Chapter 10 - Biotechnology

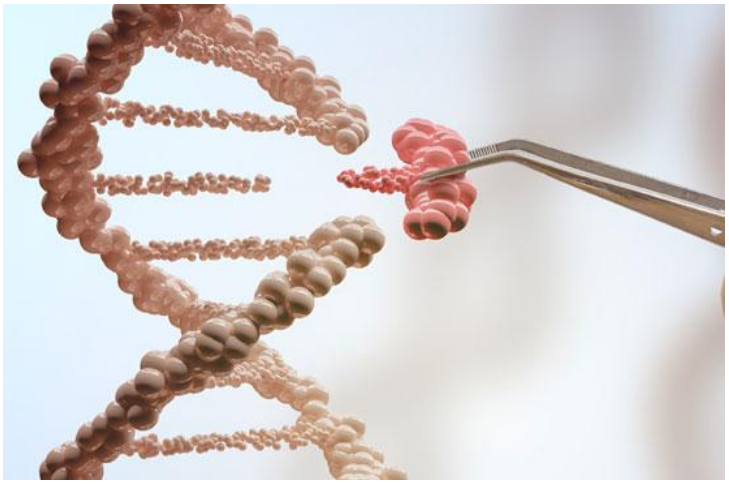
All Lectures Uploaded on YouTube:

https://tinyurl.com/fkm10-biology

10.1 Introduction To Biotechnology

- Biotechnology has existed since early human civilization through activities like planting crops, domesticating animals, producing yogurt, cheese, wine, beer, and baking bread.
- Early farmers practiced grafting to improve plant yield and quality—an early form of biotechnology.
- Increase in global population pushed humans to develop more nutritious, pest-resistant crops and improved animal breeds.
- Biotechnology is defined as **the use of living organisms or their products for human welfare**.
- Traditional biotechnology used microorganisms like yeast for fermentation and bacteria for dairy products.

- Leather tanning is also an ancient biotechnological process.
- Modern biotechnology emerged with advancements in microscopy and cellular biochemical understanding.
- Includes: **genetic engineering, cell fusion, GMOs, cell therapies, gene therapies, nanobiotechnology, single-cell proteins**.



- Modern biotechnology is a priority scientific field in Pakistan and a major part of global scientific development.

10.2 Food Biotechnology Related To Advanced Agriculture In Pakistan

- Pakistan (population ~240 million) faces rising food demand, shrinking farmland, and environmental challenges.

- Food biotechnology helps improve food yield, nutritional value, resistance to pests, environmental resilience, processing and preservation.

- Pakistani institutions include **NIBGE, NIAB, NCEMB, KIBGE, ASAB**—working on improving crops and livestock.

10.2.1 Genetically Modified (GM) Crops

- GM crops (wheat, rice, maize, sugarcane) are engineered for pest resistance, environmental tolerance, and improved yield.

Key Examples in Pakistan

- **Bt Cotton (Cry gene from *Bacillus thuringiensis*)**
    - Resistant to viruses, cotton flies, bollworms.
    - Higher productivity, reduced pesticide use, increased cotton oil and seed cake production.

- **GM Sugarcane**
    - Cry1Ac + Cry2Ab genes → resistance to sugarcane top borer.
    - Higher sugar yield.

- **GM Wheat / Sugarcane / Potato**
    - Grow in phosphate-deficient soils (AVP1 gene).
    - Resistant to drought, heat, and frost.

- **Herbicide-resistant Wheat** (CP4-epsps gene)
- **GM Tomatoes and Chilies** are also under development and cultivation.

10.2.2 Improved Nutritional Content (Bio-fortification)

- Bio-fortification enriches crops with essential nutrients (Vitamin A, iron, zinc).
- Pakistan developed 5 zinc-enriched wheat varieties:

    1. Zincol-2016
    2. Akbar-2019
    3. Nawab-2021
    4. Tarnab Rehbar
    5. Tarnab Gandum-1

- Contain **40% more zinc**, improve public nutrition, and offer high yield + rust resistance.

10.2.3 Disease-Resistant Food Crops

- Biotechnology enables crops resistant to diseases such as wheat rust.
- Rust-resistant genes identified and transformed into local varieties (e.g., Seher-2006, Punjab-11).
- Expected to improve national wheat production.

