

Course Title	Advanced Bioorganic Chemistry		
Course Code	CM4051		
Offered	Study Year 4, Semester 1		
Course Coordinator	Loh Zhi Heng (Assoc Prof)	zhiheng@ntu.edu.sg	6592 1655
Pre-requisites	{CM1051, CM2031, CM3031, CM9051} (or by permission)		
AU	3		
Contact hours	Lectures: 39		

Course Aims

This course aims to illustrate the link between organic chemistry and biochemistry by discussing the organic chemistry of selected processes of living systems. It also aims to integrate the chemical principles with biological applications via the examples drawn from biochemistry, molecular and cell biology. Finally, it will also introduce you to the modern synthetic chemistry and technology for the preparation, detection and sequencing of biomacromolecules. This course would support those of you who will seek career in biotechnology, biomedicine and pharmaceuticals.

Intended Learning Outcomes

Upon successfully completing this course, you should be able to:

1. Physical and chemical properties of protein used in modern biotechnology: a. identify pKa and pI value of amino acids, polypeptides and proteins. b. link the knowledge between pI value, buffer pH and protein mobility in several separation biotechnologies, such as gel electrophoresis and liquid chromatography.
2. Non-biosynthetic methods for proteins: a. Design the synthetic routes and mechanisms of several preparations for amino acids. b. Explain the solid phase synthesis of polypeptides, including: i. the composition of solid supports, ii. the synthesis of amino acid monomers with necessary protection groups, iii. the activation agents for the coupling steps, iv. the detection assay of the coupling efficiency. c. use chemical ligation to prepare large protein chains.
3. Sequencing methods of polypeptides: a. Demonstrate the chemical principle and mechanism of two common sequencing methods with single amino acid resolution, the Sanger method and the Edman method. b. Combine the enzymatic cleavage and amino acid sequencing to resolve the protein sequence.
4. Chemical principles of enzymatic effects: a. distinguish the binding modes between substrates and enzymes and the impacts on enzymatic activity. b. illustrate the catalytic mechanisms of enzymatic reactions.
5. Kinetic parameters of enzymatic reactions: a. deduce the Michaelis-Menten and Lineweaver-Burk equations of enzymatic catalyst and variety of inhibition conditions. b. establish and analyse experimental protocols to determine the binding affinity, turnover number and maximum reaction rate of enzymatic reactions. c. distinguish the type of enzymatic inhibition upon reaction kinetics.
6. Non-biosynthesis of polynucleotides: a. Talk about the historic events of central dogma and related biotechnology. b. Illustrate the automatic synthesis of oligonucleotides, including: i. the four cyclic steps of the addition of phosphoramidite. ii. the chemical principle of each step. iii. the deprotection and purification of oligonucleotides. c. describe the sequencing of nucleic acids. d. interpret the chemistry of Maxam-Gilbert and Sanger sequencing. e. explain the procedure of the second generation of DNA sequencing.

7. Structure features of polysaccharides: a. distinguish the stereochemistry at glycosidic linkages. b. rank the reactivity of hydroxyl groups at anomeric, cyclic and alkyl carbons
8. Non-biosynthesis of polysaccharides: a. demonstrate the design, chemical reactions and mechanisms for the preparation of monosaccharides as donor and acceptor entities. b. design the synthetic routes for polysaccharides with define stereostructures.
9. Demonstrate biotechnologies for analysis and modification of carbohydrates.
10. Work as a team on the projects: a. balance the work load among team members b. maintain a friendly and constructive learning atmosphere within a team c. Practise peer studying and peer mentoring with team members.

