Indian Institute of Science

Centre for BioSystems Science and Engineering

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BE 201 (AUG) 3:0 Fundamental of Biomaterials and Living Matter

Background, defining key elements of biomaterials science, interdisciplinary nature of biomaterials science, defining biocompatibility and related concepts, implication of biomaterials science in human healthcare, relevance of biomaterials science to biomedical device development., Biophysical processes involved in cell-material interaction (protein adsorption isotherm), cell adhesion and morphological changes on biomaterials surfaces; Cell signalling mechanism: soluble signals, classification of signalling mechanism, quantitative aspects of cell signalling, intracellular signalling mechanism, intracellular signalling proteins; Eukaryotic cell fate processes: cell differentiation, cell migration, cell division, cell death; Qualitative and quantitative assessment of cell morphological changes: some fundamentals related to microscopic analysis, fluorescence microscopy; Host response: consequences of the host response to biomaterials (foreign body response); Probing cell response, *in vitro*: cytotoxicity assays, flow cytometry, differentiation assays for oestrogenic markers, cell culture laboratory-testing, safety and ethical issues (good laboratory practice, cell culture maintenance), ethical considerations (stem cell research – ethical considerations, ethical concerns of tissue-engineered constructs); Bacterial growth and Biofilm formation: generic description of bacterial cell structure, classification of bacteria, bacteria-material interaction, bacteria growth, biofilm formation, experimental assessment of antibacterial properties, *in vitro*, experimental assessment to characterize biofilm, bacterial culture protocol; Probing tissue response, *in vivo*: tissue compatibility assessment; design of preclinical study with biomaterials.

Instructor: Bikramjit Basu

References

1. Bikramjit Basu; Biomaterials Science and Tissue Engineering: Principles and Methods; Cambridge University Press; ISBN: 9781108415156; 2017.
2. Bikramjit Basu; Biomaterials for Musculoskeletal regeneration: concepts, Springer Nature; Singapore,2017[ISBN: 978-981-10-3058-1 (Print) 978-981-10-3059-8 (Online)]
3. Bikramjit Basu and Sourabh Ghosh; Biomaterials for Musculoskeletal regeneration: Applications; concepts, Springer Nature; Singapore; 2017 [ISBN: 978-981-10-3016-1 (Print) 978-981-10-3017-8 (Online)]
4. Biomaterials Science: An introduction to Materials in Medicine, Edited by Ratner, Hoffman, Schoet and Lemons, Second Edition: Elsevier Academic Press, 2004.
5. Fredrick H. Silver and David L. Christiansen, Biomaterials Science and Biocompatibility, Springer, Piscataway, New Jersey, first edition, 1999.
6. Jonathan Black, Biological Performance of Materials: Fundamentals of Biocompatibility, Marcel Dekker, Inc., New York and Basel, 1999.

Pre-requisites

None

Additional information

Visit to Laboratory for Biomaterials in batches can be conducted for the interested students. Auditing of the course is discouraged.

Course outcomes

It is expected that the students will have broad knowledge on the science aspects of Biomaterials and its application to human healthcare.

(Updated February 21, 2019)

BE 202 (AUG) 3:0 Thermodynamics and Transport in Biological Systems

Thermodynamics: Foundations of Classical Thermodynamics, Heat and Work, First and Second Laws, Phase Rule and Phase Equilibria, Thermodynamics of Adsorption and Binding, Chemical Reactions, Applications in Biology.

Transport: Importance of Transport Processes in Biology, Fluid Statics and Kinematics, Shell Momentum Balances, Navier-Stokes Equation, Diffusion and Ficks Law, Stokes-Einstein Relationship, Convective Transport, Reaction-Diffusion Systems, Transport across Membranes, Energy Balances

Instructor: K Ganapathy Ayappa & Narendra M Dixit

References

1. Introduction to Chemical Engineering Thermodynamics, J. M. Smith, H. C. Van Ness and M. M. Abbott, Mc Graw-Hill, 2005.
2. Biological Thermodynamics, D. T. Haynie, Cambridge University Press, 2008.
3. Transport Phenomena, R. B. Bird, W. E. Stewart, E. N. Lightfoot, Wiley India, 2006
4. Transport Processes in Biological Systems, G. A. Truskey, F. Yuan and D. F. Katz, Pearson Prentice Hall, 2010

Pre-requisites

None

Additional information

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Course outcomes

An appreciation of the role of thermodynamics and transport processes in biological systems; familiarity with the use of basic ideas from classical thermodynamics and transport processes to quantify and analyze relevant processes in biological systems.

