULTUR JARINGAN

APLIKASI KULTUR JARINGAN



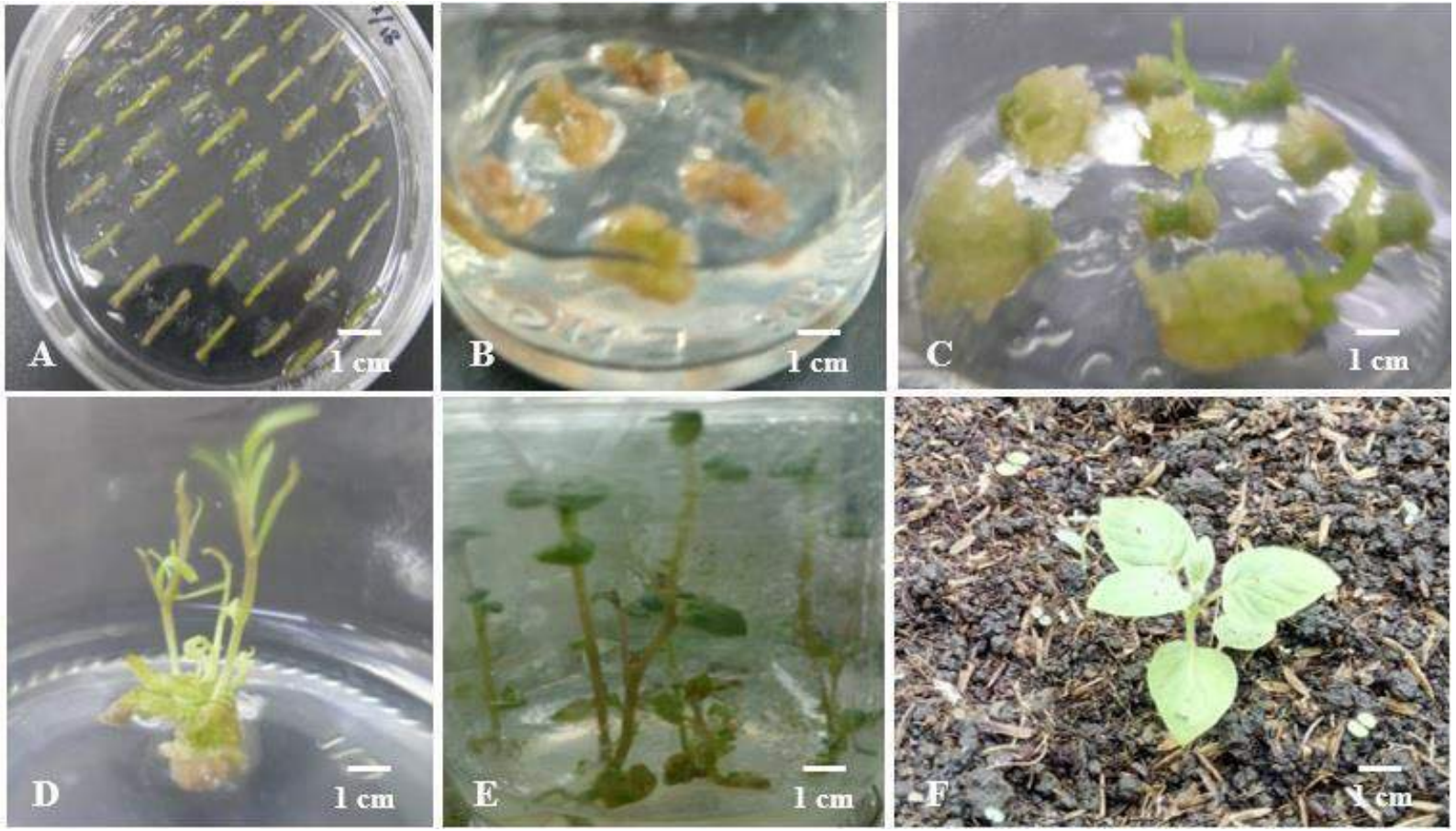
Planlet anggrek Dendroobium NS 022/27 yang telah dikeluarkan dari berbagai komposisi media proliferasi (padat).

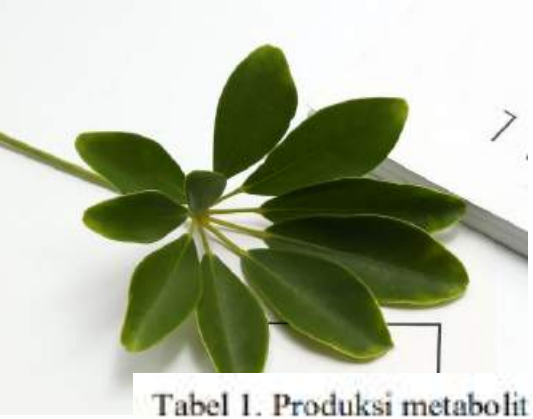
NS 02/21 NS 02/23 NS 02/27 NS 022/62

Klon 5 nomor anggrek Dendrobium hasil silangan Balithi dengan kode NS 022/21, NS 022/23, NS 022/27, dan NS 022/62

APLIKASI KULTUR JARINGAN

- tanaman kentang

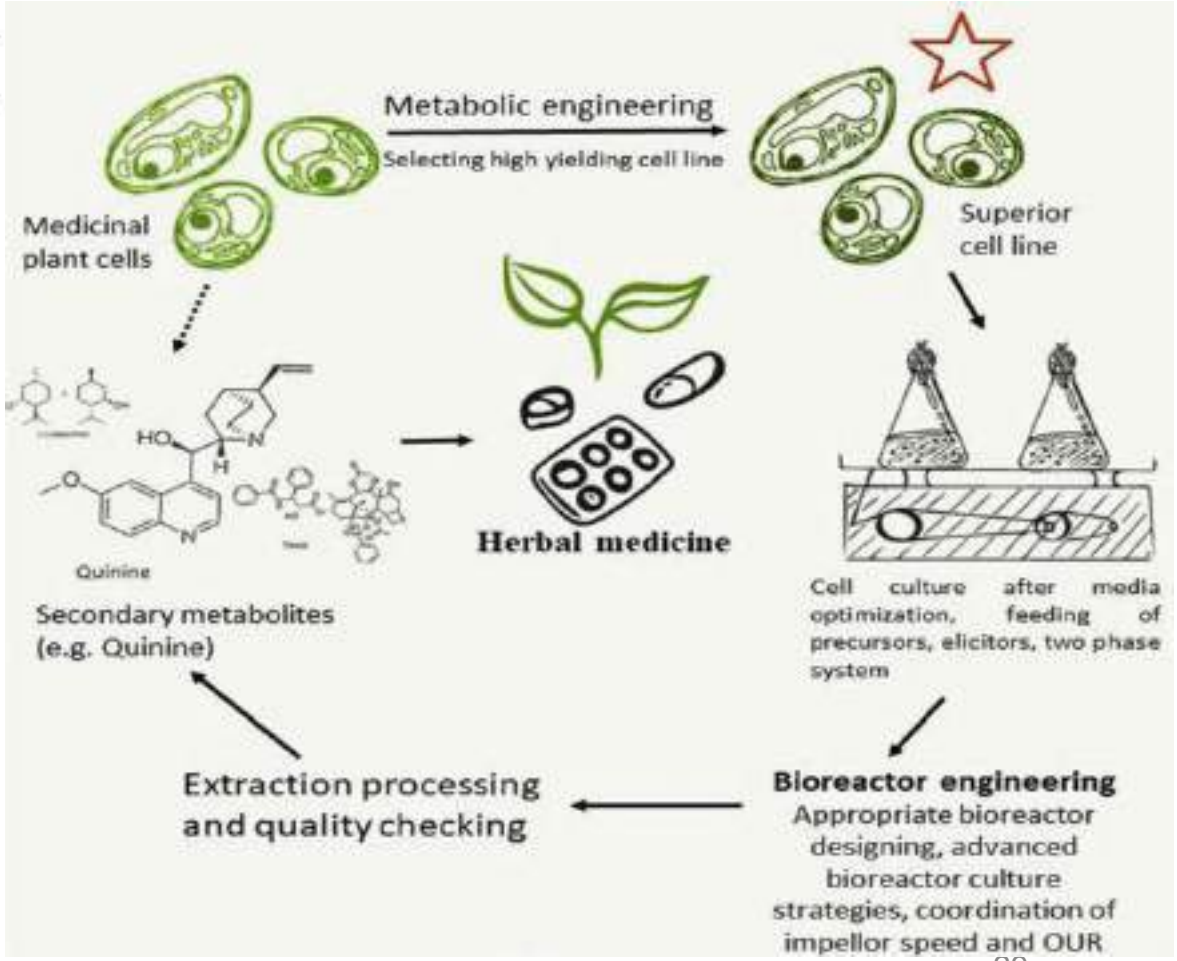




APLIKASI KULTUR JARINGAN

Tabel 1. Produksi metabolit sekunder melalui kultur jaringan

Nama Metabolit Sekunder	Nama tumbuhan penghasil
Vasine	*Adhatoda vasica*
Artemisinin	*Artemisia annua*
Azadirachtin	*Azadirachta indica*
Cathin	*Brucea javanica*
Capsiacin	*Capsicum annum*
Sennosides	*Cassia senna*
Ajmalicine, Secologanin, Indole alkaloids, Vincristine	*Catharanthus roseus*
Stilbenes	*Cayratia trifoliata*
Berberin	*Coscinium fenustratum*
Sterols	*Hyssopus officinalis*
Shikonin	*Lithospermum erythrorhizon*
Ginseng saponin	*Panax notoginseng*
Podophyllotoxin	*Podophyllum hexandrum*
Taxane Paclitaxel	*Taxus chinensis*



APLIKASI KULTUR JARINGAN

Plant regeneration from protoplasts of *K. blossfeldiana* ‘Charming Red Meadow’

a different types of isolated protoplast

- a- I: small protoplast without chloroplasts;
- a- II: dense protoplast with chloroplasts concentrated in the middle of the cell;
- a- III: dense protoplast with chloroplasts distributed homogenously throughout the cytoplasm;
- a- IV: vacuolated protoplast with chloroplasts concentrated in one zone of the cell;

b protoplast division at 3 days after culture initiation;

c microcolonies 2 weeks after culture initiation;

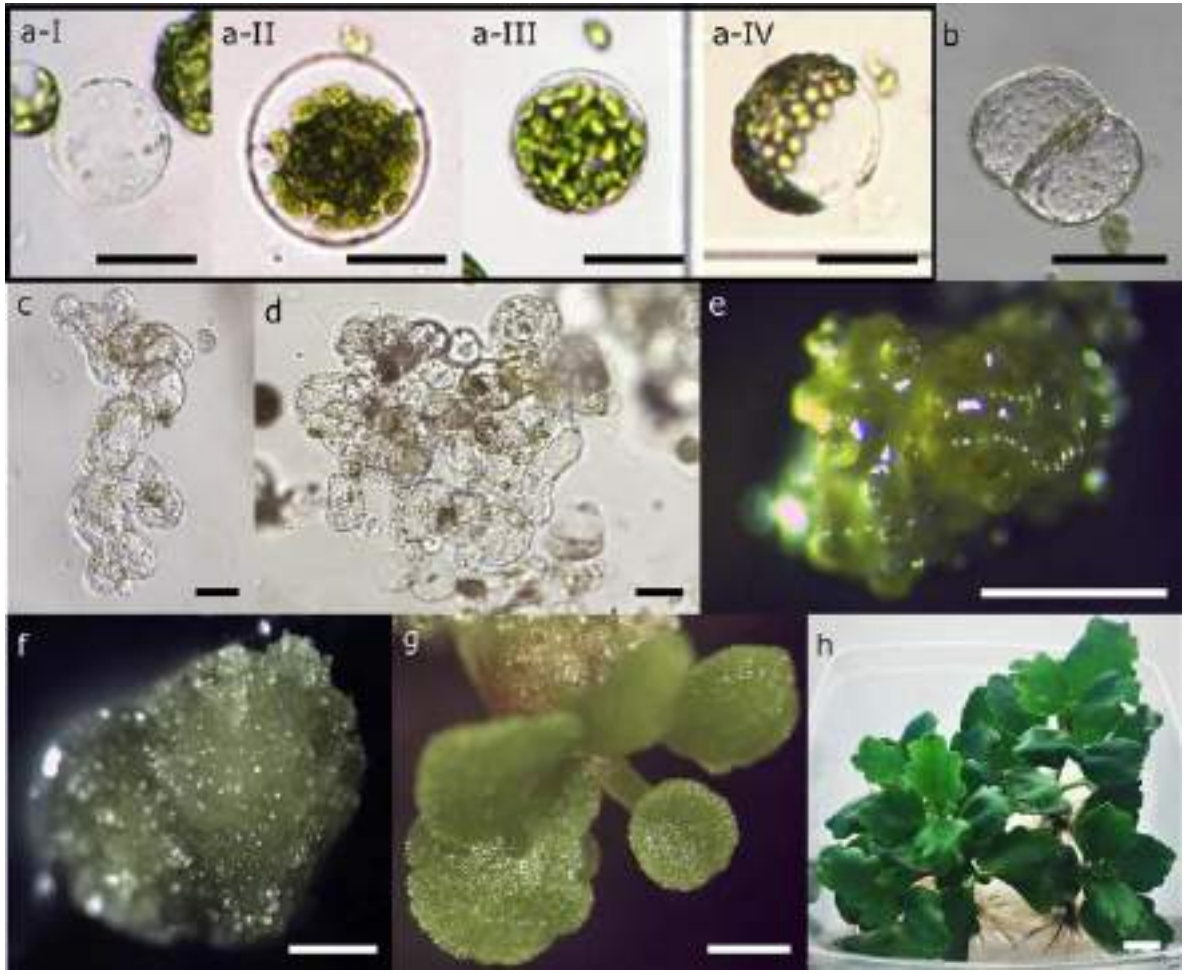
d microcolonies 4 weeks after culture initiation;

e green microcallus 8 weeks after culture initiation;

f yellow microcallus 8 weeks after culture initiation;

g shoot regenerated on the callus at 17 weeks;

h regenerated plants at 22 weeks



scale bars: a, b 25 µm; c, d 50 µm; e–h 1 mm

THANK YOU FOR YOUR ATTENTION

Link Video

- https://youtu.be/xuwV3ywCxW8?t=2
- https://youtu.be/uPuxS1kxdVY?t=33

BIOTEKNOLOGI

Pertemuan 3

apt. Trifonia Rosa Kurniasih, M.Biotech

STIKES Notokusumo Yogyakarta

Case-based learning

Topik: Kultur Jaringan dalam Produksi Metabolit Sekunder
Kasus: Produksi vincristine & vinblastine dari *Catharanthus roseus*

Latar Belakang Kasus

1. *Catharanthus roseus* (tapak dara) adalah tanaman obat penting karena menghasilkan alkaloid indol-terpenoid seperti vinblastine dan vincristine , yang digunakan dalam terapi kanker.
2. Namun, kandungan alkaloid ini di tanaman sangat rendah, sehingga sulit memenuhi kebutuhan industri farmasi.
3. Sebuah perusahaan farmasi di Yogyakarta sedang mencari metode alternatif untuk memproduksi metabolit sekunder ini. Tim peneliti mengusulkan penggunaan teknologi kultur jaringan tanaman .

Case-based learning

Topik: Kultur Jaringan dalam Produksi Metabolit Sekunder
Kasus: Produksi vincristine & vinblastine dari *Catharanthus roseus*

Skenario Kasus
Tim peneliti mencoba berbagai pendekatan:

1. Kalus Kultur
   Eksplan daun *C. roseus* diinduksi pada media Murashige and Skoog (MS) dengan penambahan auksin (2,4-D) dan sitokinin (kinetin). Terbentuk kalus putih, tetapi produksi alkaloid sangat rendah.
2. Kultur Suspensi Sel
   Kalus kemudian diadaptasi menjadi kultur suspensi cair dalam medium MS. Hasil analisis menunjukkan adanya produksi vincristine, namun tidak stabil.
3. Elicitor
   Penambahan metil jasmonat (MeJA) ke kultur suspensi meningkatkan kadar vinblastine hingga 5 kali lipat.
4. Kultur Akar Rambut (Hairy Root Culture)
   Dengan bantuan *Agrobacterium rhizogenes*, peneliti berhasil menumbuhkan akar rambut yang menghasilkan metabolit secara lebih stabil.

Case-based learning

Topik: Kultur Jaringan dalam Produksi Metabolit Sekunder
Kasus: Produksi vincristine & vinblastine dari *Catharanthus roseus*

Pertanyaan Diskusi

1. Mengapa kultur jaringan dipilih sebagai metode alternatif untuk produksi vincristine dan vinblastine dibandingkan menanam langsung *C. roseus*?
2. Apa kelebihan dan keterbatasan kalus kultur dibandingkan kultur akar rambut dalam produksi metabolit sekunder?
3. Bagaimana peran elicitor (misalnya MeJA) dalam meningkatkan biosintesis metabolit sekunder?
4. Jika Anda adalah tim peneliti, metode kultur jaringan mana yang paling efektif dan berkelanjutan untuk industri farmasi? Jelaskan alasannya.
5. Apa peluang dan tantangan penggunaan bioreaktor sel tumbuhan untuk skala produksi metabolit sekunder di farmasi?

Case-based learning

Topik: Kultur Jaringan dalam Produksi Metabolit Sekunder
Kasus: Produksi vincristine & vinblastine dari *Catharanthus roseus*

Tugas Mahasiswa

- Mengidentifikasi masalah.
- Menganalisis opsi solusi.
- Memberi rekomendasi berdasarkan literatur.

THANK YOU FOR YOUR ATTENTION

STIKES NOTOKUSUMO YOGYAKARTA

BIOTEKNOLOGI

Pertemuan 4

apt. Trifonia Rosa Kurniasih, M.Biotech

Topik Bahasan

Pendekatan bioteknologi fermentasi dalam bidang Farmasi

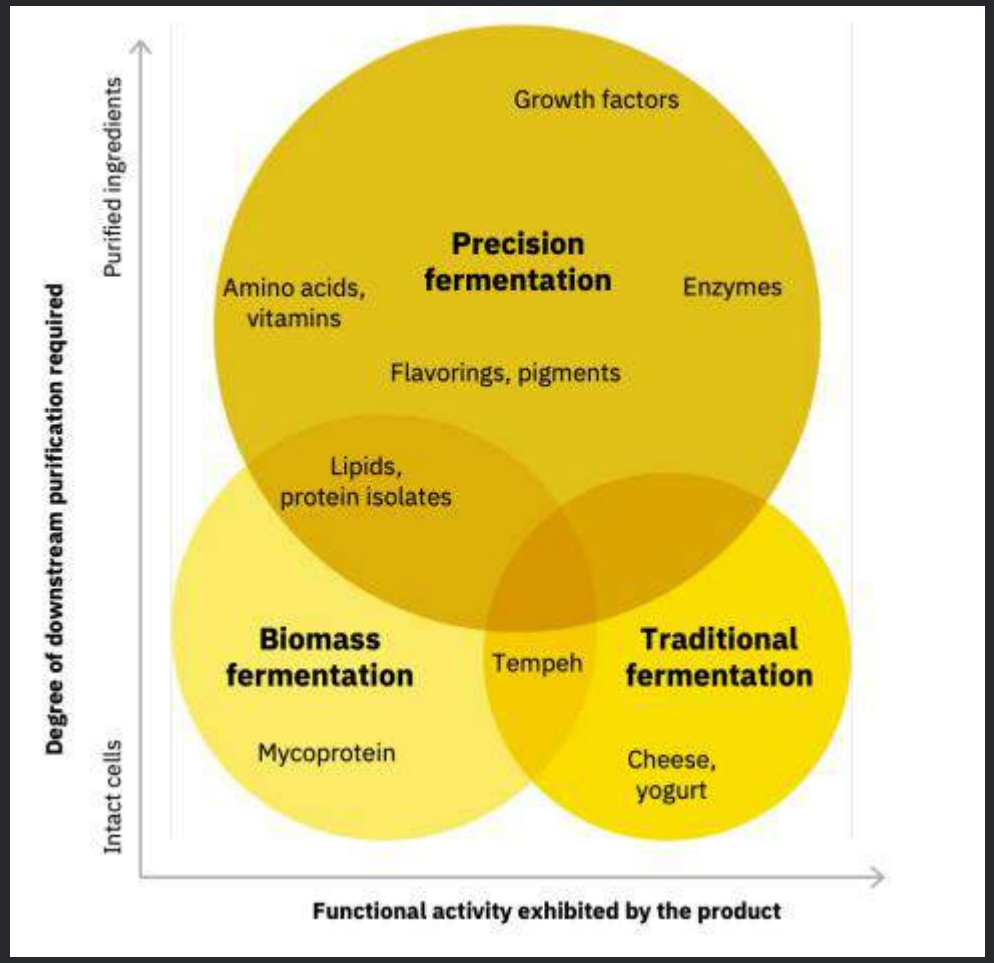
Pendahuluan

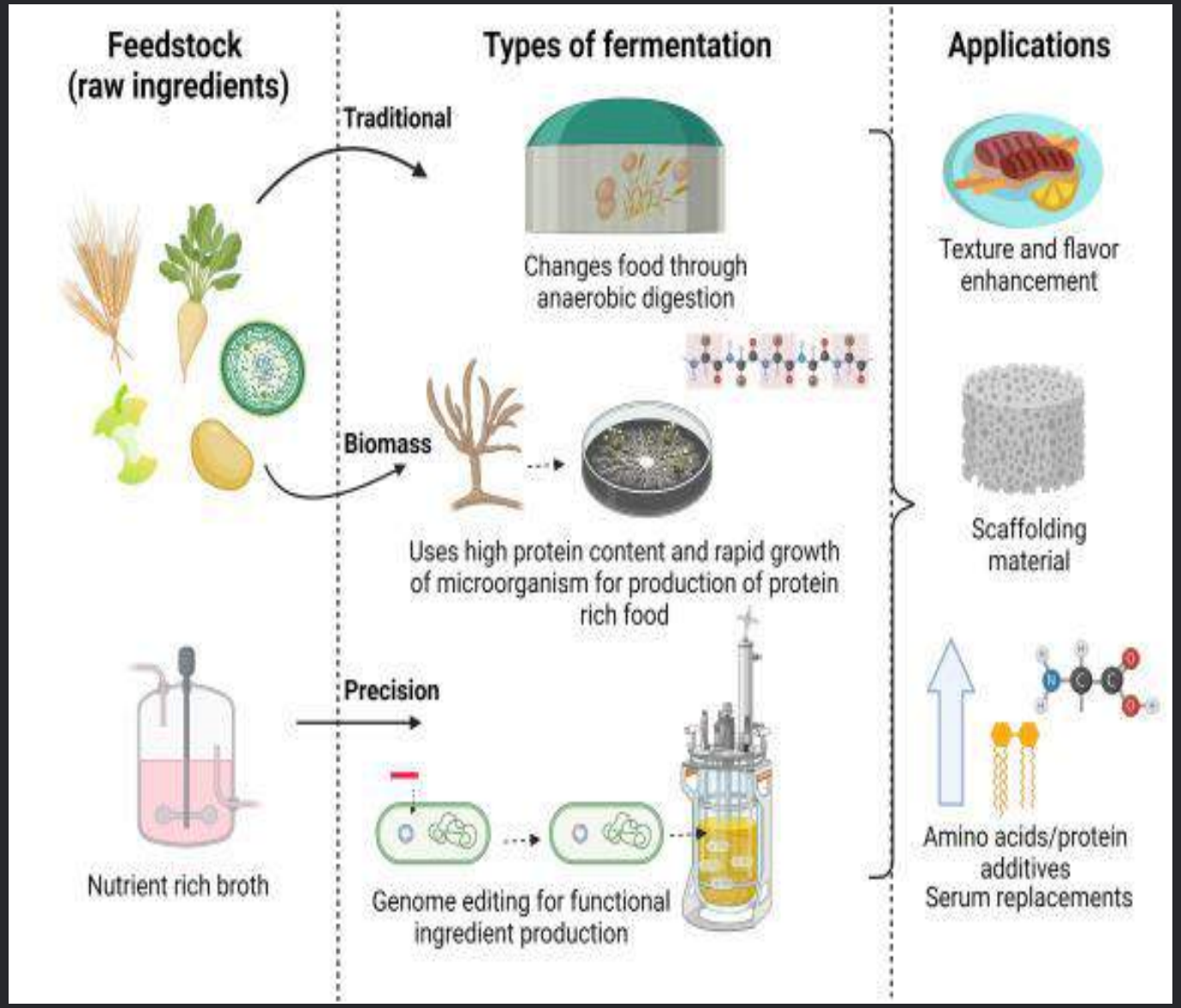
Proses fermentasi

Aplikasi teknologi fermentasi

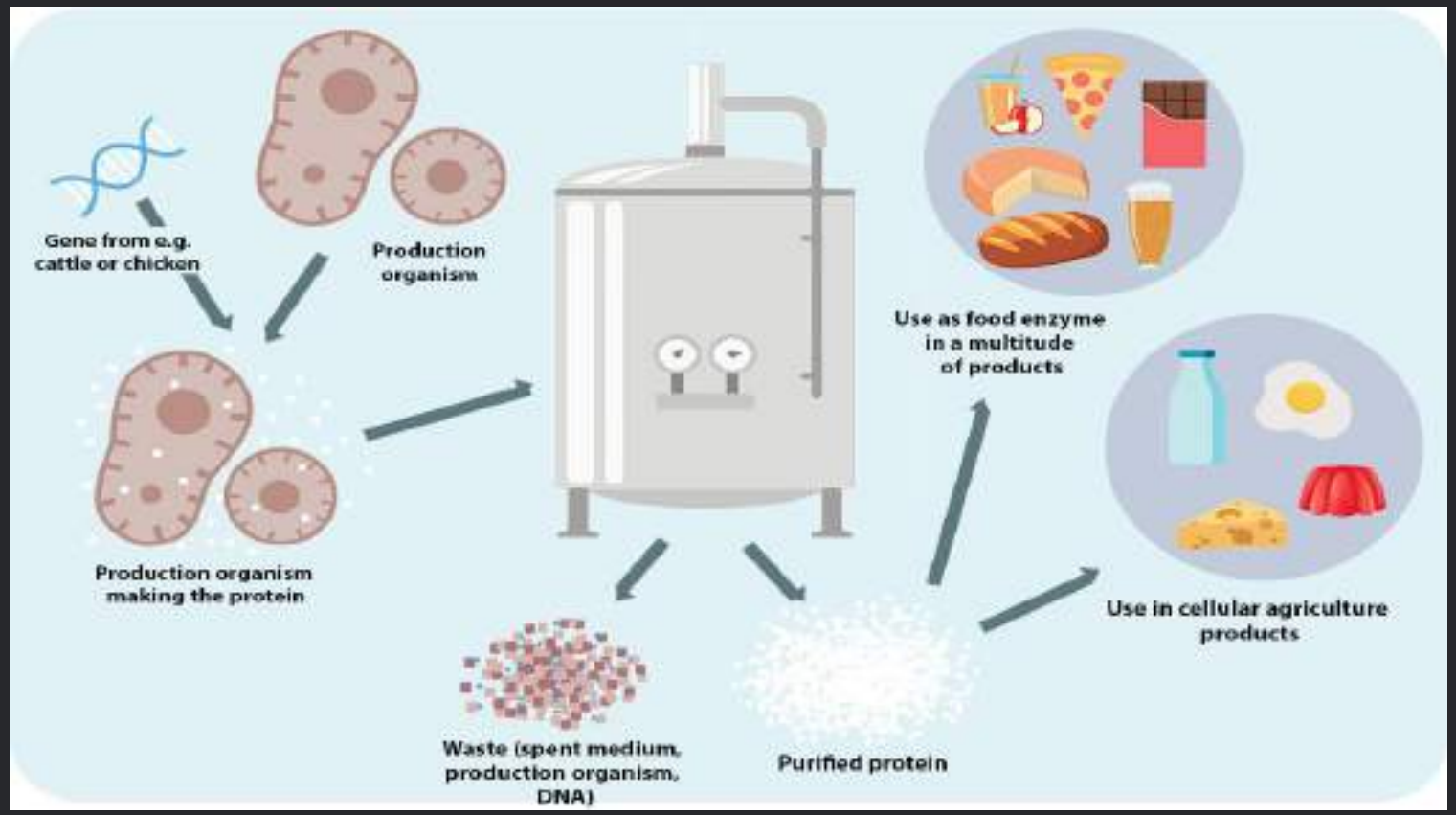
Fermentation: Humanity's Oldest Biotechnological Tool

Fermentasi ?


Degree of downstream purification required
Purified ingredients
Intact cells
Functional activity exhibited by the product
Growth factors
Precision fermentation
Amino acids, vitamins
Enzymes
Flavorings, pigments
Lipids, protein isolates
Biomass fermentation
Mycoprotein
Tempeh
Traditional fermentation
Cheese, yogurt


Feedstock (raw ingredients)
Types of fermentation
Applications
Traditional
Changes food through anaerobic digestion
Texture and flavor enhancement
Biomass
Uses high protein content and rapid growth of microorganism for production of protein rich food
Scaffolding material
Precision
Nutrient rich broth
Genome editing for functional ingredient production
Amino acids/protein additives
Serum replacements

PENDAHULUAN

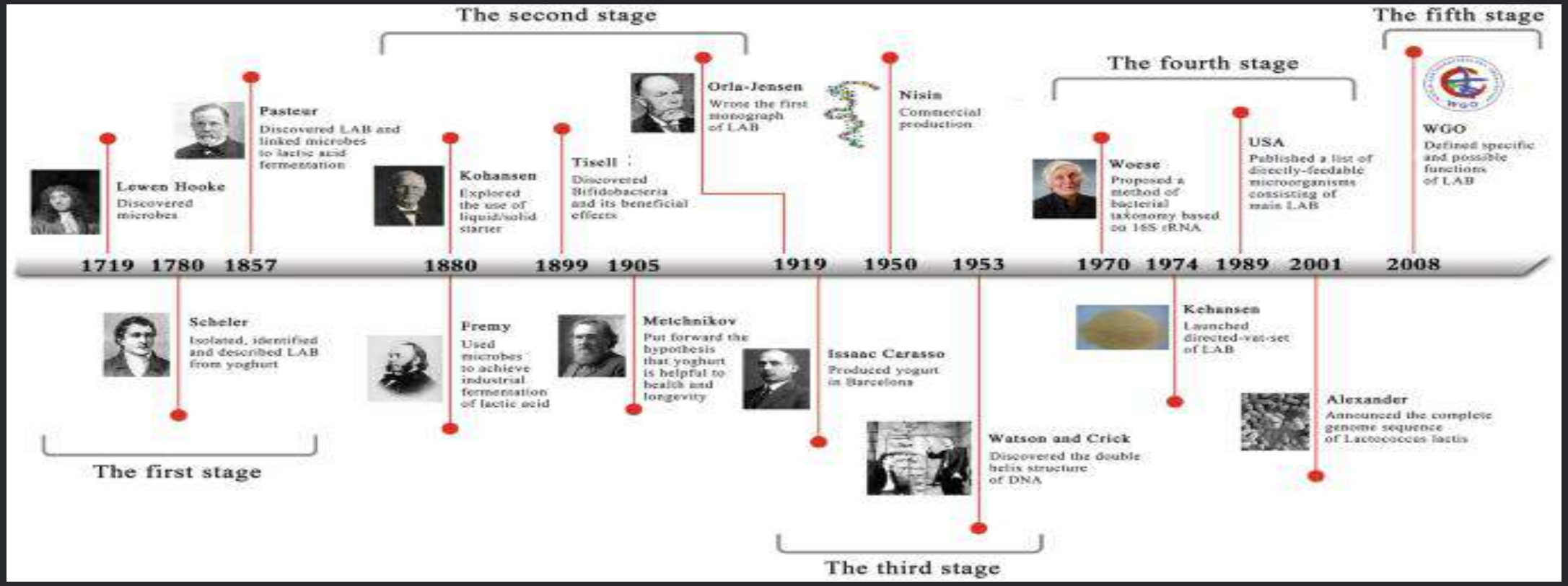


Fermentation, a chemical process by which molecules such as glucose are broken down anaerobically.

- Respirasi sel menghasilkan energi, tetapi merupakan proses aerobik (membutuhkan oksigen)
- Selain molekul energi (seperti ATP), fermentasi menghasilkan berbagai molekul, termasuk etanol, karbon dioksida, asam laktat, metanol, hidrogen, metana, asam butirat, aseton, dan asam asetat.
- Contoh organisme yang melakukan fermentasi antara lain jamur (ragi), hewan (manusia, sapi), dan bakteri (Clostridium).

PENDAHULUAN

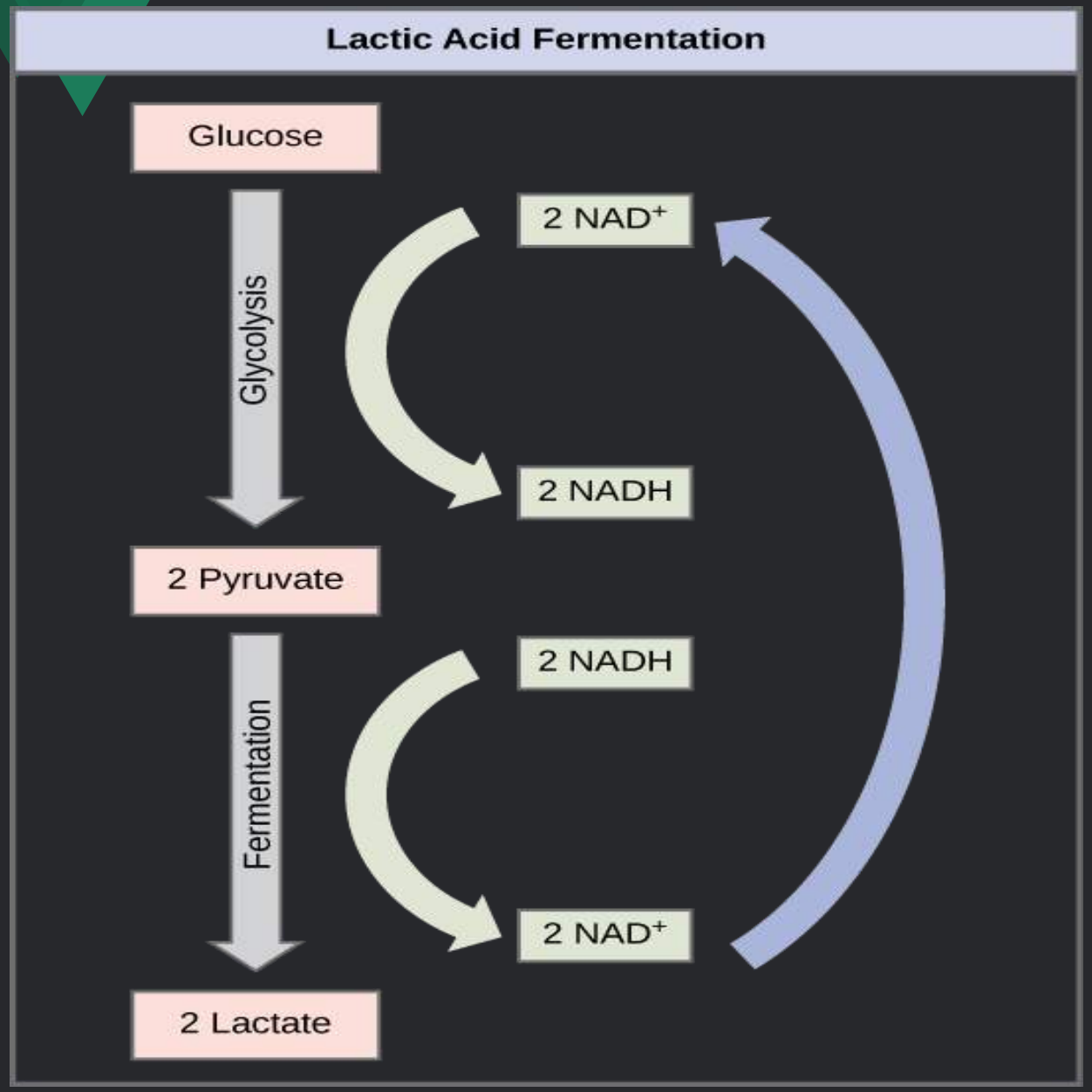
- Human-caused fermentation dates back to 10,000 BCE with the preservation of milk from camels, cattle, sheep, and goats.
- Dairy naturally ferments given the ideal climate and its essential microflora. In the searing temperatures of North Africa, milk spontaneously fermented, making the first documented yogurt

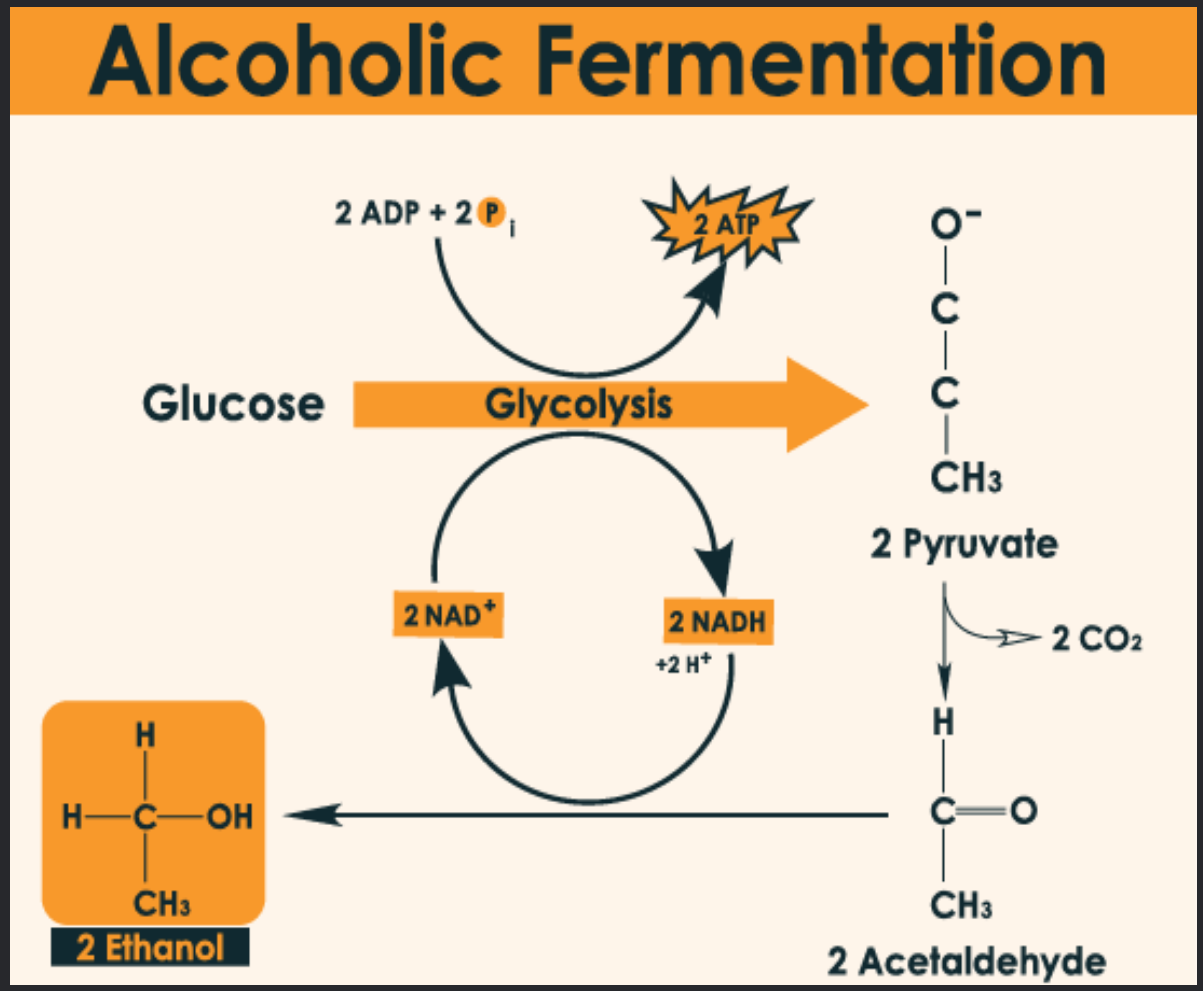


PENDAHULUAN

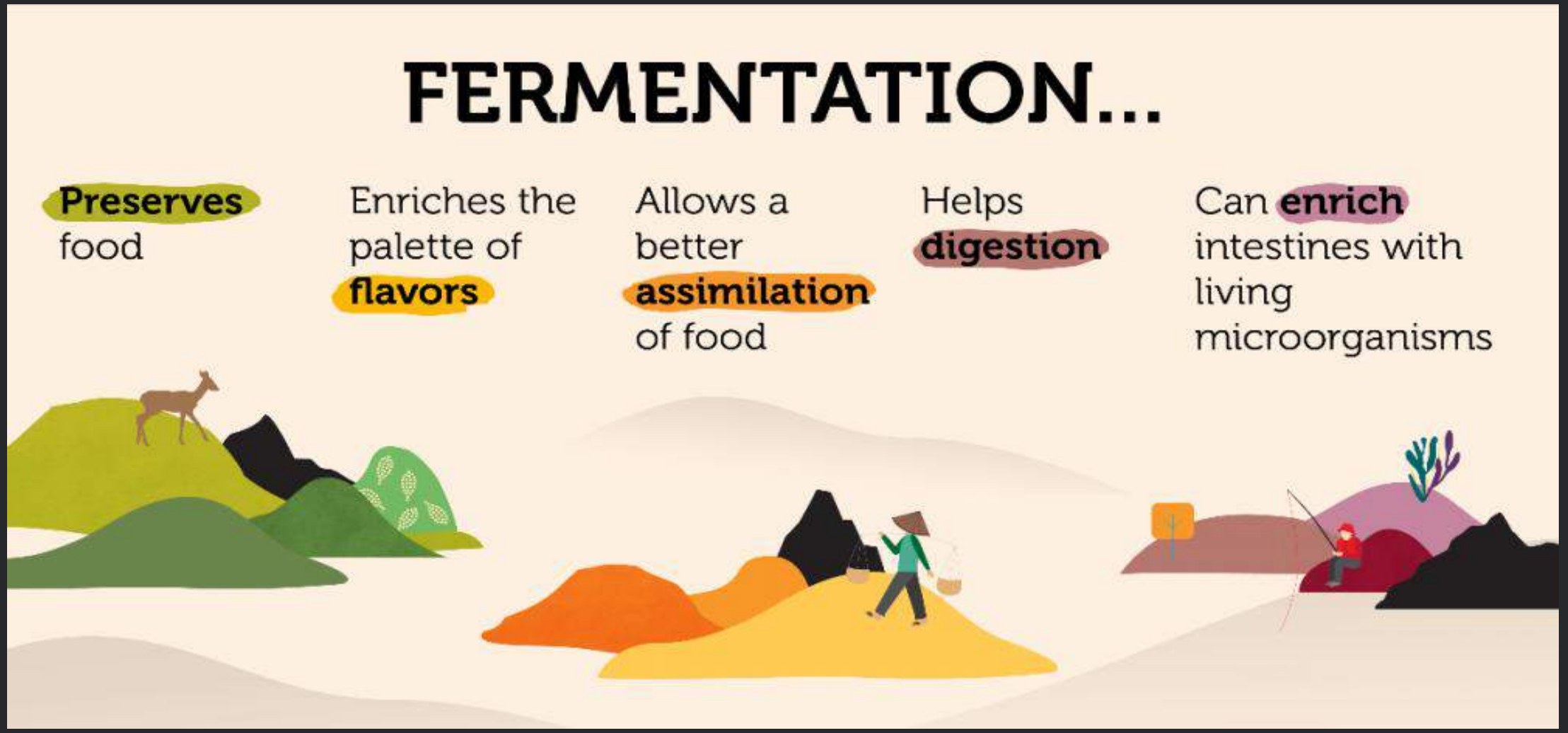
- Louis Pasteur in the 19th century used the term fermentation in a narrow sense to describe the changes brought about by yeasts and other microorganisms growing in the absence of air (anaerobically);
- He also recognized that ethyl alcohol and carbon dioxide are not the only products of fermentation.

