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6. Singapore-MIT Alliance

6.1 Introduction

The Singapore-MIT Alliance (SMA) is a global partnership between Massachusetts Institute of Technology (MIT), National University of Singapore (NUS) and Nanyang Technological University (NTU).

Founded in November 1998 to promote global graduate science & engineering education and research, SMA is the world’s largest interactive distance education initiative. The partnership taps world-class engineering expertise, ideas and technology required for cutting-edge research to fuel Singapore as well as the region’s growth as an innovation and education hub.

Please visit the SMA website at http://www.sma.nus.edu.sg for more details.

6.2 Contact Information

<table>
<thead>
<tr>
<th>Name/Title</th>
<th>Designation/ Responsibility</th>
<th>Email</th>
<th>Telephone</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professor Yue Chee Yoon</td>
<td>IMST Programme Co-Chair &amp; Faculty Fellow (Singapore)</td>
<td><a href="mailto:mcyuye@ntu.edu.sg">mcyuye@ntu.edu.sg</a></td>
<td>6790 5486</td>
<td>6791 1859</td>
</tr>
<tr>
<td>Professor David Hardt</td>
<td>IMST Programme Co-Chair &amp; Faculty Fellow (MIT)</td>
<td><a href="mailto:hardt@mit.edu">hardt@mit.edu</a></td>
<td>617 253 2252</td>
<td>617 253 2123</td>
</tr>
<tr>
<td>Professor Lee Jim Yang</td>
<td>MEBCS Programme Co-Chair &amp; Faculty Fellow (Singapore)</td>
<td><a href="mailto:cheleejy@nus.edu.sg">cheleejy@nus.edu.sg</a></td>
<td>6874 2899</td>
<td>6779 1936</td>
</tr>
<tr>
<td>Professor Gregory N. Stephanopoulos</td>
<td>MEBCS Programme Co-Chair &amp; Faculty Fellow (MIT)</td>
<td><a href="mailto:gregstep@mit.edu">gregstep@mit.edu</a></td>
<td>617 253 4583</td>
<td>617 253 3122</td>
</tr>
<tr>
<td>Associate Professor Leong Tze Yun</td>
<td>CS Programme Co-Chair &amp; Faculty Fellow (Singapore)</td>
<td><a href="mailto:leongty@comp.nus.edu.sg">leongty@comp.nus.edu.sg</a></td>
<td>6874 6519</td>
<td>6779 4580</td>
</tr>
<tr>
<td>Professor Charles Leiserson</td>
<td>CS Programme Co-Chair &amp; Faculty Fellow</td>
<td><a href="mailto:cel@mit.edu">cel@mit.edu</a></td>
<td>617 253 5833</td>
<td>617 253 0415</td>
</tr>
</tbody>
</table>

6.3. Programmes

The SMA is a bold new model for creating highly visible and quality graduate science and engineering education programmes in areas of strategic importance to academia, research institutes and the industry. The three SMA programmes offered this July are in Innovation in Manufacturing Systems and Technology (IMST), Molecular Engineering of Biological and Chemical Systems (MEBCS) and Computer Science (CS). The MEBCS and CS programmes are hosted by NUS. The IMST programme is hosted by NTU.
In all programmes, SMA Faculty Fellows from MIT, NUS and NTU develop graduate-level coursework which is delivered both through state-of-the-art distance education technology and face-to-face interaction.

All students are admitted directly into full-time graduate programmes that lead to the award of either:

- Master of Science (SM) degree; or
- Doctor of Philosophy (PhD) degree

The SM degree requires one year and PhD degree three or more years of study. The SM degree is awarded by the host university while the PhD degree is awarded by the university to which the Singapore Thesis Advisor is attached.

All SMA students interact face-to-face with the MIT faculty during an intensive two and a half-weeks of the SMA Summer Conference Programme held at MIT in August. PhD students spend one additional semester at MIT to attend graduate courses and conduct research.

6.3.1 By Coursework

Innovation in Manufacturing Systems and Technology (IMST)

The Innovation in Manufacturing Systems and Technology (IMST) degree programme offers highly competitive courses of study that explore the many facets of manufacturing technology and is intended to prepare the student to assume a role of technical leadership in the existing as well as emerging manufacturing industry. Challenging coursework integrates the process, product, system, and business aspects of this vibrant industry, while focusing on the core of manufacturing systems - the operational flow problems of the factory environment.

