MARKING SCHEME

CLASS- XII

BIOTECHNOLOGY (2025-2026)

Q.no	Questions	Marks
1.	a) Variable number of Tandem Repeats	1
2.	**a)** DNA ligase	1
3.	**c)** Single-Stranded	1
4.	**b)** Restriction Fragment Length Polymorphism	1
5.	**b)** Transfection	1
6.	**d)** PAGE	1
7.	Both A and R are true and R explains A	2
8.	Both A and R are true but R does not explain A	2

9.	Both A and R are true and R explains A	1
10.	Tissue Culture	1
11.	Plasmid	1
12.	Cryopreservation	1
13.	Virus-free plant production	1
14.	Micropropagation	1
15.	Sickle Cell Anemia	1
16.	**What are Restriction Enzymes?** **Restriction enzymes**, also known as **restriction endonucleases**, are **specialized enzymes** that can **cut DNA at specific sequences**, usually **palindromic sequences** (same forward and backward). • Naturally found in **bacteria** to defend against viral DNA. • They **recognize specific nucleotide sequences** (called recognition sites) and cut the DNA at or near those sites. 📌 **Example**:	

	EcoRI is a restriction enzyme that recognizes the sequence: GAATTC and cuts between **G and A**.	
	💡 **Why Are They So Important in DNA Technology?** 1. ✅ **Cutting DNA Precisely**: Allows scientists to cut DNA at **exact locations**. 2. ✅ **Creation of Recombinant DNA**: Used to **insert foreign genes** into plasmids (vectors). 3. ✅ **Gene Cloning**: Essential in inserting genes into **bacteria or other organisms** to replicate. 4. ✅ **Genetic Engineering**: Enables modification of DNA to create **genetically modified organisms (GMOs)**. 5. ✅ **DNA Fingerprinting & Diagnosis**: Helps in identifying individuals or detecting mutations in DNA.	2
17.	**What are Cry Proteins?** **Cry proteins** (short for **crystalline proteins**) are **toxic proteins** produced by the bacterium ***Bacillus thuringiensis*** **(Bt)**. These proteins have **insecticidal properties** and are used in **genetically modified (GM) crops** to protect them from insect pests.	2

🔍 How Do They Work?

- When an insect larva eats the **Cry protein**, it gets activated in the **alkaline gut** of the insect.
- The protein **creates pores** in the gut lining, causing the insect to **die** from dehydration or starvation.

🌾 Example of Cry Protein:

- **Cry1Ac** and **Cry2Ab**: Used in **Bt cotton** to kill **bollworms**.
- **Cry1Ab**: Used in **Bt corn** to protect against **corn borers**.

Or

Bioinformatics is the field that combines **biology, computer science, and information technology** to analyze and interpret biological data. It plays a vital role in **modern biotechnology**.

🔬 Major Uses of Bioinformatics in Biotechnology:

1. 🧬 **Genome Sequencing & Analysis**
    - Helps in reading and interpreting DNA sequences of humans, plants, and microbes.
2. 💉 **Drug Discovery & Development**
    - Identifies potential drug targets using **molecular modeling** and simulations.
3. 🌾 **Genetically Modified Organisms (GMOs)**
    - Assists in designing **genetically**

	engineered crops by analyzing gene functions.
	
	4. 🧠 **Gene Prediction & Annotation**
	  ○ Identifies coding regions and predicts **gene functions** using DNA data.
	
	5. 🦠 **Comparative Genomics**
	  ○ Compares genomes of different species to find **evolutionary relationships**.
	
	6. 🔵 **Protein Structure Prediction**
	  ○ Helps model **3D structures of proteins** for understanding their function.
	
	7. 🧍 **Personalized Medicine**
	  ○ Tailors treatments based on a person's **genetic profile**.
	
	8. 📜 **Database Management**
	Stores and organizes large volumes of biological data like NCBI, PDB, GenBank.	