PENDAHULUAN

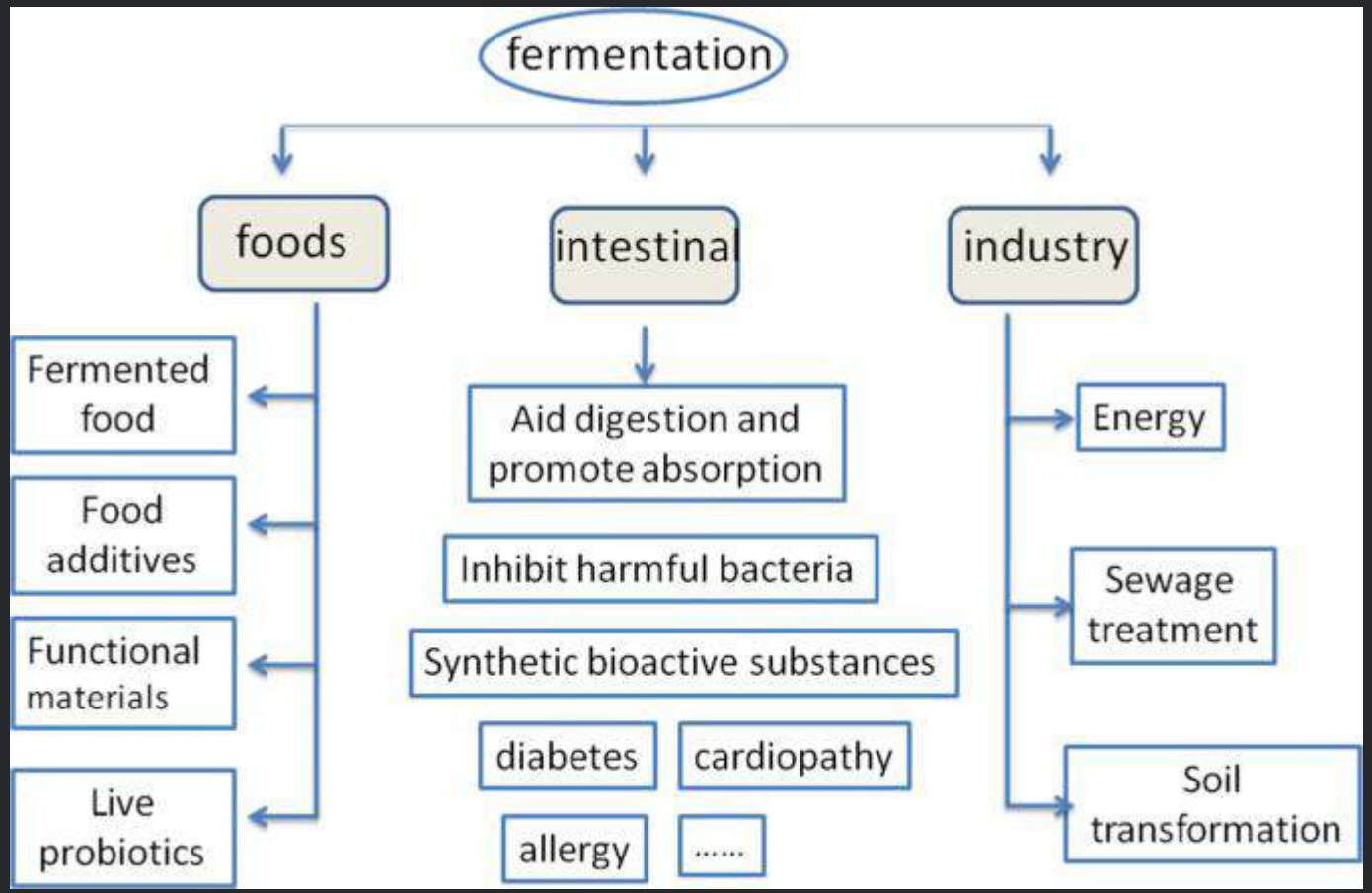




PENDAHULUAN



PENDAHULUAN



- Fermentation has currently evolved into a very important branch of bioengineering and has been a multidisciplinary focus in fields, such as microbiology, chemical engineering, genetic engineering, cellular engineering, mechanical engineering, and computer software and hardware engineering.
- With the development of modern biotechnology, fermentation has been applied to all aspects of life; microbes and metabolites are important in the production of fermented foods, in industry, and in human health

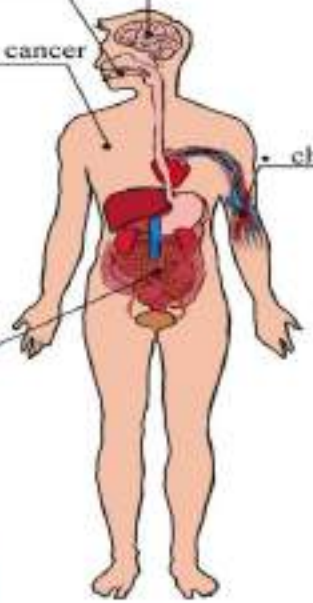
PENDAHULUAN

- breakdown of complex compounds and formation of beneficial catabolites (B vitamins, minerals or Omega-3 fatty acids)
- prevention of food spoilage
- inhibiting the growth of pathogenic microorganisms
- elimination of components toxic to humans (phytates, tannins)

FERMENTED FOOD

- beneficial modification of the composition of intestinal microbiota
- inhibition of intestinal pathogens
- prevention of constipation
- shortening the duration of viral and bacterial diarrheas
- improving mineral absorption
- reducing the symptoms of lactose intolerance
- reducing the risk of obesity
- strengthening the immune system

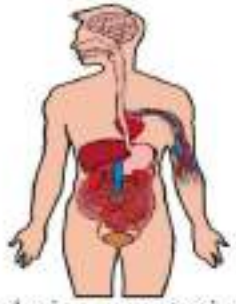
- treatment of halitosis and inflammation of the oral cavity
- improvement of the oral microbiota
- caries reduction
- mood improvement
- reduction of depression symptoms
- protection against cancer
- cholesterol reduction



use of contaminated raw materials

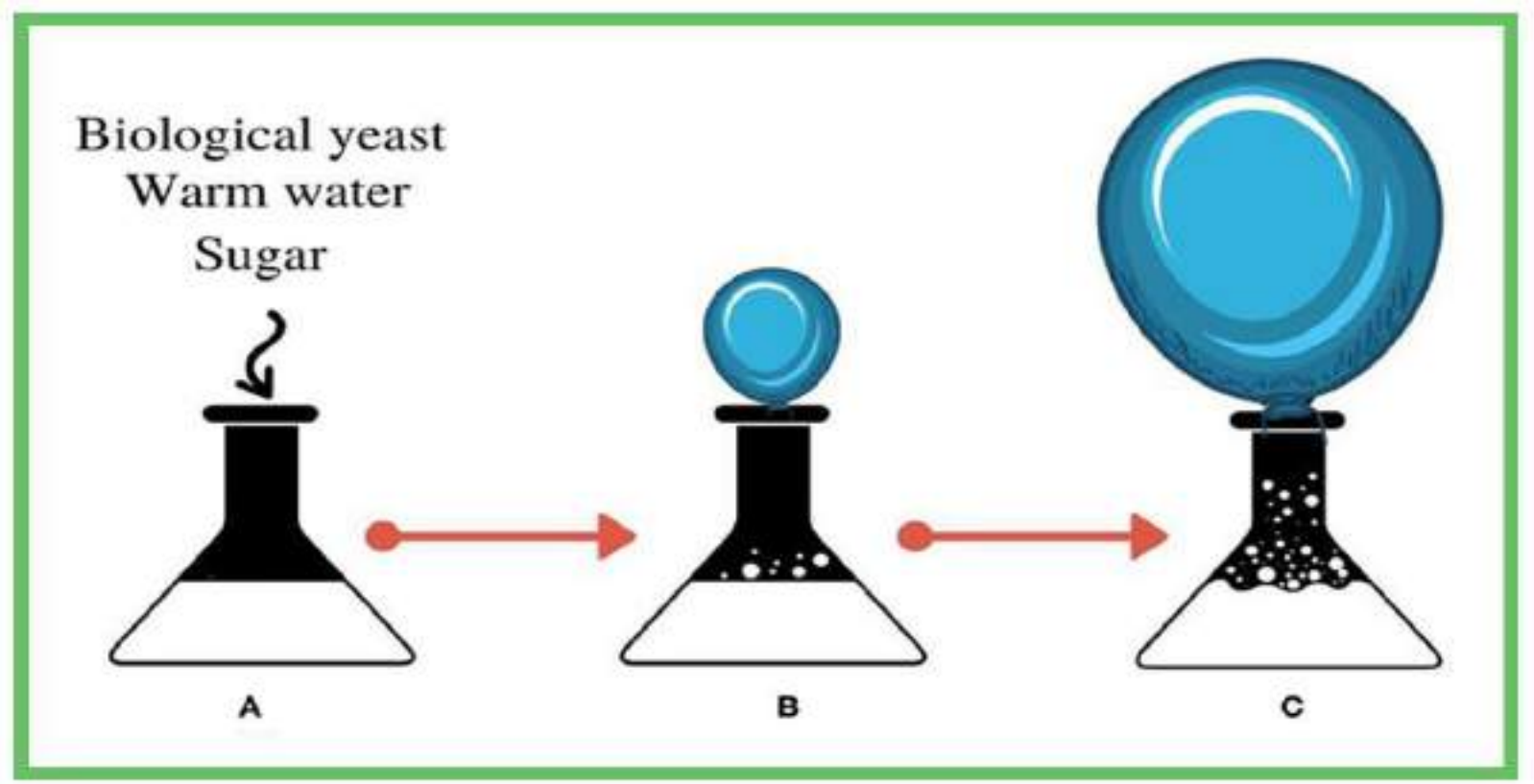
contamination of products during the production process

contamination at the distribution stage of fermented foods



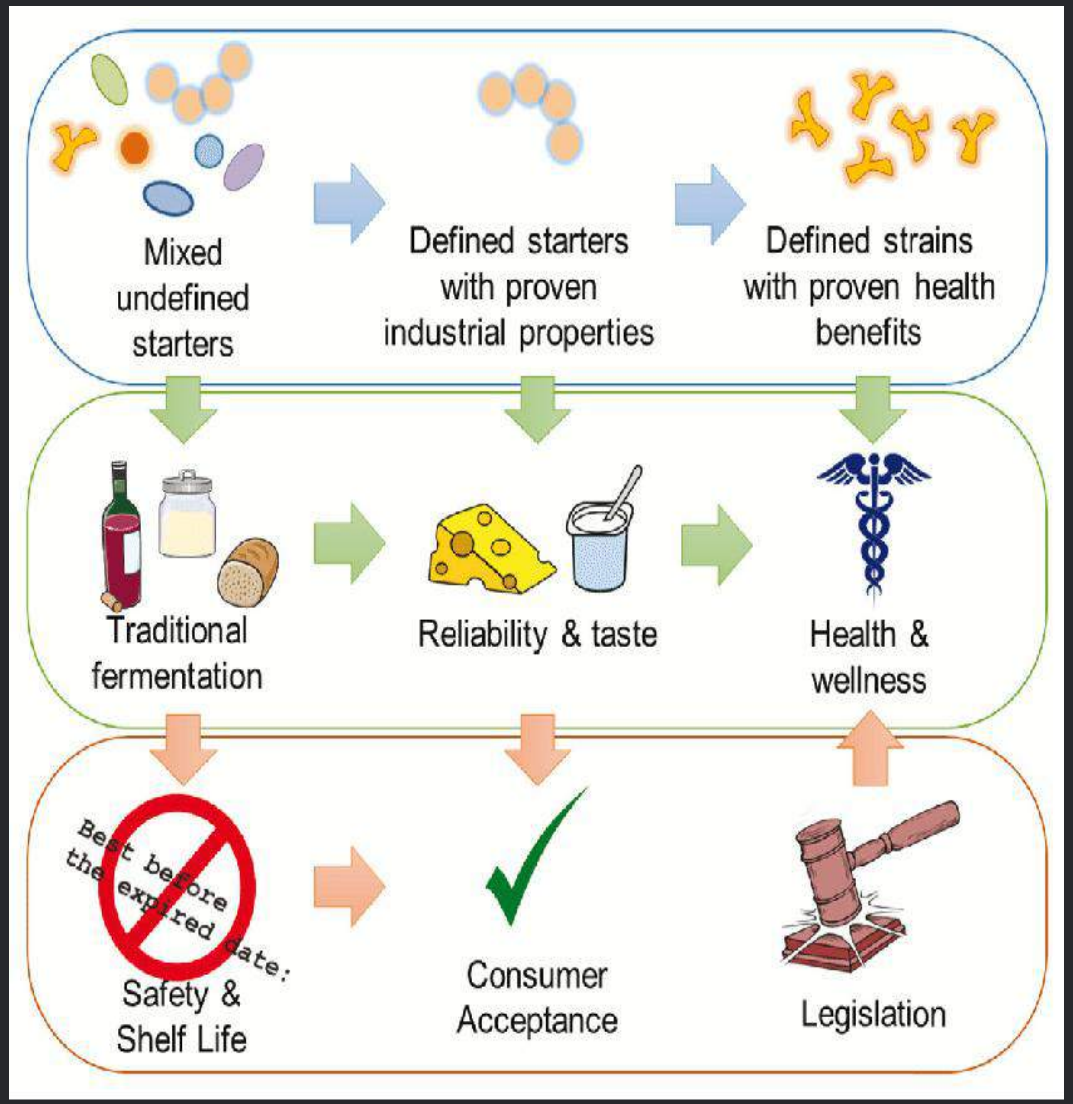
- introducing mycotoxins
- bacterial, viral, fungal infections
- formation of biogenic amines
- foods introducing drug resistance gene carriers

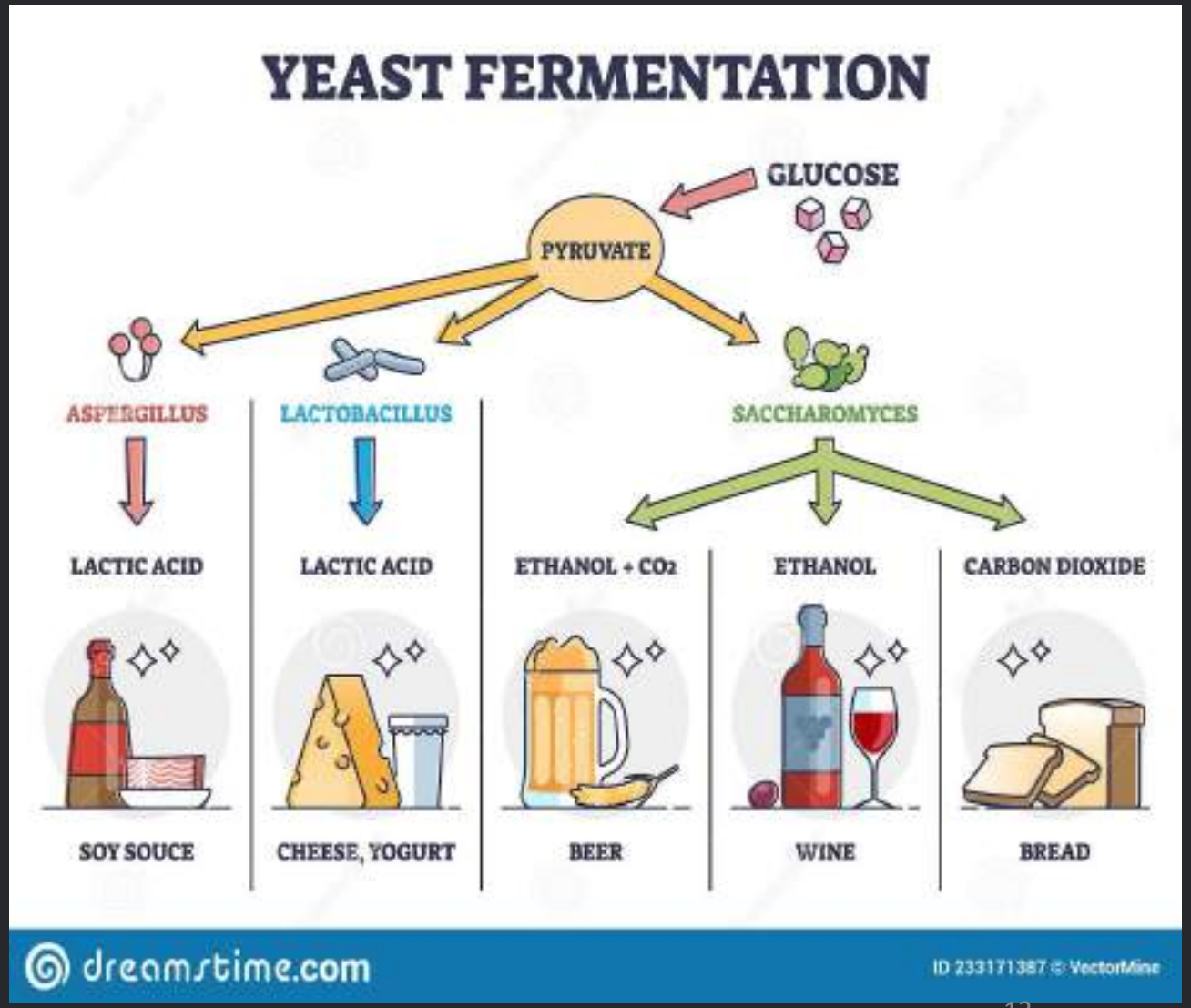
PROSES FERMENTASI



(A) Mix warm water, yeast, and sugar in a jar or flask with a small neck. (B) Place a balloon over the mouth of the flask. (C) After a few minutes, you should see the balloon inflate due to the formation of CO2 gas via fermentation of the sugar by the yeast.

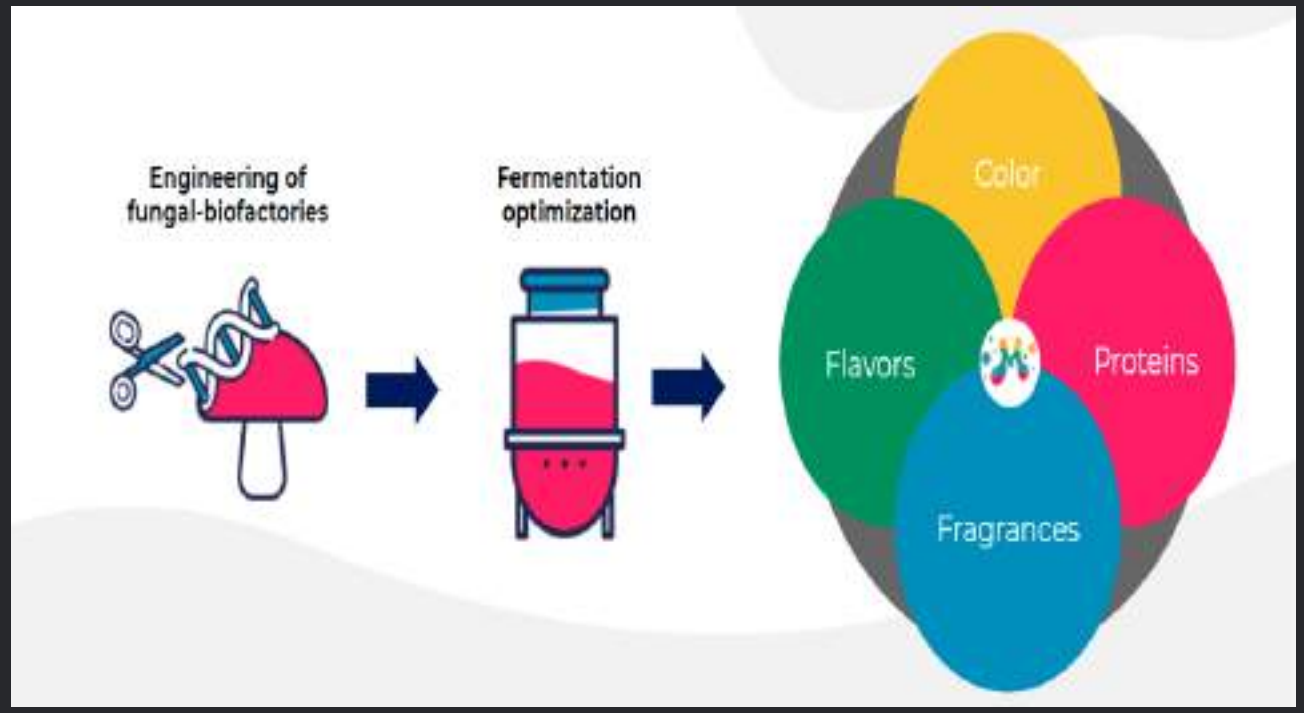
PROSES FERMENTASI

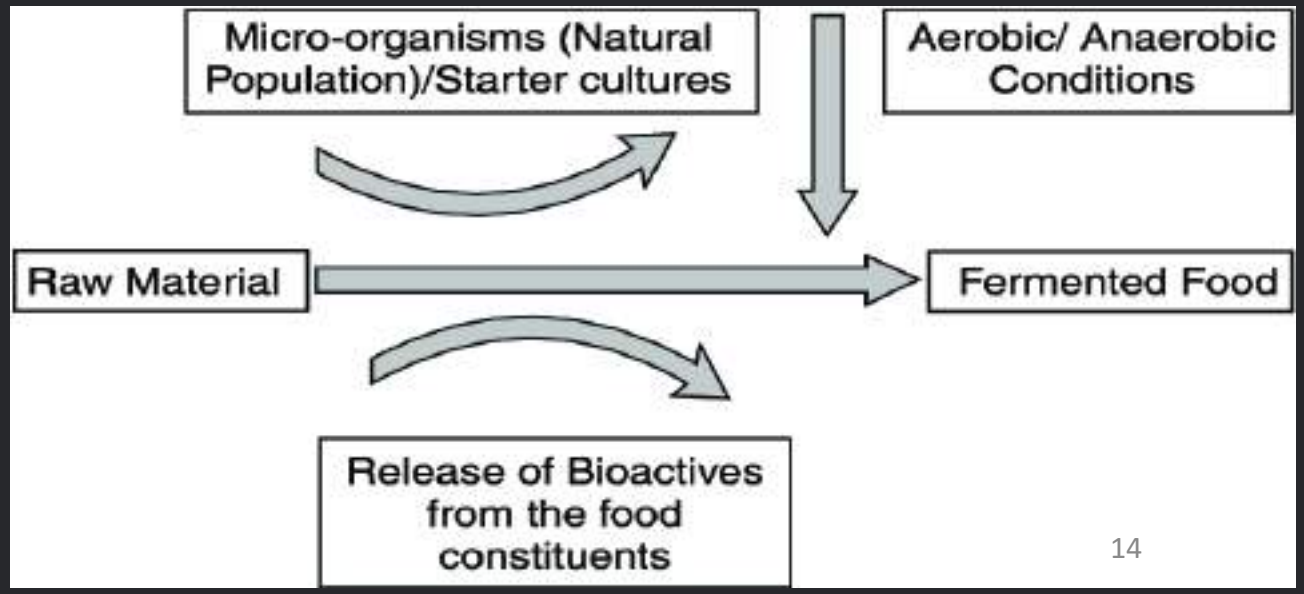




PROSES FERMENTASI

- The main principle of fermentation is to derive energy from carbohydrates in the absence of oxygen.
- Glucose is first partially oxidized to pyruvate by glycolysis.
- Then pyruvate is converted to alcohol or acid along with regeneration of NAD+ which can take part in glycolysis to produce more ATP.
- Fermentation yields only about 5% of the energy obtained by aerobic respiration.





PROSES FERMENTASI : TIPE FERMENTASI

Lactic acid homo-fermentation

- Glucose → Lactic acid
- Homolactic fermentation is carried out by bacteria belonging to the genera Lactococcus, Enterococcus, Streptococcus, and Pediococcus, and by some species of the genus Lactobacillus.
- Homofermentative LAB ferment glucose to lactic acid.
- Lactococcus spp. is used in the dairy starter culture.

Lactic acid hetero-fermentation

- Glucose → Lactic acid + Acetic acid + Ethyl alcohol + $2CO_2$ + H_2O
- Heterolactic fermentation is carried out by bacteria of the genera Leuconostoc, Oenococcus, and Weissella, and by heterofermentative lactobacilli.
- Heterofermentative LAB ferment glucose with lactic acid, ethanol/acetic acid, and carbon dioxide (CO_2) as by-products.

Propionic acid fermentation

- Glucose → Lactic acid + Propionic acid + Acetic acid + CO_2 + H_2O
- Propionic acid fermentation is carried out by several bacteria that belong to the genus Propionibacterium and the species Clostridium propionicum.
- During propionic acid fermentation, both sugar and lactate can be used as the initial substrate.
- When sugar is available, these bacteria use the EMP pathway to produce pyruvate; the pyruvate is carboxylated to oxaloacetate and then reduced to propionate via malate, fumarate, and succinate.
- The other end products of propionic fermentation are acetic acid and CO_2.

PROSES FERMENTASI : TIPE FERMENTASI

Alcoholic fermentation

- Glucose → Ethyl alcohol
- Alcoholic fermentation is the best known of the fermentation processes.
- It is carried out by yeasts and some other fungi and bacteria.
- The first step of the alcoholic fermentation pathway involves pyruvate, which is formed by yeast via the EMP pathway, while it is obtained through the ED pathway in the case of Zymomonas (bacteria).
- The redox balance of alcoholic fermentation is achieved by the regeneration of NAD+ during the reduction of acetaldehyde to ethanol.

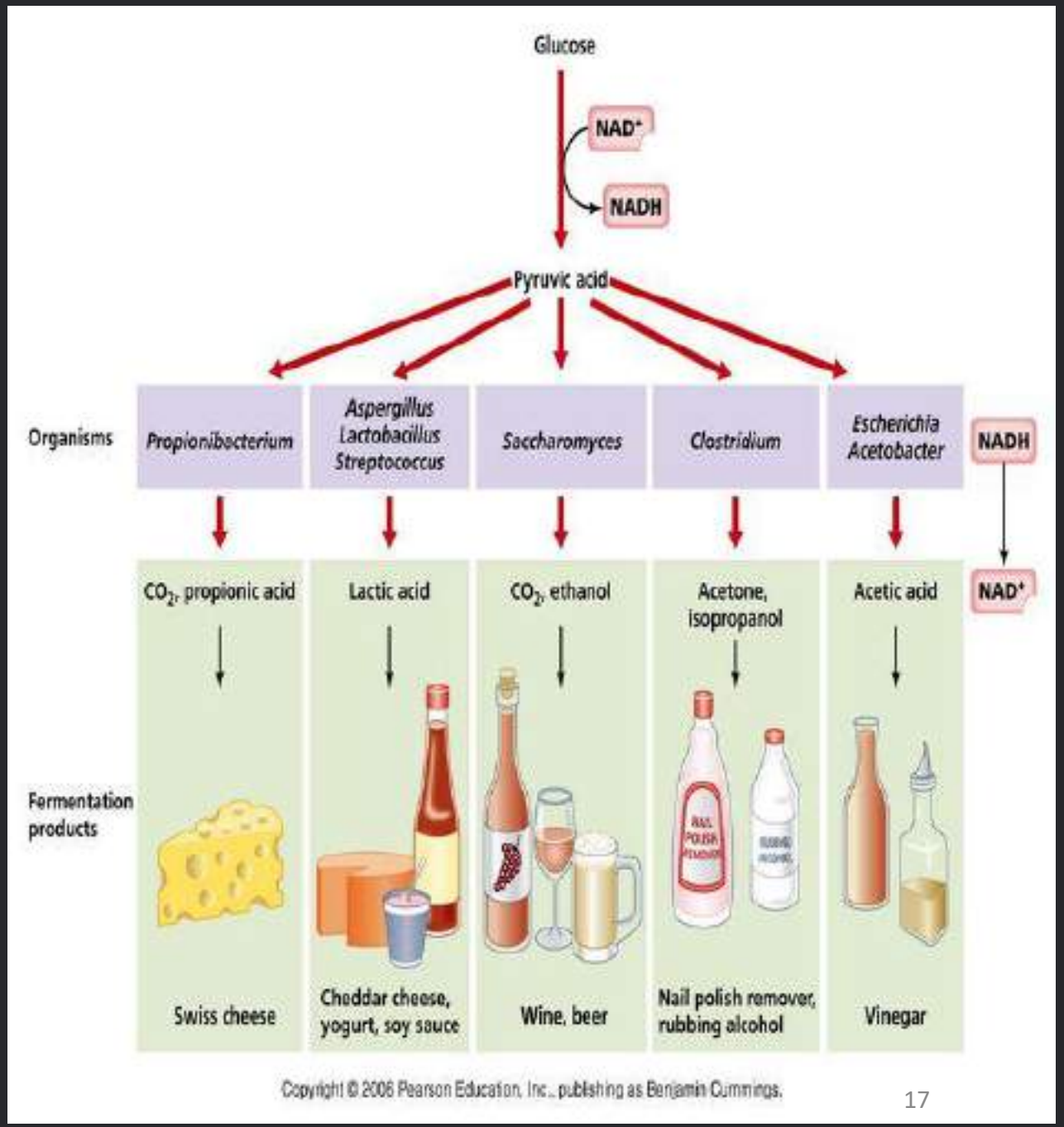
Butyric acid fermentation

- Glucose → Acetic acid + Butyric acid
- Butyric acid fermentation is characteristic of several obligate anaerobic bacteria that mainly belong to the genus Clostridium.
- Pyruvate is in turn oxidized to acetyl-CoA, with the production of CO_2 and H_2.
- Part of the acetyl-CoA is converted into acetic acid, with ATP production.
- Some bacteria, such as Clostridium acetobutylicum, produce fewer acids and more neutral products, thus carrying out acetone butanol fermentation.

Diacetyl and 2,3-butylene glycol fermentation

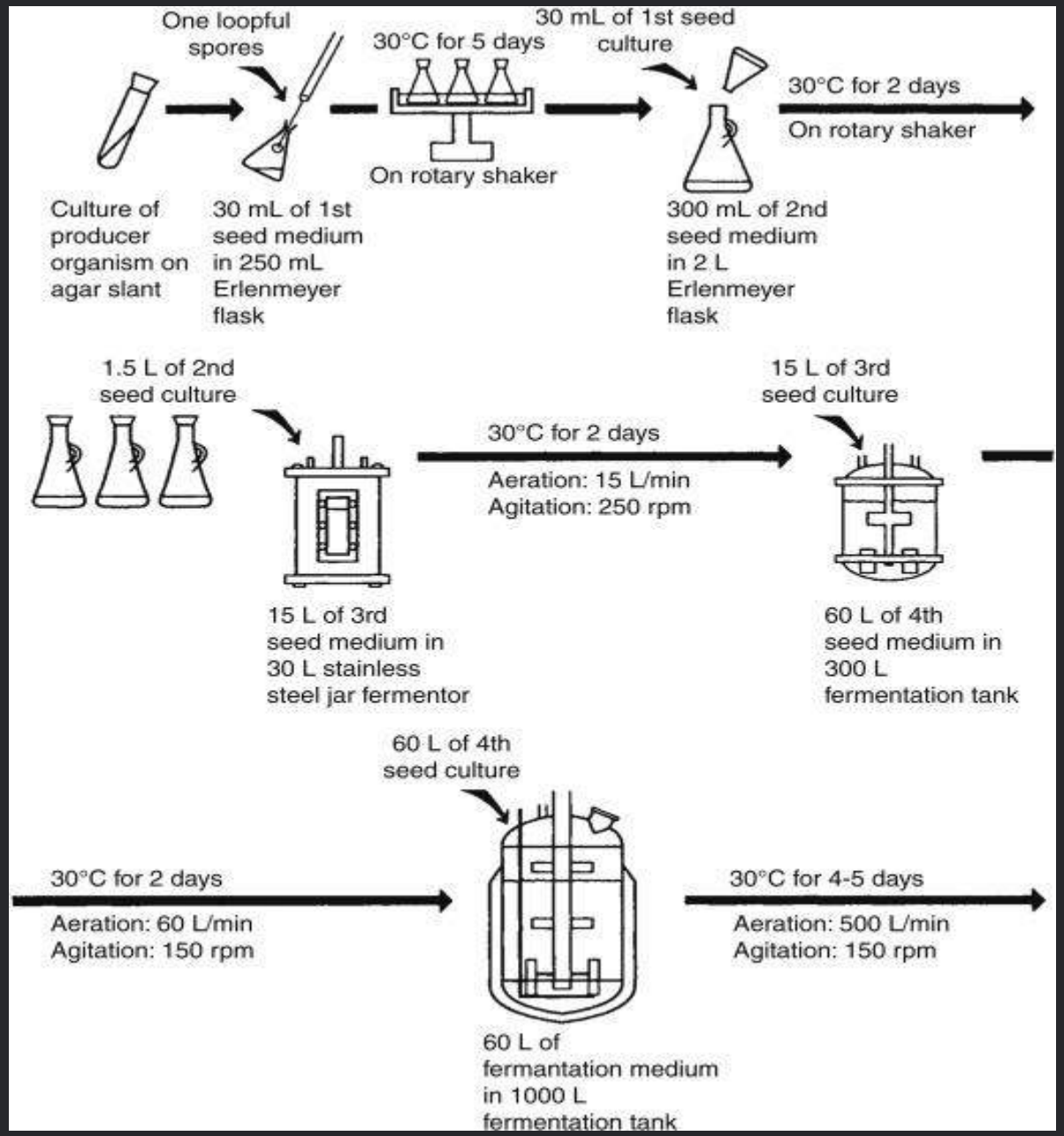
- Citric acid→ Pyruvic acid + Acetylmethylcarbon → Diacetyl ; 2,3-Butylene glycol
- Butanediol fermentation is carried out by members of the genera Enterobacter, Erwinia, Hafnia, Klebsiella, and Serratia.
- The reactions that lead to the production of 2,3-butanediol involve a double decarboxylation step.

PROSES FERMENTASI
TIPE FERMENTASI

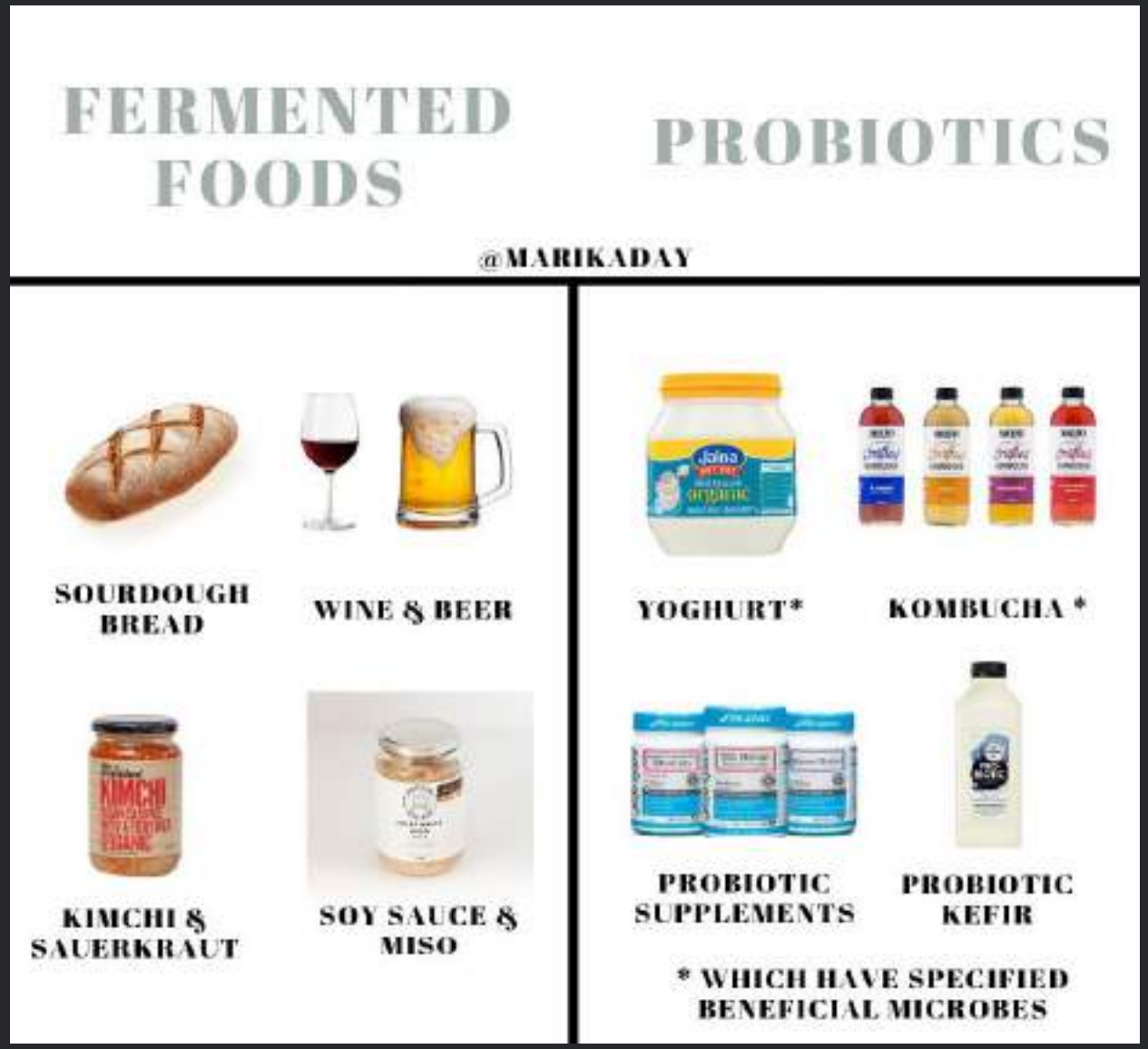


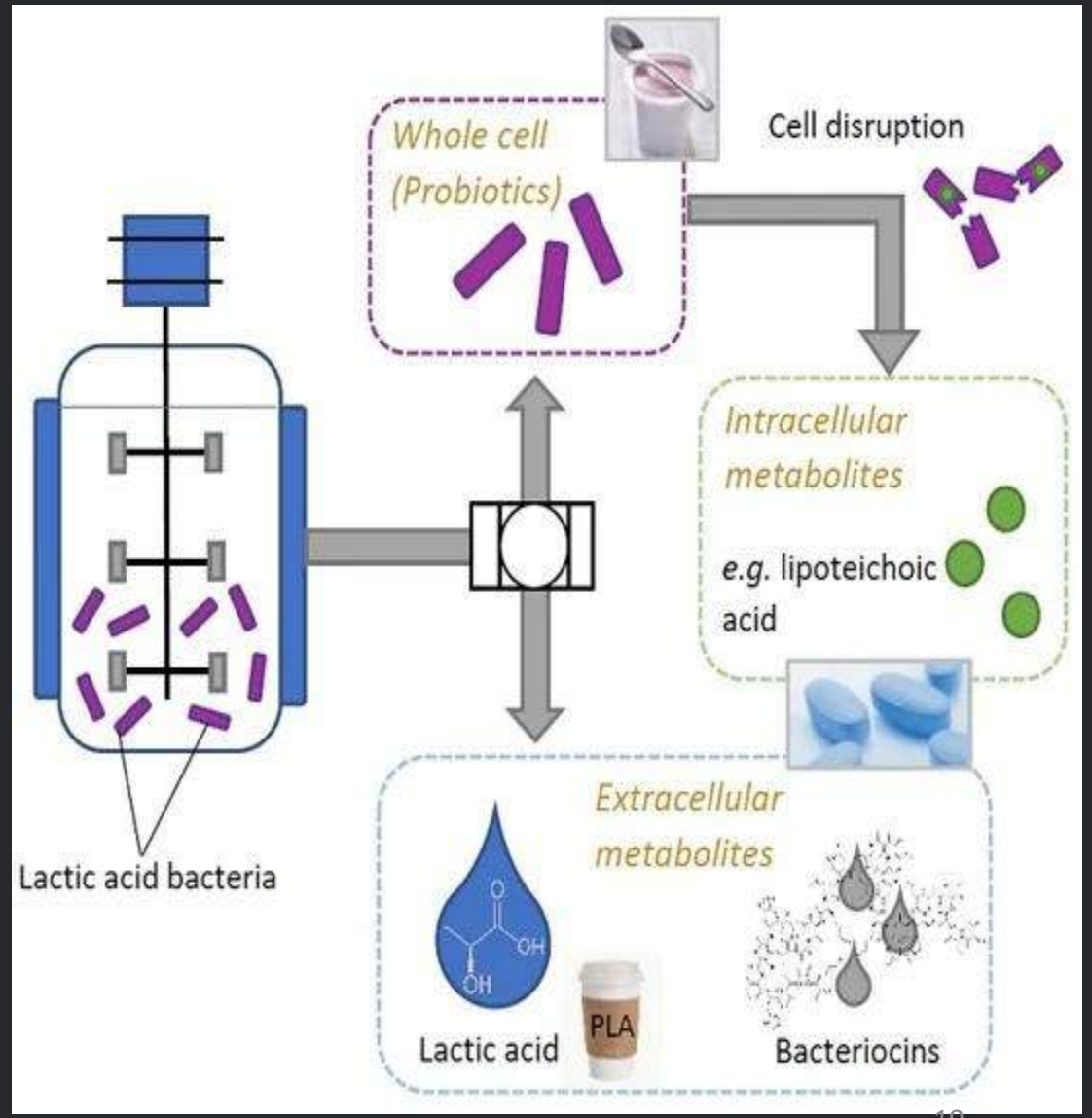
PROSES FERMENTASI

Product	Organism	Use
Ethanol	*Saccharomyces cerevisiae*	Industrial solvents, beverages
Glycerol	*Saccharomyces cerevisiae*	Production of explosives
Lactic acid	*Lactobacillus bulgaricus*	Food and pharmaceutical
Acetone and butanol	*Clostridium acetobutylicum*	Solvents
α-amylase	*Bacillus subtilis*	Starch hydrolysis

