LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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Please note that S/U option is applicable to Level 1000 LSM courses only.

Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM1111	Biological Challenges and Opportunities for Humankind	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1 and 2	Biological Sciences	Prof Antonia Monteiro antonia.monteiro@nus.edu.sg (Sem 1); Dr Wu Jinlu dbswjl@nus.edu.sg (Sem 2)	Designed as a gateway for the Life Sciences Major, this course explores biological challenges faced by humankind today and how solutions are being developed. We will use three main case studies to illustrate current struggles and how distinct approaches from sub-disciplines of Biology contribute to providing solutions. The nature of scientific inquiry and concepts in genetics, ecology, and evolutionary biology will be explained via the case studies.	1) Introduction to the course 2) The major transitions in evolution 3) Mutations and genomic increases in complexity 4) Principles of natural selection acting on small and large populations 5) How populations become species 6) Principles of development and gene regulatory networks (stem cells) 7) Biodiversity and its importance 8) The sixth extinction – caused by climate change 9) Plasticity and adaptations to climate change 10) The effect of climate change on food security 11) Current status of food production in Singapore 12) Future of food production and food security 13) Outbreaks, epidemics, pandemics 14) Emergence and evolution of viruses 15) Pandemic response 16) Vaccines, therapeutics, medical products 17) Problems associated with ageing 18) Evolution of ageing 19) Mechanism of ageing 20) Animal models of ageing 21) Ageing intervention	1. Describe some of the top challenges that humanity has faced in the past, is facing in the present, and will likely face in the future., 2. Explain fundamental biology concepts behind these challenges., 3. Elaborate connections between these challenges and other subjects outside the life sciences., 4. Become engaged in the integration of multiple disciplines for problem solving., 5. Evaluate the pros and cons of the distinct biological approaches for tackling the challenges.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignments), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 100, 0, 0, 0, 0, 0, 0
LSM1301	General Biology	No	Nil (Preclusion: GCE A-Level or H2 Biology, or equivalents)	1 and 2	Biological Sciences	Dr Zeehan Jaafar jaafarz@nus.edu.sg (Sem 1); Dr Nalini Puniamoorthy nalini@nus.edu.sg (Sem 2)	This is an introductory course that explores what a living thing is, the basics of life, and the science behind it. The course will introduce the chemistry of life and the unit of life. The question of how traits are inherited will be discussed and the field of biotechnology, including its applications and the ethical issues involved be will introduced. The diversity of life on earth will be explored, with discussions how life on earth possibly came about and how biologists try to classify and make sense of the diversity. The course will also introduce the concept of life functions from cells to tissues and from organs to systems. The concept of how organisms maintain their internal constancy and organisation of major organ systems will be discussed. The focus will be to introduce the unifying concepts in biology and how they play a role in everyday life.	1) Science of Biology: Attributes of a living thing. Classification of living things. Scientific method and the limits of science. 2) Chemistry of Life: Functional groups. Condensation and hydrolysis. Structure and function of biological molecules – carbohydrates, lipids, proteins and nucleic acids. 3) Cell Structure and Function: Size of a cell. Biological membranes. Structures and functions of prokaryotic and eukaryotic cells. 4) Energy and Life: Energy release in cells. Aerobic cellular respiration – glycolysis, acetyl-CoA formation, citric acid cycle and oxidative phosphorylation. Fermentation. Breakdown of carbohydrates, lipids and proteins. 5) DNA and Heredity: Genetic material. DNA structure and replication. DNA sequencing. Mitosis and meiosis. 6) Gene Expression: Central dogma of molecular biology. RNA molecules and genetic code. Transcription, translation and mutations. Regulation of gene expression in prokaryotic and eukaryotic cells. 7) Biotechnology: Genetically modified organisms - bacteria, plants and animals. DNA profiling. Genetic screening and gene therapy. Environmental, safety and ethical issues. 8) Evolution: History of evolutionary thought. Theory of natural selection. How populations evolve. Evidence for evolution. 9) Biodiversity: Species concepts. Identification, naming and classifying of organisms. Constructing and interpreting cladograms. 10) Plant Form and Function: Major plant groups. Plant tissue types. Photosynthesis. Plant growth and reproduction. 11) Animal Form and Function: Major animal groups. Animal tissues and selected organ systems. Homeostasis. 12) Ecology: Population growth. Community interactions. Ecosystem dynamics. Human impacts on the environment.	1. Define basic terminologies and concepts in biology., 2. Explain basic biological processes and diversity of life., 3. Describe concept of life functions from cells to tissues to organs to systems., 4. Relate knowledge acquired to everyday life, which includes dealing with common day controversies between science and society.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignments), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 50, 0, 0, 50, 0, 0, 0
LSM1303	Animal Behaviour	No	Nil (For Life Sciences Major/Minor and BES student, please appeal via CourseReg for requisite waiver.)	2	Biological Sciences	Mr N. Sivasothi sivasothi@nus.edu.sg	Understanding animal behaviour awakens the individual to the complexity of daily phenomenon in the animal kingdom - how animals live and survive in their environment. Much of this occurs around us every day and everywhere we go. But the city-dweller lives in increasing isolation of animals and understands little of the world around them. This course will highlight behaviours such as learning, sociality, territoriality, predation and defense, courtship and communication, with examples from across animal diversity. How behaviors have evolved to fit specific ecological conditions will be examined. Students will gain understanding of and empathy for animals.	1) Wildlife in Singapore & Learning Outcomes 2) Diversity, Ethology & Ethics; How to observe animal behaviour? 3) Innate Behaviour & Learning 4) Living in Groups I & II 5) Foraging 6) Territoriality I & II 7) Human - Animal Interactions 8) Communication I & II 9) Courtship & Mating 10) Animal Welfare	1. Understand the evolving ethics of animal welfare., 2. Evaluate the complexity of human-wildlife interactions., 3. Understand how animal behaviour functions in the natural world., 4. Present a scientific report (coherent, concise and evidence-based) as a group., 5. Formulate a design to observe and quantify wild animals in the natural environment., 6. Implement the scientific method to ask a question, measure, and compare in the field., 7. Conduct field work safely (risk assessment, field attire and safety, spatial awareness).	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 50, 15, 5, 0, 0, 0, 0, 30
LSM2105	Molecular Genetics	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1 and 2	Biological Sciences	Assoc Prof Chew Fook Tim dbscft@nus.edu.sg	This course covers topics on (i) the patterns of inheritance, (ii) the molecular properties of genes and chromosomes, (iii) transcription and translation, (iv) genetic methods and technology, and (v) genetic analysis of individuals and populations. This will include an in-depth understanding of mendelian patterns of inheritance and variations that could occur due to multiple alleles, lethal genes, chromosomal variations, linkage, gene interaction and other genetic phenomena. Emphasis is placed on the understanding of the underlying molecular and biochemical basis of inheritance. Quantitative and population genetics will also be discussed with the emphasis of understanding the processes and forces in nature that promote genetic changes.	(1) Introduction; Overview of Genetics and Chromosome in Eukaryotes (2) Cellular Division: Mitosis and Meiosis; Non-Disjunction and Polyploidy (3) Chromosome in Prokaryotes, Genetic Transfer and Mapping Analysis in Microorganisms (4) Chromosome Compaction, Structure, Organization (5) Chromatin Remodeling and Gene Expression (6) Chromosome Recombination (7) Molecular structure of DNA and RNA; DNA Replication (8) Gene Transcription and RNA Processing (9) Translation of mRNA (10) Molecular genetic methods (genetic screening, recombinant and transgenic technologies, RNAi, reporter tagging etc.) (11) New genetic technology (genome editing, next generation sequencing, omics) (12) Model organisms in genetic studies (13) Mendelian Genetics – Terminologies, Mendelian Laws (14) Mendelian Genetics – Sex Linkage, Modes of Inheritance, Pedigree Analysis, Penetrance, Expressivity, Pleiotropy (15) Variations to Mendelian Genetics – Multiple Alleles, Epistasis (16) Variations to Mendelian Genetics – Lethal Genes, Linkage (17) Population Genetics – Hardy Weinberg Equilibrium, Allele Frequencies, Non-random Mating (18) Population Genetics – Mutation and Selection Forces, Maintenance of Genetic Polymorphism (19) Quantitative Genetics – Statistical Description of Quantitative Traits (20) Quantitative Genetics – Polygenic Inheritance, Heritability, Breeding, Heterosis	1. Analyze and evaluate possible observations, and begin to potentially create and generate new ideas (or hypothesis) or ways to produce new understanding, products, or services., 2. Learn and re-learn the basic concepts of heredity, get used to the terminologies, basic language and concepts of modern genetics, and learn them in context of time, space, history and context of the environment., 3. Apply concepts learnt to both seen and unseen scenarios, learn to observe phenomena, hypothesize the potential underlying mechanisms and test these assumptions based on the principles and concepts built within this course.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 60, 0, 0, 0, 0, 0, 40
LSM2106	Fundamental Biochemistry	No	GCE 'A' Level or H2 Biology or equivalent or LSM1301, and GCE 'A' Level or H2 Chemistry or equivalent or CM1417/CM1417X	1 and 2	Biochemistry	Assoc Prof Deng Lih Wen bchdlw@nus.edu.sg (Sem 1); Dr Adrian Teo bchtkka@nus.edu.sg (Sem 2)	The objective is to provide the student with a firm and rigorous foundation in current concepts of the structure and functions of biomolecules in molecular cellular biology. These fundamental concepts form the basis of almost all recent advances in biological and the biomedical sciences. The lectures will introduce various cellular organelles as models to gain insights into how structures and functions of classes of biomolecules participating in important cellular processes.	1) Fundamental Forces & Chemicals in cells (Water, Acid/Bases, Buffer, Non-Covalent Forces, H-bonds, Amphiphiles, Methods of analyses) 2) Structures & Functions of Cellular Proteins (Amino Acid Structures & Properties, Protein Biosynthesis, Shape & Structure of Proteins, Domains & Motifs, Protein Families; Post-Translational Modifications, Folding and Dynamics of Proteins in Cellular Compartments) 3) Cellular Enzymes (Forms & Functions of Enzymes, Enzymatic Kinetics, Cellular and Pharmacological Inhibitors, Regulation of Enzyme Activity, Cellular Oxygenation) 4) Cellular Metabolism (Structures & Functions of Carbohydrates, Mitochondria & Bioenergetics, Integrating Catabolism & Anabolism in Cellular Energy Production, Oxidative and Non-Oxidative Metabolism, System approach to the Organization & Regulation of Metabolic Pathways, Signal Transduction) 5) Cellular Membranes & Nucleic Acids (Structures & Functions of Lipids, Cellular Membrane and Membrane Transport, Structures & Functions of Nucleic Acids, DNA Replication, Repair and Manipulation)	1. Students will learn how enzymes accelerate the rate of reactions., 2. Students will learn how biomolecules integrate in cellular function., 3. Students will learn how enzymes activity is characterized and regulated., 4. Students will learn how these macromolecules are identified, purified and studied., 5. Students will learn how cellular and biochemical processes are regulated as a system., 6. Understand the principles for macromolecules and the key biological processes that are related to the contents of the course.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 40, 6, 0, 0, 0, 0, 54

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LSM2107	Evolutionary Biology	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1 and 2	Biological Sciences	Dr Nalini Puniamoorthy nalini@nus.edu.sg (Sem 1); Dr John Ascher dbsajs@nus.edu.sg (Sem 2)	Evolutionary biology covers the history of life on our planet and the processes that produced the multiple life forms of Earth. Topics include: the origins of life, the eukaryotic cell, and multicellularity; the generation of genetic variation and the sorting of that variation through random processes and through natural and sexual selection; the origin of new traits, new life histories, and new species; the origins of sex, sociality, and altruism; the evolution of humans; and applications of evolutionary biology to solving modern-day problems.	Week 1: What is Evolution? What is the evidence for evolution? Week 2: How did life evolve? How do variations come about? Week 3: How do variations get fixed in populations via random processes? How do variations get fixed in populations via Natural Selection? Week 4: What is the outcome of Natural Selection? What is Artificial selection, and how do we use it in our lives? Week 5: How does evolution lead to variation in Life Histories? How does the environment determine phenotypes? Week 6: How do we connect genotypes to phenotypes? What are the major transitions in Evolution? Week 7: How do we reconstruct species relationships and interpret phylogenies? Week 8: What are species? How does speciation occur? Week 9: Why sex? What is sexual selection? Week 10: What is evolutionary genomics? What is evo-devo and how do novel traits originate? Week 11: What is coevolution? What is convergent evolution? Week 12: How does sociality and altruism evolve? How did humans evolve? Week 13: How does evolution affect our lives?	1. Reconstruct evolutionary relationships (e.g., interpret phylogenies, trace evolution across spatio-temporal scales)., 2. Estimate the influence of genetic and environmental components in variation (e.g., phenotypic plasticity and linkage disequilibrium)., 3. Recognise key processes that drive evolutionary changes (e.g., mechanisms of mutation, drift, selection, gene flow that meditate allele changes in populations)., 4. Apply evolutionary concepts to real world challenges (e.g., using emerging genomics techniques to study host-parasite coevolution in view of disease management)., 5. Comprehend complex theoretical concepts accompanied by case study examples (e.g., how changes in seed types can select for changes in beak shape among Darwin's finches).	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignments), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	5, 0, 0, 15, 0, 30, 20, 0, 0, 30
LSM2191A	Laboratory Techniques in Life Sciences	No	LSM2105 or LSM2106	1 and 2	Biological Sciences	Dr Lim Xin Xiang xinxiang@nus.edu.sg	This course introduces the theory and practical applications of techniques used in molecular biology and protein biochemistry. Factual knowledge in recombinant DNA techniques, such as RNA isolation, reverse transcription, polymerase chain reaction, recombinant DNA construction and recombinant protein expression; and in protein purification, such as liquid chromatography, polyacrylamide gel electrophoresis and western blotting, will be integrated with laboratory practice. *[Have final exam.]*	1) RNA isolation, mRNA expression, reverse transcription and polymerase chain reaction (PCR), and real-time PCR. 2) Recombinant DNA construction by DNA ligation and transformation. 3) Recombinant DNA isolation and characterization by restriction enzyme digestion and agarose gel electrophoresis. 4) DNA sequencing. 5) Recombinant protein expression and extraction. 6) Affinity chromatography and enzyme activity assay. 7) Native and SDS polyacrylamide gel electrophoresis. 8) Western blotting and immunodetection.	1. Isolate mRNA from tissue and amplify one specific gene., 2. Clone a gene into a bacterial expression plasmid., 3. Express and purify an enzyme from a bacterial over-expression system.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	15, 0, 0, 5, 50, 0, 0, 0, 0, 30
LSM2191B	Laboratory Techniques in Life Sciences	No	LSM2105 or LSM2106	1 and 2	Microbiology and Immunology / Biochemistry	Assoc Prof Norbert Lehming micln@nus.edu.sg; Dr Lee Seow Chong bchlees@nus.edu.sg	This course introduces the theory and practical applications of techniques used in molecular biology and protein biochemistry. Factual knowledge in recombinant DNA techniques, such as RNA isolation, reverse transcription, polymerase chain reaction, recombinant DNA construction and recombinant protein expression; and in protein purification, such as liquid chromatography, polyacrylamide gel electrophoresis and western blotting, will be integrated with laboratory practice. *[No final exam.]*	1) RNA isolation, mRNA expression, reverse transcription and polymerase chain reaction (PCR), and real-time PCR. 2) Recombinant DNA construction by DNA ligation and transformation. 3) Recombinant DNA isolation and characterization by restriction enzyme digestion and agarose gel electrophoresis. 4) DNA sequencing. 5) Recombinant protein expression and extraction. 6) Affinity chromatography and enzyme activity assay. 7) Native and SDS polyacrylamide gel electrophoresis. 8) Western blotting and immunodetection.	1. Isolate mRNA from tissue and amplify one specific gene., 2. Clone a gene into a bacterial expression plasmid., 3. Express and purify an enzyme from a bacterial over-expression system.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 70, 0, 0, 0, 0, 0
LSM2212	Human Anatomy	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1	Anatomy	Dr Jai Santosh Polepalli jpolepalli@nus.edu.sg	This course provides a basic introduction to human structure and function, comprising gross anatomy integrated with microscopic anatomy. Histological organization of the primary tissues: epithelial, connective, muscular and nervous tissues will also be covered. Clinical relevance of the anatomical structures will be discussed.	1) Cells and Tissues of the Body 2) Musculoskeletal System 3) Respiratory System 4) Cardiovascular System 5) Digestive System 6) Blood 7) Urinary System 8) Reproductive System 9) Immune System 10) Endocrine System 11) Nervous system	1. Appreciate the clinical relevance of anatomy in exemplary diseases., 2. Learn the basic structures and functions of the human organ systems., 3. Learn the histological/microscopic features of primary human tissues, including epithelial, connective, nervous and muscular tissues.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 0, 0, 0, 0, 0, 70
LSM2233	Cell Biology	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1 and 2	Biochemistry	Assoc Prof Yeong Foong May bchyfm@nus.edu.sg (Sem 1); Assoc Prof Thilo Hagen bchth@nus.edu.sg (Sem 2)	This course provides a comprehensive understanding of sub-cellular structures, functions and interactions in unicellular and multi-cellular systems. Emphasis is on cellular functions. Topics include structures and functions of organelles, organelle biogenesis (including organelle inheritance and import of proteins into organelles), intracellular protein trafficking, the cytoskeleton, and cell movements. In addition, students will be introduced to the current concepts of intercellular and intracellular signalling, molecular basis of cell proliferation and apoptosis.	Cell biology concepts related to and applied to human diseases (Parkinson's disease, Diabetes, Cancer, Infectious disease) Scientific approaches to solving cell biology-related problems: introducing cell biology related techniques, experimental design and data analysis and interpretation, with the ultimate goal for students to be able to understand research papers independently.	1. Able to work collaboratively., 2. Explain fundamental cell biology concepts., 3. Design experiments to answer cell biology related research questions., 4. Understand a research paper and explain how conclusions were obtained., 5. Explain scientific data obtained using cell biology related experimental methods.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (Participation video), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 36, 0, 0, 22, 4, 0, 0, 38
LSM2234	Introduction to Quantitative Biology	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	2	Biological Sciences	Dr Chii Jou Chan, Joe dbschii@nus.edu.sg	Over the past 30 years, there has been an explosion in the amount of quantitative biological data. This is due to advances in imaging, genetics, and sequencing. This course introduces methods necessary for understanding and analysing such quantitative biological data. We use systems from across biology, from photosynthesis to human sleep cycles, to demonstrate the power and applicability of these approaches. We introduce the mathematical and physical concepts necessary through the course. This course is suitable for all Life Sciences students regardless of background in the physical sciences.	1) Spatial and temporal scales, numbers from small to large (Introduction of basic units and scales important for the cell: space, time, force, energy, concentrations, transport, diffusion etc.) (1 lecture) 2) Building blocks of the cell by numbers (How many molecules of water, lipids, DNA, proteins; what are the concentrations; potentially include some numbers for multicellular organisms) (1 lecture) 3) Molecular forces (van der Waals, dispersion, electrostatic), hydrophobic effect, energy, entropy, energy production and usage in the cell (3 lectures) 4) Dynamics and Transport processes, diffusion and active transport, thermal conduction, transport of momentum (viscosity) and turbulent flow (Reynolds numbers) (3 lectures) 5) Kinetics: enzymatic reactions, binding reactions (2 lectures) 6) Equilibria, stable dynamic, equilibrium constants (2 lectures) 7) Stochasticity in cell dynamics (2 lectures) 8) Water and fluids; hydrodynamics and microfluidics (2 lectures) 9) Electrostatics (pH, charge of biomolecules, folding, screening, binding) (2 lectures) 10) Electricity and biology; basics of membrane conductance, channels and channel conductance (2 lectures) 11) Light and biology. Action of IR, vis, UV; the process of vision; DNA damage; photodynamic therapy (2 lectures) 12) Applications of light: fluorescence (fluorescent proteins and enzymatic reactions); optics; optogenetics; optical tweezers and laser cutting and ablation (2 lectures) 13) Conclusions: The overall picture (1 lecture)	1. In particular the student should be able to relate basic physical concepts (energy, entropy, power, force, transport, fluid dynamics, electrostatics, the interaction of light with matter) to biological systems and follow and apply physical reasoning within biology., 2. Should be able to estimate and calculate simple quantitative physical parameters in relation to biological systems., 3. Acquire a quantitative biophysical skill-set to apply to biological processes and develop estimation skills and intuition about biological systems.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (weekly problem sets), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 20, 0, 40, 0, 0, 30, 0, 0, 0
LSM2251	Ecology and Environment	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1 and 2	Biological Sciences	Mr N. Sivasothi sivasothi@nus.edu.sg (Sem 1); Dr Lim Jun Ying jylim@nus.edu.sg (Sem 2)	This course introduces students to the science of ecology and its role in understanding environmental processes. It covers both the major concepts and their real-world applications. Topics will include models in ecology, organisms in their environment, evolution and extinction, life history strategies, population biology, ecological interactions, community ecology, ecological energetics, nutrient cycling, landscape ecology.	1) What is Ecology? – the specific nature of this branch of science, wildlife and ecosystems in Singapore. 2) The Physical & Aquatic Environments – the diversity of these environments and their underpinning mechanisms. 3) Individual Ecology – physiological and behavioural adaptations to the environment, evolution and extinction. 4) Population ecology – how populations are distributed, life history variation, growth and dynamics (births, deaths, immigration and emigration). 5) Species Ecology – how species interact with their own and other species: niche, competition, predation, parasitism, disease and mutualism. 6) Community Ecology - about diversity and abundance of all species in an ecosystem, how they are structured, respond to disturbance and change (succession). 7) Ecosystem Ecology – energy flow, primary production, trophic levels, carbon and nutrient cycling.	1. Reflect on their growth objectives as an undergraduate, enhance their effective network of peers, and summarise their skill set as a science student (career intelligence)., 2. Write and orally present a scientific report, plan a group project and conduct field work safely, and apply the scientific method to identify questions in a complex system., 3. Recognise common wildlife species and the ecosystems they inhabit in Singapore, differentiate the fundamental ecological mechanisms of the natural world, and apply the scientific method to pose and answer an ecological question in the natural world.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 40, 10, 0, 0, 5, 15, 0, 30