Course Content

Syllabus and Proteins: properties and non-biosynthesis

Protein: non-biosynthesis

Protein: sequencing

Enzymatic Kinetics

Enzymatic Kinetics: inhibition

DNA: properties and non-biosynthesis

DNA: non-biosynthesis and sequencing

DNA: sequencing

Carbohydrates: structure and non-biosynthesis

Carbohydrates: non-biosynthesis

Carbohydrates: bioconjugation

Project presentation

Review on course contents

Assessment

Component	Course ILOs tested	SPMS-CBC Graduate Attributes tested	Weighting	Team / Individual	Assessment Rubrics
Continuous Assessment					
Lectures					
Homework	1, 2, 3, 4, 5, 6, 7, 8, 9	1. a, b, c	10	both	See Appendix for rubric
Presentation	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1. a, b, c 2. a, b 3. a, b	30	team	See Appendix for rubric
Technology-enhanced Learning					
ResponseWare	1, 2, 3, 4, 5, 6, 7, 8, 9	1. a, b, c	10	individual	See Appendix for rubric
Mid-semester Quiz					

Mid-term	1, 2, 3, 4, 5	1. a, b, c	20	individual	See Appendix for rubric
Examination (2 hours)					
Final Examination	1, 2, 3, 4, 5, 6, 7, 8, 9	1. a, b, c	30	individual	See Appendix for rubric
Total			100%		

These are the relevant SPMS-CBC Graduate Attributes.

1. Competence

- a. Be well-versed in the foundational and advanced concepts of chemical science
- b. Evaluate chemistry-related information critically and independently
- c. Use complex reasoning to solve emergent chemical problems

2. Creativity

- a. Synthesize and integrate multiple ideas across the curriculum
- b. Propose innovative solutions to emergent chemistry-related problems based on their training in chemistry

3. Communication

- a. Demonstrate clarity of thought, independent thinking, and sound scientific analysis and reasoning through written and oral reports to audiences with varying technical backgrounds
- b. Effectively engage other professional chemists in collaborative endeavours

Formative Feedback

You will be given feedback in four ways:

1. By working through ResponseWare questions during lectures
2. By response to postings on the course discussion board
3. By attending consultation hours
4. By studying the comments provided by the instructors after the grading of homework and midterm tests

Learning and Teaching Approach

Lectures (39 hours)	<p>ResponseWare: Allow instructor to challenge students during lecture and to achieve instant feedback. And the students to review the knowledge point right after the delivery and to master the knowledge in-depth. This approach is an online technology that can free students from the classroom and allows them to address the questions at their convenient and comfortable locations. The approach can also be applied to team work.</p> <p>team based peer studying: Develop communication skills, team bonding, team work skills while working together as a group on projects. The students also have the opportunity to conduct peer mentoring and peer studying during study.</p> <p>video: Videos and animations are prepared for technology enhance learning and will be used for e-learning and online study weeks. These videos will be placed online for students to study outside classroom or for those students who have lecture time clash or for the review and exam preparation. This will facilitate the understanding of complicate non-biosynthetic technologies. Besides reading references, this would offer students alternative learning materials for better comprehension.</p>
-------------------------------	---

Reading and References

1. Principles of biochemistry, 5th ed. by D.L. Nelson & M.M. Cox ISBN-10: 1429234148
2. Bioorganic chemistry : highlights and new aspects by U. Diederichsen & T.K. Lindhorst ISBN: 3-527-29665-4
3. Oligosaccharides, their synthesis and biological roles by Helen Osborn & Tariq Khan ISBN-10: 0198502656
4. Bioorganic chemistry : peptides and proteins by Sidney M. Hecht ISBN: 9780195084689
5. Bioorganic chemistry : a chemical approach to enzyme action by Hermann Dugas. ISBN: 978-1-4612-2426-6

Course Policies and Student Responsibilities

Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class , you have to:

1. Send an email to the instructor regarding the absence and the requests for a replacement class if necessary.
2. Submit the original Medical Certificate to administrator.
3. Attend the assigned replacement class (subject to availability).

|| The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the [Academic Integrity website](#) for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Loh Zhi Heng (Assoc Prof)	SPMS-CBC-01-19A	6592 1655	zhiheng@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	Syllabus and Proteins: properties and non-biosynthesis	1, 2	
2	Protein: non-biosynthesis	2	
3	Protein: sequencing	3	
4	Enzymatic Kinetics	4	
5	Enzymatic Kinetics: inhibition	5	
6	DNA: properties and non-biosynthesis	6	
7	DNA: non-biosynthesis and sequencing	6	
8	DNA: sequencing	6	

