Dr. Piero M. Armenante
New Jersey Institute of Technology
January 21, 2017

Principles of Pharmacokinetics and Drug Delivery
PhEn 618

Syllabus

Term: 2017 Spring Semester

NJIT Course Title: Principles of Pharmacokinetics and Drug Delivery

NJIT Course Number: PhEn 618, Section 102

Course Day and Time: Monday; 6:00-9:05 pm

Classroom: Kupfrian Hall; Room 206

Course Instructor: Piero M. Armenante, Ph.D.
Distinguished Professor of Chemical Engineering
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New Jersey Institute of Technology
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E-Mail Address: piero.armenante@njit.edu

Availability of Instructor and WebEx Sessions:
Students can contact the instructor for questions in different ways:

- In-person meetings: Monday, 5:00-6:00 pm or by appointment (for students who can come to NJIT: meetings will likely take place in 150 Tiernan Hall – CBPE Departmental Office). Students are strongly encouraged to contact Prof. Armenante via e-mail to arrange for a meeting. *Please note that Prof. Armenante will **not** be available for consultation when he is on business travel.*
- Via telephone: students can contact the instructor at the mobile number above
- Through WebEx sessions: WebEx question/answer sessions will be also held as appropriate, as specified below. The exact time and day of these sessions will be decided after the last day to add a course, i.e., once the class roster is complete.

Teaching Assistant (TA): To be announced.

TA's Office Hours: To be announced.

Computer Hardware and Software Requirements
In order to follow the course, students will require the following:

- Hardware
  - Computer with internet access (to retrieve course material, access WebEx, etc.)
  - Scanner or access to a scanner (to scan homework and then e-mail it as an attachment)

- Software and Access
  - NJIT e-mail account, including UCID and password, to access Moodle (http://moodle.njit.edu/)
  - Web browser (Firefox, Chrome, Safari, etc. - Internet Explorer is not recommended)
  - Adobe Acrobat and Adobe Flash installed and up-to-date (freeware)
  - Other software to complete assignments (e.g., Microsoft Word, Microsoft Excel, etc.)

Course Lectures, Notes, Textbooks, and Other Reference Material:

- **Course Lectures**: Armenante, P. M., 2017, *PhEn 618-Pharmacokinetics and Drug Delivery Course Lectures.* The *Lectures* are videos containing course lectures identical in content and length to the face-to-face PhEn 618 lectures routinely offered at NJIT. The *Lectures* are available through Moodle and can be accessed as described below
- **Course Notes**: Armenante, P. M., 2017, *PhEn 618-Pharmacokinetics and Drug Delivery Course Notes - PhEn 618.* The *Notes* are exact duplicates of the overheads used in the lectures. The *Notes* are also available through Moodle and can be accessed as described below
- **Textbooks**: The following books are recommended but not required as textbooks:
  - Shargel, L., Wu-Pong, S. and Yu, A. B. C., *Applied Biopharmaceutics and Pharmacokinetics*, 6th Edition, McGraw-Hill, New York, 2012.
  - Truskey, G. A., Yuan, F. and Katz, D. F., *Transport Phenomena in Biological Systems,* 2nd Edition, Pearson Prentice Hall, Upper Saddle River, NJ, 2009.
- A list of additional reference books (not required) is attached.

Availability of Course Lectures, Notes, Homework Assignments, Textbook, and References:

- Links to the *Course Lectures* are available to the students through Moodle. Students can access Moodle directly by going to http://moodle.njit.edu/ and following the instructions there. Once the appropriate course is selected, students will be able to watch streaming videos of the *Lectures* for that class period by clicking on the appropriate links
- The *Course Notes* can be downloaded from the NJIT website using Moodle, as described above. The *Course Notes* will be posted on the internet as PDF files
- The homework, homework solutions, and projects will be posted through Moodle as appropriate, depending on the material covered in that week (typically but not always on a weekly basis)
- Additional material (e.g., videos, reading material, etc.) will be posted through Moodle as appropriate
- If students experience problems and they are unable to log in or access course material they should contact the NJIT Helpdesk at 973-596-2900
- The Shargel et al. book, and Allen et al. book are available in the NJIT bookstore (973-596-3200; http://www.bkstr.com/njitstore/home) or from the publishers
- Most additional references (not required as textbooks) as well as the textbooks are available in most university libraries and have been being placed on reserve at the NJIT library.