(Updated February 21, 2019)

BE 203 (AUG) 0:1 Bioengineering Practicum 1

Bioengineering Practicum provides bioengineering laboratory experience to enable the student to do practical work in a particular field of specialization by working in the laboratories of the thesis adviser(s). The student is expected to learn the experimental techniques and practical methods pertaining to the research topic undertaken. The student is also expected to understand his/her thesis project and should be able to explain its significance in the field. They are also expected to have started performing research in the lab and understand the principles behind the experiments being conducted. The evaluation will be based on written reports and oral presentation. Generally, the adviser(s) and the student have a general research topic in mind and use that to decide the techniques to be learnt. The purpose of this course is to enable the student to get familiar with the research topic and take the first steps in thesis research. The students are advised to take the initiative to thoroughly understand all the related material of each and every technique and experiment they learn and perform.

Instructors: Rachit Agarwal, G. K. Ananthasuresh, and Sandhya S. Visweswariah

Resources

Laboratories of BSSE and adviser(s)

Pre-requisites

Admission into BSSE PhD prorgamme

Additional information

The students enrolled in this course should send half-a-page description of the work to be done and a midterm report by the dates indicated by the instructors and as per the format given. The instructors will meet the students twice during the semester for a general discussion. The students are expected to put in the required time in the laboratories of their adviser(s). Grading in this course is determined based on the half-a-page description (5 marks), midterm report (20 marks), adviser(s)' assessment (25 marks), and final oral presentation (50 marks). Advisers are expected to provide a short summary of the work done, before the oral presentation, along with the evaluation to the instructors. All advisers of the students enrolled in the course are expected to participate in the oral presentations and final evaluation of all students.

Course outcomes

After going through bioengineering practicum courses, the students understand relevant analytical, computational, and experimental techniques used in the laboratories of his/her thesis adviser(s). Additionally, the student will become thoroughly familiar with the background, objectives and projected outcomes of his/her thesis work. Typically, they start on the research problem so that it paves the way for their thesis research. The main outcome of practicum courses is to get started with their thesis research in their first two semesters of their PhD programme.

(Updated February 4, 2019)

BE 204 (JAN) 0:2 Bioengineering Practicum 2

Bioengineering Practicum provides bioengineering laboratory experience to enable the student to do practical work in a particular field of specialization by working in the laboratories of the thesis adviser(s). The student is expected to learn the experimental techniques and practical methods pertaining to the research topic undertaken. The student is also expected to understand his/her thesis project and should be able to explain its significance in the field. They are also expected to have started performing research in the lab and understand the principles behind the experiments being conducted. The evaluation will be based on written reports and oral presentation. Generally, the adviser(s) and the student have a general research topic in mind and use that to decide the techniques to be learnt. The purpose of this course is to enable the student to get familiar with the research topic and take the first steps in thesis research. The students are advised to take the initiative to thoroughly understand all the related material of each and every technique and experiment they learn and perform.

Instructors: Rachit Agarwal, G. K. Ananthasuresh, and Sandhya S. Visweswariah

Resources

Laboratories of BSSE and adviser(s)

Pre-requisites

Admission into BSSE PhD prorgamme

Additional information

The students enrolled in this course should send half-a-page description of the work to be done and a midterm report by the dates indicated by the instructors and as per the format given. The instructors will meet the students twice during the semester for a general discussion. The students are expected to put in the required time in the laboratories of their adviser(s). Grading in this course is determined based on the half-a-page description (5 marks), midterm report (20 marks), adviser(s)' assessment (25 marks), and final oral presentation (50 marks). Advisers are expected to provide a short summary of the work done, before the oral presentation, along with the evaluation to the instructors. All advisers of the students enrolled in the course are expected to participate in the oral presentations and final evaluation of all students.

