Biotechnology and its Applications Class 12 Notes

The Ultimate NCERT Revision Guide for Class 12 / 12th Biology — Full-colour diagrams

Chapter 10: Biotechnology and its Applications

Class 12 Biology — NCERT 2026-27 (New NCERT)

Also see for this chapter: NCERT Solutions | Formula Sheet | Exemplar Solutions

Why this chapter matters

Chapter 10 takes the rDNA *toolkit* you learned in Chapter 9 and shows it at work — in fields, in hospitals, in animal sheds, and in courtrooms. For NEET it is a high-yield chapter: expect 2–3 direct questions every year on Bt cotton, RNAi-based pest control, recombinant human insulin, gene therapy for ADA deficiency, and the GEAC. For board exams, the long-answer favourites are insulin production (Eli Lilly route), ADA gene therapy and the social/ethical debate around biopiracy. Lock in the species–product–application triplets and you bank easy marks.

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1 Introduction — What "Applications" Means

Biotechnology, as you saw in Chapter 9, is the industrial-scale use of living systems — microbes, fungi, plants and animals — to make useful products or run useful processes. The toolkit (restriction enzymes, vectors, PCR, gel electrophoresis, bioreactors) was the subject of the previous chapter; **Chapter 10 is the catalogue of what that toolkit has actually built**. Four broad fronts dominate the chapter:

- **Agriculture** — pest-resistant transgenic crops (Bt cotton, RNAi tobacco), nutritionally enhanced crops, stress-tolerant varieties.
- **Medicine** — recombinant human insulin, gene therapy, molecular diagnosis (PCR, ELISA, DNA probes).
- **Transgenic animals** — mice, sheep, cows engineered for biological-product harvest, disease modelling, vaccine and toxicity testing.
- **Ethics and regulation** — GEAC, biopiracy, patent law and Indian biodiversity.

The three critical research areas of any biotechnology process

1. Providing the **best catalyst** — usually an improved microbe or a pure enzyme.
2. Creating the **optimal conditions** (engineering) for the catalyst to act — the bioreactor.
3. **Downstream processing** — the purification of the protein/organic compound from the bioreactor broth.

NEET MCQs love to test this triad. The phrase "downstream processing" is the trap option that confuses students.

1.1 Roadmap of the Chapter

The NCERT chapter has four numbered sections — 10.1 to 10.4. The diagram below shows how they fit together and the way exam questions typically draw from each.

The four pillars of Chapter 10. Read each section asking "which microbe/animal made what product, and at what cost?"

Quick Tip

The chapter never asks you to write down DNA sequences or enzyme structures — the marks are in **names, processes and flow charts**. Build a one-page table of (organism / engineered product / application) and revise it the night before the exam.

2 Biotechnological Applications in Agriculture

To feed a growing population, agriculture has three broad paths: (i) **agrochemical based** (fertilisers + pesticides), (ii) **organic**, and (iii) **genetically engineered crops**. The Green Revolution tripled food supply chiefly through (i), but the upper limit of conventional breeding has been reached and agrochemicals

are too expensive (and harmful) for the developing-world farmer. Path (iii) — GM crops — is the focus of section 10.1.

2.1 Tissue Culture and Somatic Hybridisation — The Prelude to GM

Before recombinant techniques arrived, the 1950s breakthrough was that **a whole plant can be regenerated from any single cell or explant** grown on a sterile nutrient medium. This property is called **totipotency**. The technique that exploits it to mass-produce identical plants is **micropropagation**; the offspring are **somaclones** (genetically identical to the parent).

The micropropagation nutrient medium

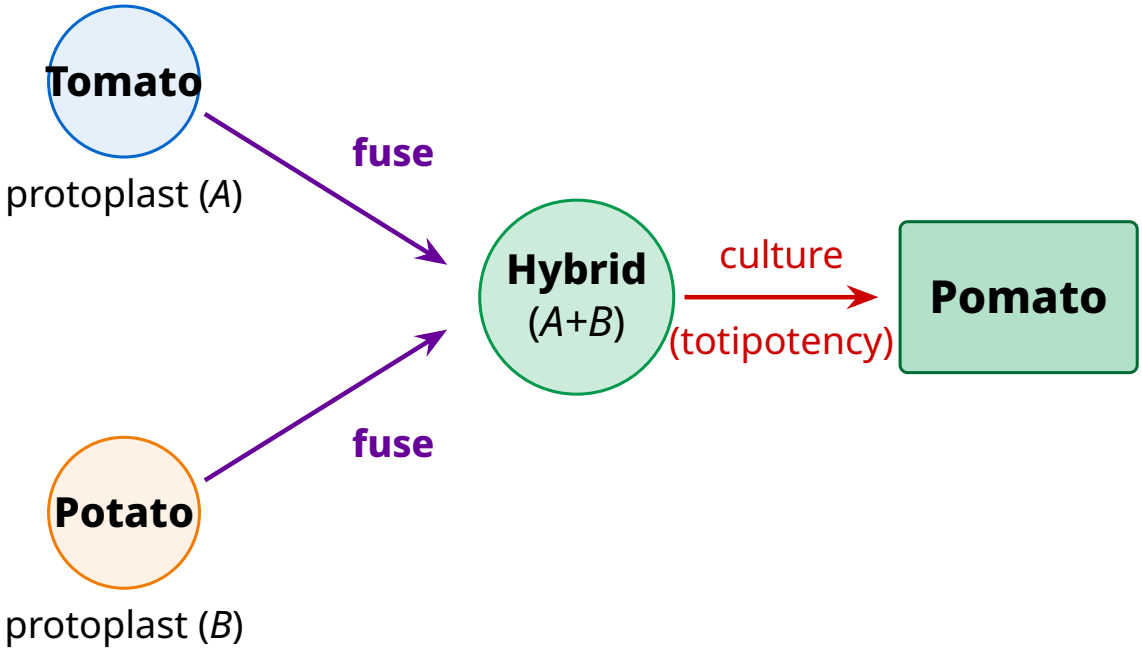
Every micropropagation broth must supply:

- a **carbon source** (sucrose),
- **inorganic salts**, **vitamins**, **amino acids**,
- **growth regulators** — chiefly **auxins** (root induction) and **cytokinins** (shoot induction).

Banana, apple and tomato plantlets sold commercially today come from this method.

A second use of tissue culture is **recovery of virus-free plants**. Even when a plant is virus-infected, the **meristem** (apical and axillary) is virus-free. Excising the meristem and growing it *in vitro* yields virus-free banana, sugarcane and potato.

Somatic hybridisation goes one step further. Naked **protoplasts** (cells with cell wall enzymatically removed) from two different varieties are fused, and the hybrid protoplast is grown into a whole plant — a **somatic hybrid**. The famous case is the **"pomato"** (potato $\times$ tomato fusion) — it worked but the agronomic traits were unimpressive.



Somatic hybridisation: protoplast-level fusion of tomato and potato gives the pomato.

Quick Tip

Two pairs to memorise: (1) **totipotency** = single cell can become a whole plant; (2) **somaclones** = micropropagation offspring (genetically identical). NEET asks both terms by definition every other year.

2.2 Genetically Modified Organisms (GMOs) — What and Why

GMOs are plants, bacteria, fungi or animals whose genes have been altered by manipulation. In agriculture, genetic modification has five proven benefits:

1. Made crops more tolerant to **abiotic stresses** — cold, drought, salt, heat.
2. Reduced reliance on chemical pesticides (**pest-resistant crops**).
3. Reduced **post-harvest losses**.
4. Increased **efficiency of mineral usage** — prevents early exhaustion of soil fertility.
5. Enhanced **nutritional value** of food — e.g. **golden rice** (Vitamin A enriched).

GM has also been used to manufacture industrial starches, biofuels and pharmaceuticals through "tailor-made" plants.

Memory Aid — the 5 GM benefits as "SPLEN-N"

Stress tolerance (abiotic) | **P**esticide-free **(P)**est resistance **L**ess post-harvest loss | **E**fficient mineral use | **N**utrition boost (golden rice).
Five letters, five NCERT bullet points — write all five and you score full marks

on the “advantages of GM crops” question.

2.3 Bt Cotton — The Bacterial Toxin Made Crop-Borne

Bt toxin is an insecticidal protein produced by the soil bacterium *Bacillus thuringiensis* (abbreviated “Bt”). During a particular growth phase, *B. thuringiensis* forms **protein crystals** that carry the toxin. Specific Bt toxin genes were cloned and inserted into cotton (and later corn, rice, tomato, potato, soyabean) — creating the **Bt cotton** line that resists bollworm attack without external pesticide spray.

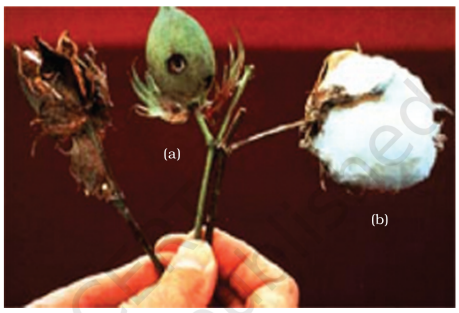


Figure 10.1 Cotton boll: (a) destroyed by bollworms; (b) a fully mature cotton boll

Fig. 10.1 (NCERT): Cotton boll — (a) destroyed by bollworms in a conventional cotton variety; (b) a fully mature, undamaged boll from a Bt-cotton plant. The Bt toxin gene, when expressed in cotton, makes the plant lethal to the lepidopteran larva.

Why does Bt toxin not kill *Bacillus* itself?

A clever piece of biochemistry: the toxin is synthesised as an **inactive proto-toxin** (a crystal). Only after an **insect ingests** the crystal does the **alkaline pH of the insect midgut** solubilise it into the **active toxin**. The activated toxin binds midgut epithelial cells, opens pores, causes the cells to swell and lyse — and the insect dies. The bacterium’s own cytoplasm is near-neutral, so the crystal stays inert inside the producer.

