A Multi-scale Chemical Engineering Product Design: Design of a Transdermal Delivery System

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Outline

- New Directions for CHE Education
- Project Goals (instructor view)
  - Product Design
  - Multi-Scale Design
- Project Goals (student view)
- Student-generated Results
- Assessment
- Conclusions

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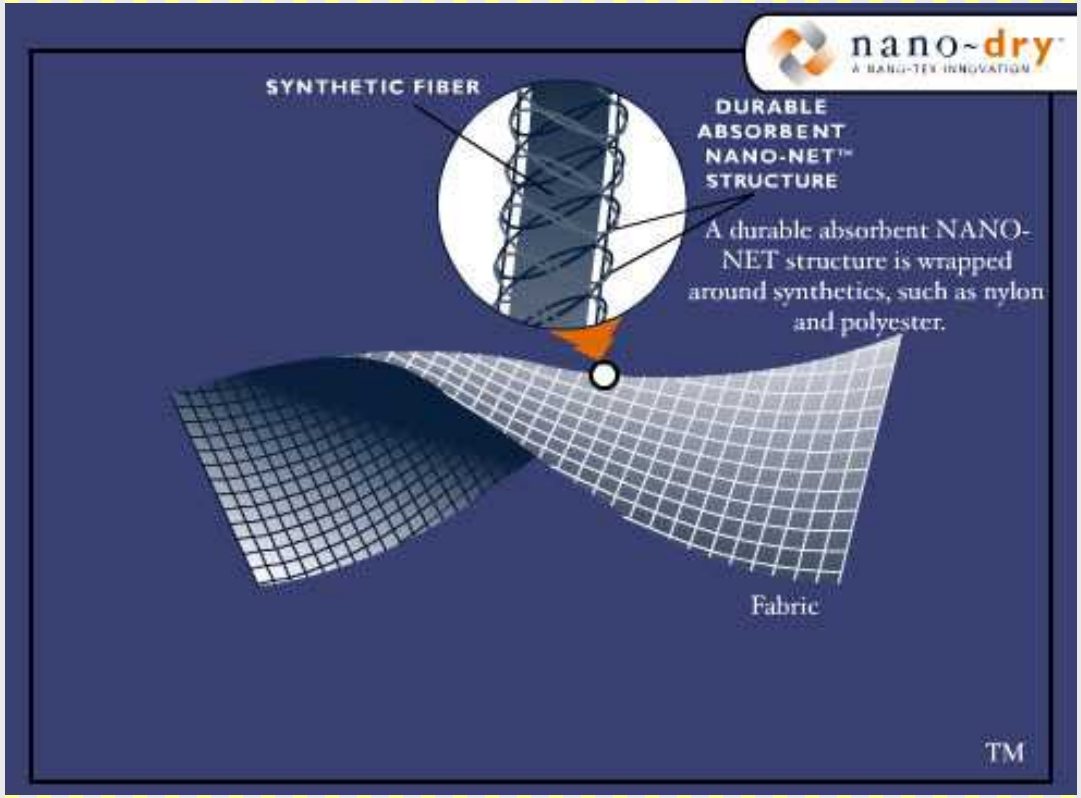
New Directions for CHE Education