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Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM2252	Biodiversity	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1 and 2	Biological Sciences	Mr N. Sivasothi sivasothi@nus.edu.sg (Sem 1); Dr Theresa Su theresasu@nus.edu.sg (Sem 2)	The course aims to inculcate in students an understanding for the need of a diverse and intricate balance of nature and the morality of conservation. It involves an introduction to the diversity of major groups of living organisms, and the importance of maintaining diversity in natural ecosystems. Emphasis is on the need for conservation of biodiversity to maintain a balance of nature. The course will highlight to the students the biodiversity in the major habitats and vegetation types in and around Singapore.	Introduction, Systematics & Conservation Introduction; Learning Outcomes & Methods Classification & Systematics The Sixth Extinction & Conservation of Biodiversity The Kent Ridge and LKCNHM Practicals (how to work in the field) Botany Botany 1: Archaea, Cyanobacteria, Algae Botany 2: Non-vascular and vascular seedless plants Botany 3: Vascular seed plants: Gymnosperms & Angiosperms (Part 1) Botany 4: Angiosperms (Part 2) & Fungi Zoology lectures Introduction & Tree of Life Zoology 1: Non-photosynthetic Protists, Trends in the Animal Kingdom Zoology 2: Animal Phyla trends; Parazoa and Radiata (Porifera, Cnidaria & Ctenophora) Zoology 3: Protostomes 1 Lophotrochozoa (Platyhelminthes & Annelida) Zoology 4: Protosomes 2 Ecdysozoa I (Mollusca, Nematoda, Tardigrada) Zoology 5: Protosomes 3 Ecdysozoa II (Arthropoda & Onychophora) Zoology 6: Deuterostomes 1 (Echinodermata, Hemichordata, Protochordata) Zoology 7: Deuterostomes 2 (Vertebrates I: Fishes & Amphibia); Deuterostomes 3 (Vertebrates II: Reptiles including Birds & Mammals)	1. Evaluate the identity of novel organisms., 2. Define biodiversity, and recognise its scope., 3. Explain the need for conserving biodiversity., 4. Discover where organisms are distributed within tropical ecosystems., 5. Prepare themselves to field work in terrestrial and inter-tidal environments., 6. Categorise and differentiate major groups of living organisms within the Tree of Life., 7. Write a coherent, precise evidence-based essay, with appropriate use of tables and figures, and cite effectively.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (post fieldtrip test), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 15, 0, 22.5, 20, 0, 12.5, 0, 0, 30
LSM2254	Fundamentals of Plant Biology	No	LSM2105 or LSM2106	2	Biological Sciences	Assoc Prof Lau On Sun onsunlau@nus.edu.sg	This course introduces students to contemporary plant biology. It focuses on the flowering plants (angiosperms), one of the most successful plant groups that sustains all life on earth, and examines how they are organized, grow, and respond to the environment. A major theme that the course will highlight is that plant growth is highly dynamic – plants control growth and development through integrating intrinsic and external signals to best adapt to the changing surroundings. The concepts and techniques of gene manipulation for studying plants, as well as their applications in plant biotechnology, will also be discussed.	1. Importance of plants; Origin of land plants/angiosperms and their life cycle - 2 lecture hours; General introduction of the course. Topics include plants as a major source of food and materials, as a player in global climate, and as an experimental system; the evolution of land plants with a focus on angiosperms; life cycle and features of angiosperms, with comparison with animals. 2. How are plants organized? Plant structure, growth and development - 4 lecture hours; Topics include plants organization and major organ systems; the meristems as the source of new cells and growth; the growth and differentiation of leaves and roots; and shoot architecture and status. Comparison of growth strategy with animals will be highlighted. 3. The model plant Arabidopsis and the molecular and genetic tools for studying plants - 2 lecture hours; Topics include the need and values of model plants; features and contributions of Arabidopsis as the go-to model system; resource for Arabidopsis research; concepts of genetic analyses for plant research; and plant transformation and molecular analyses. 4. Unique aspects of plant cells and tissues - 2 lecture hours; Topics include plant cell architecture; plant cell cycle and division; plant cell wall; plant cell expansion and shape; specialized cells and tissues in plants. 5. Coordinating growth through plant hormones - Diversity - Perception, signalling and action - 6 lecture hours; Topics include the importance of coordinating growth within plants; major plant hormones and their functions; perception of hormone by receptors; hormone signal transduction and downstream effectors; biosynthesis and transport of plant hormones. Auxin will be used as a primary example to highlight general principles. 6. Plant response to the environment - Do plants see? Importance of light perception - Responses to abiotic stress - Responses to biotic stress - 6 lecture hours; Topics include the importance of sensing and responding to environmental conditions; Light as an environmental cue; photoreceptors and light signal transduction; plant responses to abiotic stresses, such as heat and water deficits; roles of hormones in responding to abiotic stresses; plant interactions with pathogens; plant defences; plant cooperative interaction with other organisms. 7. Plant biotechnology and genetic engineering - 4 lecture hours; Topics include concepts of genetic engineering; traditional methods of improving plants; values of plant genetic engineering over traditional breeding; techniques in generating transgenic plants; Notable examples of GM crops; concerns and societal impact of GM crops. For practicals and demos: 1. Sterile and tissue culture techniques 2. Phenotypic analyses of plant mutants (e.g. hypocotyl length, stomatal numbers, etc.) - Imaging & measurements - Light microscopy 3. Gene expression analyses of plant mutants - RNA extraction in plants - Semi-quantitative RT-qPCR 4. Genotyping of mutant plants - DNA extraction in plants - PCR 5. Reporter analyses in plants - GUS staining - Fluorescent imaging	1. Describe the basic structure, growth and development of plants in relation to their life strategies., 2. Identify unique aspects of plant cells and tissues., 3. Explain the roles of model species in the study of plant processes., 4. Explain how plants sense and respond to environmental stimuli., 5. Describe how plants use hormones to coordinate growth., 6. Discuss the technology behind genetically modified plants and its application., 7. Select appropriate techniques to address questions in plant science.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 30, 0, 0, 0, 0, 40
LSM2291	Fundamental Techniques in Microbiology	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1 and 2	Microbiology and Immunology	Dr John Chen miccjy@nus.edu.sg (Sem 1); Assoc Prof Chu Jang Hann miccjh@nus.edu.sg (Sem 2)	Embark on a captivating exploration of Microbiology where students will gain a deeper understanding of microbes and techniques for studying them, through a combination of theoretical knowledge and hands-on experiments. Students will delve into the invisible world of microbes, investigating microbiomes of skin, soil and water, and exploring the role of probiotics. Moreover, students will have the unique opportunity to visit a microbiology-related industry and witness real-world applications of their learnings. By the end of the course, students should possess fundamental knowledge of microbiology and the experimental tools used and will be inspired to probe deeper into this exciting field.	Both the lectures and practical classes provide an overview of microbial diversity, the biological properties of microbes, methods and approaches in the study of microbiology with the emphasis on the fundamental experimental techniques in microbiology. The concept of biosafety in microbiology research is also introduced in this course. Lectures: •Introduction to the diversity of microbial world and phylogeny •Biosafety •Report writing •Isolation and identification of microbes •Microbes in the environment: Where are microbes found and why are they there •Microbes and immunity Practicals (Wet Lab) - 5 class sessions: (1)Soil microbiology: Isolation, identification and characterization (antibiotic producers,polysaccharide producers) (2)Water-borne pathogens: Isolation, enumeration, physiology and behaviour outsidethe host (3)Food microbiology: Isolation, enumeration and characterization (yeast, lactic acidbacteria, enteric bacteria) (4)Human skin microbiology: Isolation, are they pathogens?	1. Acquire fundamental knowledge of microbiology, including tools in the study of cells and microbes and the awareness of biosafety, and be excited by the microbial world and wishing to know more.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignments), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 60, 30, 0, 10, 0, 0, 0
LSM3201	Research and Communication in Life Sciences	No	Nil (Concurrently doing LSM2288 or LSM3288 or LSM4199 or LSM4288 variant)	1 and 2	Biological Sciences	Assoc Prof Lam Siew Hong dbslsh@nus.edu.sg	This course introduces students to the philosophy, principles and processes of life sciences research and communication. It aims to equip students with the essential knowledge that complements the hands-on research training which students undertake for UROPS and Honours projects' requirements. The course covers the essentials of scientific research including: importance and pitfalls of problem formulation and hypothesis generation; essentials of experimental designs; practical tips and pitfalls during experimental execution; good and bad practices of data collection, analysis and evaluation; form and function of scientific communication; and research ethics.	The course syllabus will be generally divided into three major parts: (I) Thinking & Questioning, (II) Searching & Finding, and (III) Communicating & Critiquing. The three major parts can further be subdivided into the following subtopics that will be covered in the course: (I) Thinking & Questioning 1. Scientific Thinking (basic philosophy, aims and assumptions of science; what makes science scientific; strength and limitation of science; difference between scientific, non scientific, pseudoscientific and unscientific; scientific process and knowledge development; ethics in research; essential aptitudes in research) 2. Scientific Observation and Approaches (What makes an observation scientific; naturalistic versus experimental observation; descriptive versus experimental studies; inductive versus deductive approaches) 3. Scientific Questioning (Where do questions come from; what makes a research problem; types and nature of research questions; problem formulation & hypotheses generation & pitfalls; thinking critically & scientifically) (II) Searching & Finding 1. Scientific Methods of Searching (Part I): Elements of Experiment (defining the variables; manipulating independent variables; measuring dependent variables, controlling extraneous secondary and random variables; variances in experiments, reliability and validity in experiments). 2. Scientific Methods of Searching (Part II): Experimental Designs (what makes a Good experimental design; criteria for evaluating an experimental design; types of experimental design; strengths, limits & pitfalls; ethical considerations) 3. Execution of experiment: Elements of sampling and measurement (function and good practices of laboratory notebook keeping; what is in a measurement; types and limits of measurement and instrumentation/tools; reasons, goals and considerations in sampling; reliability, validity & pitfalls; troubleshooting and what to do when things do not work) 4. Organizing, Analyzing & Evaluating Data (noteworthy practices for organizing and processing data; descriptive and inference statistics for data analysis; what does statistical significance implies; possible errors and their significance; how to evaluate the validity of a finding; effective evidence based conclusion; how to address negative findings) (III) Communicating & Critiquing 1.Writing [General structure & function of a scientific paper; specific formats and standards; pointers for effective scientific writing; common mistakes and pitfalls to avoid; ethical norms & considerations (plagiarism)] 2. Presenting (Pointers for preparing a successful presentation; pointers for good visual presentation; pointers for effective delivery) 3. Peer review & Critiquing [(a) Critiquing the research problem, research question and hypothesis formulation; (b) Critiquing the experimental design, execution, analysis and conclusion/generalization; (c) Critiquing the writing and presentation of the data/findings.]	1. Students would understand the scientific thinking and how scientific knowledge is generated through research and from current existing knowledge. They would be able to relate and apply them to their research projects. Students' thinking skills would be enhanced., 2. Students would be able to identify the important steps and pitfalls in the research process. They would be able to apply them in the context of their research projects. Students' research skills would be enhanced., 3. Students would learn important criteria, requirements, ethics awareness, and avoid pitfalls for effective science communication (written and oral presentation) relevant to their research projects. Students' communication skills would be enhanced., 4. Students would acquire scientific thinking and critical thinking skills, and be able to evaluate and critique scientific communication, including their own research projects.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (writing and review), Others 2 (presentation), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 10, 0, 0, 78, 12, 0, 0

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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Please note that S/U option is applicable to Level 1000 LSM courses only.

Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM3210A	Metabolism and Regulation	Yes - BMS	LSM2106	1	Biochemistry	Dr Yu Haojie bchhaoy@nus.edu.sg	Overview of the biosynthesis and catabolism of carbohydrates, proteins, lipids and nucleic acids in the context of human health and disease. Emphasis on the integration and regulation of metabolic pathways in different tissues and organs. Principles of bioenergetics and mitochondrial energy metabolism, free radicals, enzyme deficiencies in metabolic disorders will also be covered.	1. Introduction • Overview of metabolism and general features in regulation of metabolic pathways. 2. Bioenergetics • ATPases, substrate-level phosphorylation, redox potential and free energy release • Electron transport • Oxidative phosphorylation 3. Carbohydrate Metabolism • Introduction to carbohydrates, glycolysis and its regulation • Metabolism of other hexoses • TCA cycle • HMP • Glycogen: metabolism and regulation • Gluconeogenesis and pentose phosphate pathway 4. Lipid Metabolism • Digestion, absorption and transport • β-oxidation of fatty acids • Ketogenesis • Fatty acid biosynthesis • Synthesis of eicosanoids and membrane phospholipids • Cholesterol metabolism 5. Amino Acid Metabolism • Overview of amino acid metabolism • Transamination and deamination • Urea synthesis and the urea cycle • Metabolic fates of the carbon skeletons of amino acids • Metabolism of selected amino acids • Other specialised products derived from amino acid decarboxylation	1. Understand the biosynthesis and catabolism of carbohydrates, proteins, lipids and nucleic acids in the context of human health and disease, with emphasis on the integration and regulation of metabolic pathways in different tissues and organs., 2. Understand the principles of bioenergetics and mitochondrial energy metabolism, free radicals, enzyme deficiencies in metabolic disorders.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 50, 0, 0, 15, 0, 0, 35
LSM3210B	Metabolism and Regulation	Yes - BMS	LSM2106	2	Biological Sciences	Dr Lin Zhewang zlin@nus.edu.sg	Overview of the biosynthesis and catabolism of carbohydrates, proteins, lipids and nucleic acids in the context of human health and disease. Emphasis on the integration and regulation of metabolic pathways in different tissues and organs. Principles of bioenergetics and mitochondrial energy metabolism, free radicals, enzyme deficiencies in metabolic disorders will also be covered.	1. Introduction • Overview of metabolism and general features in regulation of metabolic pathways. 2. Bioenergetics • ATPases, substrate-level phosphorylation, redox potential and free energy release • Electron transport • Oxidative phosphorylation 3. Carbohydrate Metabolism • Introduction to carbohydrates, glycolysis and its regulation • Metabolism of other hexoses • TCA cycle • HMP • Glycogen: metabolism and regulation • Gluconeogenesis and pentose phosphate pathway 4. Lipid Metabolism • Digestion, absorption and transport • β-oxidation of fatty acids • Ketogenesis • Fatty acid biosynthesis • Synthesis of eicosanoids and membrane phospholipids • Cholesterol metabolism 5. Amino Acid Metabolism • Overview of amino acid metabolism • Transamination and deamination • Urea synthesis and the urea cycle • Metabolic fates of the carbon skeletons of amino acids • Metabolism of selected amino acids • Other specialised products derived from amino acid decarboxylation	1. Understand the biosynthesis and catabolism of carbohydrates, proteins, lipids and nucleic acids in the context of human health and disease, with emphasis on the integration and regulation of metabolic pathways in different tissues and organs., 2. Understand the principles of bioenergetics and mitochondrial energy metabolism, free radicals, enzyme deficiencies in metabolic disorders.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 40, 0, 0, 0, 0, 0, 60
LSM3211	Fundamental Pharmacology	Yes - BMS	LSM2106 or PHS1111 or PHS2102	1 and 2	Pharmacology	Prof Wong Wai-Shiu Fred phcwongf@nus.edu.sg (Sem 1); Dr Seah Bee Kee, Serena s.seah@nus.edu.sg (Sem 2)	This course aims to provide basic principles of receptor pharmacology and of pharmacokinetics with emphasis on molecular and cellular mechanisms of action, clinical uses and adverse effects using lectures, tutorials and practicals. The lecture topics will start with the classical drug receptor theory followed by pharmacokinetics and molecular pharmacology of drug receptors and their regulation including receptor-mediated signal transduction and membrane ion channel function. Autonomic pharmacology (adrenergic and cholinergic) will be introduced. The course also focuses on the pharmacology of autacoids, non-steroidal anti-inflammatory agents, corticosteroids, immunosuppressants, anti-asthma drugs, and anti-arthritic drugs.	1. Drug receptor theory 2. Pharmacokinetics 3. Receptor classes and signal transduction pathways 4. Autonomic pharmacology 5. Adverse drug reactions 6. Vasoactive peptides and enzyme inhibitors 7. Mechanisms of drug actions, clinical uses and adverse drug effects of selected commonly used classes of drugs	1. Know the different classes of adverse drug reactions, and the various parameters of pharmacokinetics in how we handle drugs taken by humans., 2. Know the various mechanisms of drug and receptor interactions, the 5 major classes of drug receptors and how they work., 3. Know the pharmacology of adrenergic and cholinergic drugs and their clinical uses and adverse drug effects., 4. Know the mechanisms of action, clinical uses and adverse effects of a class of enzyme (phosphodiesterase) inhibitors., 5. Know the different types of endogenous peptide ligands, their cognate receptors and their clinical uses and adverse drug effects., 6. Know the mechanisms of drug actions, clinical uses and adverse drug effects of some commonly used drugs like antihistamines, non-steroidal anti-inflammatory drugs, corticosteroid drugs, immunosuppressants, anti-asthma drugs and anti-arthritic drugs.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 60, 0, 0, 0, 0, 0, 40

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM3212	Human Physiology: Cardiopulmonary System	Yes - BMS	LSM2106	1	Physiology	Dr Zakaria Almsherqi phszama@nus.edu.sg	The heart and lungs are central to the maintenance of homeostasis in the human body by bringing essential materials to and removing wastes from the body's cells. This course covers the basic physiology of the cardiovascular and pulmonary systems using exercise to illustrate the onset of homeostatic imbalances and the body's responses to restore homeostasis. Students will be able to identify the benefits that exercise imparts to cardiorespiratory fitness and overall health.	A. Blood Physiology: • Composition and functions of blood. • R.B.C – morphology, erythropoiesis, functions, fate • ESR and its clinical importance • Haemoglobin – structure, types, compounds of haemoglobin, abnormal haemoglobin, RBC indices - PCV,MCV,MCH,MCHC, Colour index. • Anaemia - Types with examples, polyeythaemia • Platelets: structure and functions • Haemostasis: Role of platelets, Blood coagulation, anticlotting mechanisms, anticoagulants. • Bleeding disorders: Purpura, Hemophilia, Vitamin K deficiency, tests for bleeding disorders. • Thrombotic disorders: Thrombosis embolism • Blood group: different systems, Blood grouping & cross matching and clinical importance. • Blood transfusion: Hazards of blood transfusion, storage of blood B. Respiratory Systems: • Functional Anatomy and functions of respiratory system. • Mechanics of respiration. • Lung volumes and capacities: definition, normal values, their measurement and clinical importance. • Pulmonary ventilation, alveolar ventilation, dead space. • Diffusion of gases across alveocapillary membrane, diffusing capacity. • Pulmonary circulation. • Oxygen & carbon dioxide transport in blood. • Pressure changes during ventilation, pressure volume relationship including surfactant and compliance, airway resistance, work of breathing • Control of respiration: neutral control, chemical control, response to exercise, periodic breathing. • Hypoxia including high altitude physiology and acclimatization, asphyxia, cyanosis, oxygen therapy and toxicity. C. Cardio-vascular system: • Functional anatomy of heart and blood vessels. • Properties of cardiac muscle. • Origin & spread of cardiac impulse, heart block, cardiac arrhythmias.	1. Know the basic physiology of the cardiovascular and pulmonary systems by using exercise to illustrate the onset of homeostatic imbalances and the body's responses to restore homeostasis., 2. Identify the benefits that exercise imparts to cardiorespiratory fitness and overall health.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 15, 15, 0, 30, 0, 0, 0, 40
LSM3214	Human Physiology - Hormones and Health	Yes - BMS	LSM2106	2	Physiology	Assoc Prof Thai Tran phstt@nus.edu.sg	This course covers several human physiological systems using hormonal control of homeostasis as a basis for understanding normal function and health. The student will be able to appreciate the interactions occurring amongst the endocrine, digestive, renal, and reproductive systems, and be able to relate them to the body's biological rhythms (or clocks), growth, responses to stress, and reproductive processes. Major Topics Covered: endocrine system, central endocrine glands, peripheral endocrine glands, digestive system, digestive processes, energy balance, urinary system, fluid processing, fluid balance, reproductive system, male reproductive physiology, female reproductive physiology.	Major Topics Covered: endocrine system, central endocrine glands, peripheral endocrine glands, digestive system, digestive processes, energy balance, urinary system, fluid processing, fluid balance, reproductive system, male reproductive physiology, female reproductive physiology including pregnancy.	1. Understand the role of hormonal control of homeostasis as a basis for normal function in health and disease in several human physiological systems (endocrine, digestive, renal, and reproductive systems).	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 0, 0, 40, 0, 0, 0, 0, 0, 50
LSM3215	Neuronal Signaling and Memory Mechanisms	Yes - BMS	LSM2106	1	Physiology	Assoc Prof Saji Kumar Sreedharan phssks@nus.edu.sg	The course will provide fundamental knowledge about how neuronal signaling and its higher functions, such as encoding and retrieval of memory, occur in our brain. Learning and memory mechanisms are conserved in all organisms. This course covers topics including the ionic basis of resting and action potentials, molecular biology of ion and TRP channels, ion channelopathies, and the auditory system. It also focuses on neurotransmission with particular emphasis on the glutamate receptors and neuropharmacology. In addition, it touches the cellular and molecular basis of learning and memory, and energy utilization in the brain.	1. Brief Intro & functional anatomy of brain; ionic basis of electrical signalling-resting potential 2. Ionic basis of electrical signalling- action potential; molecular biology of voltage gated ion channels 3. TRP channels as sensors of temperature or chemicals 4. Mechanisms of auditory transmission; Ion channelopathies 5. Presynaptic event: neurotransmitters and neurotransmitter release mechanisms 6. Postsynaptic events: Molecular biology of neurotransmitter receptors 7. Neuronal signalling and integration 8. Synapse and neurodegenerative diseases 9. Classifications of memory: role of hippocampus and amygdala 10. Models of memory from Aplysia to Human 11. Molecules and mechanisms of memory-1 12. Molecules and mechanisms of memory-2	1. Understand the ionic basis of resting and action potentials, molecular biology of ion and TRP channels, ion channelopathies, and the auditory system., 2. Understand neurotransmission with particular emphasis on the glutamate receptors and neuropharmacology., 3. Understand the cellular and molecular basis of learning and memory, and energy utilization in the brain.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (self-directed learning), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 20, 0, 0, 20, 0, 0, 60
LSM3216	Neuronal Development and Diseases	Yes - BMS	LSM2233	2	Physiology	Dr John Chua Jia En phsjcje@nus.edu.sg	This course will focus on key events that take place in different stages of vertebrate nervous system development including neural induction, neurogenesis, glial biology, neuronal growth and polarity, axonal guidance, synapse formation, and regeneration. Pathological states such as muscular dystrophy, spinal cord injury, Parkinson's disease, and other neurodegenerative diseases will be studied, both in terms of understanding the deficits as well as examining potential solutions to improve the outcomes of these neuronal diseases. Latest findings will be discussed, allowing students to learn the current state of research in developmental neurobiology.	Neuronal Polarity Neuronal architecture, its importance in neurotransmission, how it is formed during development Protein Trafficking in Neurons The roles of intracellular transport in neuronal development and synapse formation, how transport defects cause neurological disorders Neural induction pattern formation and neurogeneis Neural induction and neurogenesis during early brain development Neuronal migration and axonal pathfinding How neurons migrate and form neuronal networks Neuronal death and neurodegeneration Neuronal death pathways and their roles in development and neurodegeneration Neuronal regeneration & neural stem cells Strategies and issues in neural regeneration Rodent models for neuroscience research (WPY) The use of rodent models to understand neurological disorders Glia biology – Parts I and II (THP) The roles of Glia in the brain and in neurodegeneration Neurotrophic factor – Parts I and II Neuronal survival signals and their clinical uses	1. Explain how perturbation of these events contribute to pathological states underlying human disorders such as muscular dystrophy, spinal cord injury, Parkinson's disease, and other neurodegenerative diseases and to outline the current approaches available to improve the outcomes of these disorders., 2. Describe and explain key events that take place in different stages of vertebrate nervous system development including neural induction, neurogeneis, glial biology, neuronal growth and polarity, axonal guidance, synapse formation, and regeneration.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (self-directed learning), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 0, 0, 30, 0, 0, 40
LSM3217	Human Ageing	Yes - BMS	LSM2233	1	Physiology	Dr Tsai Shin-Yin phsts@nus.edu.sg	This course will explore the physiological changes during ageing. Cardiovascular disease is a leading cause of mortality globally and sarcopenia is a major cause of disability and frailty among older adults, which decrease healthy lifespan. We will review the mechanism underlying the functional deterioration of system ageing. Moreover, we will also discuss the emerging evidence to explain how motor neuron and immune cells might contribute and respond to system ageing.	i) The physiology decline of cardiac muscle during aging and the risk factors for the development of cardiovascular diseases. ii) The physiology decline of smooth muscle during aging and the contribution of immune cells in vascular remodelling and age-related vascular diseases. iii) The physiology decline of skeletal muscle during aging and the molecular mechanism by which exercise promotes healthy aging. iv) The potential mechanism of motor neuron alternations contribute to muscle aging. v) The complication of aging-associated diseases such as cancer induce muscle loss.	1. Acquire general ideas on the biology of aging and its application to trigger muscle aging, and develop skills for scientific communication to the general public.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 50, 0, 0, 0, 0, 0, 50

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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Please note that S/U option is applicable to Level 1000 LSM courses only.

Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM3218	Cardiopulmonary Pharmacology	Yes - BMS	LSM3211	2	Pharmacology	Dr David Fann Yang-Wei david.fann@nus.edu.sg	This course focuses on the pharmacological drugs used to treat cardiovascular and pulmonary diseases, with emphasis on the molecular and cellular mechanisms of action, pharmacokinetics, clinical and contra-indications, and adverse effects through lectures, tutorials, and laboratory sessions. The course will commence with lecture topics on the basic anatomy and physiology of the cardiovascular and pulmonary systems, followed by an understanding of the pharmacological drugs that are used to treat common cardiovascular and pulmonary diseases. Overall, this course aims to demonstrate the principles and clinical applications of these drugs in cardiovascular and pulmonary diseases.	1. Cardiovascular and Pulmonary System: Basic Anatomy and Physiology 2. Pharmacological Treatments of Hypertension 3. Pharmacological Treatments of Hyperlipidemia 4. Pharmacological Treatments of Coronary Artery Disease 5. Pharmacological Treatments of Heart Failure 6. Diuretic and Anti-thrombotic Drug Therapy 7. Pharmacological Treatments of Pulmonary Hypertension and Fibrosis 8. Pharmacological Treatments of Asthma and COPD 9. Pharmacological Treatments of Coughs and Colds	1. Describe the basic anatomy and physiology of the cardiovascular and pulmonary systems in humans. 2. Describe the mechanism(s) of action, clinical and contra-indications, and adverse effects of pharmacological treatments of hypertension and hyperlipidemia in humans. 3. Describe the mechanism(s) of action, clinical and contra-indications, and adverse effects of pharmacological treatments of coronary artery disease and heart failure in humans. 4. Describe the mechanism(s) of action, clinical and contra-indications, and adverse effects of diuretic and anti-thrombotic drug therapy in various cardiovascular disorders and diseases in humans. 5. Describe the mechanism(s) of action, clinical and contra-indications, and adverse effects of pharmacological treatments of pulmonary hypertension and fibrosis in humans. 6. Describe the mechanism(s) of action, clinical and contra-indications, and adverse effects of pharmacological treatments of asthma and COPD, coughs and colds in humans.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 0, 0, 0, 0, 30, 0, 0, 0, 60
LSM3219	Neuropharmacology	Yes - BMS	LSM2106 or PHS2102	1	Pharmacology	Assoc Prof Judy Sng phcsngj@nus.edu.sg	This course introduces the pharmacological treatment of nervous system. It covers the actions of drugs and how they affect cellular function in the nervous system, and the neural mechanisms through which they influence behavior. Examples of drugs used to treat diseases and disorders of the nervous systems will be discussed.	Introduction and Principles of Neuropharmacology CNS drugs and their clinical uses ⍰ Sedatives and hypnotics ⍰ General and local anesthetics ⍰ Drugs used in pain management ⍰ Substance abuse and drug addiction ⍰ Drugs for depression and anxiety disorders ⍰ Drugs for psychosis and mania ⍰ Drugs used in epilepsies and neurodevelopmental disorders ⍰ Pharmacological management of Parkinsonism and othermovement disorders ⍰ Drugs used in the treatment of dementia Clinical drug trials in neurosciences Tutorials and Seminars ⍰ Basic neuropharmacology ⍰ Clinical uses of CNS drugs ⍰ Drug trials in CNS Practicals ⍰ Anesthetics ⍰ Genetics underlying Attentiveness ⍰ Neurostimulants	1. Understand drug discovery from animal models to clinical trials., 2. Grasp new paradigms and advanced knowledge on neurochemistry, neurological disease progression and evaluation., 3. Acquire the current understanding and latest information on neurological pharmacological treatments ranging from drugs with proven efficacy to experimental/conceptual drugs.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (PeerWise), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 10, 20, 0, 15, 5, 0, 50
LSM3220	Genes, Genomes and Biomedical Implications	Yes - BMS	LSM2105 and LSM2106	1 and 2	Biological Sciences	Dr Phua Siew Cheng sc.phua@nus.edu.sg (Sem 1); Dr Xue Shifeng shifengxue@nus.edu.sg (Sem 2)	This course deals with the structure, organization and function of genes and genomes in both prokaryotes and eukaryotes (e.g. DNA topology, hierarchy of packaging of DNA in chromosomes and relationship to gene activity and genome dynamics). The functional roles of DNA regulatory cis-elements and transcription factors involved in gene expression will be examined. The molecular events in the control and regulation of transcription; post-transcriptional modifications and RNA processing; temporal and spatial gene expression will be examined in detail. The cause and/or effect of dysfunction of gene expression in diseases will be discussed.	Part I: Genes & Genome Dynamics o Introduction - Landmark discoveries & current trends in molecular biology o Gene density o Complexity and genome manipulation o Chromosomes dynamics o DNA topology, packaging & hierarchy of the eukaryotic genome o Nucleosomes; solenoids; loops; scaffolds o Telomeres and centromeres o Satellite DNA; repetitive DNA; gene families o Organelle genomes (mitochondrial genomes) Part II: Gene Expression and Regulation in Prokaryotes o Prokaryotic RNA polymerase and transcriptional regulation o Prokaryotic operons and regulatory circuits o Phage lambda life cycle o DNA replication and gene transfer (transformation, conjugation and transduction) o Genetic recombination: homologous, site-specific & transpositional recombination o Mutation and DNA Repair Part III: Gene Expression and Regulation in Eukaryotes o Promoters; cis-elements (enhancers, silencers, LCRs…) in eukaryotes o Eukaryotic RNA polymerases; transcription preinitiation complex o Transcription factors (Zn fingers; homeodomains, etc.) and co-factors o Chromatin remodelling, Histone modifications o Post-transcriptional processing: 5′ capping, splicing, 3′ polyadenylation, mis-splicing and diseases o Differential gene expression (spatial and temporal); o RNA interference (RNAi) – gene silencing in control of expression	1. Understand the structure, organization and function of genes and genomes in both prokaryotes and eukaryotes (e.g., DNA topology, hierarchy of packaging of DNA in chromosomes and relationship to gene activity, gene regulation and genome dynamics)., 2. Understand the functional roles of DNA regulatory cis-elements and transcription factors involved in gene., 3. Know the molecular events in the control and regulation of transcription; RNA processing and post-translational modifications; temporal and spatial gene expression., 4. Know the cause and/or effect of dysfunction of gene expression in diseases and use of modern technologies to examine them.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 10, 0, 30, 0, 0, 0, 60
LSM3222	Human Neuroanatomy	Yes - BMS	LSM2105 or LSM2106 or LSM2212	2	Anatomy	Prof Ong Wei Yi antongwy@nus.edu.sg	A working knowledge of human neuroanatomy is essential for many fields of biomedical science, practice and research. The purpose of this course is to cover the basic functional neuroanatomy of the human nervous system, including overview, neurohistology, peripheral nervous system, autonomic nervous system and central nervous system. It takes a regional-systemic approach to understanding human nervous system structure and function - that parallels the core knowledge used in clinical practice. Emphasis is placed on the unique anatomical features and neurochemistry of different parts of the central and peripheral nervous system, while demonstrating their synaptic connectivity and interrelatedness of their functions.	Weeks 1 to 3 – • Overview of the human nervous system • Histology of peripheral nerves • Spinal nerves and reflex arc • The brachial and lumbosacral plexuses • Practical on peripheral nerves, brachial plexus and sympathetic trunk Weeks 4 to 8 – • Autonomic innervation of thoracic organs • Autonomic innervation of abdominal and pelvic organs • The vertebral column and gross morphology of the spinal cord • Ascending tracts in the spinal cord • Descending tracts in the spinal cord • The skull and meninges, gross anatomy and blood supply of the brain • Practical on the vertebral column and spinal cord, the skull and meninges, gross anatomy and blood supply of the brain Weeks 9 to 13 – • Special senses – sight and hearing • Cranial nerves • The brainstem • The thalamus and hypothalamus • Histology of the cerebral cortex • Functional anatomy of the cerebral cortex • The basal ganglia – dorsal striatum • Olfactory and limbic system – septum and hippocampus • The limbic system – the ventral striatum and amygdala • Practical on cross sectional brain anatomy	1. Understand the basic functional neuroanatomy of the human nervous system, including overview, neurohistology, peripheral nervous system, autonomic nervous system and central nervous system, with emphasis on the unique anatomical features and neurochemistry of different parts of the central and peripheral nervous system, and demonstrating their synaptic connectivity and interrelatedness of their functions.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 0, 0, 0, 0, 70