10.2.4 Drought and Salinity Tolerance

- Pakistan faces drought, floods, salinity, and waterlogging.
- New GM wheat and maize varieties developed to tolerate water scarcity and salinity.
- Help maintain yield despite irregular rainfall.

10.2.5 Improved Livestock Productivity

- Biotechnology improves dairy and meat quality via:
    - Embryo transfer
    - Artificial insemination
    - Hybrid cattle breeding
    - Disease-resistant poultry and dairy breeds
- Leads to increased productivity and better rural livelihoods.

10.2.6 Food Processing

- Biotechnology enhances food safety, preservation, value addition, and storage.

Applications

- **Food preservation:** canning, refrigeration, pasteurization, drying, smoking, fermentation.
- **Food preparation:** grinding, cooking, mixing.

- **Food safety:** reducing contamination.
- **Value-added processing:** nutrient-rich foods, additives, flavors, colors.

10.2.7 Biological Pest Control

- Biotechnology creates environmentally friendly pest management methods.
- Modified viruses, bacteria, and insects help protect crops.
- Bio-pesticides reduce reliance on harmful chemicals.

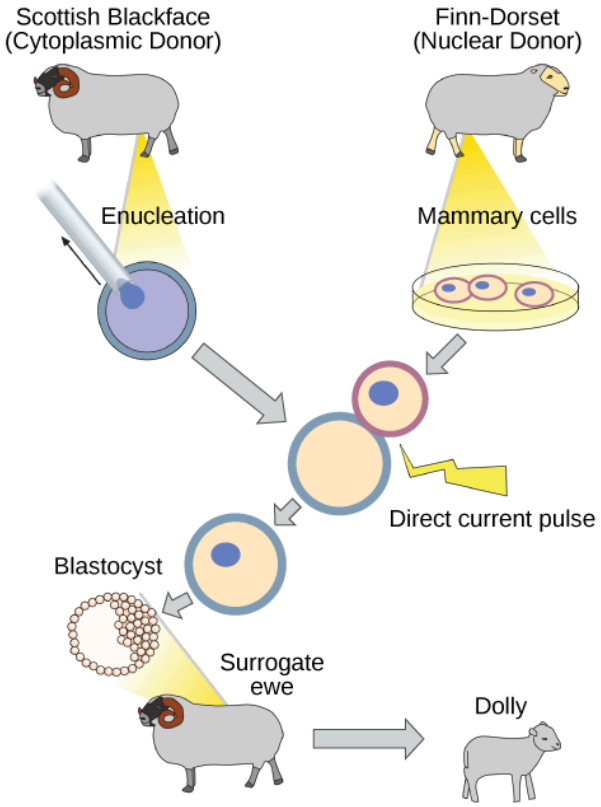
10.3 Medical Biotechnology In Advancement Of Healthcare In Diabetes And Cancer

Uses living cells/organisms to produce pharmaceuticals and diagnostics.

10.3.1 Diabetes

Diagnosis

- **Biosensors (Glucose meters):** electrodes detect enzymatic reactions with glucose → electrical signal proportional to glucose level.
- **Continuous Glucose Monitoring (CGM):** real-time glucose tracking; helps adjust insulin dosage and diet.
- **HbA1c assays:** reflect average glucose levels over 3 months.
- **Biomarkers:** identified for early detection and disease monitoring.