Bt-toxin activation pathway

$$\text{Crystal (inactive proto-toxin)} \xrightarrow[\text{alkaline pH}]{\text{insect midgut}} \text{active toxin}$$

$$\xrightarrow{\text{binds epithelium}} \text{pore} \rightarrow \text{cell lysis} \rightarrow \text{death}$$

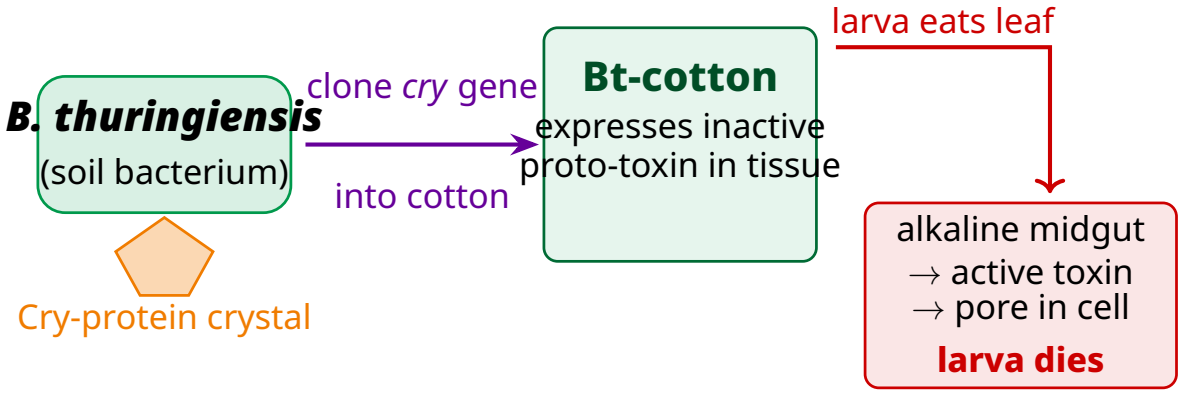
Inactive form $\Rightarrow$ safe in the bacterium and safe in the field.

The *cry* gene family

The Bt toxin gene is generally called ***cry***. Specific cry genes target specific insect groups:

- ***cryIAc*** and ***cryIIAb*** → **cotton bollworm** (Bt cotton).
- ***cryIAb*** → **corn borer** (Bt corn).

The toxin is **insect-group specific** — a cry protein that kills lepidopterans typically does not kill coleopterans or dipterans. Choice of gene depends on crop and pest.



Flow of Bt-toxin technology: from soil bacterium → transgenic cotton → insect death by gut-pore formation.

Bt cotton in India

India approved commercial Bt cotton in 2002. Within a decade, more than 90% of Indian cotton acreage was Bt cotton. Pesticide spending on the crop fell by roughly half in the early years, while yields rose. The trade-off has been the dominance of a single trait (Mon-810) and the steady emergence of pink-bollworm resistance — a textbook case of evolution acting on managed populations.

2.4 Pest-Resistant Plants by RNA Interference (RNAi)

A second route to pest resistance does not use a bacterial toxin at all — it exploits the cell's own **gene-silencing machinery**.

A nematode called *Meloidogyne incognita* infects tobacco roots and drastically cuts yield. The solution was to make the host plant produce a **double-stranded RNA (dsRNA)** that exactly matches a critical nematode mRNA. When the nematode feeds on root tissue and ingests this dsRNA, its own gene-silencing machinery destroys the matching mRNA — and the parasite cannot survive.

RNA interference (RNAi) in one sentence

RNAi is a **cellular defence mechanism** found in all eukaryotes in which a **dsRNA molecule silences a specific complementary mRNA** (preventing its translation). The natural sources of trigger dsRNA are RNA viruses and replicating transposons.

The transgenic tobacco strategy

Agrobacterium vector $\xrightarrow{\text{T-DNA transfer}}$ tobacco genome (sense + antisense)

sense mRNA + antisense mRNA $\xrightarrow{\text{base-pair}}$ dsRNA

$\xrightarrow{\text{RNAi}}$ nematode mRNA destroyed

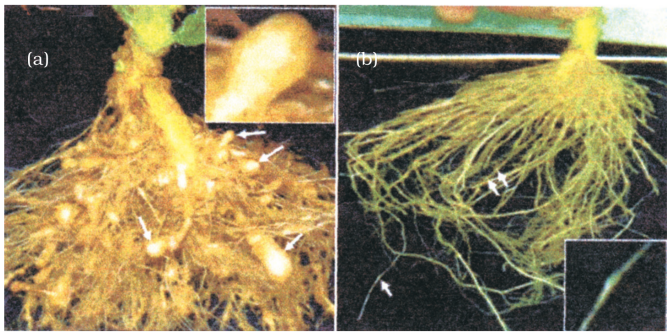
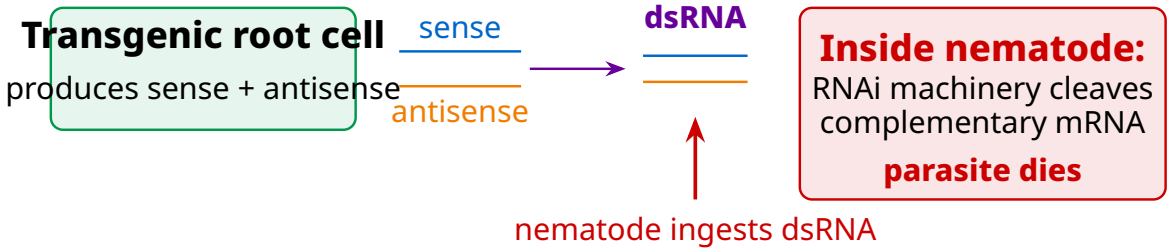


Figure 10.2 Host plant-generated dsRNA triggers protection against nematode infestation: (a) Roots of a typical control plants; (b) transgenic plant roots 5 days after deliberate infection of nematode but protected through novel mechanism.