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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LSM3223	Immunology	Yes - BMS	LSM2233 or PHS3123	1 and 2	Microbiology and Immunology	Assoc Prof Lu Jinhua miclujh@nus.edu.sg (Sem 1); Assoc Prof Zhang Yongliang miczy@nus.edu.sg (Sem 2)	This course provides the central concepts of immunology and the foundation for understanding how immunity functions. The subjects of innate immunity and haematopoiesis introduce the origin and role of different cell types in immunity. The mechanisms of how the body protects itself from disease are explored in relation to T and B cell biology, antibodies, cytokines, major histocompatibility complex and antigen presentation. Other topics include hypersensitivity, immunodeficiencies, tolerance, autoimmunity, resistance and immunization to infectious diseases.	1. Introduction to immunology - Overview of the immune system - Cells and structures of the immune system - Innate immunity I&II 2. Humoral immunity and effector mechanisms - Immunoglobulin structure and function - Complement - Cytokines and chemokines 3. Antigen recognition and immune interactions - Generation of antigen receptor diversity - Major Histocompatibility Complex - Antigen processing and presentation 4. Cellular immunology and immune regulation - T cell development - B cell development - T Cell function - T-B cell interaction (Germinal center reaction) 5. Infection immunity - Viruses - parasites - Bacteria and fungi 6. Immunity in disease - Allergy - Autoimmunity - Immunodeficiency - Tumour immunology 7. Research applications	1. Understand basic immunology concepts and disease mechanisms., 2. Able to perform common immunology-related lab techniques and understand their underlying mechanisms.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 20, 0, 0, 0, 0, 50
LSM3225	Molecular Microbiology in Human Diseases	Yes - BMS	LSM2105 or LSM2106 or LSM2233 or LSM2291	2	Microbiology and Immunology	Assoc Prof Tan Yee Joo mictyj@nus.edu.sg	By the application of advanced technologies in molecular biology to studying microbes, we can identify and detect microbes, as well as treat and prevent diseases caused by both existing and newly emerged pathogens. In this course, students will be taught molecular principles of physiological processes involved in the life cycles of different types of microbes, and how these affect human health. Emphasis will be placed on the importance of using multiple methodologies to discover, detect and study pathogens. Specialised talks by guest lecturers will illustrate the use of molecular microbiology in laboratories handling the diagnosis and surveillance of infectious diseases.	1.Introduction to molecular microbiology and host-pathogen relationships 2.Control and treatment of microbial growth 3.Molecular Virology Part 1: Implications for vaccine and antiviral development 4.Molecular Virology Part 2: Viral evolution and antiviral resistance 5.Introduction to medical parasitology 6.Diagnostic parasitology 7.Host-Parasite Interactions 8.Anti-parasite Strategies 9.Introduction to Bacteriology-Basic principles and diagnostic methods 10.Host immune responses to bacterial infection 11.Fungi and fungal infection 12.Communicable disease outbreak investigation and public health surveillance 13.Environmental surveillance of viruses and bacteria: Impact on public health, riskassessment and responses 14.Practical session 1: One-step Real-Time PCR detection and quantification ofChikungunya virus infection 15.Practical session 2: ELISA & immunofluorescence assay for the detection of influenza Avirus infection 16.Practical session 3: Analysis ELISA results and microscopy 17.Practical session 4: PCR detection of antimalarial resistance; novel drug-screeningmethods; demonstration of medically-important parasites 18.Practical session 5: Bacterial infection and host responses	1. Understand the molecular principles of the physiological processes involved in the life cycle of different types of microbes and how these affect human health and disease., 2. Know the types of methods used to detect and study microbes and understand the importance of diagnosis and surveillance of infectious diseases.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 20, 0, 0, 0, 0, 50
LSM3226	Medical Mycology and Drug Discovery	Yes - BMS	LSM2233 or LSM2252 or LSM2291	2	Biochemistry	Assoc Prof Yeong Foong May bchyfm@nus.edu.sg	With the growing aging population and number of immunocompromised patients, fungal infections are increasingly becoming relevant. This course will re-examine Koch's postulates in relation to the roles opportunistic and primary fungal pathogens play in mycoses. Issues surrounding the molecular, physiological and biochemical aspects of fungal cells that make them successful microbial pathogens will be discussed. Key mechanisms of anti-fungal resistance in relation to challenges facing the discovery of new therapeutics will be examined. Students will have the opportunity to design and conduct a typical drugsusceptibility screen and drug discovery process.	1. Overview of the fungi kingdom 2. Primary and opportunistic fungal pathogens in relation to Koch's postulate and its limitations 3. Fungal pathogenic and virulence factors 4. Host-cell interactions, innate and acquired immunity 5. Diagnostics and their limitations 6. Current therapeutics and strategies used 7. Drug resistance and emerging issues 8. Drug discovery – current approaches 9. Drug discovery – present and future challenges 10. Public health concerns	1. Evaluate the current strategies of drug discoveries., 2. Describe the molecular interactions between fungal and host cell cells., 3. Discuss the various types of anti-fungal resistance and why they are problematic., 4. Relate the molecular, physiological and biochemical aspects of fungal biology to \npathogenesis.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (Proposal and PeerMark), Others 2 (Protocols and PeerMark), Others 3 (video), Final Exam	2, 0, 0, 23, 20, 0, 4, 6, 5, 40
LSM3227	General Virology	Yes - BMS	LSM2105 or LSM2106	1 and 2	Biological Sciences	Dr Wu Jinlu dbswjl@nus.edu.sg	This course explores virology, which is the study of viruses that infect different forms of living organisms. It introduces general concepts related to the viral structure, host spectrum and replication. We will elaborate how viruses are identified, how viruses go "viral" and how we can live with viruses. The impacts of viral diseases on human health, food security and environment will be discussed. The course also includes new developments in how viruses can be used as vectors for drug delivery, nanomaterials and bio-control agents. Students will have chances to practice virus culture, isolation and infectivity assay.	Topic 1: Introduction: Viruses and Virology (1 wk) • The nature of viruses • A brief history of virology Topic 2: Virus taxonomy: the world of viruses (1 wk) • Classification and nomenclature of viruses • Major virus groups Topic 3: Virus structure, assembly and disassembly (1 wk) Topic 4: Viruses go "viral" (2 wks) • Virus entry • Host range, host specificity and host shift • Virus replication and Viral transmission Topic 5: Living with viruses (3 wks) • Viral epidemics in Asia and Singapore • Viral diseases and food security: animal and plant virus diseases • Viruses in water environments (bacteriophages, algae viruses) Topic 6: Prions (1 wk) • The nature of Prions • Prion strains • Human and animal prion diseases Topic 7: The good that viruses do (1 wk) • Viruses as a vector for gene/drug delivery • Viruses as bio-control reagent (phage for controlling bacterial infection and baculoviruses for controlling insects and pests) Guest Lecture (1 wk) Laboratory work: virus culture, isolation and infectivity assay	1. Explain the basic concepts of virus-host interactions, differences between the lifecycles of major groups of viruses and, in particular, how the virus enter the cells and replicate themselves using host machinery., 2. Design and perform experiments for cell culture, virus infection, isolation and identification., 3. Analyse and interpret experimental data., 4. Evaluate problems in viral pathogenesis and control measures of viral diseases., 5. Apply cell biology concepts to virological questions., 6. Elaborate how viruses can be used as tools for both basic research and biotech applications.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (online/in-class engagement), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 30, 0, 0, 20, 20, 0, 0, 30
LSM3228	Microbiomes and Biofilms	Yes - BMS	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1	Microbiology and Immunology	Dr Ch'ng Jun Hong micchn@nus.edu.sg	In nature, microbes exist as multispecies communities (microbiota) interacting with each other and also the environment/host. This typically occurs in the context of biofilms where organisms are in close proximity within a protected environment of the biofilm matrix. This course primarily explores the human microbiome and its effect on development and disease and explore the role of pre- and pro-biotics in health. Mechanistic insights into microbial communities can also be gained through more controlled studies focusing on experimental biofilms. Appreciating the biology of biofilms allows us to understand the context that both human and environmental microbiota operate in.	Introduction to microbes, microbiomes and research methods (sequencing approaches, analyses tools).Microbiomes in development, health, beauty and wellness.Microbiomes in disease (cancer, metabolic diseases, aging, neurological disorders etc.).Microbiome modulation (anti-, pre-, pro-, syn- and post-biotics, phage-editing.Biofilms: stages, architecture, unique biology. Inter-species interactions, from experimental biofilms to complex systems. Microbiomes beyond healthcare: agriculture, marine ecosystems, bioremediation etc. Related talks from Industry (SME, MNCs, Clinical).	1. Understand microbiomes and its far-reaching effects on our development and health, learn about methods used in microbiome research, and critically evaluate the claims of microbiome-augmenting products.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 15, 0, 50, 35, 0, 0, 0, 0, 0

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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LSM3231	Protein Structure and Function	Yes - BMS	LSM2106	1	Biochemistry	Dr Qu Kun kqu@nus.edu.sg	This course aims to provide a strong foundation in the study of protein structure and function. The following topics that will be covered: structures and structural complexity of proteins and methods used to determine their primary, secondary and tertiary structures; biological functions of proteins in terms of their regulatory, structural, protective and transport roles; the catalytic action of enzymes, their mechanism of action and regulation; various approaches used in studying the structure-function relationships of proteins.	a. Introduction to protein structures b. Protein structures and functions c. Protein folding and misfolding d. Enzymes: catalytic action and their mechanism of action and regulation e. Primary structure determination of proteins f. Secondary and tertiary structure determination of proteins	1. Understand the complex structures of proteins and how these structures can be determined., 2. Appreciate the myriad and essential functions of proteins in an organism., 3. Understand how the structures of proteins can shed light on the biological function of proteins.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 40, 0, 0, 0, 0, 60
LSM3232	Microbiology	Yes - BMS	LSM2105 or LSM2106 or LSM2291	1 and 2	Microbiology and Immunology	Assoc Prof Chu Jang Hann miccjh@nus.edu.sg (Sem 1); Dr Chris Sham miclts@nus.edu.sg (Sem 2)	Principles of Microbiology, with emphasis on the properties, functions and classification of the major classes of microorganisms, especially bacteria, fungi and viruses. Understanding microbial activities and their influence on microbial diseases, industrial applications, ecology, food and water quality.	Lectures: 1)Scope of microbiology: the diversity of the microbial world and microbial taxonomy2)Microbial structure and function: microbial physiology, microbial nutrition andmicrobial growth3)Food microbiology4)Environmental microbiology5)Medical microbiology: Microbial diseases and their control Practical (Wet Lab): 1)Basic Microscopy & Staining2)Physiological effects on microbial growth3)Microbial physiology4)Medical microbiology5)Food microbiology6)Environmental microbiology including water microbiology	1. Gain the strong foundation and the principles of microbiology, with emphasis on the properties, functions and classification of the major classes of microorganisms, especially bacteria, parasites, fungi and viruses., 2. Apply their understanding and technical skills learned in this course for their career development in working with health and biomedical sciences industries as well as other industrial applications such as ecology, food and water quality assurance.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 25, 15, 0, 0, 0, 0, 60
LSM3233	Developmental Biology	Yes - BMS and EEB	LSM2233	1	Biological Sciences	Assoc Prof Christoph Winkler dbswcw@nus.edu.sg	This course will showcase and examine embryogenesis, starting from fertilisation to birth in the case of animal development; and to germination, growth and differentiation in plants. Students will be exposed to concepts, principles and mechanisms that underlie development in plants and animals. Different organism models will be studied to demonstrate the rapid advances in this field of life sciences.	For Plant Development, there will be 5 lectures covering the following topics: 1. Introduction: Features of plant development; the model plant Arabidopsis; Pollination and fertilization 2. Embryogenesis and seedling development: development of a plant embryo and developmental plasticity towards light 3. Shoot and root development: Stem cell maintenance and gravitropic growth 4. Leaf and stomatal development: Plant organogenesis and cell differentiation 5. Flower development: Formation of floral organ and onset of flowering For Animal Development, there will be 6 lectures tentatively covering the following topics: 1. A historical overview on animal development; and: Fertilization - starting a new organism 2. From eggs to embryos: Gastrulation and the formation of a body axis 3. Patterning of the nervous system: Formation of brain and spinal cord 4. Morphogenesis and organ formation 1: Limb formation and regeneration 5. Morphogenesis and organ formation 2: Body segmentation and muscle formation 6. Reproduction: Mechanisms of sex determination and differentiation	1. Identify unique aspects of animal and plant cells and tissues., 2. Discuss the most popular technologies in animal and plant developmental biology., 3. Explain the roles of model species in the study of animal and plant development., 4. Describe the basic structure, growth and development of animal and plant tissues., 5. Describe the mechanisms that underlie pattern formation in animal and plant developments., 6. Describe how environmental stimuli and hormones can regulate plant growth and development., 7. Select appropriate techniques to address fundamental questions in animal and plant developmental biology., 8. Describe the most prominent cell signaling pathways that control animal organ formation and tissue regeneration.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 40, 60, 0, 0, 0, 0, 0
LSM3234	Biological Imaging of Growth and Form	Yes - BMS	LSM2233	1	Biological Sciences	Assoc Prof Cynthia He dbshyc@nus.edu.sg	Growth and form are fundamental to all living organisms, crucial to health and diseases. Development in imaging methods and tools has transformed biological and biomedical sciences. This course will introduce basic concepts in imaging and their applications. The major topics include basic optics, light and electron microscopy, fluorescence and related methods. Introduction of each imaging technology will be linked with a set of biological problems of fundamental interests and biomedical implications.	1. The cell theory – History, development of light microscopy and basics of optics. (Introduction of light polarization, phase contrast, DIC). Practical: What is in a microscope, how to use and how to maintain? 2. The forms of cells. (Introduction to non-fluorescent cell staining methods) Practical: visualization of various cell types 3. On the internal structure of the cell- membrane structures (Introduction of electron microscopy) 4. On the internal structure of the cell, cont'd. Focus on cytoskeleton. (Introduction of fluorescence microscopy, immunofluorescence, basics of live imaging, GFP, confocal, etc.) 5. Field trip to Orchid Garden-- plant forms, plasticity and diversity (Introduction to image acquisition, processing and presentation) 6. Field trip presentation 7. How does cell get its shape or change its shape? (Introduction to electron tomography) 8. How membrane gets its shape? (introduction to TIRF) 9. Gradient in a cell (Introduction to FRET sensors) 10. Practical: confocal microscopy and live cell imaging. 11. Understanding how molecular dynamics and interactions could be harnessed for cellular behavior (student presentation on length/size sensing paper) 12. Forms of tissue. On symmetry and break of symmetry. (Introduction to SEM) 13. Form of tissue, cont'd. On patterns. Special lecture on butterfly eyespot; plant root development; fly embryo development. (Introduction to modeling) A visit to insectarium or plant nursery.	1. Learn the basic principles of light microscopy and electron microscopy, and how these technologies are used in life sciences research and developments.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (in-class presentation), Others 2 (reports), Others 3 (if applicable & describe in notes), Final Exam	10, 0, 0, 0, 0, 0, 30, 60, 0, 0
LSM3235	Biomedical Applications of Human Epigenetics	Yes - BMS	LSM2105	1	Physiology	Dr Tee Wee Wei phstee@nus.edu.sg	This course introduces the concept of epigenetics, the relationship between the genome and the epigenome, and the translational applications of epigenetics in relation to human health and diseases. It focuses on helping students understand the relevance of epigenetic processes in human physiology (e.g., embryonic development, ageing) and how their mis-regulation underlies diseases such as cancer. It also highlights how the study of epigenetic mechanisms is important for modern biomedical research such as regenerative medicine therapies (e.g., induced pluripotency and trans-differentiation). Students will be exposed to various state-of-the-art next-generation (epi)genomic sequencing technologies widely used in biomedical research.	Molecular basis of Epigenetics 1. Introduction to Epigenetics (2hrs) 2. DNA Methylation (2hrs) 3. Writers, readers and erasers of epigenetic code (2hrs) 4. Molecular machines involved in maintaining epigenetic code (2hrs) 5. Mitochondrial Epigenetics (2hrs) Translational Epigenetics 6. Epigenetics in development (2hrs) 7. Epigenetics in Heart and Related Diseases (2hrs) 8. Epigenetics in metabolic diseases (2hrs) 9. Epigenetics in Brain and Related Diseases (2hrs) 10.Epigenetics in ageing (2hrs) 11.Environmental influences on Epigenome (2hrs) 12.Mitochondrial Epigenetics in disease (2hrs)	1. Understand the concept of epigenetics, the relationship between the genome and the epigenome, and the translational aspects of epigenetics in relation to human health and diseases.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 30, 0, 30, 0, 0, 0, 0, 0, 30
LSM3236	Pattern Formation and Self-organisation in Biology	Yes - BMS	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1	Biological Sciences	Dr Yuchen Long yuchen.long@nus.edu.sg	From zebra stripes and rose petal spirals to swarming bird flocks, the biological world is full of mesmerizing patterns. How do these patterns form, and what is the underlying mechanism that explains these seemingly unrelated phenomena? This course takes an interdisciplinary approach to introduce how complex biological phenomena can emerge from simple rules. Through interactive lectures, guided reading and hands-on tutorials and simulations, students will learn to appreciate how basic concepts like feedback and robustness generate biodiversity across multiples scales.	This course will cover topics under four main sections across 12 weeks: 1. What is a pattern? - Historical introduction (D'Arcy Thompson, Darwin, Turing). - Time and dynamic patterns in biology. - What is a feedback? 2. Reaction-diffusion model - Turing model, attractor and parameter space. - Perturbation and robustness. - Noise and variability. - Emergency property (e.g., synchronisation) 3. Multiscale dynamics - Cell polarity - Morphogen gradient. - Geometry, topology and mechanics 4. New frontier series Lectures on integrated self-organization in different biological systems: - animal - plant - ecology - synthetic biology	1. Achieve basic understanding of how mathematical models can be applied to understand pattern formation in diverse biological phenomena., 2. Able to apply feedback models to explain cellular and tissue self-organisation., 3. Apply quantitative thinking to interpret and predict (using paper-and-pen calculations) biological patterns., 4. Synthesize and integrate concepts from different systems/fields/disciplines and to encourage interdisciplinary thinking.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (assignments), Others 3 (if applicable & describe in notes), Final Exam	10, 20, 0, 0, 0, 30, 20, 20, 0, 0