Course Prerequisites:

- **PhEn/PhB Students**: PhEn 601; **and** successful completion of the bridge program (PhEn 500, PhEn 501 and PhEn 502) **if required in the student's admission conditions**, *as well as* any other undergraduate-level courses, if any. However, students who have taken PhEn 500 and PhEn 501 and are currently enrolled in PhEn 502 could take PhEn 618 provided that they did well in those courses (A or B+) or have permission from Prof. Armenante. *PhEn/PhB students who do not have these prerequisites will have to **drop** the course.* [Remark: PhEn/PhB students who are not required to take the bridge course, do not need to take bridge courses, of course]
- **Non-PhEn/PhB Students**: PhEn 601 (recommended but not required). Students with appropriate engineering backgrounds (e.g., ChE, BME) do not need to have taken the bridge courses to take this course. Students with non-engineering background should have the appropriate math background (differential equations) and be familiar with the basic engineering concepts (e.g., mass balances) required for this course. Therefore, they should talk to Prof. Armenante to make sure that they are adequately prepared for this course before taking it.

Course Objectives: This course is one of the common core courses for the Pharmaceutical Engineering and Biopharmaceutical Engineering MS Degree Programs. The main objectives of this course are to: present the different pharmacokinetic principles affecting drug adsorption, distribution, metabolism and excretion; quantitatively study and apply mathematical models used to describe these phenomena, and; provide the students with basic concepts of drug delivery, pharmacokinetics and pharmacodynamics.

Course Description: The course covers the basic principles of pharmacokinetics, including absorption, transport distribution, metabolism, and excretion of drugs and metabolites in the human body, drug transport, parenteral and enteral routes of drug administration, and factors affecting drug absorption, distribution, and metabolism. Mathematical pharmacokinetic models and drug delivery processes are also presented and quantitatively studied. The course also covers basic aspects of drug delivery of different drug delivery systems and dosage forms.

Course Outline by Topic Areas: Introduction; pharmacokinetics and its role in drug discovery; drug development and process development; drug absorption, distribution, metabolism, and excretion; routes of drug administration, drug absorption by different routes of administration; enteral and parenteral routes; drug transport in biological systems, transport across cell membrane: osmosis, passive diffusion, ion channels facilitated transport, active transport; transport across endothelial cell layers and epithelial cells layers; drug distribution; transcapillary exchange of drugs; perfusion-limited and permeability-limited distribution; binding of drugs to proteins; physiological barriers; renal excretion; renal clearance; drug metabolism; mathematical approach to pharmacokinetic modeling; one-compartment open models and data analysis; multiple-dose pharmacokinetics; two-compartment open models; physiological pharmacokinetic models; nonlinear pharmacokinetics; pharmacokinetic-pharmacodynamic modeling.

Course Learning Outcomes: Upon successful completion of this course, students will be able to:

- Identify and compare the different types of administration routes used in drug delivery
- Recognize and describe the different physiological mechanisms responsible for drug adsorption, distribution, metabolic and elimination
- Quantitatively predict key parameters and transfer rates of importance in the description of physiological processes
- Categorize, analyze, and contrast different types of pharmacokinetics models
- Interpret and analyze pharmacokinetic data to determine the underlining compartment model best describing the observed drug distribution behavior among compartments over time
- Regress pharmacokinetic data to determine the compartment model kinetic parameters
- Assemble compartment models best suited for a specific drug based on its adsorption, distribution, metabolic and elimination characteristics
- Determine the most effective drug delivery method to achieve the desired pharmacokinetic effect based on a quantitative analysis of the underlying pharmacokinetic model

Course Requirements:

- Examinations: Two exams, i.e., a midterm exam and a final exam
- Homework: Assigned by the instructor at the end of each class
- Projects: One, or possibly two, short projects will be assigned after the midterm exam (see below for details)

Grading Policy*:

- Midterm exam* 38%
- Final exam* 38%
- Homework.....12%
- Projects 12%

  Total 100%

(*) Students performing very poorly on the exams will **fail** the course *irrespective* of their performance in the homework and projects, as explained below.

Course Final Grade: a tentative guideline for the assignment of final grades is the following:

Cumulative Points	Overall Grade
85-90 to 100%	A
70-75 to 85-90%	B/B+
60 to 70-75%	C/C+
50 to 60%	"D"
0 to 50%	F

The grade of "D" is not assigned to students taking graduate courses. Students averaging a cumulative point score corresponding to a "D" in the above table could receive either a C or an F, depending on their overall performance.

Please remember that this is only a guideline designed to help the students understand how they are performing in the course. Dr. Armenante will feel free to adjust slightly the grading scale (both ways) when assigning the final grades.

> ***Important Remark***: Each exam (midterm and final) will be graded on a point scale from 0 to 100 (100 points in an exam=38% of the final grade; see above). However, **failing to achieve a combined average of at least 55/100 in the two exams** will imply **failing the course (F grade) *irrespective* of the points obtained through the homework and the projects.** In other words, students who perform extremely poorly in the exams will not be able to use the homework and the projects to pass the course. If this minimum requirement is satisfied, the final grade will be assigned based on the grading policy outlined above, including homework and projects.