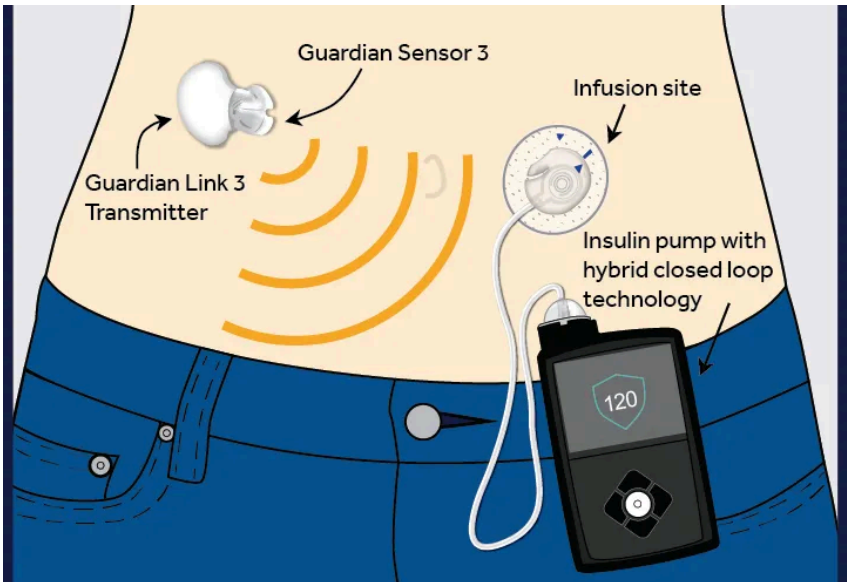


10.3.1.2 Insulin Production

- Previously obtained from animals.
- Now produced using **recombinant DNA technology** in genetically modified bacteria → pure, safe, large-scale human insulin.

10.3.4.3 Artificial Pancreas

- Closed-loop insulin delivery system.
- Combines sensor + computer algorithm + insulin pump.
- Automatically adjusts insulin based on real-time glucose → better control and fewer complications.



10.3.4 Cancer

Cancer arises from uncontrolled cell division; may be benign or malignant (spreading = metastasis).

Common cancers: lung, breast, prostate, oral, colorectal.
Pakistan (2022): 185,748 new cases; 118,631 deaths.

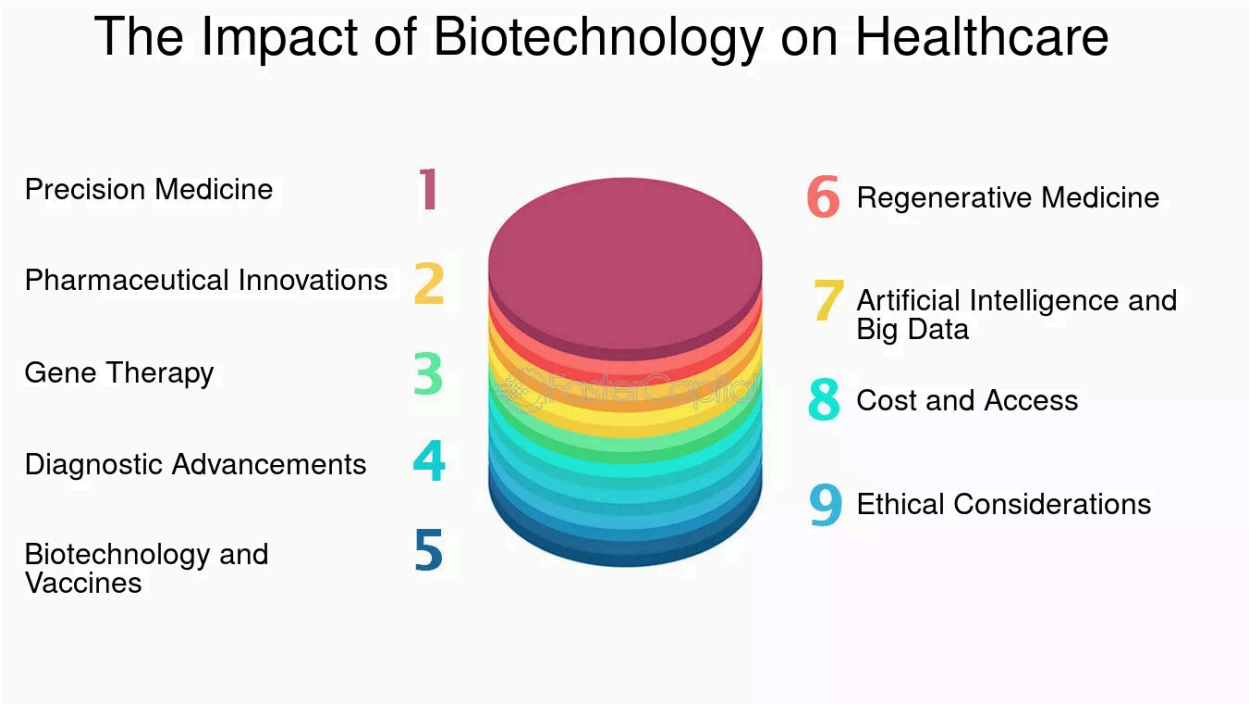
Biotechnological Contributions

Early and Accurate Diagnosis

- Study of cancer cell lines → identify genes/proteins involved in cancer.
- Protein biomarkers (HER2/neu, CA125) used for early detection.
- Tumor suppressor gene mutations (BRCA1/BRCA2) linked to high cancer risk.
- Gene knockdown/knockout in cells verifies gene function.
- Animal models confirm genetic roles.
- Liquid biopsy developed for non-invasive detection (CTCs, cfDNA).