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LSM3242	Translational Microbiology	Yes - BMS	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	2	Microbiology and Immunology	Dr Volker Patzel micvp@nus.edu.sg	This course covers the underlying principles and wide-ranging industrial, environmental, pharmaceutical, and biomedical applications of microbiology. The objectives are (a) to gain an understanding of the role of microorganisms for biotechnology applications in the fields of medicine, agriculture, organic chemistry, synthetic biology, public health, biomass conversion, bioremediation, and biomining; and (b) to review advances in genetics and molecular biology of industrial microorganisms, enzyme engineering, environmental microbiology, food microbiology, and molecular biotechnology. A particular focus will be on the meaning and impact of microbiology on human health and the development of new therapeutic approaches.	Introduction • History - Microbes and cell cultivation – Prokaryotic and eukaryotic cells • course overview - Co-evolution of life and minerals & Exhibition of mineral/gem specimen Public health - Nutrition • An 'omics' toolbox to delve into the human microbiome • Intestinal microbiology in early life and its translation into nutritional concept: prebiotics, probiotics, and synbiotics • From industrial microbiology to a functional dairy food with health benefits • Visit of Danone Nutricia Research, Singapore R&D centre Synthetic biology (Genetically engineered microorganisms) • Basics of synthetic biology – Bacterial regulation & Key concepts • Application & engineering of proteins • Modern genetic technologies & Synthetic organisms Biotechnology • Antibiotics & enzymes • Bio-mining/-leaching - Exhibition of metal ore specimen and gem stones • Microbes in bioremediation • Microbial functions in genetic therapy - Genome editing Diagnostics & therapeutics development • Microorganisms as gene shuttles & for therapy of human diseases	1. Explain some of the most important applications of microorganisms in the fields of medicine, agriculture, organic chemistry, synthetic biology, public health, biomass conversion, bioremediation, and biomining.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 20, 20, 0, 0, 0, 0, 60
LSM3243	Molecular Biophysics	Yes - BMS	LSM2106	2	Biological Sciences	Prof Yang Daiwen dbsydw@nus.edu.sg	This course provides a physical background of macromolecular conformations and a description of biophysical techniques for studies of structure, dynamics and interactions of biomolecules. Topics will include conformation of biological macromolecules, protein folding, protein-ligand interaction, biological membrane, and biophysical techniques.	1. Protein conformational analysis: dihedral angle, primary, secondary, tertiary and quaternary structures 2. Force determining protein structure: ion-ion, ion-dipole, dipole-dipole, VDW, hydrophobic, and H-bonding interactions 3. DNA/RNA conformational analysis and force that determine DNA/RNA structures 4. Membrane structure: lipid composition, lipid assembly, and lipid dynamics 5. Membrane equilibrium: chemical potential, membrane potential, osmotic pressure, Donna effect 6. Transport of small molecules across cell membrane: passive transport, active transport 7. Biophysical techniques, Circular Dichroism (CD): principle, application to life sciences 8. Biophysical techniques, Fluorescence: principle, application to life sciences 9. Biophysical techniques, Nuclear Magnetic Resonance (NMR): principle, application to life sciences 10. Conformational transition in protein and DNA 11. Protein folding 12. Protein interaction: protein-protein, protein-DNA/RNA, protein-small molecule	1. Understand different protein folding models., 2. Understand how small molecules are transported across membranes., 3. Understand the structures of micelles, bilayers, and cell membranes., 4. Be knowledgeable to the application of these techniques to life sciences., 5. Understand the factors/interactions that determine protein conformations., 6. Know the composition of cell membrane and understand unique features of membrane proteins., 7. Describe protein backbone and side-chain conformations in terms of dihedral angles and interactions., 8. Know how to determine parameters (both equilibrium and kinetics) used to monitor protein folding and interaction., 9. Know common nucleic acid conformations and to understand the interactions that stabilize such ordered conformations., 10. Understand basic concepts of spectroscopic techniques: circular dichroism (CD), fluorescence, and nuclear magnetic resonance (NMR).	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (in-class activity and assignments), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 0, 0, 5, 0, 0, 65
LSM3244	Molecular Biotechnology	Yes - BMS	LSM2105	2	Biological Sciences	Dr Robert Lieu Zi Zhao dbslzz@nus.edu.sg	Traditional genetic engineering has been relatively successful for modern applied biotechnology, however its limitations in direct manipulation of genome is apparent. For this, genome engineering has emerged as the next wave in biotechnology. Genome engineering is a direct and precise approach to whole-genome design and mutagenesis to enable a rapid and controlled exploration of an organism's phenotypic landscape for biotechnology. Key advances included de novo genome synthesis, and genome-editing technology. This course will focus on how genome engineering is used together with existing or new applications of biotechnology to tackle global problems ranging from human and animal health to agriculture.	1. Introduction and a historical perspective of Biotechnology enterprise. 2. Current topics in Biotechnology - RNA based Biotechnology - CRISPR based application - Cell culture based technology - Production of biologics, therapeutic antibodies, vaccines 4. Cell based therapeutic such as T-cell therapy 5. Diagnostic in biotechnology 6. Industrial Biotechnology 3. Analysing and finding emerging technology via SWOT 4. Identification of potential intellectual properties from basic science 5. Intellectual properties and patent analysis 6. Business database for market trends	1. Describe and apply the principles of generating transgenic plants, animals and microbes., 2. Communicate biotechnology findings effectively in the form of oral and written scientific reports., 3. Understand and be aware of the potential benefit, pitfalls, limitations in genome engineering techniques., 4. Understand and applied different gene editing tools (RNAi, CRISPR, etc.) in generation of transgenic organisms., 5. Provide students with insights on the Basics, Methodology and Applications of biotechnology in science, agriculture and industry etc., 6. Demonstrate an understanding of the basic concepts of biotechnology business, intellectual property rights, and the regulatory framework governing the biotechnology industry., 7. Evaluating examples of current applications of biotechnology and advances in the different areas like medical, microbial, environmental, bioremediation, agricultural, plant, animal, and forensic science.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (proposal presentation), Others 2 (patent reading worksheet), Others 3 (if applicable & describe in notes), Final Exam	20, 20, 30, 0, 0, 0, 20, 10, 0, 0
LSM3245	RNA Biology and Technology	Yes - BMS	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1	Microbiology and Immunology	Dr Volker Patzel micvp@nus.edu.sg	This course examines the roles of RNA, coding and in particular non-coding (ncRNA), in regulation of gene expression, host–pathogen interaction, and catalysis as well as their applications in research, diagnosis, and therapy of human diseases. The topics cover the 'RNA world hypothesis', the relation between structure and function of RNA, the mechanisms of regulation and dysregulation of gene expression by ncRNAs, selection and design of functional RNAs, features and usage of ncRNAs, the role of RNA in early-stage pharmaceutical developments, and RNA-based drug development.	1. Introduction & Coding RNA • The RNA world hypothesis - Molecular unit of genotype and phenotype, history of RNA, RNA worlds • The role of RNA in gene expression • Structure and function of RNA – secondary and tertiary structures of RNA 2. Naturally occurring non-coding RNA • Antisense RNA and ribozymes • Circular RNA – generation, detection, meaning • Bacterial Cas/CRISPR systems • Bacterial riboswitches and RNA thermometer • RNA interference: miRNA, siRNA, and piRNA – biogenesis and regulation of gene expression • Non-coding RNA and human diseases – ceRNA networks and long non-coding RNA 3. Artificial non-coding RNA • Selection and evolution of RNA: in silico, SELEX in vitro, on living cells and in vivo, modified SELEX, Monolex approach • Aptamers and 'Spiegelmers' • In vitro & in silico selection of antisense RNA • siRNA and shRNA design, activity and specificity of siRNA, esiRNAs • mRNA design for enhanced gene expression • mRNA and miRNA as targets • RNA-guided genome editing (CRISPR/Cas9) and applications • RNA splicing (cis/trans)-based therapeutic approaches 4. RNA in early-stage pharmaceutical development • RNAi-based screens for target discovery & validation • RNA-based diagnostics • High-throughput technologies: Sequencing & microarrays of RNA 5. RNA as a drug – clinical applications • Delivery and chemical modifications of RNA – viral, non-viral and bacterial vectors • Clinical Trials, FDA approval, and RNA-based drugs	1. Acquire fundamental and specific knowledge on the role of RNA in evolution of life, the mechanisms of ncRNA in regulation and dysregulation of gene expression in multicellular organisms, applications of RNA in drug discovery and development, and RNA-based diagnostics and therapeutics; able to understand, critically evaluate, and review the literature in this area.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 20, 20, 0, 0, 0, 0, 0, 60

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

For course scheduling information, please refer to NUSMODS. https://nusmods.com/timetable/
For course syllabus, please refer to website LSM Courses. https://www.dbs.nus.edu.sg/lifesciences/lsm_courses/
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Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM3246	Synthetic Biology	Yes - BMS	LSM2105 or LSM2106	1	Biochemistry	Dr Volker Patzel micvp@nus.edu.sg	The ability to rationally engineer living cells has been a long-anticipated goal dating back for more than half a century. With the advent of DNA synthesis and genome engineering tools, biological systems can now be systematically designed for a myriad of industrial applications including disease prevention, biochemicals production and drug development. This course aims to provide basic principles to the engineering of biology with emphasis on the design and construction of synthetic gene circuits in living cells. The course also discusses current and emerging applications driven by synthetic biology, and the socio-ethical responsibilities that are required of synthetic biologists.	• Introduction to Synthetic Biology • Principles of Synthetic Biology • Synthetic Genomics • Genetic Circuits • Synthetic Enzymology • Systems Biology for Synthetic Biology • Computational Modelling for Synthetic Biology • Automation for Synthetic Biology • Bioprocess Engineering for Synthetic Biology • Synthetic Cell Factories • Synthetic Biology for Therapeutics • Industrialization of Synthetic Biology	1. Describe the principles of synthetic biology., 2. Design synthetic genetic circuits., 3. Design research projects on the topic of synthetic biology., 4. Review the applications and significance of synthetic biology., 5. Provide perspectives of synthetic biology.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 0, 0, 30, 0, 0, 40
LSM3247	Practical Synthetic Biology	Yes - BMS	LSM2105 or LSM2106	2	Biochemistry	Assoc Prof Matthew Chang bchcmw@nus.edu.sg	Synthetic biology is the science of engineering biology, and is very much an experimental science. Building on the basic principles of synthetic biology introduced in the theoretical course LSM3246, this course aims to emphasize on the experimental techniques required for the design and construction of synthetic metabolic pathways and genetic circuits in living cells. The course also introduces advanced experimental protocols including CRISPR-Cas genome editing tools that are revolutionising fields in life and biomedical sciences.	Lectures 1. Introduction to Practical Synthetic Biology 2. Analytics in Synthetic Biology 3. DNA Sequencing and Writing 4. DNA Assembly 5. Cell Factories and Synthetic Biology 6. Genome Engineering Tools in Synthetic Biology 7. Biosensor and Synthetic Biology 8. Clinical Therapeutics and Synthetic Biology 9. Biosafety and Biosecurity in Synthetic Biology Laboratory experiments 1. Genetic parts characterization 2. DNA assembly 3. Biochemical production with an engineered microbe 4. Genome editing 5. Chemical biosensing	1. Comprehend how experiments in synthetic biology are designed., 2. Have hands-on experience in genetic parts assembly and engineering microbes., 3. Understand how to characterize genetic parts and engineered microbes., 4. Learn how to analyze the data acquired to understand the behavior of the engineered biological systems.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 60, 40, 0, 0, 0, 0, 0
LSM3252	Evolution and Comparative Genomics	Yes - EEB	LSM2107 or LSM2252	2	Biological Sciences	Assoc Prof Huang Danwei huangdanwei@nus.edu.sg	The objectives are to build on the students' foundation in evolutionary concepts and to advance their knowledge and skills related to comparative biology. The lectures present the theory of evolution as the unifying discipline in biology, and enhance the integrated understanding of four main themes: natural selection, palaeobiology, the tree of life and comparative genomics. Overall the course emphasises the importance and application of evolutionary biology for explaining a wide variety of phenomena in biology, from the history of life to genes, genomes and cellular processes.	Natural selection: Recap natural selection, population genetics, selection and drift, neutral theory, evolution at multiple loci, species and speciation. Palaeobiology: History of life, geologic time scale, fossil record, extinction, palaeoecology, biogeography, biostratigraphy, fossil taxa. Tree of life: Understanding relationships, inferring and reading trees, fossil calibration, diversification rates, evolutionary trends, trait evolution. Comparative genomics: Evolution of genome size, structure and organisation, complex traits, horizontal gene transfer, gene regulatory networks, metagenomics.	1. Explain how evolution is the unifying discipline in biology., 2. Apply evolutionary principles on diverse phenomena from the history of life to genomes and cellular processes., 3. Demonstrate integrated understanding of four main themes: natural selection, palaeobiology, the tree of life and comparative genomics.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	
LSM3254	Ecology of Aquatic Environments	Yes - EEB	LSM2251	1	Biological Sciences	Assoc Prof Darren Yeo Chong Jinn darrenyeo@nus.edu.sg	Aquatic environments make up more than 70% of the Earth's surface. They host a huge diversity of life and ecosystems, many of which are vital to man. Topics covered in this course include diversity and ecology of freshwater and marine habitats and organisms, the impacts of humans on these environments, and the conservation and management of these critical resources. Overall learning outcomes include an appreciation and understanding of aquatic habitats, their physical and biological properties and their associated ecosystems. The importance of both marine and freshwater environments to Singapore will be highlighted.	1. Freshwater and Marine environments: Introduction: Course overview; linking freshwater and marine biology 2. Freshwater environments: Topics covered will include: - Ecological characteristics of fresh water - A brief survey of freshwater environments including natural lotic (e.g., streams) and lentic (e.g., lakes) environments, and artificial or modified environments (e.g., urban habitats such as canals and reservoirs) and their respective biodiversity - Population and community ecology in freshwater environments - Ecology of freshwater ecosystems 3. Marine environments: Topics covered will include: - Estuaries and the interface between freshwater and marine systems. - Introduction to oceanography and the marine environment - Plankton and primary productivity - Intertidal (rocky shore and soft sediments) - Coral reefs, sea grasses and mangroves 4. Freshwater and Marine environments: Conservation and management of aquatic environments; course review	1. Appreciate and understand aquatic habitats, their physical and biological properties and their associated ecosystems.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (forum questions), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 35, 25, 35, 0, 5, 0, 0, 0
LSM3255	Ecology of Terrestrial Environments	Yes - EEB	LSM2251	2	Biological Sciences	Dr Chua Siew Chin siewchin@nus.edu.sg	This course will introduce students to principles of terrestrial ecology. Major topics will include diversity and distributions of terrestrial environments, soils and nutrient cycling, animal-plant interactions [pollination, seed dispersal, herbivory], disturbance ecology and succession, energy flow and food webs, population biology, and fragmentation. The course will have a strong quantitative focus. The course will also cover ecological processes in rural (agricultural) and urban terrestrial environments.	1 Biogeography of terrestrial vegetation 2 Species diversity: patterns and mechanisms 3 Food chains 4 Carbon and nutrient cycles 5 Phenology 6 Reproductive biology: pollination and seed dispersal 7 Population ecology 8 Disturbance and succession 9 Forest fragment ecology 10 Protected areas and community-based conservation 11 Mangrove ecology 12 Climate change and terrestrial tropical ecology 13 Invasive species	1. Articulate the fundamental concepts and principles of terrestrial ecology., 2. Make inquiry into ecological observations, processes and methods., 3. Relate eco-physiological responses of tropical forests to anthropogenic impacts., 4. Compare methods of upscaling ecosystem processes for landscape scale estimations., 5. Apply ecological principles to evaluate functionality of urban-terrestrial ecosystems.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (practical reports), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	5, 0, 15, 12, 0, 0, 28, 0, 0, 40
LSM3256	Tropical Horticulture	Yes - EEB	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	2	Biological Sciences	Dr Amy Choong dbscmfa@nus.edu.sg	This course introduces students to the fundamentals of tropical horticulture, with emphasis on the situation in Singapore, a tropical garden city. Topics include plant growth and development and factors affecting them, pests and diseases and their control, growing media, plant nutrition, tropical urban horticulture of ornamentals, vegetable and fruit crops, and native plants, vertical and roof greening, turf grass management, landscape design, organic methods and impact of horticulture on conservation. Field trips, demonstrations, and projects will enable students to enjoy hands-on experience in cultivating plants.	1. Course overview; underlying science (definitions of horticulture, tropics, plants; conditions for plant growth; plant physiology); importance of horticulture; horticulture industry in Singapore and overseas; horticultural societies, institutions, companies 2. Protecting horticultural plants against pests (acarid, insect, mollusc, nematode, small mammal), diseases (bacterial, fungal, viral), disorders (nutritional, pollution), weeds (cyanobacterium, alga, plant) 3. Propagation of horticultural plants (sexual [cross- and self-fertilization] and asexual reproduction [suckers, stolons, apomixis, etc.]; traditional methods [stem and root cuttings, grafting, layering, air-layering, etc.] and biotechnology [tissue culture, genetic engineering]) 4. Indoor plants (indoor environmental conditions, pests, diseases; use of indoor plants; indoor plant requirements, care; common indoor plant species, hybrids or cultivated varieties) 5. Outdoor plants (outdoor environmental conditions; specific information for each of these plant types: uses and economic value; pests and diseases; requirements, care; common species, hybrids, cultivated varieties) a. Cut flowers b. Ornamentals (exotic and native species) c. Vegetables and fruits (exotic and native species; organic and traditional methods) d. Turf 6. Special techniques (specific information for each of these techniques: conditions for application, uses, kinds, plants utilizable) a. Non-soil growing media or methods (hydroponics, aeroponics, biochar, etc.) b. Urban farming c. Vertical and roof greening d. Bonsai, terrariums, floral arrangements, aquatic plants 7. Landscape design (general principles: goals, budget, maintenance, site details, design styles, visual and architectural elements, examples) 8. Horticulture, conservation and environmental services in urban areas (conservation, environmental services, value of native biodiversity, role of horticulture in conservation of native biodiversity and provision of environmental services [current situation in Singapore and overseas, potential roles]	1. Define what is tropical horticulture in the context of Singapore., 2. Recognize that plants are very versatile, resilient and adaptable., 3. Demonstrate that plants are able to modify the habitat and make it suitable for other life forms and vice versa., 4. Apply the concepts learnt to grow plants, manipulate plants, propagate plants and assist in wildlife conservation under the horticulture context., 5. Able to take care of or manipulate plants better for home gardens or for an agricultural firm.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (Self-introduction), Others 2 (Reflections), Others 3 (if applicable & describe in notes), Final Exam	0, 20, 22, 0, 0, 0, 2, 20, 0, 36