While firmly grounded in the engineering sciences, advanced coursework will expose students to innovative theories and methodology, as well as a rigorous investigation of financial, strategic and global aspects of technology innovation and new business generation.

The programme includes subjects in the core areas of manufacturing physics, systems and products which are complemented by a Professional Seminar in which manufacturing business leaders and faculty explore the enterprises - wide, global and long-term strategic issues in manufacturing. Students are required to read a total of eight subjects; all of which are compulsory.

Molecular Engineering of Biological and Chemical Systems (MEBCS)

The Molecular Engineering of Biological and Chemical Systems (MEBCS) degree programme offers an exciting and innovative curriculum in the field of molecular engineering. Its innovative courses of study integrate a molecular-level understanding of biological and chemical phenomena with advances in process engineering for the life sciences and fine chemical industries. Coursework presents advanced engineering concepts that unite multiple length scales "molecular, microscopic and macroscopic" through a close coupling of biological and chemical sciences. Students will be exposed to state-of-the-art concepts in structured fluids, surface functionalisation, microstructure tailoring and materials design in relation to fine chemicals and pharmaceutical synthesis. Students will also study the molecular and cellular aspects of biotechnology, genomics, bioinformatics, proteomics, drug design and delivery that
underlie advanced bioengineering. Students are required to read a total of nine subjects; all of which are compulsory.

**Computer Science (CS)**

The Computer Science (CS) degree programme offers an in-depth understanding of, and appreciation for, the rapidly growing field of computer science. The primary goal of the Computer Science programme is to train students to discover and develop new technology with immediate economic impact while providing a solid foundation to enable adaptation. It is aimed at training students to apply their knowledge of Computer Science to industrial problems, particularly in the development of large software systems and embedded computing. Students are exposed to the broad foundations of computer science, encompassing computer architecture, software systems, algorithms, advanced applications, theory of parallel computation and pervasive computing. Through a challenging and rigorous course of study, and diverse interactions with industry leaders and young entrepreneurs, graduates will closely examine advanced developments in Web applications and infrastructure, embedded systems and computational biology. The students are required to complete at least six subjects.

**6.3.1.1 SMA Internship Programme**

SM students are required to undergo an Internship Programme with the industry as part of the degree requirement.

The objectives of the SMA internship are to:

a. provide opportunities for the students to use their initiative and creativity;
b. to challenge the students to deploy problem solving skills and use new approaches when faced with problems;
c. to stretch the student’s potential and ability to the maximum;
d. to encourage cohesiveness and synergy

Through this SMA internship, the students will familiarise themselves with the industry requirements and be able to envision the direction in which the industry should be heading to meet new challenges. The training received should be comprehensive and include achieving the following competencies:

a. innovation, creativity, entrepreneurial practices, technopreneurship, best practices, systems thinking and organisation learning.
b. team learning
c. use of up-to-date software technology
d. cost and return on investment analysis
e. total quality management and quality control circles
f. reliability measures
g. marketing and sale strategies

SMA supervisors appointed from among the SMA Fellows are assigned to assist in formulating a work schedule and tracking the progress of the student(s) during the SMA internship. This is done in collaboration with the supervisor from the company involved in the project. For the MEBCS programme, one or two managers are assigned to supervise the students together with the company supervisor.

Students are required to submit the project dissertation at the end of the internship. If the report contains propriety information, the company may request that the report be excluded from the public domain for a period mutually agreed upon.
The internship duration and period varies among the different programmes:

<table>
<thead>
<tr>
<th>Name of Programme</th>
<th>Duration of project</th>
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<tr>
<td>IMST</td>
<td>7 months (December - June) – Theme Project</td>
</tr>
<tr>
<td>CS</td>
<td>5 months (January - May)</td>
</tr>
<tr>
<td>MEBCS</td>
<td>two 5 weeks sessions (Session 1: 31 March to 2 May; Session 2: 12 May to 13 June) – Industrial Immersion</td>
</tr>
</tbody>
</table>

### 6.3.2 By Research (Research Doctorate)

Students are required to read and pass the prescribed number of SM courses before they can be considered for admission to the PhD degree. Potential candidates also have to pass the PhD Qualifying Examination, which is held after 6 months from the start date of their candidature, in order to be confirmed as PhD candidates.