Result-Oriented Targeted Therapies

- Targeted drugs affect only cancer cells → fewer side effects.
- Monoclonal antibodies (e.g., Herceptin) block specific pathways.
- Allows higher safe dosages and improved treatment success.



Patient-Specific Medicine

- Personalized treatments based on genetic profile, cancer stage, age, gender.
- Study of drug action using cancer cell lines and animal models.

Continuous Research & Innovative Tools

- Liquid biopsy
- Next-generation sequencing
- Monoclonal antibodies
- Immunotherapy (engineered T-cells)
- Gene knockdown/knockout
- Cancer vaccines and oncolytic viruses

- Nanoparticle-based drug delivery
- AI for analyzing cancer patterns and predicting treatments

10.4 Potential Advantages Of Genetic Editing With Examples In Medicine And Agriculture

Gene editing modifies DNA by adding, removing, or altering nucleotides.

Two methods

1. **Ex-vivo / In-vitro:** cells removed and edited in lab.
2. **In-vivo:** editing tools delivered directly inside the body.

Major Gene Editing Techniques

1. CRISPR–Cas9

- Guide RNA directs Cas9 enzyme to cut DNA at target site.
- CRISPR sequences originate from bacterial immunity against viruses.

2. TALENs

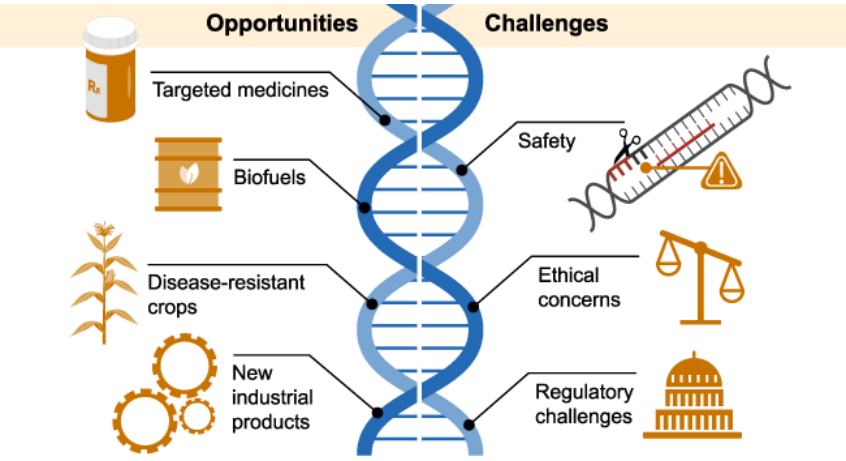
- Protein recognizes specific DNA sequence + nuclease cuts DNA.

3. Zinc-Finger Nucleases (ZFNs)

- DNA-binding proteins fused with nucleases to create breaks at precise sites.

Base Editing

- Alters individual nucleotides without cutting DNA strands.



10.4.1 Medicine

Managing Genetic Diseases

Examples: Thalassemia, Sickle Cell Anemia, Cystic Fibrosis, Duchenne Muscular Dystrophy.

Drug Development & Preclinical Testing

- Humanized mice used to test new drugs.
- Gene knockout cell lines used to test response to specific genetic defects.

Cancer Therapy

- Knockout cancer-promoting genes.
- Modify genes responsible for chemotherapy resistance.
- Create targeted cancer treatments.

Viral Resistance

- Editing genes like CCR5 for resistance to HIV and hepatitis.

10.4.2 Agriculture

Improvement in Food Crops

- CRISPR used to make disease-resistant, pest-resistant, drought-tolerant crops.
- Improves yield, taste, nutrition (e.g., rice, maize, wheat).

Improvement in Dairy Livestock

- Gene modification improves milk/meat production.
- Enhances disease resistance.
- Example: myostatin gene modification increases muscle mass.

Environment-Friendly Farming

- Gene editing reduces pesticide need by creating pest-resistant varieties.

