BP403T · B.PHARM THEORY

BP403T Pharmaceutical Biotechnology

Unit V — Immunology, Vaccines & Sera

Pills & Python Notes

From-zero teaching standard: every technical term is defined before use.

Syllabus coverage: Unit V (9 hours).

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Chapter 9 — Basics of Immunology, Vaccine Types and Immunization Strategies

9.1 Learning Objectives

1. Define immunity and its types.
2. Describe cells and molecules of the immune system.
3. Classify vaccines by type and generation.
4. Explain immunization strategies (schedules, herd immunity).
5. Distinguish active vs passive immunity.

9.2 Definitions

- **Immunity:** The body's ability to resist and fight infections.
- **Innate immunity:** Inborn, instant, non-specific defence (skin, stomach acid, phagocytes, inflammation) — the security guards.
- **Adaptive immunity:** Learned, specific, memory-based defence (B-cells make antibodies; T-cells kill infected cells) — the trained special force.
- **Vaccine:** A preparation that trains adaptive immunity without causing the disease — showing the body a safe preview of the enemy.
- **Herd immunity:** When enough people are immune, the germ cannot spread — protecting even those who cannot be vaccinated.

9.3 Terminology

- **Humoral immunity:** Antibody-based (B-cells) — fights germs in blood and fluids.
- **Cell-mediated immunity:** T-cell-based — kills infected or cancerous cells.
- **Memory cells:** Long-lived B/T cells that remember the enemy and respond fast on re-exposure (the reason vaccines give lasting protection).
- **Adjuvant:** A helper substance added to vaccines (e.g., aluminium salts) that strengthens the immune response.
- **Booster dose:** A later repeat dose that refreshes immune memory.

9.4 Explanation

How immunity works (the short story): Innate defences act in minutes. If the invader survives, dendritic cells carry its pieces to lymph nodes, show them to T and B cells, and the adaptive army builds specific weapons (antibodies, killer T-cells) plus memory cells. Next time the same germ comes, memory cells strike within hours — that is why second infections are milder or silent.

Active vs passive immunity: Active = your body makes its own defence (after infection or vaccination) — slow to build, long-lasting. Passive = ready-made antibodies given to you (mother's milk/colostrum, or sera/antiserum injections) — instant but short-lived.

Types and generations of vaccines:

1. **First generation — live-attenuated:** Weakened whole germ (e.g., BCG for TB, OPV for polio, MMR). Strong, long immunity; not for weak immune systems.
2. **First generation — inactivated (killed):** Dead whole germ (e.g., IPV for polio, rabies vaccine). Safer; may need boosters.
3. **Second generation — subunit/toxoid:** Only a piece (Hep-B surface protein) or detoxified toxin (tetanus/diphtheria toxoids). Very safe.
4. **Third generation — recombinant/DNA and mRNA:** Instructions for the antigen delivered as DNA or mRNA (e.g., COVID-19 mRNA vaccines) — fast to design, no live germ.

Immunization strategies:

- **Routine schedules:** National programmes (India's Universal Immunization Programme) give vaccines at fixed ages (birth, 6/10/14 weeks, 9 months, etc.).
- **Catch-up and campaigns:** Pulse polio rounds, measles-rubella campaigns to cover missed children.
- **Ring vaccination:** Vaccinating contacts around each case (used in outbreak control).
- **Herd immunity target:** Coverage must stay high; when it drops, diseases return.

> **Analogy:** Vaccination is a fire drill — the building (body) practises evacuation (immune response) with a fake alarm (safe antigen), so when a real fire (infection) comes, everyone knows exactly what to do.

> **Key takeaway:** Immunity is innate (fast, general) plus adaptive (specific, with memory). Vaccines safely create memory via live-attenuated, inactivated, subunit/toxoid, or nucleic-acid platforms. Strategy = routine schedules + campaigns + herd immunity.