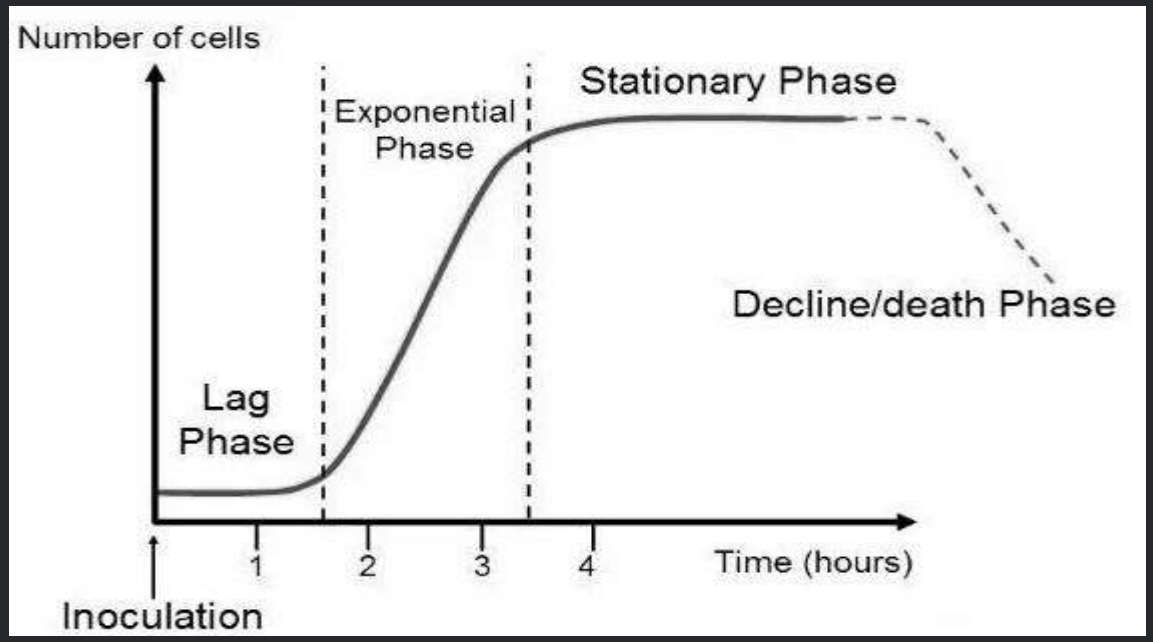


PROSES FERMENTASI



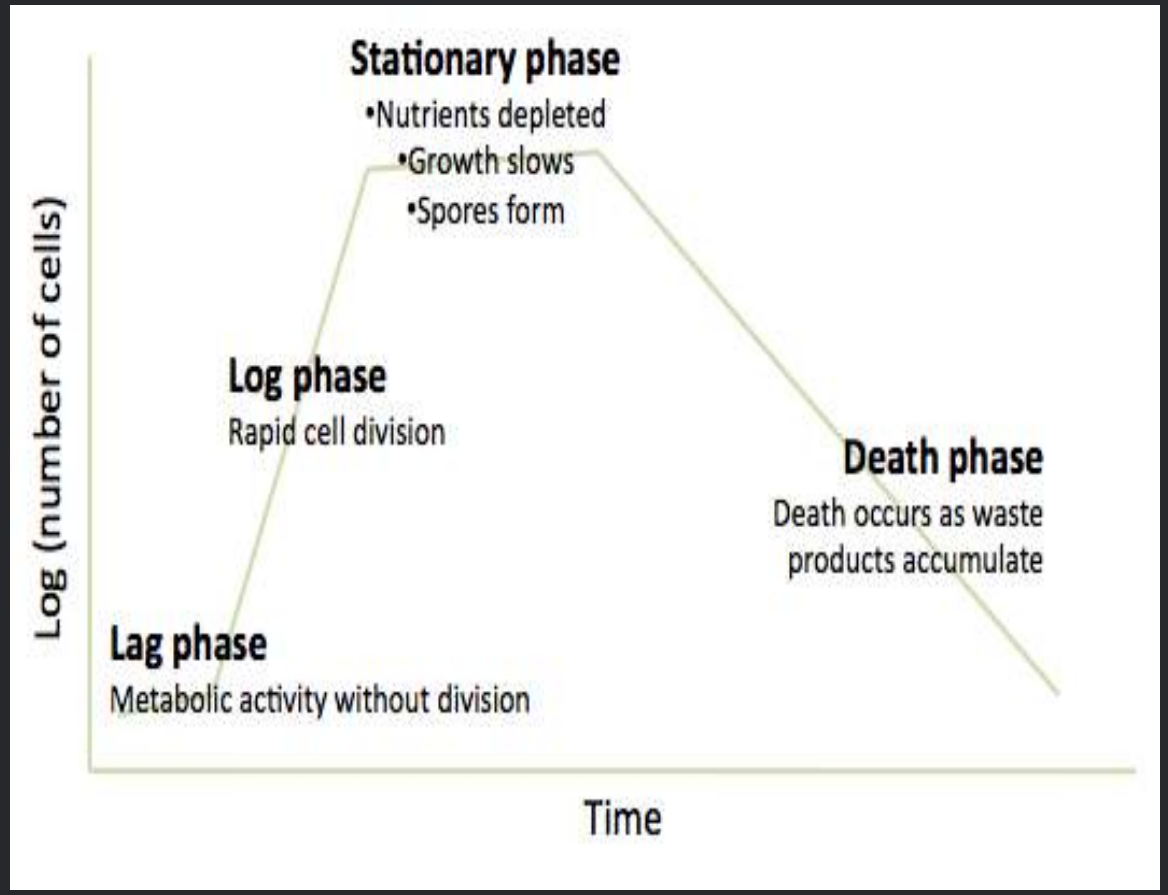


PROSES FERMENTASI : PERTUMBUHAN MIKROORGANISME



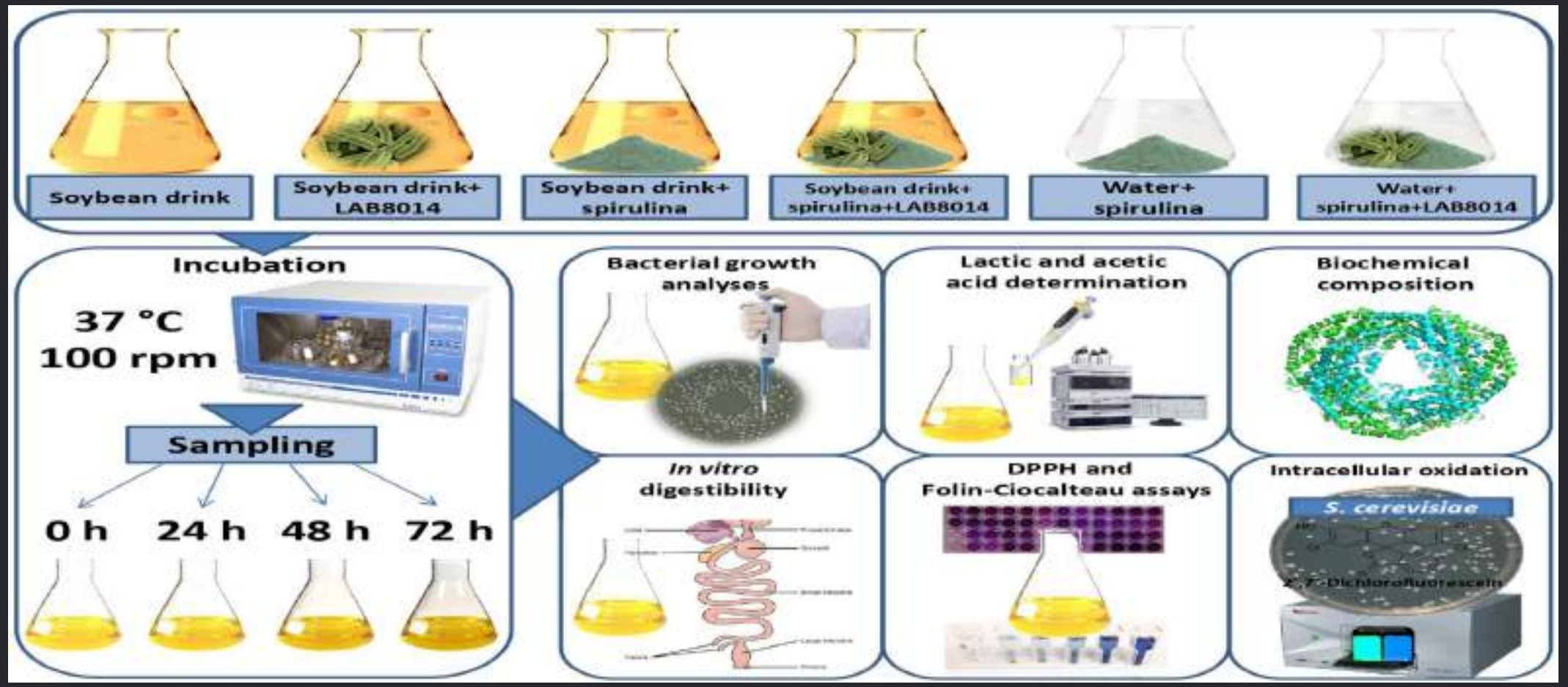
Growing phase	Microbes	Metabolisms	Metabolites
Lag phase	Individual growth	Anabolic metabolism dominates in cell, extracellular enzyme synthesis and transshipment, substrate begin to degrade	Enzymes
Logarithmic phase	Individual reproduction, population growth increasing geometrically	All kinds of metabolism are very high	Enzymes, functional polysaccharide, polypeptides, etc. Primary metabolites, such as alcohol, amino acid, pyruvate, and citric acid
Stationary phase	Population growth and the rate equal to the death	Accumulation of metabolites begins the secondary metabolism	Secondary metabolites, such as antibiotics, hormones, toxins, and pigments
Decline phase	Growth is inhibited by substrate, and the cells begin to autophagy	Old cell degradation, and new microbe population begins the new metabolism	Nucleotide, spore, sulfide, amino, monosaccharide, secondary metabolites

PROSES FERMENTASI : PERTUMBUHAN MIKROORGANISME



- For fermentation products (lactic acid, etc.) whose production depends on increasing bacterial growth or for other metabolic products whose production parallels bacterial growth, the stationary phase is the best time for harvest.
- To avoid the adverse effects of accumulating certain metabolic products during growth, some microbes begin using a type of metabolism conducive to survival; they start to synthesize secondary metabolites via complex secondary metabolic pathways.
- Secondary metabolites, such as antibiotics, hormones, pigments, and toxins, are low molecular mass, structurally complex organic compounds with diverse biological activities. Secondary metabolites are not directly involved in growth, development, or reproduction

PROSES FERMENTASI : PERTUMBUHAN MIKROORGANISME



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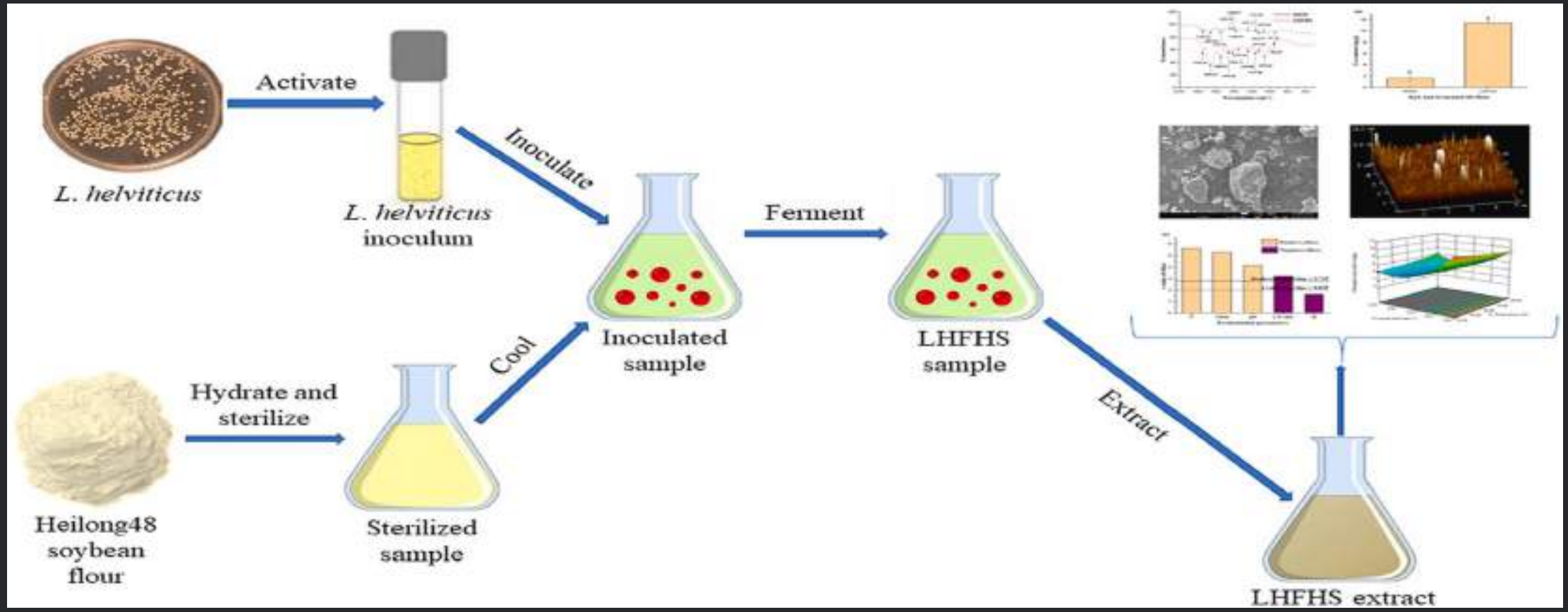
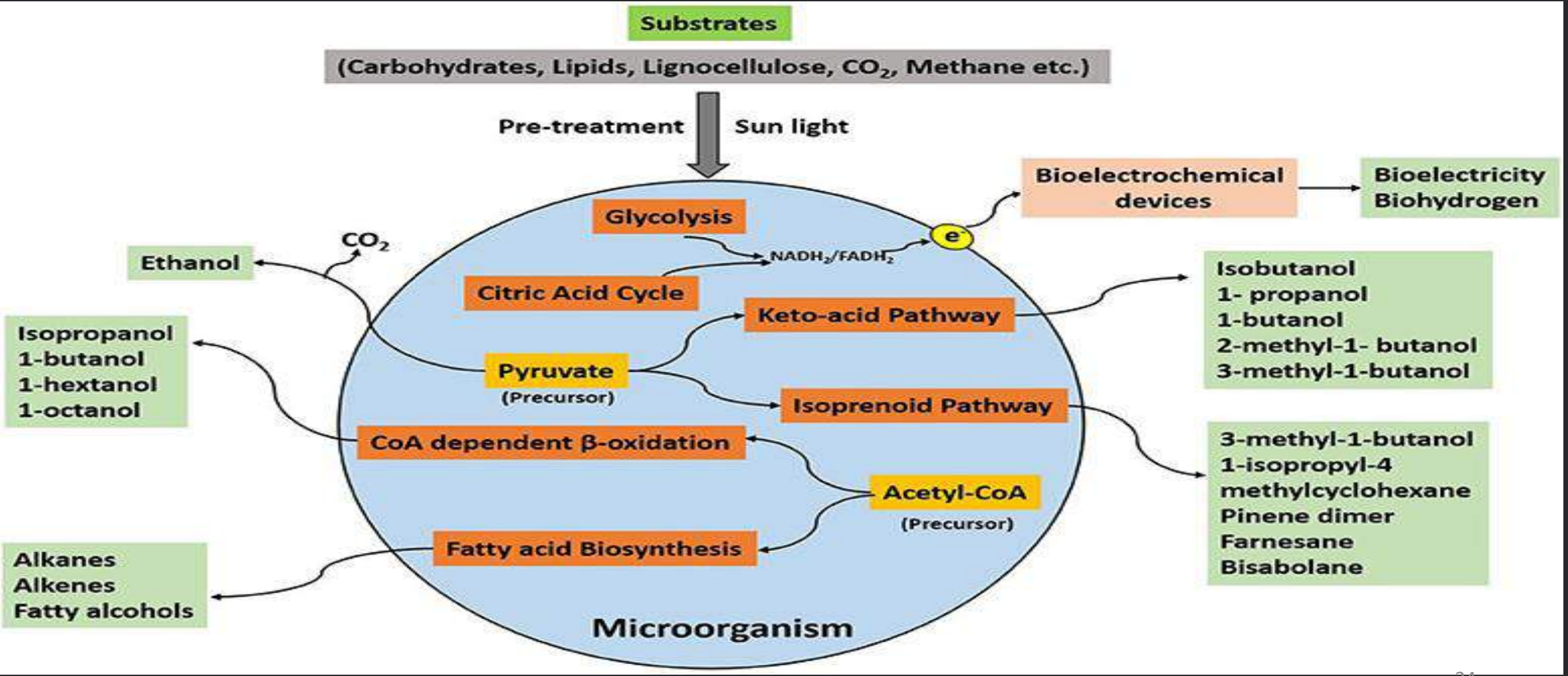


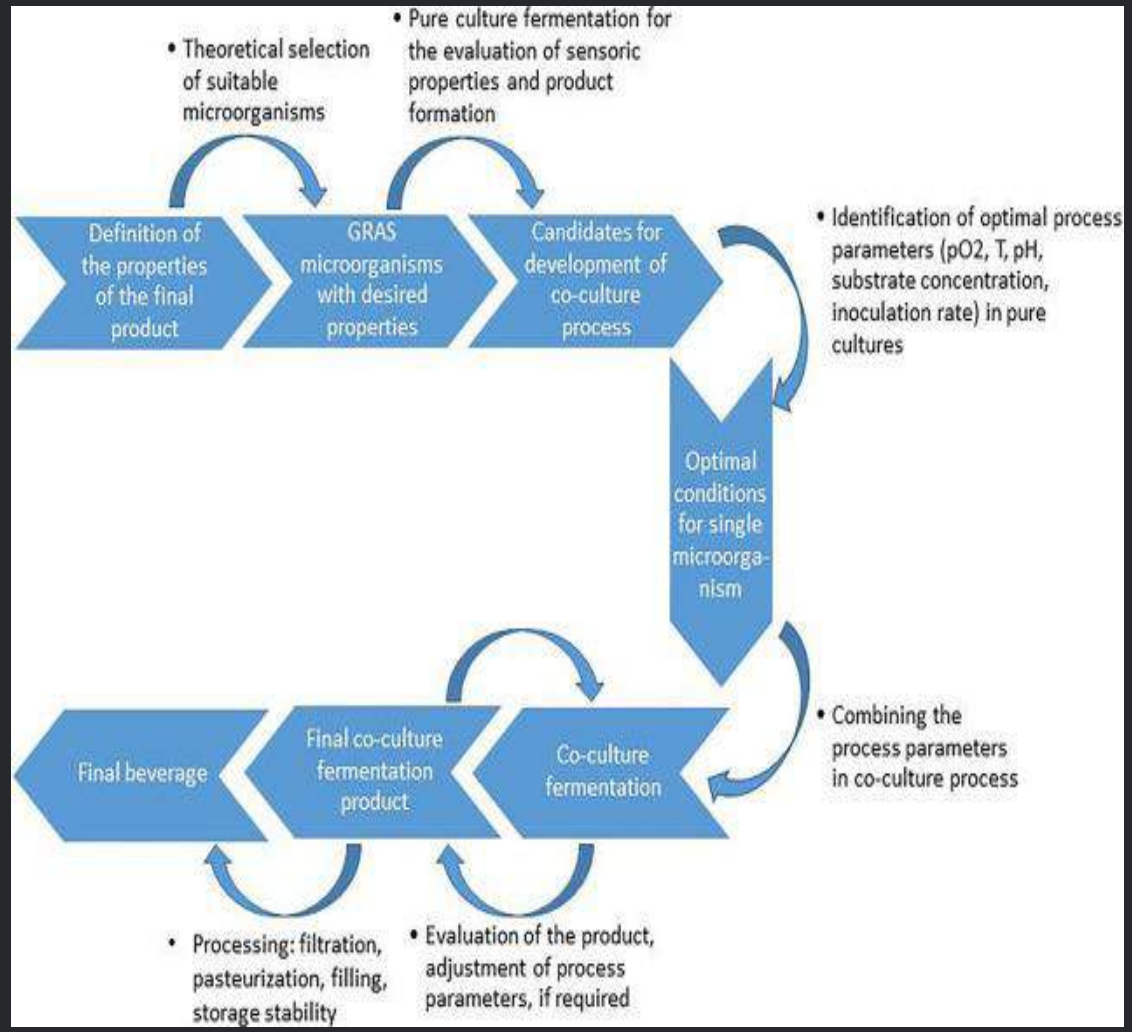
Novel solid-state fermentation extraction of 5-O-caffeoylquinic acid from heilong48 soybean using *Lactobacillus helviticus.* 5-CQA has tremendous application in food, pharmaceutical and cosmetic industries.

Chlorogenic acid (CGA), also known as 5-O-caffeoylquinic acid, is a polyphenol commonly found in human dietary products, especially in coffee beans.

PROSES FERMENTASI :
PERTUMBUHAN MIKROORGANISME MENGHASILKAN BIOFUEL



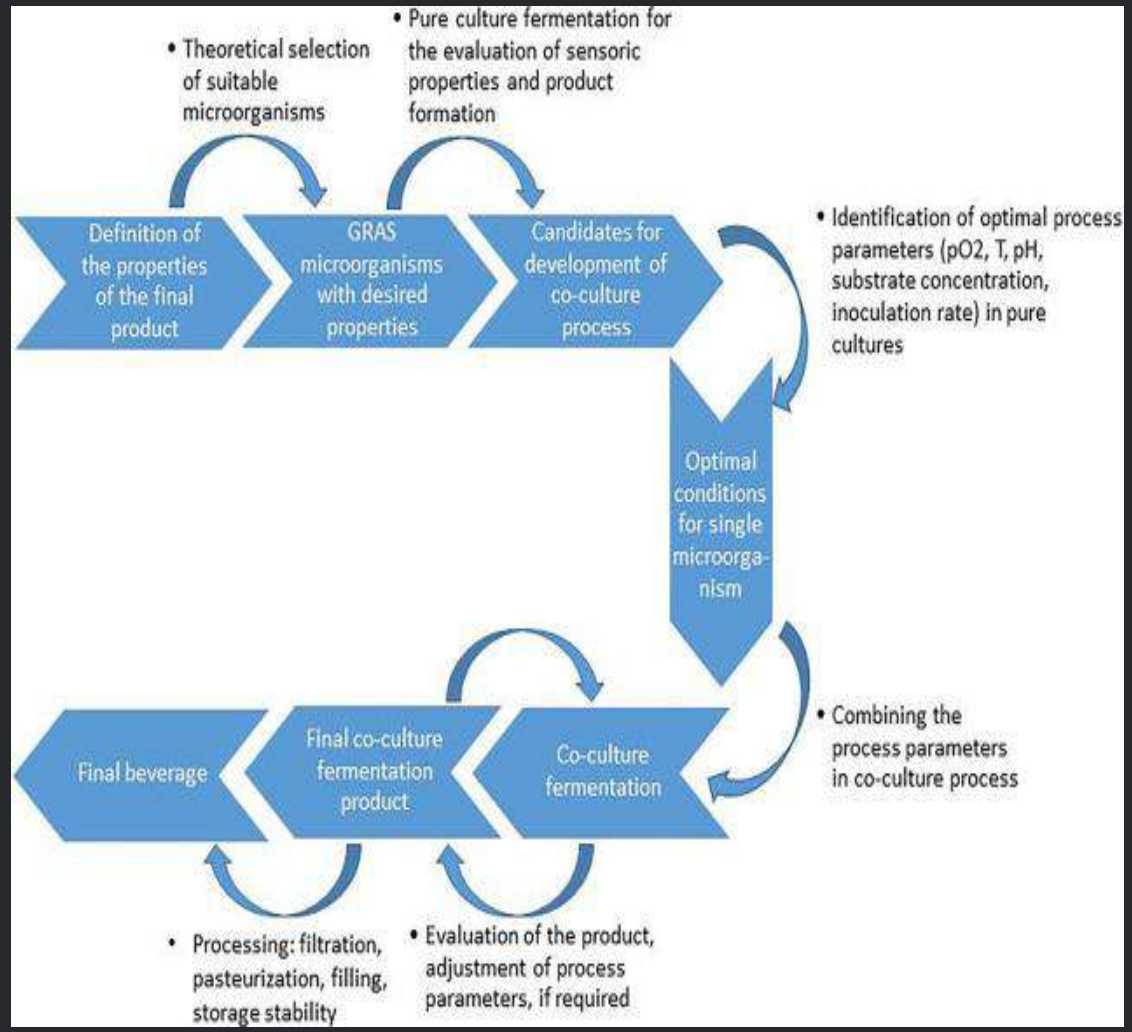
PROSES FERMENTASI : PERTUMBUHAN MIKROORGANISME



Mixed-culture fermentations offer a number of advantages over conventional single-culture fermentations:

- Product yield may be higher. Yogurt is made by the fermentation of milk with *Streptococcus thermophilus* and *Lactobacillus bulgaricus*.
- The growth rate may be higher
- Mixed cultures are able to bring about multistep transformations that would be impossible for a single microorganism. Examples are the miso and shoyu fermentations in which *Aspergillus oryzae* strains are used to make koji.
- In some mixed cultures a remarkably stable association of microorganisms may occur.
- Compounds made by a mixture of microorganisms often complement each other and work to the exclusion of unwanted microorganisms.
- Mixed cultures permit better utilization of the substrate.
- Mixed cultures can be maintained indefinitely by unskilled people with a minimum of training. Mixed cultures offer more protection against contamination.
- Mixed-culture fermentations enable the utilization of cheap and impure substrates.
- Mixed cultures can provide necessary nutrients for optimal performance

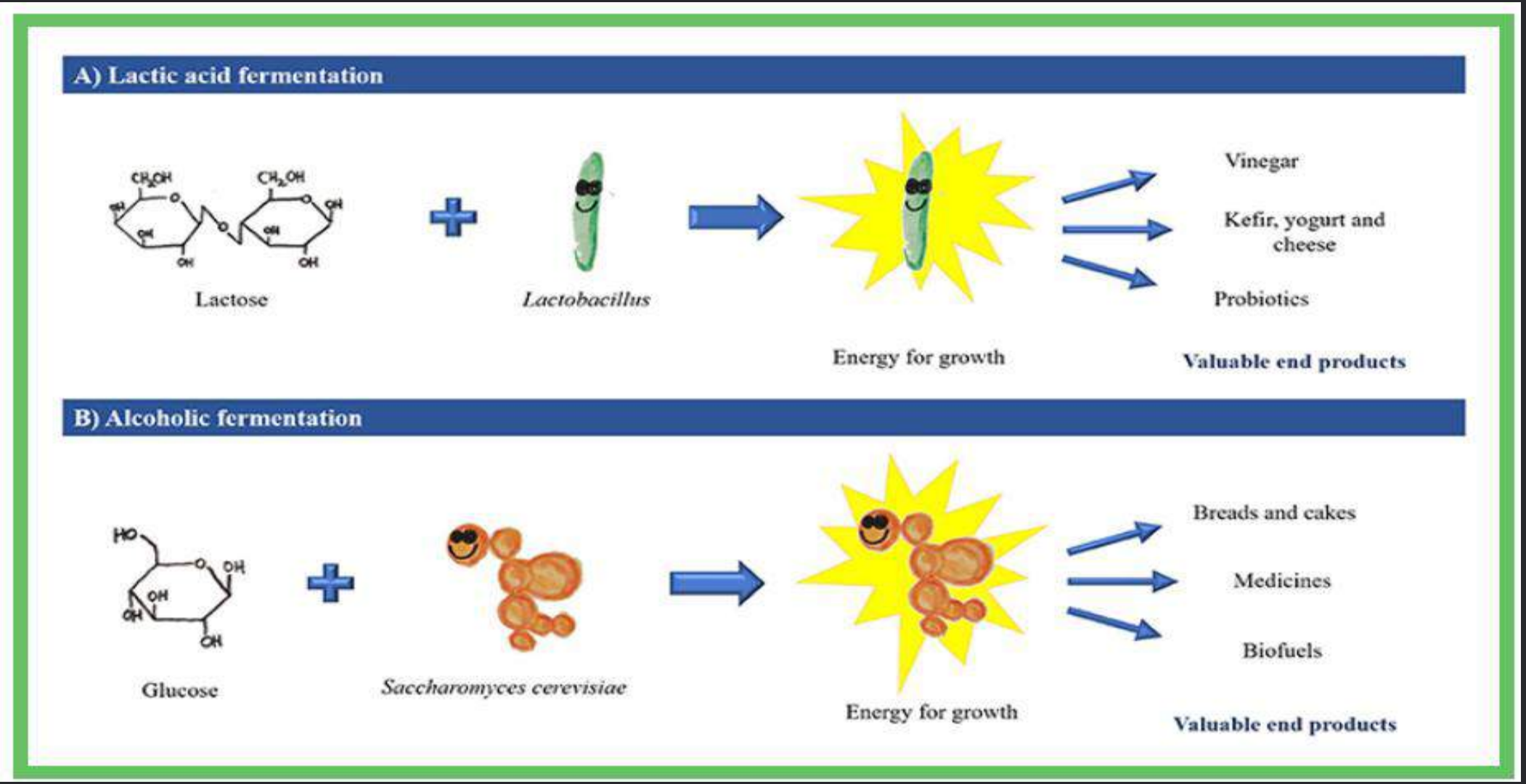
PROSES FERMENTASI : PERTUMBUHAN MIKROORGANISME



Mixed-culture fermentations also have some disadvantages

- Scientific study of mixed cultures is difficult
- Defining the product and the microorganisms employed becomes more involved in patent and regulatory procedures.
- Contamination of the fermentation is more difficult to detect and control.
- When two or three pure cultures are mixed together, it requires more time and space to produce several sets of inocula rather than just one.
- One of the worst problems in mixed-culture fermentation is the control of the optimum balance among the microorganisms involved. This can, however, be overcome if the behavior of the microorganisms is understood and this information is applied to their control.

APLIKASI TEKNIK FERMENTASI



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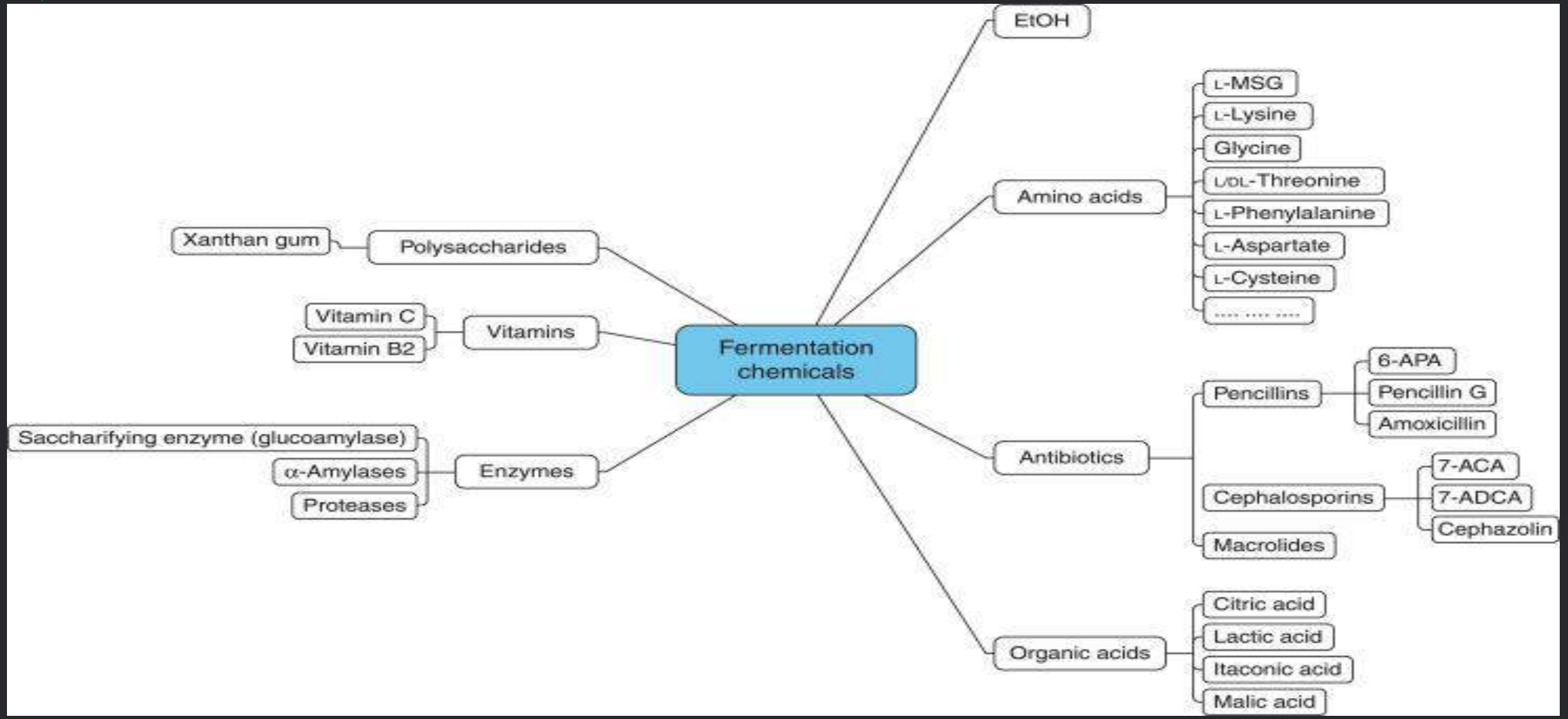
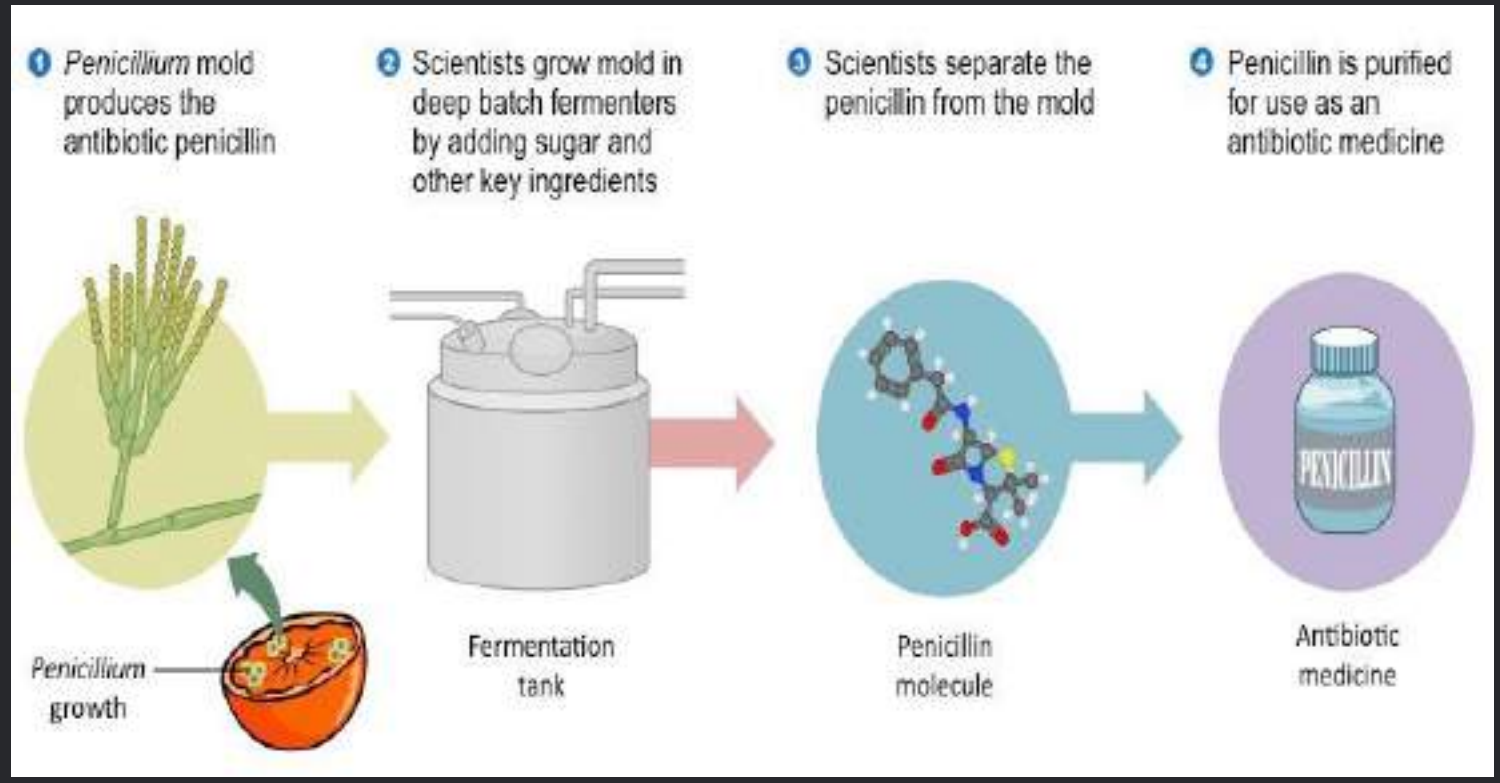


https://www.sciencedirect.com/science/article/abs/pii/B9780444533494002582

APLIKASI TEKNIK FERMENTASI

Application in medicine

- Production of antibiotics
- Production of insulin
- Production of growth hormones
- Production of vaccines
- Production of interferon



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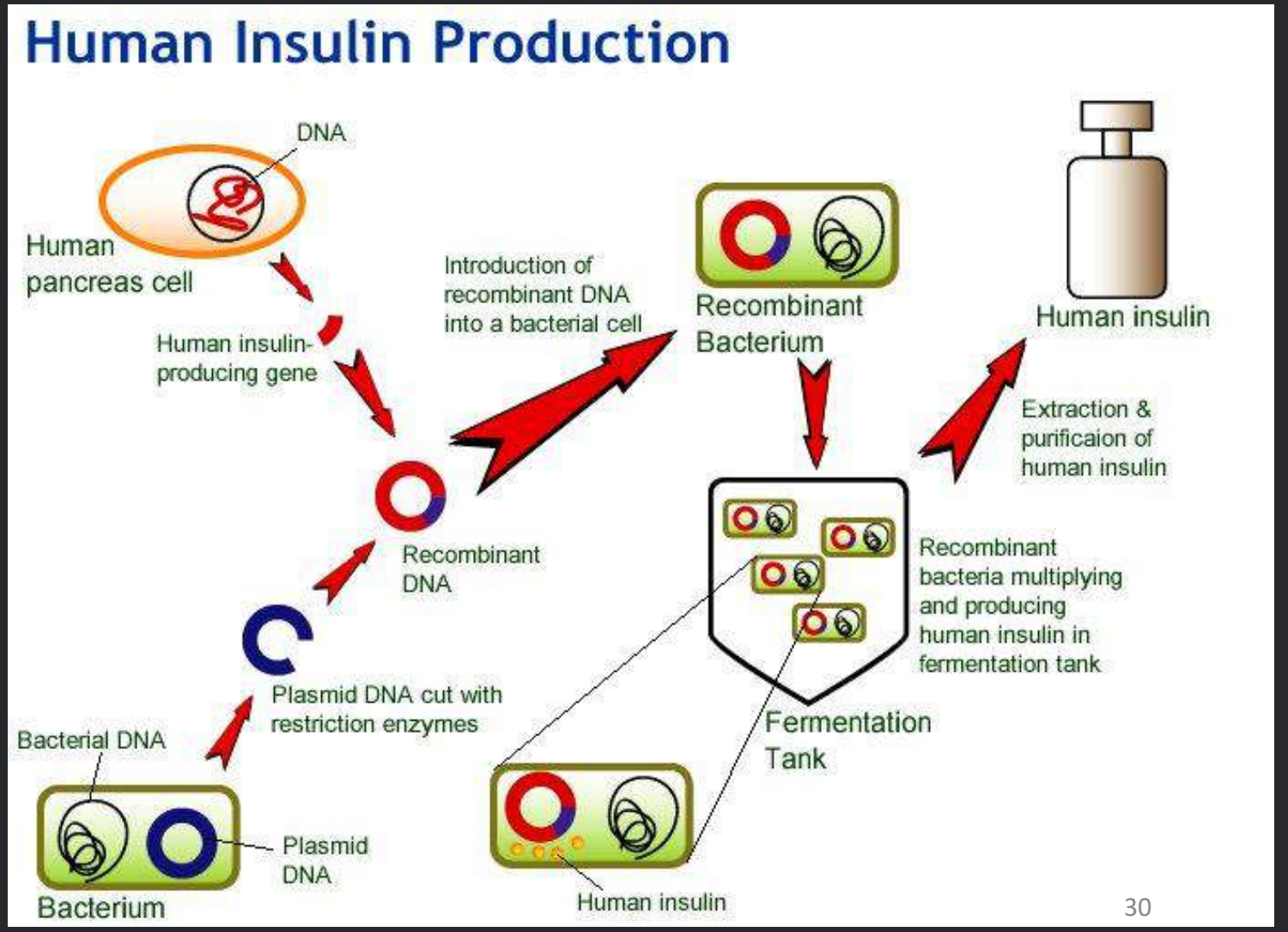

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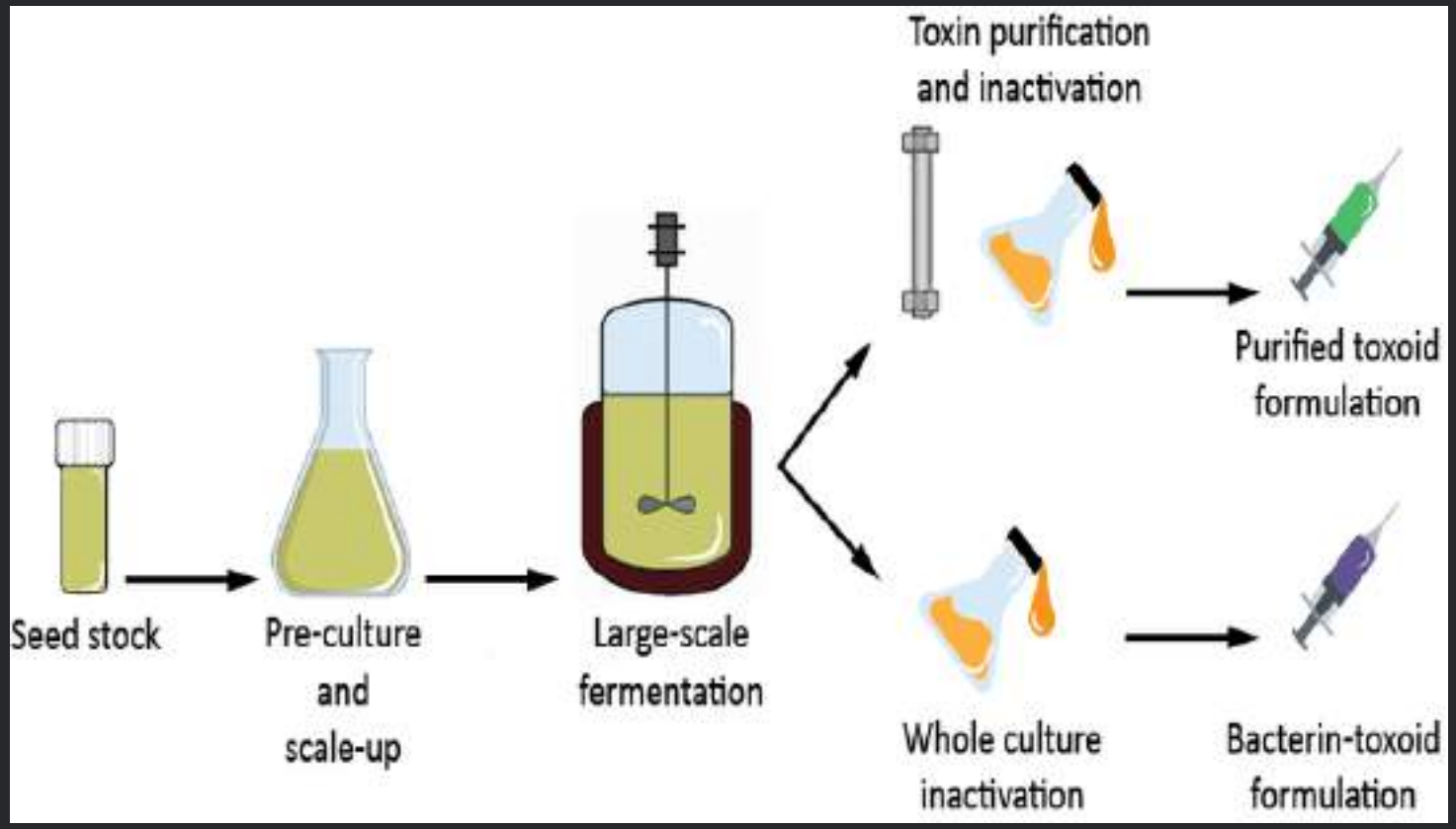