Course outcomes

After going through bioengineering practicum courses, the students understand relevant analytical, computational, and experimental techniques used in the laboratories of his/her thesis adviser(s). Additionally, the student will become thoroughly familiar with the background, objectives and projected outcomes of his/her thesis work. Typically, they start on the research problem so that it paves the way for their thesis research. The main outcome of practicum courses is to get started with their thesis research in their first two semesters of their PhD programme.

(Updated February 4, 2019)

BE 205 (JAN) 3:0 Introduction to Biomechanics of Solids

Intended to be a broad introduction to multiple aspects of biomechanics of solids, the course comprises five modules, viz., statics and dynamics of rigid bodies; elastic mechanics; mechanics of biological materials; statistical mechanics and rubber elasticity; and cell mechanobiology. Topics covered include: force-balance, Lagrange's equations of motion, Euler's equations for rigid-body dynamics with applications to human body; concepts of stiffness, inertia, and damping pertaining to bones, muscles, tissues, cells, and biological molecules; state of stress and strain, energy methods, basic concepts of elasticity and viscoelasticity; applications of statistical mechanics to cells and motor proteins, Langevin equations; and introduction to mechanotransduction.

Instructors: G. K. Ananthasuresh and Namrata Gundiah

References

1. J. D. Humphrey and S. L. Delange, *An Introduction to Biomechanics*, Springer, Berlin, 2004.
2. J. Howard, *Mechanics of Motor Proteins and the Cytoskeleton*, Sinauer Associates, Inc., Sunderland, MA, USA, 2001.

Pre-requisites

Multivariable calculus and vector algebra

Additional information

Biomechanics is a vast subject. As J. D. Humphry defined it, it deals with application, extension, and development of principles and techniques of mechanics to biological entities and systems. In this course, we limit ourselves to solids. The purpose of this course is to provide basic understanding of mechanics and its application to biological systems. One should not hope that they become experts in mechanics by taking this course. Nevertheless, one can hope that they will be exposed to basic principles and methods of mechanics so that they can begin to analyze biological solids and systems. The course lays equal emphasis on fundamental principles and practical implementation using computation.

Course outcomes

After taking course, a student will be able to:

- write governing equations for statics and dynamics of rigid and elastic objects and solve simple problems.
- do deformation analysis of elastic and viscoelastic bodies
- interpret stress, strain, and constitutive relationships of biomaterials and living matter.
- analyse problems in statistical mechanics pertaining to cells and small organisms.

(Updated February 27, 2019)

BE 206 (AUG) 3:0 Biology for Engineers

The course provides an introduction to fundamental concepts in Biology for PhD students with little to no knowledge of Biology past 10th or 12th standard school curriculum. The course will cover the following topics: biomolecules, fundamentals of biochemistry, protein structure and function, basic molecular biology, genetics, and an introduction to the cellular architecture. A combination of theoretical concepts and basic experimental methodologies in biology will be discussed. In addition, an introduction to how cells form tissues will be covered, which includes lectures on classification of tissues. The concepts covered here will aid in the skill development required to study diverse problems in bioengineering.

Instructor: Siddharth Jhunjhunwala & Vaishnavi Ananthanarayanan

References

There is no prescribed textbook for this course. Course material will include lecture notes (not provided, but taken by students during the lecture), a few slide-handouts (provided), and classic papers in biology (link will be provided). In addition, the principle reference book is
Biology: concepts and connections (Third Edition), by Campbell, Mitchell and Reece

Pre-requisites

None

Additional information

None

Course outcomes

Course outcomes upon completion of the course, students will be able to:

1. Understand various chemical interactions between molecules in biological systems

2. Describe the structure and function of biological molecules
3. Explain basic concepts in enzyme kinetics and protein interactions
4. Discuss different aspects of molecular biology including DNA replication, transcription and RNA translation
5. Demonstrate an understanding of Mendelian laws of inheritance
6. Describe cellular architecture
7. Understand fundamental concepts in tissue architecture

(Updated February 4, 2019)

BE 207 (JAN) 3:0 Mathematical Methods for Bioengineers

The course offers exposure to basic mathematical and statistical principles and techniques of importance to bioengineers.