Fig. 10.2 (NCERT): Host plant-generated dsRNA triggers protection against nematode infestation. (a) Roots of a typical control plant — visible nematode galls (arrows). (b) Transgenic plant roots 5 days after deliberate infection of nematode but protected through the novel RNAi mechanism — almost no galls.



RNAi-mediated nematode resistance: the plant feeds the parasite its own death signal.

Quick Tip

For the NEET fill-in: "the nematode *Meloidogyne incognita*" attacks **tobacco**

roots. The defence *technique* is **RNAi**. The transformation *vector* is ***Agrobacterium***. Memorising these three names buys you two MCQs.

Common Mistake

RNAi $\neq$ antisense therapy alone. Antisense is single-stranded RNA that blocks translation by binding mRNA. RNAi requires a **double-stranded** trigger that gets diced into 21–23 nt siRNA. NCERT calls the trigger "dsRNA" — write the full "**double-stranded RNA**", not just "RNA".

Solve the NCERT Exercises for this Chapter

3 Biotechnological Applications in Medicine

The 1980s ushered in a quiet revolution in pharmacy: instead of harvesting hormones and clotting factors from cadavers or animals, drug companies started **engineering bacteria and yeast** to make human proteins directly. Today about **30 recombinant therapeutics** have been approved worldwide; **12 are marketed in India**. Three NCERT case studies dominate this section — insulin, gene therapy and molecular diagnosis.

3.1 Genetically Engineered Insulin — The Eli Lilly Story

Adult-onset (Type 2) diabetes is managed by periodic injection of insulin. Before recombinant technology, insulin was **extracted from the pancreas of slaughtered cattle and pigs**. Animal-source insulin worked, but it occasionally provoked an immune reaction — the patient developed antibodies to the foreign protein.

Insulin is a small hormone made of **two short polypeptide chains**:

- **Chain A** (21 amino acids),
- **Chain B** (30 amino acids),

linked by **disulphide (S–S) bridges** — two interchain bridges between A and B, plus one intrachain bridge within A.

The C-peptide problem

In mammals (humans included), insulin is first synthesised as a single-chain **pro-hormone called pro-insulin**. Pro-insulin contains an **extra stretch called the C peptide** that holds the loop in a folding-friendly geometry. **The C peptide is cleaved off during maturation**; it is not present in the mature, active hormone. The challenge for rDNA production of insulin was assembling the two chains *without* starting from the full pro-insulin precursor.

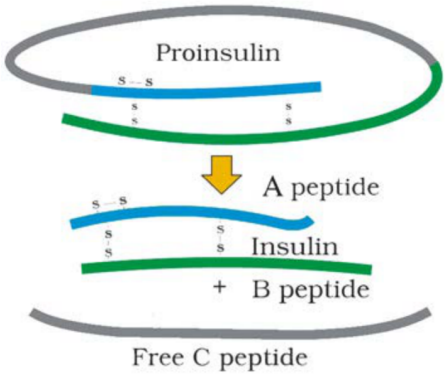


Figure 10.3 Maturation of pro-insulin into insulin (simplified)

Fig. 10.3 (NCERT): Maturation of pro-insulin into insulin (simplified). The grey loop is the C peptide that is cleaved away; the blue strand is chain A, the green strand is chain B; both are linked by S–S bonds (red dashes) in the mature insulin.

The Eli Lilly route (1983)

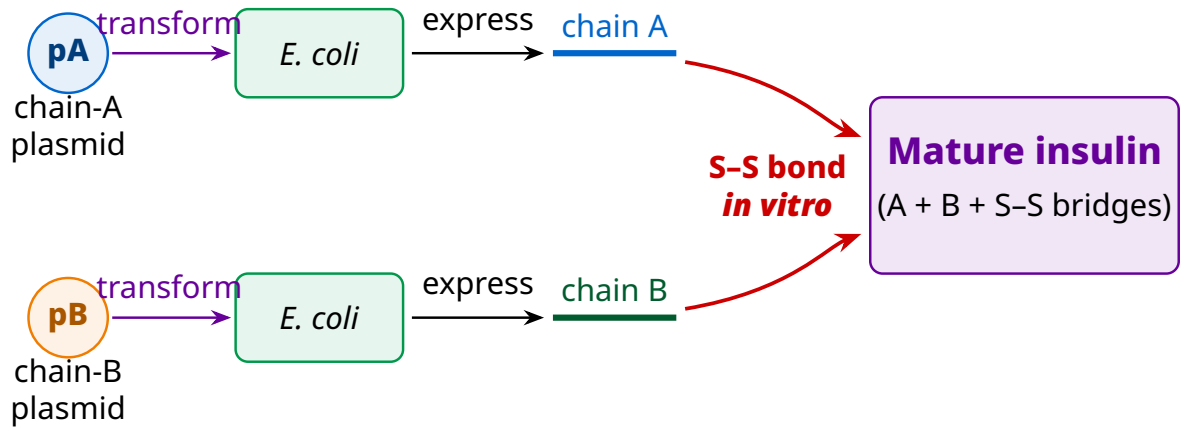
In 1983, the American company Eli Lilly engineered the first recombinant human insulin by:

1. Preparing two synthetic **DNA sequences** corresponding to chain A and chain B of human insulin.
2. Introducing each sequence into separate **plasmids of *E. coli***.
3. Letting the bacteria **produce chain A and chain B separately** as proteins.
4. Extracting both chains and combining them **in vitro by creating disulphide bonds** — giving mature human insulin.

