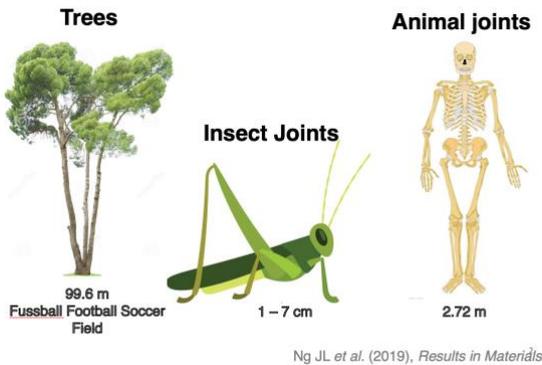


COURSE DETAILS

Units of Credit	6	
Contact hours	3 hours per week	
Integrated Lecture and Tutorial	Weeks 1 to 11 Fridays, 10:00 - 13:00	Online delivery, pre-recorded lectures
		Live Tutorials through BlackboardCollaborate
Course Coordinator	Professor Melissa Knothe Tate, Inaugural Paul Trainor Chair of Biomedical Engineering Best quick communication route via Moodle (“dedicated channel”) email: m.knothetate@unsw.edu.au (“competing channel”) Zoom office link office hours: Wednesday afternoons, 1 p.m. – 5 p.m. via Zoom	
Course Assistance	Ms. Vina Putra Ms. Lara van Leeuwen	

INFORMATION ABOUT THE COURSE



HAVE YOU EVER WONDERED?

Why do biological materials and their biomaterial substitutes fail?
 e.g. hips and hip replacements
 blood vessels and stents

What properties of natural (biological) materials make them so resilient and robust?

How can we understand natural materials like gum (eucalyptus) trees that bend like blades of grass in gusts of wind and almost never snap?

Can we use our understanding of mechanics of biological materials to design and manufacture mechanically superior biomaterials?

FUTURE PERSPECTIVES

Five years after taking my course, my students will still **know, value and be able to do the following** (written as a hypothetical scenario, taking place in the year 2025)?

In the year 2025, several of my students came to visit during my office hours. We were all long vaccinated for COVID and back to hugging one another after not seeing each other in such a long time. A highly engaged student, Martha, enthusiastically shared that she and several students from her cohort started an Australian med tech company modeled on the Failure Analysis Associate and Exponent models they learned about and role played in class. They hired senior engineers with decades of experience who had been let go in the Greater Depression of 2020 – with their breadth of industry experience and my student’s energy and enthusiasm to build a company devoted to understanding how failures occur in medical materials, devices, therapies and processes. Whilst my class concentrated on the mechanical aspects of failure, their company had a bigger vision and had sections devoted to different aspects of failure, from mechanical to chemical and biological, to find root causes and prevent them in the future. The company was already winning industry awards and preparing to open offices globally, using the internet model used in class where no face-to-face interaction or travel was needed to work together.



COURSE ‘IN A NUTSHELL’

This course addresses the interlinked theme of engineering smart materials and devices by learning from Nature’s paradigms. The course goal is to use fundamentals of mechanics and strength of materials to understand the remarkable material and mechanical properties of biological materials and biomaterials.

In addition, the course aims to develop the capacity to characterise, optimise and even create advanced functional biomaterials by

- using fundamental knowledge of strength of materials to increase a depth and breadth of understanding of biological materials and biomaterials, their mechanical properties, and their potential change in properties when used in implantable and wearable human-based applications [[understanding and application of material covered in lectures and exams](#)],
- carrying out root cause analyses of device and material failures [[interactive activities and assessments in TUTORIAL SET 1](#)], and
- applying reverse engineering strategies for creation and application of nature inspired materials [[interactive activities and assessments in TUTORIAL SET 2](#)].

Mechanical properties inherent to specific manufacturing methods will be addressed as well as materials' different properties in *in vivo* and other environments. This course aims to provide students with a foundation, based on nature's design and optimisation criteria for engineering tissues and smart materials, as well as to give students the opportunity to develop their professional engineering practice and engineering innovation capabilities through two sets of multi-week class tutorial projects.