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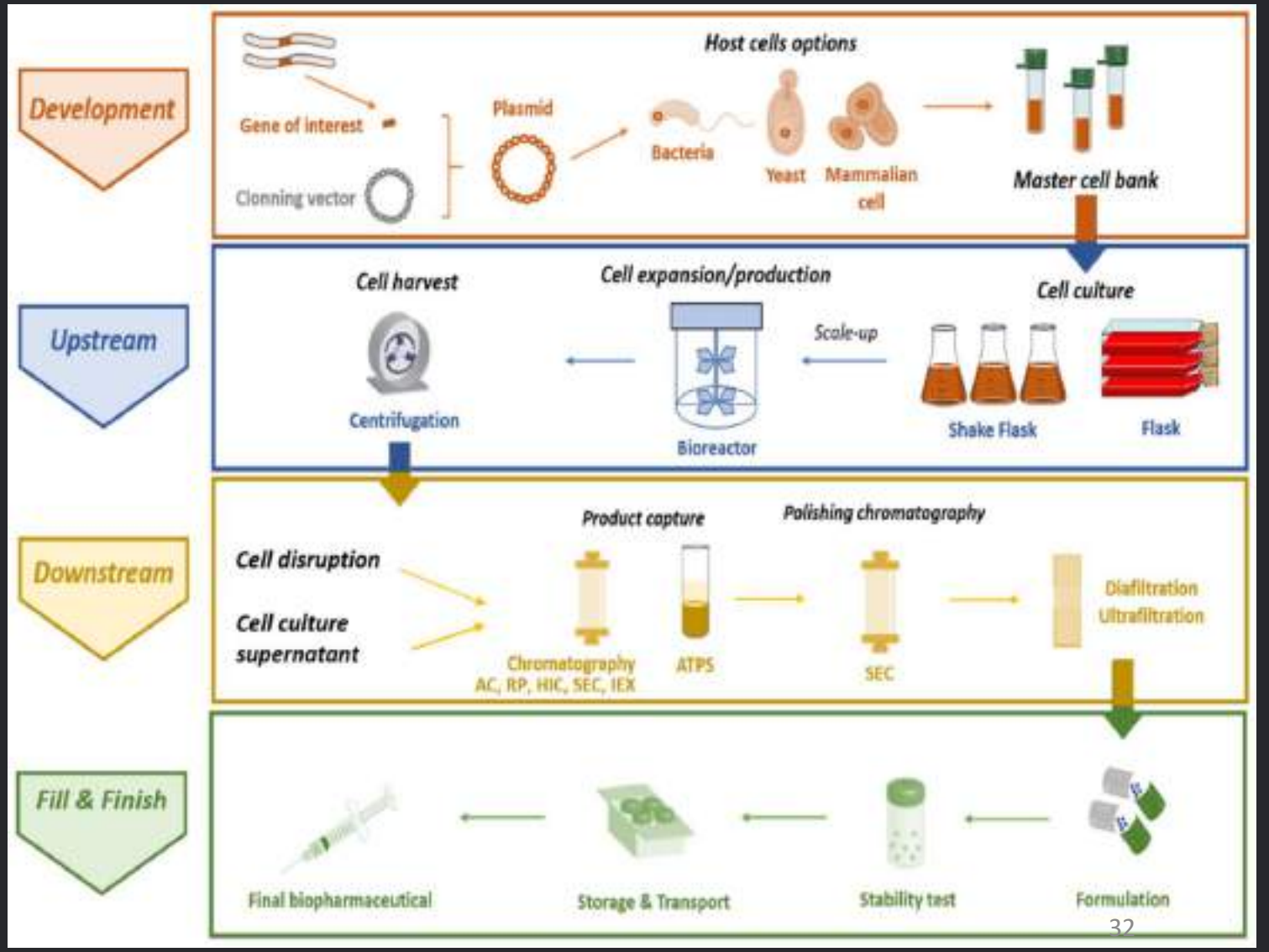
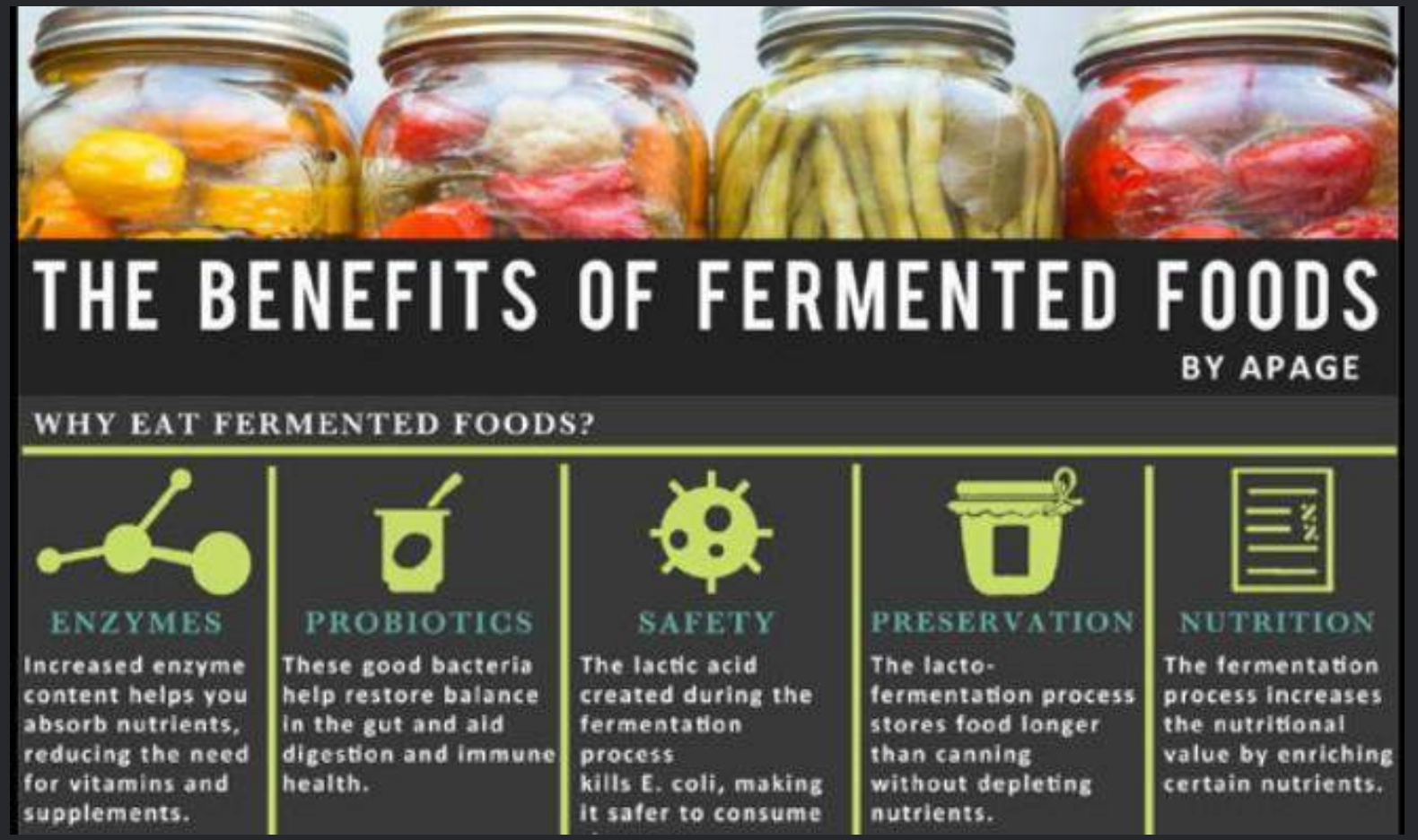


APLIKASI TEKNIK FERMENTASI

Application in the food industry

- Production of fermented foods as cheese, wine, beer, and bread to high-value products
- Food grade bio preservatives
- Functional foods/Neutraceuticals
- Production of single-cell protein



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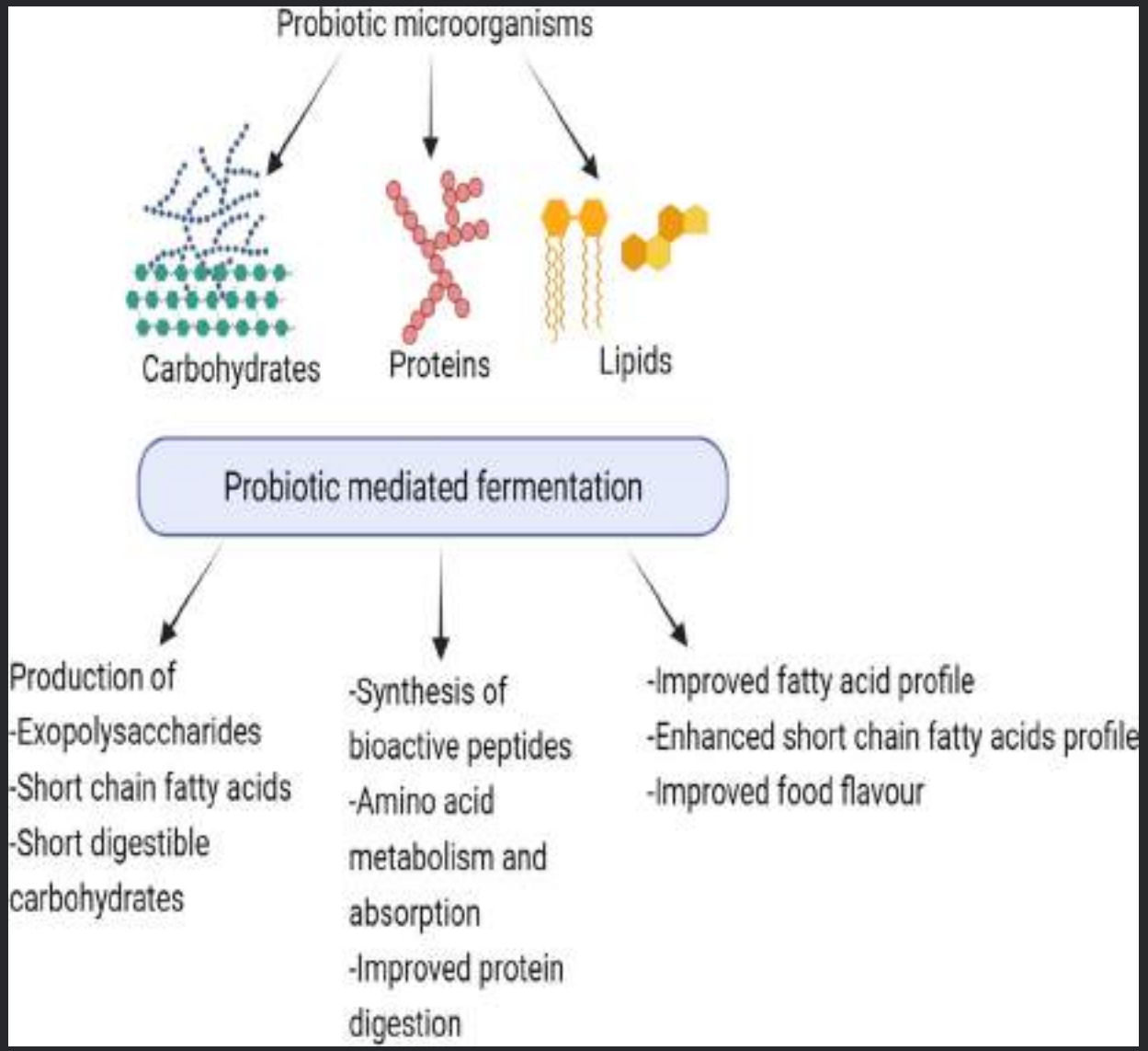
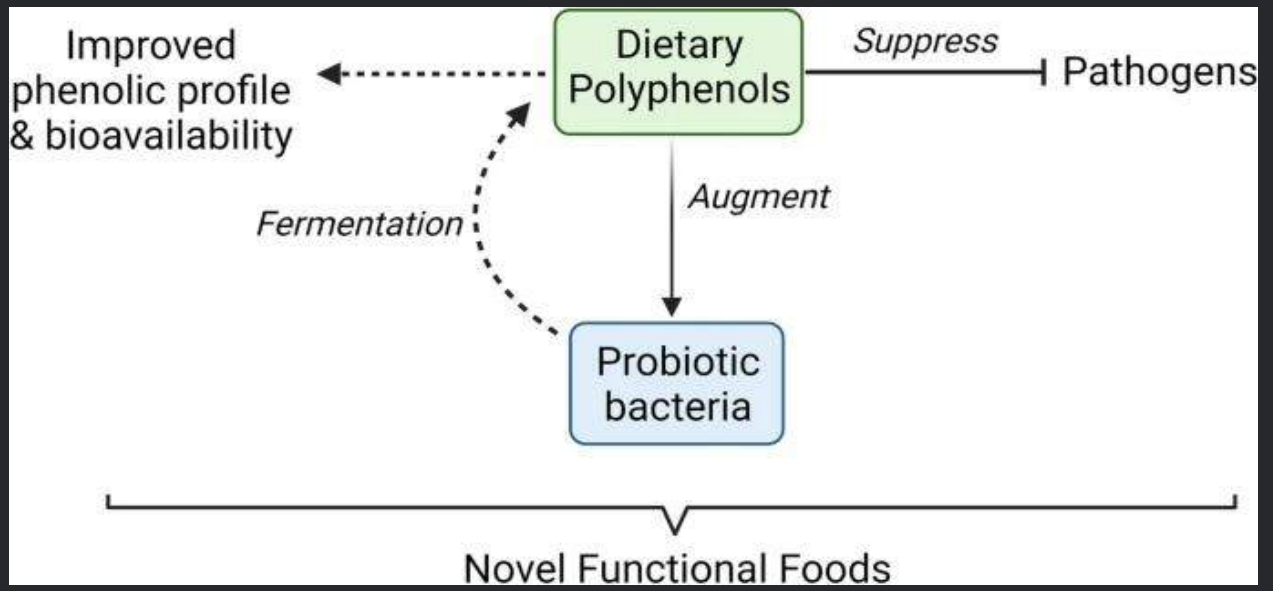
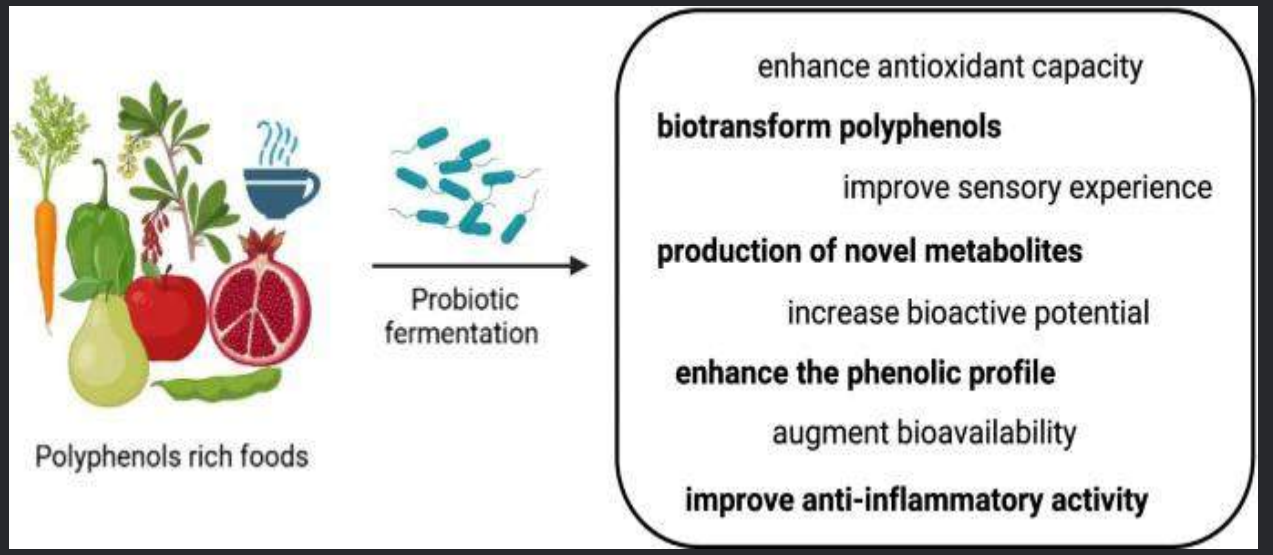






https://fppn.biomedcentral.com/articles/10.1186/s43014-022-00101-4

PROBIOTIC FERMENTATION

S. no	Phenolic food source	Probiotic microorganisms used	Effect of fermentation	Reference
1	Tea extracts	Lactic acid bacteria	Production of novel compounds (quercetin and pyrogallol); increased cellular bioavailability (over 90%) for EGCG	Zhao & Shah 2016a
2	Kiwifruit juice	Lactic acid bacteria	Production of novel compounds- Protocatechuic acid and catechin; increased phenolic content and antioxidant activity	Wang et al. 2022
3	Apple juice	Six lactic acid bacterial strains	Enhanced the levels of caffeic acid and phlorizin; improved aroma; increased antioxidant activity (90%)	Wu et al. 2020
4	Soymilk	*Lactobacillus fermentum*	Increased free soy isoflavones content (up to 6 folds)	Zhou et al. 2021
5	*Capsicum annuum*	*Lactobacillus plantarum, Lactobacillus acidophilus,* and *Bacillus subtilis*	Production of novel metabolites- nordihydrocapsaicin, dihydrocapsaicin, homocapsaicin and homodihydrocapsaicin	Liu et al. 2019
6	Vegetable juice from four crops	Lactic acid bacteria	Increased phenolic content (up to 24%); improved antioxidant activity	Lee et al. 2021

https://fppn.biomedcentral.com/articles/10.1186/s43014-022-00101-4

PROBIOTIC FERMENTATION

Fermented Food vs. Probiotic

Probiotic

- Must contain live microbes
- Must be tested and shown to have health benefit
- Must deliver level of live microbes shown to confer benefit

Fermented Food

- Made by live microbes
- Live microbes might not survive into the food you consume (post-fermentation processing)
- May not have been tested for health benefits beyond basic nutritional value
- Likely healthy dietary components, but may not meet the bar to be called a probiotic

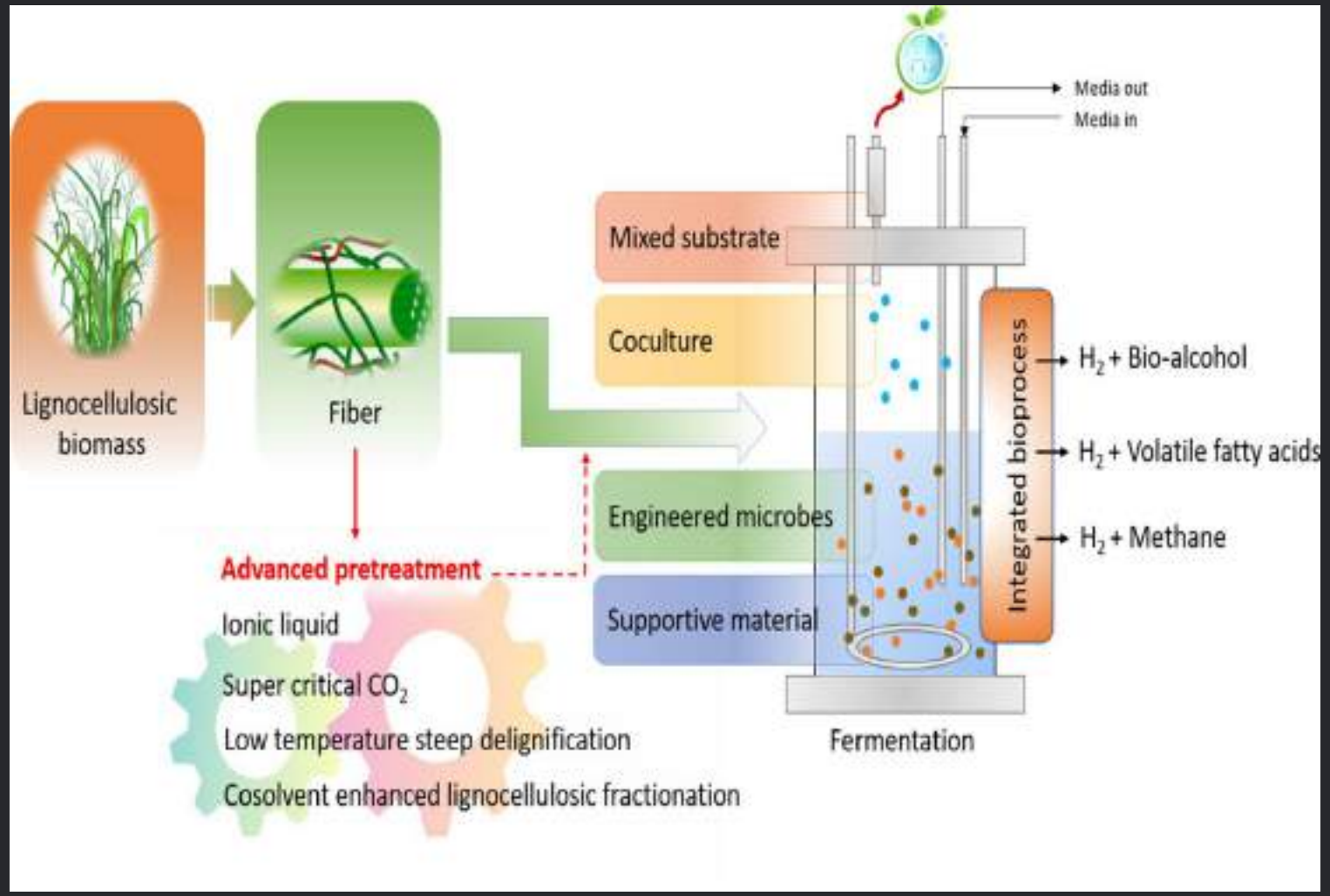
Probiotic Fermented Food

- Must contain live microbes
- Must be tested and shown to have health benefit
- The health benefit must result, at least in part, from the live microbes present
- The health benefit must go beyond meeting basic micro- and macro-nutrient nutritional needs
- Must deliver level of live microbes shown to confer benefit

APLIKASI TEKNIK FERMENTASI

Other Applications

- It is also used for waste management such as biofuels production (biodiesels, bioethanol, butanol, biohydrogen, etc).
- It is also used to produce bio-surfactant, polymers production such as bacterial cellulose production.
- Development of bioremediation processes (involving microbes or their isolated enzymes) for soils and wastewater treatments.



APLIKASI TEKNIK FERMENTASI

Other Applications

- It is also used for waste management such as biofuels production (biodiesels, bioethanol, butanol, biohydrogen, etc).
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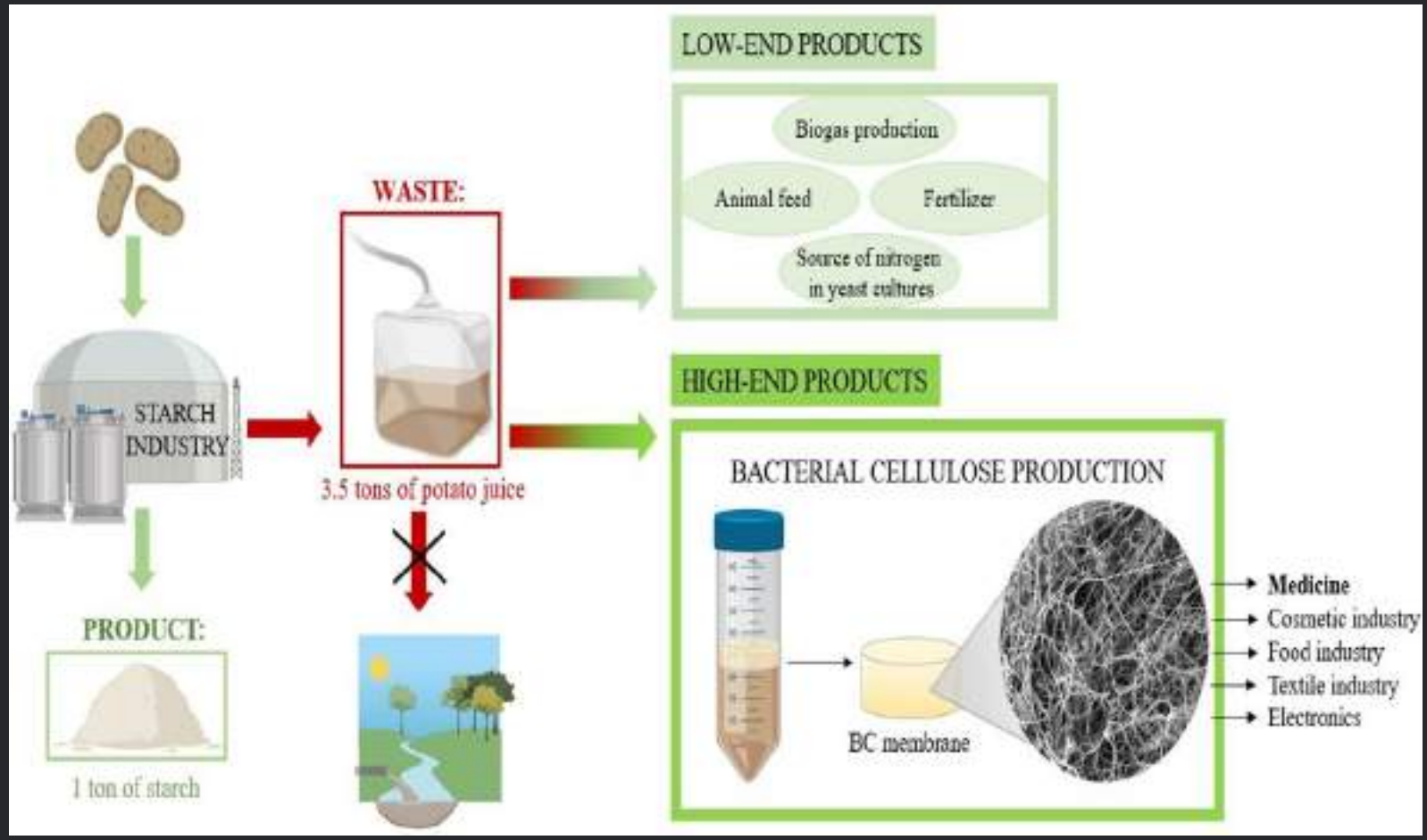

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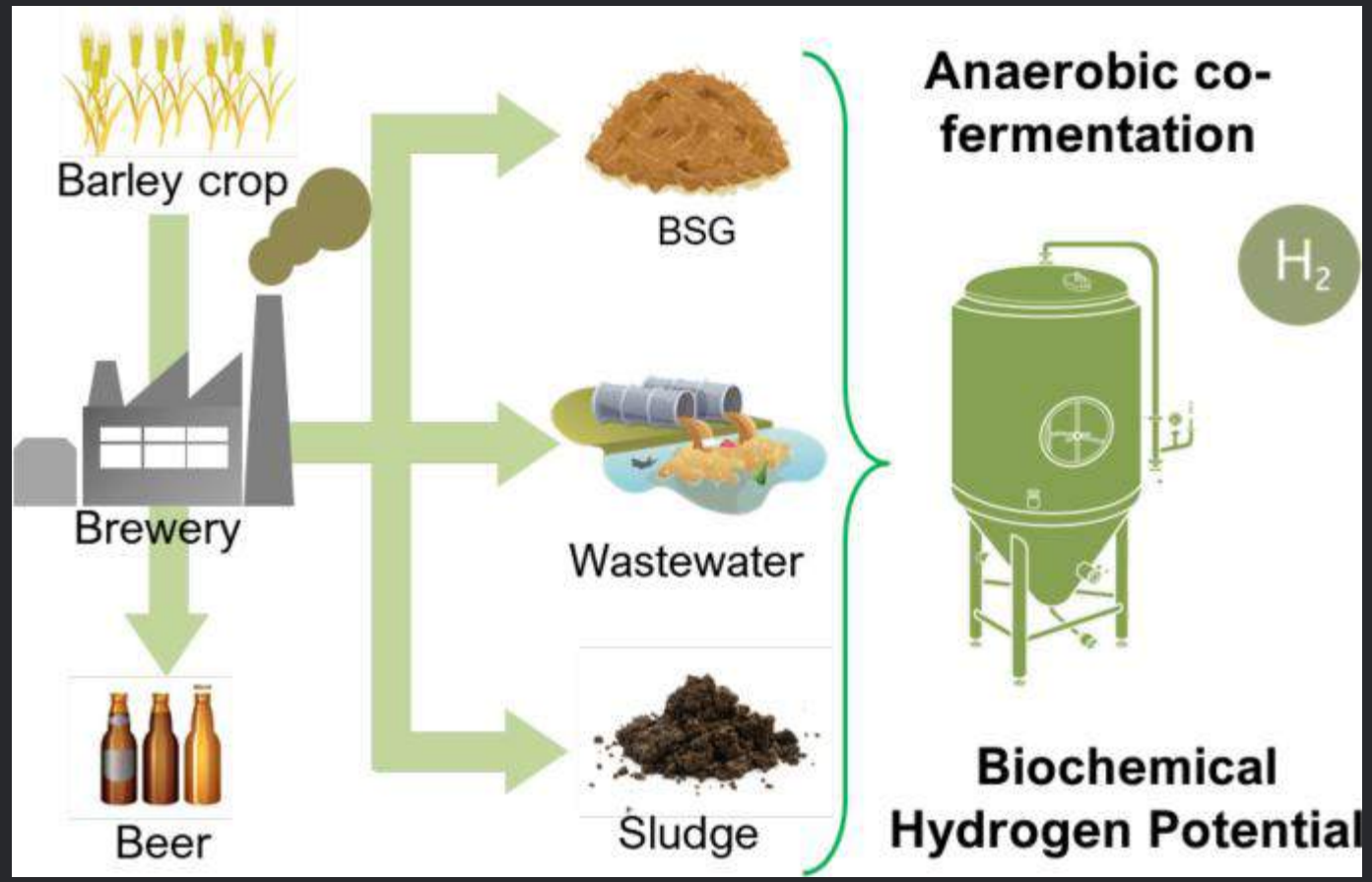

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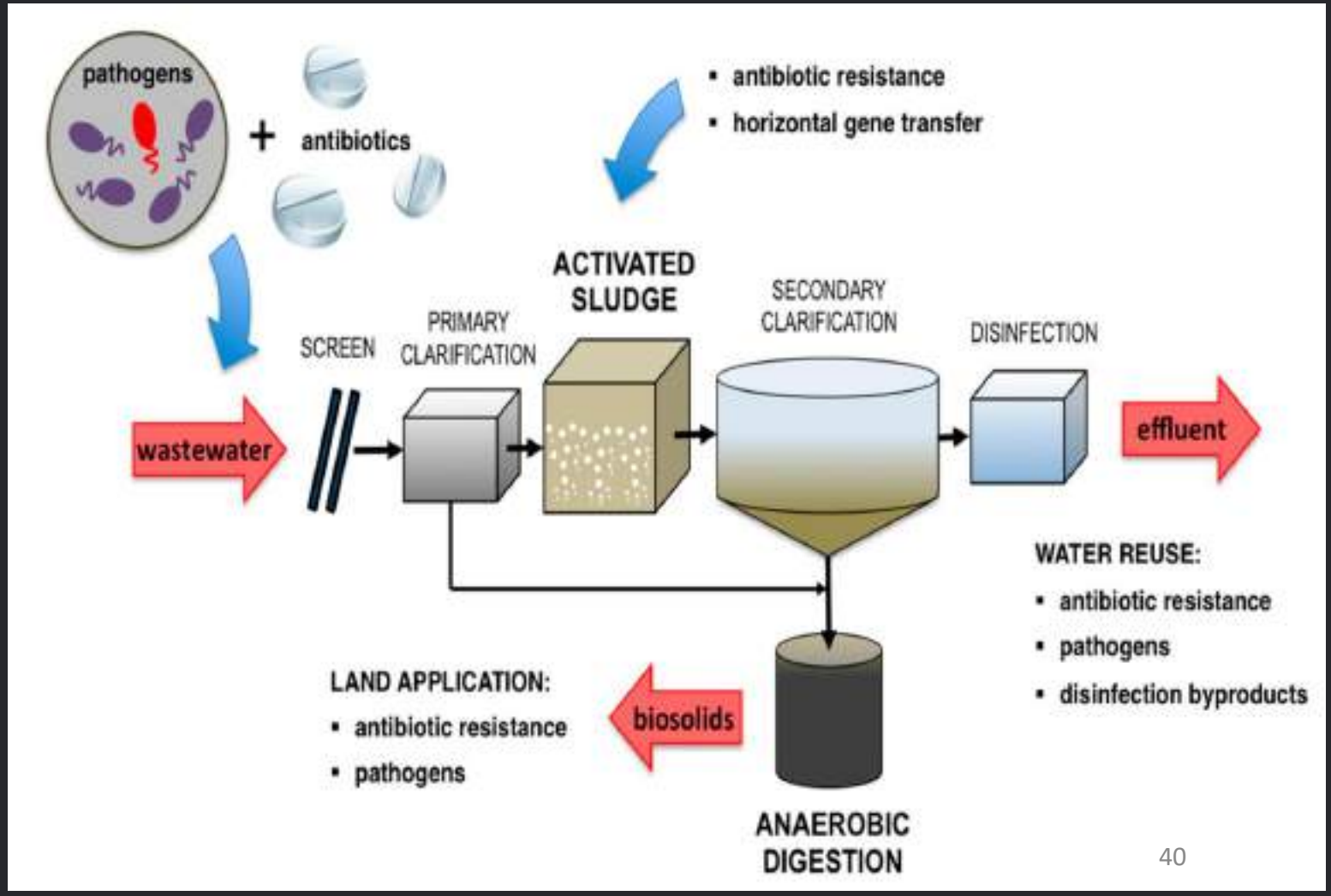
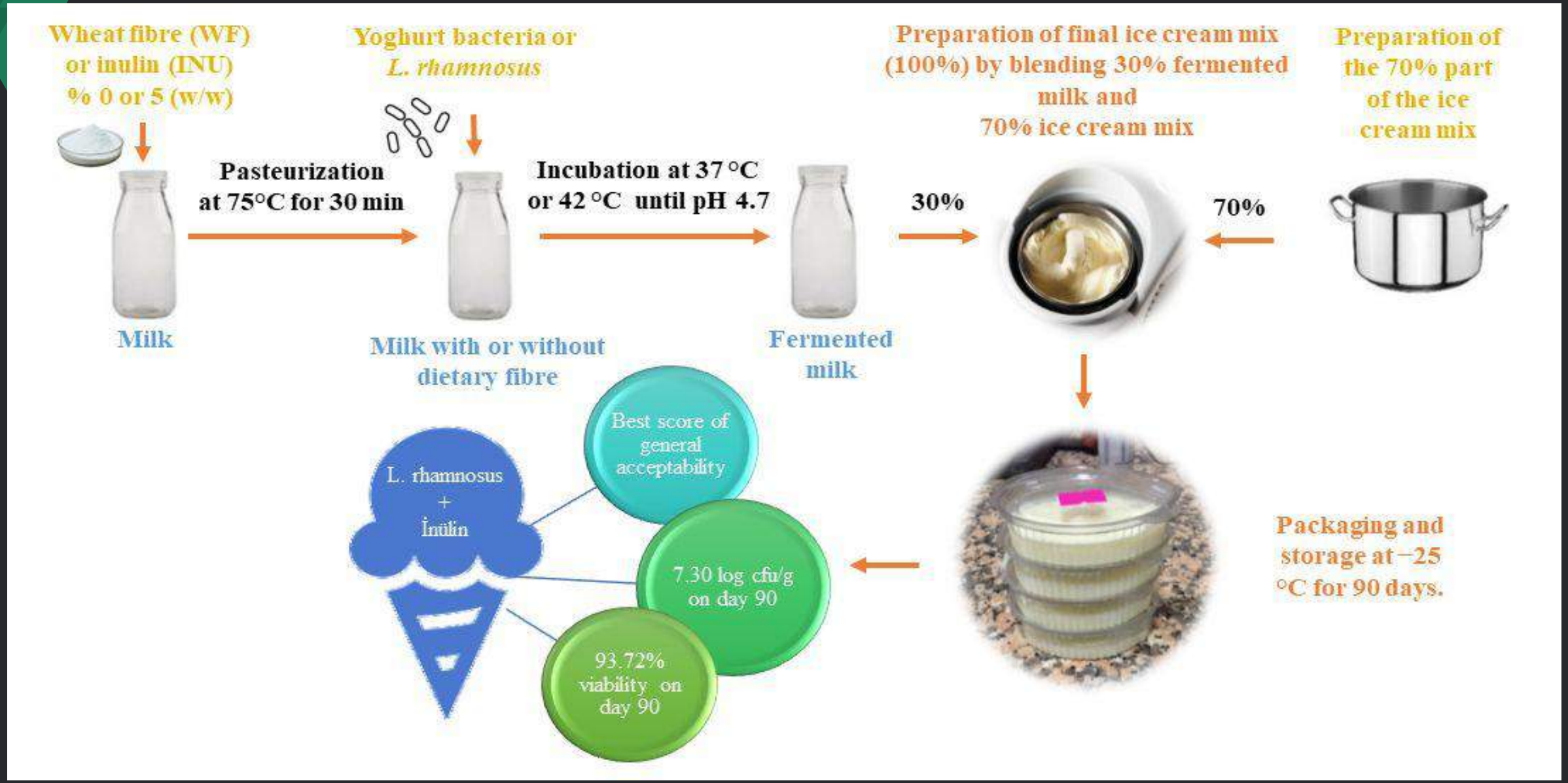


- Kombucha is a fermented beverage made from brewed tea and sugar.
- The kombucha process resembles Vinegar fermentation. Like vinegar, kombucha is a yeast fermentation of sugar to alcohol followed by a bacterial fermentation of alcohol to acetic acid.
- Ferment for 7 to 10 days: Keep the jar at room temperature, out of direct sunlight, and where it won't get jostled.
- Ferment for 7 to 10 days, checking the kombucha and the scoby periodically. It's not unusual for the scoby to float at the top, bottom, or even sideways during fermentation



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7. Jurnal Fermentation : https://www.mdpi.com/journal/fermentation

Video :
https://youtu.be/5eKdZ0dVCCo?t=299
https://youtu.be/bWxPpK7t5lE

GLOSARY

- Microorganisms: Organisms that cannot be seen with the naked eye, requiring a microscope.
- Biotechnology: The science of creating new or modified products using living organisms.
- Anaerobic Pathway: Biochemical reactions that do not require the presence of oxygen.
- Lactic Acid Fermentation: Biological process where sugar is converted into lactate and cellular energy (ATP).
- Alcoholic Fermentation: Biological process where sugar is converted to ethanol and cellular energy (ATP).
- ATP: Main energy coin used by living beings.
- Ethanol: It is the most common alcohol present in our lives.
- Probiotic: A usually dairy food or a dietary supplement containing microorganisms that replace or add to the beneficial bacteria normally present in the gastrointestinal tract.
- Pathogen: Capable of causing disease.
- Biofuel: A type of fuel made using living or once living material, such as plant material, which can serve as a replacement for petroleum-based fuels like gasoline.

Thank you

See you next week

STIKES NOTOKUSUMO YOGYAKARTA

BIOTEKNOLOGI

Pertemuan 5

apt. Trifonia Rosa Kurniasih, M.Biotech

Case-based learning

Topik :
“Dari Mikroba ke Molekul: Inovasi Produksi Senyawa Bioaktif Melalui Fermentasi Modern”

Tujuan Pembelajaran (Learning Outcomes):

- ✓ Mampu menjelaskan **proses produksi antibiotik, hormon, enzim, dan vitamin** melalui fermentasi mikroba.
- ✓ Mampu membedakan **karakteristik kultur murni dan kultur campuran**, serta aplikasinya.
- ✓ Mampu mengidentifikasi **faktor yang memengaruhi yield dan kestabilan produk fermentasi**.
- ✓ Mampu menilai **peran teknologi modern (bioreaktor cerdas, fermentasi berkelanjutan, biosensor)** dalam optimalisasi proses industri.
- ✓ Mampu mengembangkan **strategi pemecahan masalah nyata** di industri bioteknologi.

Case-based learning

DESKRIPSI KASUS

- BioSyn Farma adalah perusahaan bioteknologi yang sedang mengembangkan berbagai produk berbasis fermentasi, antara lain **antibiotik, hormon rekombinan, enzim industri, dan vitamin**.
  Perusahaan menghadapi tantangan ketika melakukan **scale-up fermentasi** ke skala industri: hasil produksi menurun, aktivitas enzim tidak stabil, dan kontrol proses menjadi lebih kompleks.
- Manajemen kemudian mempertimbangkan pendekatan baru, yaitu **penggunaan kultur campuran (co-culture)** dan **teknologi fermentasi modern** berbasis sensor serta kontrol otomatis.
  Tim pengembang diminta menganalisis berbagai aspek agar proses produksi dapat dioptimalkan.

Case-based learning

Pertanyaan Pemicu Diskusi (Pilih 1 Pertanyaan per Kelompok)

Tiap kelompok memilih **satu pertanyaan** yang akan menjadi fokus analisis utama.

Pastikan seluruh pertanyaan terdistribusi agar kelas mencakup keseluruhan alur proses fermentasi.

No	Pertanyaan Pemicu	Fokus Analisis
1	Mengapa hasil produksi antibiotik atau vitamin dapat menurun ketika fermentasi diskalakan ke volume besar?	Aspek teknis proses (pH, aerasi, nutrisi, desain fermentor).
2	Apa kelebihan dan tantangan produksi hormon rekombinan melalui fermentasi dibandingkan sintesis kimia?	Rekayasa genetika, ekspresi protein, dan kontrol kualitas.
3	Faktor apa yang paling berpengaruh terhadap kestabilan dan yield enzim hasil fermentasi mikroba?	Fisiologi mikroba, induksi enzim, kondisi fermentasi.
4	Bagaimana konsep kultur campuran (co-culture) dapat meningkatkan hasil fermentasi dibandingkan kultur tunggal?	Interaksi mikroba, sinergi metabolit, dan kontrol ekologi.
5	Teknologi fermentasi modern apa yang paling potensial untuk mengoptimalkan produksi bioteknologi?	Sensor in-line, sistem otomatis, AI-based process control.

Case-based learning

Petunjuk Kegiatan Diskusi

a. Baca dan pahami deskripsi kasus bersama kelompok.
b. Pilih **satu pertanyaan pemicu** sebagai fokus analisis kelompok.
c. Diskusikan dan tuliskan hasil analisis dengan memperhatikan:
    1. Latar belakang ilmiah terkait pertanyaan.
    2. Faktor-faktor yang memengaruhi masalah dalam kasus.
    3. Strategi atau solusi yang bisa diterapkan BioSyn Farma.
    4. Ilustrasi atau bagan pendukung jika diperlukan.

Case-based learning

Lembar Kerja Kelompok

Nama Kelompok / Anggota:

.....

Pertanyaan yang Dipilih:

.....

Analisis Singkat:

1. Masalah yang Dihadapi BioSyn Farma:

.....

2. Faktor-Faktor yang Berpengaruh:

.....

3. Analisis Ilmiah / Penjelasan Mekanisme:

.....

4. Usulan Solusi atau Inovasi:

.....

5. Bagaimana Tahap Ini Terkait dengan Alur Produksi Bioteknologi Secara Keseluruhan?

.....