This product (sold as **Humulin**) is biochemically *identical* to natural human insulin and does not provoke immune rejection.

Recombinant insulin — in one workflow

synthesise $cDNA_A$, $cDNA_B$ → insert into separate *E. coli* plasmids → express chain A, chain B → S–S bonding *in vitro* → mature human insulin



The Eli Lilly route: two plasmids in two E. coli *cultures, two pure chains, one in-vitro S–S coupling.*

Quick Tip

Three numbers and one company name — that is the entire MCQ stock for this topic: **1983 | Eli Lilly | two chains (A, B) | *E. coli* as host**.

Common Mistake

Students often write that "*E. coli* makes pro-insulin which is then matured". NCERT explicitly says Eli Lilly produced chains A and B **separately** and joined them **in vitro**. The C-peptide route is the natural mammalian pathway — not the engineered one.

Why insulin cannot be a pill

Insulin is a protein. Taken orally, the stomach's pepsin and intestinal proteases would digest it long before it reached the bloodstream. That is why diabetics inject (or, increasingly, inhale) insulin — the chapter's "Think About It" box hints at this point.

3.2 Gene Therapy — Curing a Defective Gene

Gene therapy is the insertion of a *healthy gene* into a person's cells and tissues to correct a hereditary disease. The goal is to give a defective cell a functional copy of the gene it is missing — so the cell can make the missing protein.

The first clinical case: ADA deficiency (1990)

The first clinical gene therapy was performed in 1990 on a 4-year-old girl suffering from **adenosine deaminase (ADA) deficiency**. ADA is an enzyme critical

for the immune system — a child without it is essentially defenceless against infections ("severe combined immunodeficiency" — SCID). The disorder is caused by the **deletion of the ADA gene**.

Two earlier (non-curative) approaches existed:

- **Bone-marrow transplantation** — works in some children, not all.
- **Enzyme replacement therapy** — functional ADA injected periodically. Works but is not curative.

The gene-therapy protocol used in 1990 was a ***ex vivo*** approach:

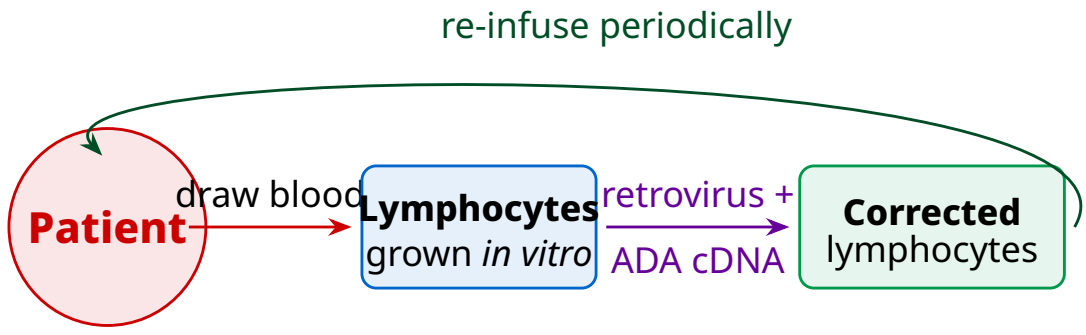
1. **Lymphocytes** were withdrawn from the patient's blood and grown in culture.
2. A **functional ADA cDNA** was inserted into the lymphocytes using a **retroviral vector**.
3. The genetically corrected lymphocytes were **returned to the patient's circulation**.

Because these mature lymphocytes are mortal, the patient needed **periodic re-infusion**. NCERT notes that a **permanent cure** would require introducing the functional ADA gene into a cell that is still in the early embryonic stage — so that all descendant cells carry the corrected gene.

ADA gene therapy — the four-step recipe

Patient blood $\rightarrow$ isolate lymphocytes
$\rightarrow$ infect with retrovirus carrying $cDNA_{\text{ADA}}$ $\rightarrow$ re-infuse

Limitation: lymphocytes die in weeks $\Rightarrow$ infusion must repeat. *Permanent* cure requires correction in bone-marrow stem cells or embryonic cells.



ADA gene therapy: an ex-vivo loop of lymphocyte correction. Not yet permanent — patients require repeat infusion every few weeks.

Quick Tip

For boards: list the **three steps** (isolate $\rightarrow$ transduce $\rightarrow$ re-infuse) and end

with the line "*not a permanent cure because lymphocytes are mortal — permanent correction needs embryonic cells*."

3.3 Molecular Diagnosis — PCR, ELISA and DNA Probes

For most diseases, early diagnosis is the single biggest determinant of cure. Conventional serum and urine analysis catch the pathogen only after symptoms have appeared — by which time the load is already enormous. **rDNA technology, PCR and ELISA** let us catch infection *before* symptoms arrive.

(a) Polymerase Chain Reaction (PCR)

PCR amplifies a target DNA sequence exponentially in a thermocycler. Even **a vanishingly small amount of viral or bacterial nucleic acid** can be doubled, redoubled, and detected by gel electrophoresis. Two NCERT applications:

- **HIV detection** in suspected AIDS patients — the standard test before symptoms.
- **Mutation detection** in suspected cancer patients and for many other genetic disorders.

