BP307T · B.PHARM SEMESTER III

BP307T Pharmaceutical Engineering

Unit I — Size Reduction, Size Separation & Mixing

Pills & Python Notes

Unit Operations Associated with Solids

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UNIT I — Unit Operations Associated with Solids

CHAPTER 1: Size Reduction and Size Separation

1.1 Learning objectives

After studying this chapter you will be able to:

1. Define size reduction and size separation in your own words.
2. Explain the four mechanisms of size reduction — impact, attrition, compression, and cutting.
3. Describe the construction and working of the ball mill, hammer mill, fluid energy mill, edge runner mill, and cutter mill.
4. Compare size-reduction equipment using advantages–disadvantages tables.
5. Explain sieve numbers, sieve standards, and the methods of agitating sieves.
6. Describe the construction and working of the cyclone separator, air separator, bag filter, and elutriation tank.
7. State the pharmaceutical applications of each equipment in this chapter.

1.2 Definitions

- **Size reduction (comminution):** Breaking a large solid drug or excipient into smaller pieces (powder).
- **Size separation:** Dividing a powder into fractions according to particle size — keeping the required size and rejecting the rest.
- **Unit operation:** A single physical step in manufacturing (like size reduction, mixing, filtration) that can be studied separately. Pharmacy factories are built from chains of unit operations.
- **Degree of size reduction:** Feed size ÷ product size (how many times smaller the powder became).
- **Comminution:** The technical name for size reduction (from the Latin for "to break into small pieces").

1.3 Terminology you must know first

Term	Simple meaning
Impact	Breaking by a sudden hit, like a hammer on a stone
Attrition	Breaking by rubbing particles against each other, like grinding wheat between stones
Compression	Breaking by slow squeezing, like cracking a nut in a door
Cutting	Breaking by sharp blades, like a kitchen knife on vegetables
Mesh	Number of openings per inch in a sieve — mesh 60 means 60 openings in one inch
Oversize	Powder that stays on top of the sieve (too big)
Undersize	Powder that passes through the sieve (fine enough)
Sieve analysis	Shaking powder through a stack of sieves to find how much of each size is present
Critical speed (ball mill)	Speed at which balls stick to the mill wall by centrifugal force and no grinding happens
Elutriation	Separating fine and coarse particles using a rising stream of air or water

1.4 Introduction — why do we make powders smaller in pharmacy?

Technical concept: Reducing the particle size of a drug increases its surface area, and most physical processes in pharmacy depend on surface area.

Simple explanation: Take one sugar cube and crush it. The total sugar is the same, but the crushed powder dissolves in tea in seconds while the cube takes a minute. The same happens with medicines: smaller drug particles dissolve faster, and faster dissolving often means faster and better absorption of the drug in the body.

Example: Griseofulvin (an antifungal drug) dissolves very poorly in water. When it is ground to a very fine powder, its absorption in the stomach improves so much that a smaller dose works — this is why micronized (very finely ground) griseofulvin tablets exist.

Key takeaway: Size reduction → more surface area → faster dissolution → better drug action. That is why it is the first operation in almost every tablet and capsule factory.

1.5 Classification of size-reduction mechanisms

Size reduction mechanisms
├── Impact (sudden hit) → Hammer mill, ball mill (at high speed)
├── Attrition (rubbing) → Ball mill (at low speed), colloid mill
├── Compression (squeezing) → Edge runner mill, end runner mill
└── Cutting (sharp blades) → Cutter mill

Mnemonic: "I Ate Cold Cake" — **I**mpact, **A**ttrition, **C**ompression, **C**utting.

1.6 BALL MILL

What it does (one line): A rotating cylinder filled with heavy balls that crush and grind material into a fine powder.

Principle: Impact and attrition. When the cylinder rotates, the balls are lifted up and fall down on the material (impact); at lower speeds the balls roll over the material and rub it (attrition).

Construction (sketch this):

- A hollow cylinder (metal or porcelain), mounted horizontally, with a lid for loading and unloading.
- Inside: heavy balls of steel, flint, or porcelain (about one-third of the cylinder volume is filled with balls).
- The cylinder rotates on its long axis, driven by a motor.
- There are trunnions (shaft ends) on both sides for rotation.

Working (numbered steps):

1. Load the coarse material and balls into the cylinder through the lid and close it.
2. Start the motor; the cylinder rotates at 60–75% of its critical speed.
3. The balls cascade down over the material — impact breaks large particles, attrition grinds them finer.
4. Run until the required fineness is reached; open the lid and unload the powder.

Advantages vs disadvantages:

Advantages	Disadvantages
Gives a very fine powder (down to about 20–30 microns in the closed mill)	Slow — grinding can take many hours
Can grind wet or dry material (wet grinding reduces dust and heat)	Noisy and high power consumption
Suitable for sterile products (closed system keeps microbes out)	Wears out the balls and cylinder — metal contamination possible
Simple to operate and clean	Not suitable for soft, sticky, or fibrous material

Pharmaceutical applications: Grinding of drugs and excipients for tablets and capsules; milling of ointment bases; size reduction of hard crystalline drugs like paracetamol.

> **Key takeaway:** Ball mill = rotating cylinder + falling balls → very fine powder by impact and attrition.

1.7 HAMMER MILL

What it does (one line): High-speed swinging hammers smash brittle material into powder in seconds.

Principle: Impact. Hammers attached to a fast-rotating disc strike the material repeatedly until the particles are small enough to pass through a screen at the bottom.

Construction (sketch this):

- A steel casing (housing) with a feed inlet (hopper) on top.
- Inside: a rotor (disc) carrying 4–8 hammers, hinged so they swing freely; the rotor spins at very high speed (up to about 10,000 rpm in some designs).
- Below the rotor: a removable screen/sieve that sets the final particle size.