9.5 Classifications

- Immunity: innate | adaptive (humoral + cell-mediated); active | passive (natural | artificial).
- Vaccines: live-attenuated | inactivated | subunit/recombinant | toxoid | nucleic acid (DNA/mRNA).
- Strategies: routine | catch-up | campaign | ring vaccination.

9.6 Mechanisms

Memory response (conceptual): First exposure → naive B-cells activate slowly (days), make IgM then IgG, some become memory cells → second exposure → memory cells activate in hours, flood the body with high-affinity IgG → germ cleared before symptoms.

9.7 Diagrams (describe for drawing)

- Draw primary vs secondary immune response curves: slow low peak (first dose) vs fast high peak (booster).
- Draw the four vaccine generations as four panels: weakened germ, dead germ, protein piece, mRNA instruction.

9.8 Flowcharts

> **Vaccination logic:** Safe antigen → Dendritic cell presents → B/T cell activation → Antibodies + memory → Future real infection blocked fast.

9.9 Infographic Concept Box

🛡️ **TRAIN BEFORE THE BATTLE:** Innate = guards (fast). Adaptive = special force (specific + memory). Vaccines: weakened germ | killed germ | protein piece | mRNA instructions. Strategy: routine schedule + catch-up campaigns + herd immunity shield. Active = you learn (lasting); passive = borrowed antibodies (instant, brief).

9.10 Tables

Vaccine type	Example	Live?
Live-attenuated	BCG, OPV, MMR	Yes (weakened)
Inactivated	IPV, rabies	No
Subunit/toxoid	Hep-B, tetanus toxoid	No
mRNA	COVID-19 mRNA vaccines	No

Feature	Active immunity	Passive immunity
Made by	Your own body	Given ready-made
Speed	Slow (days–weeks)	Instant
Duration	Long (memory)	Short (weeks–months)

9.11 Examples

- A newborn in a PHC receives BCG, OPV and Hep-B at birth per the national schedule.
- Tetanus antiserum (passive) is given immediately after a dirty wound, while tetanus toxoid (active) builds long-term protection.

9.12 Analogies

- Adjuvant as the loudspeaker that makes sure the immune "audience" hears the vaccine's message.

9.13 Pharmacy Relevance

- Pharmacists maintain vaccine cold chain, follow immunization schedules, counsel hesitant parents with facts, and report adverse events following immunization (AEFI).

9.14 India Context

- India's Universal Immunization Programme is among the world's largest, covering millions of infants; pulse polio campaigns made India polio-free — a landmark public-health victory.

9.15 Key Points

1. Innate = fast/general; adaptive = specific/with memory (B-cells → antibodies, T-cells → killers).
2. Active immunity (vaccine/infection) is lasting; passive (sera, maternal) is instant but brief.
3. Vaccine generations: live-attenuated, inactivated, subunit/toxoid, nucleic acid.
4. Strategies: routine schedules, catch-up, campaigns, ring vaccination, herd immunity.
5. Memory cells explain why boosters work fast.

9.16 Common Confusions

- **Vaccination vs immunization:** Vaccination = giving the vaccine; immunization = the resulting protection (usually, but not always, achieved).
- **Live vs inactivated:** Live contains weakened germ (stronger, avoid in immunocompromised); inactivated is dead (safer, needs boosters).

9.17 Common Mistakes

- Saying vaccines "give you the disease" — they give safe antigens; mild fever after vaccination is the immune system training, not the disease.
- Confusing adjuvant with preservative — adjuvant boosts response; preservative prevents contamination.

9.18 Mnemonics

- Generations: **"L-I-S-N"** — Live, Inactivated, Subunit, Nucleic acid ("Let's Immunize Safely Now").

9.19 Exam Summary

Immunity comprises innate (immediate, non-specific) and adaptive (specific, memory-based; humoral and cell-mediated) arms. Vaccines generate active immunity through live-attenuated, inactivated, subunit/toxoid or nucleic-acid platforms, each with distinct safety and dosing profiles. Immunization strategies combine routine schedules, catch-up drives, campaigns and ring vaccination to achieve herd immunity. Passive immunity via sera gives instant, temporary protection.