Units of Credit: 6

BIOM9561 is a 6 Units of Credit (UOC) course. The course is organised as an interactive, "inverted" course. Hence, it is expected that **students will prepare for class in advance and attend every online class session, as critical discussion of material, tutorials, and assessments will take place in the online class session.** Reading and lecture materials will be provided at least one week prior to each class. You should spend several hours each week prior to class to prepare for class, by reading, watching the lecture, and studying these materials prior to each week's class time. This is particularly the case if you have not been engaged recently with the engineering concepts underpinning the course.

Adjustment of course to respond to myExperience feedback & to adapt to COVID-19 restrictions

All lectures will be pre-recorded to give students more flexibility to learn from where-ever they are based, and in advance of class time, when tutorials and in-class assessments will take place. As it will be challenging if not impossible to ensure social distancing in this large cohort, the course will run online, as a flipped classroom, with an hour of interactive discussion and two hours of tutorials weekly, via zoom, and with break out rooms for groups. I see this as a positive challenge, as future work environments will likely necessitate meeting of teams made up of individuals from potentially far-flung places and opportunities for face-to-face meetings necessitating travel will likely be reduced. I will organise the tutorial groups into small "start up companies" (role play) from the start, and will run the three hour class block in a rotating fashion.

Recorded lectures with interactive modules for student self-assessment and input from me (outside of class time)

In class, rotate three, 45 minute periods to include

- A. In class board meetings to discuss lecture materials and how they apply to the start-up companies' mission
- B. Tutorial hour 1 to present and discuss a "real life simulated" assessment to be completed by the start-up companies
- C. Tutorial hour 2 for the completion of the assessments, which will be in the form of technical reports.

The last class of the term will be a simulated angel investor conference as *per* previous years

In sum, the new format

1. continues to develop and hone students' critical thinking skills and innovation capacity, building on their basic knowledge of mechanics.
2. New, streamlined lecture notes will be integrated tightly with pre-recorded lectures.
3. Assessments using translational paradigms will be linked to mechanics of materials at different length and time scales.
4. Critical reading of journal articles will be used as well as use of data from these articles to develop and assess design solutions.
5. Communication with and feedback to students will be improved through small group direct interactions with Prof Knothe Tate and support of markers/demonstrators who will be responsible for uploading marks and feedback within 24h of assessments due dates.
- 6./7. Real world examples of existent biomaterials and devices and their failures/successes, as well as cutting edge and "blue sky" design solutions will be used consistently to demonstrate basic and develop a more sophisticated understanding of mechanics principles at multiple length and time scales and in context of material properties and their characterisation.

Prerequisites and presumed knowledge

Students taking this course should have had prior exposure to materials science, mechanics and strength of materials.

How this course relates to other courses

This course aligns well with all four broad categories of study and research in the Graduate School of Biomedical Engineering as well as different programs offered by the Schools of Mechanical Engineering, Materials Science, and Chemical Engineering. In particular, it complements courses of study integrating elements of biomaterials and tissue engineering, biomechanics, modeling and instrumentation, and medical technology. The course integrates concepts of engineering innovation and entrepreneurship, integrated within the scientific and engineering themes.

HANDBOOK DESCRIPTION

See link to virtual handbook:

<http://www.handbook.unsw.edu.au/undergraduate/courses/current/BIOM9561.html>

LEARNING OBJECTIVES & LEARNING OUTCOMES

Five Course Level Learning Objectives

- 1 **Recognise** and describe mechanical properties of commonly implemented biomaterials and **relate** their mechanical properties to reconstruct root causes of material/device failure when used in human health (wearable or implantable) applications.
- 2 **Relate** properties of contemporary biomaterials to those of commonly idealised materials used for the built environment (e.g. steel, concrete, polyethylene) and natural materials. **Predict** likely differences in their spatial and temporal mechanical properties that will determine their likely failure mechanisms when used in human health (wearable or implantable) applications.
- 3 **Propose** and **illustrate** different test methods to distinguish and measure properties of real biomaterials, closest current built environment equivalents, and idealised “blue sky” materials that will in the future outperform current materials.
- 4 Drawing inspiration from nature, **use** reverse engineering to build conceptually a new “blue sky” material that emulates properties of nature’s own and **create** a dossier demonstrating its creation and translation to a medical context.
- 5 **Assess** your peers’ solutions for failure root cause analyses and new blue sky solutions and **predict** which solutions are likely to meet with greatest engineering and commercial success.

Five Unit Level Learning Outcomes – Unit 1

- 1 **Make** a hypothesis relating an independent variable of a biomaterial to a dependent variable (outcome measure, material property).
- 2 **Propose** at least three mechanical test scenarios to test the hypothesis.
- 3 **Relate** given datasets (e.g. plots of independent versus dependent variables) for the material to the material’s mechanical properties, first testing the hypotheses (2) and then interpreting the test results.
- 4 **Integrate** your understanding of the materials’ known properties and predict why the material failed when implemented in a given real life medical wearable or implantable device scenario.
- 5 **Write** a technical report describing a root cause analysis for device failure.

Five Unit Level Learning Outcomes – Unit 2

- 1 **Lottery** assignment of an inspirational property intrinsic to a natural material.
- 2 **Research** and **pose a hypothesis** as to how the property emerges from the structure-function of the material at different length and/or time scales.
- 3 **Develop** a engineering model of the system and your proposed mechanism.
- 4 **Brainstorm** how this property may be beneficial in a wearable or implantable product for human health or safety.
- 5 **Prepare** a translational pitch deck to engage and encourage angel investor investment.

TEACHING & LEARNING STRATEGIES

Teaching strategies

As noted above, the course is organised as an interactive, "inverted" course. Hence, it is expected that students attend and engage actively in every class. Reading and lecture materials will be provided at least one week prior to each class. You should spend several hours each week prior to class to prepare for class, by reading and studying these materials. This is particularly the case if you have not been engaged recently with the engineering concepts underpinning the course.

Suggested approach to learning

This course requires you to understand the lecture material and then apply the knowledge to scenarios using creative and analytical approaches. It is important to understand the fundamental concepts as soon as possible and to ask for help if you do not understand. Watch all the lectures prior to class and if something is unclear, please ask questions in class. Make sure you review all the lecture notes and read all material that is suggested or handed out. Class participation through attendance at lectures and participation in class exercises and group work is expected.

The material is diverse and not as tightly linked into an overall analytical structure as might be the case in some other subjects. You will need to be prepared to assimilate facts relating to a large number of different materials and measurement principles. Emphasising principles and developing an intuitive understanding of the principles in different engineering scenarios is the best strategy for success in the course.

Summary of the teaching strategies that will be used and their rationale, with suggested approaches to learning in the course

Private study	Watch lecture prior to class time Download reading materials from Moodle Review lecture materials and reading provided Reflect on class problems and assignments Carry out individual assignments and upload to Moodle prior to class. Keep up with notices and marks via Moodle
Class - integrated lectures and tutorials	Come to class on time Participate actively and ask questions Listen to others Work respectfully with your fellow students on tutorials Invest yourself in class to maximise your learning and contribution to others' learning (phones and internet off unless needed for class, focus on learning)
Assessments (tests, exams, assignments, reports, etc.)	Demonstrate your knowledge and skills (literacy) Demonstrate higher understanding and problem solving Demonstrate analytical thinking and critical analysis Demonstrate developing innovation skills Demonstrate the capacity to present information in a way that experts from other disciplines can understand and evaluate your conclusions

EXPECTED LEARNING OUTCOMES

Expected learning outcomes, their association with the teaching strategies and with the suggested approaches to learning. Student-centred and self-directed learning (expectations of the students where relevant). For each hour of contact, it is expected that students will put in at least 1.5 hours of private study, *i.e.* 4.5 hours per week outside of class.