Working (numbered steps):

1. Feed coarse material through the hopper into the casing.
2. The rotor spins; swinging hammers hit the particles again and again (impact).
3. Particles are also flung against the casing wall and break further.
4. When particles are small enough to pass the bottom screen, they fall out; bigger ones stay inside until hammered enough.

Advantages vs disadvantages:

Advantages	Disadvantages
Very fast — continuous process, large output	Generates heat — not suitable for heat-sensitive (thermolabile) drugs
Handles almost all brittle materials	Very noisy and dusty
Output size easily changed by changing the screen	Fibrous or sticky materials choke the hammers and screen
Relatively low cost machine	Fine dust can be an explosion hazard

Pharmaceutical applications: Milling of dry granules before tablet compression; size reduction of dried plant material (crude drugs); breaking agglomerates in bulk powders.

> **Key takeaway:** Hammer mill = swinging hammers at high speed → fast coarse-to-medium powder by pure impact.

1.8 FLUID ENERGY MILL (MICRONIZER)

What it does (one line): Uses high-pressure air jets to make an extremely fine powder (down to a few microns) without any moving parts.

Principle: Attrition and impact — particle against particle. Compressed air blasted through nozzles throws particles against each other at great speed, so they break by colliding.

Construction (sketch this):

- A flat, circular, loop-shaped (oval/torpedo) chamber with no moving parts.
- Several air nozzles fitted tangentially (at an angle) around the chamber wall.
- A feed inlet for powder and an outlet with a cyclone or collector for the fine product.
- Air pressure used is very high (about 7–10 bar).

Working (numbered steps):

1. Feed powder into the chamber and switch on high-pressure air through the nozzles.
2. Air jets create a fast-circulating vortex; particles spin at hundreds of metres per second.
3. Particles collide with each other violently — impact and attrition break them.
4. Only the finest particles escape with the air to the collector; coarser ones stay inside the loop until fine enough.

Advantages vs disadvantages:

Advantages	Disadvantages
Gives the finest powder of all mills (about 1–30 microns — "micronized")	Very high consumption of compressed air → costly
No moving parts → no heat from friction → safe for thermolabile drugs	Low output — only small batches at a time
No metal contamination (nothing rubs the product)	Only for free-flowing, already-fine feed material
Self-classifying — product comes out uniformly fine	Noisy

Pharmaceutical applications: Micronizing poorly soluble drugs (griseofulvin, steroids, aspirin) to improve dissolution and absorption; making inhalation powders for asthma inhalers, where particles must be 1–5 microns to reach the lungs.

> **Key takeaway:** Fluid energy mill = air jets throw particles at each other → finest powder, no heat, no metal touching the drug.

1.9 EDGE RUNNER MILL AND END RUNNER MILL

What they do (one line): Heavy rollers (runners) roll over material in a pan and crush it by compression.

Principle: Compression and attrition. Heavy stones or metal rollers press the material against the pan and rub it as they move.

Construction: A large circular stone or metal pan (bed) with two heavy rollers mounted on a central shaft. In the edge runner the rollers rotate on their edge around the pan; in the end runner a single roller moves around a stationary or rotating pan. Scrapers push material under the rollers.

Working:

1. Material is spread on the pan.
2. The heavy rollers roll over it repeatedly, crushing by compression.
3. Scrapers keep pushing material under the rollers; attrition between pan and roller grinds further.

Advantages	Disadvantages
Good for grinding sticky or waxy material that other mills choke on	Slow, batch process
Cheap and simple	Not for sterile products; open pan gets contaminated
Low heat generation	Coarse product compared to ball mill

Pharmaceutical applications: Grinding of ointment bases and pastes; size reduction of sticky or resinous crude drugs (e.g., in Ayurvedic/phytopharmaceutical units).

> **Key takeaway:** Edge runner = heavy rollers in a pan → compression crushing, best for sticky material.

1.10 CUTTER MILL

What it does (one line): Sharp rotating knives cut fibrous or tough material into pieces.

Principle: Cutting. High-speed rotating knives cut the material against fixed (stationary) knives.

Construction: A casing with a feed hopper; inside, a rotor carrying sharp knives rotates at high speed close to fixed knives on the casing wall; a screen below controls the size.

Working:

1. Feed fibrous/tough material into the hopper.
2. Rotating knives cut it against the fixed knives.
3. Cut pieces fall through the bottom screen.

Advantages	Disadvantages
Only mill that handles fibrous, tough, rubbery material well	Not for brittle or very hard material (blades get damaged)
Low heat, no dust explosion risk	Coarse product; knives need frequent sharpening
Easy to clean	

Pharmaceutical applications: Cutting of crude drugs (roots, bark, leaves) before extraction; size reduction of rubber stoppers waste and packaging material.

> **Key takeaway:** Cutter mill = knives cut tough/fibrous material — the only mill for things that are not brittle.

1.11 Comparison table of size-reduction equipment

Equipment	Main mechanism	Product size	Best for
Ball mill	Impact + attrition	Fine (20–30 μm)	Hard, brittle drugs; sterile grinding
Hammer mill	Impact	Medium	Fast, large-scale dry grinding
Fluid energy mill	Attrition + impact	Very fine (1–30 μm)	Heat-sensitive drugs; inhalation powders
Edge runner mill	Compression	Coarse	Sticky, waxy, resinous material
Cutter mill	Cutting	Coarse pieces	Fibrous, tough, rubbery material

1.12 SIZE SEPARATION — SIEVES

What sieves do (one line): Sieves sort a powder into size fractions — big particles stay on top, fine particles pass through.