- Biology as enabling science
- Product design
- Multi-scale analysis and design

Traditional Chemical Engineering

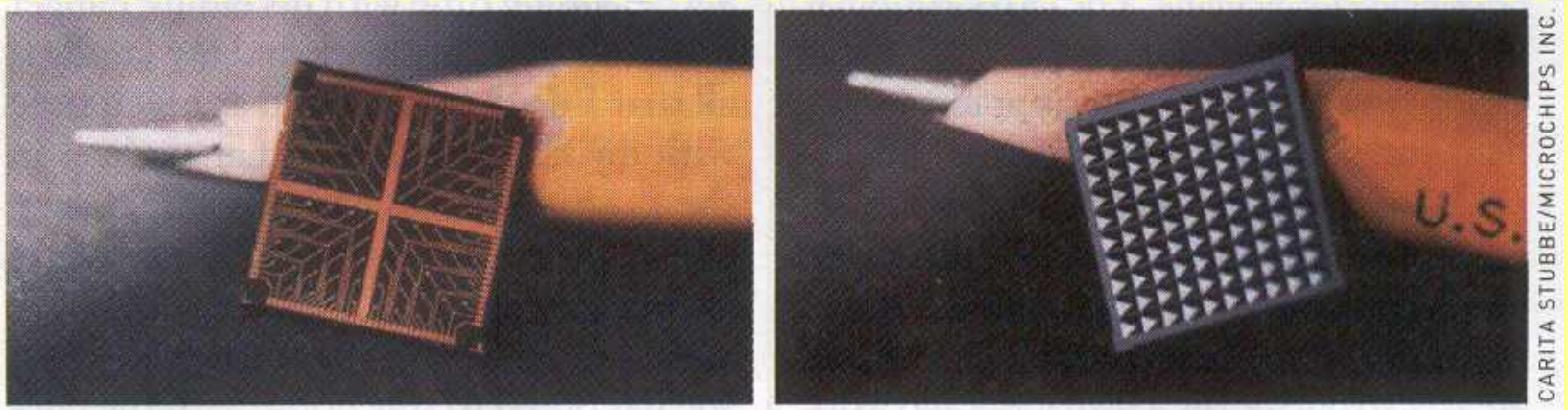
source: AIChE

The Future of Chemical Engineering



http://www.nanotechbook.com/resources.php

The Future of Chemical Engineering



CARITA STUBBE/MICROCHIPS INC.

DRUGS-ON-A-CHIP Front of a controlled-release microchip (left), based on a concept developed in Langer's lab, shows an array of 100 gold reservoir caps and their electrodes. The back of the chip (right) shows the 150-nL reservoirs that potentially could release doses of drug or a combination of drugs.

Source: C&E News, February 18, 2002

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Project Goals (instructor view)

- Product design
  - Need, ideas, screening, manufacturing
- Multi-scale design
  - From molecular to macroscopic
- Life sciences orientation
- Lifelong learning, teamwork, communication

Project Goals (student view)

- Identify candidate drugs for use in transdermal systems
  - Properties of such drugs (molecular weight, solubility, concentration in blood, desired dosage)
- Ideas for such drugs
  - Birth control, motion sickness, blood pressure control, nicotine withdrawal
- Identify suitable markets
  - Developing economy
  - Professional, educated women

Project Goals (student view) [continued]

- Screening of alternatives
- Design of birth control patch
  - Components of patch
    - Adhesive, enhancers, excipients, liners
  - Manufacture of patch
    - Mixing processes
    - Coating processes
    - Cutting, packaging, shipping, warehouse facilities

Project Goals (student view) [continued]

- Technical understanding of drug delivery process
  - Transdermal transport phenomena (transport through multiple immiscible layers)
- Pharmacokinetics
  - Compartment models, fitting published data
- Demonstration experiment
  - Diffusion cell

