UNIVERSITY OF OTAGO
Cell and Molecular Biology (CELS191)

Cell and Molecular Biology (Semester 1 2021)

CELS191 provides an introduction to the biology of cells, fundamentals of molecular biology, organismal and molecular genetics, human genetic variation, diversity and biology of microorganisms, microbial virulence and disease processes. It is a very popular course as it provides a foundation for a variety of science and health science papers. It consists of three 1-hour lectures each week and includes four Health Sciences Integrated Context Lectures (ICLs), designed to encourage wider learning and interest and to apply student knowledge in new areas. There will be five 3-hour laboratory (practical) sessions, occurring every second week. It is an 18-point paper (0.15 EFTS) and students are expected to attend all lectures and labs, undertake essential readings from the prescribed textbook prior to each lecture, and complete an additional 7 hours independent study per week. We run an electronic discussion group on blackboard, moderated by staff, where students can try to answer other students' questions.

Administration

The course is administered by the Academic Convener Professor Richard Macknight, the Course Coordinator Dr Lisa Russell, four Teaching Fellows and an Administrative Assistant. We are situated on the ground floor (G.04 & G.05) of the Mellor Laboratories building. Any enquiries concerning this course can be made by contacting Dr. Lisa Russell via telephone (03) 479 9618 or email lisa.russell@otago.ac.nz.

The prescribed textbook for this course is:

- Biology: A Global Approach 11th Edition
  (Campbell et al., 2018 Pearson Education, ISBN 13: 978-1-292-17043-5).

Page references for the 12th Edition of *Biology: A Global Approach* will be provided in the course material, and page references for the 10th Edition of *Biology: A Global Approach* will be on Blackboard.

Learning Aims and Objectives for CELS191

The learning aims and objectives for CELS191 are based on the philosophy integral to the goals, objectives and strategies of the University's 2013-2020 Teaching and Learning Plan:

- To foster learning through research-informed teaching and assessment of high international standing.
- To motivate students to develop intellectual independence.
- To promote active learning and develop life-long learning skills.
- To instill in students a love of learning.
- To equip students with a sense of interconnectedness between different fields of knowledge.
- To equip students with the ability to integrate and synthesise perspectives gained from a range of papers.

- ❖ To encourage students to reflect upon and evaluate the ethical and social implications of their knowledge.
- ❖ To ensure students gain fundamental facts and concepts of the disciplines of cell biology, molecular biology, genetics, genomics and microbiology.
- ❖ To ensure students have the basic learning skills for advancement to 200-level study.

The objectives for CELS191 are:

- ❖ To gain a firm understanding and grounding in cell biology, molecular biology, genetics and microbiology.
- ❖ To progress towards achievement of good skills in accessing, synthesising and interpreting information, including interpreting graphical and numerical data to solve problems.
- ❖ To develop an evidence-based approach to biological and biomedical knowledge.
- ❖ To develop technical and computer-based skills for acquiring biological and biomedical knowledge.
- ❖ To work and communicate well in groups.
- ❖ To develop and appreciate the value of intellectual independence.
- ❖ To ensure students are adequately prepared in fundamental biology for advancement to both science and 200-level professional programmes.

CELS191 Lecture Outline 2021

Module One - Cell Structure and Diversity	
1	Course Introduction
2	The Diversity of Life
3	Building Blocks of Cells
4	Plasma Membrane & Organelles
5	Endomembrane System & Bulk Transport Processes
6	Regulation of Animal Cell Shape
7	Cell Walls & Their Role in Regulating Cell Shape
8	Cellular Respiration
9	Photosynthesis
10	Nucleus
Module Two – Molecular Biology & Genetics	
11	DNA Structure
12	DNA Replication
13	Eukaryotic Cell Division - Mitosis
14	Eukaryotic Cell Division - Meiosis
15	Errors in Meiosis & X-inactivation
16	Gene Expression - Transcription
17	Gene Expression - Translation
18	Introduction to Mendelian Genetics
19	Extensions of Mendelian Genetics
20	X-linked Traits & Recombination
21	Population Genetics & Natural Selection

Module Three - Human Molecular Genetics	
22	Why Sequence the Human Genome?
23	What Does the Genome Tell Us About Being Human?
24	The Human Genome & Disease
25	Investigating the Function of Individual Genes
26	Cellular Differentiation, Stem Cells & Modern Medicine
Module Four – Microbiology	
27	Introduction to Prokaryotic Cells
28	Microbial Population Growth
29	Microbes & Energy Flow
30	The Human Microbiome
31	Introduction to Viruses
32	Microbial Pathogenicity
33	Antibiotics
34	Microbial Genetics
35	Cellular Basis for the Spread of Infectious Diseases
36	Evolution & Medicine

CELS191 Lectures Objectives

After each student has revised each lecture they should be able to:

1. ***Introduction to CELS191 – Cell and Molecular Biology***
Outline the assessment timetable, procedures and policies as they relate to CELS191. Outline the importance of time management. Define the expectations and workload of a CELS191 student. Identify the differences between 'surface' and 'enquiry-based' learning.

