A Preliminary Proposal for a Pharmaceutical Engineering Graduate Program

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The Need

• FDA PAT Guidance
  – “A system for **designing**, **analyzing**, and **controlling manufacturing** through timely **measurements** (i.e., during processing) of critical quality and performance attributes of raw and in-process materials and processes with the goal of ensuring final product quality.”
  – “The ability to **predict** reflects a high degree of **process understanding**.”

• Quality by Design rather than Quality through Testing

• AAPS PT survey of pharmaceutical executives
  – shortage of entry-level scientists with appropriate background in product development and pharmaceutical technology
  – <50% have advanced degrees in pharmaceutics or industrial pharmacy/pharmaceutical technology and <25% have UG or G degrees in an engineering field
## Existing U.S. Pharmaceutical Engineering Programs

<table>
<thead>
<tr>
<th>University</th>
<th>Degree</th>
<th>Web Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Jersey Institute of Technology</td>
<td>MS</td>
<td>chemicaleng.njit.edu.academics.ms/pharm.php</td>
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<tr>
<td>University of Michigan</td>
<td>MEng</td>
<td>interpro.engin.umich.edu/pharmaceutical/</td>
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<td>Stevens Institute of Technology</td>
<td>MS, MEng, Certificate</td>
<td><a href="http://www.stevens.edu/engineering/me/Graduate/pharma.html">www.stevens.edu/engineering/me/Graduate/pharma.html</a></td>
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<td>California State University, Fullerton</td>
<td>Certificate</td>
<td><a href="http://www.csufextension.org/Courses/Certificate/CertDetail.asp?GN=3184&amp;GV=3&amp;LID=">www.csufextension.org/Courses/Certificate/CertDetail.asp?GN=3184&amp;GV=3&amp;LID=</a></td>
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<tr>
<td>Illinois Institute of Technology</td>
<td>Certificate</td>
<td><a href="http://www.chee.iit.edu/academics/graduate/pharma_eng_certificate.html">www.chee.iit.edu/academics/graduate/pharma_eng_certificate.html</a></td>
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<td>University of Wisconsin</td>
<td>no degree / EPD courses</td>
<td>epdweb.engr.wisc.edu/courses/index.lasso?myRegion=Pharmaceutical%20Engineering&amp;myRegionHead=R-05</td>
</tr>
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Desired Skill Set

• Knowledge of the drug discovery-to-shelf process
• Knowledge of existing pharma industry practices (e.g. API and dosage form unit ops, regulation)
• Fundamental knowledge of pharmaceutical materials and processes (biopharmaceutics, microbiology, materials science, transport, powder mechanics)
• Data analysis skills
• Instrumentation and measurements
An Important Issue to Consider

- Student backgrounds will be varied ⇒ need to consider prerequisites carefully
  - engineering BS degrees: ABE, ChE, ME, MSE
  - pharmaceutical sciences BS degrees: BSPS
  - returning after several years in industry
  - distance education
Overview of the Proposed Program

• Still in the design stage
• Masters of Science: 30 credit hours, non-thesis
• Six core courses (18 hours) with supporting concentration courses (e.g. solid dosage forms)
• Faculty from ABE, ChE, IE, IPPH, ME, and MSE
• Use existing courses where possible
• Make use of Engineering Professional Education to reach off-campus students
• Possible Certificate program?
Course Descriptions: Core

Principles of Pharmaceutical Engineering (CHE 597E, 3 hrs)
This course is designed to provide engineering and pharmacy students with an understanding of the structure, economic and regulatory context, product discovery and development pipeline dynamics and the manufacturing technology of the global pharmaceutical industry as it is today.
Course Descriptions: Core

Introduction to Pharmaceutical Manufacturing Processes (IPPH 562, 3 hrs)
A course intended to provide the student with basic understanding of both the theoretical and practical aspects of pharmaceutical manufacturing by combining a thorough classroom treatment of the underlying principles of each pharmaceutical unit operation with hands-on execution of these activities in the laboratory.

Pharmaceutical Process Development and Design (CHE 597D, 3 hrs)
Key API unit operations, such as batch reaction, solid-liquid separation, crystallization, drying, batch distillation and other separation systems, will be reviewed. Both dedicated and multi-product production system design and batch and semi-continuous operating modes will be covered. Software for physical property estimation, simulation, and optimization will be introduced and used to solve industrially relevant applications. The cGMP requirements will also be reviewed. Case studies will be used to demonstrate the overall design strategy and its operational implementation and to integrate the course material.
Course Descriptions: Core

**Advanced Biopharmaceutics** *(IPPH 583, 3 hrs)*
A comprehensive course dealing with the interaction of biological and physico-chemical considerations relating to drug effectiveness and dosage form design.