> **Technical concept:** A sieve is a mesh with openings of known size. Powder shaken on it separates into oversize (retained) and undersize (passed).

Sieve standards (definitions):

- **Mesh number:** Number of openings per linear inch. Higher mesh = smaller openings = finer powder.
- **Sieve number (Indian Pharmacopoeia):** Approximate number of meshes per cm; e.g., sieve no. 85 has about 85 meshes per cm length.
- **Nominal aperture:** The nominal (average) size of the openings.

Methods of agitating (shaking) sieves:

1. **Mechanical shaking** — the stack of sieves is vibrated by a machine (gyratory or vibratory motion).
2. **Hand sieving** — shaking by hand for small batches (used in teaching labs).
3. **Wet sieving** — water washes fine particles through; used for sticky powders.
4. **Air-jet sieving** — an air jet blows powder through the sieve; good for very fine powders that clog meshes.

Pharmaceutical applications of sieves: Sieve analysis (quality control of powder size for tablets); grading granules before compression; removing lumps from powders; classifying microspheres.

> **Key takeaway:** Sieves = mesh of known size; shaking separates powder into oversize and undersize; mesh number tells you the opening size.

1.13 CYCLONE SEPARATOR

What it does (one line): Uses a spinning air vortex to separate coarse powder from air (dust collection and powder recovery).

Principle: Centrifugal force. Air carrying powder is forced to spin; heavier particles are flung to the wall and fall down, while clean air escapes from the top.

Construction (sketch this):

- An inverted cone (conical vessel) with a cylindrical top.
- Tangential air inlet near the top (air enters sideways, starting the spin).
- A central outlet pipe at the top for clean air.
- A dust outlet (collection bin) at the narrow bottom.

Working (numbered steps):

1. Dust-laden air enters tangentially at high speed and starts spinning.
2. The vortex throws heavier powder particles outward to the cone wall.
3. Particles slide down the cone wall into the collection bin at the bottom.
4. Clean air spirals up through the central pipe and exits at the top.

Advantages	Disadvantages
No moving parts — cheap and maintenance-free	Cannot catch very fine dust (below about 5 µm)
Handles hot and corrosive dust	Needs a steady high air velocity to work
Continuous operation	Less efficient than bag filters for fine particles

Pharmaceutical applications: Collecting powder from the air outlet of fluid energy mills and spray dryers; dust control in tablet compression rooms; separating dried granules from drying air.

> **Key takeaway:** Cyclone = spinning air flings coarse powder to the wall — simple dust recovery with no moving parts.

1.14 AIR SEPARATOR

What it does (one line): Separates fine powder from coarse powder using an air stream (classification).

Principle: Particles are thrown into a rising air current; light fine particles are carried away by air, heavy coarse particles fall — a controlled version of winnowing.

Construction: A chamber with an air inlet at the bottom, a feed inlet, a fine-particle outlet at the top connected to a cyclone or bag filter, and a coarse outlet at the bottom.

Working:

1. Powder is fed into a rising stream of air.
2. Fine particles are carried upward with the air to the collector.
3. Coarse particles are too heavy and fall to the bottom outlet.
4. Air velocity is adjusted to set the "cut size" (the dividing size).

Advantages	Disadvantages
Dry process — no water contamination	Less sharp separation than sieves
Continuous and fast	Fine dust control needed

Pharmaceutical applications: Classifying milled powders for inhalers and tablets; removing fines from granules.

> **Key takeaway:** Air separator = air current carries fines up, coarse falls down — continuous dry classification.

1.15 BAG FILTER

What it does (one line): Cloth bags trap fine dust from air — the final fine-dust collector.

Principle: Filtration of air through fabric. Dusty air passes through long cloth bags; dust sticks to the cloth, clean air passes through.

Construction: A chamber containing many long cylindrical cloth bags (cotton, nylon, or polyester) hung from the top; dusty air inlet, clean air outlet, and a dust collection hopper below. A shaking or reverse-air mechanism dislodges collected dust from the bags.

Working:

1. Dusty air enters the chamber and flows through the bags from outside to inside (or inside to outside).
2. Dust is trapped on the bag surface; clean air passes through and exits.
3. Periodically the bags are shaken (or pulsed with reverse air) so the dust cake falls into the hopper.

Advantages	Disadvantages
Catches very fine dust (much finer than cyclones)	Bags wear out and need replacement
Large air volumes handled	Not for hot, wet, or sticky dust

Pharmaceutical applications: Final dust collection in tablet and capsule plants; collecting expensive fine powders (e.g., micronized drugs); clean-room air cleaning support.

> **Key takeaway:** Bag filter = cloth bags trap fine dust from air — the finisher after the cyclone.

1.16 ELUTRIATION TANK

What it does (one line): Separates fine and coarse particles using a rising stream of water in a conical tank.

Principle: Particles settle in water according to size; an upward water flow carries away fines while coarse particles settle — same idea as the air separator, but in liquid.

Construction: A conical (or cylindrical) tank with a water inlet at the bottom, an overflow outlet at the top for fines, and a discharge at the bottom for coarse particles.

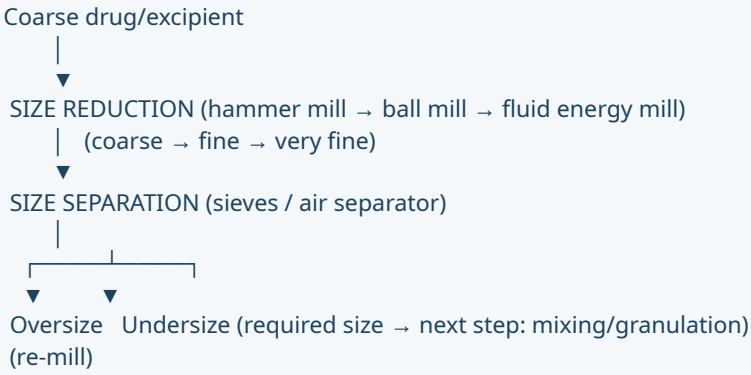
Working:

1. Powder suspension is fed into the tank.
2. Water flows upward at a controlled velocity.
3. Fine particles are carried up and overflow at the top.
4. Coarse particles settle to the bottom and are discharged.