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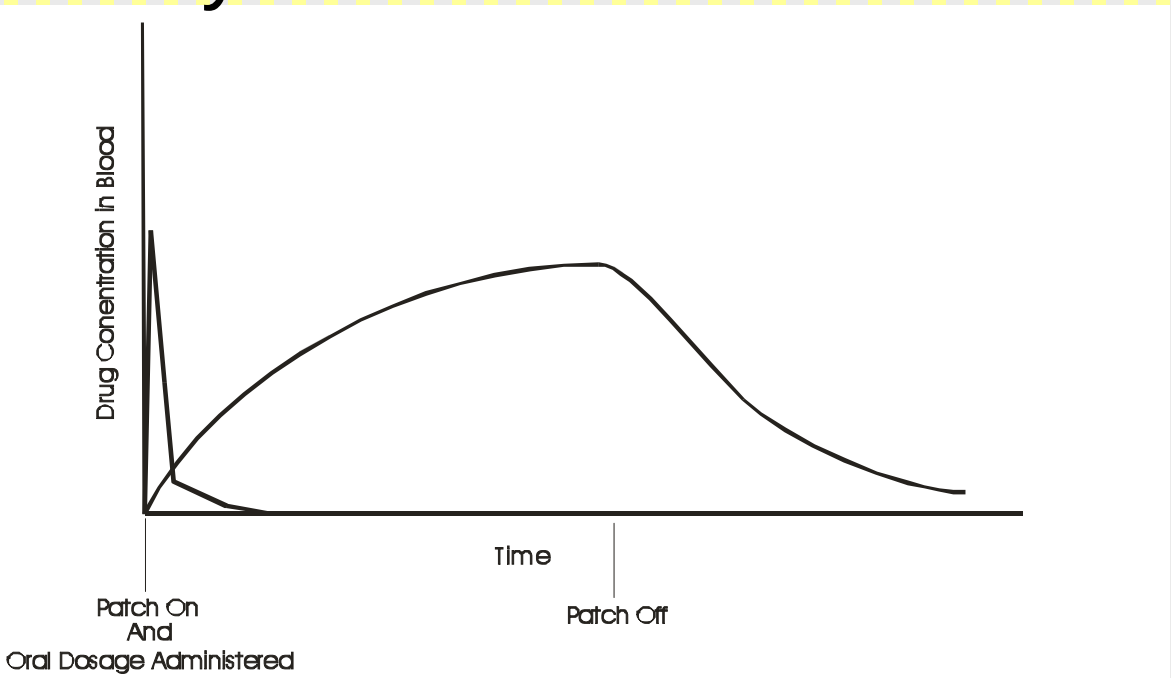
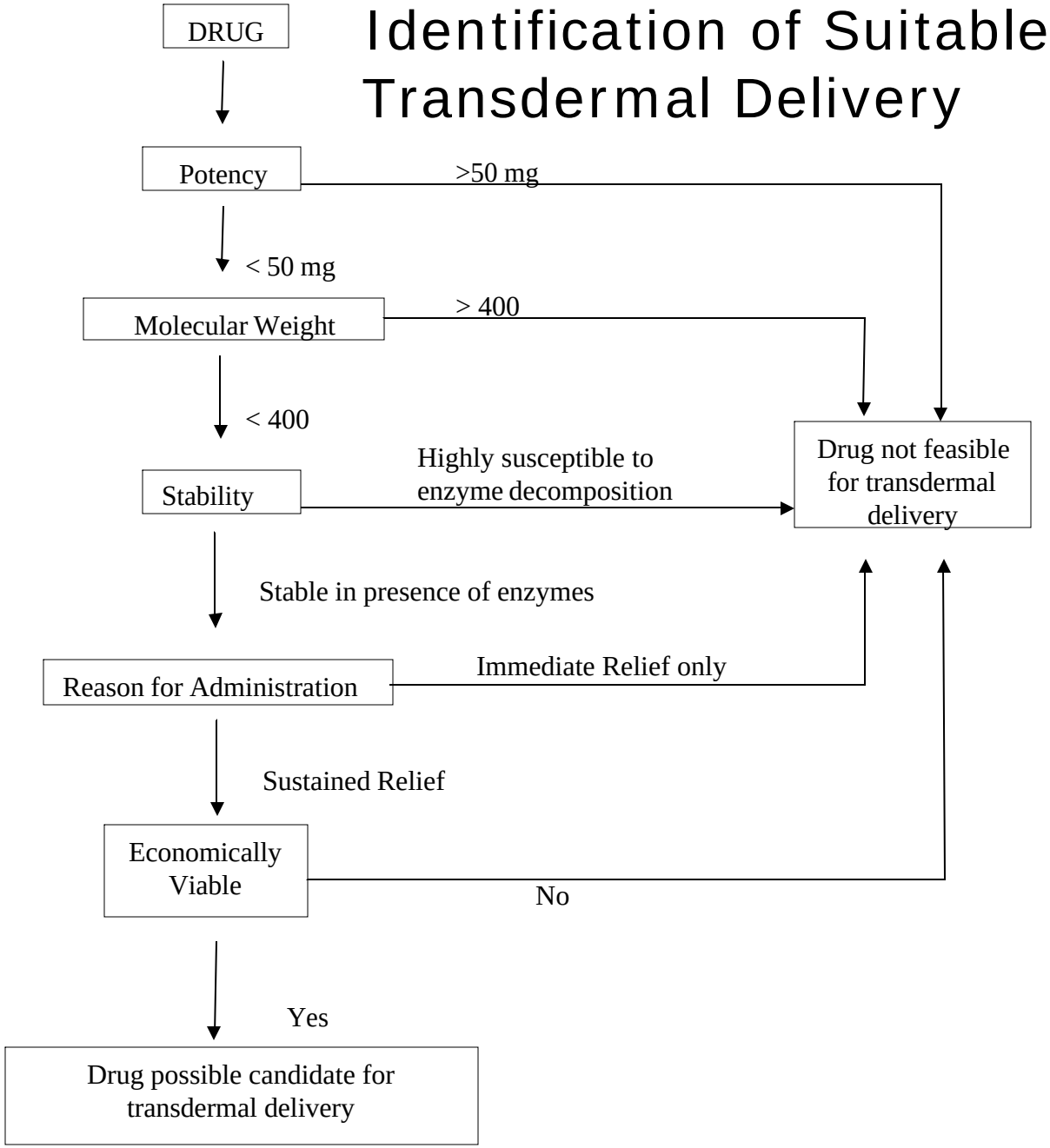
Student-Generated Results