**Innovation in Manufacturing Systems and Technology (IMST)**

The PhD degree programme in IMST is a research programme that prepares students for careers in industrial research and development centres, research institutes or academic departments interested in fundamental research in manufacturing. The PhD degree programme has the same basis as the SM degree programme but delves more deeply into new theories, methods and technologies in manufacturing. PhD students participate in cutting-edge work in processes, equipment design and control, systems or integrated product-process design. The IMST programme works in close association with the Singapore Institute of Manufacturing Technology (SIMTech).

The PhD degree programme also includes reading eight manufacturing core subjects from the SM programme but adds a selection of subjects at MIT and in Singapore on advanced topics in each of the fundamental areas. In addition, the students may be required to take up to two minor subjects based upon the Thesis Advisors' recommendations.

**Molecular Engineering of Biological and Chemical Systems (MEBCS)**

The PhD degree programme prepares graduates for advanced careers in industrial research and development centres, research institutes or academic departments interested in biological and chemical engineering processes, with emphasis on synthesis skills, engineering design, and interdisciplinary approaches. The PhD programme includes advanced coursework that emphasises molecular engineering as it pertains to advanced materials synthesis and biotechnology and independent research. SMA students have the opportunity to interact with scientists and engineers at a number of leading research institutes and centres, such as the Institute of Molecular and Cell Biology (IMCB), Institute of Materials Research and Engineering (IMRE), and Bioprocessing Technology Centre (BTC), all of which are internationally renowned for their basic and applied R&D programmes. The PhD candidates also read nine core subjects. The students may be required to take up to two minor subjects based upon the Thesis Advisors' recommendations.

**Computer Science (CS)**

The PhD degree programme in Computer Science is a research programme that provides the necessary depth to equip graduates for careers in industrial research and development centres, research institutes or academic departments interested in cutting-edge research in all aspects of Computer Science. The
PhD candidates read six core subjects. The students may be required to take up to two elective and minor subjects each based upon the Thesis Advisors’ recommendations.

For all the three programmes, the PhD students have the opportunity to read subjects during their semester stay at MIT, in addition to performing research in collaboration with MIT students and the faculty. The PhD degree also requires the completion of a PhD thesis.

### 6.4 SMA Policies

- **Policy on Academic Performance**

Criteria for continuation of candidature and graduation:

1. Students whose CGPA first falls below 3.5 in either the Summer OR Fall term will be issued with a warning letter at the end of that term. The letter would state that the students’ candidature would be terminated at the end of the following term (in this instance Fall OR Spring) if the CGPA remained below 3.5. The students concerned would be counselled on his/her performance by both the subject and course co-ordinators.
2. Students whose CGPA first falls below 3.5 in the Spring term will not be allowed to graduate.
3. Students who obtain a grade ‘F’ in any subject in any term will have the candidature terminated once the Joint Academic Committee (JAC) endorses the termination, with no prior warning given.
4. Students who obtain a grade ‘C’ or ‘D’ in any subject in any term would be given a warning letter for poor performance. The students concerned would be counselled by both the subject and course co-ordinators.
5. To graduate, a student must maintain a cumulative grade-point average (CGPA) of 3.5 and above.

The above applies to all the subjects taken by the students including elective subjects but excluding minor subjects (applicable to PhD students).

**Appeal**

A student whose candidature has been terminated may appeal to the SMA Co-Directors for reconsideration. The appeal will be put up to the Programme Chair Committee (PCC) which may recommend to the JAC to either maintain or change the decision. The JAC will then make the final decision.
• Examination Policy

Beginning of the Term

Early in the term, the subject co-ordinator should remind students of expectations regarding academic conduct and performance for all subjects.

By the end of the third week, the subject/course co-ordinator must:
- 
  - provide the approximate schedule of tests/examinations and due dates for presentations
  - inform the SMA Office if there would be a final examination for each subject

Academic Honesty

Cheating, plagiarism, unauthorised collaboration and other forms of academic dishonesty are considered serious offences for which disciplinary penalties would be imposed.