ASSESSMENTS & MARKING CRITERIA

Signature Assignments BIOM9561 – Tutorial Units 1, 2

Assessment Title: Medical Device Failure Analysis	
Tutorial Unit 1 Assessment	
Roles	<p>Investigator - All students (individually) before class meets</p> <p>Start Up Roles</p> <p>Manager – Keeps the company team on target, addressing action items and milestones in a timely manner</p> <p>Technical Researcher – Seeks out new information and references to cite in technical report</p> <p>Recorder and Strategist – records notes of discussion and puts them together to make a strategy for pulling together and presenting the information</p> <p>Producer – responsible for production of 5-minute presentation, to be handed in at the end of the 3rd week tutorial</p> <p>Technical Report Editor - responsible for organisation and editing of final technical report, to be handed in at the end of the 3rd week tutorial</p>
Audience	The technical report and case report are being prepared for a client of <i>Start Up</i> , role played by Prof Knothe Tate. The client may be a multinational medical device company such as Medtronic or it might be a small start-up company focusing on preclinical studies of a medical device.
Format	<p>Your <i>Start Up</i> will receive three dossiers (one each sequential week of tutorial). The dossier will contain</p> <p>Summary from company of the product and details known about its failure</p> <p>Data sheets from the device, e.g. material data sheets and drawings of device, mechanical testing data for device materials</p> <p>Pictures of failed device – may include stereoscopic and microscopic images</p> <p>Observational data from clinicians, surgeons, caregivers</p>
Task	<p>Predict (hypothesise) a most likely failure mechanism using the dossier data, critical analysis of the data, and further research to make conclusions based on your testable hypotheses</p> <p>Prepare a technical report to present your findings (each week, with final “polished” report due in final week.</p> <p>Prepare a 5 minute video presenting your case to your client.</p>
<p>Short description: Your <i>Start Up</i>, modeled on Failure Analysis Associates, receives sequential dossiers (one set of files for each of 3 tutorial weeks) to investigate, analyse, and predict how a medical device failed. The tutorial will span three weeks, with deliverables due in class each week, first from each student (due at beginning of class) and then from each <i>Start Up</i>, where upon discussion, a technical report update will be submitted each week at class’ conclusion. The weekly deliverables will tied directly to learning outcomes from each week, building with weekly progression in the course. The fourth week of tutorial will be used to finalise the report and 5-minute presentation of the case. The tutorial is designed so that all work will be completed in class, and Prof Knothe Tate will coach.</p>	

Assessment Title: Blue Sky Device or Material Design Emulating a Smart Natural Material

Tutorial Unit 2 Assessment

Role(s)	<p>Investigator - All students (individually) before class meets</p> <p>Start Up Roles</p> <p>Manager – Keeps the company team on target, addressing action items and milestones in a timely manner</p> <p>Technical Researcher – Seeks out new information and references to cite in technical report</p> <p>Recorder and Strategist – records notes of discussion and puts them together to make a strategy for pulling together and presenting the information</p> <p>Producer – responsible for production of 5-minute presentation, to be handed in at the end of the 3rd week tutorial</p> <p>Technical Report Editor - responsible for organisation and editing of final technical report, to be handed in at the end of the 3rd week tutorial</p>
Audience	<p>The technical report and pitch deck are being prepared for your own <i>Start Up</i>, in preparation for the Angel Investors Conference at the end of class. Each of you will receive \$50,000 Angel dollars and will have the opportunity to invest those dollars in the most promising start ups, from a technical and commercial perspective.</p>
Format	<p>Your <i>Start Up</i> will receive three dossiers (one each sequential week of tutorial). The dossier will contain</p> <p>Description of a natural material.</p> <p>Dossier of data sheets from the material.</p> <p>Templates for tutorial</p>
Task	<p>Individually, find an inspirational material from nature that exhibits smart or advanced mechanical properties</p> <p>Predict (hypothesise) how the smart property emerges from the structure and function of the material at different time and length scales, providing</p> <ul style="list-style-type: none">• a dossier of data for the material,• critical analysis of the data, and• further research to make conclusions based on your testable hypotheses <p>Brainstorm and develop a product (material or device or process) inspired by the material</p> <p>Prepare a technical report to present your findings (each week, with final “polished” report due in final week.</p> <p>Prepare a 5 minute video pitching your material/device to investors.</p>