- Learned about transdermal delivery



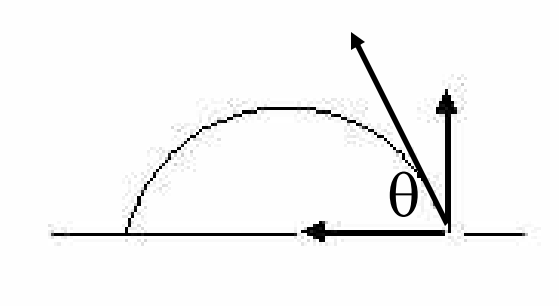
Identification of Suitable Drugs for Transdermal Delivery



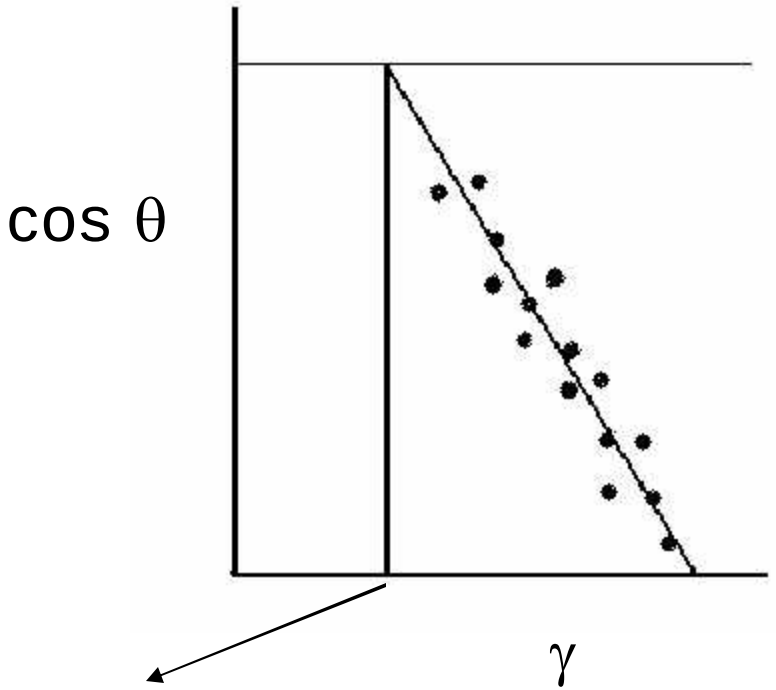
Student-Generated Results (cont'd)