Some academic offences by students can be handled directly between the Subject Co-ordinator and the students involved. In some cases, it may be necessary for the Programme Co-Chair to review, or otherwise to assist in, the resolution of the matter. When a dispute cannot be resolved satisfactorily within the programme, or if it seems appropriate, a complaint against a student can be brought to the Programme Chair Committee (PCC) which is the final authority for academic conduct. Based on the PCC decision, the student will be informed of the penalty to be imposed. This could include not taking into account the marks and grades for that particular assignment/quiz/examination

Excused Absences from Quizzes/Examinations

A student may be excused from scheduled quizzes/examinations for reasons of illness. In the event a student falls ill on the scheduled date of quizzes/examinations, the student should contact the SMA Office which will then inform the Subject Co-ordinator and the Programme Co-Chair. The student then needs to submit the Medical Certificate together with the University’s prescribed form certified by the medical doctor.

The Subject Co-ordinator, in consultation with the Course Co-ordinator and Programme Co-Chair, will review the case and if they make a decision not to take into account the particular component when collating the final marks and grades for that particular assignment/quiz/examination, they must be prepared to submit a final mark and grade based on other evidence.
6.5 Faculty Members

**Innovation in Manufacturing Systems and Technology (IMST)**

Singapore Fellows:
- Lam, Yee Cheong, Professor, PhD B.E (Melb.), CPEng (Aust), FIEAust
- Nee, Andrew Yeh Ching, Professor, PhD (UMIST), Active Member CIRP, Fellow SME
- Yoon, Soon Fatt, Professor, PhD (Wales), MIEE B.Eng. (Wales)
- Yue, Chee Yoon, Professor & Programme Co-Chair, PhD B.E. (Hons)(Monash)
- Appa Iyer, Sivakumar, Associate Professor, PhD B. Eng. (Hons)(Bradford), CEng, MIMechE, MIEE (London)
- Chen, I-Ming, Associate Professor, PhD (California Institute of Technology)
- Loh, Han Tong, Associate Professor, PhD M.S. (Michigan), M.Eng. (NUS), B.Eng.(Hons) (Adelaide)
- Ngoi, Bryan KA., Associate Professor, PhD (Canterbury), B.Eng. (NUS)
- Tor, Shu Beng, Associate Professor & Course Co-ordinator, PhD B.Sc. (Hons) (Westminster, UK)
- Bhatnagar, Rohit, Associate Professor, PhD (Canada), B.Tech. (Institute of Technology, India), P.G.D.M. (Indian Institute of Management)
- Subramaniam, Velusamy, Assistant Professor, PhD (MIT)
- Lu, Wen Feng, PhD (Minnesota)

Singapore Associates:
- Chan, Bee Eng Mary, Associate Professor, PhD (MIT), B.Eng. (NUS)

MIT Fellows:
- Anand, Lallit, Professor, PhD M.S. (Brown), B.Tech. (IIT Kharagpur)
- Chun, Jung-Hoon, Professor, PhD (MIT), M.A.Sc. (Ottawa), B.S. (Seoul National)
- Hardt, David, Professor & Programme Co-Chair, PhD M.S. (MIT), BSME (Lafayette College)
- Graves, Stephen C., Professor, PhD MBA (Rochester), M.S. A.B. (Darthmouth)
- Youcef-Toumi, Kamal, Professor, Sc.D. SM (MIT), B.S (Cincinnati)
- Boning, Duane, Professor, PhD, SM, SBEE, SBCS (MIT)
- Gershwin, Stanley, PhD M.A. (Harvard), B.S. (Columbia)

MIT Associates:
- Simchi-Levi, David, Professor, PhD M.Sc. (Tel-Aviv University, Israel), B.Sc. (Technion Israel Institute of Technology)
- Gallien, Jeremie, Assistant Professor, PhD (MIT), Engineering degree (Ecole Des Mines De Paris)