Why PCR is so sensitive

After n cycles, the amount of target DNA is roughly 2^n times the starting amount. Thirty cycles can amplify a single molecule into about 10^9 copies — enough to load a gel. That is why a virus present in *copies per microlitre* can be unambiguously detected.

(b) DNA probes (autoradiography)

A **single-stranded DNA or RNA tagged with a radioactive isotope** is allowed to hybridise with its complement in a clone of cells. After autoradiography, only clones whose DNA matches the probe show up on the X-ray film. **A clone with a mutated gene does *not* appear** (the probe's complementarity is lost).

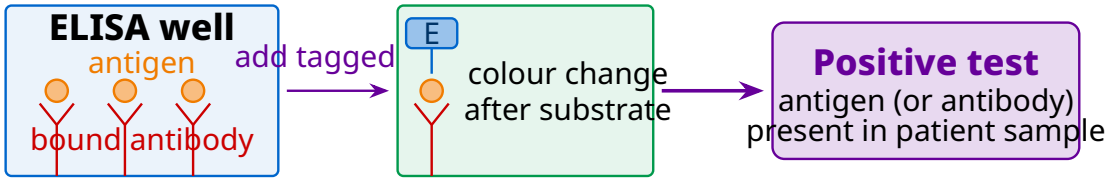
(c) Enzyme-Linked Immuno-Sorbent Assay (ELISA)

ELISA exploits **antigen–antibody specificity**. Infection can be detected in two complementary ways:

- By the **presence of the pathogen's antigens** — proteins, glycoproteins of the bacterium or virus.
- By the **presence of antibodies** that the patient's own immune system has synthesised against the pathogen.

Three diagnostic techniques at a glance

Technique	Detects	Typical use
PCR	nucleic acid (DNA/RNA)	HIV, cancer mutations
DNA probe	complementary DNA in cells	mutation screening
ELISA	antigen *or* antibody (protein)	HIV, dengue, COVID



ELISA sandwich format: bound antibody captures the antigen, a second enzyme-tagged antibody binds on top, and substrate converts to a measurable colour.

Memory Aid — "PDE" for diagnosis

PCR detects **D**NA | D-probe detects mutation | **E**LISA detects protein.
P-D-E. Three letters, three techniques, three molecular targets.

The RT-PCR that the world learnt during COVID-19

COVID-19 test reports famously read "RT-PCR positive". RT stands for **reverse transcriptase**: SARS-CoV-2 is an RNA virus, so its RNA is first converted to cDNA by RT and only then amplified by PCR. The same principle (RT + PCR) is used to detect HIV. Both viruses are retroviruses or RNA viruses in spirit — their genome must enter DNA space before amplification.

4 Transgenic Animals

Transgenic animals are animals whose DNA has been altered to carry and express an extra (foreign) gene. Rats, rabbits, pigs, sheep, cows and fish have all been engineered — but **over 95% of all transgenic animals in existence are mice**. NCERT lists five reasons why we make them.

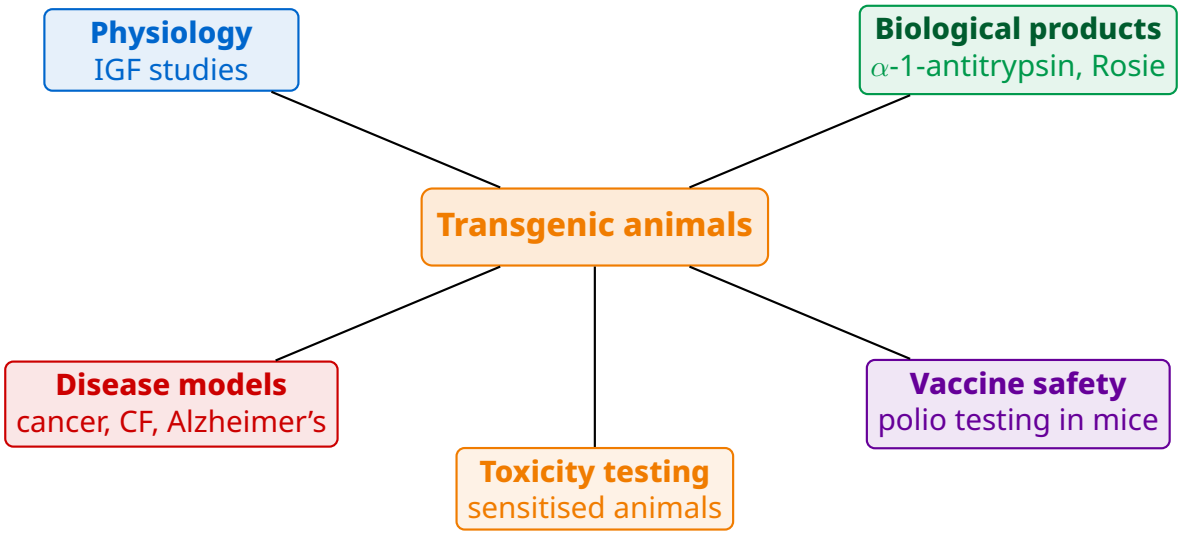
4.1 Five Reasons Animals Are Made Transgenic

1. **Normal physiology and development** — to study how genes are regulated and how they affect body function. Example: insulin-like growth factor (IGF) studies use mice carrying altered IGF formation genes.
2. **Study of disease** — transgenic models of *cancer*, *cystic fibrosis*, *rheumatoid arthritis*, *Alzheimer's* let researchers test treatments.

