

Chemical Engineering In The Pharmaceutical Industry

[1]

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Topic 1 - Introduction

Topic 1 - Introduction

[2]

Reference: Chemical Engineering in the Pharmaceutical Industry; Edited by M. T. am Ende & D. J. am Ende, 2nd edition, Chapter 1, Wiley, 2019.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

What are Pharmaceuticals?

Pharmaceuticals in general are
drug delivery systems in which
drug-containing products are
designed and manufactured
to *deliver precise therapeutic response*.

API and Drug Product

- The Drug
 - == Active Pharmaceutical Ingredient
 - == API
- The *formulated final product*
 - == Drug Product

Food and Drug Administration

- Food and Drug Administration == FDA
 - Responsible for protecting the public health by assuring the
 - safety*
 - efficacy*
 - security*
 of human and veterinary drugs, biological products, medical devices, and cosmetics.
 - ***What are the roles and responsibilities of Jordan FDA?***

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Drug Research & Development

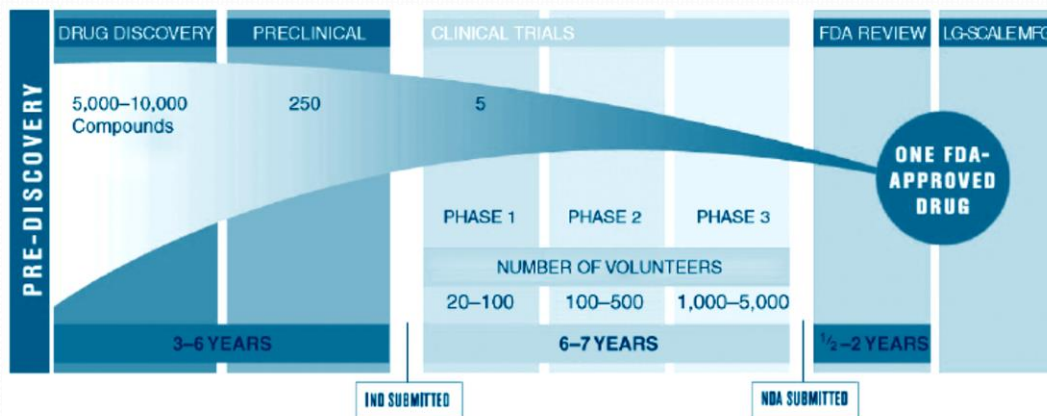


FIGURE 1.3 Drug research and development can take 10–15 years with one approval from 5 to 10,000 compounds in discovery. IND: investigational new drug; NDA: new drug application. *Source: Pharmaceutical Industry Profile 2009, Pharmaceutical Research and Manufacturers of America (PhRMA) (www.phrma.org).*

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Drug Research & Development

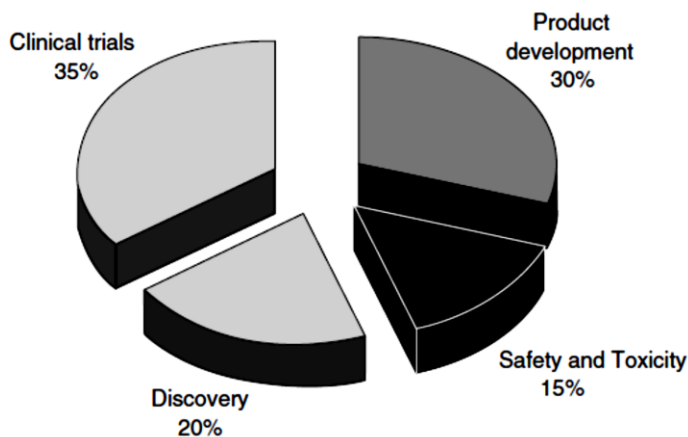


FIGURE 1.4 Estimated distribution of product development costs within R&D with the total cost to bring a new chemical entity to market in the range of \$1–3.5 billion. *Source:* Ref. 16.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Drug Research & Development