**Molecular Engineering of Biological and Chemical Systems (MEBCS)**

Singapore Fellows:
- Lee, Jim Yang, Professor & Programme Co-Chair, PhD M.S.E. (Michigan), B.S. (Hons)(Sing)
- Chow, Gan-Moog, Associate Professor, PhD M.S. (Connecticut), B.S. (SUNY Stony Brook)
- Tam, Michael K.C., Associate Professor, PhD B.Eng. (Hons)(Monash)
- Too,Heng-Phon, Associate Professor, PhD (Imperial College)
- Vallyaveettil, Suresh, Assistant Professor & Course Co-ordinator, PhD (Victoria), M.Tech. (IIT Delhi), M.S. B.S. (Calicut)
- Wang, Chi-Hwa, Associate Professor, PhD M.A. (Princeton), M.S. (Johns Hopkins), B.S. (NTU, Taiwan)
Singapore Associate:
Yap, Miranda G S, Professor, PhD (Toronto), M.S. D.U.C. (UCL), B.S. (Hons)(Sing)

MIT Fellows:
Brown, Robert A., Professor & Programme Advisor, PhD (Minnesota), M.S. B.S. (Texas)
Hatton, T. Alan, Professor, PhD (Wisconsin), M.Sc. B.Sc. (Natal, South Africa)
Lodish, Harvey F., Professor, PhD (Rockefeller), A.B. (Kenyon College)
Smith, Kenneth A, Professor, Sc.D. SM S.B. (MIT)
Stephanopoulos, Gregory N., Professor & Programme Co-Chair, PhD (Minnesota), M.S. (Florida)
Wang, Daniel I.C., Professor, PhD (Pennsylvania), M.S. B.S. (MIT)
Ying, Jackie Y., Professor, PhD M.A. (Princeton), B.E. (Cooper Union)
Laibinis, Paul E., PhD M.A. (Harvard), S.B. (MIT)

MIT Associate:
Suresh, Subra, Professor, PhD (MIT), M.S. (Iowa), B. Tech. (Hons) (IIT Madras)
Trout, Bernhardt L., Associate Professor, PhD (UC Berkeley), SM S.B. (MIT)

Computer Science (CS)

Singapore Fellows:
Ooi, Beng Chin, Professor, PhD (Australia)
Cham, Tat Jen, Associate Professor, PhD B.A (St Catherine’s College)
Chin, Wei Ngan, Associate Professor, PhD (Imperial College, University of London)
Hsu, Wen Jing, Associate Professor, PhD (National Chiao Tung), SrMIEEE
Leong, Tze Yun, Associate Professor & Programme Co-Chair, PhD SM S.B. (MIT)
Tan, Kian Lee, Associate Professor, PhD M.Sc. B.Sc. (NUS)
Teo, Yong Meng, Associate Professor, PhD CEng MBCS MIEEE MSCS (Manchester)
Wong, Weng Fai, Associate Professor & Course Co-ordinator, Dr.Eng.Sc. (Tsukuba), M.Sc. B.Sc. (NUS)
Lee, Wee Sun, Associate Professor, PhD (Australia)
Hsu, David, Assistant Professor, PhD (USA), B.Sc. (Canada)

Singapore Associates:
Hsu, Wynne, Associate Professor, PhD (Purdue)
Ng, Teck Khim, PhD (Carnegie Mellon)
Ng, Hwee Tou, Associate Professor, PhD (Austin)
Teh, Hung Chuan, Associate Professorial Fellow, PhD (McMaster)

MIT Fellows:
Edelman, Alan, Professor, PhD (MIT) M.A., BS (Yale)
Kaelbling, Leslie, Professor, A.B. PhD (Stanford)
Leiserson, Charles, Professor & Programme Co-Chair, PhD (Carneige-Mellon), B.S. (Yale)
Lozano-Perez, Tomas, Professor, PhD SM S.B. (MIT)
Madnick, Stuart, Professor, PhD SM S.B. (MIT)
Amarasinghe, Saman, Associate Professor, PhD SM (Stanford)
Rinard, Martin, Associate Professor, PhD (Stanford), B.Sc. (Cornell)
Rudolph, Larry, Principal Research Scientist, PhD (New York)

MIT Associate:
Durand, Fredo, Assistant Professor, PhD,DEA (France)
Popovic, Jovan, Assistant Professor, PhD MS (Carneige-Mellon)
6.6 Modules Listing

**Innovation in Manufacturing Systems and Technology (IMST)**

**SMA6301 Manufacturing Physics I**  
Modular credits: 12  
Workload: 6-1.5-3-NA-3  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA  
Brief Module Description: The basic modes of transformation in processes: removal, addition, phase change and deformation. Various means for performing these transformations and the effect of material constitutive properties. Introduction of the concepts of process characterisation, parameters of cost, quality, rate and flexibility. Organised by modules, each of which treats the various manifestations of a single transformation method.