Short description: Your *Start Up* will develop a blue sky material or device that emulates the smart or advanced **mechanical** properties of a natural material. The tutorial will span three weeks, with deliverables due in class each week, first from each student (due at beginning of class) and then from each *Start Up*, where upon discussion, a technical report update will be submitted each week at class’ conclusion. The weekly deliverables will be tied directly to learning outcomes from each week, building with weekly progression in the course. The third week of tutorial will be used to finalise the report and 5-minute presentation of the case, which will be assessed by peers at the Angel Investor Conference in the 4th week. **The tutorial is designed so that all work will be completed in class, and Prof Knothe Tate will coach.**

How Assessments will be marked

Overall rationale for assessment components and their association with course objectives.

The final mark for the course will be based

- 20% on in-class work including interim steps and full portfolios submitted for Tutorial Units 1,2
- 10% from individually prepared failure analysis assessment tasks (Tutorial Unit 1) submitted each week prior to class start
- 10% from individually prepared blue sky mechanical materials design assessment tasks (Tutorial Unit 2) submitted each week prior to class start
- 25% on Mid-term Examination
- 35% on Final Examination

Students who perform poorly on assignments or exams are recommended to discuss progress and to get coaching from Prof Knothe Tate during the term.

Overall rationale for assessment components and their association with course objectives

The in-class assessment tasks are designed to foster

- in depth engagement with the discipline as well as its relationship to other disciplines
- the capacity to practice and hone analytical and critical thinking as well as creative problem solving
- honing of skills for collaborative and multidisciplinary work and
- the development and refinement of skills for effective communication

The Mid-term and Final Examinations are designed to assess information literacy and the capacity for analytical and critical thinking as well as to demonstrate in-depth engagement and gaining of knowledge, both within and across disciplines.

Details of each assessment component, the marks assigned to it, the criteria by which marks will be assigned will be provided with each assessment, which will be completed individually and/or as part of a company (a group organised in company structure)

Late submission - make up work - missed class policy

It is important to complete work on time to keep up with the class.

COURSE PROGRAM

TERM 3, 2020 *NOTE: classes are online – please refer to Moodle for all updates and announcements!

Supplementary readings for in-depth engagement with the material are listed in the lecture notes

Week	Date	Topic	Lecturer	Prior to Class	In class assessment - Tutorials
1	18/09/2020	1A - Classical approaches to mechanics of materials based on human-made and natural materials 1B - Advantages/limitations of human-made and natural materials when implemented as biomaterials 1c - Failure Analysis: how and why materials break	MKT	LECTURE SERIES 1 – TOP DOWN APPROACHES to Understanding Strength of Human-made, Biological and Biomaterials A. Structure – Function relationships B. Materials characterisation and testing C. Spatial and temporal properties D. Manufacturing impacts on properties E. <i>In situ</i> , Environmental impacts on properties	Intro – Failure Analysis Associates, Exponent as Case Studies FORMATION OF COMPANIES tutorial scenarios - brainstorming
2	25/09/2020	2 - How cells manufacture tissues, aka smart, adaptive materials	MKT	LECTURE SERIES 2 – BOTTOM UP APPROACHES to Understanding Strength of Human-made, Biological and Biomaterials A. Material manufacture by cells B. Plants compared to Animals C. Adaptation and remodeling vs. failure	COMPANIES first pass at failure analysis
3	02/10/2020	3 - Mechanics of Skin and Bones and Skin-on-bones – the ‘real deal’	MKT	LECTURE SERIES 3 – Periosteum (skin-on-bones) Case study	COMPANIES ROOT FAILURE MECHANISMS
4	09/10/2020	4A - Substitute materials (biomaterials) and how well they recapitulate nature's engineering paradigms	MKT	LECTURE SERIES 4A – TOP DOWN APPROACHES Biomaterials Case studies	COMPANIES PRESENTATION AND FEEDBACK
5	16/10/2020	Midterm Exam (1 hour) Company project launches	MKT	NO LECTURE	MIDTERM EXAM COMPANIES blue sky project/product launches
6	23/10/2020	Mid term break – Flexibility week			