The topics to be covered include: linear algebraic equations; eigenvalues and eigenvectors; nonlinear algebraic equations; fixed-point iteration and optimization methods; linear and nonlinear least squares; first and second order ordinary differential equations; Euler, RK4, and predictor-corrector methods; discrete and continuous random variables; Markov processes; Gillespie algorithm; Monte Carlo methods; hypothesis testing; parametric and non-parametric statistical tests.

Instructor: Narendra M Dixit

References

1. Gilbert Strang, Differential equations and linear algebra, Wellesley-Cambridge,2015
2. Michael Heath, Scientific computing: an introductory survey, McGraw Hill,2005
3. Steven Strogatz, Nonlinear dynamics and chaos, Westview, 2015
4. Sheldon Ross, Introduction to probability models, Academic, 2014
5. Sheldon Ross, Introductory statistics, Academic, 2010

Pre-requisites

Undergraduate engineering mathematics

Additional information

None

Course outcomes

Facility with basic mathematical and statistical techniques of relevance to bioengineers; facility with associated numerical methods; exposure to the use of mathematical methods in biological systems.

(Updated February 4, 2019)

BE 208 (JAN) 3:0 Fundamentals of Bioengineering

This course will introduce concepts in the interdisciplinary areas of bioengineering, biomedical engineering and biotechnology. The following topics will be covered - introduction to mathematics and biology; polymer science engineering; transport phenomena through polymeric matrices and its applications in drug delivery; biological and immune responses to polymeric implants; principles of tissue engineering; computational approaches to study biological phenomena; and bioprocess engineering that includes an introduction enzyme kinetics, metabolic pathways and bioreactors.

Instructor: Siddharth Jhunjhunwala

References

There is no prescribed textbook for this course. Class notes (to be taken during the lecture) will be primary course material. Papers from contemporary literature will be provided for class discussions. In addition, a few reference books include:

1. Biomedical Engineering: Bridging Medicine and Technology, W. Mark Saltzman, Cambridge University Press, 2009.
2. Introduction in biomedical engineering, John Enderle and Joseph Bronzino,Academic Press, 2011.

Pre-requisites

Biology for Engineers (BE206) or equivalent biology course, and undergraduate level mathematics

Additional information

This course is open to all graduate students and undergraduate students who have completed their 2nd year

Course outcomes

Upon completion of the course, students will be able to:

1. Describe concepts in polymer science and engineering
2. Discuss fundamental principles in biomaterials and explain the Vroman effect
3. Write diffusion equations and describe basic transport phenomena in solids and liquids
4. Explain concepts in bioprocess engineering including reactor design, product separation and purification techniques
5. Design polymeric scaffolds for growing cells
6. Describe concepts in stem cell biology and their use in tissue engineering
7. Understand fundamental ideas in computational and systems biology
8. Assess and critique bioengineering literature

(Updated February 4, 2019)

BE 209 (AUG) 1:0 Digital Epidemiology

Epidemiology is the study of health and disease in populations. Google's Flu Trends, Flowminder, Healthmap, Biodiaspora are several examples of digital epidemiology already in play. Engineered systems that are built from and depend upon, the seamless integration of computational algorithms and physical components is how National Science Foundation defines the field of cyber physical systems (CPS). Digital Epidemiology can be viewed as a health care application of CPS. The foundations of CPS include a focus on the modeling of dynamic systems with attention to integrating computing, communication and control in uncertain and heterogeneous environments. Modeling paradigms include linear and non-linear, stochastic, discrete-event and hybrid models that are analyzed by methods of optimization, probability theory and dynamic programming. The purpose of this course is to introduce this emerging discipline of digital epidemiology to students at IISc. This offering of the course will be limited to a class size of 20 students. Pre-requisites: The only prerequisite for this course is a reasonable preparation in computational mathematics.