**SMA6302 Manufacturing Physics II**  
Modular credits: 12  
Workload: 3-1-NA-3-3  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): 2.996 (MIT)  
Brief Module Description: Emphasizes a systems approach to equipment selection and/or design. Provides exposure to selected industrial automation practices and develops the ability to select appropriate automation methods. Fundamental building blocks: system kinematics and dynamics, modeling uncertainty, measurement and actuation uncertainty, control-system theory. Performance limitations: hardware kinematics and dynamics. Use of feedback control system to meet equipment performance specifications. Use of case studies from different applications (such as optoelectrical assembly, laser cutting, semiconductor, etc.).

**SMA6303 Manufacturing Physics III**  
Modular credits: 12  
Workload: 3-1-6-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): 2.830 (MIT)  
Brief Module Description: Process control in manufacturing processes. Discrete system feedback control theory, empirical/adaptive modeling, and basic process physics understanding. A general framework for modeling and control of manufacturing processes is developed. Various existing forms of process control are studied, including off-line optimisation, statistical process control, and real-time machine and process control. The control approach to process physics is examined in the context of specific manufacturing processes.

**SMA6304 Manufacturing Systems I**  
Modular credits: 12  
Workload: 3-1-NA-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): 15.968 (MIT)  
Brief Module Description: Provides ways to conceptualize and analyze manufacturing systems and supply chains in terms of material flow, information flow, capacities, and flow times. Fundamental building blocks: inventory and queuing models, forecasting and uncertainty, optimisation, process analysis, linear systems and system dynamics. Factory planning: flow planning, bottleneck characterisation, buffer and batch-size tactics, seasonal planning, dynamics and learning for various process flow topologies and for various market contexts.
SMA6305 Manufacturing Systems II
Modular credits: 12
Workload: 4.5-NA-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): 15.762 (MIT)
Brief Module Description: Introduces applicable models and software, and provides exposure to industrial applications and cases. Focus on impact of demand and process variability, as well as process and policy constraints on performance of supply chains and manufacturing systems. Examines application of key tactics and countermeasures, such as inventory, flexibility and risk pooling. Supply chain planning topics include network inventory models, flow planning, system dynamics, value from supply chain integration for various network topologies and for various market contexts. Manufacturing system design topics include: integration with product development, capacity planning and flexibility, network location decisions, impact of product variety, impact of short product life cycles, make-buy and supplier choice decisions.

SMA6306 Product Design and Development
Modular credits: 12
Workload: 3-NA-3-6-6
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: Covers modern tools and methods for product design and development. The cornerstone of this subject is a project in which teams of management, engineering and industrial design students conceive, design, and prototype a physical product. Class sessions are conducted in workshop mode and employ cases and hands-on exercises to reinforce key ideas.

SMA6307 Business Fundamentals
Modular credits: 12
Workload: 6-1-NA-NA- NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: Provides exposure to key principles and practices used in business management. Provides opportunities to analyze cases in management of innovation.

SMA6308 Professional Seminar in Manufacturing
Modular credits: 6 (3 credit points per semester)
Workload: 2-NA-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): 2.996 (MIT)
Molecular Engineering of Biological and Chemical Systems (MEBCS)

SMA5401 Molecular and Cellular Aspects of Biotechnology
Modular credits: 9
Workload: 10-Included in lectures-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: This introductory course will provide a basic understanding of molecular biology, cell structure, cell growth and division, and cell regulation by internal and external signals. The second part will focus on production of recombinant proteins by cultured animal cells, including the processes of protein secretion; protein folding; glycosylation and other post-translational modifications; and protein quality control. It will also address how the process of receptor-mediated endocytosis can be used to target therapeutic proteins and genes to specific cells in the body. Genetic engineering of bacteria and animal cells, including techniques for site-specific mutation of proteins and for expression of foreign genes in mammalian cells will be discussed. The generation and use of transgenic animals and plants for production of recombinant proteins will also be covered.

SMA5402 Biotechnology Laboratory
Modular credits: NA
Workload: NA-NA-34-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: The objective of this laboratory component to SMA5401 is to introduce basic microbiological and biochemical techniques to familiarize students with biological systems through experiments.