- Chose drug
  - Norelgestromin/ethinyl estradiol (similar to Ortho-Evra®)
- Chose excipient – oleic acid
- Chose enhancer – propylene glycol monolaurate
- Chose adhesive – polyisobutylene (and learned about adhesion)

Adhesion



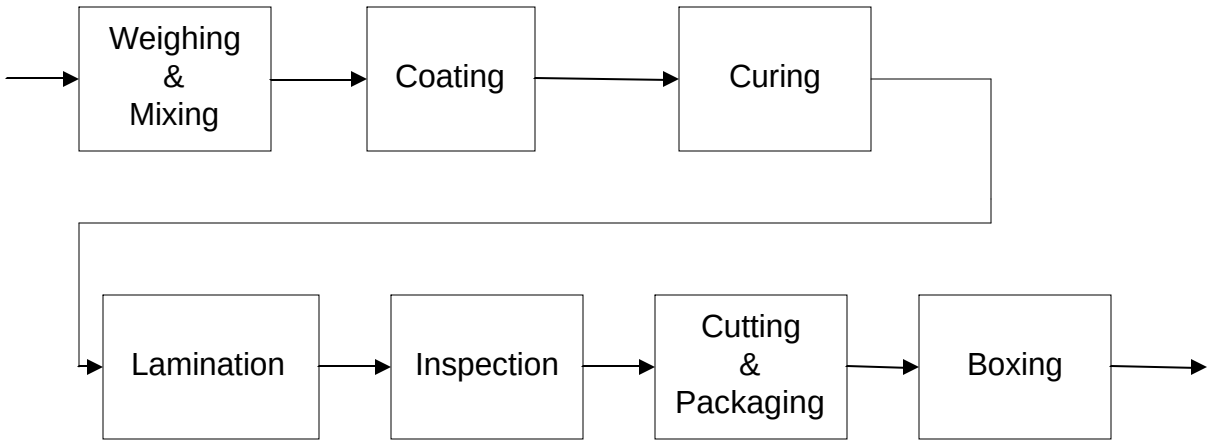
contact angle



critical surface tension

Student-Generated Results (cont'd)