3. **Biological products** — animals can be engineered to secrete a human protein in milk. Example: **α-1-antitrypsin** (treats emphysema), human alpha-lactalbumin in cow milk. Other targets in development: **phenylketonuria (PKU)** and **cystic fibrosis**.
4. **Vaccine safety testing** — transgenic mice can replace monkeys in testing polio-vaccine batches.
5. **Chemical / toxicity safety testing** — animals carrying genes that make them *more sensitive* to toxic substances allow faster, more sensitive toxicity assays.

The flagship case: Rosie the cow (1997)

In 1997 the world's first transgenic cow, **Rosie**, produced milk enriched in **human protein alpha-lactalbumin (2.4 grams per litre)**. The milk was a more nutritionally balanced food for human babies than ordinary cow milk. Rosie is the textbook example of a transgenic animal used as a "biological product factory".



The five NCERT roles of a transgenic animal — worth memorising as one diagram for the 5-mark board question.

Memory Aid — "PDBVT"

Physiology | **D**isease model | **B**iological products | **V**accine safety | **T**oxicity testing.
Five reasons; five letters; aces every "Why make transgenic animals?" question.

Quick Tip

NEET-only one-liner: "95% of all transgenic animals are **mice**." This MCQ has appeared three times in five years.

Pharming — animals as drug factories

Beyond Rosie, transgenic goats secreting recombinant antithrombin (drug name: ATryn, FDA-approved 2009) treat patients with hereditary antithrombin deficiency. The general term for using transgenic livestock as bioreactors is *pharming* — a portmanteau of pharma and farming. NCERT does not name the term, but it is fair game in NEET PYQs.

5 Ethical Issues, GEAC and Biopiracy

The fourth section of the chapter is a deliberate counterweight to the previous three. The same toolkit that gives us insulin and Bt cotton can also generate ecological surprises, social inequities, and intellectual-property disputes. NCERT highlights three concerns: **ecological unpredictability, regulatory oversight (GEAC), and biopiracy**.

5.1 Ecological Unpredictability

When you release a genetically modified organism into the open ecosystem, the consequences are **not always predictable**. Examples NCERT alludes to: gene flow from GM crops to wild relatives; insect resistance to the Bt toxin; non-target effects on beneficial insects. Hence **regulation is essential before any GM release**.

5.2 GEAC — India's Regulatory Body

The **Genetic Engineering Approval Committee (GEAC)** was set up by the Indian Government to:

- **Validate the safety** of GM research being undertaken in India.
- **Approve or refuse** the introduction of GM organisms into the public domain (food crops, drugs, environmental release).

Why GEAC sits at the top of the GM food chain

Any Indian institute or company wanting to test, field-trial or commercially release a GM organism must apply to GEAC. The 2002 Bt-cotton release and the 2010 Bt-brinjal *moratorium* (still in force) are both GEAC decisions. Knowing the *full form* of the acronym is the standard MCQ.

Quick Tip

GEAC = **G**enetic **E**ngineering **A**pproval **C**ommittee. NCERT spells out the acronym in section 10.4 — learn it letter-perfect.

5.3 Biopiracy and the Patent Wars

Biopiracy is the use of bio-resources (and the associated traditional knowledge) by multinational companies or other organisations **without proper authorisation and without compensatory payment** to the country and the people that originally developed them.

The classic NCERT case studies:

- **Basmati rice (1997)** — an American company obtained a US patent on a "new" Basmati variety that had been derived by crossing Indian farmer varieties with semi-dwarfs. The 27 documented Basmati varieties of India had been grown for centuries.
- **Turmeric (haldi)** — patent applications on wound-healing uses of turmeric had to be challenged on the basis of centuries of traditional Indian use.
- **Neem** — similar patent challenges over anti-fungal and pesticidal uses.

Why biopiracy persists

Industrialised nations are typically **rich financially but poor in biodiversity**; the developing world is the opposite — **rich in biodiversity and traditional knowledge but financially weaker**. Without strong patent laws and active vigilance, the genetic and traditional wealth of a country can be appropriated, repackaged, and sold back at a premium.

India's response: the Indian Parliament has cleared the **second amendment of the Indian Patents Bill** taking into account patent terms, emergency provisions, and research/development initiatives, so that traditional knowledge can be safeguarded.

Case	Bio-resource involved	Issue
Basmati patent (1997)	27 Indian varieties of Basmati rice	US company patented a "new" Basmati derived from Indian farmer varieties
Turmeric (haldi)	Wound-healing properties of turmeric	Patent applications challenged — centuries of Indian traditional use
Neem	Pesticidal/antifungal extracts	Patent applications challenged on traditional-knowledge grounds

The three flagship biopiracy disputes that NCERT names by example.

Common Mistake

Biopiracy is **not** the smuggling of biological samples across borders. NCERT defines it as the *use of bio-resources without authorisation or compensation*. "Smuggling" is biopiracy only when accompanied by patenting / commercialisation without consent.