Pharmaceutical applications: Separating fine and coarse fractions of insoluble powders (e.g., kaolin, chalk); washing and classifying precipitated powders.

> **Key takeaway:** Elutriation tank = upward water stream; fines overflow at top, coarse settle at bottom.

1.17 Flowchart — from coarse drug to tablet-ready powder



1.18 INFOGRAPHIC CONCEPT BOX — Unit I, Chapter 1

"From Stone to Powder — the Size Journey" (one-page visual for the PDF): left column shows a large rock labelled "crude drug"; an arrow through a hammer-mill icon to "coarse powder"; an arrow through a ball-mill icon to "fine powder"; an arrow through a fluid-energy-mill icon to "micronized powder (inhaler fine)". Below, a sieve stack drawing shows oversize on top, undersize at bottom. A banner reads: "Smaller particles → more surface → faster dissolution → better drug action." Side icons: cyclone (dust), bag filter (fine dust).

1.19 Pharmacy relevance

Nearly every solid dosage form starts with size reduction and separation. Tablets need uniform powder so each tablet has the same drug amount (content uniformity). Capsules need free-flowing powder. Inhalers need 1–5 µm particles. Ointments need fine powders to feel smooth. Without this chapter's equipment, none of these products can be made reliably.

1.20 India context

Indian tablet and capsule plants — concentrated in manufacturing hubs like Baddi (Himachal Pradesh), Hyderabad, Ahmedabad, Mumbai, and Goa — use hammer mills and ball mills at the start of almost every batch. Because India manufactures a large share of the world's generic medicines, size-reduction equipment runs in three shifts in many plants. Crude-drug grinding (cutter mills) supports India's large Ayurvedic and herbal industry.

1.21 Key points

1. Four mechanisms: impact, attrition, compression, cutting.
2. Ball mill → impact + attrition; fine powder; sterile possible.
3. Hammer mill → impact; fast; hot and noisy.
4. Fluid energy mill → finest powder; no heat; costly air.
5. Edge runner → compression; sticky material. Cutter mill → cutting; fibrous material.
6. Sieves separate by mesh size; agitation methods: mechanical, hand, wet, air-jet.
7. Cyclone → coarse dust from air (centrifugal). Bag filter → fine dust (cloth). Air separator → fines vs coarse in air. Elutriation tank → fines vs coarse in water.

1.22 Common confusions

- **Ball mill vs hammer mill:** Ball mill is slow and fine (balls fall on material); hammer mill is fast and medium (hammers smash material). Do not mix them up.
- **Cyclone separator vs centrifuge:** A cyclone has NO moving parts — air spins by itself. A centrifuge spins a basket with a motor. Different chapters, different principles.
- **Mesh number vs sieve number:** Mesh = openings per inch; IP sieve number ≈ meshes per cm. Higher number = smaller opening in both.
- **Fluid energy mill has no moving parts** — do not draw blades or rotors in it.

1.23 Common mistakes

- Writing that the ball mill works only by impact (it is impact + attrition; speed decides which dominates).
- Drawing moving parts in the fluid energy mill or cyclone separator.
- Forgetting to state the critical-speed idea for the ball mill.
- Mixing up oversize (retained on sieve) and undersize (passed through).

1.24 Mnemonic

"Big Hamsters Fight Every Cat" — equipment in decreasing particle-size order: **B**all mill, **Ham**mer mill... (reverse it) — better exam order, coarse to fine: **"Cows Hate Eating Fine Barley"** → **C**utter, **H**ammer, **E**dge runner, **F**luid energy, **B**all mill (very rough: cutter coarsest, ball/fluid-energy finest). Use it to recall which mill gives which fineness.

1.25 Exam summary

Size reduction increases surface area → faster dissolution. Mechanisms: impact, attrition, compression, cutting. Ball mill (rotating cylinder + balls; impact + attrition; fine; sterile ok), hammer mill (swinging hammers; impact; fast; hot), fluid energy mill (air jets; finest; no heat; costly), edge runner (rollers; compression; sticky material), cutter mill (knives; fibrous material). Size separation: sieves (mesh, agitation methods), cyclone separator (centrifugal, no moving parts, coarse dust), air separator (fines vs coarse in air), bag filter (cloth bags, fine dust), elutriation tank (upward water, fines overflow).

1.26 One-minute revision

Impact-attrition-compression-cutting → Ball, Hammer, Fluid-energy, Edge-runner, Cutter → sieves (mesh, oversize/undersize) → cyclone (spin, no moving parts) → air separator (air current) → bag filter (cloth bags) → elutriation (water stream).

1.27 Practice questions

Long answers (10 marks):

1. Describe the construction and working of a ball mill with a neat labelled diagram. Give its advantages, disadvantages, and pharmaceutical applications.
2. Explain the principle, construction, and working of a fluid energy mill. Why is it preferred for thermolabile drugs?
3. What is size separation? Describe the cyclone separator with diagram and applications.

Short answers (2–5 marks):

1. Define size reduction and list its four mechanisms.
2. What is the critical speed of a ball mill? What happens above it?
3. Define mesh number and sieve number.
4. List four methods of agitating sieves.
5. Differentiate between a cyclone separator and a bag filter.