Thank you

See you next week

STIKES Notokusumo Yogyakarta

Pertemuan 6

apt. Trifonia Rosa Kurniasih, M.Biotech

CONTENT

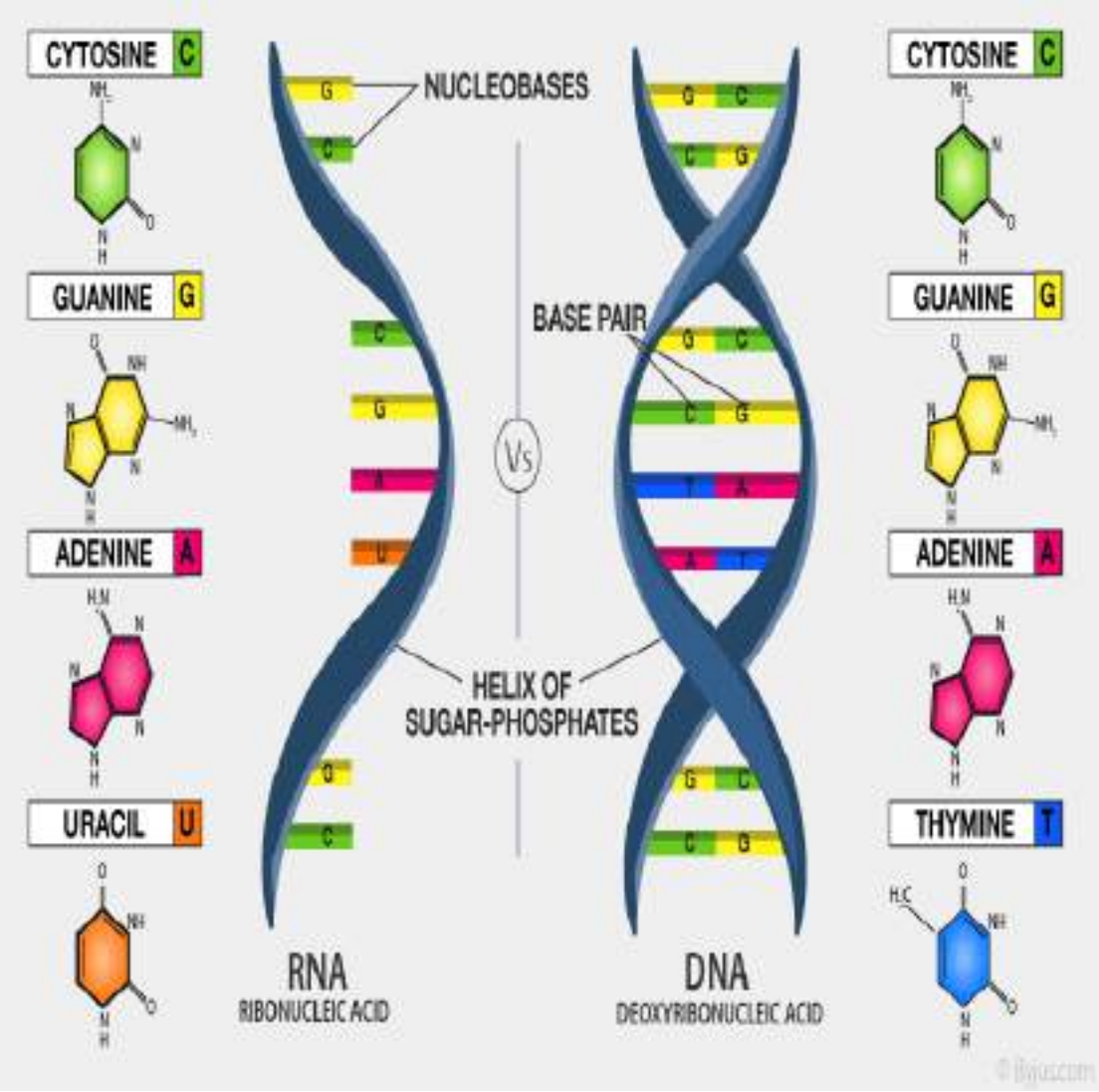
Rekayasa Genetika dan Protein

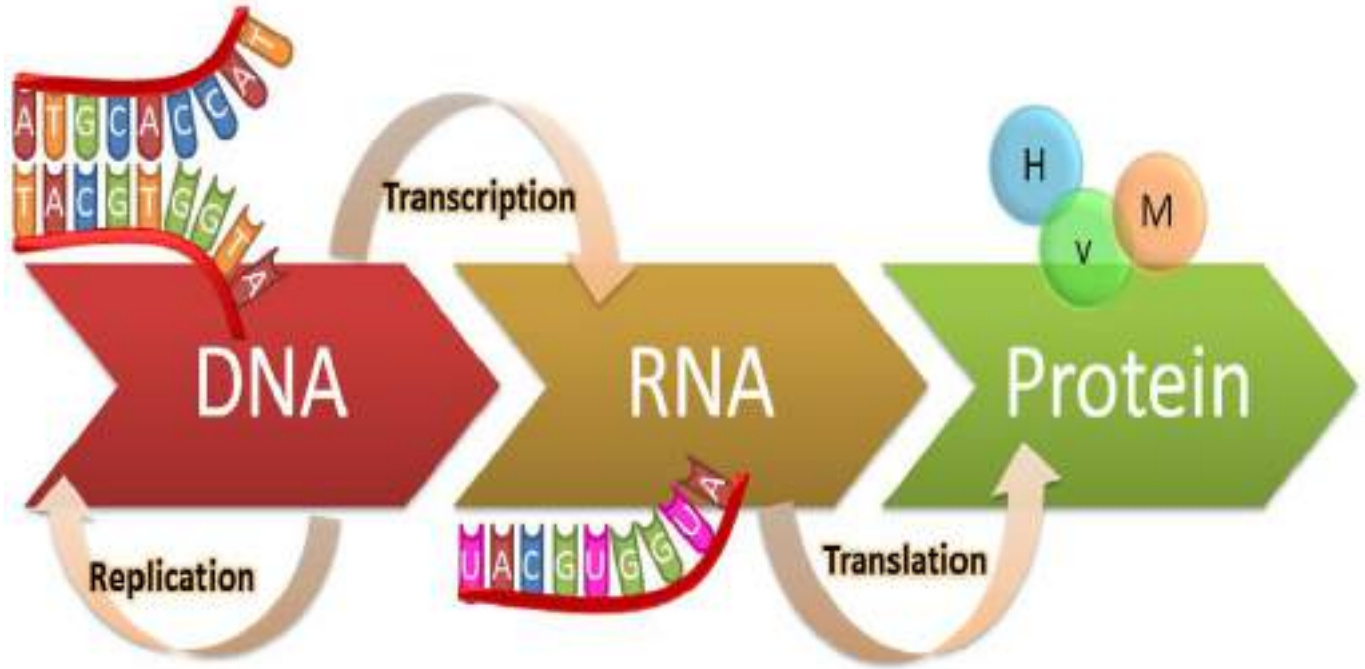
PENDAHULUAN

REKAYASA GENETIKA

PENDAHULUAN

REKAYASA GENETIKA



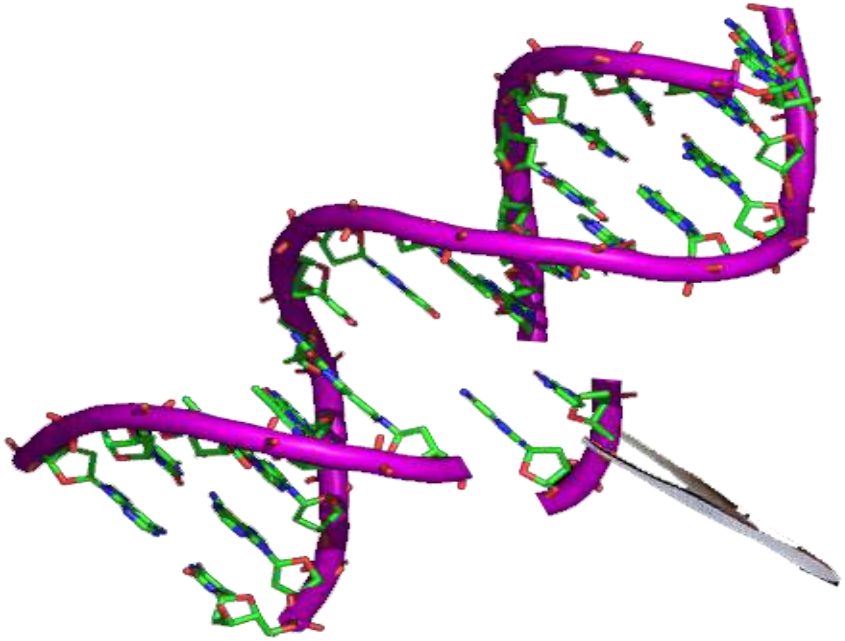


PENDAHULUAN

REKAYASA GENETIKA

Genetic engineering (also called genetic modification) is a process that uses laboratory-based technologies to alter the DNA makeup of an organism. This may involve changing a single base pair (A-T or C-G), deleting a region of DNA or adding a new segment of DNA.

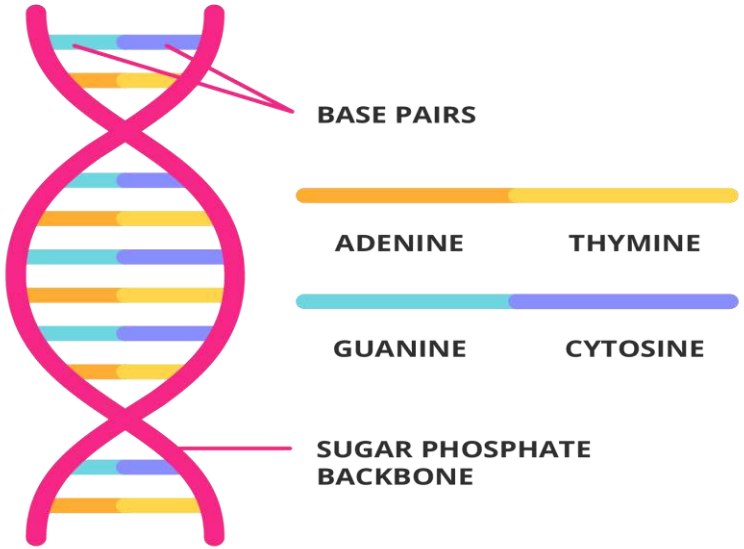
Organisms created by genetic engineering are called genetically modified organisms (GMOs).



PENDAHULUAN

REKAYASA GENETIKA

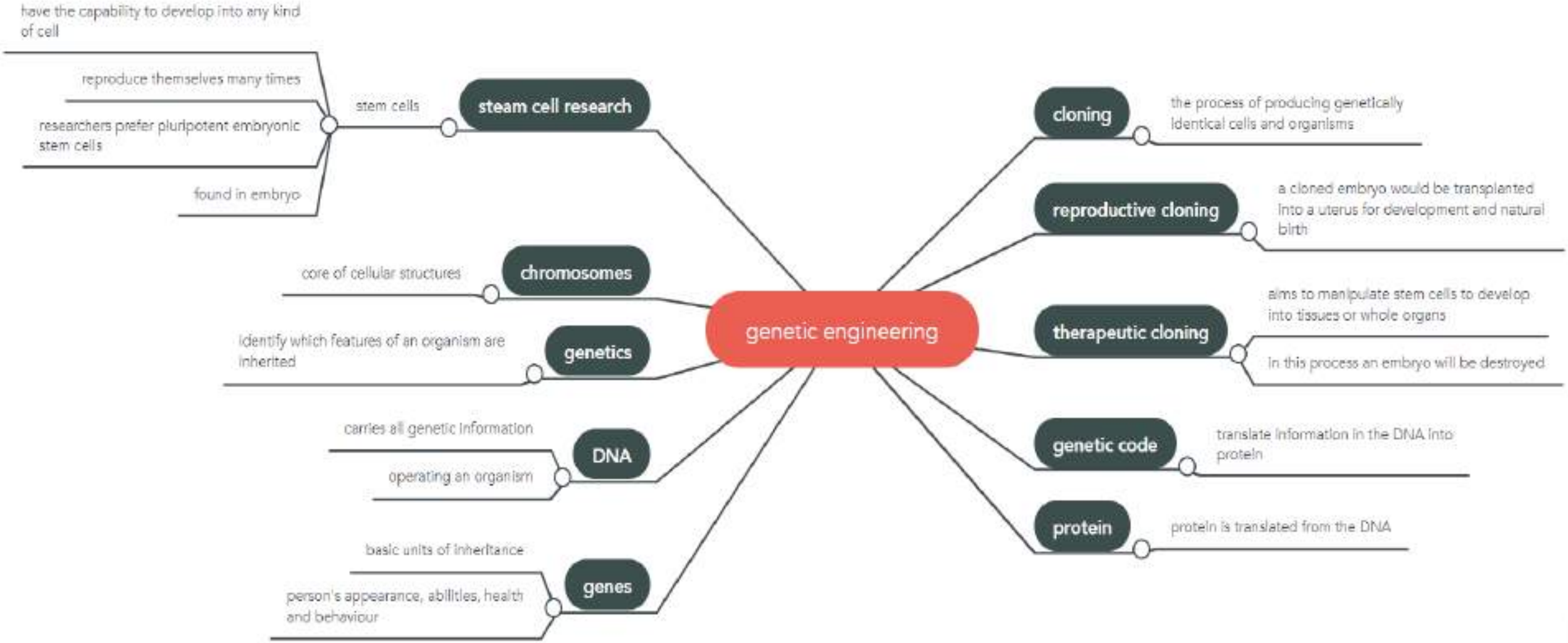
For example, genetic engineering may involve adding a gene from one species to an organism from a different species to produce a desired trait. Used in research and industry, genetic engineering has been applied to the production of cancer therapies, brewing yeasts, genetically modified plants and livestock, and more.



Source: (Mar, 2019). 'What is DNA?'. Retrieved from U.S. National Library of Medicine.

KLASIFIKASI

REKAYASA GENETIKA



KLASIFIKASI

REKAYASA GENETIKA

Recombinant DNA

- A recombinant DNA technology is a type of genetic engineering technology in which an artificial DNA molecule is constructed by ligating two different DNAs using physical methods. For that, the gene of interest is inserted into the plasmid vector and used for gene transfer experiments.

Gene delivering

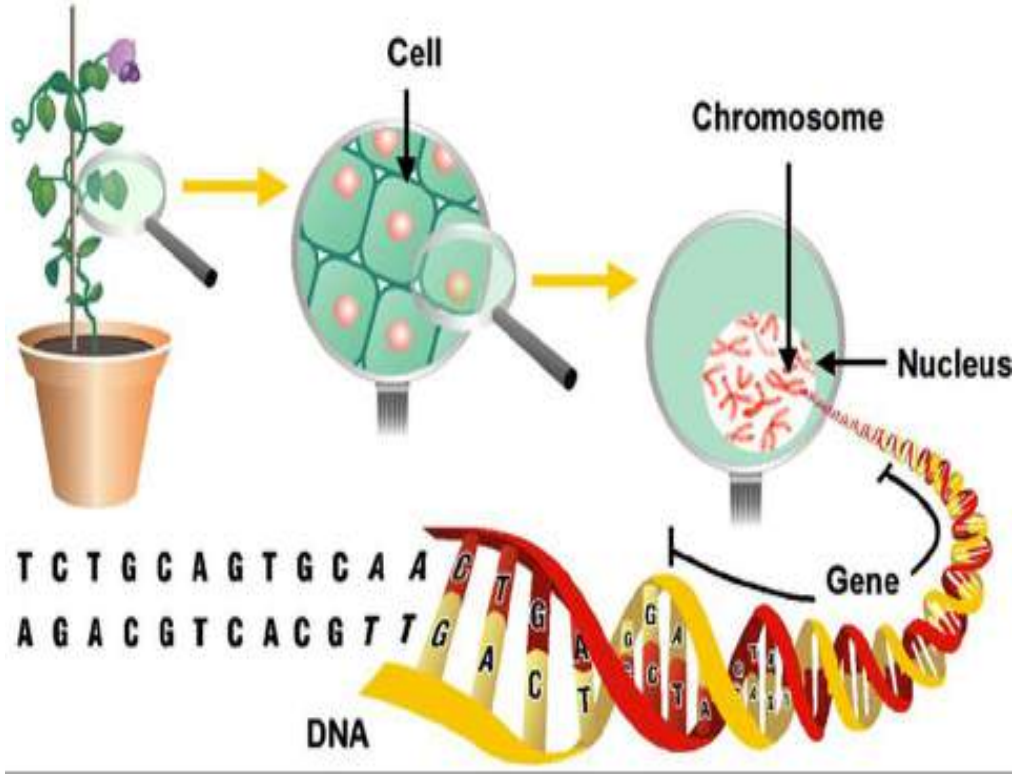
- Gene delivering technique is employed for the insertion of a gene of interest into the host genome.

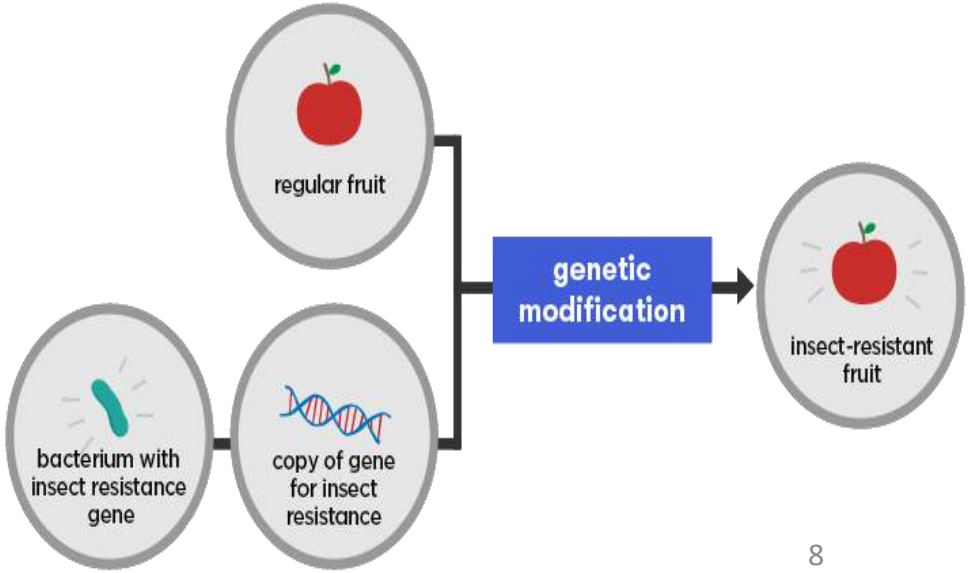
Electrophoration, solicitation and viral vector

- mediated gene transfer, liposome-mediated gene transfer, transposon-mediated gene transfer are some of the methods used for that

Gene editing

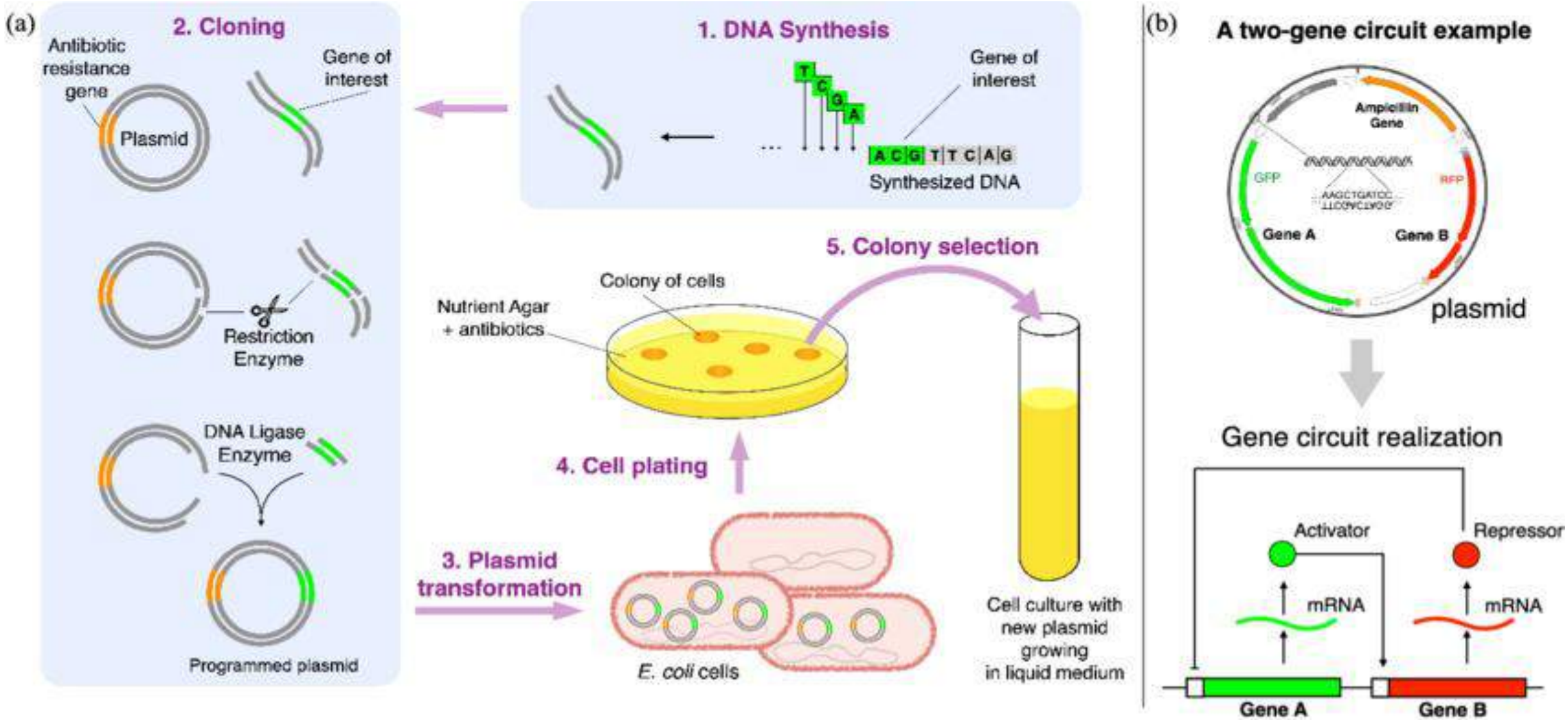
- A gene-editing technique is used to edit the genome in which an undesired DNA sequence is removed or a new gene can be inserted into the host genome. CRISPR-CAS9, TALEN and ZFN are some known gene-editing tools used in gene therapy experiments





PROSES DAN TEKNIK

REKAYASA GENETIKA



PROSES DAN TEKNIK

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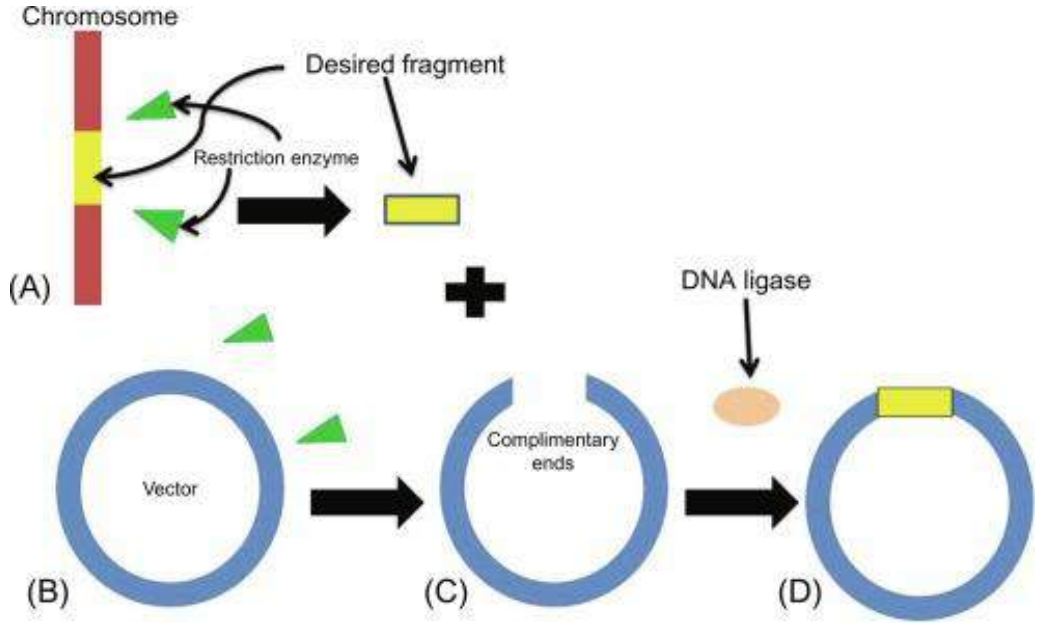


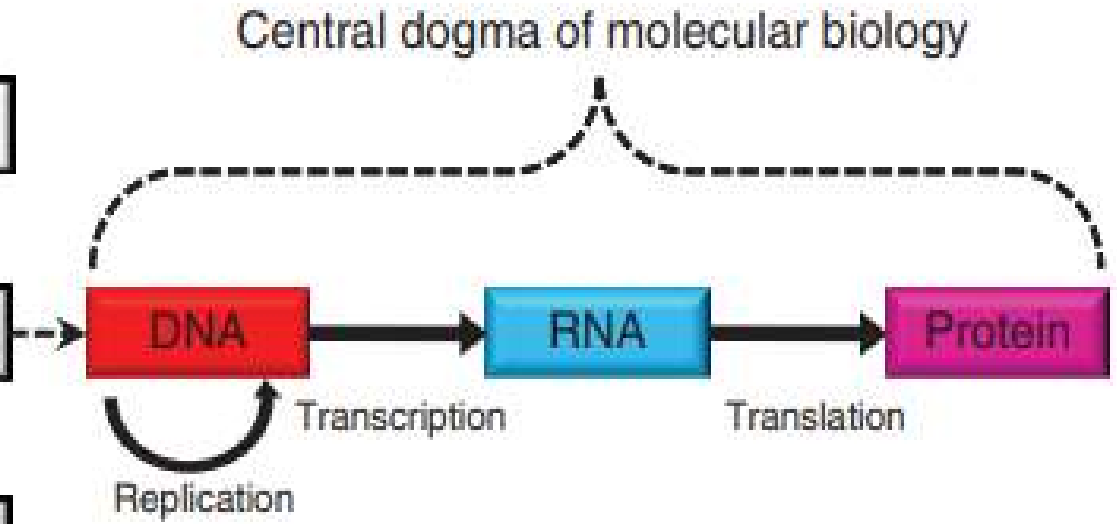
Extraction and purification of total cellular DNA

Splicing and insertion of DNA into cloning vector

Introduction of cloning vector into host strain

Replication and expression of recombinant DNA

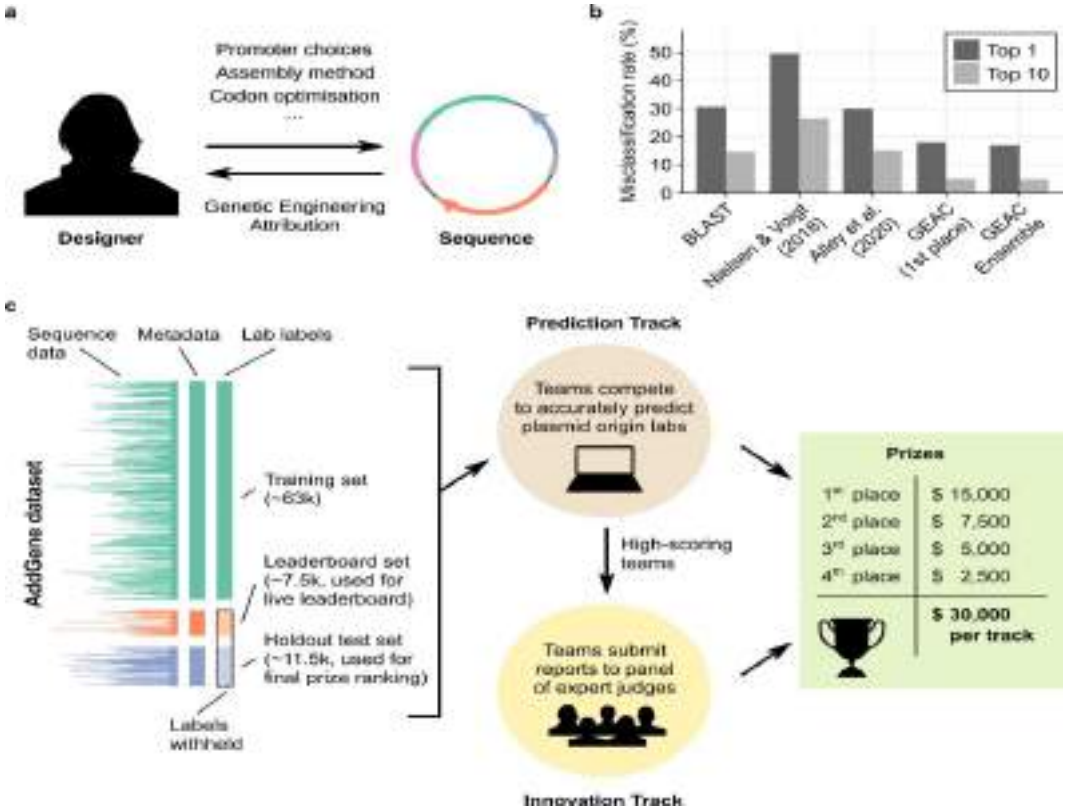
Selection of recombinant progeny

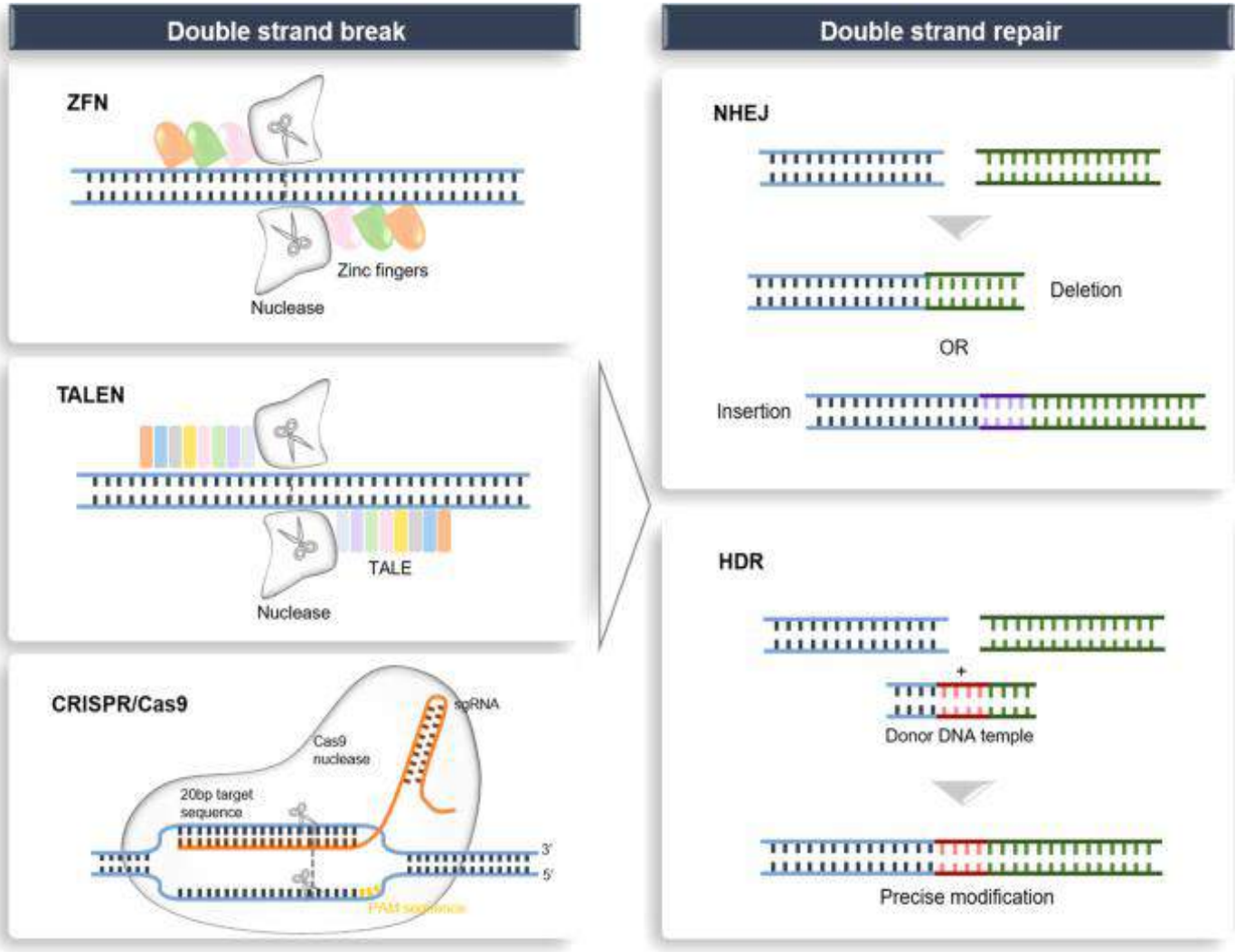


REKAYASA GENETIKA

GENOME EDITING

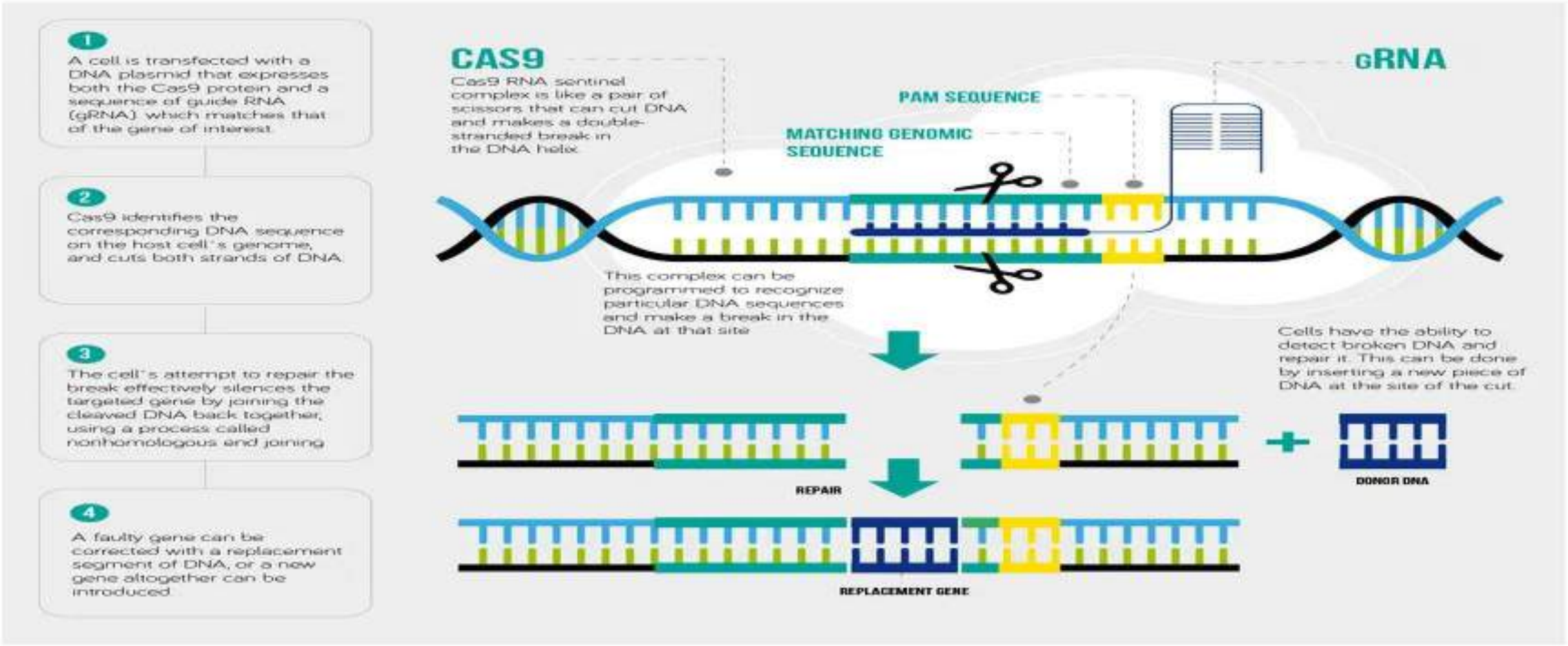
- In the 1970s, the development of genetic engineering (manipulation of DNA or RNA) established a novel frontier in genome editing





**ZFN* Zinc-finger nuclease, *TALEN* Transcription activator-like effector nuclease, *CRISPR* Clustered regularly interspaced short palindromic repeat

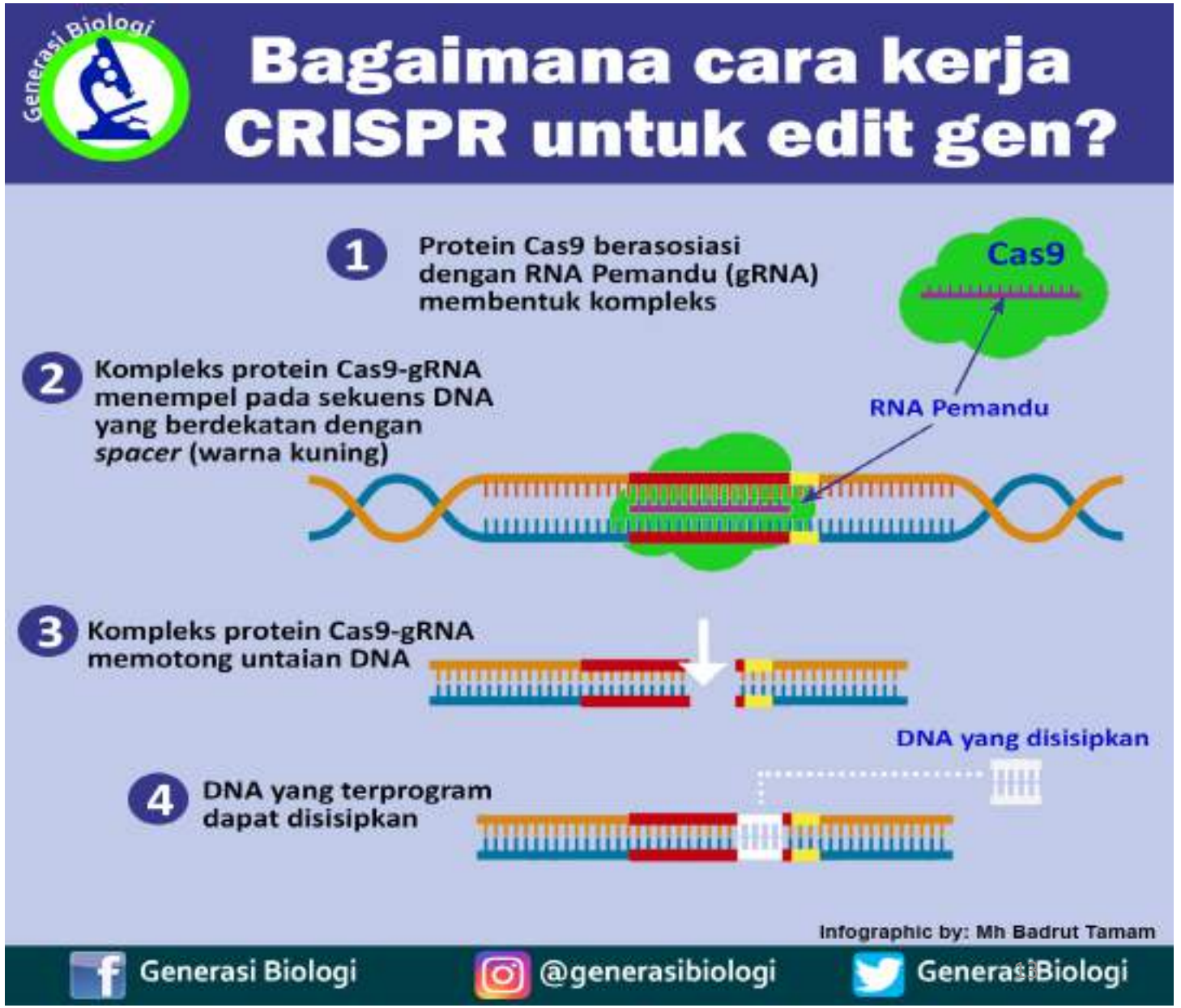
REKAYASA GENETIKA



PROSES DAN TEKNIK

REKAYASA GENETIKA

- **CRISPR** : Clustered Regularly Interspaced Short Palindromic Repeats
- **Cas9** : CRISPR associated protein 9
- CRISPR/Cas9 edits genes by precisely cutting DNA and then letting natural DNA repair processes to take over.
- The system consists of two parts: the Cas9 enzyme and a guide RNA
- A short DNA sequence, **the protospacer-adjacent motif (PAM),** is frequently used to mark proper target sites. Cas proteins have evolved a multitude of PAM-interacting domains, which enables them to cope with viral anti-CRISPR measures that alter the sequence or accessibility of PAM elements.

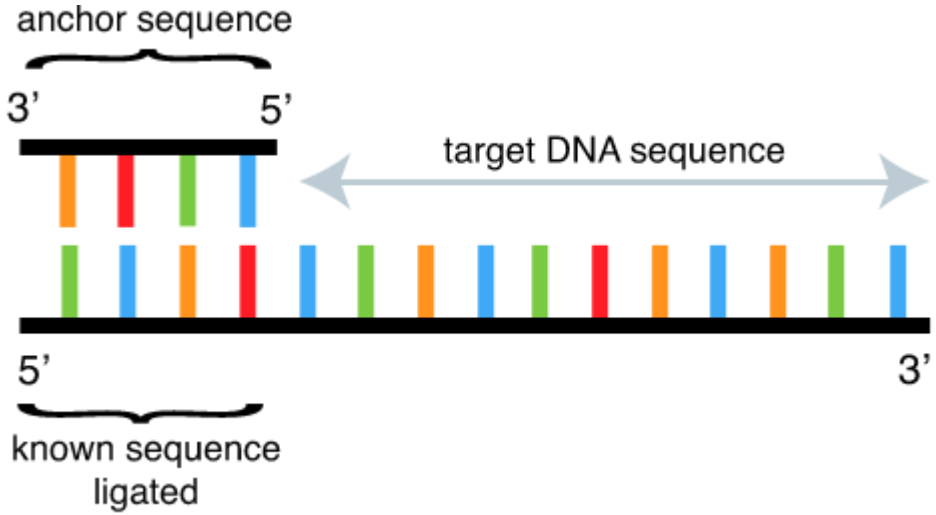


PROSES DAN TEKNIK

REKAYASA GENETIKA

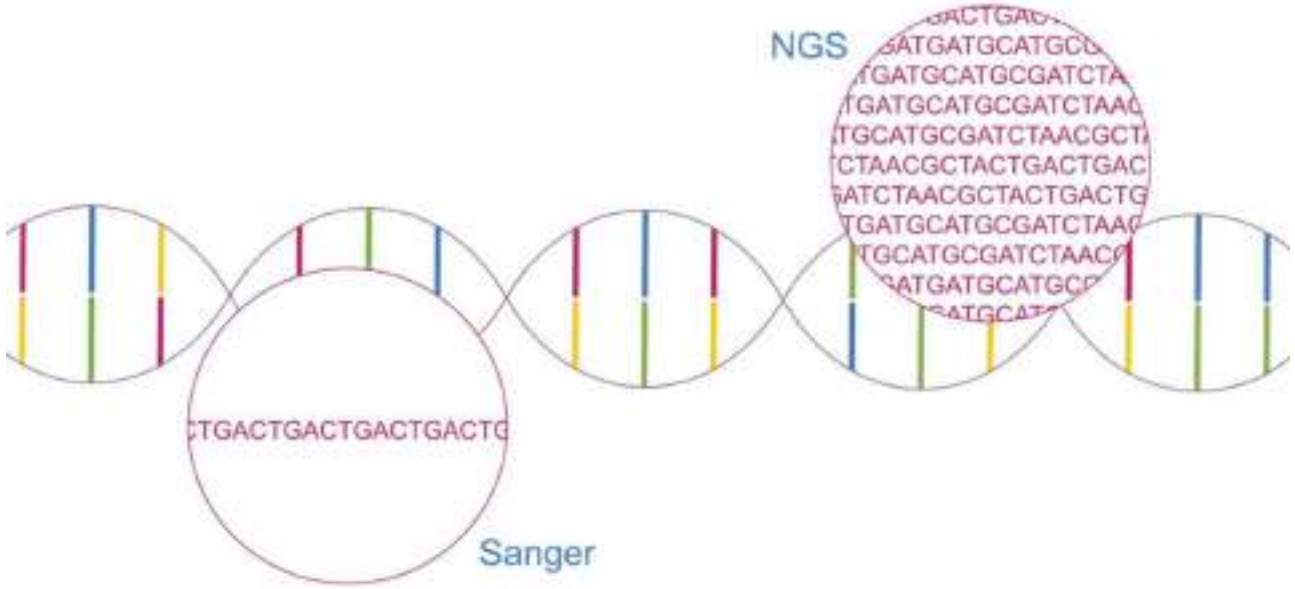
Approach	Characteristic	Advantages	Limitations
HR	Point mutation, insertion, deletion; Dividing cells	High specificity	Extremely low efficiency
ZFN-HDR	Point mutation, insertion, deletion; Dividing cells	High specificity	DSB dependent; Labor intensive cloning; Low efficiency
TALEN-HDR	Point mutation, insertion, deletion; Dividing cells	High specificity	DSB dependent; Labor intensive cloning; Low efficiency
Cas9-HDR	Point mutation, insertion, deletion; Dividing cells	Easy to engineer	DSB dependent; PAM site necessary; Off-target effects; Low efficiency
Cre-loxP	Excision, Inversion, translocation; Dividing and non-dividing cells	High specificity; High efficiency	Not useful for insertion or correction; Need prior insertion of loxP sites
HITI	Insertion; Dividing and non-dividing cells	Easy to engineer	DSB dependent; PAM site necessary; Off-target effects; Low efficiency
BE	Point mutation; Dividing and non-dividing cells	High efficiency; non-dividing cells	PAM site necessary; Off-target effects; Only conversion of C•G to T•A, A•T to G•C, or C•G-to-G•C
PE	Point mutation, small insertion, and deletion; Dividing and non-dividing cells	Non-dividing cells	PAM site necessary; off-target effects; low efficiency; limited to small edits.
CAST	Large DNA insertion	Large DNA insertions	Low efficiency

REKAYASA GENETIKA



DNA sequencing refers to the general laboratory technique for determining the exact sequence of nucleotides, or bases, in a DNA molecule. The sequence of the bases (often referred to by the first letters of their chemical names: A, T, C, and G) encodes the biological information that cells use to develop and operate

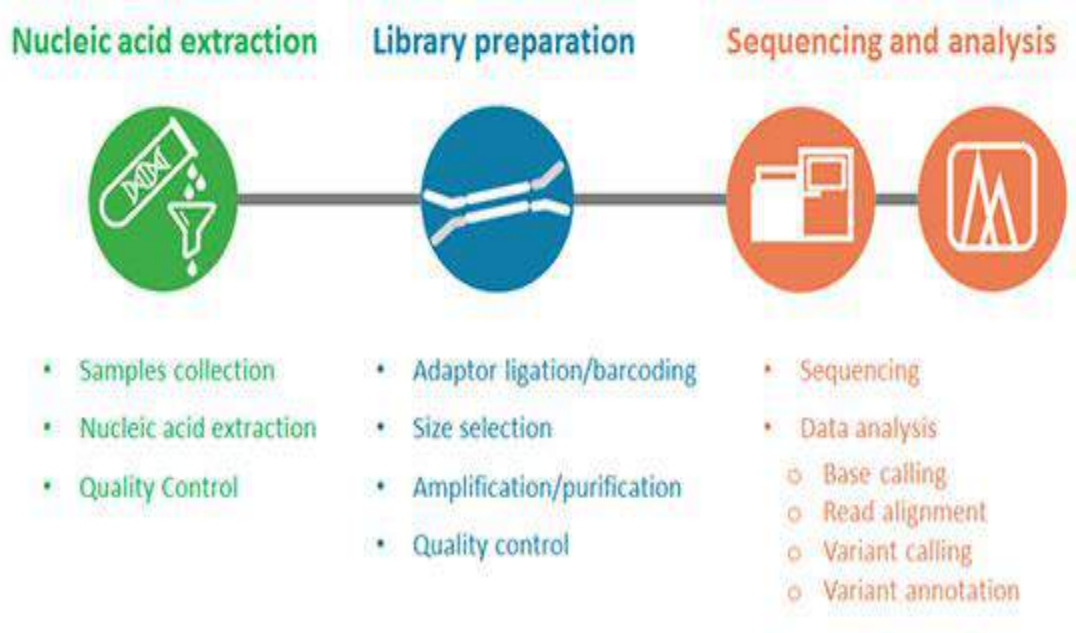
The gene must contain a sequence of DNA that we want to study and for that, a gene has some special characteristics. A candidate gene should have high GC content and a lower repetitive DNA sequence