18.		2

Feature	Stirred Type Bioreactor	Sprayed Type Bioreactor
Working Principle	Uses mechanical **stirrers or impellers** to mix nutrients and cells	Uses **spray nozzles** to spray culture media over surfaces
Oxygen Supply	Supplied through **spargers and agitation**	Supplied through **air or gas spray**
Mixing	Efficient due to **mechanical agitation**	Limited or uneven mixing
Used For	**Suspension cultures** (microbial/animal cells)	**Immobilized cell cultures** or **surface growing organisms**
Design	Typically a **cylindrical tank with baffles and stirrer**	Tall **chamber or column with trays or surfaces**
Example	Used for making **antibiotics, vaccines, enzymes**	Used in **wastewater treatment** or **plant tissue cultures**

19.	**Cloning Vectors** are DNA molecules used to carry foreign genetic material into a host cell for replication or expression. ◆ **Two Common Types of Cloning Vectors:** 1. **Plasmids** o Small, circular, double-stranded DNA found in bacteria o Example: **pBR322**, **pUC19** 2. **Bacteriophages (Phage Vectors)** o Viruses that infect bacteria and can carry	5

	larger DNA fragments ○ Example: **Lambda (λ) phage**	
	✅ **Option 2: Define the Terms** **a) Callus** A **callus** is an unorganized, **mass of undifferentiated plant cells** that forms when plant tissues are cultured on a nutrient medium. • It can later differentiate into shoots or roots under specific conditions. **b) Explant** An **explant** is a **small piece of plant tissue** (like leaf, root, or stem) that is taken from a plant and used to start a tissue culture.	
20.	Gene cloning is the process of making identical copies of a gene using biological tools and host organisms (usually bacteria).	
	🧬 Steps in Gene Cloning: 1. Isolation of Gene of Interest ○ Extract DNA and isolate the gene you want to clone. 2. Cutting DNA with Restriction Enzymes ○ Use enzymes to cut the gene and plasmid at specific sites. 3. Insertion into Vector (Recombinant DNA)	

- Insert the gene into a plasmid/vector using DNA ligase.

4. Transformation
    - Introduce recombinant DNA into a host cell (like *E. coli*).
5. Selection of Transformed Cells
    - Use markers (e.g., antibiotic resistance) to identify successful clones.
6. Cloning and Expression
    - Allow transformed cells to multiply and express the cloned gene.

Role of Enzymes in PCR (Polymerase Chain Reaction)

PCR is a technique to amplify DNA. Enzymes play a vital role at each step.

🧪 Key Enzyme Used:

1. Taq DNA Polymerase
    - Heat-stable enzyme from *Thermus aquaticus*.
    - Synthesizes new DNA strands during extension step.

🧬 Role in PCR Steps:

1. Denaturation (94–95°C)
    - DNA strands separate – no enzyme involved.

	2. Annealing (50–65°C)
	  ○ Primers bind to template DNA.
	3. Extension (72°C)
	  ○ Taq polymerase adds nucleotides to build the new DNA strand.	

21.	Genetic Engineering (also called Recombinant DNA technology) plays a key role in developing crops with better yield, disease resistance, and improved nutrition by modifying their genetic material.	
	🌾 1. Improved Yield • Genes responsible for faster growth or larger produce are inserted. • Crops can be made to withstand drought, extreme temperatures, or salinity, ensuring consistent yield. • ✅ Example: High-yield Bt cotton and Golden Rice.	
	🦠 2. Disease Resistance • Crops are engineered to produce proteins that kill pests or viruses. • Reduces the need for chemical pesticides. • ✅ Example: ○ Bt crops (cotton, corn) produce Cry proteins that kill insect larvae.	

	○ Virus-resistant papaya (resistant to Papaya ringspot virus).	
	🧠 3. Nutritional Enhancement (Biofortification) • Crops are modified to produce more vitamins, minerals, and essential nutrients. • Helps fight malnutrition and deficiency diseases. • ✅ Example: ○ Golden Rice is enriched with Vitamin A (β-carotene). ○ Iron-enriched wheat and zinc-enriched rice.	
	🌍 Advantages of Using Genetic Engineering in Crops: • Reduces use of chemical fertilizers and pesticides • Increases crop shelf-life • Supports sustainable agriculture • Helps in feeding a growing population OR Potential Applications of Plant and Animal Cell Culture	3
	🌿 Applications of Plant Cell Culture Plant cell culture involves growing plant cells or tissues in a controlled, sterile environment. It has a wide range of agricultural, pharmaceutical, and	

industrial uses.

