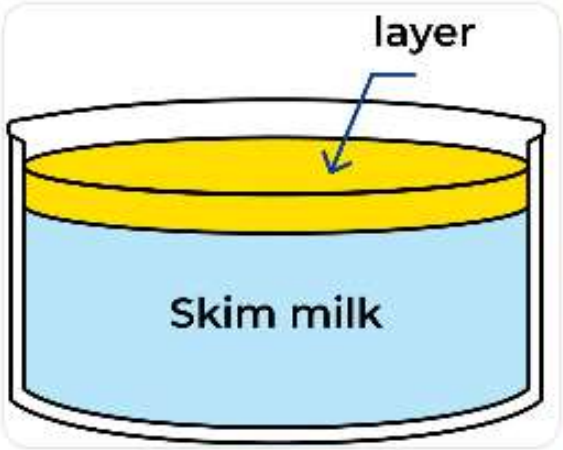
TRL vs IRL
Centrifugal Cream Separation

From Scientific Discovery to
Investment Decision

🧪 TRL 1 – Basic Observation



🧠 Concept

Milk, when left undisturbed, naturally separates into layers.

⚙️ What is happening?

- Cream (fat-rich phase) rises to the top
- Skim milk remains below

📌 Key Insight

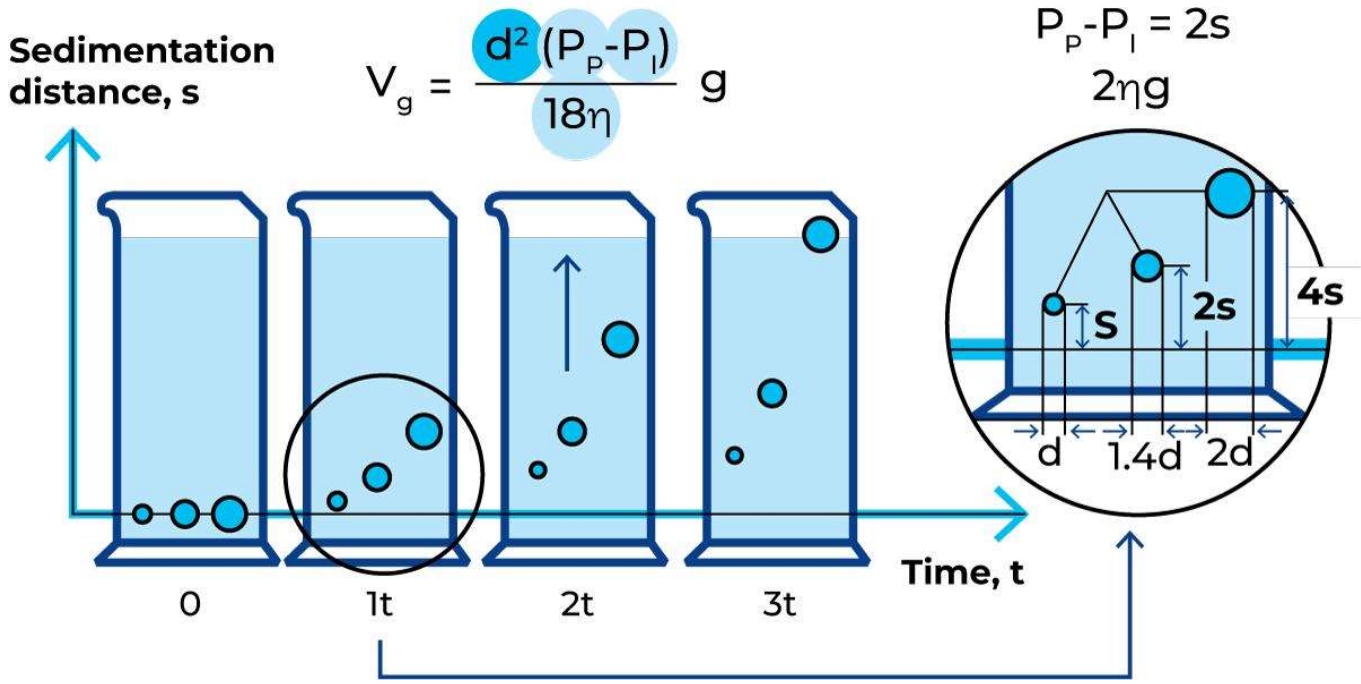
👉 **Nature shows separation is possible**

(No theory yet—just observation)

🎯 Infographic Tagline

"Separation exists in nature"

TRL 2 – Concept Formulation



🧠 Concept

Milk is an **oil-in-water emulsion.**

⚙️ What is happening?