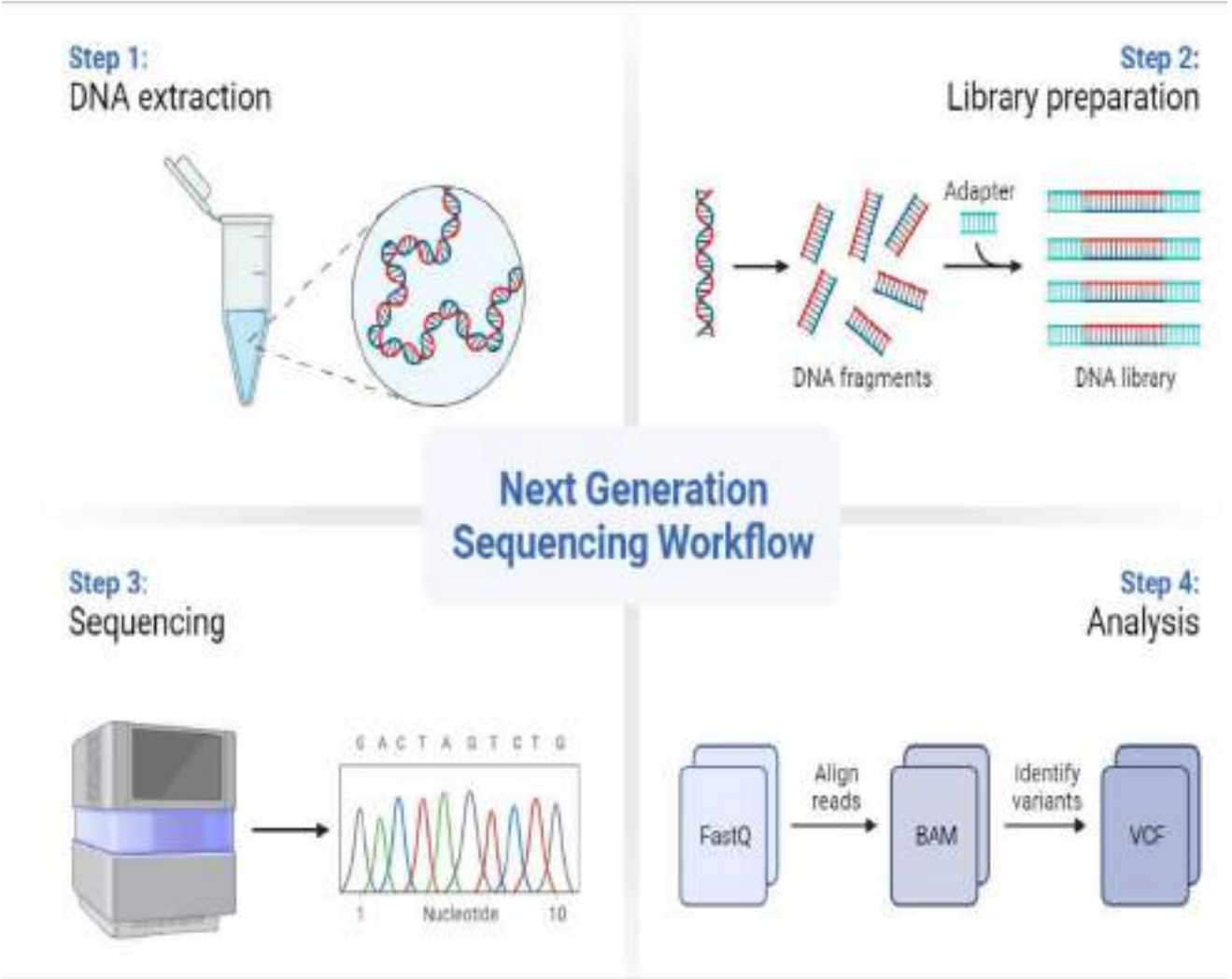


PROSES DAN TEKNIK

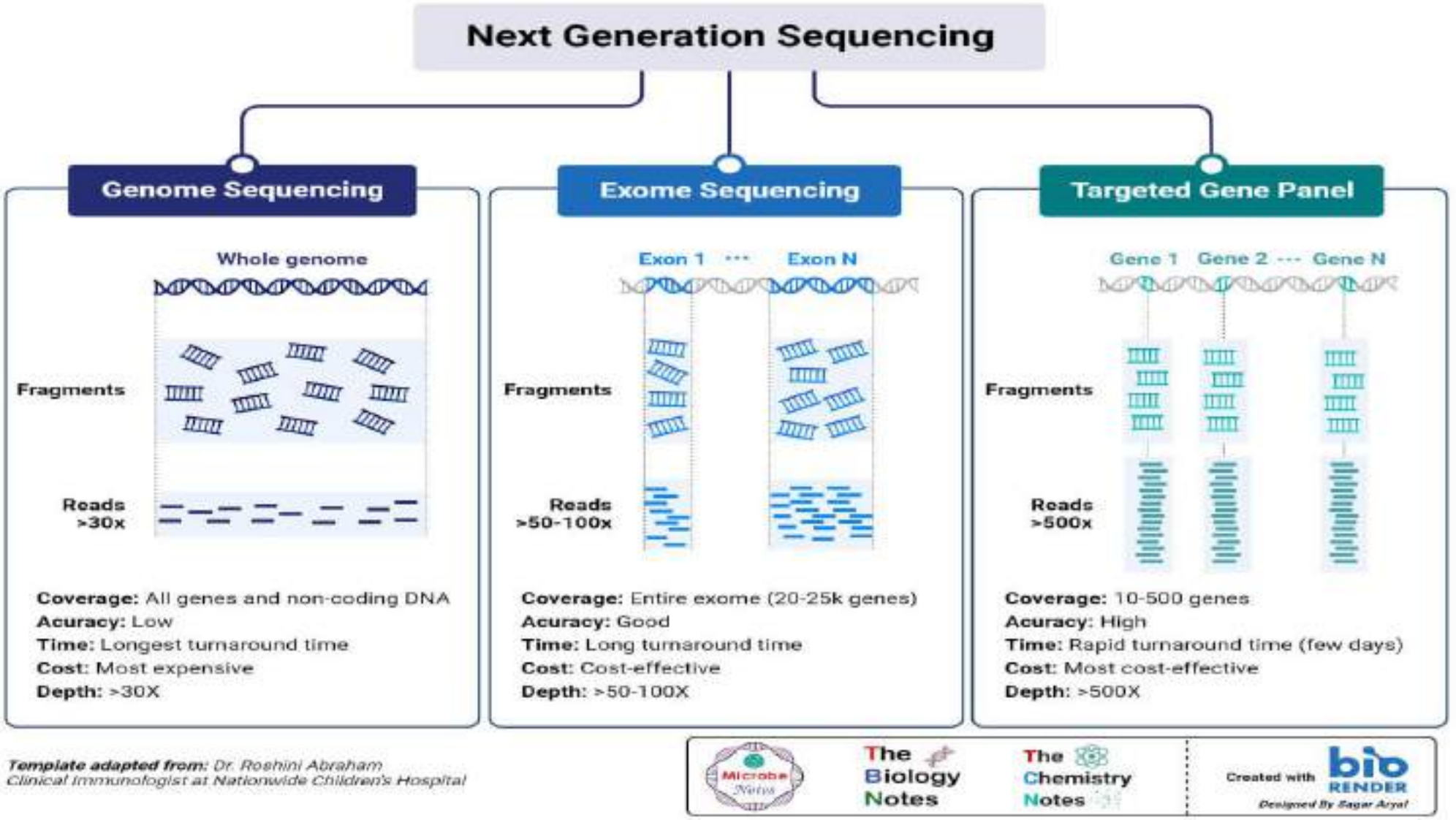
REKAYASA GENETIKA

- **Next-generation sequencing (NGS)** is a massively parallel sequencing technology that offers ultrahigh throughput, scalability, and speed.
- The technology is used to determine the order of nucleotides in entire genomes or targeted regions of DNA or RNA



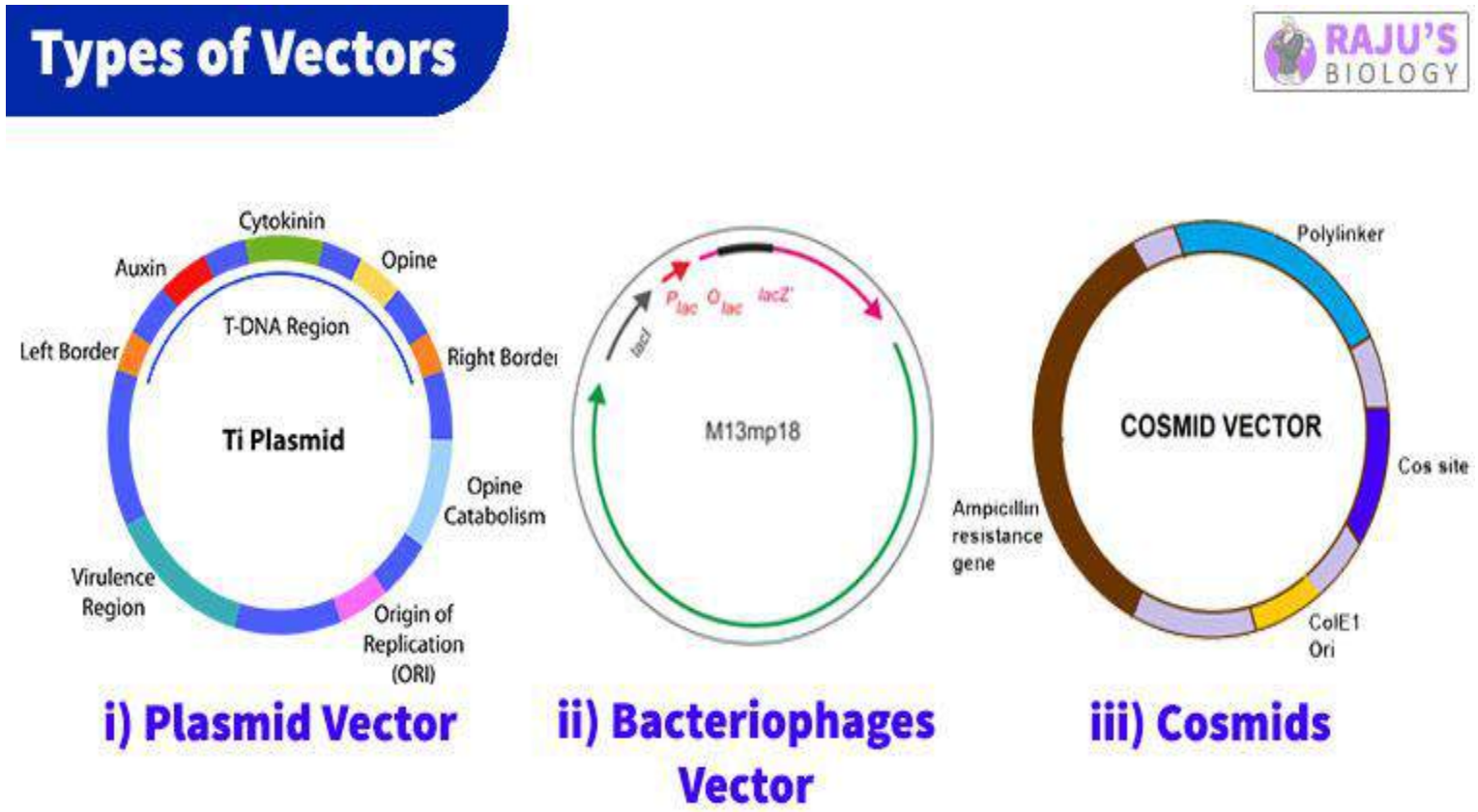


REKAYASA GENETIKA



REKAYASA GENETIKA

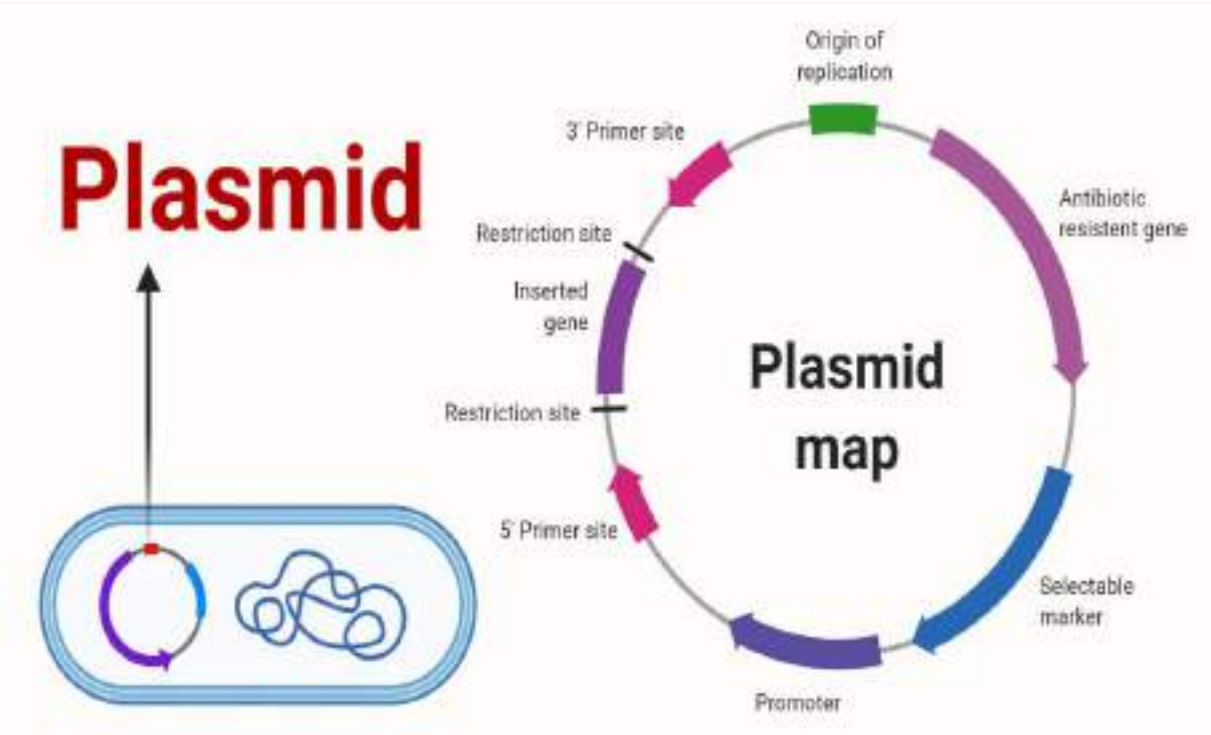
Vectors act as vehicles to transfer genetic material from one cell to the other for different purposes like multiplying, expressing, or isolation

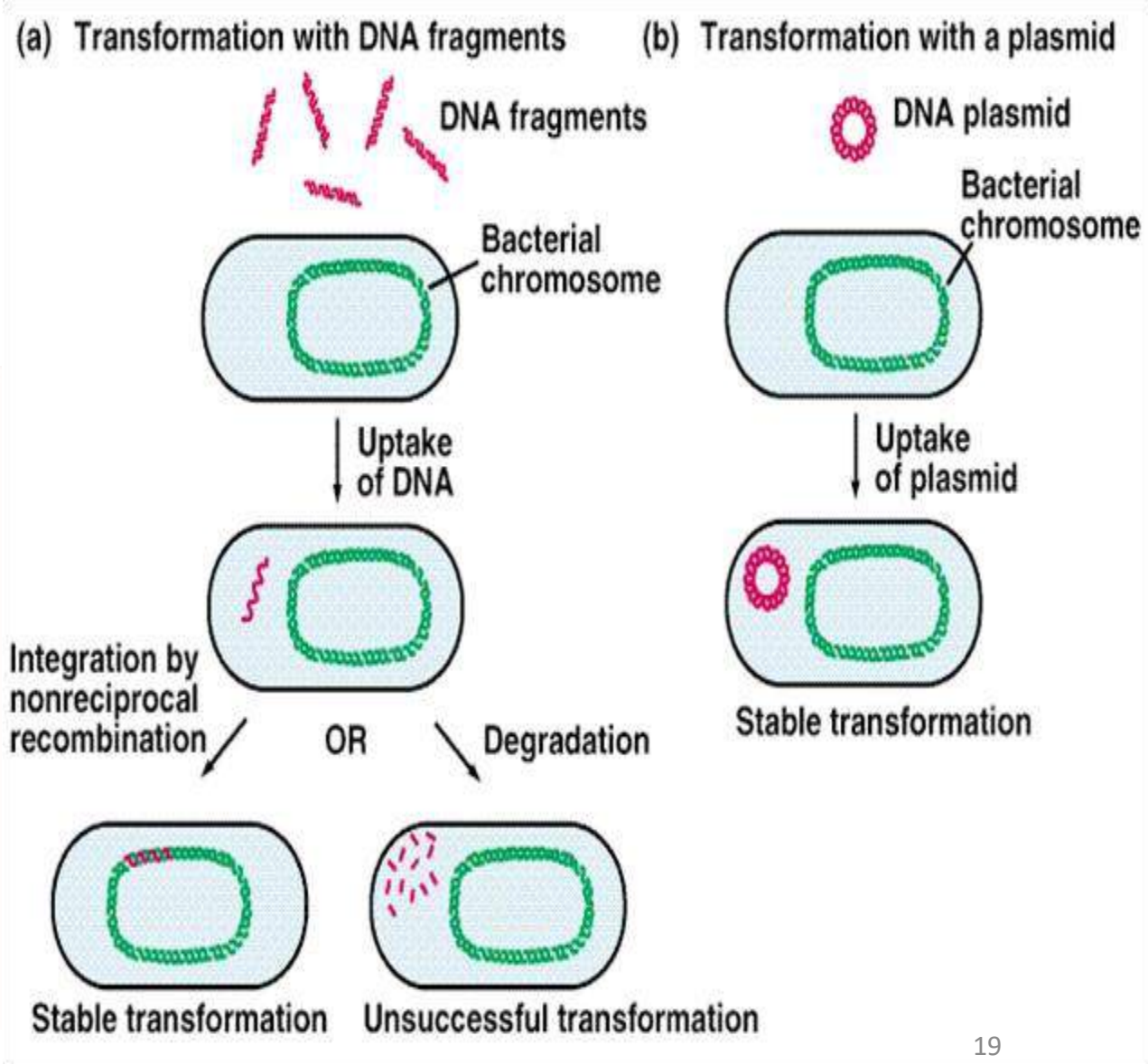


a) Plasmids
b) Cosmids
c) Fosmids
d) Phages
e) Yeast artificial chromosomes (yacs)
f) Transposons
g) Bacterial artificial chromosomes (bacs)
h) Viruses
   - Retroviruses
   - Adenoviruses
   - Adeno-associated viruses
   - Herpes simplex virus
   - Rhinoviruses
   - Human immunodeficiency virus (HIV)

REKAYASA GENETIKA

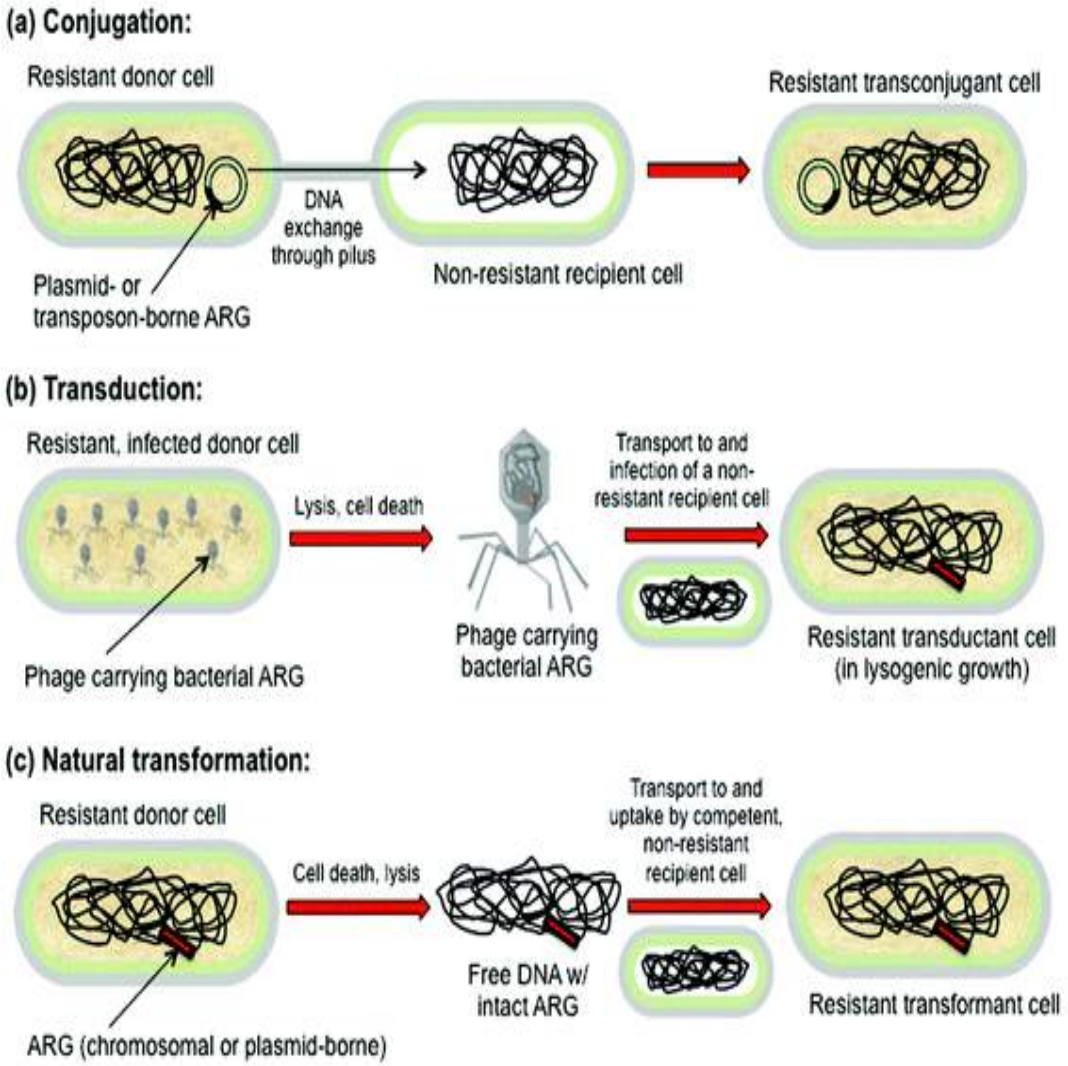
Selecting plasmid for the genetic engineering experiment is one of the crucial steps in the entire experiment. Before selecting the plasmid, we must understand why the plasmid is used in the gene transfer experiments

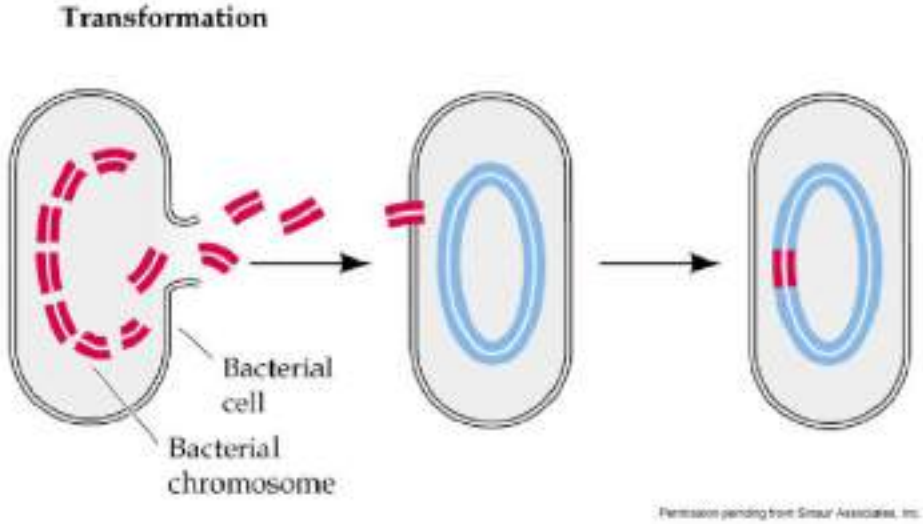




REKAYASA GENETIKA

Transformation into the host genome

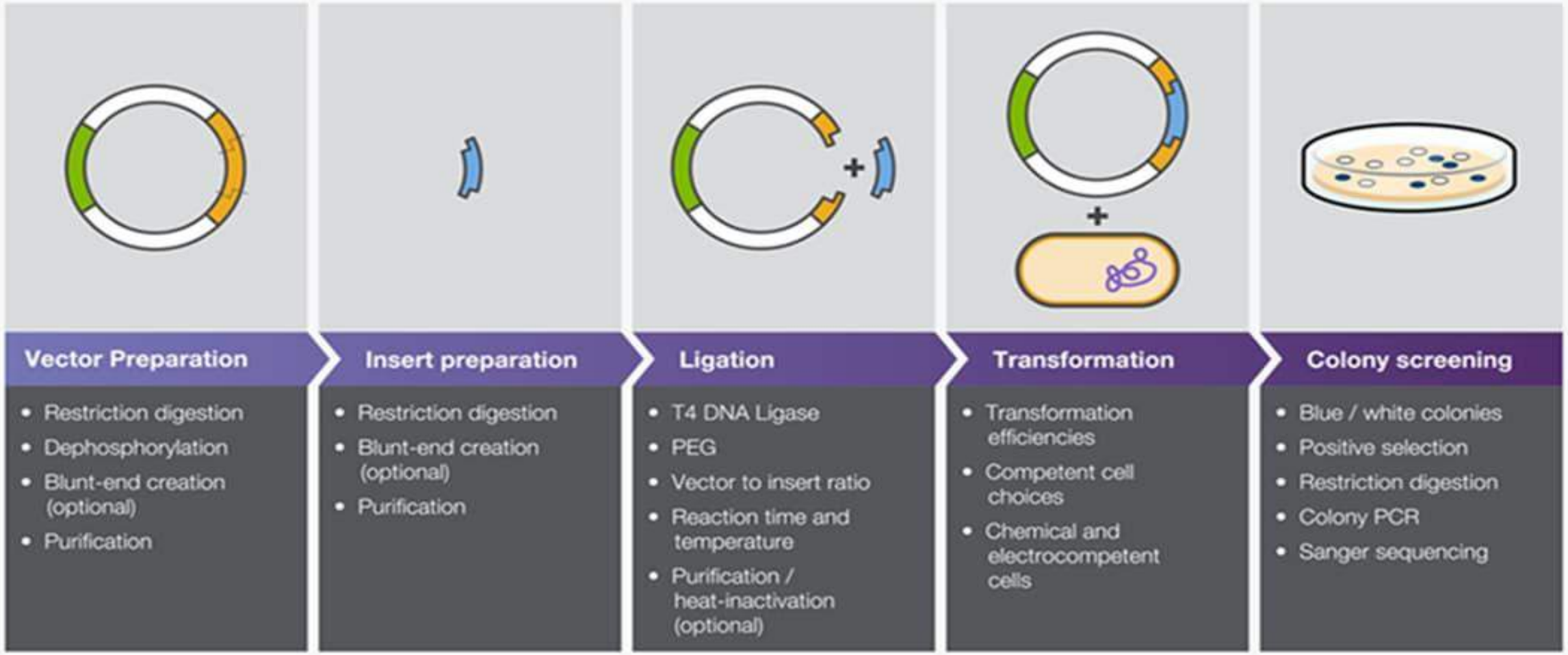




Conventional Gene Delivery Methods		Strengths	Limitations
Physical	Biolistic Particle Delivery	• Easy • Transfers large sizes and amounts of DNA	• Low integrity of delivered DNA • Short-term and low-level expression • Cell damage
	Electroporation	• Fast • Inexpensive	• Limited range of plant species • Low integrity of delivered DNA • Toxicity
Chemical	PEG-Mediated Delivery	• High-efficiency protoplast transfection	• No regeneration of protoplasts into whole and fertile plants
Biological	*Agrobacterium*-Mediated Delivery	• Low cost • High efficiency • Stable transformation	• Limited host range

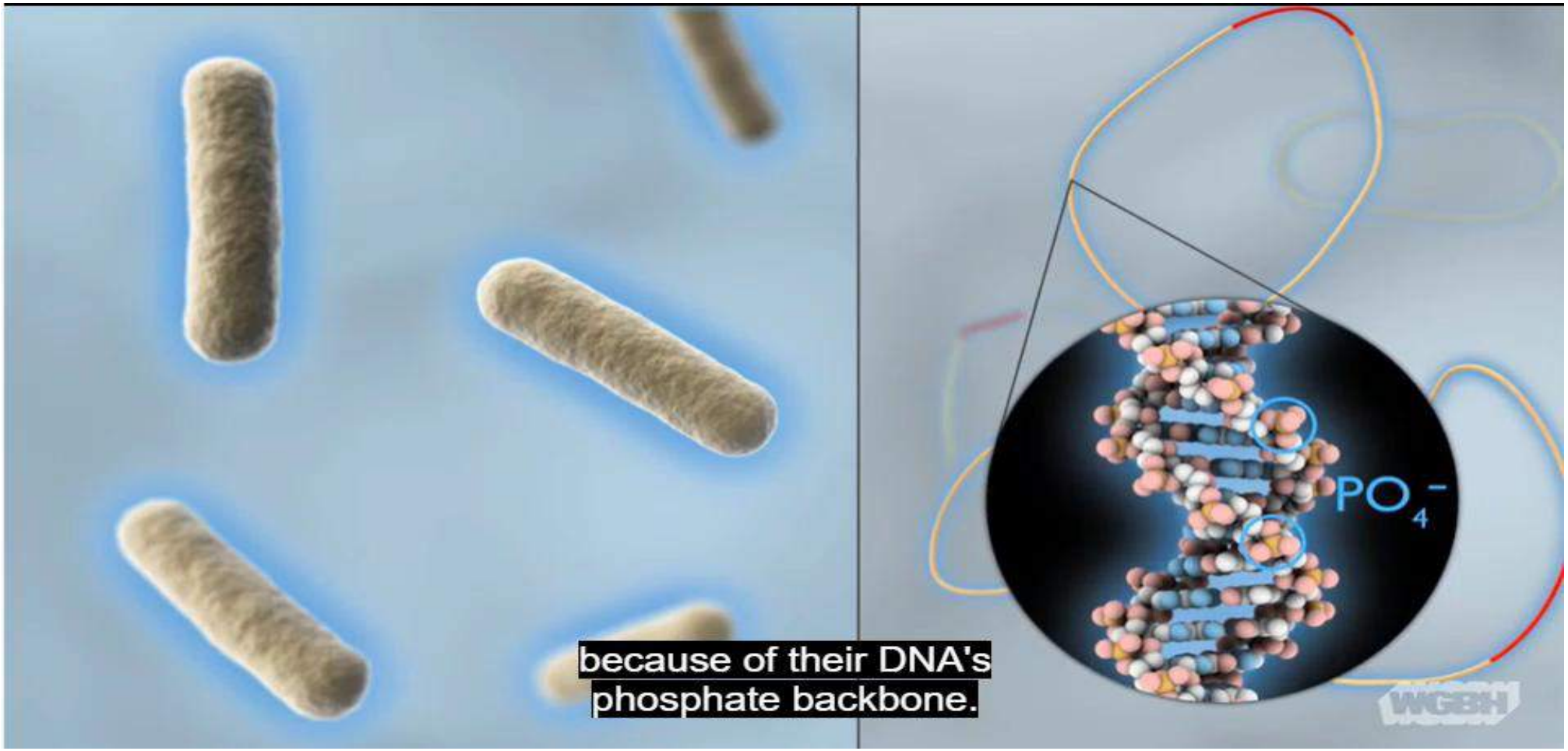
REKAYASA GENETIKA

Traditional cloning



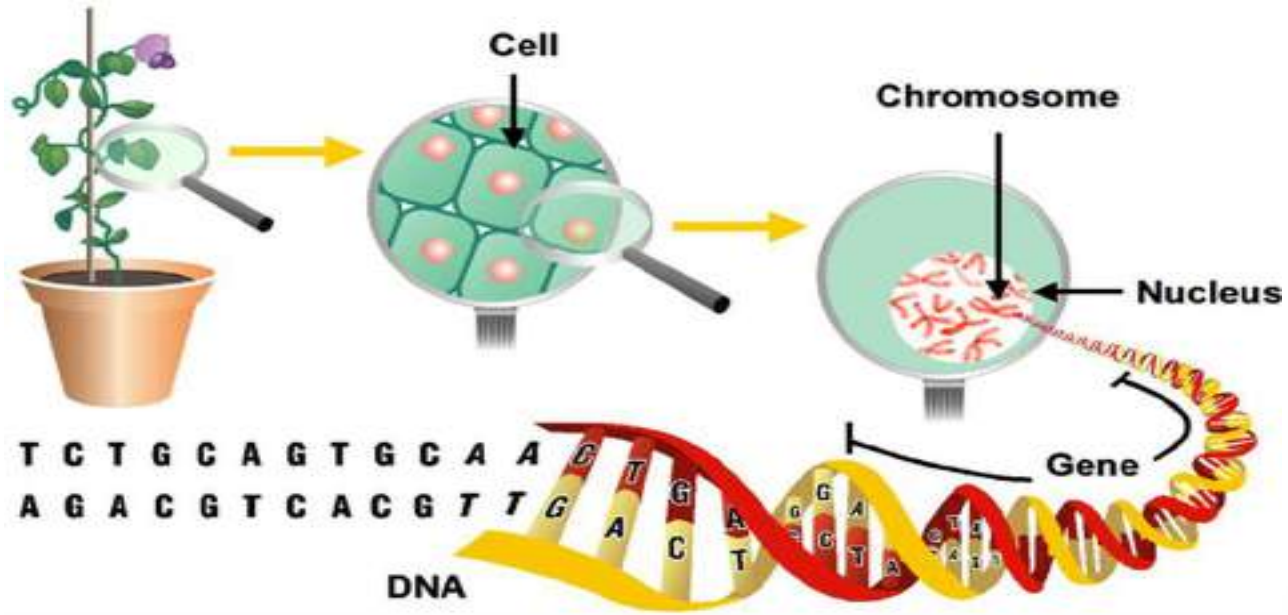
REKAYASA GENETIKA

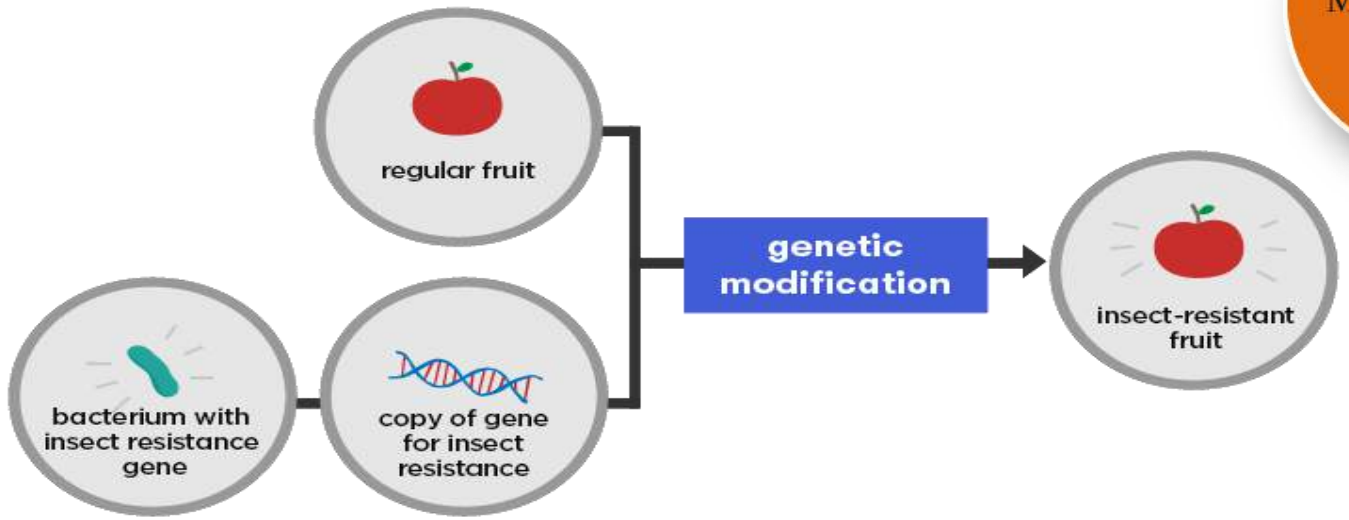
Bacteria transforming

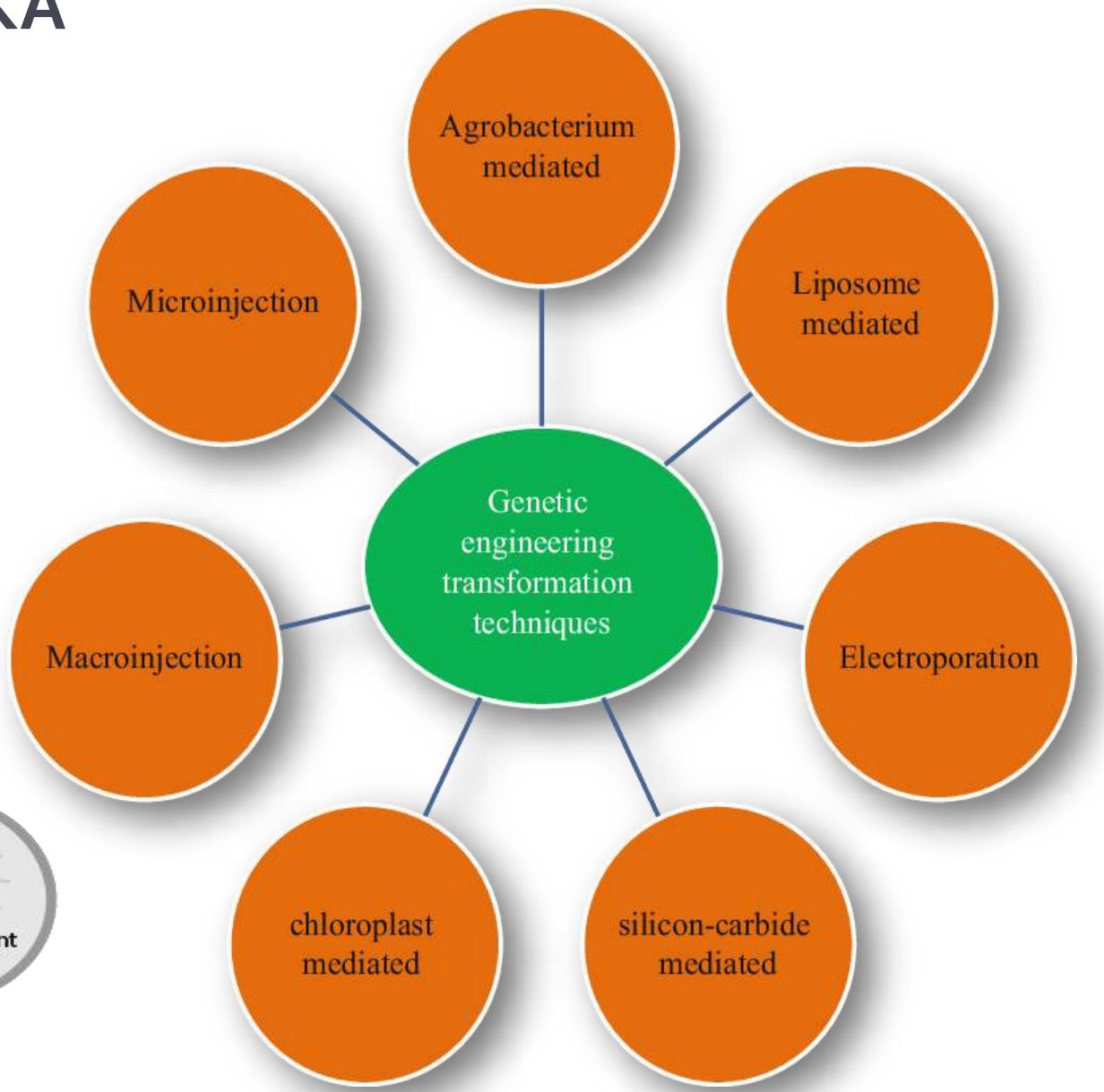


PROSES DAN TEKNIK

REKAYASA GENETIKA







REKAYASA GENETIKA

Transformation into the host genome

	Advantages	Disadvantages
Naked DNA	No special skills needed Easy to produce	Low transduction efficiency Transient gene expression
Physical methods		
Microinjection	Up to 100% transduction efficiency (nuclear injection)	Requires highly specialized skills for delivery Limited to ex vivo delivery
Gene gun	Easy to perform Effective immunization with low amount of DNA	Poor tissue penetration
Electroporation	High transduction efficiency	Transient gene expression Toxicity, tissue damage Highly invasive
Sonoporation	Method well tolerated for other applications	Transient gene expression Toxicity not yet established
Laser irradiation	Can achieve 100% transduction efficiency	Special skills and expensive equipment necessary
Magentofection	Safety of method established in the clinic	Poor efficiency with naked DNA
Chemical methods		
Liposomes	Easy to produce Fusion liposomes improve transduction efficiency	Transient gene expression Toxicity, mildly immunogenic
Cationic polymers	Easy to manipulate for targeting	Transient gene expression Toxicity, mildly immunogenic

Source: From Mehier-Humbert and Guy, 2005; Conwell and Huang, 2005; Miyazaki et al., 2006.

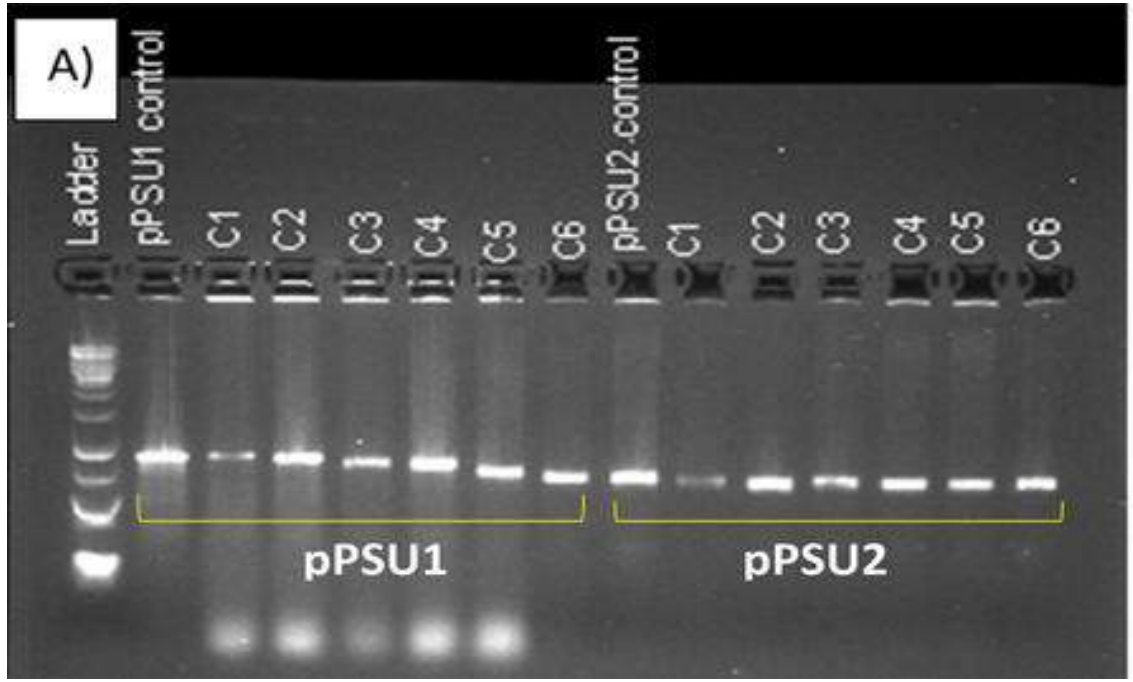
Table 6 Summary of non-viral methods used for gene transfer.