- 🔹 1. Micropropagation

- Rapid multiplication of disease-free plants
- Used in agriculture, horticulture, and forestry

- 🔹 2. Production of Secondary Metabolites

- Produces valuable compounds like alkaloids, flavonoids, and essential oils
- Example: Shikonin, Taxol, Ajmalicine

- 🔹 3. Germplasm Conservation

- Storage of rare or endangered plant species in vitro
- Useful in biodiversity conservation

- 🔹 4. Genetic Engineering

- Used for gene transfer and creation of transgenic plants
- Improves traits like drought resistance or pest tolerance

- 🔹 5. Somatic Hybridization

- Fusion of two different plant cells to create hybrid plants
- Combines traits from different species

🐄 Applications of Animal Cell Culture

Animal cell culture involves growing animal cells in a nutrient medium under sterile conditions. It plays a vital role in biotechnology,

	medicine, and research. 🔹 1. Vaccine Production • Cultured animal cells are used to produce vaccines like Hepatitis B, polio, and rabies. 🔹 2. Monoclonal Antibody Production • Used in diagnostics and cancer therapy 🔹 3. Tissue Engineering & Regenerative Medicine • Helps in creating artificial organs and tissues for transplantation • Example: Skin grafts, artificial cartilage 🔹 4. Drug Testing & Toxicology • Used to test new drugs and chemicals on cultured cells before animal or human trials 🔹 5. Genetic Studies & Cancer Research • Helps in understanding cell behavior, cancer development, and gene functions	
22.	Biosafety regulations are a set of guidelines and laws that ensure the safe handling, use, transport, and release of Genetically Modified Organisms (GMOs) to protect human health and the environment. These regulations are essential for maintaining ethical and scientific standards in biotechnology.	
	🔒 Why Biosafety Regulations Are Important: 1. ✅ Prevents Health Hazards	

- Ensures GMOs do not cause allergies or toxic effects in humans or animals.

2. ✅ Environmental Protection
   - Avoids unintended harm to non-target organisms, biodiversity, and ecosystems.
3. ✅ Regulates Field Trials
   - Controls where, how, and when GMOs can be tested or released.
4. ✅ Risk Assessment
   - Scientific evaluation is done before approving any GMO for commercial use.
5. ✅ Monitoring and Labeling
   - Helps in tracking GMO products and ensures proper labeling for consumer awareness.
6. ✅ Waste Disposal and Containment
   - Ensures safe disposal of GMO materials and prevents accidental spread.

🏛️ Agencies Involved in India:

- GEAC (Genetic Engineering Appraisal Committee)
- RCGM (Review Committee on Genetic Manipulation)
- DBT (Department of Biotechnology)

Or

What Are Transgenic Plants?

Transgenic plants are those into which one or more foreign genes (transgenes) have been inserted using genetic engineering techniques to give them desirable traits, such as pest resistance, drought tolerance, or better nutrition.

🧬 Steps to Create Transgenic Plants:

1. Gene Identification
    - Select the desired gene (e.g., insect resistance gene from *Bacillus thuringiensis* – Bt gene).
2. Gene Cloning
    - The selected gene is isolated and inserted into a vector (like a plasmid).
3. Gene Insertion into Plant Cells
    - The gene is introduced into plant cells using methods like:
        - Agrobacterium-mediated transformation
        - Gene gun (biolistics)
        - Electroporation
4. Selection
    - Use of marker genes (e.g., antibiotic resistance) to select successfully transformed cells.
5. Regeneration
    - Transformed plant cells are grown on a nutrient medium to regenerate into a whole transgenic plant.