9	Carbohydrates: structure and non-biosynthesis	7, 8	
10	Carbohydrates: non-biosynthesis	8	
11	Carbohydrates: bioconjugation	9	
12	Project presentation	1, 2, 3, 4, 5, 6, 7, 8, 9	
13	Review on course contents	1, 2, 3, 4, 5, 6, 7, 8, 9	

Appendix 1: Assessment Rubrics

Rubric for Lectures: Homework (10%)

Standards	Criteria
A+ (Exceptional) A (Excellent)	Actively participate and answer Responseware questions correctly in and out of class. Complete homework punctually and correctly, working very effectively as a team to maintain a highly supportive and constructive learning atmosphere with well-balanced workload among team members (Learning Outcome 10). Able to apply the knowledge learned very well with referenced to the learning outcomes (LO) 1 to 9 in order to answer the questions in written exams.
A- (Very good) B+ (Good)	Actively participate in Responseware questions in and out of class. Complete homework punctually and be correct on majority of the questions, working effectively as a team to maintain a supportive and constructive learning atmosphere with balanced workload among team members (LO 10). Able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	Participate in Responseware questions in and out of class. Complete homework with average marks, working somewhat effectively as a team to maintain a somewhat supportive and constructive learning atmosphere with a somewhat balanced workload among team members (LO 10). Partially able to apply the knowledge learned with referenced to the LO 1 to 9 to answer some of the questions in written exams.
C (Bordering unsatisfactory) C- (Unsatisfactory)	Seldom participate in Responseware questions in and out of class. Not able to complete homework on time or achieve average marks, working somewhat ineffectively as a team to maintain a supportive and constructive learning atmosphere with a somewhat unbalanced workload among team members (LO 10). Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer some of the questions in written exams.
D, F (Deeply unsatisfactory)	Does not participate in Responseware questions in and out of class. Not able to complete homework, and work ineffectively as a team to maintain a supportive and constructive learning atmosphere with unbalanced workload among team members (LO 10). Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.

Rubric for Lectures: Presentation (30%)

Performance Level	Criteria
Excellent	Demonstrates complete achievement of the learning outcomes 1-9. Able to connect to the topics covered and how it can be used to solve the problem. Able to organize the team to present the assigned topic and answer the comments/questions after the oral presentation. Show good communication ability to lead the learning team and peer tutor the team members.
Good	Demonstrates complete achievement of the learning outcomes 1-9. Able to connect to the topics covered and how it can be used to solve the problem at hand. Able to present the assigned topic and have good communication with the team members.
Satisfactory	Demonstrates partial achievement of the learning outcomes 1-9. Able to apply the technique or methodology taught in class only in direct way. Able to present the assigned topic but may not be precise or concise enough.
Unsatisfactory	Demonstrates minimal achievement of the learning outcomes 1-9. Not able to apply the knowledge to the problems or not able to present the assigned topic well or have difficulty to maintain good communication with the team member.

Poor	Do not possess sufficient understanding of problem and lack solution for it. Not able to complete presentation and join team study.
------	---

Rubric for Technology-enhanced Learning: ResponseWare (10%)

Standards	Criteria
A+ (Exceptional) A (Excellent)	Actively participate and answer Responseware questions correctly in and out of class. Complete homework punctually and correctly, working very effectively as a team to maintain a highly supportive and constructive learning atmosphere with well-balanced workload among team members (Learning Outcome 10). Able to apply the knowledge learned very well with referenced to the learning outcomes (LO) 1 to 9 in order to answer the questions in written exams.
A- (Very good) B+ (Good)	Actively participate in Responseware questions in and out of class. Complete homework punctually and be correct on majority of the questions, working effectively as a team to maintain a supportive and constructive learning atmosphere with balanced workload among team members (LO 10). Able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	Participate in Responseware questions in and out of class. Complete homework with average marks, working somewhat effectively as a team to maintain a somewhat supportive and constructive learning atmosphere with a somewhat balanced workload among team members (LO 10). Partially able to apply the knowledge learned with referenced to the LO 1 to 9 to answer some of the questions in written exams.
C (Bordering unsatisfactory) C- (Unsatisfactory)	Seldom participate in Responseware questions in and out of class. Not able to complete homework on time or achieve average marks, working somewhat ineffectively as a team to maintain a supportive and constructive learning atmosphere with a somewhat unbalanced workload among team members (LO 10). Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer some of the questions in written exams.
D, F (Deeply unsatisfactory)	Does not participate in Responseware questions in and out of class. Not able to complete homework, and work ineffectively as a team to maintain a supportive and constructive learning atmosphere with unbalanced workload among team members (LO 10). Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.