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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LSM3257	Applied Data Analysis in Ecology and Evolution	Yes - EEB	LSM2107 or LSM2251 or LSM2252	2	Biological Sciences	Dr Ian Chan ianchan@nus.edu.sg	Managing, analyzing, interpreting and displaying data to support-decision making has become a fundamental skill for environmental biology. This course will train students with the skills and knowledge to design and perform data analysis on typical problems in the areas of ecology, conservation and environmental sustainability. Students will learn the R language with an emphasis on spatial data, on the-ground ecological data collection and geographic information systems. Students will use the collected spatial data to support environmental impact assessment and sustainability reporting.	Introduction to R. Experimental design in ecology and evolution. Linear and multiple regression. ANOVA, ANCOVA. Data visualization with R. Generalized linear models. Spatial data management and analysis (GIS). Generalized least squares. Linear mixed-effects models (LMEs) Generalized linear mixed-effects models (GLMMs). Multivariate statistics.	1. Train students with the skills and knowledge to design and perform data analysis on typical problems in the areas of ecology, conservation and environmental sustainability., 2. Use the collected spatial data to support environmental impact assessment and sustainability reporting., 3. Learn the R language with an emphasis on spatial data, onthe-ground ecological data collection and geographic information systems.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 40, 40, 0, 0, 20, 0, 0, 0
LSM3258	Comparative Botany	Yes - EEB	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1	Biological Sciences	Dr Amy Choong dbscmfa@nus.edu.sg	This course explores the basic relationships between the diverse forms and functions in plants. Each plant group shares a common basic structural plan but contains many members that deviate from the basic plan in response to selection pressures from the environment. Knowledge of organismal biology is enhanced through selected topics in morpho-anatomical designs and functional adaptions.	1. A meaningful learning experience - the NUS Honour Code; course overview; land plant phylogeny; diagnostic characteristics of land plants, bryophytes, ferns, fern allies, gymnosperms and angiosperms; morphology, form, function. 2. The plant body; shoot and root systems; tissue systems; tissues; cells 3. Meristems; primary and secondary growth; plant development. 4. Leaf structure and function; modifications 5. Stem structure and function; modifications 6. Root structure and function; modifications 7. Flower structure and function; modifications 8. Inflorescence structure and function; modifications 9. Fruit structure and function; modifications 10. Seed structure and function; modifications 11. Plant hormones and development 12. Light signals and plant development; plant responses to herbivores and pathogens 13. Review	1. Have the foundation to identify plants., 2. Have the ability to interpret plant forms or unusual traits of plants., 3. Describe the origins of different plant products, which part of the plant, functions and medicinal properties., 4. Describe how plant forms affect photosynthesis and how plant physiologies help plants with pollination, plant-animal interactions.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (self-introduction), Others 2 (practical submissions), Others 3 (if applicable & describe in notes), Final Exam	0, 20, 17, 0, 14, 0, 2, 12, 0, 35
LSM3259	Fungal Biology	Yes - EEB	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	2	Biological Sciences	Dr Amy Choong dbscmfa@nus.edu.sg	This course provides an overview of the diversity of fungi which include the mushrooms, yeasts, molds, rusts, and toadstools. Fungal symbionts such as lichens and mycorrhizae are also covered. Fungi are one of the four main eukaryotes on Earth (the other three being animals, plants and protists). Without fungi, decomposition and nutrient recycling will be severely impacted. Almost all land plants form symbiotic relationships with fungi which help the living plants absorb scant minerals such as phosphates and nitrates and to protect the hosts from diseases. Fungi are exploited for food, medicine, bioremediation and biotechnology.	1. Fungal diversity: recognize the diverse forms and ubiquity and what were considered fungi in the past but no longer. 2. Selected fungal orders: learn to differentiate and identify some fungi. 3. Fungal hyphae and mycelia: explain how fungi grow and how they can grow through asphalt and digest wood. 4. Asexual and sexual reproduction: why they reproduce so fast and the same fungus undergoing asexual reproduction may look so different from a sexually reproducing one. 5. Dispersal of spores: how fungi release spores and disperse them far and wide. 6. Nutrition and physiology: how they can break down persistent organic pollutants, why some are ephemeral, lasting a few hours while others last for weeks and years. Why some are bioluminescent? 7. Symbiotic relationships with other organisms: lichens, truffles (with angiosperms), help plants grow better and defend against pathogens 8. Fungal-human interactions: both positive (cheese, yeast, tempeh, cyclosporin) or negative (allergens, toxins and diseases). 9. Fungal pathogens of plants and crops: Dutch elm disease, banana fusarium wilt, rice and wheat blast diseases. 10. Fungal-animal interactions: how fungi sicken bats, amphibians, fish, insects; serve as food and breeding ground for animals; help termites and ruminants digest cellulose. 11. Ecosystem functions: supporting, provisioning, regulating and cultural services. These include changing rainfall patterns, food provisioning, carbon cycling, maintain biodiversity by relaxing competitions. 12. Biotechnology: using fungi to produce sake, rice wine, soy sauce, ripped jeans, biopulping, cosmetics, mycoremediation, antiviral and antibiotics. 13. Conservation: how fungal species may be lost and how that will impact other flora and fauna, learn about the principles of and challenges to the conservation of fungi.	1. Recognize that fungi are very diverse and ubiquitous., 2. Explain the physiology of fungi and why they are able to carry out diverse roles such as decomposition of wood, breakdown persistent organic pollutants, sequester carbon in the soil and in their fungal bodies., 3. Explain how they form associations with plants, cause diseases in organisms, provide ecosystem services., 4. Appreciate the various applications using fungi, examples include packaging materials, beauty moisturizing products, Oud perfume, pest-control agents, breakdown oil spills, etc.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (self-introduction), Others 2 (class attendance), Others 3 (assignments), Final Exam	0, 10, 0, 20, 10, 0, 2, 6, 12, 40
LSM3260	Plant-Microbe Interactions	Yes - EEB	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	2	Biological Sciences	Dr Ying Chang ying.chang@yale-nus.edu.sg	Plants and microbes interact with each other on different levels and in various ways. Plant-microbe interactions have played a vital role in shaping the ecosystems since the emergence of plants on the planet. This course covers different types of plant-microbe interactions at general and detailed levels. Students will learn about the microbial infection mechanisms, establishment of symbiotic relationships, and plant immunity system responses to different microbes. There will be discussions on the broad impact of plant-microbe interactions from evolutionary, ecological and economical perspectives.	1. Introduction to the diversity of microbes interacting with plants. Virus, archaea, bacteria; True fungi; Fungus-like organisms 2. General biology of plants. Basic anatomy and cell structures; Plant immunity 3. Types of plant-microbe interactions. Mutualistic; Commensal; Parasitic; Long-term and stable interactions versus short-term and dynamic interactions 4. Mutualistic interactions – mechanisms & examples. Virus - Cyanobacteria; Bacteria - Rhizobium and relatives; Fungi - Mycorrhizal fungi 5. Parasitic interactions – mechanisms & examples. Bacterial pathogens; Fungal pathogens; Oomycete pathogens; Plants parasitic on microbes 6. Plant microbiomes. Endophytes and ectophytes; Phylosphere; Rhizosphere 7. Plant-microbe interactions in the changing globe. Urbanisation; Range shifts; Changing climate	1. Appreciate the ubiquitous presence of plant-microbe interactions., 2. Distinguish different types of interactions between plants and various microbe groups., 3. Comprehensively discuss the mechanisms for plant-microbe interactions., 4. Appraise the evolutionary/ecological/economical importance of plant-microbe interactions	Class participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Test, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	30, 40, 0, 30, 0, 0, 0, 0, 0
LSM3265	Entomology	Yes - EEB	LSM2251	1	Biological Sciences	Assoc Prof John Ascher dbsajs@nus.edu.sg	Insects and other related terrestrial arthropod groups are the most diverse forms of life on earth. Insects are ideal models for studies in evolution, ecology, behaviour and the environment as the same body plan has been adapted to diverse functions, in almost all terrestrial environments, and in most human endeavour. This course will equip students with knowledge in insect dentification, phylogeny, ecology, beneficial and pestiferous interactions with humans, and methods for their control.	⍰ Introduction of insects and related terrestrial invertebrates ⍰ Body plan and anatomy, with life histories ⍰ Macroevolution over geological time ⍰ Use of dichotomous keys for identification ⍰ Collecting insects in air, from plants, from litter, in soil and in water ⍰ Quantifying sampling for diversity and biomass ⍰ Differences between natural and human modified environments ⍰ Preparing insect samples for identification, curation or for molecular analysis ⍰ Ecological functions, with emphasis on co-evolutionary history with plants and animals ⍰ Pestiferous insects: why they are pests, impacts ⍰ Control strategies, including physical, chemical and biological ⍰ Development & use of insecticides, with microevolutionary impacts ⍰ Beneficial insects & use in IPM strategies ⍰ Forensic entomology	1. Equip students with knowledge of insect identification and morphology in relation to their phylogeny and ecology.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 50, 10, 0, 0, 0, 0, 0, 40
LSM3266	Avian Biology and Evolution	Yes - EEB	LSM2252	1	Biological Sciences	Assoc Prof Frank Rheindt dbsrfe@nus.edu.sg	Birds are widely studied and constitute a model for many scientific disciplines from genetics to ecology. This course explores bird biology from an evolutionary perspective. Topics include: (1) birds' dinosaur origins; (2) present-day diversity with emphasis on Asian bird families; (3) evolutionary processes that may have led to avian flight, small genome size and other avian traits; and (4) challenges birds face in Earth's modern extinction crisis. This course is suitable for students passionate about biological processes ranging from organismic evolution at the molecular level to broad ecological and biogeographic contexts.	Five major themes: (1) Birds' origins with theropod dinosaurs and palaeontology: early birds ('terror birds'), Archaeopteryx, evolution of flight, evolution of feathers. (2) Present-day bird diversity: early radiation around K-T boundary, ecological release after dinosaurian extinction, phylogenetics, summary of most important bird families (ratites, Galloanseres and Neoaves). (3) Bird diversification: allopatric speciation, Sundaland and Wallacea, adaptation to various ecological niches, biogeography, distribution. (4) Bird morphology: hollow bone structure, syrinx, small genome size, karyotypic conservatism, micro- and macrochromosomes, physiology, behaviour, seasonal migration, sexual selection, polyandry, lekking, song behaviour. (5) Bird ecology: frugivory, insectivory, seed dispersal, threatened species, conservation, CITES, Red List, local and global extinction, habitat degradation and destruction.	1. Outline the major stages in the evolution of the present diversity of birds found on Earth., 2. Explain the ecological significance of birds and the major niches they occupy in our planet's eco-systems., 3. Elaborate on the many different ways in which birds have differentiated into the many forms and shapes we encounter today., 4. Discuss the most important factors that have led to the present extinction crisis of this vertebrate class and many other animals., 5. Identify the current frontiers in ornithological research and the ways modern ornithologists address research questions of contemporaneous interest.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (practicals), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 20, 0, 0, 80, 0, 0, 0