6. Testing and Propagation
    - Transgenic plants are tested for the trait, grown in controlled fields, and multiplied for large-scale use.

🌍 Benefits of Transgenic Plants:

✅ Benefit	🌱 Example
Pest resistance	Bt cotton kills bollworm larvae
Disease resistance	Virus-resistant papaya
Herbicide tolerance	Roundup Ready Soybeans
Improved nutrition	Golden rice with Vitamin A
Higher yield & stress tolerance	Drought-resistant maize or rice
Reduced chemical use	Less pesticide and herbicide needed

⚠️ Potential Risks of Transgenic Plants:

❌ Risk	💭 Concern
Environmental impact	Harm to non-target species, biodiversity loss
Gene transfer	Genes may transfer to wild plants (superweeds)
Human health	Allergic reactions or unknown long-term effects

	Ethical concerns	Mixing genes across species boundaries	
	Economic issues	Seed dependency on biotech companies	
23.	PCR stands for Polymerase Chain Reaction. It is a laboratory technique used to amplify (make many copies of) a specific DNA segment — even from a very small amount.		
	🔬 Steps in a PCR Reaction: PCR typically consists of three main steps, repeated for 25–35 cycles:		
	1️⃣ Denaturation (94–95°C) • The double-stranded DNA is heated to separate into single strands.		
	2️⃣ Annealing (50–65°C) • Primers (short DNA sequences) bind to the target DNA strands at specific sites.		
	3️⃣ Extension/Elongation (72°C) • The enzyme Taq DNA polymerase adds nucleotides to extend the primers and synthesize new DNA strands.		

🔁 Cycle Repeats

These steps are repeated multiple times to exponentially increase the DNA quantity.

Or

DNA isolation (or extraction) is the process of separating DNA from cells or tissues in pure form for analysis or experiments.

🧪 Basic Steps of DNA Isolation:

1️⃣ Cell Lysis (Breaking the Cells)

- The cell membrane and nuclear membrane are broken using a lysis buffer containing detergents like SDS (sodium dodecyl sulfate).
- This releases DNA, proteins, and other cell contents.

2️⃣ Removal of Proteins and Cell Debris

- Protease enzymes or chemicals (like chloroform or phenol) are added to break down proteins.
- Centrifugation is used to separate the clear DNA-containing solution from the debris.

3️⃣ DNA Precipitation

- Cold alcohol (usually ethanol or isopropanol) is added.
- DNA is insoluble in alcohol, so it precipitates

	(becomes visible) as white threads or clumps.	
	4️⃣ DNA Washing • The DNA pellet is washed with 70% ethanol to remove impurities and salts. • It is then air-dried or dried using vacuum.	
	5️⃣ DNA Resuspension • Finally, DNA is dissolved in TE buffer or sterile water for storage or further use.	
	📌 Summary Table: Step — Purpose Cell lysis — Break open the cells Removal of proteins — Remove unwanted proteins/debris Precipitation — Make DNA visible and collectable Washing — Purify the DNA Resuspension — Store DNA in usable form	
24.	DNA fingerprinting is a technique used to identify individuals based on unique patterns in their DNA. The principle is based on the presence of VNTRs (Variable Number of Tandem Repeats) or STRs (Short Tandem Repeats) — these are highly variable regions in the non-coding part of the genome.	

	🧬 Core Principle: • Every individual (except identical twins) has a unique DNA sequence. • Specific regions of DNA have repeating sequences that vary in number between individuals. • These regions are extracted, amplified (via PCR), and compared to create a DNA profile.	
	⚖️ Use in Paternal Disputes (Paternity Testing): In cases where the identity of a child's biological father is disputed: 1. DNA is extracted from the child, mother, and alleged father. 2. The child's DNA profile is compared with both parents. 3. Since a child inherits half DNA from each parent, the father's DNA should match with the child's non-maternal bands. 4. If there is no match, the alleged person is not the biological father.	3
	📌 Applications in Paternity Cases: • Settling legal disputes about biological fatherhood. • Used in custody cases, inheritance claims, and adoption confirmation.	