- Manufacturing process



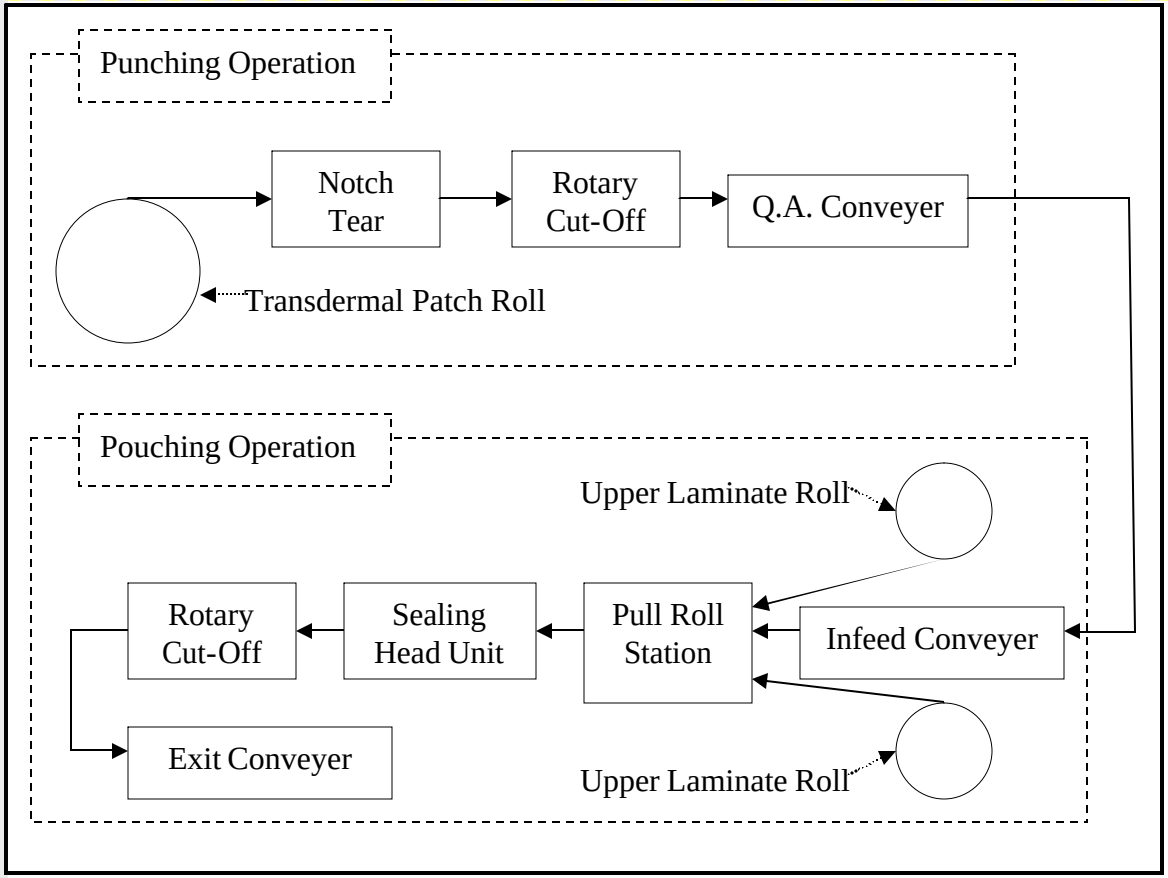
Student-Generated Results (cont'd)

- Production process

http://www.mathisag.com/en/

Student-Generated Results (cont'd)