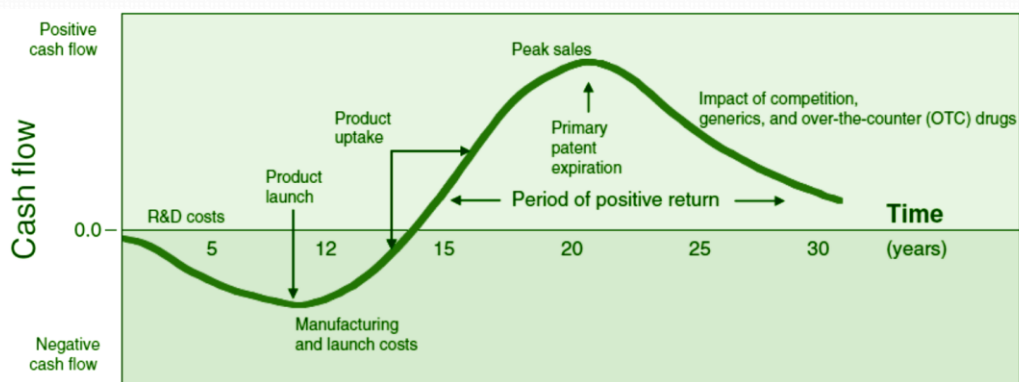


FIGURE 1.2 A hypothetical cash flow curve for a pharmaceutical product includes 10–15 years of negative cash flows of typically \$1–3 billion. Reasonably high margins are needed, once the drug is on the market, if it is to recoup and provide a positive return on investment (ROI) over its life cycle.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Opportunities for Chemical Engineers

[9]

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Opportunities for Chemical Engineers

- Challenges faced by the pharmaceutical industry create several opportunities for its members, including chemical engineers.
 1. Pressures to reduce costs ➔ economies of scale and application of efficient technology.
 2. Technological innovation and engineering analysis enhance products to create meaningful differentiation for patients, which provide values in the face of revenue constraints.
 3. Strategic management of technology used to meet industry challenges by chemical engineers is an additional opportunity.

[10]

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

REDUCING COSTS WITH ENGINEERING PRINCIPLES

(11)

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Reducing Costs with Engineering Principles

- Across many industries, chemical engineers are employed to use process modeling and physical/chemical properties estimation to:
 - maximize yield and
 - minimize energy consumption and waste production associated with desired products.
- In the pharmaceutical industry, engineers
 - use computational tools to optimize distillation and solvent recovery,
 - apply thermodynamic solubility modeling to optimize crystallization, etc.

(12)

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Reducing Costs with Engineering Principles

- The use of sound fundamental chemical engineering science can:
 - eliminate bottlenecks,
 - improve production,
 - unlock the full potential of biological, chemical, and formulation processes used to make medicine.
- Chemical engineers can also help reduce costs.

Reducing Costs with Engineering Principles

- In the R&D area, the use of high-throughput screening tools and multi-reactor laboratory systems efficiently promotes the generation of data at faster rates.
- When modeling and estimation technology cannot provide complete picture, engineers can get the data they need quickly with high-efficiency technology.

Reducing Costs with Engineering Principles

- Not all of the advanced laboratory technology works universally well in all situations:
 - A reactor system suitable for homogeneous reactions may have insufficient mixing for heterogeneous reactions.
- Selection of the appropriate laboratory technology and proper interpretation of results produced by these laboratory tools benefit from the perspective of chemical engineering principles (mass transfer, heat transfer, reaction kinetics, fluid mechanics, etc.)

Reducing Costs with Engineering Principles

- With appropriate equipment in hand, engineers can utilize a statistically driven design of experiments to maximize the value of data generated via the experimental methodology.
- Process understanding that comes from combining models and experimental data is a key opportunity for chemical engineers.
 - Quality by Design (QbD)

IMPROVING PRODUCT VALUE

(17)

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Improving Product Value

- Chemical engineers have opportunity to meet market demands for pharmaceutical products that deliver greater value to patient, payer, and physician.
- They don't care about manufacturing process, but they do care about product convenience, safety, and compliance.
- Two examples of engineers contribution to product value: drug delivery, and diagnostics.