9.20 One-Minute Revision

⚡ Innate = guards, adaptive = special force + memory. Vaccines L-I-S-N: live, inactivated, subunit, nucleic acid. Active = lasting, passive = instant/brief. Strategy: schedule + campaigns + herd shield.

9.21 Exam Questions

Short answer:

1. Define herd immunity.
2. Distinguish active and passive immunity.
3. What is an adjuvant? Give an example.
4. Why do inactivated vaccines need boosters?

Long answer:

1. Classify vaccines with examples, merits and demerits of each type.
2. Describe the cells and mechanisms of adaptive immunity and how vaccines exploit them.

MCQs:

1. BCG is a: (a) killed vaccine (b) live-attenuated vaccine (c) toxoid (d) mRNA vaccine — Answer: (b)
2. Tetanus vaccine is a: (a) live vaccine (b) toxoid (c) mRNA (d) serum — Answer: (b)
3. Passive immunity is: (a) long-lasting (b) instant but short-lived (c) only natural (d) only from vaccines — Answer: (b)

Viva:

1. Why are live vaccines avoided in immunocompromised patients? (Even weakened germs can cause disease when immunity is very low.)

Application-based:

1. A mother fears the MMR vaccine will give her child measles. How do you counsel her? (Explain attenuated = weakened, cannot cause disease in healthy children; mild fever/rash shows immunity building; benefits far outweigh risks.)

9.22 References

- Kuby Immunology. W. H. Freeman.
- Janeway, C. A. Janeway's Immunobiology. Garland Science.
- Plotkin, S. A. Plotkin's Vaccines. Elsevier.

Chapter 10 — Vaccine and Sera: Preparation, Evaluation, Standardization, Regulation, Marketed Products and Newer Approaches

10.1 Learning Objectives

1. Outline steps in vaccine preparation and manufacture.
2. Describe evaluation (potency, safety) and standardization of vaccines.
3. Explain regulatory aspects of vaccines and sera.
4. Describe sera therapy and its products.
5. List marketed products, challenges and newer approaches.

10.2 Definitions

- **Standardization:** Making every batch meet fixed specifications for identity, purity, potency and safety.
- **Potency assay:** The test proving each batch is strong enough to protect.
- **Cold chain:** The unbroken refrigerated (2–8 °C for most vaccines; frozen for some) storage and transport network from factory to patient.
- **Sera therapy (serotherapy):** Treating with serum containing ready-made antibodies (antiserum) — passive immunity as medicine.
- **AEFI:** Adverse Event Following Immunization — any medical event after vaccination, investigated for cause.

10.3 Terminology

- **Seed lot system:** Master and working stocks of the production organism/cell — every batch starts from the same tested seed (consistency's foundation).
- **In-process controls:** Tests done during manufacture (not just at the end).
- **Lot release:** Official approval of each batch before sale — for vaccines, often by a national control laboratory.
- **Pharmacovigilance (vaccines):** Monitoring safety after launch, including AEFI surveillance.
- **Antivenom:** Serum with antibodies against snake venom — the classic sera-therapy product.

10.4 Explanation

Vaccine preparation (the manufacturing story):

1. **Seed and culture:** Start from a tested master seed (virus, bacterium or recombinant cell).
2. **Growth/production:** Grow in eggs, cell culture or fermenters (for recombinant proteins).
3. **Harvest and purification:** Separate the antigen; inactivate or attenuate as per type.
4. **Formulation:** Add adjuvant, stabilizers; fill into vials/syringes aseptically.
5. **QC battery:** identity, purity, potency (animal/cell assay or validated alternative), safety (sterility, endotoxin, general safety), stability.

Evaluation and standardization: Each batch must prove: it IS the right antigen (identity), it is clean (purity/sterility), it is strong enough (potency vs a reference standard), and it is safe. Reference standards let labs worldwide compare results. Stability studies fix the expiry date and storage conditions.