MCQs:

1. The mechanism of size reduction in a hammer mill is mainly:
   a) Attrition b) Impact c) Compression d) Cutting — **Answer: b**
2. The finest powder is produced by:
   a) Cutter mill b) Hammer mill c) Fluid energy mill d) Edge runner mill — **Answer: c**
3. In a ball mill, grinding is most efficient at:
   a) Critical speed b) Above critical speed c) 60–75% of critical speed d) Very low speed — **Answer: c**
4. Oversize in sieve analysis means:
   a) Powder passing the sieve b) Powder retained on the sieve c) Broken sieve d) Fine dust — **Answer: b**
5. Which equipment has NO moving parts?
   a) Hammer mill b) Ball mill c) Cyclone separator d) Cutter mill — **Answer: c**

Viva questions:

1. Why does micronized griseofulvin work better than coarse griseofulvin?
2. Name one mill each for: sticky material, fibrous material, heat-sensitive drug.
3. What is elutriation?

Application-based:

1. A company wants 1–5 µm powder for a dry powder inhaler. Which mill will you select and why?
2. Tablet granules contain lumps that block the tablet press. Which equipment and which operation will solve this?

1.28 References

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CHAPTER 2: Mixing

2.1 Learning objectives

After studying this chapter you will be able to:

1. Define mixing and explain why uniform mixing is critical in pharmacy.
2. Classify mixing into solid–solid, solid–liquid, and liquid–liquid mixing.
3. Explain the mechanisms of mixing — convective, shear, and diffusive mixing.
4. Describe the construction and working of the double cone blender, ribbon blender, sigma mixer, and planetary mixer.
5. Describe the construction and working of the propeller mixer, turbine mixer, and paddle mixer.
6. Describe the construction and working of the homogenizer and colloid mill.
7. Compare mixers using advantages–disadvantages tables and state their pharmaceutical applications.

2.2 Definitions

- **Mixing:** Distributing two or more materials uniformly throughout each other so that any small sample has the same composition as the whole batch.
- **Homogeneity:** The state of being perfectly uniform — every spoonful identical.
- **Mixing time:** The time needed to reach the required uniformity; over-mixing can separate powders again (demixing).
- **Shear:** A sliding/ cutting force inside the mixture that breaks lumps and spreads particles.
- **Homogenization:** Mixing so intense that droplets or particles become extremely small and uniform (e.g., milk, creams).

2.3 Terminology you must know first

Term	Simple meaning
Convective mixing	Bulk movement — whole groups of particles move from one place to another (like stirring)
Shear mixing	Sliding layers break lumps apart (like spreading butter)
Diffusive mixing	Random movement of single particles spreading out (like sugar slowly spreading in unstirred tea)
Segregation / demixing	Mixed powder separating again (big particles rise, small sink)
Dead spots	Corners of a mixer where material does not move and stays unmixed
Tumbling	End-over-end rotation of a closed vessel (like a cement mixer)

2.4 Introduction — why must medicines be perfectly mixed?

Technical concept: Every tablet, capsule, or cream must contain exactly the same amount of drug in every dose. That is only possible if the drug is uniformly distributed in the powder or liquid.

Simple explanation: Imagine making 1,000 tablets from a powder containing a drug and sugar. If mixing is poor, one tablet may get double the drug (overdose → side effects) and another almost none (no effect). Perfect mixing = safe, effective, identical doses.

Example: A low-dose drug like digoxin (heart tablet, dose in micrograms) mixed with a large amount of filler. If the digoxin is not uniformly distributed, some tablets could be dangerous. Such low-dose drugs are often first mixed with a small part of filler (geometric dilution) and then with the rest.

Key takeaway: Mixing is a safety operation — uniformity of dose depends on it.

2.5 Classification of mixing

Mixing
├── Solid–solid (powder–powder) → double cone blender, ribbon blender, tumbling mixers
├── Solid–liquid (powder in liquid) → propeller, turbine, paddle mixers; sigma mixer (pastes)
└── Liquid–liquid (two liquids) → propeller, turbine mixers; homogenizer (emulsions); colloid mill

Mechanisms: convective (bulk flow) → shear (sliding) → diffusive (random spreading). All three act together in every mixer.

Mnemonic: "Convection Carries, Shear Slices, Diffusion Drifts" — the three mixing mechanisms.

2.6 DOUBLE CONE BLENDER

What it does (one line): Two cones joined at their bases tumble end-over-end to mix dry powders gently.

Principle: Tumbling (diffusive + convective mixing). As the vessel rotates, powder falls from one cone to the other, folding over itself.

Construction (sketch this):

- A closed vessel made of two cones joined base-to-base (like two ice-cream cones stuck together at the wide ends), made of stainless steel.
- Mounted on a horizontal rotating shaft through its centre; rotates slowly.
- A charging port on one side and a discharge valve (butterfly valve) at the bottom centre.
- An intensifier bar (optional) inside breaks lumps.

Working (numbered steps):

1. Load powders through the charging port (fill only 50–60% — powder needs empty space to tumble).
2. Close and rotate slowly (a few rpm) for the set mixing time.
3. Powder cascades from one cone to the other, folding and spreading — gentle mixing without crushing.
4. Stop, open the discharge valve, and unload the uniform blend.

Advantages vs disadvantages:

Advantages	Disadvantages
Gentle — does not break fragile granules	Slow mixing compared to ribbon blender
Closed system — no dust, no contamination	Not for wet or sticky material
Easy to clean and validate (GMP-friendly)	Dead spots possible near the centre shaft
No shear damage to particles	Fixed batch size

Pharmaceutical applications: Final blending of tablet granules with lubricants; mixing dry powders for capsules; blending antibiotic powders for dry syrups.