(18)

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Improving Product Value

Drug Delivery

- **Inhalers:**

- The application of particles engineering and convection modeling to inhalers can improve the consistency with which a dose is administered via the respiratory system independent of the strength of the patient's breathe.
- Greater consistency of delivery increases the associated compliance.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Improving Product Value

Drug Delivery

- **Orally administered capsules and tablets:**

- Engineers can manipulate polymer properties and transport driving forces to afford a consistent extended release of an API.
- A steady slow release of medicine from a single delivery vehicle can reduce the frequency with which the medicine need to be taken and potential side effects, which in turn improve conveniences for the patient, and compliance with the dosing regimen.
- Controlled release requires consistent API particle size distribution → engineering effort applied to maintain control of crystal sizes during crystallization, filtration, and drying unit operations for drug substance.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Improving Product Value

Diagnostics

- Engineering principles can be used to improve diagnostic tools used to treat diseases.
- A diagnostic tool that enables physicians to initially assign the best treatment without trial and error approach reduces the cost charged to the payers through the preemptive elimination of ineffective options.
- Chemical engineering skills contribute to improvements in making diagnostic technology.
 - Advances in polymer technology and manufacturing processes can lead to devices that are lighter, smaller, and more resilient to being dropped.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

STRATEGIC TECHNOLOGY MANAGEMENT

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Strategic Technology Management

- Engineers have the opportunity to help direct strategic investments in technology.
- The availability of global development and supply options creates relatively new decisions for the pharmaceutical industry.
- Technology investment must be managed through a careful balance of internal capabilities, strategic partnerships, and reliance on external vendors.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Strategic Technology Management

- In the context of strategic management, technology can be defined as a system comprising of

technical knowledge

Understanding of fundamental principles and relationships that provide foundation of the technology

processes

procedures

techniques

best practices associated with the technology

equipment used to accomplish specific goal

devices

instruments

machinery

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Strategic Technology Management

- Strategic technology management goal:
 - To make value–driven decisions around investments in the advancement, capacity, and capability with each of the technology components.
- Engineers can contribute to investment choices among various emerging technology with technical assessments of probability of success and potential applicability across a company’s portfolio of products.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Break Time

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Manufacturing

(28)

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Manufacturing

- Pharmaceutical production plants of APIs and drug products can be generally characterized as primarily *batch-operated multipurpose* manufacturing plants.
- At these facilities,
 - commercial supplies of API intermediates,
 - APIs, and
 - drug productsare manufactured before being *packaged, labeled, and distributed* to various customers.

(29)

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Pharmaceutical Production Plants

- Flexible
 - Allow a number of different products to be run in separate equipment trains, depending on the demand.
- Have various degrees of *automation*, high level of *documentation*, and *change control* to manage reconfiguration, with *long downtimes* for cleanup and turnover of the plant between product changes.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Manufacturing

- Often accounts for more than one-third of company's human resources and a third of the total costs with expenses exceeding that of R&D.
- COGs = Cost of Goods
= manufacturing cost
- Margin = profit margin

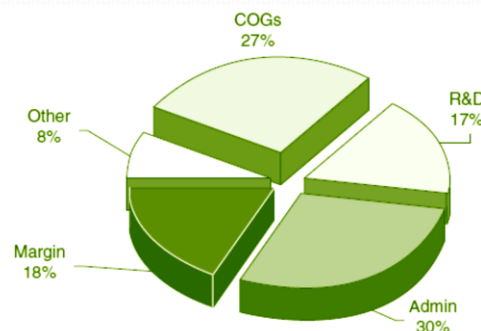


FIGURE 1.6 Distribution of revenue and expenses as a percentage of sales was averaged over 17 major pharmaceutical companies (listed in Table) based on 2008 annual reports.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Lean Manufacturing

- By adopting the principles of Lean Manufacturing, pharmaceutical companies on average, could save in the range of \$20-50 billions/year ➡ 10 – 25% reduction in COGs
 - **Lean manufacturing** describes a management philosophy concerned with improving profitability through the systematic elimination of activities that contribute to waste
- **Waste** is considered the opposite of **Value**

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud

Lean Manufacturing

- In Lean manufacturing the following are considered waste:
 - **Overproduction**
 - **Waiting**
 - **Transportation**
 - **Unnecessary process**
 - **Unnecessary inventory**
 - **Unnecessary motion**
 - **Defects**

The challenge that batch processing inherently leads to **overproduction** (e.g. inventory build-up of intermediates) leading to **longer cycle times** and **excess inventory**, is addressed through the concepts of continuous manufacturing.



Continuous Processing is one application of lean thinking.

Chemical Engineering Department | University of Jordan | Amman 11942, Jordan
Tel. +962 6 535 5000 | 22882

Dr. Linda Al-Hmoud