Cell Structure & Diversity:

2. ***The Diversity of Life***
Outline the characteristics that define life. Outline the scale of life. Outline the requirements of natural selection in shaping life. Outline the tree of life, how we know what it looks like and key features including endosymbiosis. Outline what a phylogenetic tree represents. List the three domains of life.

3. ***Building Blocks of Cells***
Describe the relationship between molecular 'building blocks' and higher order structures in cells. Identify the structure of the major types of macromolecules in cells. Describe the roles of carbohydrates, lipids, proteins and nucleic acids in cells.

4. ***Plasma Membrane & Organelles***
Identify some of the key organelles in eukaryotic cells. Outline the importance of organelles and subcellular compartments in cells. Describe the structure of the plasma membrane and outline its importance to cell function. Outline the mechanisms by which substances cross the cell membrane *(simple diffusion, facilitated diffusion, active transport and co-transport).* Outline the role of membrane proteins.

5. *Endomembrane System & Bulk Transport Processes*

Define what is meant by the endomembrane system. Describe function of the endomembrane system. Outline the bulk transport processes of endocytosis *(phagocytosis, pinocytosis, receptor mediated endocytosis)* and exocytosis *(constitutive and regulated).* Outline the role of the lysosome.

6. *Regulation of Animal Cell Shape*

Identify the major components of the cytoskeleton *(microtubules, microfilaments, intermediate filaments)*. Explain how these structures regulate cell shape. Outline the importance of cell junctions *(tight, gap and desmosomes).* Describe the composition and origin of the extracellular matrix.

7. *Cell Walls & Their Role in Regulating Cell Shape*

Describe the structure and function of the primary plant cell wall and outline how it is synthesized. Outline the structure of the vacuole its role in maintaining cell shape. Outline the structure and function of the secondary plant cell wall and plasmodesmata.

8. *Cellular Respiration*

Identify the major energy requirements of plant and animal cells. Describe the basic structure and function of the mitochondrion. Describe the importance of cellular compartments in energy conversion. Outline the mechanism of ATP synthesis and the role played by ATP in powering cellular activity.

9. *Photosynthesis*

Describe the structure and function of the chloroplast. Outline how cells capture light energy and transduce it to cellular energy in the two stages of photosynthesis. Outline the main inputs and outputs of photosynthesis. Outline the process of energy supply in both plant and animal cells. Outline the origin of chloroplasts and mitochondria *(endosymbiosis).*

10. *Nucleus*

Describe the basic structure and function of the nucleus. Describe the structure of the nuclear pore complex and its role in nucleo-cytoplasmic exchange. Outline the organisation of DNA within the nucleus. Outline the functional differences between euchromatin and heterochromatin.

Molecular Biology & Genetics:

11. *DNA Structure*

Outline the components of DNA and the main features of the Watson-Crick model of DNA, including the orientation of the monomeric units, the geometry of the molecule and the role / features of base pairing in the model. Outline semiconservative DNA replication and understand how this allows genetic information to be passed to the next generation.

12. *DNA Replication*

Describe the mechanism of DNA replication and the specific function of all the molecules required. Outline the importance of understanding DNA replication. Describe how errors in the DNA sequence can be corrected and explain why this is important. Outline *'in vitro'* DNA replication by the Polymerase Chain Reaction (PCR) and its importance.

13*. Eukaryotic Cell Division - Mitosis*
Interpret a karyotype. Identify the structures of mitosis and summarise the order of events. Explain the mechanics and function of mitosis in the context of the cell cycle.

14*. Eukaryotic Cell Division - Meiosis*
Explain what the sexual life cycle is. Identify the structures of meiosis and summarise the order of events. Compare and contrast the events that occur in meiosis and mitosis. Outline how meiosis leads to gametic and zygotic diversity and explain why this diversity is important in evolution.

15*. Errors in Meiosis & X-inactivation*
Outline various chromosomal abnormalities *(non-disjunction, aneuploidy, translocation, deletion, duplication, inversion)* and their consequences in humans. Describe how these chromosomal rearrangements happen and behave at meiosis and state their contribution to birth defects in humans. Define the term polyploidy. Outline the concept of X inactivation and explain the effects of odd-numbers of chromosomes on meiotic segregation.