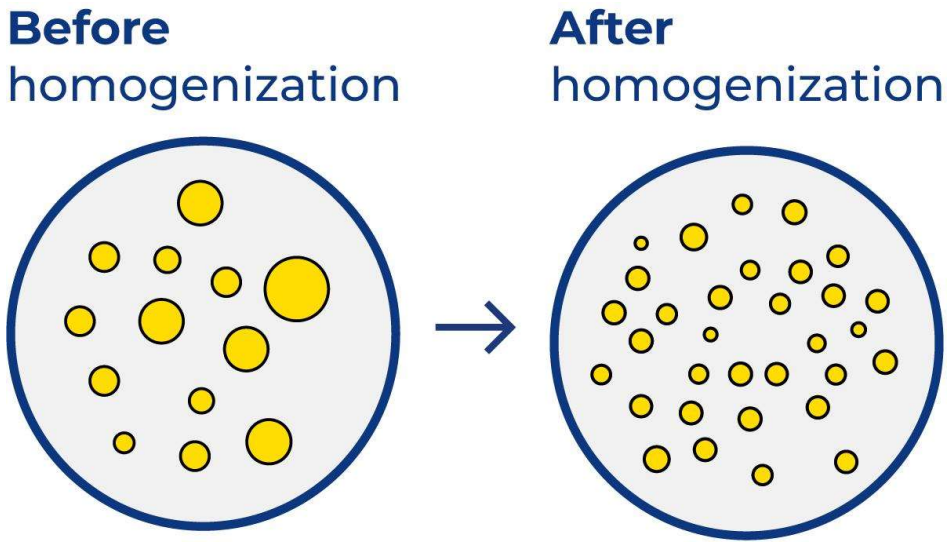
- Fat globules are **less dense** than water
- They rise due to **buoyancy forces**

📌 Scientific Interpretation

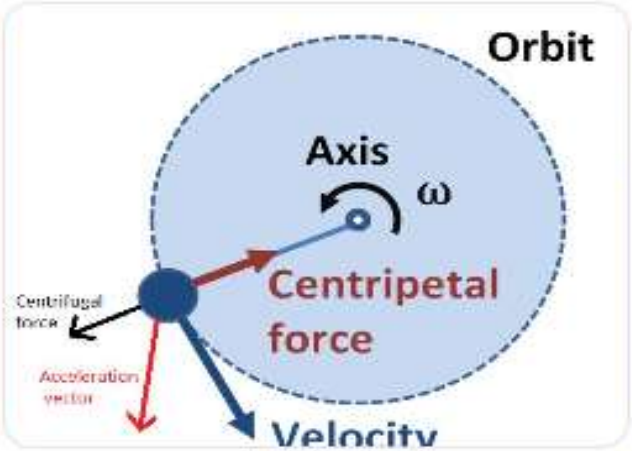
- Governed by **density difference**
- Leads to **terminal velocity-based separation**

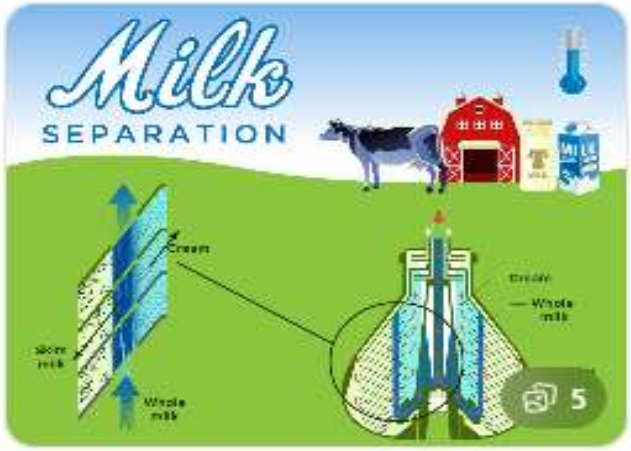
🎯 Infographic Tagline

"Separation has a physical explanation"



TRL 3 – Experimental Proof





Concept

Separation can be **accelerated artificially.**

What is happening?

- Centrifugal force replaces gravity
- Effective acceleration increases dramatically

Engineering Insight

- Terminal velocity increases
- Separation becomes **rapid and controllable**

Infographic Tagline

"Separation can be engineered and intensified"

TRL 4 – Laboratory Validation of Technology Components

- A **lab-scale centrifugal separator** is built (bench-top prototype).
- Key parameters are tested:
  - Rotational speed (RPM)
  - Temperature of milk
  - Feed rate
- Measurements:
  - Cream yield
  - Fat recovery efficiency
- Governing equations (e.g., modified Stokes' law under centrifugal field) are validated.