Bioethical Limitations

- Safety concerns
- Unequal access
- Unpredictable long-term effects
- Need for strict regulation

10.5 Benefits Of Marine Biotechnology

Marine biotechnology ("blue biotech") uses marine organisms for medicine, cosmetics, food, fuel, and environmental protection.

Discovery of New Pharmaceutical Drugs

- Marine organisms (sponges, algae, bacteria) produce unique chemical compounds.

- Drug examples:

    - **Ziconotide** – pain treatment (from cone snail).

- **Trabectedin** – cancer treatment (from marine tunicate).

Medicinal & Cosmetic Products

- Marine fish/algae → omega-3 supplements for heart & brain health.
- Algae/seaweed used in moisturizers, anti-aging creams, antioxidants.
- Astaxanthin (from microalgae/shrimps) used in skin allergy medicines.

Improved Aqua-Feed Formulation

- Algae and seaweed used to produce high-quality feed for fish/shrimp farming.
- Improves growth and reduces disease.

Marine Enzymes with Unique Properties

- Work in extreme temperature, pressure, pH.

- Used in:

    - Food processing
    - Cosmetic industry
    - Detergents
    - Textile industry

Examples:

- α-amylase
- β-agarase
- Xylanase

Genetically Modified Aquaculture

- Produces disease-resistant and nutritious fish species.
- Genetic study of marine organisms helps improve stability and resilience.

Biofuels from Marine Algae

- Marine microalgae produce lipids → biodiesel.
- Grow in saline water, reducing freshwater usage.
- Renewable energy source.

Bioremediation

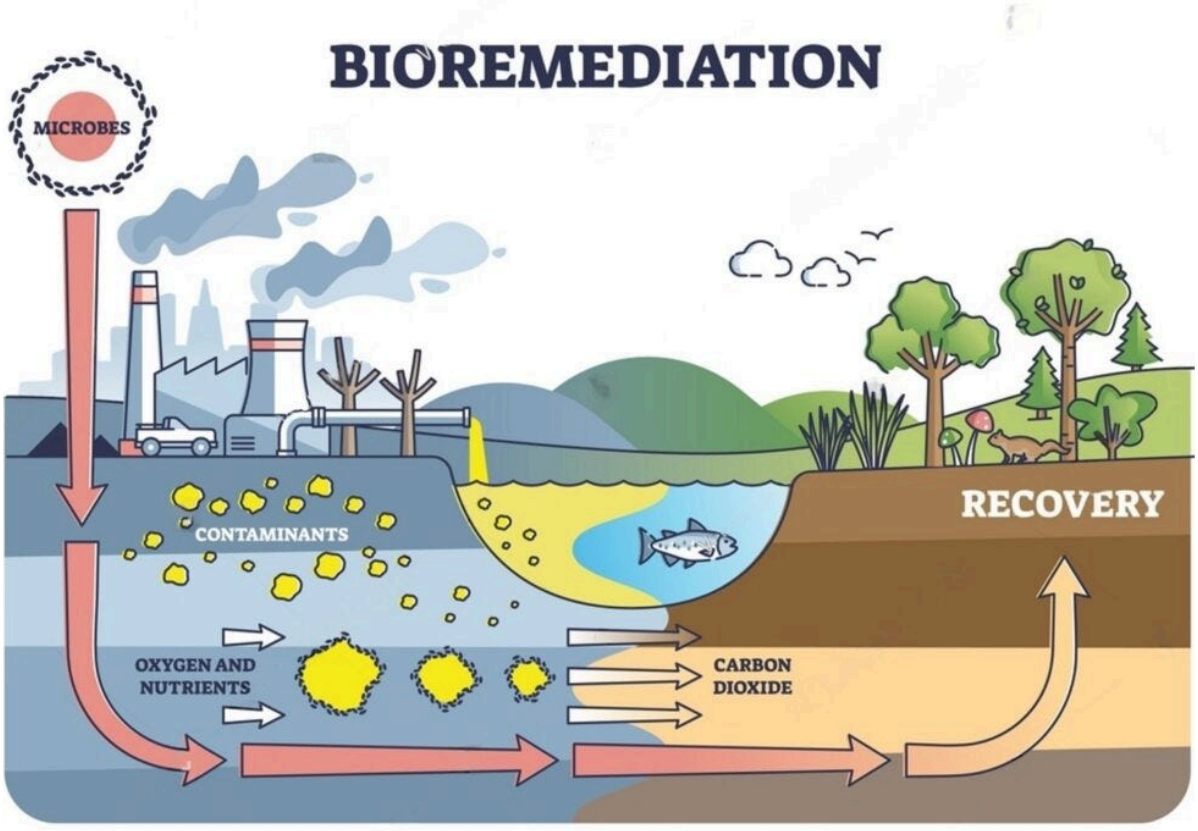
- Marine bacteria/fungi naturally degrade oil, plastics, heavy metals.
- Example: *Alcanivorax borkumensis* breaks down crude oil.