Regulatory aspects (cautious wording): Vaccines are among the most tightly regulated medicines: manufacturing needs licences and GMP compliance; each batch is tested and released (lot-release by national control laboratories in many countries, including India's system); clinical trials follow phased evaluation before approval; post-marketing AEFI surveillance continues lifelong. Always refer to current national regulatory guidelines for exact requirements.

Sera therapy: When there is no time to wait for active immunity — snakebite, rabies exposure, tetanus-prone wounds, diphtheria — ready-made antibodies in antiserum/antivenom neutralize the toxin or venom immediately. Made by immunizing animals (classically horses) and purifying the antibodies; human immunoglobulins are preferred where available to reduce serum-sickness reactions.

Marketed products (categories): childhood vaccines (BCG, OPV/IPV, pentavalent, MMR, Hep-B), adult vaccines (tetanus, influenza, HPV, COVID-19), antisera/antivenoms (snake antivenom, rabies immunoglobulin, tetanus antiserum), and immunoglobulin preparations.

Challenges: cold-chain gaps in remote areas, vaccine hesitancy fuelled by misinformation, high cost of newer vaccines, emerging pathogens needing rapid platforms, and equitable access.

Newer approaches: mRNA platforms (rapid redesign for variants), virus-like particles, needle-free delivery (nasal sprays, microneedle patches), thermostable formulations reducing cold-chain dependence, and combination vaccines cutting the number of injections.

> **Analogy:** Lot-release is like a driving licence test for every single batch — no licence, no road (market), no matter how good the driving school (manufacturer).

> **Key takeaway:** Vaccines are made under the strictest manufacturing and batch-release discipline (seed → produce → purify → formulate → test → release), guarded by cold chain and AEFI surveillance. Sera give instant passive protection for emergencies like snakebite and rabies. Newer platforms (mRNA, patches, thermostable forms) aim to beat the old challenges.

10.5 Classifications

- QC tests: identity | purity | potency | safety | stability.
- Sera products: antivenoms | antitoxins (diphtheria, tetanus) | immunoglobulins (rabies, hepatitis).
- Challenges: logistic (cold chain) | social (hesitancy) | economic (cost) | scientific (new pathogens).

10.6 Mechanisms

Antivenom action (conceptual): Venom toxins circulate → infused antibodies bind toxins specifically → toxin–antibody complexes are cleared by the body → tissue damage stops. Speed matters: give as early as possible.

10.7 Diagrams (describe for drawing)

- Draw the vaccine factory pipeline: seed → culture → harvest → purify → formulate → fill → QC → lot release → cold chain → clinic.
- Draw the cold chain: factory freezer → refrigerated truck → district store → PHC ice-lined fridge → vaccination session (vaccine carrier).

10.8 Flowcharts

> **Batch release:** Manufacture → In-process tests → Final QC (identity/purity/potency/safety) → National control lab lot-release → Market → AEFI surveillance.

10.9 Infographic Concept Box

💉 **FROM FACTORY TO ARM:** Seed → grow → purify → formulate → test (identity, purity, potency, safety) → lot release → cold chain (2–8 °C) → clinic. Sera = borrowed antibodies for emergencies (snakebite, rabies). Future: mRNA speed, patches instead of needles, vaccines that survive heat.

9.10 Tables — (see 10.10)

10.10 Tables

QC test	Question answered
Identity	Is it the right antigen?
Potency	Is it strong enough to protect?
Sterility/endotoxin	Is it safe to inject?
Stability	Good till expiry?

Product	Type	Use
Pentavalent vaccine	Combination	Childhood immunization
Snake antivenom	Serum	Snakebite emergency
Rabies immunoglobulin	Serum	Post-exposure prophylaxis
Tetanus antiserum	Serum	Dirty wounds (with toxoid for lasting cover)

10.11 Examples

- A PHC nurse carries vaccines in an ice-packed carrier to a village session, checking the vaccine vial monitor for heat damage.
- A farmer bitten by a viper receives polyvalent antivenom at the district hospital within hours.

10.12 Analogies

- Cold chain as a relay race where the baton (vaccine) must never leave the ice box between runners.