SMA5403 Molecular Aspects of Materials Design
Modular credits: 9
Workload: 2-NA-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: The course provides a molecular perspective for engineering the properties of organic, inorganic, and composite systems. It focuses on the atomic-level energetic relationships that affect structure and interfacial interactions and give rise to many macroscopic properties. Various thermodynamic analyses of aggregation, surface effects, and phase behaviour are used to provide a molecular perspective and insight into the prediction of physical properties, the design of self-assembling systems, and the tailoring of a material's properties. Practical case studies are used to demonstrate the relationships between structure and function across many length scales and to develop a chemical intuition for the design of complex chemical systems.

SMA5411 Molecular Thermodynamics
Modular credits: 12
Workload: 10-NA-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: The goals of this course are to develop a quantitative basis for estimation of the equilibrium properties of mixtures found in biological and chemical systems. The course will draw on both classical and statistical thermodynamics to develop analytical tools for the description of multicomponent solution phase equilibria in electrolyte and non-electrolyte systems (both monomeric and polymeric), and in gels, membranes and protein solutions. The conformational and structural stability of proteins will be covered, as will the thermodynamics of self-aggregating systems such as micelles, vesicles and other structured fluids. An introduction to surface thermodynamics (surface tension, adsorption) will round out the course. Practical examples will be used throughout to reinforce the fundamental principles introduced in this course.
SMA5412 Transport and Reaction Processes  
Modular credits: 12  
Workload: 4-NA-NA-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA  
Brief Module Description: The initial portion of this subject will provide a unified introduction to momentum, mass, and heat transfer. Topics will include diffusion, conduction, and convection in both homogeneous and heterogeneous media. Diffusional Limitations on the rate of heterogeneous reactions will be explored. The latter portion of the subject will treat chemical kinetics in some detail with an emphasis on heterogeneous systems for which adsorption/desorption phenomena are particularly important. Reactor applications will include both conventional reactors for which concepts such as the residence time distribution are important and also physiological systems.

SMA5413 Kinetics of Biological and Chemical Systems  
Modular credits: 12  
Workload: 4-NA-NA-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): 10.541 (MIT)  
Brief Module Description: This course provides a comprehensive treatment of the kinetics of basic chemical reactions and biological processes. It begins with a fundamental analysis of reaction order in homogeneous reactions and proceeds with the kinetics of heterogeneous systems and catalytic reactions. Methods of measuring and calculating reaction rate constants will be included. After a basic stoichiometric analysis of biological reaction networks, the course will discuss kinetics of enzymatic reactions and extensions to kinetic characteristics of reaction pathways and bioreaction networks. Similarities and differences between chemical and biological kinetics are discussed along with concepts of rate-limiting steps and distribution of control among several reactions in a pathway. The course concludes with applications to the kinetics analysis of chemical and biological reaction systems in the chemical and bioprocess industries.

SMA5421 Nanostructured Catalysts Design and Organic Synthesis  
Modular credits: 9  
Workload: 4-NA-NA-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): 10.422/10.522 (MIT)  
Brief Module Description: Catalytic processes are critical to the synthesis of chemicals, materials, and pharmaceuticals. This subject describes the tailoring of materials with unique pore structures and nanocrystallinity to provide for designed functionalities in catalytic applications. Strategies for surface modification and compositional design targeted towards enhancing catalytic activity, selectivity and stability will be discussed. The characterization and use of nanostructured catalysts in organic synthesis will be presented; of particular interest are the synthetic transformations and catalytic chemistry underlying oxidation/reduction, hydrogenation, self-assembly concept and its application in materials engineering.

SMA5422 Special Topics in Biotechnology  
Modular credits: 6  
Workload: 2-NA-NA-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA  
Brief Module Description: This course reviews current topics in biology and biotechnology with particular emphasis on technologies catalyzed by developments in the field of genomics. These developments are changing the landscape of the chemical and medical industries through the introduction of biology as the enabling technology of manufacturing operations and biomedical information upgrade. The course will provide an in-depth analysis of the scientific fundamentals and technological extensions of topics like: sequencing and genomics, bioinformatics, expression phenotyping via DNA microarrays, rational drug design, proteomics technologies and analysis, drug delivery and others.
SMA5423 Bioprocess Engineering
Modular credits: 6
Workload: 4-NA-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: The use of animal cells is now the major way to produce biological therapeutics. This course will cover the pertinent concepts in the use of animal cells for production of recombinant proteins and monoclonal antibodies. Comparison on the use of bacterial hosts with animal cells for therapeutic protein production will be considered. Topics will include nutritional requirements for cell growth, kinetics of cell growth, cell death and product formation. Bioreactors for suspension and anchorage-dependent cells will also be discussed. Issues related to process validation and safety in the use of animal cells will be address from a regulatory point of view.