- Punching and pouching

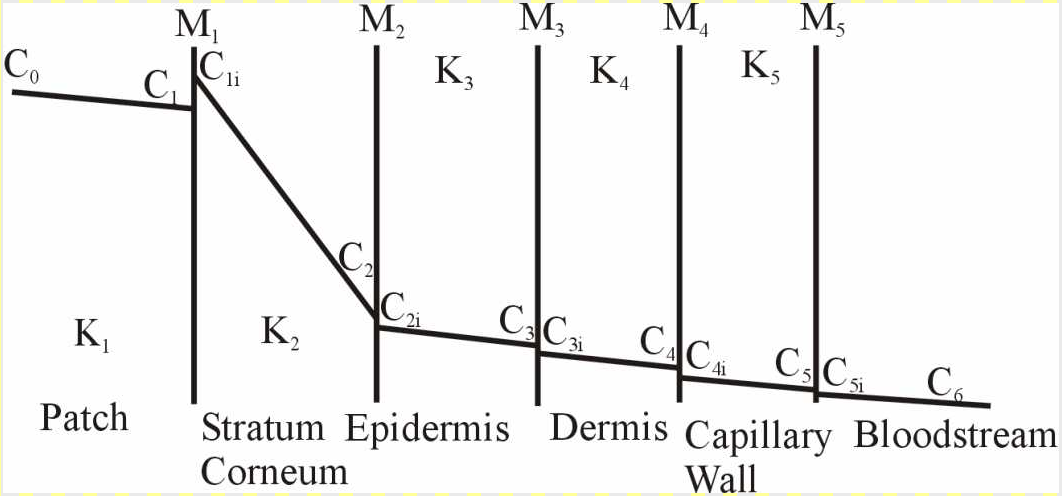


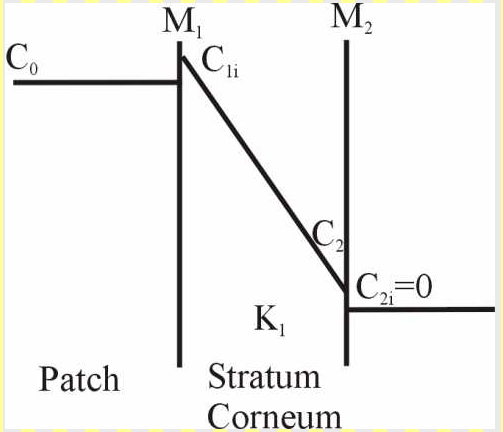
Student-Generated Results (cont'd)

- Cartoning
- Solvent recovery
- Personnel
- Scheduling
- Economic analysis
  - $0.30/patch to manufacture
  - Current price (non-generic) $11.00/patch

Student-Generated Results (cont'd)

- Diffusion through skin



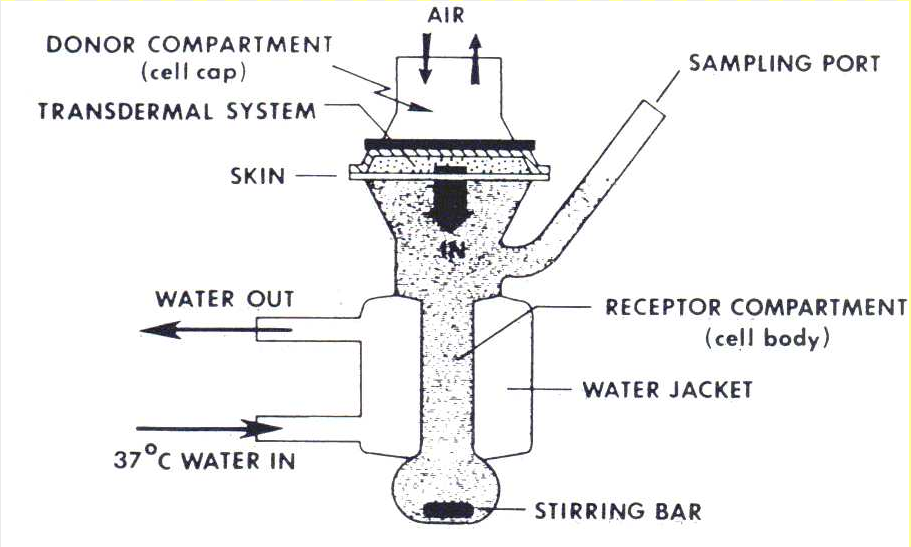


$$j = \frac{C_0 - \frac{C_n}{\prod M_j}}{\frac{1}{K_0} + \sum_{j=1}^{n} \frac{1}{K_j(\prod_{j=1}^{n} M_j)}}$$

$$j = C_0 K_1 M_1$$

Student-Generated Results (cont'd)

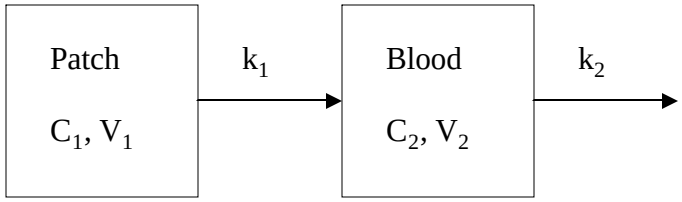
- Diffusion cell experiment



Apparatus used to perform *in vitro* experiments to determine the flux of a drug through skin, from Kydonieus, A. F. and B. Berner, *Transdermal Delivery of Drugs* , Volume II (Boca Raton, FL:CRC Press, 1987).