> **Key takeaway:** Double cone = gentle tumbling of two cones → best for fragile dry powders.

2.7 RIBBON BLENDER

What it does (one line): A horizontal trough with a rotating helical ribbon that sweeps powder from end to end for fast solid mixing.

Principle: Convective mixing. An inner and outer helical ribbon rotate inside a trough, moving powder in opposite directions — from ends to centre and centre to ends.

Construction (sketch this):

- A horizontal U-shaped trough (stainless steel) with a top lid.
- A central horizontal shaft carrying a double helical ribbon — outer ribbon moves powder one way, inner ribbon moves it the opposite way.
- A discharge valve at the bottom centre.

Working (numbered steps):

1. Load powders into the trough through the top lid.
2. Start the shaft; the outer ribbon pushes powder toward the centre while the inner ribbon pushes it toward the ends.
3. The counter-current (opposite-direction) movement mixes rapidly and thoroughly.
4. Discharge through the bottom valve.

Advantages vs disadvantages:

Advantages	Disadvantages
Fast mixing — much quicker than double cone	Shear can break fragile granules
Large batch sizes possible	Harder to clean (ribbon and shaft corners)
Handles slightly damp powders	Dead spots near shaft ends if overloaded
Simple and sturdy	Open-top versions allow dust

Pharmaceutical applications: Blending large batches of tablet granulation mix; mixing powder for effervescent tablets; blending animal-feed and bulk powders in allied units.

> **Key takeaway:** Ribbon blender = two opposite-moving ribbons in a trough → fast convective mixing of dry solids.

2.8 SIGMA MIXER (KNEADER)

What it does (one line): Two Z-shaped (sigma) blades knead thick pastes and dough-like masses.

Principle: Shear and kneading. Two heavy sigma-shaped blades rotate toward each other inside a trough, folding and shearing the thick mass.

Construction (sketch this):

- A heavy U-shaped trough (often jacketed for heating/cooling).
- Two sigma (Z-shaped) blades on parallel shafts rotating at different speeds toward each other.
- A tilting mechanism to discharge the thick mass.

Working (numbered steps):

1. Load the thick paste/granulation mass into the trough.
2. The sigma blades rotate toward each other, pulling, folding, and shearing the mass.
3. The jacket can heat or cool the mass during mixing.
4. Tilt the trough to discharge the uniform paste.

Advantages vs disadvantages:

Advantages	Disadvantages
Only mixer that handles very thick, sticky pastes	Batch process; slow discharge
Jacket allows heating/cooling during mixing	Very high power consumption
Strong shear breaks lumps in pastes	Difficult to clean

Pharmaceutical applications: Wet granulation (mixing powder with binder solution into dough); mixing ointment and toothpaste bases; preparing chewing-gum bases.

> **Key takeaway:** Sigma mixer = two Z-blades kneading toward each other → for thick pastes and wet granulation dough.

2.9 PLANETARY MIXER

What it does (one line): A beater moves like a planet — spinning on its own axis while orbiting the bowl — mixing creams and light pastes.

Principle: Planetary motion gives every part of the bowl equal mixing — the beater reaches all areas, leaving no dead spots.

Construction (sketch this):

- A stainless steel bowl (removable) on a stand.
- A mixing head with beaters/whisks that rotate on their own axis AND revolve around the bowl (like planets around the sun).
- Interchangeable tools: flat beater, wire whisk, dough hook.

Working (numbered steps):

1. Place ingredients in the bowl and attach the right tool.
2. Start the machine; the beater spins and orbits simultaneously.
3. The planetary path covers the whole bowl — uniform mixing.
4. Remove the bowl and scrape out the product.

Advantages vs disadvantages:

Advantages	Disadvantages
No dead spots — whole bowl is covered	Small batches only
Gentle — good for creams and emulsions	Not for dry powder blending at scale
Interchangeable tools for different products	Open bowl — dust and contamination risk

Pharmaceutical applications: Mixing creams, ointments, and gels in small batches; pharmacy compounding; whipping emulsions.

> **Key takeaway:** Planetary mixer = beater spins + orbits → dead-spot-free mixing of creams and pastes.

2.10 PROPELLER MIXER

What it does (one line): A marine-type propeller creates a fast axial flow to mix low-viscosity (thin) liquids.

Principle: Axial flow. The angled propeller blades push liquid downward (or upward), creating a circulating loop that mixes the whole tank.

Construction (sketch this):

- A tank (vessel) with the propeller mounted on a shaft — usually off-centre or angled to avoid a central vortex.
- A 3-blade marine propeller at the shaft end, driven at high speed by a top-mounted motor.

Working (numbered steps):

1. Fill the tank with the liquids to be mixed.
2. Start the propeller at high speed.
3. The propeller drives liquid axially down, which rises along the walls — a continuous circulation loop.
4. The loop sweeps the whole tank; mixing completes quickly.

Advantages vs disadvantages:

Advantages	Disadvantages
Very fast mixing of thin liquids	Only for low-viscosity liquids — useless in thick syrups
Cheap and simple	Air entrapment if a vortex forms (avoided by off-centre mounting)
Low power	Cannot break lumps or disperse powders well

Pharmaceutical applications: Mixing syrups and elixirs; diluting liquid formulations; dissolving salts and sugars in water for injections (WFI).

> **Key takeaway:** Propeller = high-speed axial flow → fastest mixer for thin liquids only.

2.11 TURBINE MIXER

What it does (one line): A flat-bladed turbine throws liquid outward radially, handling thicker liquids than a propeller.

Principle: Radial flow with high shear. The turbine's flat blades fling liquid outward to the tank wall, where it splits up and down, creating strong turbulence.