Computer Science (CS)

SMA5502 Computer Language Engineering
Modular credits: 12
Workload: 3-2-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: Analyses issues associated with the implementation of higher-level programming languages. Fundamental concepts, functions, and structures of compilers. The interaction of theory and practice. Using tools in building software. Includes a multi-person project on compiler design and implementation.

SMA5503 Analysis and Design of Algorithms
Modular credits: 12
Workload: 2-1-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: Techniques for the design and analysis of efficient algorithms, emphasising methods useful in practice. Topics: sorting; search trees, heaps, hashing; divide-and-conquer; dynamic programming; amortized analysis; graph algorithms; shortest paths; network flow; computational geometry; number-theoretic algorithms; polynomial and matrix calculations; caching; parallel computing.

SMA5504 Artificial Intelligence
Modular credits: 12
Workload: 2-2 (Seminar)- NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: Investigates the application of the methods and tools of artificial intelligence via problems in the use and implementation of intelligent Web services. Emphasis on mastery and application of programs embodying many basic representations and problem-solving methods in artificial intelligence, including search, constraint propagation, rule-chaining, planning, deduction, and machine learning. Includes an individual and a multi-person project on real problems drawn from the milieu of the World Wide Web.

SMA5505 Applied Parallel Computing
Modular credits: 12
Workload: 1-1-NA-NA-NA
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA
Brief Module Description: Advanced interdisciplinary introduction to applied parallel computing on modern supercomputers. Numerical topics include dense and sparse linear algebra, N-body problems, multigrid, fast-multipole, wavelets and Fourier transforms. Geometrical topics include partitioning and mesh generation. Other topics include applications oriented architecture, software systems, MPI, cilk,
DATA Parallel systems, Parallel MATLAB, caches and vector processors with hands-on emphasis on understanding the realities and myths of what is possible on the world's fastest machines.

**SMA5506 Database Technology**  
Modular credits: 12  
Workload: 6-2-NA-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA  
Brief Module Description: Studies the concepts and implementation related to database management systems. Topics include the relational data model, SQL, storage management, access methods, query processing and optimisation, concurrency control and recovery, security and authorization, and advanced database topics such as data warehousing, data mining and multimedia databases. Includes a project on implementing components of a mini-DBMS.

**SMA5507 Computer Graphics**  
Modular credits: 12  
Workload: NA-NA-NA-NA-NA (Student to view videotape as and when required)  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA  
Brief Module Description: Introduction to computer graphics hardware, algorithms, and software. Topics include: line generators, affine transformations, line and polygon clipping, splines, interactive techniques, perspective projection, solid modeling, hidden surface algorithms, lighting models, shading, and animation. Substantial programming experience required. 6 Engineering Design Points.

**SMA5508 Pervasive Computing**  
Modular credits: 12  
Workload: 2.5-1.5-NA-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA  
Brief Module Description: Covers important issues when computers become small, pervasive and are in constant connectivity. Relevant technologies in input/output, networking, information infrastructure, and ease-of-use. Hands-on experimentation with handheld GUI, speech, vision, gesture, location-aware input methods and several output mechanisms. Middleware for rapid device integration in the environment. Case-studies of other pervasive and ubiquitous systems. Includes a collaborative group project.

**SMA5509 Theory of Parallel Computation**  
Modular credits: 12  
Workload: 2-2-NA-NA-NA  
Pre-Requisite(s)/Preclusion(s)/Cross-listing(s): NA  
Brief Module Description: Theoretical foundations of parallel computing systems. Algorithms and analysis of fixed-connection networks, message routing, VLSI layout, shared-memory consistency, load balancing, dynamic multithreading, synchronization. Focus on problem solving and term project.