10.6 Bioremediation: Taking Better Care Of Our Environment

Bioremediation uses microorganisms and plants to detoxify polluted soil, water, and air.

Types

1. **In-situ:** treatment at contamination site.
2. **Ex-situ:** removal and treatment at another location.



Advantages

- Natural and sustainable
- Cost-effective
- Requires minimal machinery
- Environmentally friendly (less chemical use)
- Supports long-term ecosystem health
- Microbes can be genetically engineered
- Applicable for:

- Oil spills
- Heavy metal contamination
- Pesticide degradation

Mechanism

1. Microorganisms are stimulated to grow in polluted environments.
2. They use pollutants as energy/food.
3. Convert them into harmless substances (CO_2, water).
4. The process requires proper temperature, oxygen, moisture, and nutrients.
5. Bioremediation can be accelerated by adding nutrients or air.

Examples in Pakistan

1. Tasman Spirit Oil Spill (Karachi)

- NIBGE introduced oil-degrading bacteria.
- The 75-day treatment cleaned the sandy shore.

2. Lahore Industrial Waste

- Heavy metals and toxins from tanneries, paints, textile industries.
- Wetland-based bioremediation using plants + microbes to clean water.

Concept and Applications of Industrial Biotechnology (White Biotechnology)

Uses microorganisms, enzymes, and plants to produce industrial products sustainably.

Components

- Microorganisms
- Enzymes
- Biological system manipulation
- Genetic engineering