	• Admissible as legal evidence in court.	
25.	GEAC is the Genetic Engineering Appraisal Committee, which functions under the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India.	
	🔍 Main Role: GEAC is the apex body in India responsible for: • Approving research and release of genetically modified organisms (GMOs) and products. • Ensuring biosafety in the use of GM crops and biotechnology products.	
	📋 Key Functions: 1. ✅ Evaluate GM Research Projects o Approves lab and field trials of transgenic plants. 2. ✅ Assess Environmental Impact o Analyzes risk to humans, animals, and biodiversity. 3. ✅ Authorize Commercial Release o Gives final clearance for GM crops like Bt cotton.	3

	4. ✅ Ensure Biosafety Regulations Compliance ○ Makes sure all activities follow India's biosafety laws.	
	📌 Important Point: • GEAC works according to the rules under the Environment (Protection) Act, 1986. • It plays a crucial role in balancing biotechnology progress with public safety and ethics.	
26.	Animal cell culture refers to the in vitro (outside the body) growth of animal cells under controlled conditions, and it plays a key role in biopharmaceutical production, especially for therapeutic proteins.	
	🧬 What are Therapeutic Proteins? These are proteins used to treat diseases by replacing a deficient or abnormal protein in the body. Examples: Insulin, Interferons, Monoclonal antibodies, Human Growth Hormone	
	💉 Applications of Animal Cell Culture in Therapeutic Protein Production:	
	1. ✅ Production of Recombinant Proteins • Animal cells like CHO (Chinese Hamster Ovary) cells are genetically modified to produce:	

	○ Insulin for diabetes ○ Erythropoietin (EPO) for anemia ○ Interferons for viral infections and cancer therapy	
	2. ✅ Monoclonal Antibody Production • Used in treatments for cancer, autoimmune disorders, and infectious diseases. • Example: Trastuzumab (Herceptin) for breast cancer.	
	3. ✅ Vaccine Production • Cultured animal cells are used to produce safe and effective vaccines. • Example: Polio, Hepatitis B, and COVID-19 vaccines.	
	4. ✅ Gene Therapy Products • Animal cells are used to grow viral vectors that carry therapeutic genes to treat genetic disorders.	
	5. ✅ Tissue Engineering and Regenerative Medicine • Culturing cells to create artificial skin, cartilage, or even organs, often with proteins that aid healing. Or Stem cells are undifferentiated cells that have the	5

	unique ability to: • Self-renew (divide and make more stem cells) • Differentiate into various specialized cell types (like muscle, nerve, or blood cells)	
	🩻 What is Regenerative Medicine? Regenerative medicine is a field of medicine that focuses on repairing, replacing, or regenerating damaged tissues and organs using cells, genes, or biologically engineered materials.	
	🌱 Role of Stem Cell Technology in Regenerative Medicine:	
	1️⃣ Tissue Repair and Regeneration • Stem cells can replace damaged cells in tissues like skin, liver, heart, or nerves. • Example: Treating burn victims using skin stem cells.	
	2️⃣ Organ Regeneration • Research is ongoing to grow entire organs (like liver, kidney) in the lab using stem cells — a future solution to organ donor shortage.	
	3️⃣ Treatment of Degenerative Diseases • Helps in treating diseases like:	

- Parkinson's disease
- Alzheimer's
- Spinal cord injuries
- Type 1 diabetes

4 Bone Marrow Transplantation

- The oldest and most common form of stem cell therapy using hematopoietic stem cells to treat blood cancers like leukemia.

5 Personalized Medicine

- Patient's own stem cells can be used to reduce the risk of rejection and create customized treatments.

⚠ Challenges:

- Ethical concerns (especially with embryonic stem cells)
- Risk of tumor formation
- High cost and technical complexity

27. Both PCR (Polymerase Chain Reaction) and Gene Cloning are used to amplify DNA, but they differ in methods, tools, and applications.