Exams:

- A calendar of exams is included in the Course Outline given below
- All exams are typically 3 hours long unless otherwise stated
- All exams are typically open-book and open-note. However, changes could be made and will be announced by the instructor prior to the exams
- No computers, telephones, i-Pads, etc. will be allowed during the exams
- Possible additional exam policy changes will be announced by the instructor prior to the exams
- The final exam will be on all material covered throughout the course (although the main emphasis of the exam will be on the material covered after the midterm exam);
- Make-up exams will only be given to students who cannot attend the regular exam time, *and only under documented and extraordinary circumstances*. In any case, no student will be allowed to take a make-up exam unless he/she has the prior consent of the instructor. *If a student will simply not come to an exam, the exam grade will automatically be zero.*
- Because of confidentiality issues, the Office of the **Dean of Students** now handles all issues related to **medical conditions** (including justification for postponing exams)

Homework:

- The homework will be posted on Moodle
- It will be assigned as appropriate (typically on a weekly basis), depending on the material covered in that week
- Students should turn in the homework by scanning it and attach it as a PDF file to an e-mail message addressed to the TA for the course
- The homework will not be returned to the students unless practical to do so
- No late homework will be accepted unless a valid reason is provided **in advance** (e.g., an upcoming business trip)
- Homework solutions will be posted on Moodle after the homework has been collected.

***Important Remark**: Previous experience has clearly shown that those students who do not work on the assigned problems (or at least seriously try to solve them) typically perform very poorly on the exams.*

Homework Grading: The homework will be graded by the TA on the basis of the effort that the student puts into using solving it using a simplified grading scale, i.e., 0 (no or minimal effort); 5 (intermediate effort); 10 (significant effort). Any questions regarding homework grades should be discussed with the instructor.

Projects: Students will complete one, or possibly two, small projects, which will be assigned after the midterm exam and collected on the day of the final exam. The first project will consist of critically reviewing (critiquing) 2 papers published in scientific journals (as if the papers had been submitted for publication to the student). The papers will have to be related to each other and to be within the scope of the course. The students will be asked to write a short review of the papers. The student will have to justify whatever conclusions he/she may reach. The second project (if assigned) will consist of a small case study assigned by the instructor. The problem will be open-ended to allow each student to come up with his/her own analysis of the problem and solution.

Class Attendance: As with all graduate courses at NJIT, attendance is not mandatory, but strongly recommended. Experience shows that students who do not regularly attend class typically perform poorly in the course. In addition, examples are worked out during the lectures. These examples are not in the *Course Notes*. Students are responsible for all material covered in class.

Time Commitment: Students are expected to allocate some three to six hours per week to study and work on the assignments for this course.

Students with Disabilities: NJIT adheres to Section 504 of the Rehabilitation Act (ADA) of 1990. Appropriate accommodations are provided at no cost to the student. Additional questions should be directed to Dr. Phyllis Bolling, Center for Counseling and Psychological Services (C-CAPS), Campbell Hall, (entry level), Room 205, (973) 596-3420. For further information, visit the http://www5.njit.edu/studentsuccess/disability-support-services/ website.

Code of Conduct and Academic Integrity: The NJIT University Code on Academic Integrity, found at http://www5.njit.edu/doss/code-student-conduct-article-11-university-policy-academic-integrity/, will be followed. The Code is being upheld on all issues related to the course. Students are expected to be familiar with the code and conduct themselves accordingly.

Important Dates According to NJIT Calendar (Spring 2017):

January	16	Monday	Martin Luther King, JR Day
January	17	Tuesday	First Day of Classes
January	21	Saturday	Saturday Classes Begin
January	23	Monday	Last Day to Add/Drop a Classes
January	23	Monday	Last Day for 100% Refund, Full or Partial Withdrawal
January	24	Tuesday	W Grades Posted for Course Withdrawals
January	30	Monday	Last Day for 90% Refund of Tuition (no refund for fees), Full or Partial Withdrawal - no refund for partial withdrawal after this date
February	13	Monday	Last Day for 50% Refund of Tuition (no refund for fees), Full Withdrawal
March	6	Monday	Last Day for 25% Refund of Tuition (no refund for fees), Full Withdrawal
March	12	Sunday	Spring Recess Begins - No Classes Scheduled
March	19	Sunday	Spring Recess Ends
March	**27**	**Monday**	**Last Day to Withdraw**
April	14	Friday	Good Friday - No Classes Scheduled. University Closed
May	2	Tuesday	Friday Classes Meet
May	2	Tuesday	Last Day of Classes
May	3	Wednesday	Reading Day
May	4	Thursday	Reading Day
May	5	Friday	Final Exams Begin
May	11	Thursday	Final Exams End
May	16	Tuesday	Final Grades Due

Additional important dates are available on the web at the following site: http://www5.njit.edu/registrar/calendars/.