Nagoya Protocol — the global response

At the international level, the **Nagoya Protocol (2010)** on Access and Benefit-Sharing now requires that any commercial use of genetic resources from a country must be authorised by — and benefits shared with — that country. India is a signatory. The protocol is the global counterpart of the Indian Patents Bill amendment.

6 NEET / JEE Extensions [Beyond NCERT]

The bullets below are exam-relevant facts that go a little beyond the printed NCERT chapter but appear regularly in NEET and AIIMS papers.

6.1 Extra Transgenic / GM Facts

- **Flavr Savr tomato (1994)** — the first commercial GM crop, engineered for delayed ripening using *antisense* polygalacturonase RNA.
- **Golden rice** — carries three transgenes (*psy* from daffodil/maize + *crtI* from *Erwinia uredovora*) to make β-carotene (provitamin A) in the endosperm. NCERT names golden rice but does not give the genes.
- **Bt brinjal** — received GEAC approval in 2009 but was placed under a **moratorium** in 2010 after public opposition.
- **T-DNA region of the Ti plasmid** of *Agrobacterium tumefaciens* is the workhorse vector for dicot transformation. Monocots are usually transformed by **biolistics (gene gun)**.
- **First transgenic animal** = the "**super mouse**" (1982, Palmiter and Brinster) carrying the rat growth-hormone gene.

6.2 Diagnostic-Technique Numbers

- **PCR steps and temperatures**: denaturation $\sim 94^{\circ}$C, annealing ~ 54–60°C, extension $\sim 72^{\circ}$C. The enzyme is ***Taq* polymerase** from *Thermus aquaticus*.
- **ELISA variants**: direct, indirect, sandwich, competitive. Sandwich ELISA is the COVID antigen test format.
- **Western blot** (protein detection by antibody) confirms an ELISA-positive HIV result — not in NCERT but appears in NEET PYQs.

6.3 Recombinant Therapeutic Drugs (Beyond Insulin)

- **Human growth hormone** (somatotropin) — used to treat pituitary dwarfism.
- **Recombinant Factor VIII** — replaces the missing clotting factor in haemophilia A.
- **Hepatitis B vaccine** — recombinant surface antigen produced in yeast; first recombinant vaccine (1986).
- **Erythropoietin (EPO)** — treats anaemia of kidney failure.

Quick Tip

NEET PYQ favourites: "First recombinant vaccine" = **Hepatitis B**. "First transgenic cow" = **Rosie** (1997). "First clinical gene therapy" = **ADA deficiency, 1990, 4-year-old girl**. "First Bt-toxin source" = ***Bacillus thuringiensis***.

CRISPR — the next chapter of this chapter

Bt cotton uses bacterial *cry* genes; RNAi uses dsRNA. The newest layer is **CRISPR/Cas9**, a precise DNA-editing system. It is not in the 2026-27 NCERT but is now mentioned routinely in NEET keyword lists. Watch for it as a future "which technology is genome editing?" MCQ.

7 Quick Reference Summary

A one-page table to revise the morning of the exam.

Topic	Key organism / molecule	Application / outcome
Tissue culture	Any explant + auxin + cytokinin	Micropropagation, virus-free plants
Somatic hybridisation	Tomato + Potato protoplast	"Pomato" (proof of concept)
Bt toxin	*Bacillus thuringiensis*	Bt cotton (*cryIAc, cryIIAb*), Bt corn (*cryIAb*)
RNAi pest resistance	Tobacco vs *Meloidogyne incognita*	dsRNA silences nematode mRNA
Recombinant insulin	*E. coli* + chain A + chain B	Eli Lilly, 1983 (Humulin)
Gene therapy	Retroviral vector + ADA cDNA	1990, 4-y-old girl, ADA deficiency
PCR	*Taq* polymerase	Detect HIV, cancer mutations
ELISA	Antigen–antibody binding	Detect HIV antigens *or* antibodies

Topic	Key organism / molecule	Application / outcome
DNA probe	Radiolabelled ss-DNA/RNA	Detect mutated genes (autoradiography)
Transgenic cow	Rosie (1997)	Human α-lactalbumin in milk
Transgenic mouse	95% of all transgenic animals	Disease models, vaccine + toxicity testing
GEAC	Indian Government body	Approves all GM research/release
Biopiracy	Basmati, turmeric, neem	Patents on traditional bio-resources

Five must-know facts

1. **Bt toxin is inactive in the bacterium** (crystal) and **activated in the insect midgut** (alkaline pH).
2. *cryIAc* and *cryIIAb* kill **cotton bollworm**; *cryIAb* kills **corn borer**.
3. **Eli Lilly (1983)** produced insulin chains A and B **separately in *E. coli*** and joined them in vitro by S–S bonds.
4. **First clinical gene therapy: 1990, 4-y-old girl, ADA deficiency, retroviral vector, ex-vivo lymphocytes.**
5. **GEAC = Genetic Engineering Approval Committee.** Govt of India regulator for GMO research and release.

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- NCERT Solutions
- Formula Sheet
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Continue learning:

- Ch 9: Biotechnology - Principles and Processes
- Ch 11: Organisms and Populations
- Class 12 Biology — All Chapters

End of Chapter 10 Notes — Biotechnology and its Applications. Class 12 Biology — NCERT 2026-27.