Feature	PCR (Polymerase Chain Reaction)	Gene Cloning
Definition	In vitro method to amplify DNA using enzymes and	In vivo method to make copies of a gene inside

		temperature	a host cell
	Process Type	Artificial (test tube-based)	Biological (cell-based)
	Enzyme Used	Taq DNA Polymerase	DNA ligase, Restriction enzymes
	Time Required	Very fast (few hours)	Slower (may take days)
	Tool Used	Thermal cycler (PCR machine)	Vectors like plasmids, bacteria (E. coli)
	Accuracy	High, but may introduce errors with long sequences	Very accurate and maintains stable long inserts
	Purpose	Rapid amplification of DNA	Cloning, expression, or storage of desired genes
	Product	Only DNA copies	DNA integrated in living cells for further use

- PCR is like photocopying DNA quickly in a machine.
- Gene cloning is like putting the DNA in a cell and letting the cell multiply naturally.

Or

5

Taq polymerase is a heat-stable DNA polymerase enzyme that was originally isolated from the thermophilic bacterium *Thermus aquaticus*, which lives in hot springs.

- It is capable of withstanding high temperatures (up to 95°C), making it ideal for use in PCR (Polymerase Chain Reaction).
- It synthesizes new DNA strands by adding nucleotides to a DNA template during the extension step of PCR.

⚙️ Key Properties:

- Thermostable: Doesn't denature at high PCR temperatures

	• Optimal temperature: Works best at around 72°C • Fast: Can replicate thousands of base pairs in a few seconds	
	📌 Important Application: ✅ Used in PCR (Polymerase Chain Reaction) • Taq polymerase is essential for DNA amplification in PCR because it can repeatedly synthesize DNA even after the high-temperature denaturation step. Without Taq polymerase, PCR would not be possible, as regular enzymes would break down at high heat.	
28.	What is Biopiracy? Biopiracy refers to the unauthorized use or patenting of biological resources (like plants, animals, or traditional knowledge) by companies or researchers, often without proper credit or compensation to the local communities or countries from where they originated.	
	🌍 Famous Examples of Biopiracy:	
	1️⃣ Neem (Azadirachta indica) – India • A U.S. company tried to patent the antifungal properties of neem oil, a plant used in Indian traditional medicine for centuries. • The patent was later revoked after a legal	

	challenge.	
	2 Basmati Rice – India • A U.S.-based company, RiceTec, tried to patent a variety of Basmati rice developed from Indian strains. • This led to a major biopiracy dispute with India defending its traditional crop.	
	3 Turmeric (Haldi) – India • Two U.S. scientists were granted a patent on the wound-healing properties of turmeric, known in Indian Ayurvedic medicine. • The patent was eventually canceled after evidence of prior traditional use was presented.	5
	4 Hoodia – South Africa • A plant used by San tribes to suppress hunger during long hunts. • A pharmaceutical company patented it for weight-loss drugs without initially compensating the indigenous people.	

29.	Gene transfer refers to the insertion of a foreign gene (transgene) into a plant's genome to modify or improve its traits (e.g., pest resistance, drought tolerance, nutrition).	
	🔁 Two Major Methods of Gene Transfer in Plants:	
	🌿 1. Agrobacterium-Mediated Gene Transfer (Biological Method) • Uses Agrobacterium tumefaciens, a soil bacterium that naturally transfers genes into plant cells. • Scientists modify the Ti plasmid of the bacterium to carry desirable genes (instead of tumor-causing genes). • The bacterium infects plant cells, and the foreign gene is integrated into the plant genome. 📌 Example: • Used to develop Bt cotton (with insecticidal Cry gene) • Used in virus-resistant papaya	5
	💥 2. Gene Gun or Biolistics (Physical Method) • Tiny gold or tungsten particles coated with DNA are shot into plant cells using high pressure. • The DNA enters the nucleus and integrates into the plant's genome. 📌 Example:	

	• Used in rice, corn, and wheat, especially for monocots, which are hard to infect using Agrobacterium.	
	📌 Other Gene Transfer Methods (Less Common): • Electroporation – Using electric pulses to open cell membranes. • Microinjection – Directly injecting DNA into plant cells (rare in plants).	