Student-Generated Results (cont'd)

- Pharmacokinetics

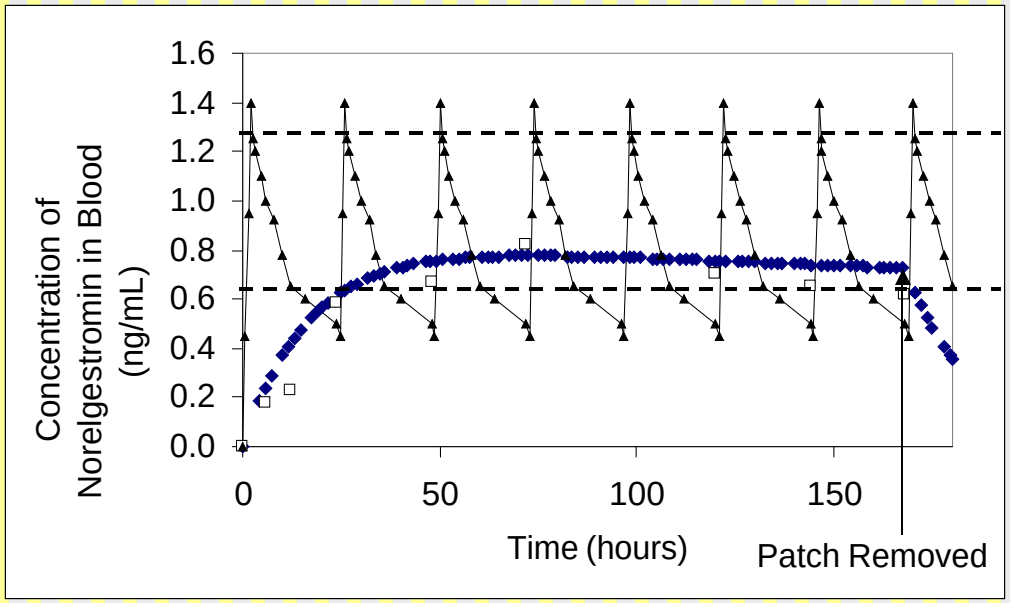


$$\frac{dC_1}{dt} = \frac{-k_1 C_1}{V_1}$$

$$\frac{dC_2}{dt} = \frac{k_1 C_1 - k_2 C_2}{V_2}$$

Student-Generated Results (cont'd)

- Pharmacokinetics



Predicted concentration of norelgestromin in blood. (represents experimental values collected from human samples, dotted line represents reference range for which drug is effective, from OrthoEvra® Full Prescribing Information. Ortho-McNeil Pharmaceuticals. Raritan, New Jersey. May 2003. ^ represents experimental values collected from human samples for tablet administration, from Kydonieus, A. F. and B. Berner, *Transdermal Delivery of Drugs* , Volume II (Boca Raton, FL:CRC Press, 1987).)

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Assessment

- Students
  - Feedback on evaluation of instruction
  - Feedback on surveys/interviews
- Faculty
  - Use of rubric

Assessment by Students

- *Tackling the non -traditional problem posed in the large - group project enhanced my confidence in solving new problems.*

4.90/5.00

Assessment by Students

- *I feel that my experience with the group design taught me the importance and the need for continuously learning new material.*

4.17/5.00

Assessment by Faculty

Design of equipment, understand interrelationship between equipment in process	3
Apply chemistry, math, physics, engineering science	3.5
Resolve complex problem into components	3
Apply economic, physical constraints and optimization methods to obtain solution	3
Use of computer-based and other information systems	3
Demonstrate ability to learn new material not taught in class	4
Demonstrate ability to function in assigned role	3
Demonstration of ethical behavior	3
Demonstrate understanding of societal impact and need for assigned design	3

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Conclusion

- Project was successful
- Students met or exceeded all expectations
- Can include product design, life sciences, multi-scale design in traditional design class

Web Site

http://www.che.cemr.wvu.edu/publications/projects/index.php