Course Outline (Spring 2017)

Week	Date	Topic
1	January 23-29	Introduction; pharmacokinetics and its role in drug discovery; drug development and process development; drug absorption, distribution, metabolism, and excretion; routes of drug administration
2	January 30-February 5	Routes of administration; enteral and parenteral routes
3	February 6-12	Drug transport in biological systems - Transport across cell membranes: osmosis, passive diffusion
4	February 13-19	Drug transport in biological systems (continued) - Transport across cell membranes: ion channels facilitated transport, active transport
5	February 20-26	Drug transport in biological systems (continued) - Transport across endothelial cell layers and epithelial cells layers
6	February 27-March 5	Drug distribution; transcapillary exchange of drugs; perfusion-limited and permeability-limited distribution; binding of drugs to proteins; physiological barriers
7	March 6-12	Renal excretion; renal clearance. Drug metabolism
	March 13-19	*Spring Break – No class*
8	**March 20**	**Midterm exam**
9	March 27-April 2	Mathematical approach to pharmacokinetic modeling
10	April 3-9	One-compartment models and data analysis – IV Injections
11	April 10-16	One-compartment models and data analysis (continued) - Oral dosage models; method of residuals
12	April 17-23	One-compartment models and data analysis (continued) - Oral dosage models; Wagner-Nelson model. Models for other routes of administration
13	April 24-30	Multiple-dose models
14	May 1-7	Two-compartment models and data analysis
15	**May 8**	**Final exam**

Important: It is conceivable that some changes in the above outline will take place, depending on the overall performance of the class and the time actually required to cover the most important subjects of the course.

Reference Books

- *The United States Pharmacopoeia & The National Formulary. The Official Compendia of Standards, USP 39–NF 34, Pharmacopeial Convention Inc., 2016.*
- Amiji, M. M. and Sandmann, B. J., *Applied Physical Pharmacy*, McGraw-Hill, New York, 2003.
- Allen, L. V., Popovich, N. G., and Ansel, H. C., *Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems*, 9th Edition, Lippincott Williams & Wilkins Publishers, 2010.
- Banker, G. S. and Rhodes, C. T., *Modern Pharmaceutics*, 3rd Edition, Marcel Dekker, New York, 1995.
- Boroujerdi, M. *Pharmacokinetics: Principles and Applications*, McGraw-Hill, New York, 2002.
- Chien, Y. W., *Novel Drug Delivery Systems*, 2nd Edition, Marcel Dekker, New York, 1991.
- Gennaro, A. R. (editor), *Remington: The Science and Practice of Pharmacy*, 20th Edition, Philadelphia College of Pharmacy and Science, 2000.
- Lieberman, H. A., Rieger, M. M., and Banker, G. S., *Pharmaceutical Dosage Forms: Dispersed Systems*, Vol. 1 (1996); Vol. 2 (1996), Vol. 3, (1998), Marcel Dekker, New York.
- Lieberman, H. A., Lachman, L., and Schwartz, J. B., (eds.), *Pharmaceutical Dosage Forms: Tablets*, Vol. 1 (1989); Vol. 2 (1990), Vol. 3 (1990), Marcel Dekker, New York.
- Avis, K. E., Lieberman, H. A., and Lachman, L., (eds.), *Pharmaceutical Dosage Forms: Parenteral Medications*, Vol. 1 (1991); Vol. 2 (1992), Vol. 3 (1993), Marcel Dekker, New York.
- Mitra, A. K., Kwatra, D., Vadlapudi, A. D., *Drug Delivery*, Jones & Bartlett Learning, 2014.
- Martin, A. N., Bustamante, P. and Chun, A. H. C., *Physical Pharmacy: Physical Chemical Principles in the Pharmaceutical Sciences*, Lippincott Williams & Wilkins Publishers, Philadelphia, 1993.
- Notari, R. E., *Biopharmaceutics and Clinical Pharmacokinetics: An Introduction*, Marcel Dekker, New York, 1986.
- Shargel, L., Wu-Pong, S. and Yu, A. B. C., *Applied Biopharmaceutics and Pharmacokinetics*, 6th Edition, McGraw-Hill, New York, 2012.
- Tyle, P. (ed.) *Drug Delivery Devices: Fundamentals and Applications*, Marcel Dekker, New York, 1988.
- Truskey, G. A., Yuan, F. and Katz, D. F., *Transport Phenomena in Biological Systems,* 2nd Edition, Pearson Prentice Hall, Upper Saddle River, NJ, 2009.
- Welling, P. G., *Pharmacokinetics: Processes, Mathematics, and Applications*, American Chemical Society, 1997.
- Welling, P. G. and Tse, F. L. I. (eds.), *Pharmacokinetics: Regulatory-Industrial-Academic Perspectives*; 2nd Edition, Marcel Dekker, New York, 1995.