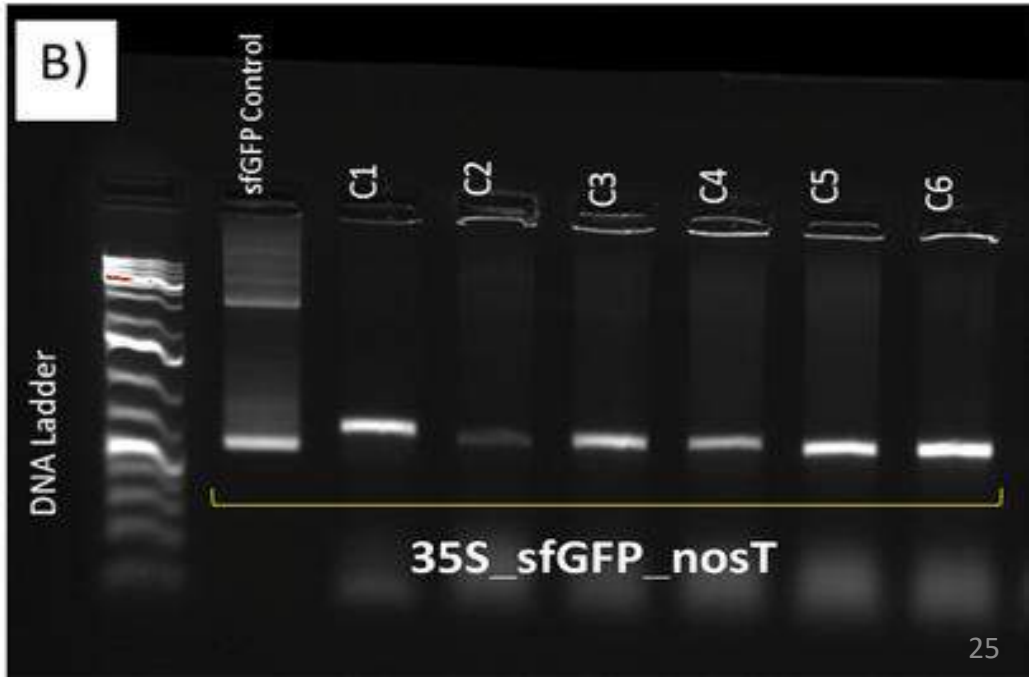
REKAYASA GENETIKA

Confirmation of insertion DNA

PCR- Metode deteksi berbasis reaksi berantai polimerase.

- DNA diekstraksi dari sel yang diubah dan diamplifikasi menggunakan primer yang melengkapi gen yang kita minati atau DNA rekombinan kita.
- Jika DNA rekombinan ada, pasti diperkuat, jika tidak, tidak ada amplifikasi yang diperoleh. Untuk konformasi dua faktor, satu set primer yang melengkapi DNA rekombinan spesifik dan satu set primer yang melengkapi urutan penanda yang dapat dipilih diambil dan PCR multipleks dilakukan.

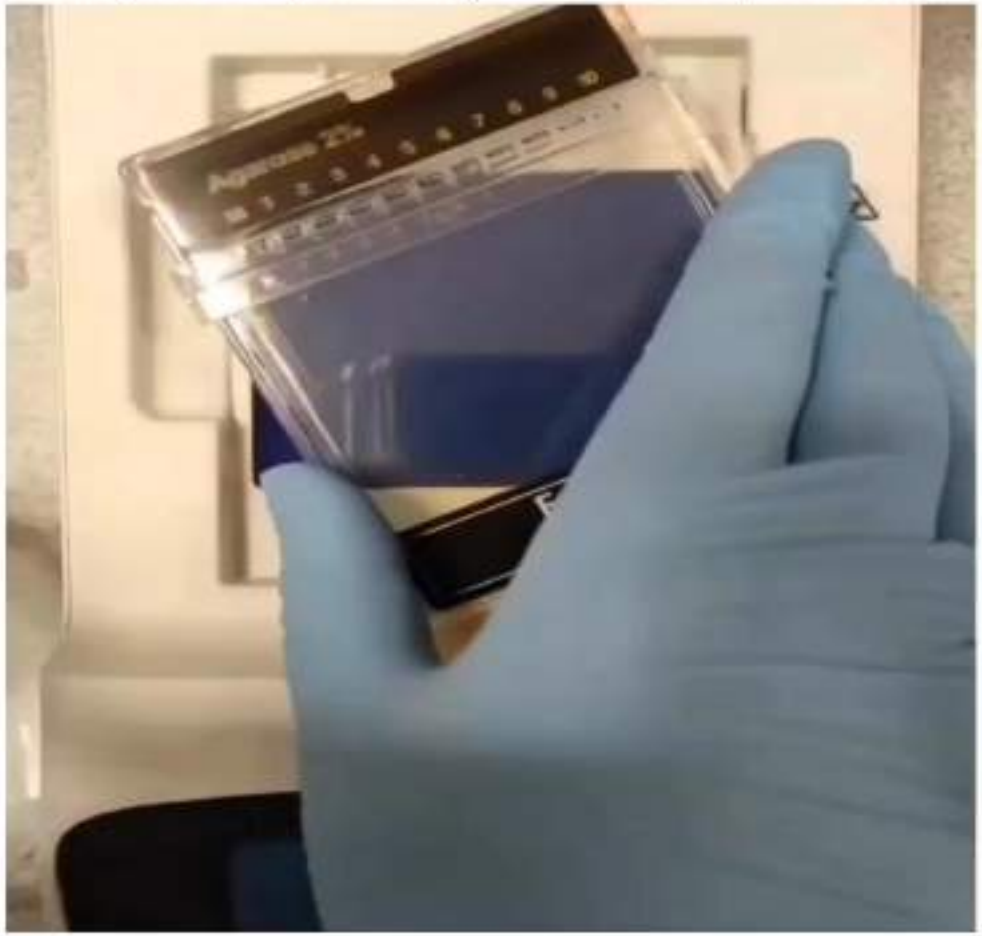




REKAYASA GENETIKA

Confirmation of insertion DNA

Fancy E-Gel electrophoresis system. Watch the DNA pieces separate by size in an elapsed 7 min.



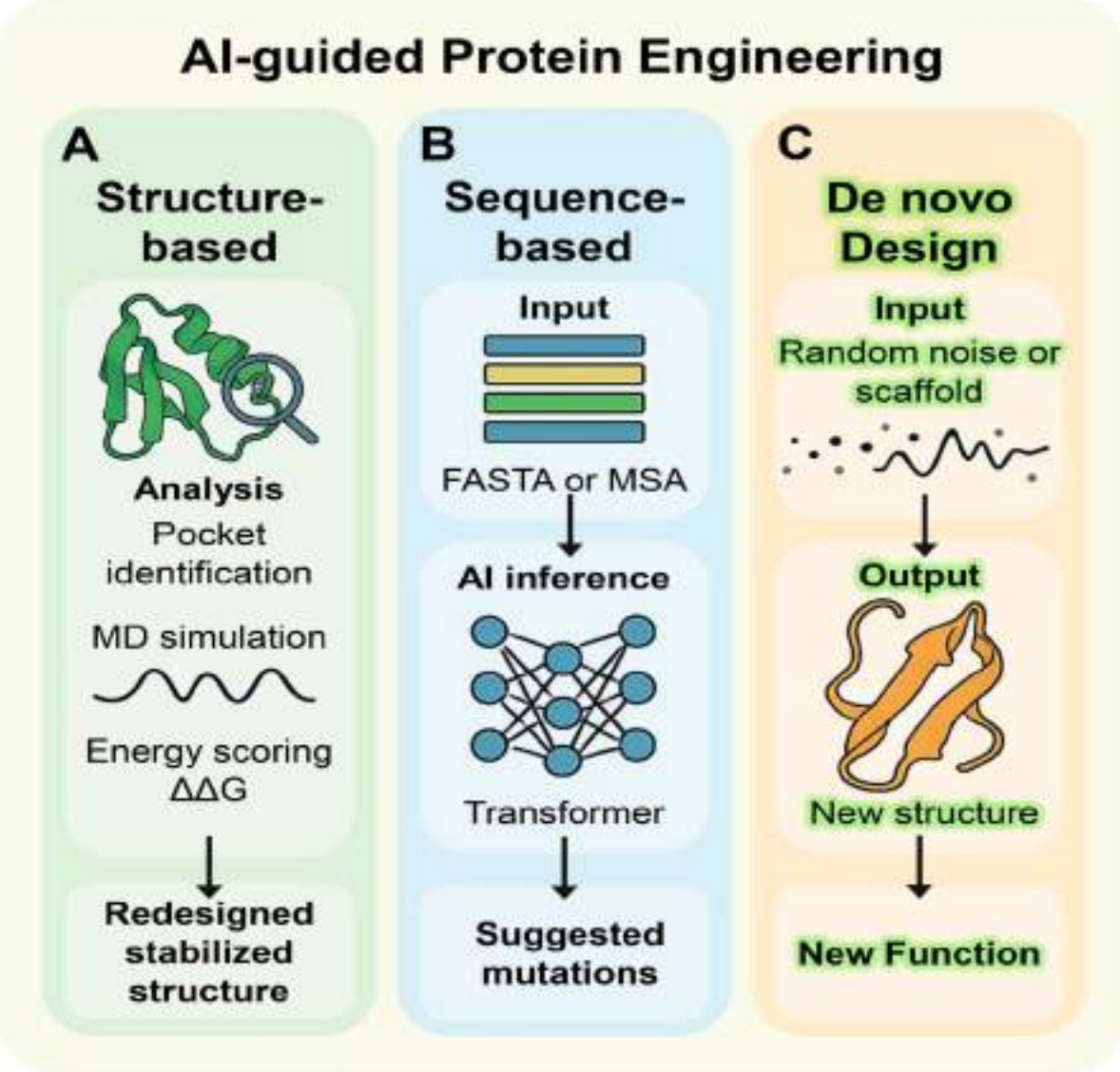
https://www.instagram.com/reel/CsNnFbjIOrD/?igshid=MzRlODBiNWFlZA==
https://www.instagram.com/reel/CvdyD1MISrc/?igshid=MzRlODBiNWFlZA==

PROSES DAN TEKNIK

REKAYASA PROTEIN

Protein engineering is the **direct modification of an amino acid sequence** or its coding genes to increase stability, activity, or specificity.

Approach	Principle	Example
Site-directed mutagenesis	Changing specific amino acids to alter protein properties	Enzyme with increased heat stability
Directed evolution	Mimicking natural selection: random mutation + selection of the best variants	Industrial enzyme with high activity
Fusion protein / chimera	Combining two different protein domains	Enzyme-labeled antibody (ELISA)
De novo design	Designing a new protein from scratch with the help of AI	Synthetic protein for new drug development



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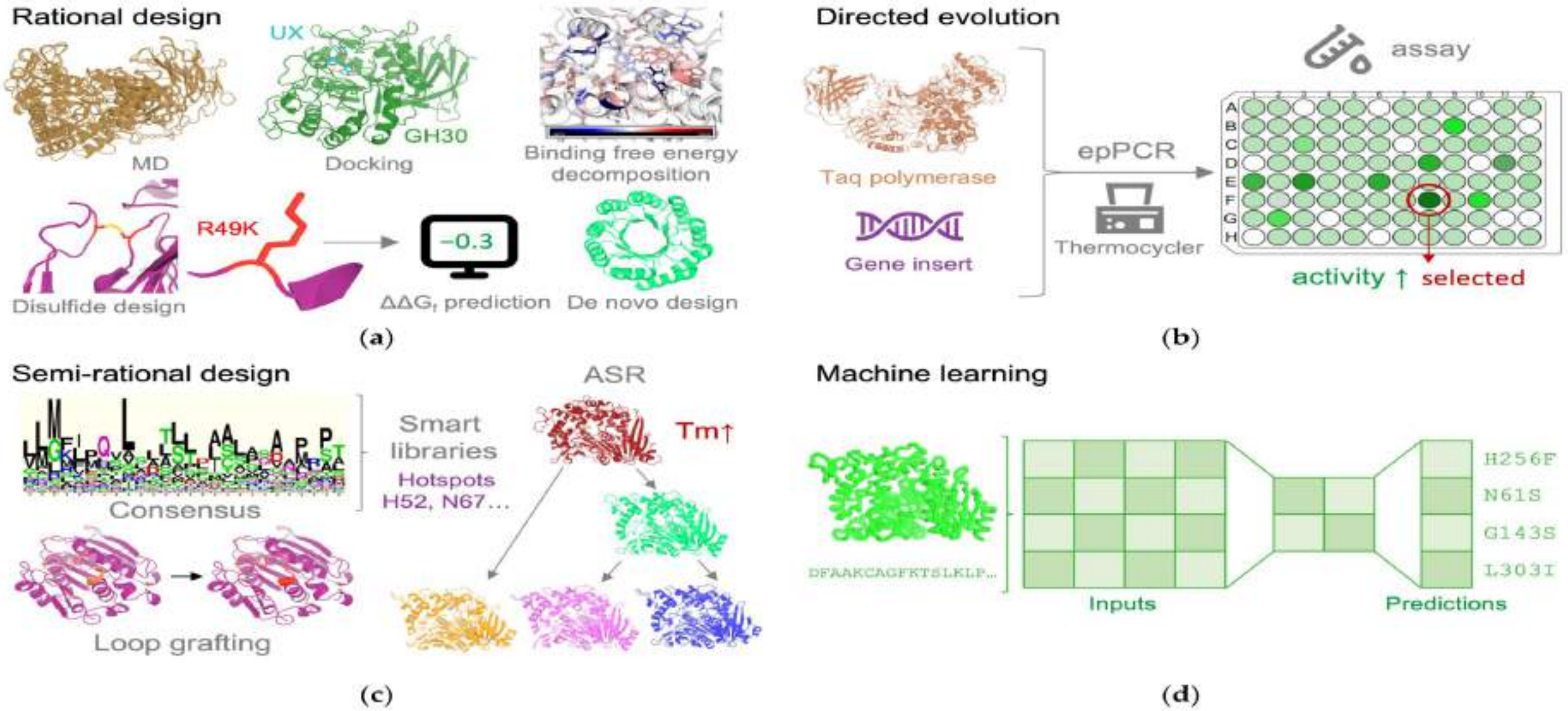
REKAYASA PROTEIN



https://doi.org/10.3390/catal15020147

APLIKASI

REKAYASA GENETIKA

Rekayasa genetika memiliki nilai industri dan pertanian yang besar. Teknik ini dipraktekkan dalam kedokteran, penelitian genetik, pertanian, perbaikan tanaman, dan untuk produksi obat terapeutik

Genetic Engineering

Pros

- Fighting diseases
- Increase in life expectancy
- Increased variety of foods and drinks
- Nutritious food
- Decrease in the use of pesticides
- Medical foods
- Decrease in the use of resources
- Increase in growth rates of animals and plants
- Development of specific characteristics

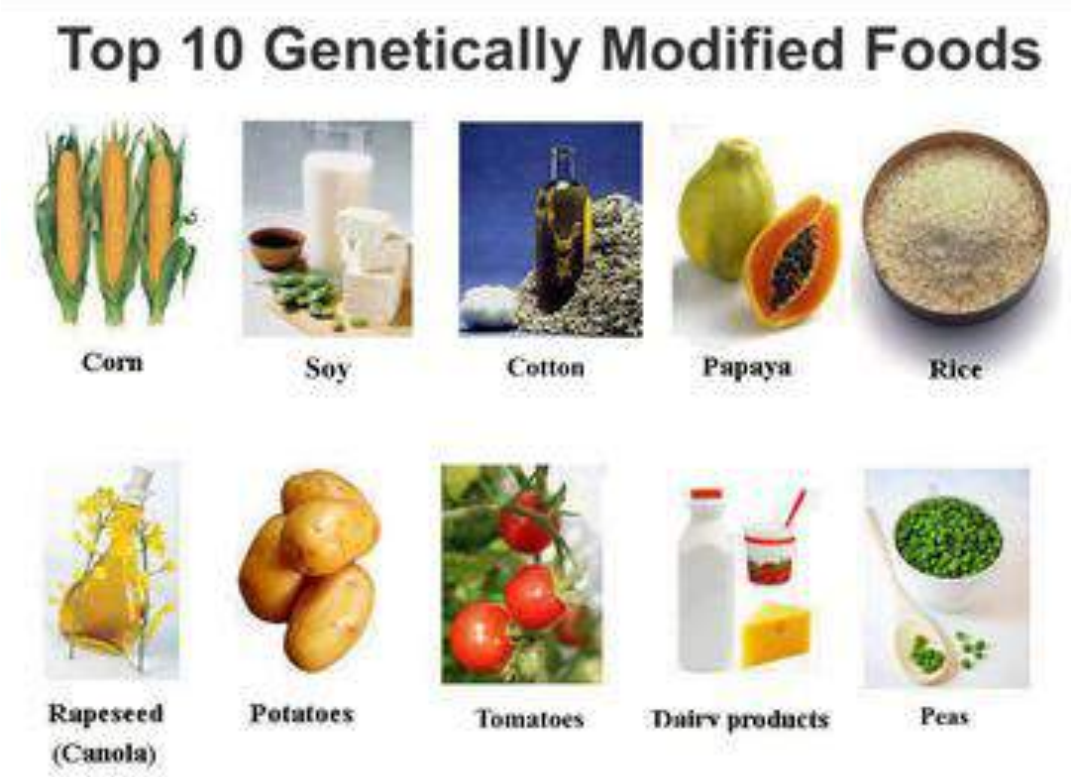
Cons

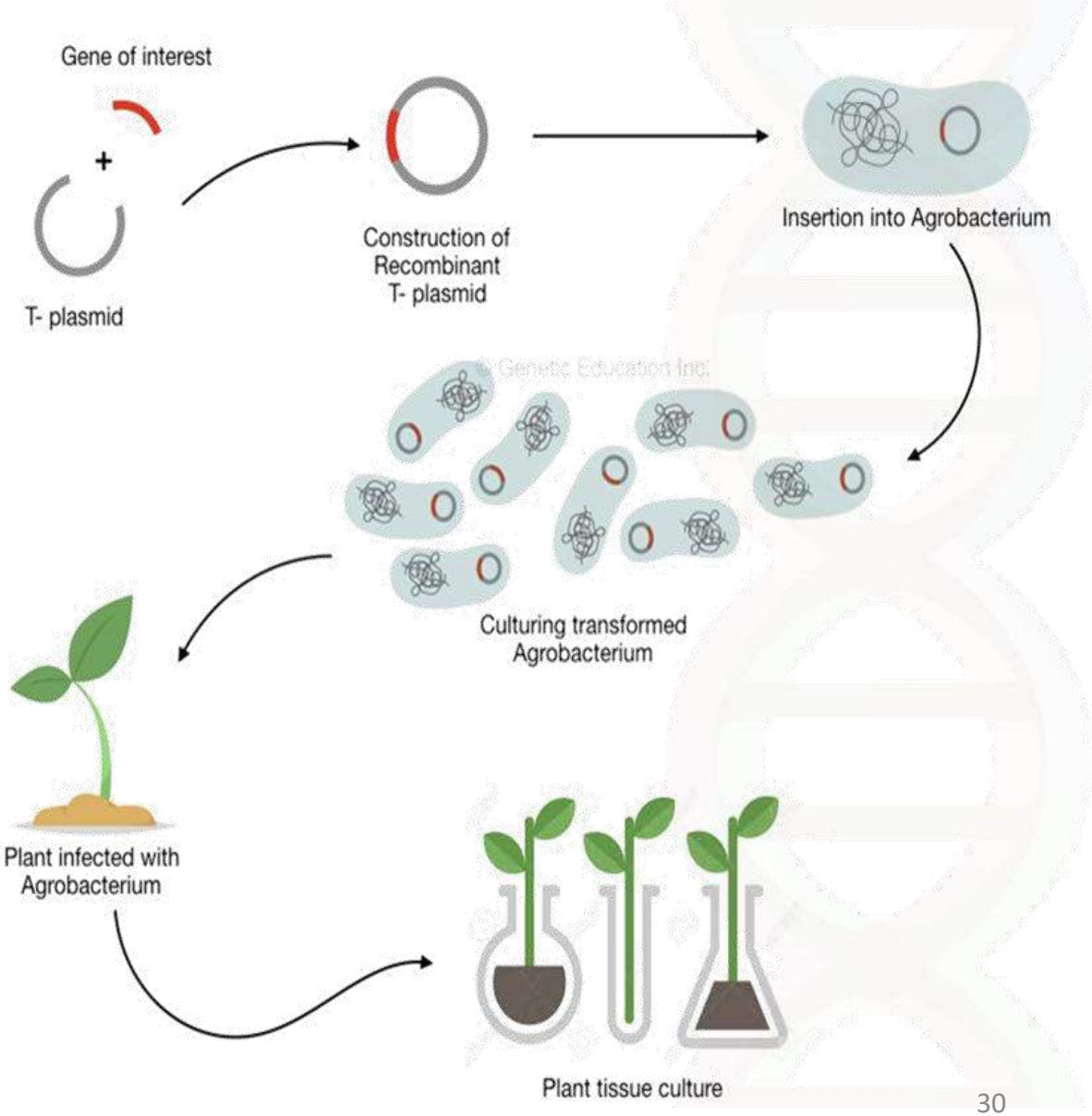
- Religious and ethic concerns
- Genetic issues
- Health issues
- Allergies
- Resistant insects and pests
- Antibiotic resistance
- Reduction in genetic variety
- Effects on wildlife
- Soil pollution
- Displacement of natural species
- Influence of certain industries and interest groups

APLIKASI

REKAYASA GENETIKA

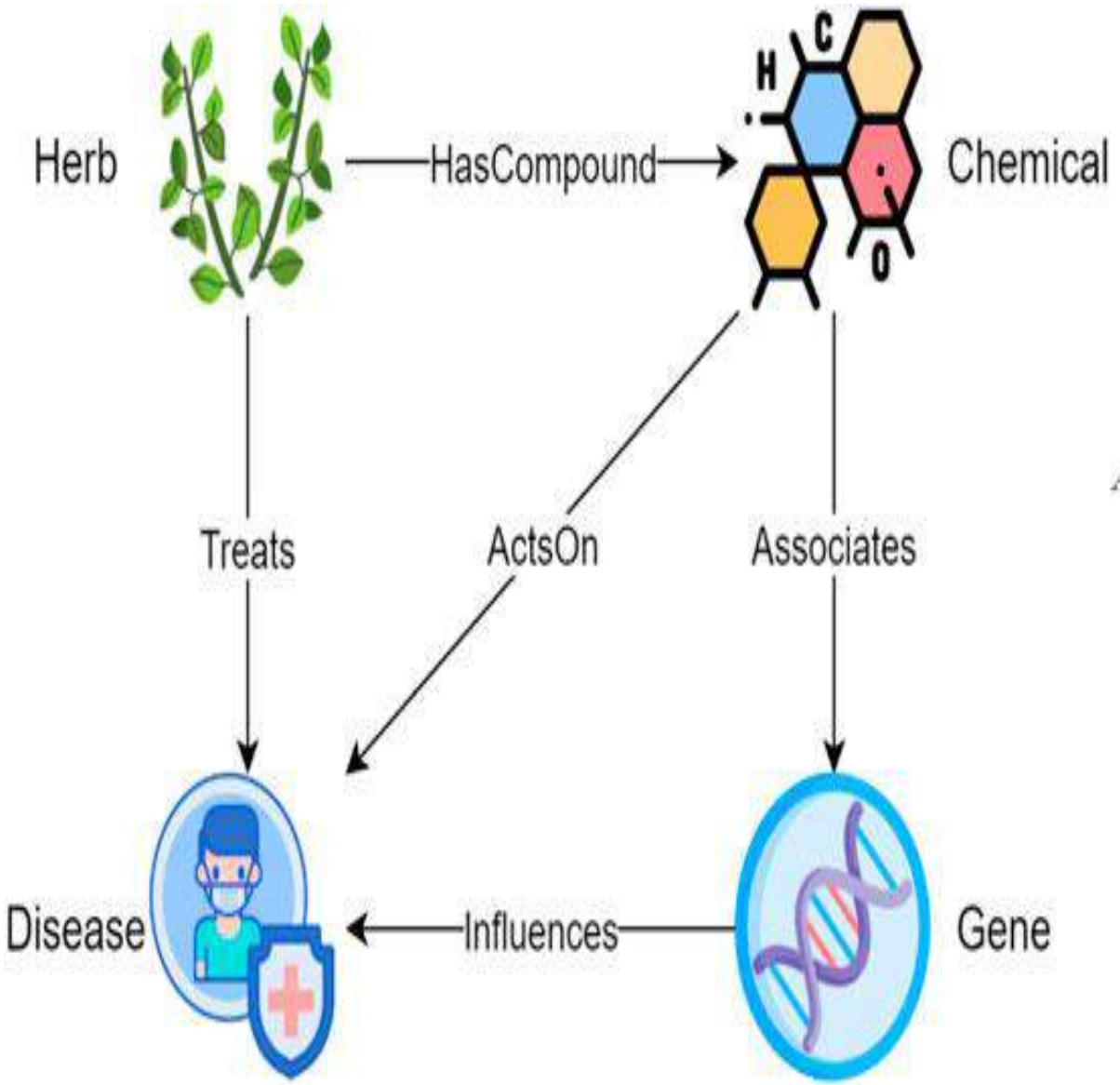
Genetic engineering, including gene editing, can have numerous benefits: faster and more precise breeding, higher crop yields, development of more nutritious food, and decreased need for herbicides and pesticides

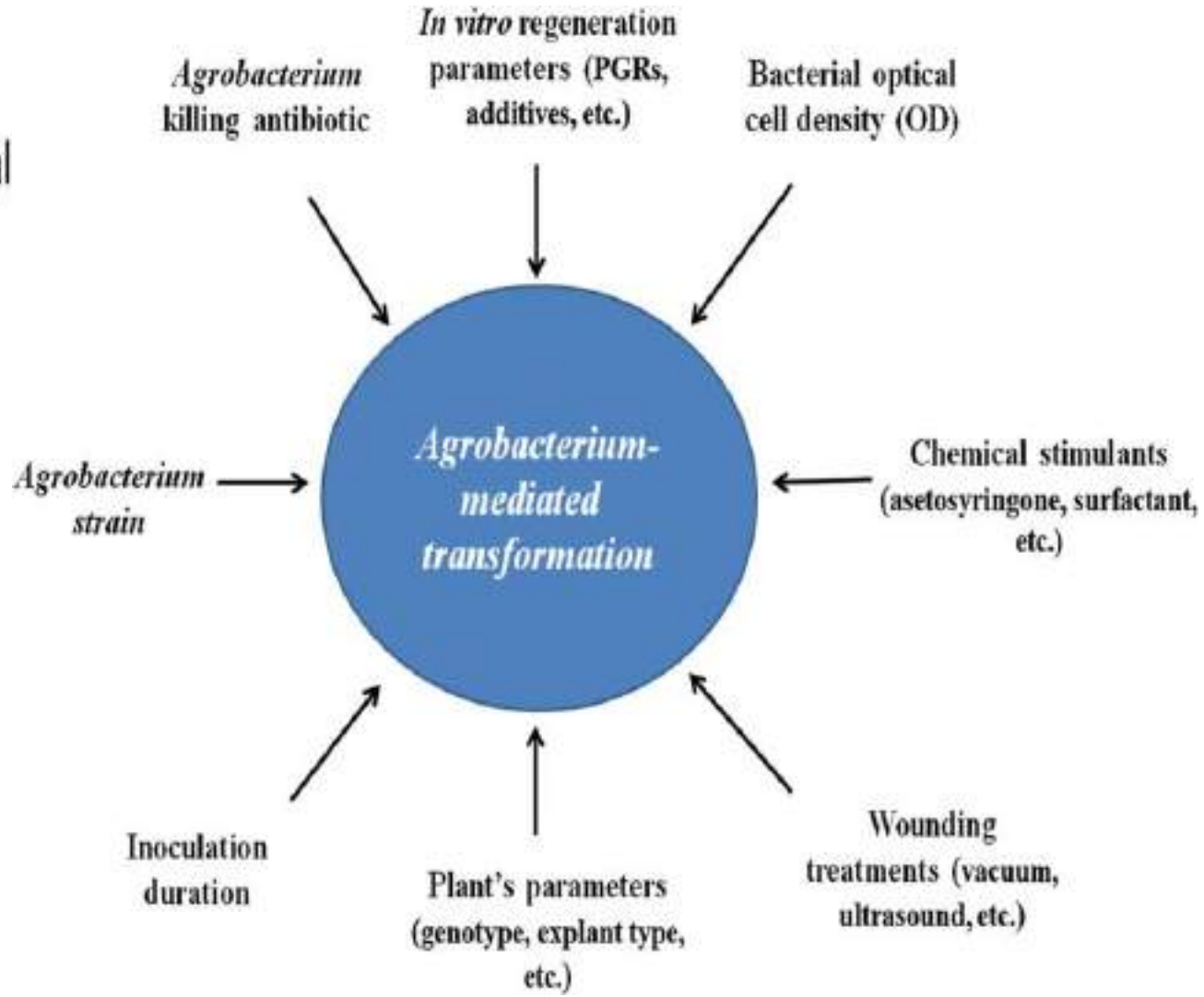




APLIKASI

REKAYASA GENETIKA



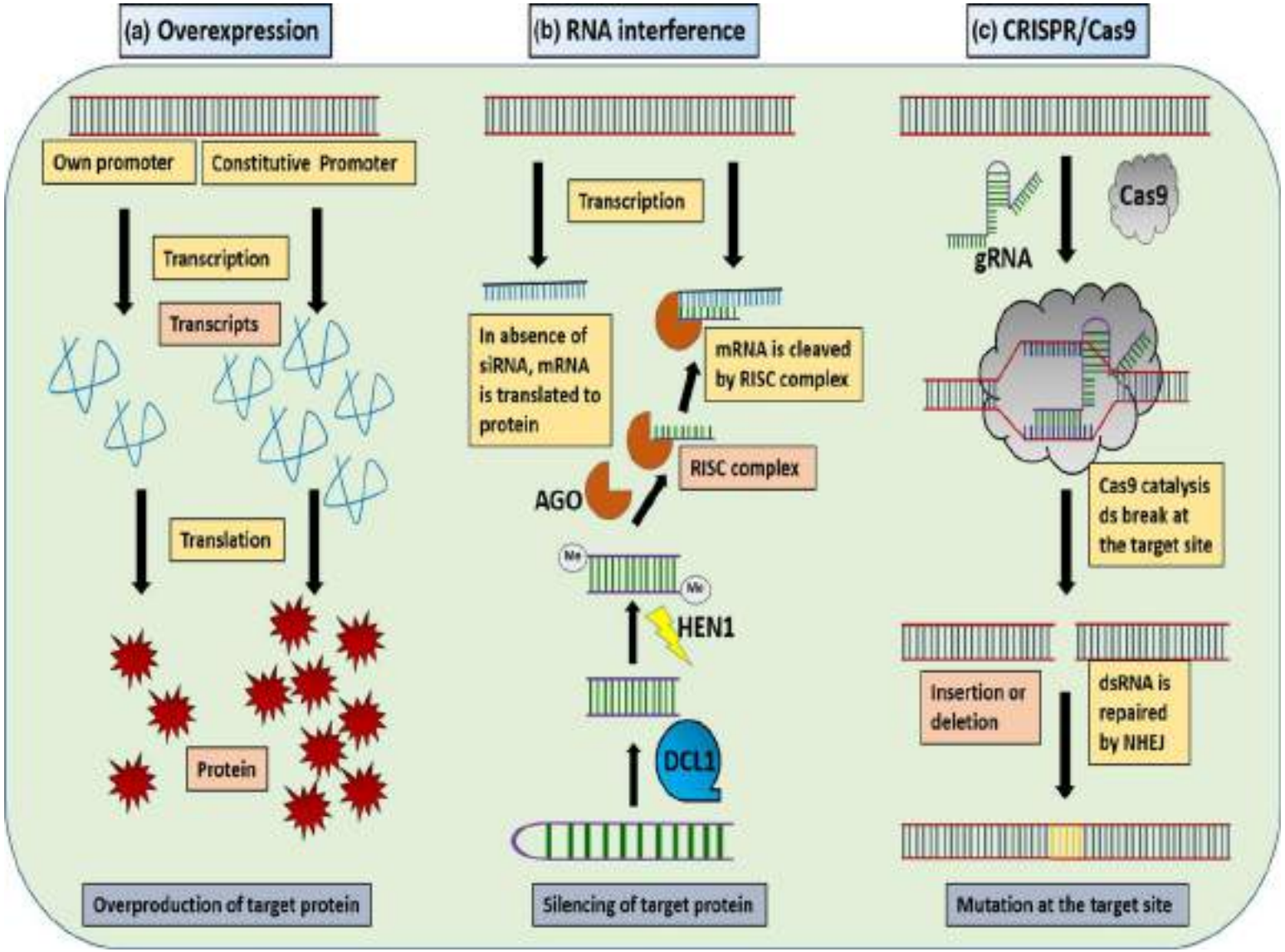


APLIKASI

REKAYASA GENETIKA

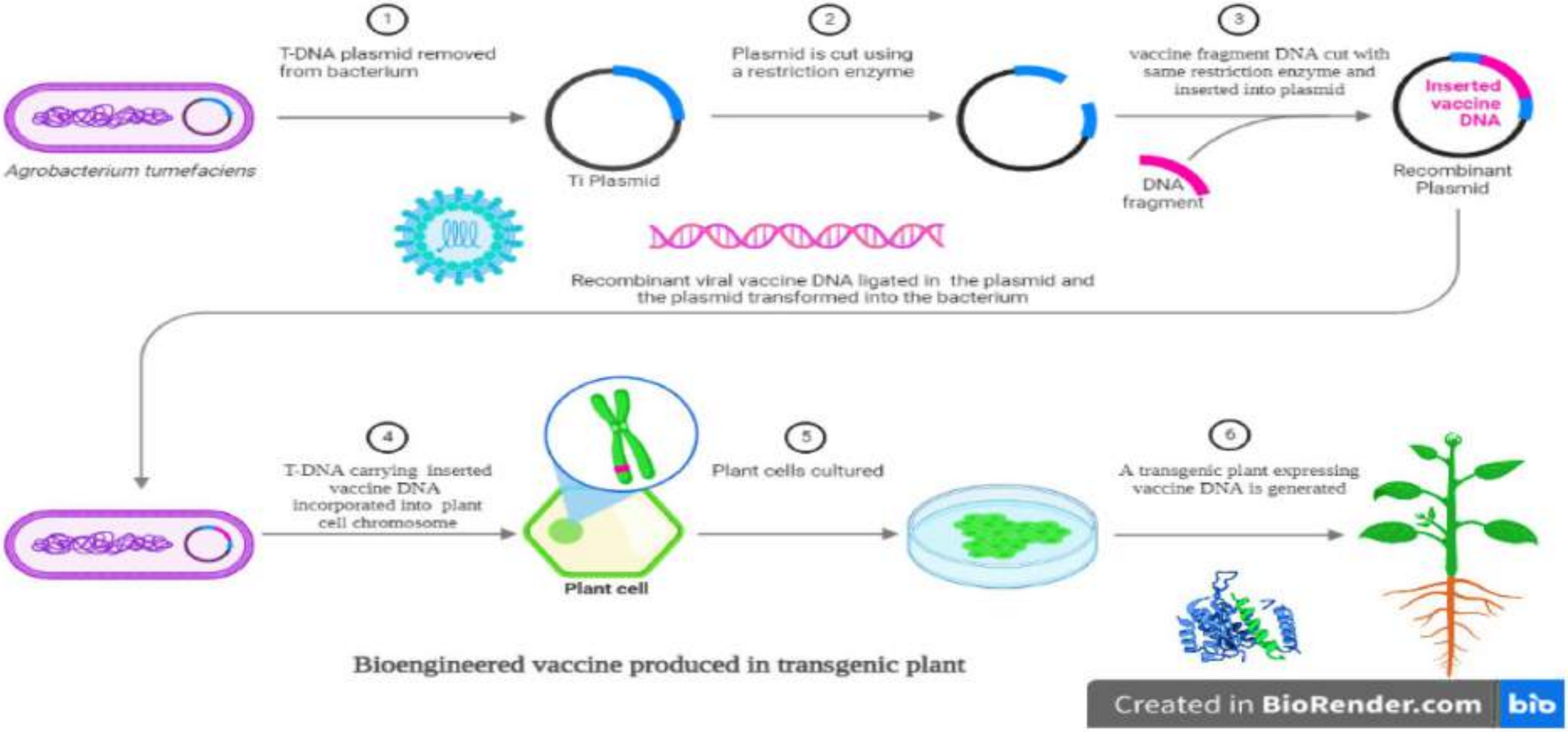
Strategies for crop improvement through biotechnological approaches.

- Overexpression leads to greater transcription of target gene which can be translated into protein
- RNA interference leads to downregulation of target gene;
- **Gene editing through CRISPR/Cas9** leads to insertions or deletions at target site which gives rise to mutations



APLIKASI

REKAYASA GENETIKA

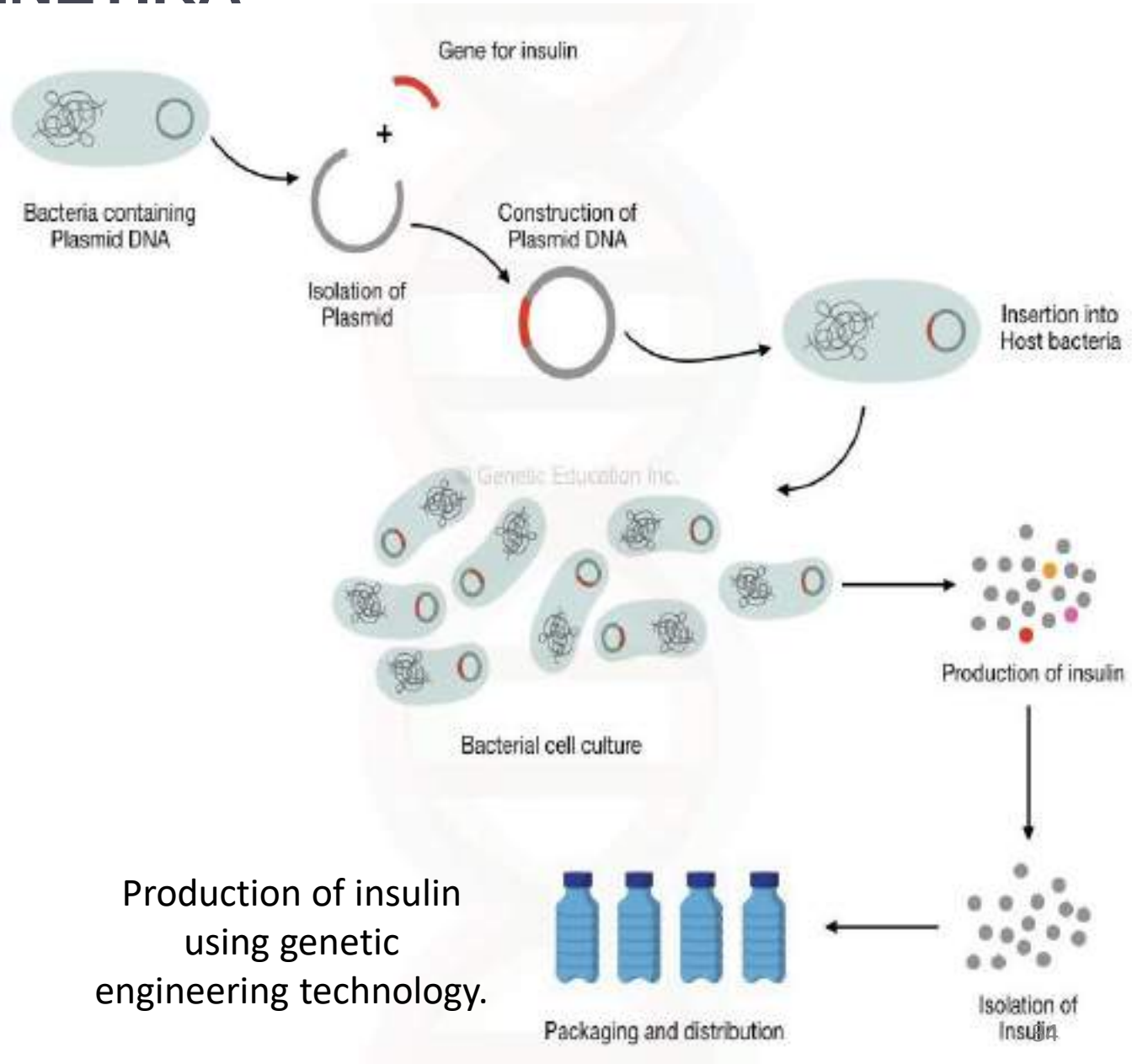


Bioengineered vaccine produced in transgenic plant

APLIKASI

REKAYASA GENETIKA

- Low-cost drugs, hormones, enzymes, and vaccines are created using genetic engineering tools
- A gene for insulin is isolated by restriction digestion or through PCR and inserted int the plasmid. The recombinant plasmid DNA is immediately inserted into the bacterial or yeast cell in which the plasmid is multiplying. As the microorganism starts dividing it starts making artificial insulin.



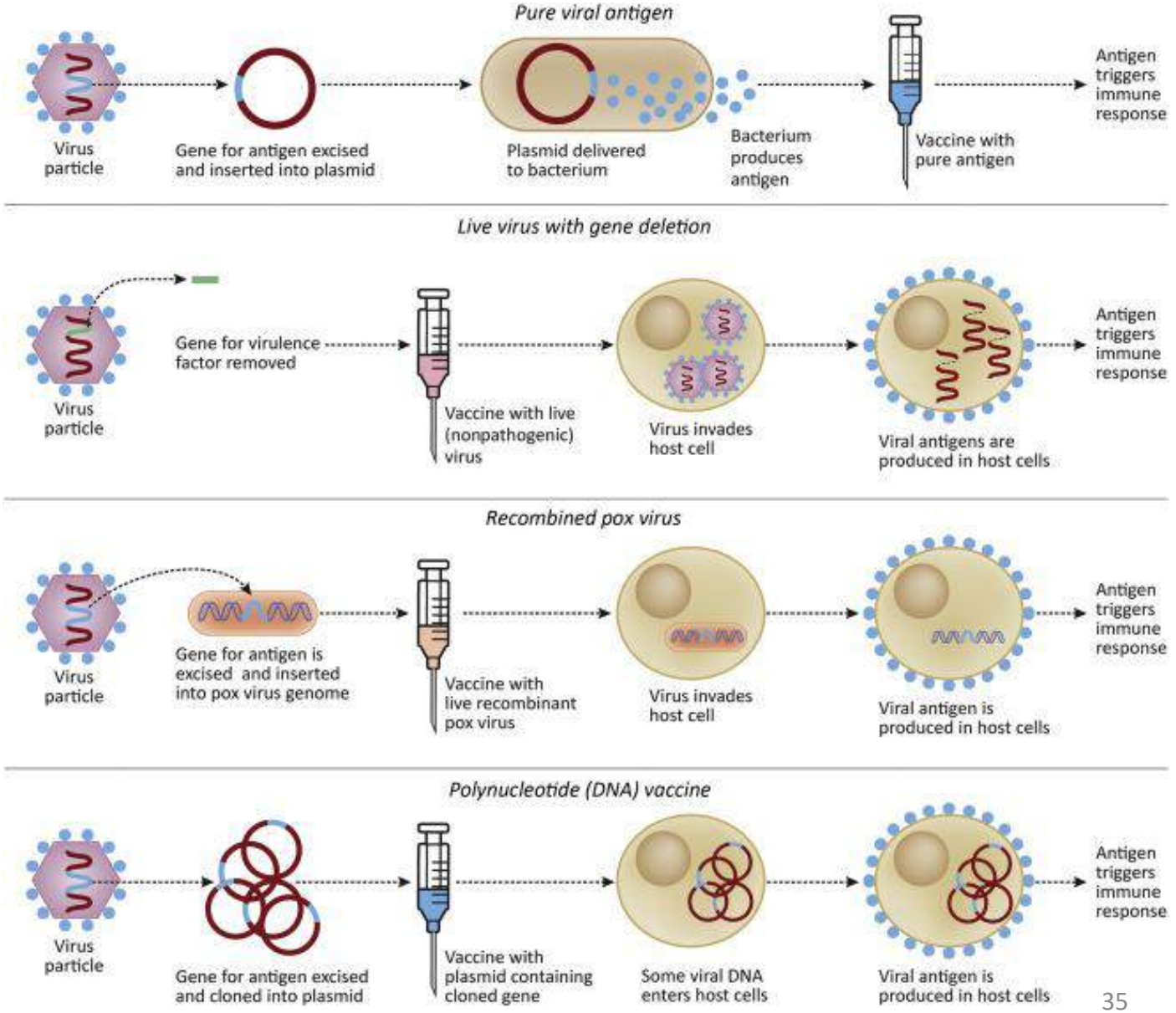
Production of insulin using genetic engineering technology.