10.13 Pharmacy Relevance

- Pharmacists are cold-chain guardians: monitor refrigerators, never freeze freeze-sensitive vaccines, track expiry, report AEFI, counsel on schedules, and stock antisera for emergencies.

10.14 India Context

- India manufactures a large share of the world's vaccines (major producers in Hyderabad and Pune), runs one of the largest immunization programmes, and produces polyvalent snake antivenom suited to Indian snake species.

10.15 Key Points

1. Vaccine manufacture: seed → production → purification → formulation → fill → QC → lot release.
2. Every batch: identity, purity, potency, safety, stability — released officially before sale.
3. Cold chain (mostly 2–8 °C) must never break; AEFI surveillance never stops.
4. Sera = ready-made antibodies for emergencies (antivenom, rabies immunoglobulin, antitoxins).
5. Newer approaches: mRNA platforms, needle-free delivery, thermostable vaccines, combinations.

10.16 Common Confusions

- **Antiserum vs vaccine:** Antiserum gives instant borrowed antibodies (passive, short); vaccine trains your own immunity (active, long).
- **Potency vs safety testing:** Potency = does it work strongly enough; safety = does it cause no harm. Both compulsory.

10.17 Common Mistakes

- Storing all vaccines in a freezer — most need 2–8 °C; freezing destroys freeze-sensitive vaccines (e.g., aluminium-adjuvanted ones).
- Thinking one QC test at the end is enough — in-process controls run throughout manufacture.

10.18 Mnemonics

- Batch QC: **"I-P-P-S-S"** — Identity, Purity, Potency, Safety, Stability ("I Protect People Safely, Surely").

10.19 Exam Summary

Vaccine manufacture follows seed-lot discipline through production, purification, formulation and aseptic filling, with in-process and final QC (identity, purity, potency, safety, stability) and official lot release before marketing. Regulation covers GMP licensing, phased trials and lifelong AEFI surveillance; pharmacists uphold the 2–8 °C cold chain. Sera therapy provides immediate passive immunity via antivenoms, antitoxins and immunoglobulins for emergencies. Challenges include cold-chain gaps, hesitancy and cost; newer approaches feature mRNA platforms, needle-free and thermostable vaccines.

10.20 One-Minute Revision

⚡ Make: seed → grow → purify → fill. Test: I-P-P-S-S. Release officially. Keep cold (2–8 °C). Watch AEFI. Sera = emergency borrowed antibodies. Future: mRNA, patches, heat-stable.

10.21 Exam Questions

Short answer:

1. What is lot release?
2. Define cold chain and AEFI.
3. When is sera therapy preferred over vaccination?
4. Name two Indian-relevant marketed sera products.

Long answer:

1. Describe the preparation, evaluation and standardization of vaccines.
2. Discuss sera therapy: products, preparation principle, uses and limitations.

MCQs:

1. Most vaccines are stored at: (a) –20 °C (b) 2–8 °C (c) room temp (d) 37 °C — Answer: (b)
2. Snake antivenom provides: (a) active immunity (b) passive immunity (c) no immunity (d) lifelong memory — Answer: (b)
3. Lot release is done: (a) before manufacture (b) per batch before marketing (c) once per year (d) never — Answer: (b)

Viva:

1. Why must aluminium-adjuvanted vaccines not be frozen? (Freezing damages the adjuvant gel structure and reduces potency.)

Application-based:

1. A PHC refrigerator shows 12 °C on Monday morning. What do you do about the vaccine stock? (Quarantine stock, label "do not use", check vial monitors and temperature logs, inform the medical officer, follow national cold-chain protocol — do not use heat-exposed vaccines without clearance.)

10.22 References

- Plotkin, S. A. Plotkin's Vaccines. Elsevier.
- Kuby Immunology. W. H. Freeman.
- Crommelin, D. J. A., Sindelar, R. D. and Meibohm, B. Pharmaceutical Biotechnology: Fundamentals and Applications. Springer.