**Pharmaceutical Materials Science** *(~MSE 382, 3 hrs)*
This course encompasses deformation-based microscopic mechanisms, including dislocation motion, diffusion, and visco-plasticity. Macroscopic mechanical response of metals, ceramics, polymers, and composites will be related to elasticity and plasticity concepts for single crystal, polycrystalline, and amorphous materials. Practical design considerations for deformation will be included as well as an introduction to fracture mechanisms.

**Statistical Modeling and Analysis** *(CHE 597?, 3 hrs)*
Statistical modeling methods, design of experiments, error analysis, curve fitting and regression, analysis of variance, confidence intervals, quality control and enhancement: emphasizes preparation for designing laboratory experiments and analyzing data.
Course Descriptions: Electives

**Design of Dosage Forms** (3 hrs)
A course describing strategies for dosage form design including first in-man, marketed, controlled release, injectible, and drug-device combination dosage forms. Dosage forms for proteins, peptides, and vaccines will also be addressed. A major focus of the course will be Quality by Design.

**Advanced Transport** (~CHE 540, 3 hrs)
Topics in fluid mechanics, heat transfer, and mass transfer including unsteady state transport problems, stream functions, hydrodynamic and thermal layers, turbulence, and multi-component diffusion.
Course Descriptions: Electives

Powder Mechanics (3 hrs)
Introduction; review of stress and strain; principle stresses and strains; Mohr’s circles; yield criteria; introduction to plasticity, flow rules; dilatation and consolidation; flowability; flow function; applications: hoppers and bins (method of differential slices; switch stresses; velocity distributions; mass flow rate); roller compaction (Johanson analysis); tableting

Spray Applications and Theory (ME 526, 3 hrs)
Theory of spray formation and evolution as well as treating a host of spray applications. Topics include drop size distributions, breakup of liquid sheets and ligaments, drop formation and breakup, drop motion and the interaction between a spray and its surroundings, drop evaporation, nozzle internal fluid mechanics, external spray characteristics, nozzle performance, and experimental techniques relevant to these subjects. Applications include: (1) agricultural sprays, (2) consumer products, (3) gas turbine combustion, (4) heat transfer, (5) internal combustion engines, (6) paints and coatings, (7) pharmaceutical and medicinal sprays, and (8) spray drying.
Course Descriptions: Electives

Instrumentation and Measurements (2 hrs + 1 hr lab)
A combined lecture and laboratory course reviewing properties critical to the performance and processing of common pharmaceutical materials, the instruments that can be used to measure these quantities (e.g. mass spectrometry, x-ray diffraction, HPLC, NIR, pressure transducers, and thermocouples) and the basic principles behind these measurements, and discuss issues concerning the quality of measurements such as time and spatial resolution and signal-to-noise ratio.

Microbiology (~BIOL 438, 3 hrs + 1 hr lab)
An examination of microbial diversity that emphasizes the interrelationship of bacteria and their environments. This includes aspects of cell composition, metabolism, and growth of microorganisms.

Sterile Product Systems (IPPH 557, 3 hrs)
A study of the design and manufacture of safe, effective, and reliable sterile pharmaceutical products with emphasis given to parenteral products.
Course Descriptions:
Additional Possible Elective Courses

- Wet Granulation
- Milling
- Discrete Element Modeling (ME 595D, 1 hr)
- Particle and Powder Characterization
- Sampling Methods
- Pharmaceutical Facility Design
- Pharmaceutical Packaging Technology
- Reaction Engineering for Pharmaceutical Production (~CHE 348)
- Pharmaceutical Separation Processes
- Validation and Regulatory Affairs in Pharmaceutical Manufacturing (~IPPH 522)
- Aseptic Processing
- Information Management
- Project Management
- Additional bio-pharmaceutical related courses
Management

• Engineering Professional Education
  – Program administration
  – Advisory Committee
    • Six members elected to a three year term
  – Distribution to off-campus students
Related Issues

- Make use of Engineering Professional Education to reach off-campus students via TV and web
  - Weekend lab courses for off-campus students?
- Certificate program?
- Make use of the Chao Center
- Course “modules” through the NSF ERC: Center for Structured Organic Composites
- NIPTE short courses
- Collaboration with ISPE
- Training for regulators
Questions?