Instructor: Vijay Chandru and G. K. Ananthasuresh

References

1. Epidemiology, A Very Short Introduction, Rodolfo Saracci, Oxford University Press
2. Statistical models in Epidemiology, D. Clayton and M. Hills, Oxford University Press
3. Statistical Methods in Epidemiology, the Environment and Clinical Trials, Halloran, M. Elizabeth, Berry, Donald
4. Marcel Salathé et al., Digital epidemiology, PLoS Computational Biology, 8(7), 2012.
5. M. Newman. The structure and function of complex networks. SIAM Review, 45, 2003.
6. F. Brauer, P. van den Driessche, and J. Wu, editors. Mathematical Epidemiology. Springer Verlag, Lecture Notes in Mathematics 1945.
7. R.M. Anderson and R.M. May. Infectious Diseases of Humans. Oxford University Press, Oxford,1991
8. N. T. J. Bailey. The Mathematical Theory of Infectious Diseases and Its Applications. Hafner Press, New York, 1975.
9. M. Gersovitz and J. S. Hammer. Infectious diseases, public policy, and the marriage of economics and epidemiology. The World Bank Research Observer, 18(2):129–157, 2003.

BE 210 (AUG) 3:0 Drug Delivery: Principles and Applications

This course will aim to introduce concepts of drug delivery for medical challenges. The course is designed to be modular, with each module focusing on the following topics: Diffusion and permeation of drugs in biological systems; Pharmacokinetics; Challenges and strategies for various drug delivery routes; Polymers; Drug delivery systems: polymer-drug conjugates, matrix based systems, reservoir and erodible systems; Nano and Micro-particles; Protein adsorption and tissue engineering; Immune response to biomaterials; Vaccine; Responsive and targeted delivery systems; Nanotoxicology and Regulatory pathways. Students are expected to work on a group project to propose a drug delivery application for an existing medical need.

Instructor: Rachit Agarwal

References

1. Drug Delivery: Engineering Principles for Drug Therapy, W. Mark Saltzman, Oxford University Press, 2001
2. Drug Delivery: Fundamentals and Applications, Anya M. Hillery and Kinam Park, 2nd Edition, CRC Press, 2016

Pre-requisites

None

Additional information

The course is open to all undergraduates that have completed their second year, masters and PhD. students.

Course outcomes

At the end of this course the students are expected to understand the requirements for various requirements and challenges in delivering drug for a particular application. They should also be rationally think and choose the best delivery system that is best suited for their current and future research.

(Updated February 21, 2019)

BE 211 (AUG) 3:0 Cell Mechanics

This course will provide an in-depth understanding of mechanics of the cell including theory of cellular architecture, mechanical forces, deformations, and adhesions, leading up to force generation and interaction of cells with the external environment. Additionally, practical aspects, including measurement of cell mechanics using experimental techniques such as micropipette aspiration, single particle tracking and atomic force microscopy will be presented. The topics covered will culminate in broad applications of cell mechanics in physiology, cell biology and biophysics with the syllabus comprising cell shapes, biomaterials (soft filaments and sheets in cells), forces inside cells, random walks, movement in a viscous fluid, viscoelasticity (background, constitutive models and measurement in cells), complex filaments, rheology of cytoskeletal filaments, biomembranes (bilayers, micelles, vesicle formation), cell-cell and cell-matrix interactions, micropipette aspiration, single particle tracking, atomic force microscopy, applications of cell mechanics viz. cell division, migration, morphogenesis, cancer metastasis.

Instructor: Vaishnavi Ananthanarayanan

References

1. David Boal, Mechanics of the Cell, Cambridge University Press (2012)

2. Christopher R. Jacobs, Hayden Huang, Ronald Y. Kwon, Introduction to Cell Mechanics and Mechanobiology, Garland Science (2013)

3. Ronald Kaunas, Assaf Zamal, Cell and Matix Mechanics, CRC Press (2014)

4. Jonathon Howard, Mechanics of Motor Proteins and the Cytoskeleton, Sinauer Associates Inc. (2001)

Pre-requisites

Introductory course in Mathematics and Biology at the under-graduate level.