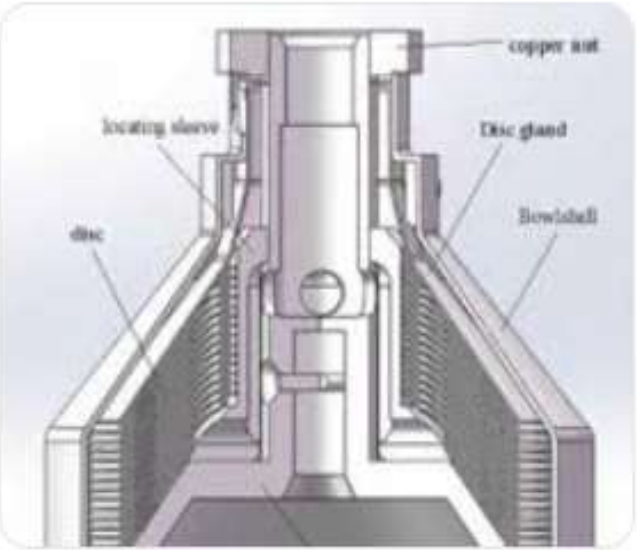
👉 **Outcome:** Physics works in a controlled lab setup.

TRL 5 – Validation in Relevant Environment

- Transition to **pilot-scale system**.
- Real milk (with variability in fat, temperature, impurities) is used.
- Issues identified:
  - Fouling of discs
  - Variability in separation efficiency
  - Impact of preheating

👉 **Outcome:** Technology works with real-world milk conditions, not just lab samples.

TRL 6 – Prototype Demonstration in Relevant Environment



- Development of a **continuous disc-stack centrifuge prototype**.
- Integrated features:
  - Continuous feed and discharge
  - Temperature control
  - Flow regulation
- Demonstrated in a **small dairy processing line**.

👉 **Outcome:** Engineering design begins resembling industrial equipment.

TRL 7 – System Prototype in Operational Environment

- Installed in a **working dairy plant.**
- Operates alongside other unit operations:
  - Pasteurization
  - Homogenization
- Performance evaluated for:
  - Throughput consistency
  - Hygiene (CIP systems)
  - Reliability over long runs

👉 **Outcome:** Works under real industrial constraints.

TRL 8 – Qualified System (Pre-commercial)

- Final system design is **standardized and validated**.
- Meets:
  - Food safety standards
  - Regulatory norms
  - Industrial reliability benchmarks
- Optimization:
  - Energy efficiency
  - Fat loss minimization
  - Automated controls

👉 **Outcome:** Ready for commercialization.

TRL 9 – Fully Commercial Deployment



- Technology is **widely deployed across dairy industries.**
- Characteristics:
  - Robust, automated systems
  - Integrated with digital monitoring
  - High throughput (thousands of liters/hour)

👉 **Outcome:** Mature, industry-standard technology.

TECHNOLOGY READINESS LEVEL (TRL)

IRL 1 – Idea with Potential Value

- Observation: Cream naturally separates.
- Initial thought: *"Can this be accelerated for economic gain?"*

👉 **Investor view:** No investment yet—just curiosity.

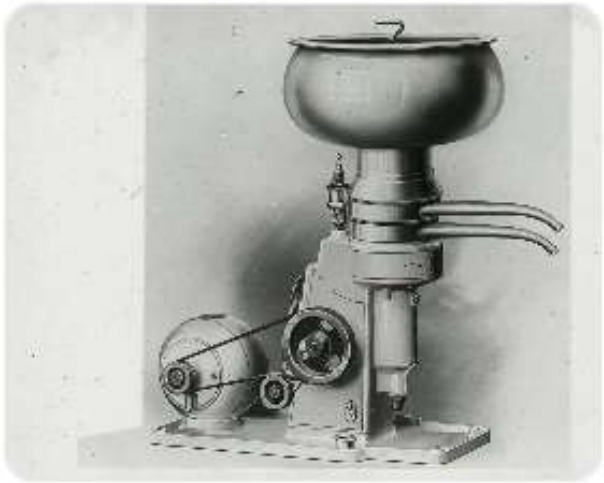
IRL 2 – Value Proposition Identified

- Cream → butter, ghee → higher value products.
- Faster separation = higher throughput.