Construction (sketch this):

- A tank with a central shaft carrying a disc with 4–6 flat vertical blades (the turbine).
- Often fitted with wall baffles (vertical strips) that stop swirling and increase turbulence.

Working (numbered steps):

1. Fill the tank with liquid (can be moderately viscous).
2. Run the turbine; blades throw liquid radially outward at high speed.
3. Baffles convert the swirl into top-to-bottom turbulence — strong mixing with shear.
4. Continue until uniform.

Advantages vs disadvantages:

Advantages	Disadvantages
Handles moderate-viscosity liquids	Higher power than propeller
High shear — good for dispersing powders in liquids	More complex; baffles needed
Baffles give excellent turbulence	Not for very thick pastes

Pharmaceutical applications: Preparing suspensions (dispersing insoluble drug powder in liquid); mixing viscous syrups; dissolving polymers for gels.

> **Key takeaway:** Turbine = radial flow + baffles → high-shear mixing for thicker liquids and suspensions.

2.12 PADDLE MIXER

What it does (one line): Slow, large flat paddles gently stir thick liquids without whipping in air.

Principle: Gentle bulk movement at low speed. Large paddles sweep the whole tank slowly, folding the liquid over.

Construction (sketch this):

- A tank with a central shaft carrying two or more large flat paddles that nearly touch the tank walls.
- Driven slowly by a geared motor.

Working (numbered steps):

1. Fill the tank with thick liquid or slurry.
2. Rotate paddles slowly (tens of rpm).
3. The paddles sweep the full volume gently, folding material over itself.
4. No vortex, no air entrapment — gentle uniform mixing.

Advantages vs disadvantages:

Advantages	Disadvantages
Gentle — no air bubbles, no foam	Slow mixing
Good for very viscous liquids	Poor for thin liquids (too slow)
Simple and cheap	Cannot break lumps

Pharmaceutical applications: Mixing thick syrups and mucilages; stirring crystallization tanks; blending viscous ointment bases.

> **Key takeaway:** Paddle = slow big paddles → gentle mixing of thick liquids without air.

2.13 Comparison table — liquid mixers

Mixer	Flow pattern	Speed	Best for
Propeller	Axial	High	Thin liquids (syrups, solutions)
Turbine	Radial	Medium–high	Moderate-viscosity liquids, suspensions
Paddle	Bulk/gentle	Low	Very thick liquids, no air entrapment

2.14 HOMOGENIZER

What it does (one line): Forces a coarse emulsion through a tiny gap at very high pressure, breaking oil droplets into extremely fine, uniform droplets.

Principle: High-pressure shear. Liquid is pumped at very high pressure (tens to hundreds of bar) through a narrow adjustable valve gap; the sudden pressure drop and shear tear droplets apart.

Construction (sketch this):

- A high-pressure pump feeding a homogenizing valve — a narrow gap between a valve seat and a spring-loaded valve head.
- The gap is adjustable with a spring/handwheel; product enters the valve, exits as fine emulsion.

Working (numbered steps):

1. Prepare a coarse emulsion (oil + water + emulsifier, roughly mixed).
2. Pump it at high pressure into the homogenizing valve.
3. The emulsion is forced through the hairline gap — extreme shear and cavitation shatter oil droplets to sub-micron size.
4. Collect the fine, stable, milky emulsion; repeat passes for extra fineness.

Advantages vs disadvantages:

Advantages	Disadvantages
Extremely fine, stable emulsions (no quick separation)	Very high pressure → expensive, high maintenance
Continuous process	Generates heat — cooling may be needed
Sterile models available	Only for liquid emulsions

Pharmaceutical applications: Making stable pharmaceutical emulsions and creams; homogenizing milk-type nutritional emulsions; preparing intravenous fat emulsions; reducing globule size in lotions.

> **Key takeaway:** Homogenizer = high-pressure valve gap → finest stable emulsions.

2.15 COLLOID MILL

What it does (one line): A high-speed rotor spinning close inside a stator grinds suspended particles to colloidal (near-molecular) fineness.

Principle: High shear in a narrow gap. A conical rotor spins at thousands of rpm inside a matching stator with only a hairline gap; material passing through is sheared intensely.

Construction (sketch this):

- A conical rotor inside a conical stator, gap adjustable (a few microns to mm).
- Feed hopper on top, product outlet at the bottom; motor drives the rotor at very high speed.

Working (numbered steps):

1. Feed the coarse suspension or emulsion into the hopper.
2. The rotor spins at high speed; material is dragged into the narrow rotor–stator gap.
3. Extreme shear breaks particles/droplets to colloidal size.
4. Fine product flows out continuously at the bottom.

Advantages vs disadvantages:

Advantages	Disadvantages
Continuous; very fine grinding of suspensions	High heat generation — needs cooling for sensitive products
Also emulsifies (dual use)	High power; rotor–stator wear
Compact	Not for dry powders

Pharmaceutical applications: Grinding suspensions (e.g., antibiotic suspensions); making fine emulsions and creams; dispersing pigments in ointments.

> **Key takeaway:** Colloid mill = rotor spins in a hairline stator gap → colloidal-size grinding of suspensions.