Rubric for Mid-semester Quiz: Mid-term (20%)

Standards	Criteria
A+ (Exceptional) A (Excellent)	Actively participate and answer Responseware questions correctly in and out of class. Complete homework punctually and correctly, working very effectively as a team to maintain a highly supportive and constructive learning atmosphere with well-balanced workload among team members (Learning Outcome 10). Able to apply the knowledge learned very well with referenced to the learning outcomes (LO) 1 to 9 in order to answer the questions in written exams.
A- (Very good) B+ (Good)	Actively participate in Responseware questions in and out of class. Complete homework punctually and be correct on majority of the questions, working effectively as a team to maintain a supportive and constructive learning atmosphere with balanced workload among team members (LO 10). Able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	Participate in Responseware questions in and out of class. Complete homework with average marks, working somewhat effectively as a team to maintain a somewhat supportive and constructive learning atmosphere with a somewhat balanced workload among team members (LO 10). Partially able to apply the knowledge learned with referenced to the LO 1 to 9 to answer some of the questions in written exams.
C (Bordering unsatisfactory) C- (Unsatisfactory)	Seldom participate in Responseware questions in and out of class. Not able to complete homework on time or achieve average marks, working somewhat ineffectively as a team to maintain a supportive and constructive learning atmosphere with a somewhat unbalanced workload among team members (LO 10). Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer some of the questions in written exams.

D, F (Deeply unsatisfactory)	Does not participate in Responseware questions in and out of class. Not able to complete homework, and work ineffectively as a team to maintain a supportive and constructive learning atmosphere with unbalanced workload among team members (LO 10). Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.
------------------------------	---

Rubric for Examination: Final Examination (30%)

Standards	Criteria
A+ (Exceptional) A (Excellent)	Actively participate and answer Responseware questions correctly in and out of class. Complete homework punctually and correctly, working very effectively as a team to maintain a highly supportive and constructive learning atmosphere with well-balanced workload among team members (Learning Outcome 10). Able to apply the knowledge learned very well with referenced to the learning outcomes (LO) 1 to 9 in order to answer the questions in written exams.
A- (Very good) B+ (Good)	Actively participate in Responseware questions in and out of class. Complete homework punctually and be correct on majority of the questions, working effectively as a team to maintain a supportive and constructive learning atmosphere with balanced workload among team members (LO 10). Able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.
B (Average) B- (Satisfactory) C+ (Marginally satisfactory)	Participate in Responseware questions in and out of class. Complete homework with average marks, working somewhat effectively as a team to maintain a somewhat supportive and constructive learning atmosphere with a somewhat balanced workload among team members (LO 10). Partially able to apply the knowledge learned with referenced to the LO 1 to 9 to answer some of the questions in written exams.
C (Bordering unsatisfactory) C- (Unsatisfactory)	Seldom participate in Responseware questions in and out of class. Not able to complete homework on time or achieve average marks, working somewhat ineffectively as a team to maintain a supportive and constructive learning atmosphere with a somewhat unbalanced workload among team members (LO 10). Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer some of the questions in written exams.
D, F (Deeply unsatisfactory)	Does not participate in Responseware questions in and out of class. Not able to complete homework, and work ineffectively as a team to maintain a supportive and constructive learning atmosphere with unbalanced workload among team members (LO 10). Not able to apply the knowledge learned with referenced to the LO 1 to 9 to answer most of the questions in written exams.