16*. Gene Expression - Transcription*
Outline the "Central Dogma of Molecular Biology" and use it to explain how the information content of a gene is expressed. Outline the structure (anatomy) of a eukaryotic gene, focusing on understanding the importance of the non-coding regions. Outline the process of transcription.

17*. Gene Expression - Translation*
Outline the key features of the genetic code. Outline the roles of mRNA, tRNA and ribosomes in protein synthesis. Describe the process of translation, i.e. how ribosomes 'read' mRNA sequences and thus determine the order of amino acids in a protein molecule. Outline the relationship between genetic and phenotypic variation.

18*. Introduction to Mendelian Genetics*
Outline concepts in genetic variation (alleles & heterozygosity). Explain the difference between phenotype and genotype. Define Mendel's laws and understand their chromosomal basis.

19*. Extensions of Mendelian Genetics*
Explain Mendelian inheritance patterns based on probability laws. Identify causes of deviations from simple Mendelian ratios *(incomplete dominance, co-dominance, polymorphism).* Discuss how environmental factors may affect phenotype. Explain that some phenotypic traits are affected by several loci *(polygenic traits).*

20*. X-linked Traits & Recombination*
Identify the inheritance patterns of genes on sex-linked chromosomes. Explain that linked genes show non-independent assortment. Explain that crossing over leads to recombination of linked gene.

21*. Population Genetics and Natural Selection*
Calculate genotype frequencies using the Hardy-Weinberg equilibrium. Identify that random genetic drift occurs rapidly in small populations. Explain how populations evolve over time in response to selection.

Human Molecular Genetics:

22. ***Why Sequence the Human Genome?***
Explain why the genome was sequenced. Outline the key findings of the human genome. Explain the importance of variation in the human genome. Describe the different types of variation in the human genome.

23. ***What Does the Genome Tell Us About Being Human?***
Outline the function and evolution of the genome using comparative genomics. Outline how comparing genomes helps us understand human biology. Outline how comparing genomes with our relatives can help us understand human origins and human adaptation to the environment.

24. ***The Human Genome and Disease***
Apply pedigree analysis to explain different ways in which mutations can be inherited. Explain how disease-causing genes are found with next generation sequencing. Outline examples of monogenic and polygenic diseases. Describe determinism in genetics and gene-environment interactions.

25. ***Investigating the Function of Individual Genes***
Explain how we can get information about the function of a gene from its phenotype. Outline how we use genetic techniques in model organisms to find out what a gene does. Outline how we use genetic techniques to determine if a gene variant is pathogenic *(disease-causing).* Outline how gene editing and gene therapy can be used to correct some genetic disorders.

26. ***Cellular Differentiation, Stem Cells & Modern Medicine***
Outline the basic principle of embryonic development. Describe how cells differentiate. Outline what makes a stem cell special. Compare and contrast adult and embryonic stem cells. Compare and contrast adult and embryonic stem cells. Outline why stem cells are important in modern medicine.

Microbiology:

27. ***Introduction to Prokaryotic Cells***
Describe the basic structure of a generalized prokaryotic cell. Outline the function of key cellular components of bacterial cells. Identify the key characteristics that distinguish Gram-positive and Gram-negative bacteria. Describe the structure of peptidoglycan.

28. ***Microbial Population Growth***
Describe the process of binary fission. Describe the growth characteristics of bacteria in a 'closed' batch culture system. Outline the importance of different growth stages and the role of persisters. Describe what microbes need to grow and how they harvest and store energy.

29. ***Microbes & Energy Flow***
Define the terms microbial ecology. Outline the basic components of microbial metabolism, energy and carbon acquisition. Outline the four key trophic groups of microorganisms *(chemoautotrophs, chemoheterotrophs, photoautotrophs, photoheterotrophs).* Explain the differences between anoxygenic and oxygenic photosynthesis. Outline how microbes exploit different environments.

30. *The Human Microbiome*
Outline the goals of the human microbiome project. List examples of human gut microflora. Define and provide examples of functional foods and probiotics. Outline how modifying our microbiome can influence us (e.g. fecal transplants for CDI – *Clostridium difficile* infections).

31. *Introduction to Viruses*
Describe the basic structural characteristics of viruses. Describe the difference between 'naked' and 'enveloped' viruses. Outline the different types of viral capsid symmetry. Compare the lytic and lysogenic replication cycles of bacteriophages. Outline the replication cycle of enveloped mammalian cell viruses.

32. *Microbial Pathogenicity*
List some examples of medically important pathogens. Outline Koch's postulates. List the key stages of microbial pathogenesis. List the broad classes of bacterial virulence factors and provide examples of each. Define endotoxins and exotoxins.