2.16 Flowchart — selecting the right mixer

What are you mixing?
├── Dry powders, fragile → DOUBLE CONE BLENDER (gentle tumbling)
├── Dry powders, large batch, fast → RIBBON BLENDER
├── Thick paste / wet granulation → SIGMA MIXER
├── Creams, small batch → PLANETARY MIXER
├── Thin liquids → PROPELLER MIXER
├── Thicker liquids / suspensions → TURBINE MIXER
├── Very thick liquids, no air → PADDLE MIXER
└── Emulsions needing fine droplets → HOMOGENIZER / COLLOID MILL

2.17 INFOGRAPHIC CONCEPT BOX — Unit I, Chapter 2

"Choose Your Mixer" (one-page visual): a central question "What are you mixing?" with arrows to six illustrated mixer icons — double cone (two cones), ribbon (trough with helix), sigma (Z-blades), propeller (3-blade), turbine (flat blades + baffles), homogenizer (valve gap). Each icon has a one-line caption ("gentle powders", "fast powders", "thick pastes", "thin liquids", "suspensions", "fine emulsions"). Bottom banner: "Right mixer → uniform dose → safe medicine."

2.18 Pharmacy relevance

Mixing decides dose uniformity — the most safety-critical quality of tablets, capsules, creams, and syrups. Regulatory quality checks (content uniformity tests) directly measure how well mixing was done. Every formulation department owns several of these mixers.

2.19 India context

Indian generic-drug plants use double cone blenders for final tablet blending and ribbon blenders for large granulation batches. Planetary mixers are common in small-scale cosmetic and Ayurvedic cream units across India. Homogenizers are standard in plants making emulsions, creams, and nutritional products.

2.20 Key points

1. Mixing mechanisms: convective, shear, diffusive.
2. Double cone → gentle tumbling, fragile powders. Ribbon → fast convective, large batches.
3. Sigma → kneading thick pastes/wet granulation. Planetary → creams, no dead spots.
4. Propeller → axial flow, thin liquids. Turbine → radial flow + baffles, suspensions. Paddle → slow, thick liquids, no air.
5. Homogenizer → high-pressure valve → finest emulsions. Colloid mill → rotor–stator gap → colloidal grinding.
6. Over-mixing can cause demixing (segregation) of powders.

2.21 Common confusions

- **Propeller vs turbine:** Propeller pushes liquid along the shaft (axial), turbine throws it outward (radial). Propeller = thin liquids; turbine = thicker liquids.
- **Homogenizer vs colloid mill:** Both make fine emulsions, but the homogenizer uses a high-pressure valve gap while the colloid mill uses a spinning rotor inside a stator.
- **Sigma mixer vs planetary mixer:** Sigma kneads thick pastes with Z-blades; planetary orbits a beater for creams — different viscosity ranges.
- **Ribbon blender vs double cone:** Ribbon is fast with shear (trough + helix); double cone is gentle tumbling (rotating cones).

2.22 Common mistakes

- Recommending a propeller mixer for a thick ointment (it only works for thin liquids).
- Forgetting baffles when describing a turbine mixer.
- Saying the double cone blender is fast (it is deliberately slow and gentle).
- Ignoring demixing — writing "mix longer for better mixing" without limits.

2.23 Mnemonic

"Do Re Si Pa Pro Tu Pa Ho Co" — mixer order: **Do**uble cone, **R**ibbon, **Si**gma, **P**lanetary, **Pr**opeller, **Tu**rbine, **Pa**ddle, **Ho**mogenizer, **Co**lloid mill. Or remember by job: **"Gentle powders tumble, thick pastes knead, thin liquids spin, emulsions squeeze."**

2.24 Exam summary

Mixing = uniform distribution for dose safety. Mechanisms: convective, shear, diffusive. Solid mixers: double cone (gentle tumbling), ribbon (fast convective), sigma (kneading pastes), planetary (orbiting beater, creams). Liquid mixers: propeller (axial, thin liquids), turbine (radial + baffles, suspensions), paddle (slow, thick liquids). Homogenizer (high-pressure valve, fine emulsions); colloid mill (rotor–stator gap, colloidal grinding).

2.25 One-minute revision

Convective-shear-diffusive → double cone (gentle) → ribbon (fast) → sigma (paste) → planetary (cream) → propeller (thin) → turbine (suspension) → paddle (thick, no air) → homogenizer (pressure valve) → colloid mill (rotor-stator).

2.26 Practice questions

Long answers (10 marks):

1. Classify mixers. Describe the construction and working of the double cone blender and ribbon blender with diagrams. Compare them.
2. Describe the construction and working of a homogenizer with a neat labelled diagram. Give advantages, disadvantages, and applications.
3. Explain propeller, turbine, and paddle mixers with diagrams. When would you select each?

Short answers (2–5 marks):

1. Define mixing and state three mixing mechanisms.
2. What is demixing? How can it be avoided?
3. Why is the propeller mounted off-centre in a mixing tank?
4. What are baffles? Why are they used with turbine mixers?
5. Differentiate between a sigma mixer and a planetary mixer.

MCQs:

1. The gentlest mixer for fragile granules is:
   a) Ribbon blender b) Double cone blender c) Sigma mixer d) Turbine mixer — **Answer: b**
2. Baffles are used with:
   a) Propeller mixer b) Turbine mixer c) Paddle mixer d) Planetary mixer — **Answer: b**
3. A homogenizer works on the principle of:
   a) Tumbling b) High-pressure shear through a narrow valve c) Kneading d) Axial flow — **Answer: b**
4. The sigma mixer is used for:
   a) Thin syrups b) Thick pastes and wet granulation c) Dry powder blending d) Emulsions — **Answer: b**
5. Over-mixing of powders can cause:
   a) Better uniformity always b) Demixing/segregation c) Sterility d) Dissolution — **Answer: b**

Viva questions:

1. Why must every tablet contain the same drug amount?
2. Which mixer would you use for a low-dose drug like digoxin? Why gentle mixing?
3. What is the difference between axial and radial flow?

Application-based:

1. A cream separates into oil and water layers on storage. Which equipment will fix the emulsion and how?
2. A factory needs to blend 500 kg of tablet granules quickly. Double cone or ribbon blender? Justify.

2.27 References

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