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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LSM3267	Behavioural Biology	Yes - EEB	LSM2251	2	Biological Sciences	Dr Lim Lek Min, Matthew matlim@nus.edu.sg	This course provides an in-depth coverage of the relationships that organisms have with each other and with the environment. Key concepts in organismal interactions, illustrated with examples from general diverse animals and ecological systems, to ultimate and proximate explanations of animal interactions and other life history characteristics, will be covered. Students will be given the opportunity to assimilate and critically evaluate contemporary literature on relevant current issues. Experimental studies will be designed, proposed and carried out by students to improve the understanding of animal behaviour and to appreciate the significance of behaviour in ecology as well as other related disciplines.	1. Questions about behaviour 2. Formulating and testing hypotheses about behaviour 3. Sensory mechanisms, perception and behaviour 4. Learning 5. Foraging 6. Territoriality 7. Anti-predator behaviour 8. Animal communication 9. Sexual selection 10. Social behaviour 11. Animal personality 12. Human behaviour	1. Understand how selection shapes behaviour., 2. Understand the basic principles of animal behaviour., 3. Provide basic tools for testing hypotheses about animal behaviour., 4. Provide opportunities to develop critical skills in animal behaviour., 5. Appreciate the significance of behaviour in ecology, conservation, environmental sciences, as well as other related disciplines.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (article review), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 40, 0, 0, 0, 20, 0, 0, 40
LSM3272	Global Change Biology	Yes - EEB	LSM2251 or LSM2251 (Precludes BES students and pass in ENV1101)	2	Biological Sciences	Dr Lim Lek Min, Matthew matlim@nus.edu.sg	The objective of this course is to promote an understanding of Global Change Biology from a multidisciplinary approach. Students will discuss and explore selected themes of prevailing environmental, biological, socio-economical and technological issues and solutions through lectures based on literature reviews and documentaries of relevant themes, field trips and group projects.	1. Conservation (a) Defining Habitat Loss & Degradation, and impacts on biodiversity & humans (b) Impacts on (selected) Ecosystem Functions & Services (eg sexual selection, carbon sequestration) (c) Human-wildlife conflicts & zoonotic diseases (eg bushmeat) 2. Climate Change (a) Drivers & Mechanisms: what drives human-induced climate change (b) Effects on Abiotic and Biotic environments: how does it change the physical & biological environment? How are organisms reacting (ie. behavioural changes) to these changes? (c) Mitigations & Solutions: What are the viable solutions (greening the Earth? Protecting our blue carbon storage such as mangroves?), and what are the mitigations (renewable energy, vegan diet) 3. Pollution (sound) (a) How quiet/noisy are our oceans today? (b) Is our shipping industry sustainable from an acoustic perspective? (c) Is shipping noise detrimental to marine biodiversity and the ecosystem functions and services provided by these organisms? (d) How can we mitigate ocean noise pollution?	1. Identify and discuss drivers and mechanisms of climate change (e.g., deforestation, GHGs emissions)., 2. Understand how climate change changes the physical (e.g., temperature, sea levels, habitats) and biological environments (e.g., animals, plants, soil microbes), and the ecosystem functions & services provided by the organisms., 3. Define habitat loss and degradation, and its consequences (loss of biodiversity & ecosystem functions/services)., 4. Discuss and evaluate how humans can mitigate and provide solutions to environmental changes brought about by climate change.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (reports), Others 2 (opinions), Others 3 (peer review participation), Final Exam	0, 0, 30, 0, 0, 0, 35, 30, 5, 0
LSM4210	Topics in Biomedical Science: Brain, Metabolism, Ageing	Yes - BMS	LSM2233 or LSM3210 or LSM3220	2	Biological Sciences	Dr Phua Siew Cheng sc.phua@nus.edu.sg	Biomedical science is the spectrum of Life Sciences that addresses human health and diseases. From genetics to metabolism, developmental biology to ageing, neurobiology to physiology, these key topics interplay to build up our understanding of the human body and how it responses to internal disruptions and external disturbances especially in disease conditions. This course puts a focus on selected topics in biomedical science with strong emphasis on the techniques used to study metabolic disorders and ageing, and how the human brain faces both challenges.	Part 1: Metabolism, metabolic disease and diabetes (Adrian Teo)1) Overview on metabolism and monogenic metabolic disorders2) Metabolic syndrome3) Various types of diabetesPart 2: Neuronal control of metabolism (Soong Tuck Wah)1) Ion channels in neurophysiology and disorders2) Glucose-sensing in appetite and diabetes3) Neural control of feeding Part 3: Autophagy and ageing (Esther Wong)1) Autophagy and proteostasis2) Autophagy in diseases3) Autophagy in ageing and longevity Part 4: The human brain and metabolic disorders (Christoph Winkler)1) Neuron formation in the embryonic brain: Evolution of human brain complexity2) Adult brain neurogenesis: Metabolic control of stem cell niches3) Metabolic disorders resulting in brain diseases	1. Understand important experimental strategies to address research questions related to metabolic disorders, ageing and brain function., 2. Understand the interplay of metabolic control and body functions, including those of the brain., 3. Identify and formulate open questions in emerging research fields, and design experimental approaches to address these open questions.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (research proposal writing), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 0, 30, 30, 0, 0, 30, 0, 0, 0
LSM4211	Toxicology	Yes - BMS	LSM3211	1	Pharmacology	Dr Rajkumar Ramamoorthy rajkumar@nus.edu.sg	This course is designed to provide students with a good understanding of the basic principles and modern concepts of toxicology. It explores the adverse effects of chemicals on humans and the biosphere, emphasising the skills needed to make quantitative risk assessments and understand the intricacies of exposure to hazardous compounds. The course delves into the extrapolation from animal data and the linkage of adverse effects at the molecular level to overall toxic responses in humans.	Health hazards from drugs, naturally occurring toxins, industrial chemicals, and environmental toxicants. Toxicokinetics and Toxicodynamics. Cellular and molecular mechanisms of toxicity. Organ-selective toxicity. Safety evaluation of drugs and other chemicals. General concepts will be illustrated with a number of both classical and highly topical examples.	1. Understand the fundamental principles of toxicology. 2. Apply quantitative risk assessment techniques for exposure to hazardous compounds. 3. Extrapolate findings from animal data to human scenarios. 4. Identify and comprehend adverse effects at the molecular level. 5. Evaluate safety and toxicity of drugs, industrial chemicals, and environmental toxicants.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	5, 0, 25, 10, 0, 20, 0, 0, 0, 40
LSM4213	Systems Neurobiology	Yes - BMS	LSM3215 or LSM3216	1	Physiology	Dr Andrew Tan phstya@nus.edu.sg	The primary goal of this course is to understand how (a) neurons, assembled into circuits, mediate behaviour and (b) pathophysiology of neurons leading to dysfunctional cellular and molecular processes and behaviour. It draws on basic knowledge of the cell biology and physiology of neurons, as well as the use of elementary calculus which will be gently introduced from scratch and needs no prior background in calculus.	Sensation and motor behavior Functional neuroanatomy General scheme of sensory processing Somatosensation and pain Basis of vision Organizational features of motor processing Higher brain function and synaptic plasticity Object recognition: edge detection and simple forms Object recognition: complex objects, face recognition and beyond Memory Memory and goal directed behaviour Neural basis of working memory Developmental plasticity in vision Plasticity and simple motor learning Neurotechnology Parkinson's disease and deep brain stimulation Tetraplegia and brain-machine interfaces Practical: Introduction to computational neuroscience & artificial intelligence	1. Understand how (a) neurons, assembled into circuits, mediate behaviour and (b) pathophysiology of neurons leading to dysfunctional cellular and molecular processes and behaviour.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 60, 0, 0, 0, 0, 0, 0, 0, 40
LSM4214	Cancer Pharmacology	Yes - BMS	LSM3211	1 and 2	Pharmacology	Assoc Prof Gautam Sethi phcgs@nus.edu.sg	This course will introduce students to the general principles of drug actions that underpin their therapeutic applications against cancers, from conventional (non-specific) chemotherapy to target-specific drugs. It will provide details of drugs used in specific cancer types, ranging from those with proven efficacy in clinics (e.g. Gleevec) to experimental agents in trials. Conceptual and theoretical targets (e.g. RNAi and gene therapies) will also be introduced.	1. Cancer overview - biology, pathology, epidemiology and treatments 2. Current cancer drugs- chemotherapeutics, anti-inflammatory, targeted therapies/biotherapeutics 3. Drug discovery, screening, validation and trials 4. Oncogenes/growth factor receptors	1. Understand drug discovery process from screening to trials against cancer types currently without cure., 2. Grasp new paradigms and advanced knowledge on cancer initiation, progression, drug development and evaluation., 3. Acquire the current understanding and latest information on cancer treatments ranging from drugs with proven efficacy to experimental/conceptual drugs.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 0, 0, 20, 0, 0, 50
LSM4215	Extreme Physiology	Yes - BMS	LSM3212	2	Physiology	Dr Ivan Low Cherh Chiet phsilcc@nus.edu.sg	This course describes how the human body responds to exposure and exercise in environmental extremes such as hypoxic and hyperbaric conditions, thermal stressors, microgravity and trauma. Latest research findings, including some of the controversial topics, will be presented and discussed. Students will understand what the physiological changes are under extreme conditions and how acute and chronic adaptations occur in response to these stresses. This will allow students to appreciate how the human body adapts to changing environments.	1. Extreme Exercises 2. Heat Stress 3. Cold stress 4. Hyperbaric & Underwater 5. Hypoxia & Altitude 6. Trauma 7. Field visit I – Naval Diving Unit 8. Field visit II – Singapore Aeromedical Centre 9. Human Trials on Exercise and Applied Physiology	1. Describe how the human body responds to physical exposure and exercise in environmental extremes., 2. Critically discuss and debate on controversial topics in the field of exercise and environmental physiology., 3. Design simple human experimental trials to investigate critical topics in human performance and applied physiology., 4. Critically analyse current evidence on physiological changes, adaptations and limitations in responses to extreme exercise and environmental conditions., 5. Describe, design and apply mitigation strategies to overcome physiological limitations during exposure to extreme exercise and/or environmental conditions.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (field trip report), Others 2 (debate presentation), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 0, 0, 0, 20, 20, 0, 60

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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LSM4216	Molecular Nutrition and Metabolic Biology	Yes - BMS	LSM3210	1	Biochemistry	Dr Long Yun Chau bchlongy@nus.edu.sg	Nutrients are essential for sustenance. Nutrients and metabolites have a deep impact on cellular response and adaptation at the genetic, epigenetic and signalling level and vice versa. Nutrients also have an effect on intestinal microbiota, which in turn alters the absorption and utilization of nutrients. This course will cover interactions between nutrients and genes, epigenetics, cell signalling and microbiota. Molecular approaches to conduct nutrition related research would be discussed.	Nutrient sensing and metabolic signaling • Nutrient signaling in health and diseases • Nutrient sensing, metabolic signaling and energy homeostasis • Nutrient-gene interactions and metabolic adaptations Nutrition and Epigenetics • Nutrients and metabolism in epigenetic processes • Molecular approaches to study nutrition and epigenetics Nutrition and Omics • Omics approaches to identify biomarkers in health and disease • Metabolites and nutrients • Analysis of small molecules which provide distinct properties to different diets Nutrition and Microbiota • Gut bacteria (microbiota) and its functions in the host • Effects of nutrition on gut bacteria • Microbiota and host metabolism • Microbiome profiling by next-generation sequencing	1. Explain and propose how cellular nutrient and metabolite regulate cellular activities and energy homeostasis., 2. Explain the effects of nutrient and metabolism on cellular epigenetic processes., 3. Explain and propose how dietary intake and nutrients affects energy homeostasis., 4. Explain and propose the interactions between gut microbiome and host metabolism., 5. Analyse and interpret experimental and research data on molecular nutrition and metabolic biology.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (journal club), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 40, 0, 0, 15, 0, 0, 45
LSM4217	Functional Ageing	Yes - BMS	LSM3217	2	Physiology	Asooc Prof Manoor Prakash Hande phsmph@nus.edu.sg	Populations around the world are rapidly ageing and it is important to understand the functional decline in ageing populations. Functional age is defined as a combination of chronological, biological and psychological ages. Molecular processes governing ageing will be covered during the first half while the second half will be on societal perception, burden of disease, healthy ageing interventions and ageless society. The ageing process will be explained based on the experimental and epidemiological studies. This course will integrate biology and sociology of ageing which will provide avenues for better understanding of ageing in a society.	1. Theories of ageing 2. Telomeres and DNA damage theory of Ageing and others 3. Age related diseases 4. Epidemiology of Ageing – Lifestyle factors (Diabetes etc.) 5. Evolution and Ageing; Ageing and Cancer 6. Determinants of Health-Span 7. Interventions – calorie restriction and stem cell therapies 8. Ageing Society – or Age-less society 9. Life span, health-span and demography of ageing 10. Ageing and quality of life – cognitive decline, dementia, frailty, sarcopenia 11. End-of-life challenges and long term healthcare 12. Societal challenges in the ageing population 13. Future of ageing 14. Visit to Institute of Mental Health Geriatric Ward	1. Understanding of the ageing process, particularly functional ageing in a population as a whole, concerning societal perception, burden of disease, healthy ageing interventions and ageless society.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (group presentation), Others 2 (reflection paper), Others 3 (if applicable & describe in notes), Final Exam	10, 15, 0, 30, 0, 0, 30, 15, 0, 0
LSM4218	Biotechnology and Biotherapeutics	Yes - BMS	LSM2105	1 and 2	Biological Sciences	Assoc Prof Ge Ruowen dbsgerw@nus.edu.sg	The revolutionary advances of modern biotechnology and biomedical science have had significant impacts on how a drug is discovered and developed. This course focuses on the contributions of biotechnology to the advancement in drug discovery and development by exploring how genes, proteins and cells are transformed into biotherapeutic drugs. Topics covered include: recombinant protein and peptide drugs, antibody and nanobody therapeutics, DNA and siRNA drugs, cell therapeutics, new technology in vaccine generation and cancer vaccines, diagnostics-based targeted therapeutics (theranostics), as well as how the omics technology (genomics, proteomics and metabolomics) changes drug discovery.	Lectures: 1. Introduction and historical perspectives. 2. Principles of biotechnology and its application in drug discovery and development. 3. DNA as drugs: gene therapy. 4. RNA as drugs: siRNA as drugs. 5. Cells as drugs: cell therapeutics. 6. Peptides as drugs. 7. Antibody therapeutics. 8. Proteins as drugs: hormones, growth factors, cytokines, interferons, enzymes, coagulation factors, etc. 9. Vaccines: new technology and development. 10. Diagnostics-based targeted therapeutics: theranostics. 11. Omics and their impact on drug discovery: Genomics, Proteomics and Metabolomics. Practical: 1. Expression and purification of nanobody 2. Generation of virus-like particles (VLPs) for vaccine development and TEM observation	1. Have an overall understanding on the central role biotechnology played in advancing drug discovery and development., 2. Appreciate the revolutionary advances in biotherapeutics in recent years., 3. Have a keen sense of history of biotherapeutics from the humble beginning of recombinant insulin in 1982, 4. Be aware of the challenges in biotherapeutic development., 5. Acquire hands-on experience through practicals of how nanobody and Virus Like Particles (VLPs) are produced.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 60, 0, 0, 40, 0, 0, 0
LSM4220	Molecular Basis of Human Diseases	Yes - BMS	LSM2233 or LSM3210 or PHS3123	2	Biochemistry	Assoc Prof Yeong Foong May bchyfm@nus.edu.sg	This course aims to provide students with in-depth knowledge of the basic molecular mechanisms of common human diseases, such as genetic diseases, metabolic diseases, cancers and infectious diseases. The course is structured around discussions of data and ideas from current research articles and reviews. Students are expected to participate in presentations and discussions. As the focus of this course is on the molecular mechanisms underlying the pathogenesis of each disease, prospective students should have basic knowledge of molecular and cell biology, genetics and general human physiology before registering for this course.	Genetic diseases Examples: • sickle cell anaemia and thalassemia - monogenic • obesity due to leptin deficiency - monogenic • obesity - polygenic Metabolic diseases Examples: • diabetes – type 2 • obesity Infectious diseases • microbial factors and pathogenecity • immunity and host-cell interactions Cancer • genetics • pathways • model systems Techniques and approaches - using simulated clinical samples and cohort studies • Basic diagnostic lab tests for metabolic diseases • Basic lab tests for infectious diseases • PCR-based methods • Basic histopathology	1. Define what diseases are and explain the underlying causes of different examples of diseases., 2. Relate basic clinical tests to molecular functions of enzymes and pathways., 3. Explain the differences between basic research and clinical research., 4. Design and execute laboratory techniques related to research or diagnostic laboratory investigation., 5. Analyse and interpret medical sciences data, and apply skills for solving ill-structured problems in the biomedical field., 6. Discuss how understanding the molecular basis of diseases can contribute to the development of therapeutics, diagnostics and screening methods and the impact of medical sciences advancements to society, and work collaboratively.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	5, 0, 20, 20, 0, 0, 5, 0, 0, 50
LSM4221	Drug Discovery and Clinical Trials	Yes - BMS	LSM3211	1 and 2	Pharmacology	Assoc Prof Edward Kai-Hua Chow phcekc@nus.edu.sg (Sem 1) Dr Le Thi Nguyet Minh phcltnm@nus.edu.sg (Sem 2)	This course will cover the stages that a drug that is developed for clinical use goes through before it is marketed: discovery/synthesis, preclinical studies, clinical drug trials, registration and post-market surveillance. The different phases of clinical drug trials and the guidelines for ethics and good clinical practice will be discussed. Students are also divided into groups to design clinical trials. At the end of the course the students will have an overview of the processes involved in bringing a drug from the laboratory to the market.	1. Drug discovery and synthesis a. Target selection and lead identification b. Lead optimization c. Biomarker identification 2. Preclinical studies a. Biomarker validation b. Therapeutic validation 3. Clinical drug trials, registration, and post-market surveillance a. Good clinical practice b. Clinical trial ethics and informed consent c. Clinical trials phases 1-3 d. Post-market surveillance activities 4. New trends in the biotech industry 5. Artificial intelligence in drug development 6. Drug regulation in Singapore 7. Case studies 8. Group project: design clinical trials	1. Gain an overview of the processes involved in bringing a drug from the laboratory to the market., 2. Understand the different phases of clinical drug trials and the guidelines for ethics and good clinical practice.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 20, 0, 0, 30, 0, 0, 50
LSM4222	Advanced Immunology	Yes - BMS	LSM3223	1 and 2	Microbiology and Immunology / Biochemistry	Dr Chen Kaiwen kaiwen.chen@nus.edu.sg (Sem 1); Assoc Prof Gan Yunn Hwen bchganyh@nus.edu.sg (Sem 2)	The objective of this course is to provide students with a current and up-to-date view of immunology. Breakthrough areas will certainly vary from year to year, but the broad subject matter will remain. The highly competitive areas of immunology research focus on innate immunity, macrophage and dendritic cell biology, anti-viral defence, molecular mechanisms of cell death and inflammation, mucosal immunity and host-microbiome interaction, lymphocyte development and differentiation, induction of tolerance, mechanism of autoimmunity and allergy, and vaccine development.	Overview of course/immunity Innate immunity and PRRs NK and gamma delta T cells Dendritic cells and macrophages Leukocyte trafficking T cell subsets (Th1, Th2, Th17 and regulatory T cells) Autoimmunity and tolerance Tumor Immunology Cancer immunotherapy Mucosal Immunology Microbiome and the immune response Magic Bullets come of age (antibodies)	1. Aim to provide students with a current and up to date view of immunology., 2. Aim to provide students with a current and up to date view of immunology and its applications; and the ability to evaluate, review and critic immunological data.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignment), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 20, 0, 0, 0, 20, 0, 0, 60