33. *Antibiotics*
Explain what is meant by the term 'selective toxicity'. Identify bacterial cell components targeted by different classes of antibiotics *(with a special focus on penicillin and its action on bacterial cell walls.).* Describe some of the mechanisms of the development of antibiotic resistance. Outline how to reduce the spread of antibiotic resistance.

34. *Microbial Genetics*
List the properties of the bacterial genome. Outline the difference between vertical and horizontal gene transfer. Outline the four strategies that generate genetic diversity in bacteria *(mutation, transformation, transduction and conjugation).* Describe how microorganisms exchange genes to alter their virulence.

35. *Cellular Basis for the Spread of Infectious Diseases*
Outline the five stages of an infectious disease. Describe and explain the components of the 'chain of infection' and 'how to disrupt the chain of infection'. Outline how infectious diseases are classified epidemiologically.

36. *Evolution & Medicine*
Explain that by comparing DNA sequences we can understand their relationship. Explain how patterns of relationships between sequences might provide evidence for evolution. Outline the selective pressures the HIV virus is under. Outline the role of evolutionary change in the virulence of pathogens. Describe the importance of evolutionary thought to our understanding of disease.

CELS191 Laboratories Objectives

Lab 1: Cell Structure and Diversity (Part I)
This lab provides students with an induction to the laboratory, covering essential health and safety provisions. Students are then introduced to the fundamentals of microscopy including proper microscope use and techniques used to view cells by completing a wet mount and performing a simple stain. Students use a biological drawing of a plant cell to record what they see. Students are introduced to eukaryote cells (plant vs animal cells). The role that cytoskeleton components play in transporting material around the cell by cytoplasmic streaming is also examined.

Lab 2: Cell Structure and Diversity (Part II)
Microscopy is used in this lab to explore the key features of eukaryote cells. Students complete a wet mount of pond water to explore the biological classification, identifying bacteria and both single-celled and multi-cellular eukaryotic organisms. The rate of photosynthesis is investigated using leaf samples under different light conditions. Students then explore the fundamentals of preparing histological specimens for study by completing a differential stain of animal tissue.

Lab 3: Cell Division – Mitosis & Meiosis
In this lab, students explore cell division, interpreting the stages of mitosis through independent and collaborative work. The concepts of meiosis and non-disjunction are modelled using chromosome beads.

Lab 4: Inheritance of Disease and Intro to Microbiology
In this lab, students interpret and construct universally recognisable pedigrees. Disease analysis is introduced using an experimental set up investigating the inheritance of a single gene disorder (Huntington's Disease). Through this exercise students learn skills in gel electrophoresis and interpretation, pedigree construction and critical thinking by applying these. Relevant health and safety precautions and aseptic techniques are detailed as a range of classical microbiological experimental procedures are introduced, with students setting up experiments for interpretation in Lab 5.

Lab 5: Analyses in Microbiology
This lab introduces techniques used in the identification, treatment and control of bacteria. A case study is introduced requiring students to ascertain the cause of illness in a hypothetical patient using classical microbiological techniques based on their own experimental set up from Lab 4. Students also conduct a Gram stain. The effectiveness and correct application of antimicrobial agents including bacteriophages and antibiotics (including interpretation of Kirby –Bauer Disc diffusion tests) are discussed.

CELS191 Learning Modules

The Learning Modules are designed to support the learning and understanding of the course material. Each Learning Module provides worksheets, video tutorials, and an end of module quiz designed to provide formative feedback that will help assess understanding of the course content.

CELS191 Assessment Criteria

The assessment for CELS191 comprises:

- Lab Assessment Tests: 10% (2% per test)
- Progress Test: 20%
- Final Exam: 70%

During the semester students are required to sit five online Lab Assessment Tests, each worth 2%. Each of these tests consists of ten open book questions that cover information from their practical laboratory sessions. They can submit multiple attempts, and only their highest mark counts.

The progress test assesses student understanding of material covered in lectures 2-14. The final exam is three hours long. It assesses understanding of the material covered over the entire course. The exam comprises both multiple-choice and structured answer questions.

CELS191 Terms Requirement

In order to pass the terms requirements for CELS191, students must attend each lab rotation and complete all of the lab assessment tests to a satisfactory standard.

CELS191 Examination Requirement

In order to pass the examination requirement for CELS191, students must gain a minimum grade of 40% for the final examination component for this paper (28/70). If they do not meet this requirement, they will not pass CELS191.

Note: to pass CELS191 a student must pass both the terms and examination requirements and attain a grade of at least 50% for the **entire course.**

CELS191 Contact Information

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