Additional information

Traditionally, biochemical signals have been at the crux of all aspects of biology. Recently, there has been a growing body of science implicating mechanical phenomena in the functioning of cells in the context of both health and disease.

Course outcomes

After taking the course, the students will be able to:

1. understand the mechanical phenomena that operate inside cells
2. relate cell mechanics to biology and physiology of the cell in normal and disease states
3. plan and execute experiments that probe cellular mechanics at multiple levels

(Updated Feb 14, 2019)

BE 212 (AUG/ JAN) 1:0 Research Communication

INSTRUCTOR: Dr. Karthik Ramaswamy, Archives and Publications Cell, IISc

SCHEDULE: The 8-week course will begin on 19 Feb and end on 11 April. The class will meet twice a week (Tuesdays and Thursdays) from 10:00 AM to 11:30 AM at the CES classroom in the Biological Sciences building.

SYLLABUS (subject to modification at the discretion of the Instructor)

Date	Topic
19 Feb	On Writing
21 Feb	Sentences
26 Feb	Flow + **Introduction to Project 1**
28 Feb	Exercises + **Introduction to Project 2**
5 Mar	Concision and Shape
7 Mar	Paragraphs + **Project 1: Literature Survey due**
12 Mar	The Research Poster
14 Mar	**Project 2: Deadline for choosing research paper**
19 Mar	The Research Paper
21 Mar	The Research Paper + **Project 1: Deadline for submitting first draft**
26 Mar	**Project 1: Peer review**
28 Mar	Ethics in Research Communication + **Project 1: Deadline for submitting second draft**
2 Apr	The Research Talk
4 Apr	**Project 1: Feedback from Karthik**
9 Apr	**Project 2: Presentations** + Course Evaluations
11 Apr	**Project 2: Presentations**
14 Apr	**Project 1: Deadline for submitting final draft** (No Class!)

GOAL

You may be doing dazzling research in your lab or in the field, but it is pointless if you cannot communicate it effectively. Communication in science and engineering typically takes the form of the written word (though researchers also give talks and present posters). Unfortunately, in spite of the importance communication in research, it is not part of the curriculum in most science and engineering programmes. The *Research Communication* course seeks to fill this gap.

LEARNING OUTCOMES

- Writing clearly and concisely
- Designing and presenting a research poster
- Reading a research article (without freaking out)
- Writing the *Introduction* to a research article

SUGGESTED READINGS

1. JM Williams and GG Colomb (2012*) Style: The Basics of Clarity and Grace*. 4th Edn. Pearson Longman Press.
2. SB Heard (2016) *The Scientist's Guide to Writing: How to Write More Easily and Effectively Throughout Your Scientific Career*. 1st Edn. Princeton University Press.
3. GD Gopen and J Swan (1990) The Science of Scientific Writing*. American Scientist*. 78:550-558
4. Gopen GD (2004) The Sense of Structure: Writing from the Reader's Perspective. 1stEdn. Pearson Longman Press.
5. Silvia PJ (2007) *How to Write a Lot: A Practical Guide to Productive Academic Writing* 3rd Edn. APA Life Tools

GRADING

1. Attendance and participation (15%)*
2. Project 1 (50%)
    a. Literature Survey (10%)
    b. First draft (10%)
    c. Peer review (10%)
    d. Second draft (10%)
    e. Final Draft (10%)
3. Project 2 (35%)
    a. Choosing appropriate research paper (5%)
    b. Poster Content (10%)
    c. Poster Design (10%)
    d. Oral Presentation (10%)

* We all may have the occasional emergency. But you cannot miss more than one class. If you do, you have to talk to me in person (ideally before class). If you miss more than two classes, I reserve the right to cut your grade by half irrespective of your performance in class