APLIKASI

REKAYASA GENETIKA

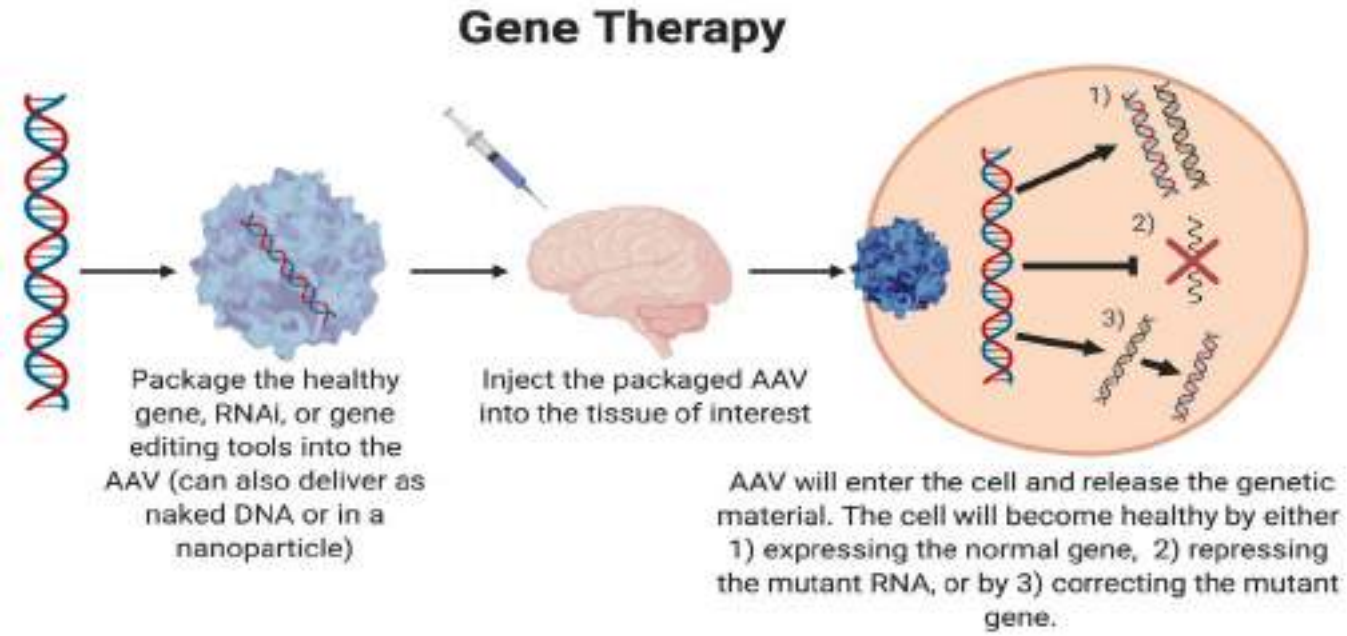
Recombinant vaccines

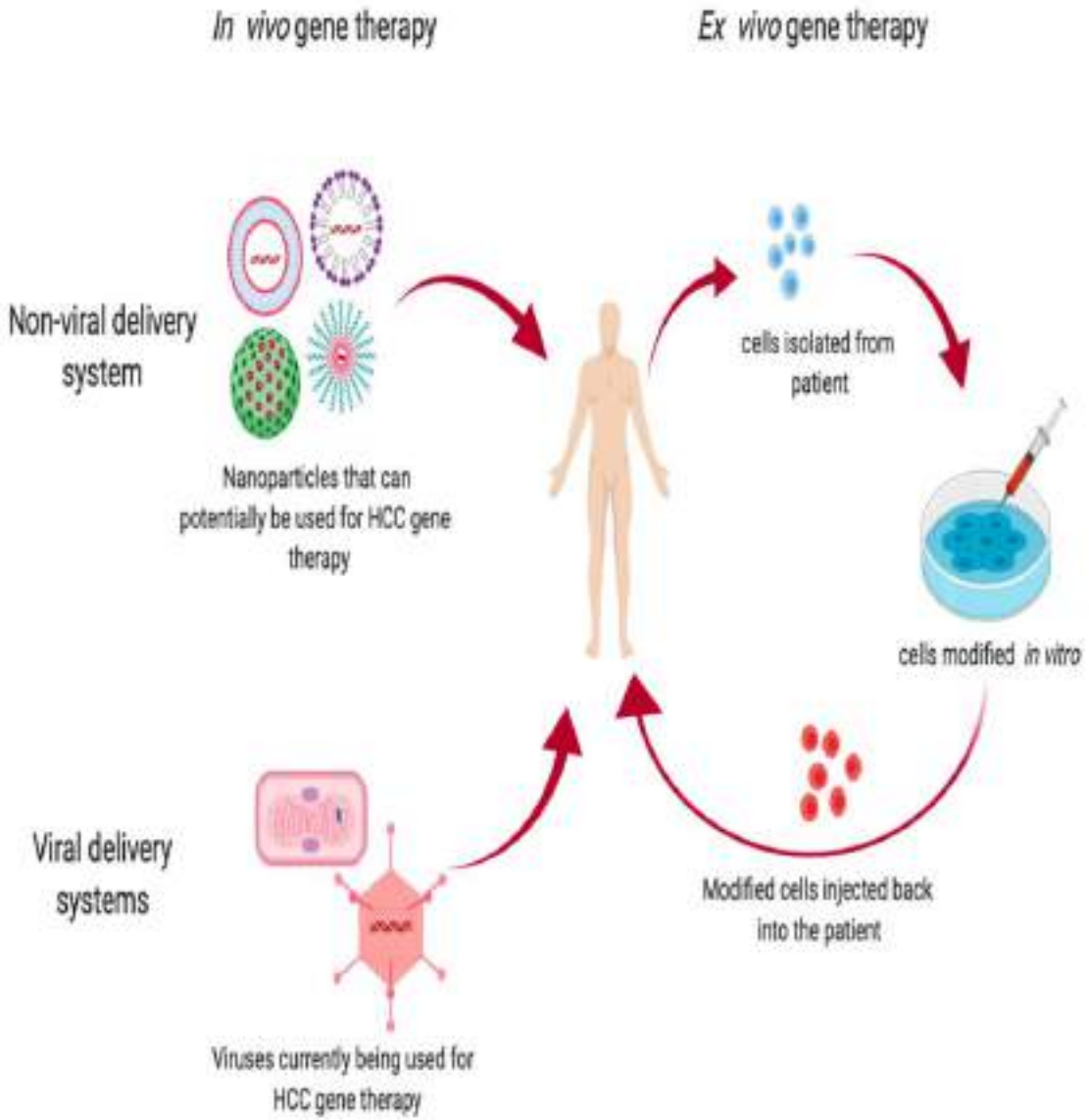
- Vaccines against smallpox, herpes simplex virus and hepatitis are produced using the genetic engineering technique. The vaccines are the inactivated viral particles used to induce an immune response against that pathogen, however, the chance of contamination is high in it.
- Using the recombinant DNA technology scientists has created a unique type of vaccines that only contains the DNA for viral coat protein thus the pathogen can never be activated again. The main advantage of it is that it is safer, contamination-free and more reactive



APLIKASI

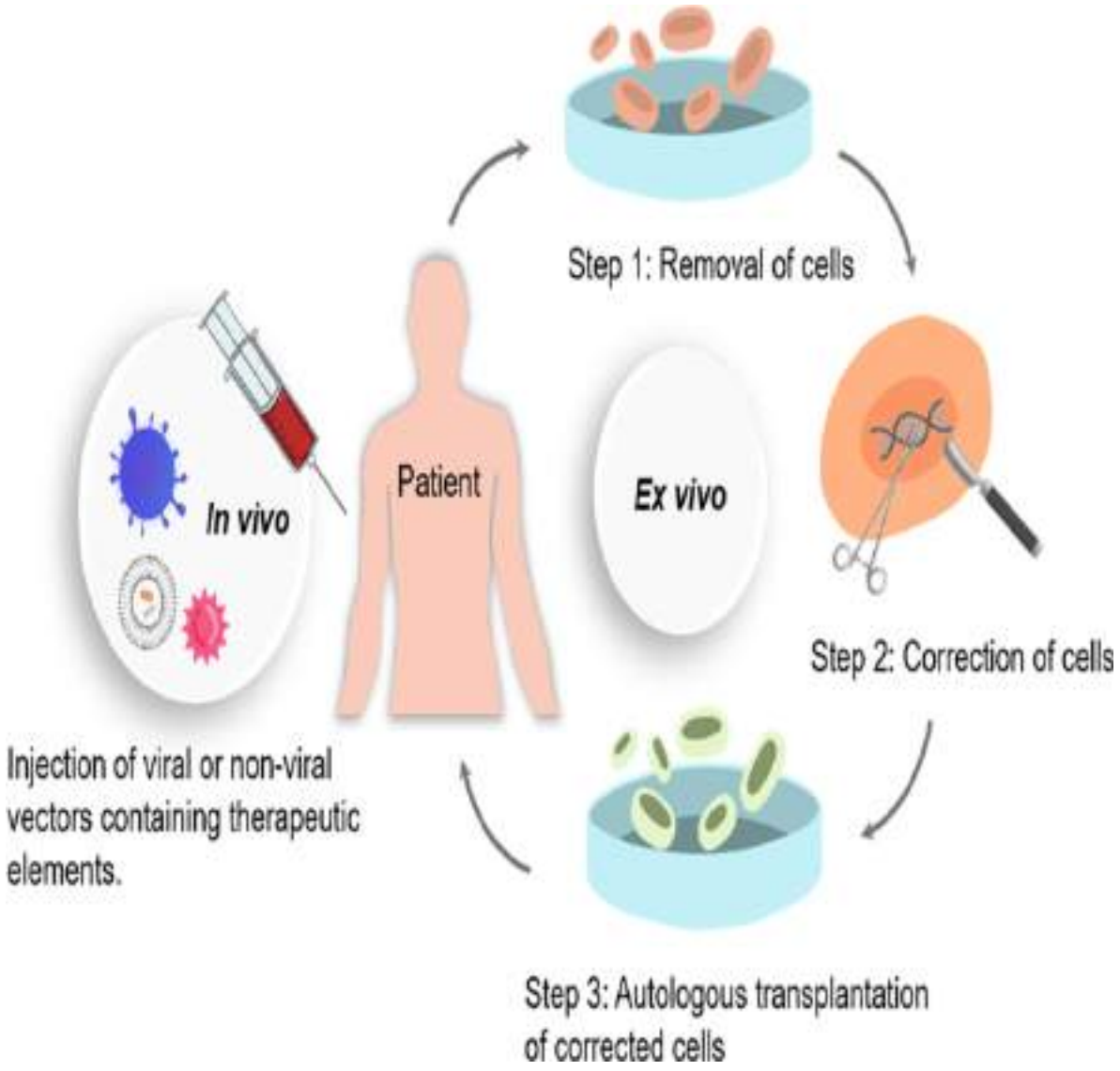
REKAYASA GENETIKA





- Using the gene therapy or gene transfer technique, inherited genetic disorders can be cured. In the gene therapy, a faulty, non-function or mutated gene is replaced with the wild type one.
- Cystic fibrosis, Duchenne muscular dystrophy and sickle cell anemia like gene therapies are now under the final clinical trial phase and ready to use on patients.

REKAYASA GENETIKA



Ex vivo and in vivo genome editing for clinical therapy

- **Right**: For in ex vivo editing therapy, cells are isolated from a patient to be treated, edited and then re-engrafted back to the patient. To achieve therapeutic success, the target cells must be able to survive in vitro and return to the target tissue after transplantation.
- **Left**: For in vivo editing therapy, engineered nucleases are delivered by viral or nonviral approaches and directly injected into the patient for systemic or targeted tissue (such as the eye, brain, or muscle) effect.

APLIKASI

REKAYASA GENETIKA

Transgenic Fish

- Scientists in Taiwan created luminous fish by incorporating jellyfish genes into the DNA of carp fish. This innovative approach aims to enhance the understanding of how pollutants affect the organs of fish.

REKAYASA GENETIKA

genetic engineering

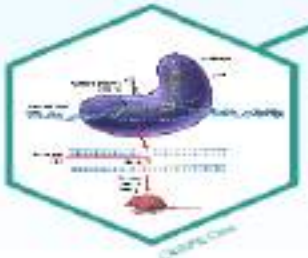
new horizons in medicine

Since genetic engineering (also known as **recombinant DNA technology** or **genetic modification**) was first developed in the 1970s, scientists have discovered more and more ways in which the technology can be used in human medicine. Now techniques, including the gene editing tool known as CRISPR-Cas9, are opening up even more possibilities for us to change the DNA in the cells of bacteria, animals and plants – and potentially change medicine for ever.

Pharming

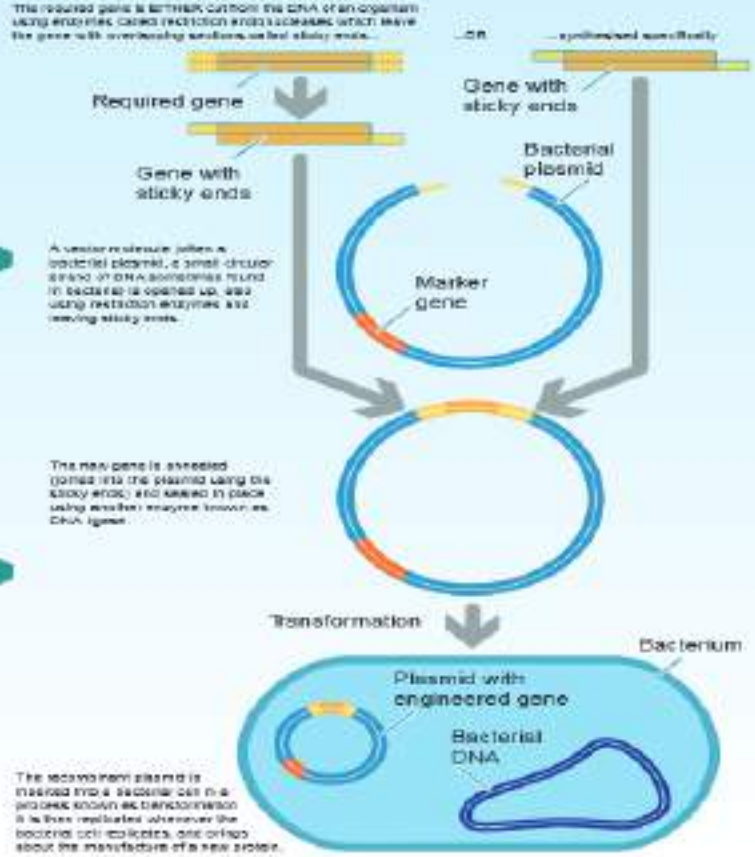
Microorganisms, animals and plants can be genetically modified to produce medically useful products. These transgenic organisms are already used regularly to produce substances such as human insulin, human growth hormone and blood clotting factors for haemophiliacs.

CRISPR-Cas9 technology

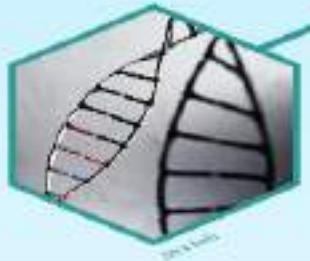


CRISPR-Cas9 is a genome editing tool which is changing the world of genetic engineering fast. It enables scientists to directly remove, add or change sections of the DNA sequence in a living cell. CRISPR-Cas9 is much faster, much cheaper and much more accurate than the traditional ways of editing DNA. Scientists think it has great potential for treating any diseases which involve the genome, including cancers, heart disease and even the high cholesterol levels which are a risk factor for heart disease.

The basic steps in traditional genetic engineering of a bacterium



Gene therapy



Gene therapy is still in its very early stages. It involves modifying human DNA either to repair or replace a faulty gene. The idea of gene therapy is to overcome the effects of a mutation which cause a genetic disease or tendency to a disease. Progress so far has been relatively slow, although there are early signs of success in treating some childhood leukaemias, HIV/AIDS and muscular dystrophy. The speed and precision of CRISPR-Cas9 gene editing technology gives scientists hope for the future.

Vaccines

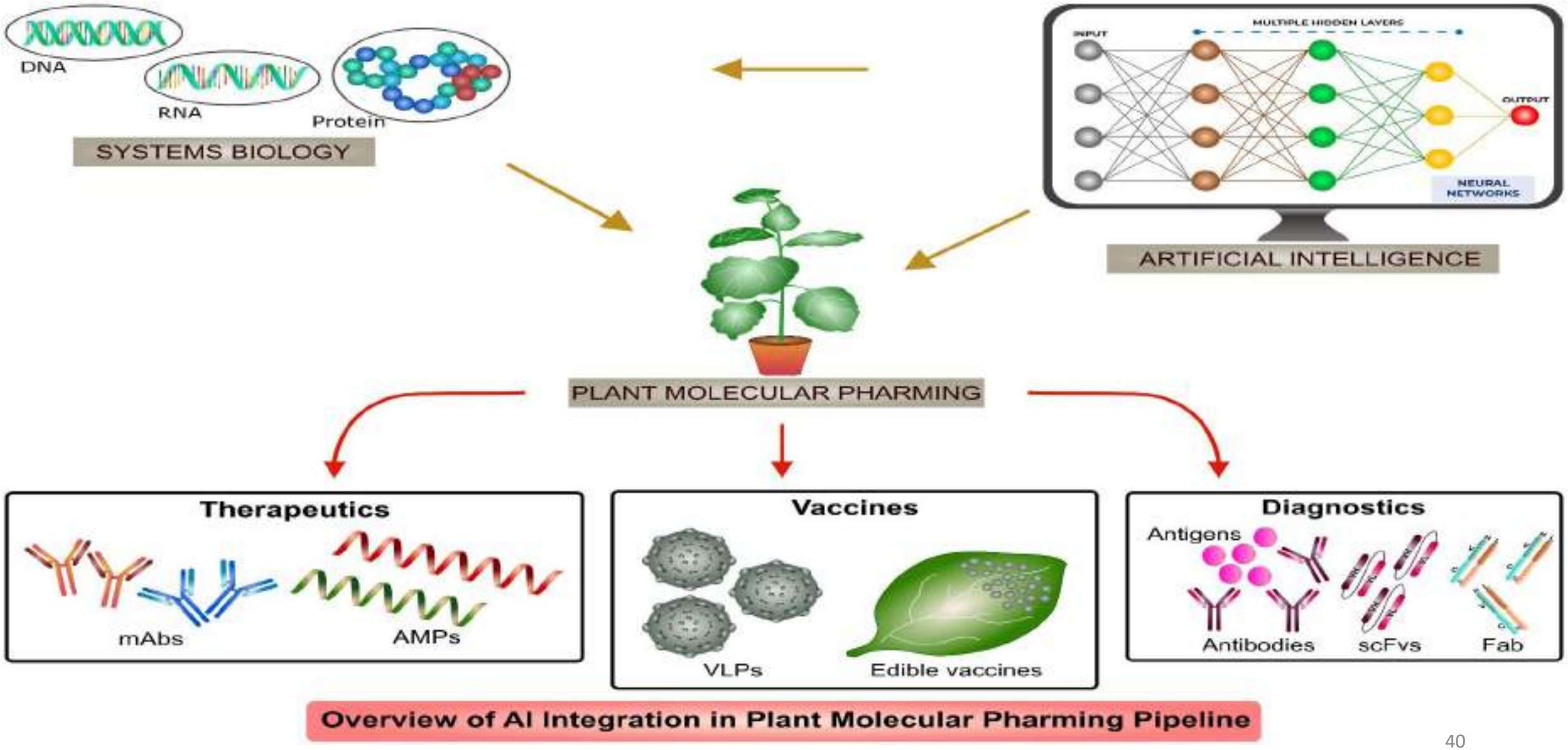
Some vaccines are very dangerous to make using conventional methods. Genetically engineered microbes can be used to produce the antigens needed in a safe and controllable way. The use of genetically modified yeast cells to produce a vaccine against the hepatitis B virus has been a major success story.

Xenotransplantation

The DNA of pigs has been modified using recombinant DNA technology so their cells develop without certain genes which trigger the human immune response. Other genes can be added which express human antigens. Work in this area has been slow, partly due to ethical and safety concerns, but interest is growing. Recent successes include German scientists using CRISPR-Cas9 to deliver multiple gene modifications in pigs, greatly reducing the human immune response to the pig cells.

APLIKASI

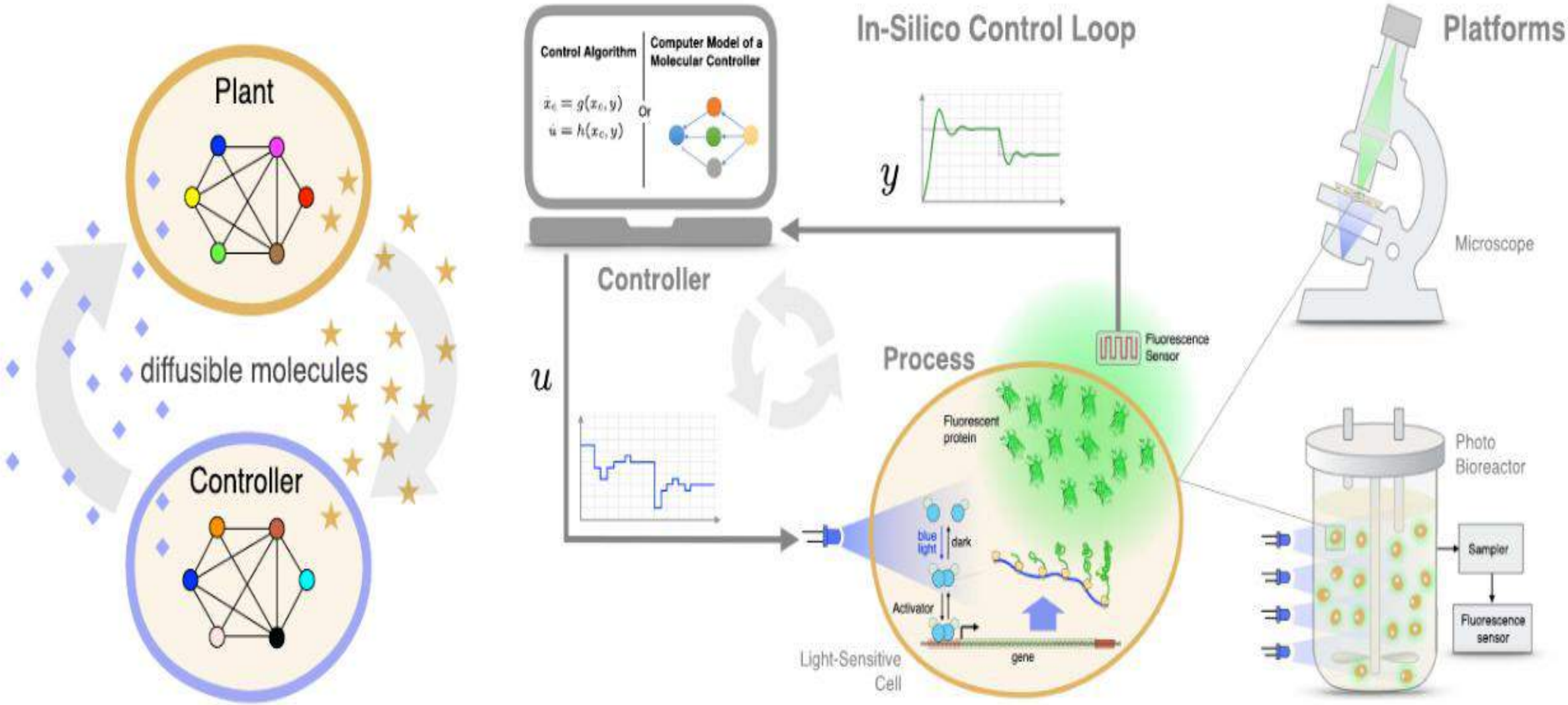
REKAYASA GENETIKA



Overview of AI Integration in Plant Molecular Pharming Pipeline

APLIKASI

REKAYASA GENETIKA

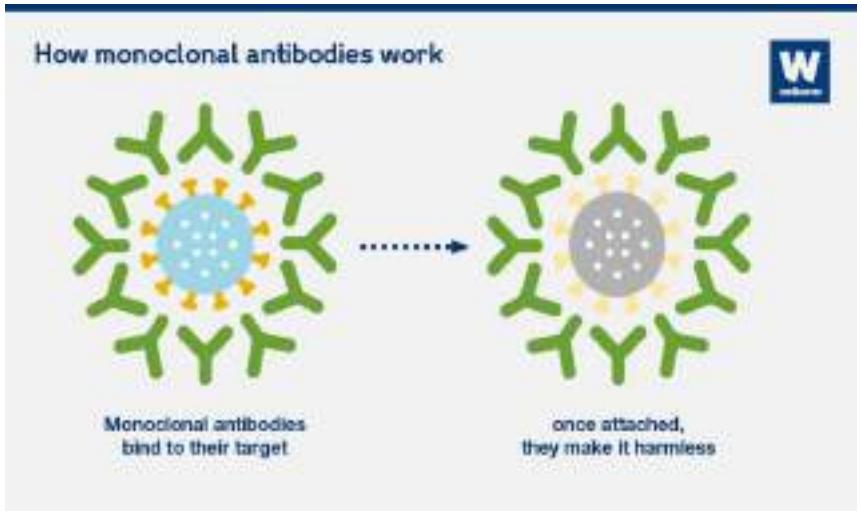


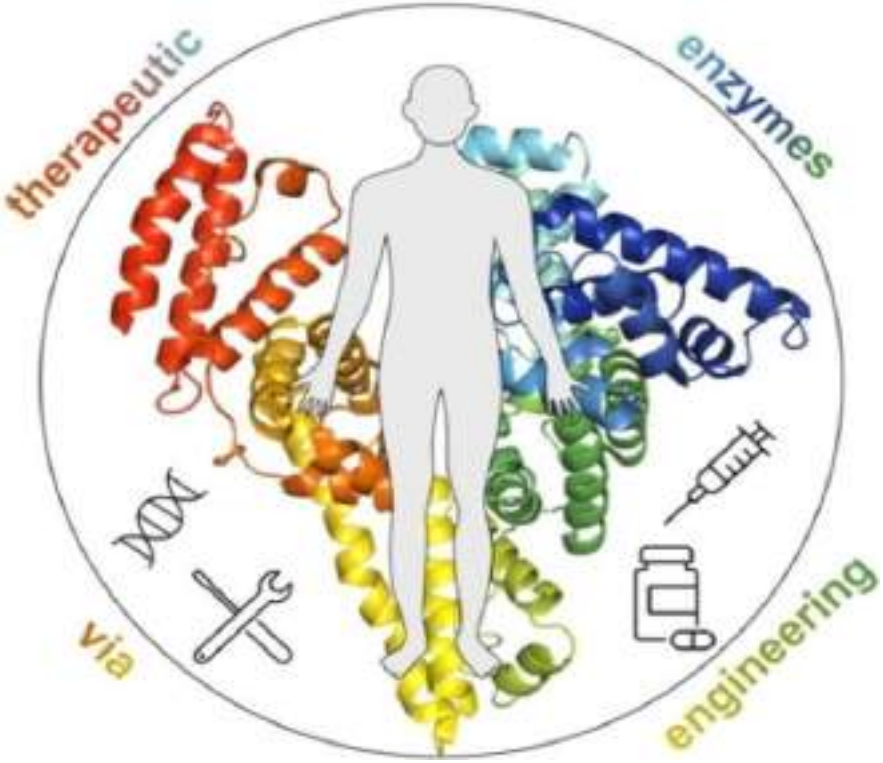
Computer control of living cells

APLIKASI

REKAYASA PROTEIN

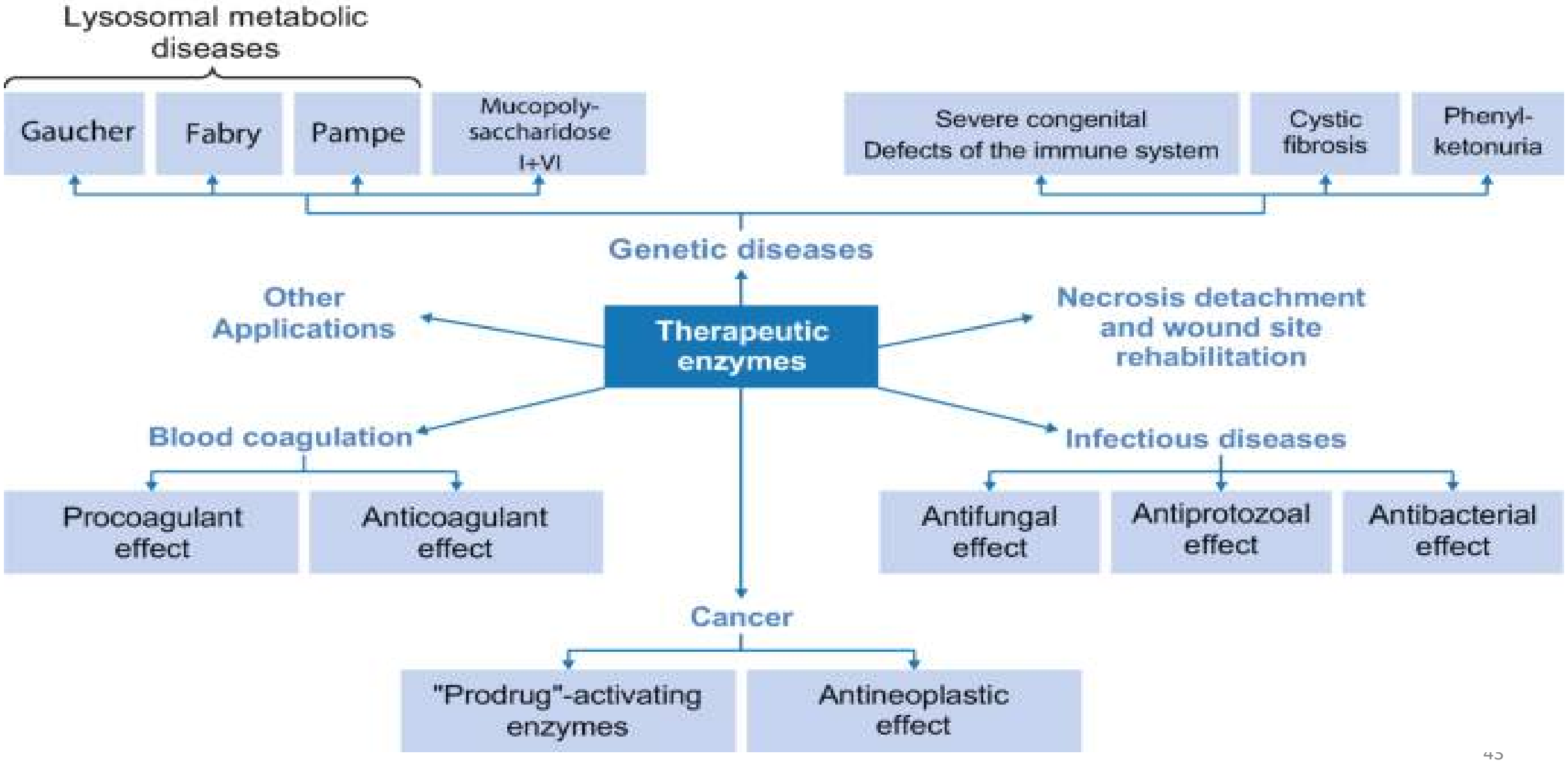
Field	Example of Application	Description
Recombinant Protein Drug Production	Insulin, growth hormone, interferon, clotting factors	Proteins are modified to enhance stability and biological activity
Antibody Therapy	Monoclonal antibodies, humanized antibodies, bispecific antibodies	Designed to specifically target tumors or viruses
Recombinant & Subunit Vaccines	HPV vaccine, hepatitis B vaccine, protein spike–based COVID-19 vaccine	Proteins are optimized to be more immunogenic
Therapeutic Enzymes	tPA, asparaginase, DNase	Used in the treatment of genetic disorders or cancer
Therapeutic Peptides	Structural modification to prolong half-life	Example: GLP-1 analog (semaglutide) for diabetes





APLIKASI

REKAYASA PROTEIN



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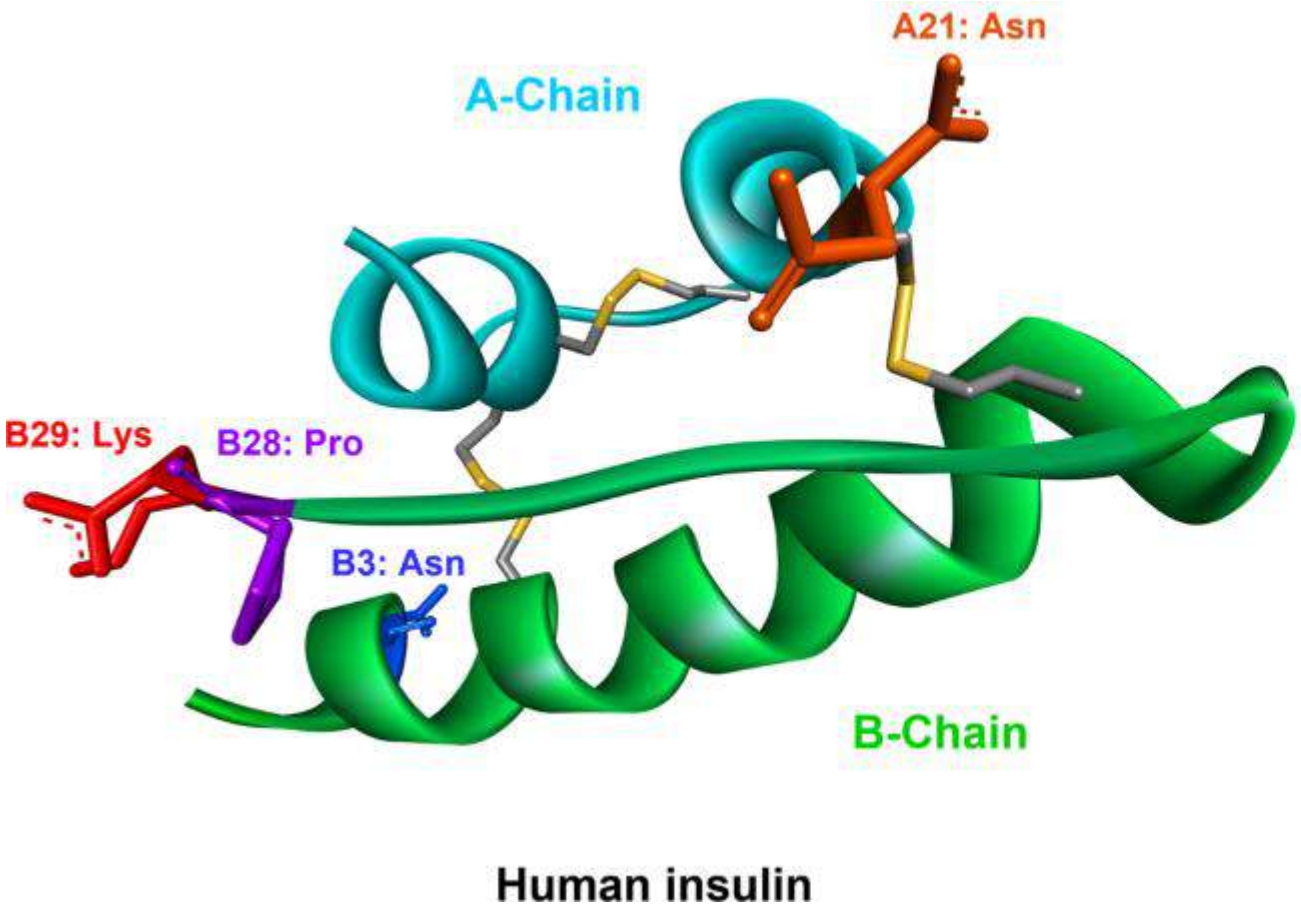
REKAYASA PROTEIN



Human insulin

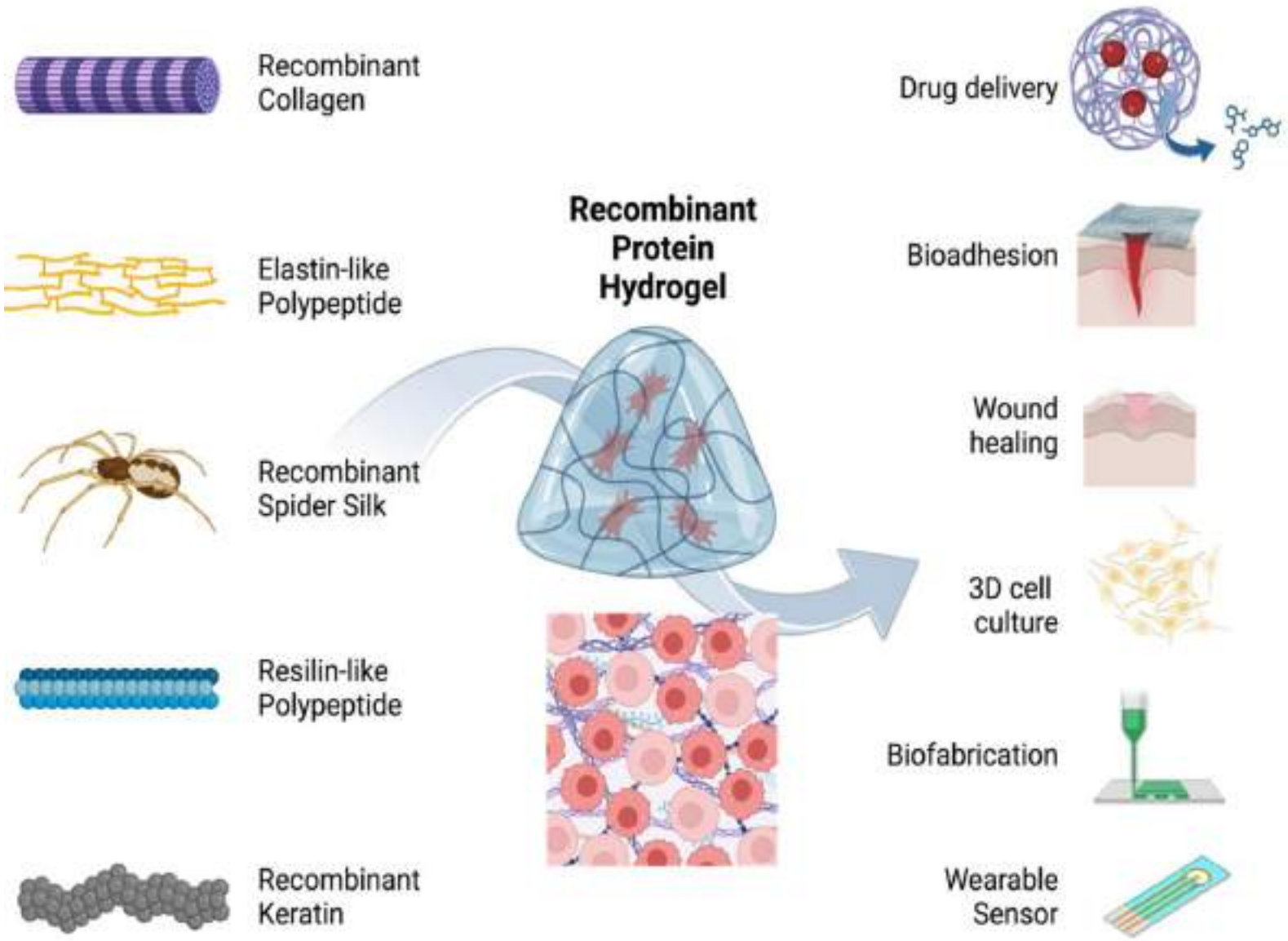
Insulin derived drugs		Sequence Modification
Short-acting insulin	Insulin lispro	B28: Lys B29: Pro
	Insulin aspart	B28: Asp
	Insulin glulisine	B3: Lys B29: Glu
Long-acting insulin	Insulin glargine	A21: Gly; addition of two Arg to the C-terminus of the B-chain(B31 and B32)
	Insulin detemir	B29: Lys linked with myristic acid
	Insulin degludec	B29: Lys linked with hexadecanedioic acid

Structure of human insulin and human insulin-derived drugs. Structure of human insulin (left, PDB: 1XDA). Modifications on its residues (B-Chain: B3: Asn, B28: Pro, B29: Lys; A-Chain: A21: Asn) resulted in several short- and long-acting insulin drugs (right, see table)

https://doi.org/10.1038/s41392-022-00904-4

APLIKASI

REKAYASA PROTEIN



The applications of microbially produced protein hydrogels. Recombinant or engineered collagen, elastin-like polypeptide, spider silk protein, resilin-like polypeptide, and keratin have been engineered to create hydrogels that were used for bioadhesion, drug delivery, wound healing, 3D cell culture, biofabrication, and wearable sensors.

https://doi.org/10.3390/molecules28134988

Video Pembelajaran

REKAYASA GENETIKA

Genetic Engineering | Genetics | Biology | Don't Memorise

- https://youtu.be/4fBQ2umTaMA?t=55

Genetic Engineering Will Change Everything Forever – CRISPR

- https://www.youtube.com/watch?v=jAhjPd4uNFY

Bacteria transforming

- https://www.pbslearningmedia.org/resource/biot11.sci.life.gen.transbact/transforming-bacteria/

Referensi ;

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THANKS

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Pertemuan 7

apt. Trifonia Rosa Kurniasih, M.Biotech

TUGAS

CASE-BASED LEARNING (CBL)

Topik: ***Rekayasa Genetik dan Rekayasa Protein dalam Inovasi Terapi Modern***

Tujuan Pembelajaran (Learning Outcomes)

- Menjelaskan prinsip dasar **rekayasa genetik** dan **rekayasa protein**.
- Mengidentifikasi **pendekatan dan teknik** yang dapat digunakan dalam modifikasi gen/protein.
- Menganalisis **hubungan antara struktur dan fungsi protein**.
- Mengevaluasi **pertimbangan etis dan keamanan** dalam penerapan teknologi genetik pada manusia.
- Merancang **strategi penelitian** untuk menghasilkan protein terapeutik yang lebih stabil dan aktif.

TUGAS

CASE-BASED LEARNING (CBL)

Topik: *Rekayasa Genetik dan Rekayasa Protein dalam Inovasi Terapi Modern*

DESKRIPSI KASUS

→ Sebuah perusahaan bioteknologi, **GenNova Biotech**, sedang mengembangkan **protein terapeutik baru** untuk mengobati penyakit genetik *defisiensi enzim X* yang menyebabkan penumpukan senyawa toksik dalam tubuh. Protein alami *enzim X* tidak stabil pada suhu tubuh dan cepat terdegradasi sehingga efektivitas terapinya rendah.

→Tim peneliti mempertimbangkan dua pendekatan:

1. **Rekayasa genetik** pada sel mamalia agar mampu mengekspresikan enzim X dalam jumlah tinggi.
2. **Rekayasa protein** untuk meningkatkan stabilitas dan aktivitas enzim X tanpa mengubah fungsinya.

→ Namun, muncul dilema:

- ✓ Mutasi tertentu dapat meningkatkan stabilitas, tetapi menurunkan aktivitas katalitik.
- ✓ Penggunaan sistem ekspresi bakteri lebih cepat dan murah, tetapi protein hasilnya sering tidak berfungsi optimal karena salah lipat (misfolding).
- ✓ Ada pula pertimbangan etis dan regulasi dalam penggunaan teknologi rekayasa genetik untuk terapi manusia.

TUGAS

CASE-BASED LEARNING (CBL)

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Pertanyaan Pemicu Diskusi

1. Apa **perbedaan mendasar** antara rekayasa genetik dan rekayasa protein dalam konteks kasus ini?
2. Teknik **apa yang paling sesuai** untuk meningkatkan stabilitas enzim X tanpa menurunkan aktivitasnya? Jelaskan alasannya.
3. Jika kamu anggota tim riset, apakah kamu akan memilih **sistem ekspresi bakteri, yeast, atau mamalia**? Mengapa?
4. Apa risiko **off-target** atau efek samping yang mungkin muncul dari penggunaan teknologi **CRISPR-Cas9** untuk memodifikasi gen penghasil enzim X?
5. Bagaimana **pertimbangan etis** dan **regulasi** dalam penggunaan protein hasil rekayasa untuk terapi manusia?

You are encouraged to use AI tools to support your learning process. However, please use them critically — not as a replacement for your own thinking.

In your submission, briefly describe how you used AI and what personal insights you gained from the process

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Tugas Mahasiswa

- **Diskusi kelompok (60–90 menit):**
  1. Analisis kasus dan jawab pertanyaan pemicu.
  2. Gunakan sumber literatur ilmiah (artikel, database protein, dsb.).
- **Produk akhir:**
  1. **Laporan singkat (2–3 halaman)** berisi hasil analisis dan rekomendasi.
  2. Mahasiswa boleh menggunakan AI untuk generate ideas, outline, atau proofread, tapi wajib menulis bagian refleksi:"*Which part of your work was assisted by AI, and how did you evaluate or modify it*?"
- **Presentasi singkat (opsional):**
  1. Setiap kelompok mempresentasikan solusi selama 5 menit.