Applications

1. Food & Beverage

- Fermentation (baking, brewing)
- Rennet enzyme for cheese production

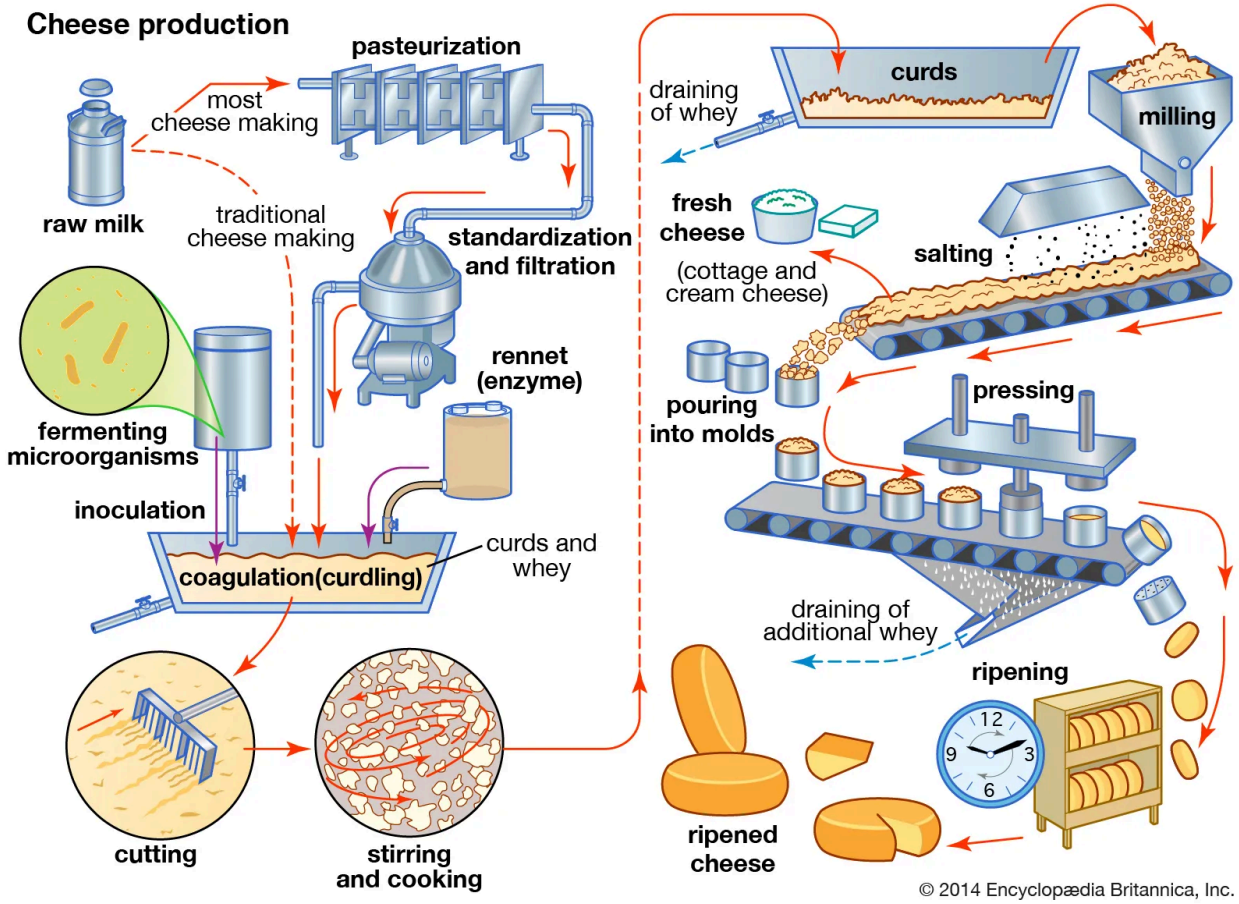
- Amylase for starch breakdown

2. Biopharmaceuticals

- Large-scale production of insulin, vaccines, vitamins, antibodies.

3. Agriculture

- Bio-fertilizers, bio-pesticides.
- Genetic engineering for crop improvement.



4. Useful Chemicals

- Citric acid, acetic acid, acetone

- Alcohols, amino acids from fermentation

5. Biofuels

- Bioethanol and biodiesel from sugarcane, corn, algae.

6. Bioremediation & Environmental Protection

- Use of microorganisms for waste cleanup.
- Reduces pollution, supports sustainability.

PAKISTAN'S ONE OF THE BEST EDUCATIONAL PLATFORM FOR FEDERAL BOARD PREPARATION - FEDERAL KA MANJAN

FEDERAL KA MANJAN

Online Batch For Class (9,10,11 & 12)

SUBJECTS:

1. BIOLOGY
2. CHEMISTRY
3. PHYSICS
4. MATH
5. COMPUTER SCIENCE
6. ENGLISH

INCLUDES:

1. CHAPTER TESTS
2. Live Class Recordings
3. MONTHLY TESTS
4. HOME WORK
5. Topper Notes
6. Full Book Notes
7. TARGET / GUESS PAPERS
8. QUESTION AND ANSWERS
9. 24/7 TEACHER SUPPORT
10. DOUBT CLASSES & Support
11. Get 95+% in Board Exams
12. LIVE GRAND TESTS
13. MOST IMPORTANT EXAM WRITING METHOD SESSIONS

CONTACT US ON WHATSAPP +92 336 8079808
For Registration: REGISTER NOW

ONLY Rs. 2,999 /= For One YEAR (1 SUBJECT)

ONLY Rs. 250 / Month

GET 95+% IN FEDERAL BOARD EXAMS

GET 95+%

IN FEDERAL BOARD EXAMS

FEDERAL KA MANJAN

BATCH 1.0 | Grade 9 & 10 FBISE

SUBJECTS OFFERED:

- Biology / Computer Science
- Chemistry
- Physics
- Math
- English

PROGRAM INCLUDES:

- ✓ Chapter Tests
- ✓ Monthly Tests
- ✓ Assignments
- ✓ MCQs Sheets
- ✓ Notes and Short Tricks
- ✓ Target / Guess Papers
- ✓ 24/7 Teacher Support
- ✓ Doubt Classes
- ✓ WhatsApp Group
- ✓ Mock Tests
- ✓ Live Grand Tests
- ✓ Most Important Exam Writing Method Sessions

AMAZING OFFER!

1 SUBJECT For Full One YEAR (12 Months)

~~Rs 12,000~~ **NOW ONLY Rs 3,000!**

(Per Subject for the Entire Year)

READY TO ACE YOUR EXAMS?

REGISTER ON WHATSAPP

0336-8079808