7	30/10/2020	4B - Biological threads (structural protein fibres) & their engineered equivalents (sutures, meshes)	MKT	LECTURE SERIES 4B – BOTTOM UP APPROACHES Biomaterials Case studies	COMPANIES mechanics of material assessment
8	06/11/2020	5A – Mechanics of biological composites and their engineered biomaterial equivalents - subcell to cell to tissue scale	MKT	LECTURE SERIES 5A – BOTTOM UP APPROACHES Biomaterials Composites & their engineered equivalents	COMPANIES product brainstorming
9	13/11/2020	5B - Mechanics of biological composites and their engineered biomaterial equivalents - tissue to organ to organism scale	MKT	LECTURE SERIES 5B – TOP DOWN APPROACHES Biomaterials Composites & their engineered equivalents	COMPANIES Dossier completion
10	20/11/2020	Engineering Innovation – Angel Investor Conference	MKT	NO LECTURE	COMPANIES Angel Investor Conference

RELEVANT RESOURCES

Online course material can be accessed through Moodle, which is managed by the UNSW Technology Enabled Learning and Teaching unit: <https://moodle.telt.unsw.edu.au>. Once you are enrolled in the course, BIOM9561 will be visible to you after the session starts, when you log into Moodle using your zPass.

Group discussions, lecture notes and resource materials will be made available on this site during session. Announcements made on Moodle will be forwarded to your student email; remember to check your student email frequently for updates or, alternatively, have your unsw student email forwarded to your private email.

Tutorial tasks and assessments will be provided online and handed in online before the end of class.

COURSE EVALUATION AND DEVELOPMENT

Student feedback has helped to shape and develop this course, including feedback from online evaluations as part of UNSW's Course Evaluation program. Changes to the course have resulted from changes in course coordination as well as the goal to include more mechanics of materials-based as well as innovation activities in the curriculum. The course is being delivered fully online in 2020 to best accommodate students and accommodate social distancing measures. Every effort will be made to encourage interactions online.

With special acknowledgement to the UNSW Course Design Institute, which Prof Knothe Tate attended in August 2020 and which provided great opportunities to further develop this course in context of experiential learning.

DATES TO NOTE

Refer to MyUNSW for Important Dates available at:
<https://my.unsw.edu.au/student/resources/KeyDates.html>

PLAGIARISM

It is expected that all students must at all times submit their own work for assessment. Submitting the work or ideas of someone else without clearly acknowledging the source of borrowed material or ideas, is plagiarism. Education is a process of multidimensional learning, engaging with new material, thinking critically, and using this knowledge to create new knowledge. **Plagiarism short changes you on this multidimensional learning experience and diminishes your educational benefit.**

All assessments which you hand in **must** have a **Non Plagiarism Declaration Cover Sheet**. This is for both individual and group work. Attach it to your assignment before submitting it to the Course Coordinator or at the School Office.

Plagiarism is the use of another person's work or ideas as if they were your own. When it is necessary or desirable to use other people's material you should adequately acknowledge whose words or ideas they are and where you found them (giving the complete reference details, including page number/s). The Learning Centre provides further information on what constitutes Plagiarism at:
<https://student.unsw.edu.au/plagiarism>

ACADEMIC ADVICE

For information about:

- Notes on assessments and plagiarism,
- Special Considerations,
- School Student Ethics Officer, and
- BESS

Refer to the School website available at:
<http://www.engineering.unsw.edu.au/biomedical-engineering/>