👉 **Investor view:**

- Potential **market value identified** (dairy products).
- Still no clear business model.

IRL 3 – Proof of Commercial Concept



- Early centrifuge prototypes show:
  - Faster separation
  - Higher fat recovery
- Small-scale economic benefit demonstrated.

👉 **Investor view:**

- *"This could make money."*
- Seed-level interest begins.

IRL 4 – Lab-Validated Economics


1. To separate coagulated milk from mixture of fresh milk and Acetic Acid by Centrifugation
2. To determine the relationship of speed of centrifugation with the coagulation of milk that occurs from the mixture
3. To study the process of centrifugation

MATERIALS

Centrifuge

Centrifuge tubes (10ml)

Micropipettes

Pipettes

Fresh Milk

50% Acetic Acid

PROCEDURE

1. 10ml of 50% of acetic acid was drawn by a pettee with plastic pipette pump and released into 50ml falcon tube. 5ml of fresh milk was then drawn and released into a falcon tube with 10ml of acetic acid.
2. The falcon tube was inverted gently for a few times and both solutions are mixed.
3. The milk sample was centrifuged at 1400 rpm for 10ml minutes, then the coagulated milk solid was pelleted.

- Data generated:
  - % fat recovery
  - Energy consumption
- Preliminary **cost–benefit analysis** done.

👉 **Investor view:**

- Unit economics emerging
- Still **high technical risk**

IRL 5 – Pilot-Scale Business Feasibility

- Pilot plant data:
  - Operating cost
  - Maintenance
  - Yield variability
- Market testing (local dairies)

👉 **Investor view:**

- **Business model tested**
- Early adopters identified

IRL 6 – Scalable Business Model



- Questions answered:
  - Can it scale to 10,000 L/hr?
  - What is ROI?
- Supply chain and manufacturing considered.

👉 **Investor view:**

- **Series A-type investment stage**
- Risk reduces significantly

IRL 7 – Market Validation


- Multiple dairies adopt the system.
- Proven:
  - Reliability
  - Profitability
- Customer feedback available.

👉 **Investor view:**

- Strong confidence
- Expansion funding viable

IRL 8 – Bankable Investment

- Technology is:
  - Standardized
  - Low-risk
- Financial institutions willing to fund large plants.

👉 **Investor view:**

- **Bank loans, institutional funding possible**

IRL 9 – Mature Investment Asset

- Cream separators are now:
  - Industry standard
  - Integrated in all dairy plants
- Investment is routine infrastructure.

👉 **Investor view:**

- Low risk, stable returns
- Part of established industry

Investment Readiness Level (IRL): Idea-to-Start-up-to-VC

IRL.1 Basic Research (Need Identification & Peer Review Publications) & Completed First-Pass Business Model Canvas (BMC)

IRL 2 Applied Research (Market Size and Competitive Analysis) & Business Plan - Value Propos1tion & IP Identification

IRL 3 _Validate Problem - Solution Fit (Confirmed Value Proposition & Techno-Economic Analysis) & Minimum Product Cost (Maturity of Core Technology

IRL 4 Prototype Low-Fidelity Minimum Viable Product (MVP): Low-fidelity: A representative of the component or system that has limited ability to provide anything but initial information about the end product

IRL 5 Validate Product-Market Fit (Integrated Validation of the Minimum Viable Process and Process Engineering). "High-fidelity" - A high-fidelity laboratory environment would involve testing with equipment that can Simulate and validate all system specifications within a laboratory setting.

IRL 6 Validate Business/Revenue Model: Integrated Pilot Development – understanding operational nuances

IRL 7 Prototype High Fidelity MVP Integrated Pilot Continuous Operation

IRL 8 Pre-Commercial Demonstration - Operating Conditions and quality stabilized

IRL 9 Full Commercial Development - A full time process engineering staff continuously verifies that operations are meeting cost, yield and productivity targets.

TRL vs IRL

- TRL: Does the technology work?
- IRL: Is it worth investing?
- TRL driven by engineers
- IRL driven by investors

Both must align for success

SRL–TRL Mapping Table

Software Stage (SRL)	Typical TRL Range	Interpretation
Pre-Alpha	TRL 2–3	Concept and proof-of-concept code
Alpha	TRL 3–5	Core functionality, unstable, lab validation
Beta	TRL 5–7	Real-world testing, user feedback
Release Candidate	TRL 7–8	Near production, minor fixes
Production	TRL 8–9	Fully deployed, stable system

THANKS