Course Title: Bioen. 457 – Advanced Molecular Bioengineering

Course Instructor: Stayton, P.S. **Credits:** 4

UW General Catalogue Course Description: Fundamentals of molecular recognition: thermodynamics, forces, kinetics. Manipulation of recognition processes for current molecular bioengineering research and development. Fundamental physical chemistry of molecular recognition in the context of biomedicine. Therapeutics based on cells.

Instructor's Detailed Course Description: Engineers have traditionally played a major role in developing macroscopic medical technologies such as medical devices and instrumentation. There are also many important new opportunities for engineers to apply their design and analytical skills toward more molecular medical technologies. These opportunities are being created by fundamental advances in our understanding of how biomolecules control healthy physiology, how cells communicate, how the body protects itself against the initiation of cancer, etc. Recognition and Design in Molecular Medicine will introduce engineering students to the quantitative aspects of biomolecular recognition through the use of design-oriented case studies of recent molecular medicine advances. After an introduction to fundamental molecular recognition energetics in the context of biomolecular structure, the course will progress from design strategies for molecular therapeutics up through the design of cellular therapeutics and recognition in synthetic materials.

Prerequisites By Topic: Introduction to Molecular Bioengineering (Bioe 357), General Biochemistry (Biochem 405 or 440)

Textbooks: No single textbook required, uses Chapters from "Enzyme Structure and Mechanism" by Fersht, "Physical Chemistry" by Alberty, and from different reaction kinetics textbooks.

Learning Objectives:

a. Define thermodynamic principles in context of biomolecular recognition and stability
b. Define kinetic theory and reaction kinetics in context of biomolecular recognition and stability
c. Define how non-covalent bonding energetics relate to biomolecular recognition and stability
d. Apply biomolecular energetics to biotherapeutic design from a modeling and computational standpoint
e. Apply combinatorial and directed evolution approaches to biotherapeutic design
f. Evaluate engineering systems analysis to receptor trafficking in context of how biological feedback systems affect therapeutic strategies
g. Define molecular design strategies for modifying cells to develop cellular therapeutics

Topics Covered:

1. Molecular Recognition Fundamentals 1: thermodynamics of biomolecular interactions, non-covalent forces underlying bioenergetics: hydrogen bonding, van der Waals, hydrophobic effect, water in context of molecular recognition biomolecular stability

2. Molecular Recognition Fundamentals 2: kinetic theory, reaction kinetics, enzyme energetics

3. Rational Biotherapeutic Design: molecular modeling, computational approaches to predicting energetics

4. Directed Evolution for Biotherapeutic Design: random mutagenesis approaches and techniques, phage display and selection techniques, combinatorial approaches and techniques

5. Cellular Warfare: receptor-mediated recognition in immune system surveillance, macrophage-B-Cell collaboration, T-Cell and natural killer cell function, vaccines

Class Schedule: Lectures and Case Studies (2 x 100 minute lectures per week)

Computer Use: Class problems and tests require solution of algebraic equations by calculators or utilize programs such as Excel, software algorithms, or statistical software packages. Students also use computers to prepare literature reports.

Goals: Introduce engineering students to how biomolecular structure and recognition are tied to thermodynamics and reaction kinetics; apply these fundamental structure/energetic principles to the design of biotherapeutics and molecular materials; familiarize engineering students with cutting-edge molecular medicine problems and provide rationale for bringing engineering analysis and design tools into the medical field.

Case Study Projects:
Case studies focus on application of knowledge and concepts covered in lecture to medical problems, as well as on molecular design as connected to medical technology development.

1. Protein Stability: Antibody-Antigen Energetics, Streptavidin-Biotin Energetics

2. Catalytic Antibodies

3. PeptidoMimetic therapeutics

4. Antibody Engineering, enzyme engineering, phage display

5. Engineered T-Cell Therapeutics, Vaccines

Course Outcomes and Assessments:
Bioen 457 contributes to the following ABET outcomes with the corresponding assessment mechanisms at a High Priority Level:

1.1 Apply knowledge of mathematics, science and engineering – students are required to solve problems relating to topics such as protein stability, ligand binding thermodynamics, enzyme kinetics; they are also required to consider how to engineer thermodynamic and kinetic properties from first principles. The Assessment mechanisms include written in-class problem solving, Case Studies, and Exams

1.3 Ability to design a system, component, or process to meet desired needs – students are required to design protein properties for biomedical applications. The Assessment mechanisms include Problem Solving, Case Studies, and Exams

1.7 Communicate effectively – students are required to discuss problems and engineering solutions in small groups and in the larger class, as well as to write one page literature paper summaries that communicate the question and result to outside readers. The Assessment mechanism is the graded write-up of the literature paper summaries that correspond to each of the modular themes.

The course contributes to the following criteria at a Medium Level:

1.2 Design and conduct experiments, as well as analyze and interpret data – students are required to read scientific articles that describe designing and conducting experiments, and then to extrapolate those methods to their own analysis and interpretation of real literature data. The Assessment mechanisms include Problem Solving, Case Studies, and Exams

Relationship of Course to Department Objectives:

Bioen. 457 is an advanced course that helps prepare students interested in the more molecular areas of Bioengineering for graduate programs in molecular bioengineering, medical school, MD/Ph.D. programs, and to biotechnology or medical device industries.

The course also addresses the following specific departmental goals at a High Level:

. Bioen. 457 integrates thermodynamic and reaction kinetics engineering concepts and uses design and quantitative analysis to derive molecular bioengineering solutions to current biomedical problems.

. Bioen. 457 connects biological and evolutionary solutions to the design of molecular materials and devices that address biomedical and molecular medicine problems and needs.

. Bioen. 457 requires engineering students to gain knowledge in the basic sciences fields (chemistry, biology, physics), and the biotechnology field, so that they will be able to work efficiently in multidisciplinary teams and communicate problems and their solutions effectively with physicians, basic scientists, and other engineers.