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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LSM4223	Advances in Antimicrobial Strategies	Yes - BMS	LSM3225 or LSM3232	1	Microbiology and Immunology	Dr Jaishree Tripathi jtmic@nus.edu.sg	An advanced course in the study of infectious diseases of man with emphasis on new and emerging infections as well as those of major clinical/economic importance. Core topics include understanding the principles and practice of Medical Microbiology, the nature and emergence of antimicrobial resistance, changing epidemiology of infections and laboratory diagnosis using classical diagnostic techniques and current molecular approaches. Seminars will be conducted as team presentations to explore current topics on infectious diseases in depth. A strong practical component is included.	Not Available	1. Understand the principles and practice of Medical Microbiology, the nature and emergence of antimicrobial resistance, changing epidemiology of infections and laboratory diagnosis using classical diagnostic techniques and current molecular approaches.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	
LSM4225	Genetic Medicine in the Post-Genomic Era	Yes - BMS	LSM2105	2	Biochemistry	Assoc Prof Lee Guat Lay, Caroline bchleec@nus.edu.sg	This course is intended to provide a good foundation and stimulate students' interest in specialized topics in Genetics and Genomics related to translational research. The course will provide students with knowledge of current practices in Genetic Medicine. Students will also know how gene identification, diagnostic and therapeutic strategies are formulated and performed. They will also be expected to show how to translate new genetic and genomic discoveries into novel diagnostic and therapeutic strategies. Major topics covered are gene identification, genetic diagnosis, and gene therapy. Ethical, legal, and social issues (ELSI) in genetic medicine will also be covered.	• Introduction and Review of Human Genetics relevant for Genomic Medicine • Disease Gene Identification. (Focus on Complex Disorders) • Ultra-high throughput strategies for Genomic Medicine (next-generation sequencing technologies) • Genetic Testing o Chromosomal Abnormalities o Molecular Diagnostics • Molecular Therapy • Gene Therapy • Ethics in Genomic Medicine	1. Know how gene identification, diagnostic and therapeutic strategies are formulated and performed., 2. Know how new state-of-the-art genomic strategies are translated in genomic medicine., 3. Expected to show how to translate new genetic and genomic discoveries into novel diagnostic and therapeutic strategies through reading current literature and presenting to the class.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	5, 0, 0, 0, 0, 0, 40, 0, 0, 55
LSM4226	Infection and Immunity	Yes - BMS	LSM3223 and either LSM3225 or LSM3232	1	Microbiology and Immunology	Assoc Prof Sylvie Alonso micas@nus.edu.sg	This course aims at providing an in-depth knowledge in the field of host-pathogen interactions, i.e., how the immune system deals with pathogens, and how the pathogens deal with the host's immune system. An introductory lecture series covers the basics in microbiology (bacteriology, virology, parasitology), immunology, vaccinology, and general principles of host-pathogen interactions. Selected diseases illustrate host-pathogens interactions along with the consequences for vaccine and drug design. The following set of lectures covered by clinicians and professionals focus on patient management, field study, as well as safety aspects when working with pathogens in a research lab. Tutorials are broken into 'journal club', 'article write-up exercise' and 'problem-based study' and are directly related to the topics developed during the lectures.	Basic principles lectures: - Microbiology (bacteriology, virology, parasitology) - Immunology - Vaccinology - General principles of host-pathogen interactions Disease-specific lectures: - Examples of host-pathogens interactions - Consequences for vaccine and drug design Guest lectures (practitioners) on patient management and pathogen research.	1. Equip students with strong understanding of the complex dynamics between pathogens and their host, and develop problem-solving skills, and the ability to conduct a critical and objective review of a particular topic.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 40, 0, 0, 0, 0, 0, 0, 60
LSM4227	Stem Cell Biology	Yes - BMS	(LSM2232 or LSM3220) and LSM2233	1 and 2	Biological Sciences	Assoc Prof Chan Woon Khiong dbscwk@nus.edu.sg	This course will provide a detailed and critical introduction in the biology of stem cells and regenerative medicine. Students will investigate the origin of embryonic and adult stem cells and learn biological concepts relating to pluripotency, self-renewal, transdifferentiation, reprogramming and regeneration. The cell-fate determination and differentiation of selected types of cells, with a focus on their potential biological and medical applications, will be presented. Specialized topics on cancer stem cells, wound healing and tissue regeneration will provide a glimpse of how mankind's future could be further shaped.	Weeks 1 to 3: Introduction to stem cells. The biological and developmental origin of different types of human stem cells, with an emphasis on ES and iPS cells, will be the focus. Comparative aspects of stem cell biology of selected vertebrate models will be discussed. The introduction of research techniques commonly used in the isolation and characterization of human stem cells will be conducted. Weeks 4 to 6: Key concepts of stem cell biology. The major concepts of stem cell biology, namely pluripotency, self-renewal, transdifferentiation, reprogramming and regeneration will be introduced and extensively discussed. Weeks 7 to 9: Fate determination and differentiation of selected types of cells. The wide spectrum of terminally differentiated cell types (eg. cardiomyctes, pancreatic islet, neurons) that could be of therapeutic importance in the regenerative medicine will be discussed. Weeks 10 to 13: Specialized topics on regenerative medicine. Topics that will be covered include cancer stem cells, wound healing and organ and tissue regeneration.	1. Demonstrate knowledge about the developmental and biological nature of the different types of stem cells (adult, iPS and ES) and comprehend the molecular and cellular mechanisms involved in the maintenance of pluripotency and continual self-renewal of human ES and iPS cells., 2. Demonstrate knowledge about reprogramming of somatic cells into pluripotent cells and transdifferentiation into other cell types., 3. Appreciate and gain detailed knowledge of the biology of the various types of human stem cells and linking them to biological and medical problems., 4. Explain the biological processes involved in the cell fate determination and differentiation of various cell types like cardiomyocytes, pancreatic islets, neurons, etc., 5. Apply basic scientific knowledge of stem cells for biological and clinical applications, particularly in selected areas of regenerative medicine including wound healing, organ and tissue regeneration.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 20, 0, 0, 0, 20, 0, 0, 0, 60
LSM4228	Experimental Models for Human Disease and Therapy	Yes - BMS	LSM2105	Not offered until further notice	Biological Sciences	-	Experimental models including animal and cellular models are pivotal for the study of human diseases and development of therapeutics. They help to characterize disease pathophysiology, evaluate the mechanism of action of existing drugs, discover and validate new drug targets and candidates, establish pharmacodynamic/pharmacokinetic (PK/PD) relationships, estimate clinical dosing regimens and determine safety margins and toxicity. Recent advancement of genomic and gene editing technology facilitated the establishment of more disease models that can closely mimic human diseases, including diseases that involve environmental factors. In this course, we will discuss the technology, application as well as limitations of the current experimental models.	Lectures and tutorials: 1. Cellular and animal models for human disease and therapy: values and challenges. 2. Cellular models for cancer 3. Mouse models for cancer (including environmental factors) 4. Rodent models of cardiovascular diseases (including environmental factors) 5. Mouse models for neurodegenerative diseases 6. Fish models for human diseases, technical capability, suitability and applicability. 7. Fish in drug development 8. Genetic engineered animals for disease models and drug development 9. Human gene therapy in cellular and animal models. 10. Stem cell therapy. 11. Therapuetic monoclonal antibody: production from recombinant technology and transgenic mice & testing. 12. Experimental models & cancer immunotherapy. Practical: Zebrafish liver cancer induction and chemical inhibition in transgenic larvae	1. Learn the science and logics behind the development of suitable experimental models for human diseases., 2. Be able to appreciate the value and limitation of each disease model in the discovery and development of therapeutics., 3. Be aware of the role technology played as well as the recent advancements in human disease therapy., 4. Gain practical experiences in zebrafish cancer models.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 0, 20, 30, 0, 0, 0, 50
LSM4229	Therapeutic and diagnostic agents from animal toxins	Yes - BMS	LSM3211 or LSM3231	Not offered until further notice	Biological Sciences	-	Toxins are thought as villains as they cause death and debilitation. In reality, they have contributed more to improving our lives than cause death. This course will introduce the contributions of toxins to our knowledge in biomedical and pharmacological fields. Toxin research has helped in understanding molecular mechanisms of a number of processes such as neurotransmission, blood coagulation and platelet aggregation. Toxins have been useful in the development of therapeutic agents, diagnostic reagents and research tools. The course will examine the recent advances and future prospects in toxin research.	1. Toxins and acetylcholine transmission 2. Toxins in neurobiology and neuropharmacology 3. Toxins affecting thrombosis and hemostasis 4. Toxins and blood pressure 5. Toxins, enzymes, ion channels and receptors 6. From toxins to therapeutics 7. Toxin-based diagnostic agents 8. Toxins and chemistry 9. Future prospects in toxin research	1. Learn how most toxic components from various animal venoms have contributed to life-saving drugs, top-class diagnostic agents and precision research tools., 2. Be exposed to various strategies that are being used in developing novel therapeutic and diagnostic agents and understand step-by-step processes involved in their development.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (term papers), Others 2 (presentation), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 50, 0, 0, 30, 20, 0, 0

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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Please note that S/U option is applicable to Level 1000 LSM courses only.

Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM4231	Structural Biology	Yes - BMS	LSM2106, and GCE 'A' Level or H2 Mathematics/Further Mathematics or equivalent or MA1301 or MA1301X	2	Biological Sciences	Prof Yang Daiwen dbsydw@nus.edu.sg	This course provides an overall view on the structure determination of protein molecules, protein complexes, protein-DNA complexes and viral assemblies. Topics will include the theory and practice of the three major methods - electron microscopy (EM), nuclear magnetic resonance (NMR) and X-ray crystallography.	1. Protein-ligand interaction & NMR spectroscopy: concept of structural biology, principle of NMR 2. One-dimensional (1D) NMR and its application: NMR measurable (chemical shift, coupling constant, signal intensity), structure determination of small molecules by NMR 3. Two- & three-dimensional (2D & 3D) NMR: principles of 2D and 3D NMR 4. Application of 2D and 3D NMR: Binding site identification, Protein dynamics 5. Sample preparation & Protein structure determination 6.The why and what of cryo-EM 7.What are 3-D reconstructions 8. Sample issues and example studies 9. How do we make cryo-EM even better? 10. Overview of cellular cryo-ET 11. Applications 12. Crystallization 13. Crystal systems and symmetries 14. X-ray diffraction and data collection and processing 15. Model building, refinement and analysis	1. Understand the principles of structure determination by EM, X-ray crystallography and NMR., 2. Know the applications of NMR to drug screening, structure-based drug design, structure-function relationship., 3. Learn recent applications of cryo-EM., 4. Know the applications of X-ray crystallography.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignments and presentations), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 59, 0, 0, 41, 0, 0, 0
LSM4232	Advanced Cell Biology	Yes - BMS	LSM2233	1	Physiology	Dr Tsai Shih-Yin phsts@nus.edu.sg	Technological advances allow us to study and modulate various cellular processes generated from the dynamic remodeling of cytoskeleton in cells and explore the roles and interplay of mechanical forces and biochemical signaling on how they migrate the cell, mediate intracellular trafficking and eventually move our body. This course explores the mechanism of cytoskeleton dynamics and apply it to the process of cell movement and intracellular trafficking, which are important for our body physiology such as skeletal muscle performance. Emphasis will be placed on understanding the cellular and molecular mechanisms that lend themselves to experimental manipulation and for future therapeutic intervention.	(i) The mechanism(s) of cytoskeleton dynamics and its applications in cellular motility and intracellular trafficking, particularly in the field of skeletal muscle physiology. There will be increased focus on understanding cell dynamics from basics principles of how actin and microtubules work in response to biochemical and mechanical cues that involve Rho and Rab GTPases and their regulators and scaffold proteins. This will be further extended to better understand how some of the dynamic processes such as intracellular trafficking and actin-microtubule interplay control cell motility and neuronal differentiation. (ii) Additional focus will also be placed into the application of these concepts in muscle development and mechanics at the physiological level, the integration of cytoskeletal dynamics in skeletal muscle biology, and its further application in understanding the underlying pathology of skeletal muscle diseases.	1. Understand how to develop testable hypotheses, design appropriate experiments, and present reasoned analyses and interpretations of results., 2. Have general ideas of how the cytoskeleton of eukaryotic cells provides structure and organization for the physiological movement processes in humans.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (in-class and presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 20, 0, 0, 40, 0, 0, 40
LSM4234	Mechanobiology	Yes - BMS	LSM2233 and LSM3220	2	Biological Sciences	Assoc Prof Yusuke Toyama dbsty@nus.edu.sg	This course introduces students to mechanobiology, an emerging field of life sciences that explores mechanical regulation and implications underlying numerous biological events from prokaryotes to higher organisms. It covers regulation of cell functions by cytoskeletal networks, mechanics of movement of tissue/cell/sub-cellular organelle, cellular/molecular force-sensing, mechanical modulation of biochemical signaling, physical landscapes of peri-/trans-/intra-nuclear events including transcription, and mechanical control of multicellular living organization. It also refers to physical and engineering aspects of physiological or pathological backgrounds of human health and diseases. In addition, students learn cutting-edge technologies to dissect mechanical/physical aspects of cellular/molecular functions.	1. Overview of Mechanobiology 2. Regulation of self-assembly of actin cytoskeleton (I) 3. Regulation of self-assembly of actin cytoskeleton (II) 4. Regulation and multiple functions of microtubule network 5. Intermediate filaments and other cytoskeletal linkers 6. Small G-proteins as major regulators of cytoskeleton 7. Trafficking of intracellular organelles 8. Cell division (I): self-organization of mitotic spindle 9. Cell division (II): Mitosis and cytokinesis 10. Regulation of cytoskeleton in cell adhesion and migration 11. Cytoskeleton-nucleus links 12. Spatial organization of cell nucleus 13. Chromosome assembly and function 14. Mechano-feedback genetic circuits 15. Cells as part of a tissue 16. Mechanics of tissue morphogenesis 17. Functional organization tissue patterning 18. Cellular transmigration 19. Cells and forces 20. Concluding lecture	1. Understand basic concept of mechano-sensing and mechanotransduction - how mechanical environments and stimuli are perceived by cells and transduced as biological signals., 2. Acquire up-to-date knowledge on mechanical regulation of integrated operation of complex life system., 3. Understand significant implication of mechanical force in formation of live organisms., 4. Understand physical and engineering aspects of physiological or pathological backgrounds of human health and diseases., 5. Learn cutting-edge technologies to dissect mechanical/physical aspects of cellular/molecular functions.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assigment and report), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 0, 0, 20, 0, 0, 50
LSM4236	Human Microscopic Anatomy	Yes - BMS	LSM2105 or LSM2106	2	Anatomy	Prof Ong Wei Yi antongwy@nus.edu.sg	This course develops the foundations of human microscopic anatomy essential for research or clinical applications. It covers the visualization of biomolecules in tissues of the body. Interpretation of images occurs in the context of knowledge about the normal microscopic anatomy of different tissues and organs of the human body. Suitable clinical problems will be introduced throughout the course to show the application of scientific knowledge.	• Epithelial Tissue • Skin • Connective Tissue and Adipose Tissue • Cartilage • Bone • Muscle Tissue • Nervous System • Endocrine System • Cardiovascular System • Respiratory System • Digestive System • Organs Associated with the Digestive Tract • Immune System and Lymphoid Organs • Urinary System • Male Reproductive System • Female Reproductive System • Sample Preparation for Light Microscopy • Sample Preparation for Transmission Electron Microscopy • Sample Preparation for Scanning Electron Microscopy • Sample Preparation for Immunoelectron Microscopy	1. Determine an appropriate sample preparation and instrumentation approach to answer questions about human microscopic anatomy., 2. Possess a background knowledge of normal human microscopic anatomy that facilitates interpretation and critical analysis of the observed microscopic images.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 30, 0, 0, 0, 0, 0, 70
LSM4241	Functional Genomics	Yes - BMS	LSM3231 or LSM3241	2	Biochemistry	TBC	This course aims to introduce selected topics on functional genomics. Areas covered include: the assignment of functions to novel genes following from the genome-sequencing projects of human and other organisms; the principles underlying enabling technologies: DNA microarrays, proteomics, protein chips, structural genomics, yeast two-hybrid system, transgenics, and aspects of bioinformatics and its applications; and to understand the impact of functional genomics on the study of diseases such as cancer, drug discovery, pharmacogenetics and healthcare.	Genome sequencing methodologies Fundamental features of eukaryotic genes Epigenetic modifications of the genome Tools and strategies for functional genomics DNA microarray technologies, experimental design and analysis SNPS, HAPS, and pharmacogenomics Proteomics technologies, protein chips, tissue microarrays, structural proteomics and bioinformatics Application of these technologies in the study of human diseases and biomarker discovery	1. Learn genome sequencing methodologies., 2. Learn strategies for functional genomics., 3. Learn methods used in proteome and lipidome analyses., 4. Learn the importance of the human genome project (HGP),, 5. Learn (a) The importance of the human genome project (HGP), (b) Strategies for functional genomics, (c) Genome sequencing methodologies, (d) Tools used for genomics and transcriptomics, (e) Methods used in proteome and lipidome analyses, and (f) Application of these technologies in the study of human diseases and personalized medicine., 6. Learn application of these technologies in the study of human diseases and personalized medicine.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 20, 20, 0, 0, 0, 0, 0, 60

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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For course syllabus, please refer to website LSM Courses. https://www.dbs.nus.edu.sg/lifesciences/lsm_courses/
Please note that S/U option is applicable to Level 1000 LSM courses only.

Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM4242	Protein Engineering	Yes - BMS	LSM3220 or LSM3231	1	Biological Sciences	Assoc Prof Pan Shen Quan dbspansq@nus.edu.sg	This course will familiarize students with the technologies that can be used to produce and engineer various proteins for basic biological research and biotechnology applications. The fundamental principles for manipulating protein production as desired and the common expression systems will be presented. The emphasis will be on the experimental strategies and approaches to improve protein properties and to create novel enzymatic activities. The topics include gene expression and protein production systems, uses of gene fusions for protein production and purification, directed molecular evolution and DNA shuffling, and engineering of proteins and enzymes for improved or novel properties.	• Prokaryotic and eukaryotic systems for protein production • Strong and regulatable promoters • Uses of cleavable fusion proteins for affinity purification • Cell-free in-vitro translation systems • Site-directed mutagenesis • Directed molecular evolution • Phage display • In vitro display technologies • Strategies and approaches to enhance biological properties of proteins and enzymes • Increasing protein solubility • Increasing enzymatic activity, stability and specificity • Modifying cofactor requirements • Engineering of regulatable enzymes • Incorporation of unnatural amino acids • Specific examples of protein engineering o Microbial, plant and animal cells as bioreactors o Therapeutic proteins o Industrial enzymes • Genome editing	1. Understand the fundamental principles for manipulating protein production as desired and the common expression systems, with emphasis on the experimental strategies and approaches to improve protein properties and to create novel enzymatic activities.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 25, 25, 0, 0, 0, 0, 0, 0, 50
LSM4243	Tumour Biology	Yes - BMS	LSM2233	1 and 2	Physiology	Dr Derrick Ong phsostd@nus.edu.sg (Sem 1); Prof Reshma Taneja phsrt@nus.edu.sg (Sem 2)	This course deals with the understanding of processes that regulate cell growth and proliferation, and the intricate mechanism(s) that result in abnormal proliferation and oncogenesis. Molecular basis of immortalization and the acquisition of the neoplastic phenotype, namely oncogene activation, immune evasion, potential for local and distant spread, and resistance to cell death etc. will be discussed. Role of DNA damage/repair, telomere/telomerase in genome instability and tumourigenesis will be examined. A brief session on target therapies including gene therapy approaches will also be included. Tumour immunology role of inflammation in tumours will be discussed.	a. Apoptosis – pathways, detection techniques, and regulators b. Cell cycle, senescence c. Cancer stem cells – model, methods of analysis, interaction with the tumour microenvironment, and therapy resistance d. DNA repair, telomeres, telomerase e. Guest lectures by clinician scientists	1. Provide students with a broad perspective of pathways that influence carcinogenesis, including cell cycle, apoptosis and DNA repair, as well as their intricate mechanisms.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (presentation), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 25, 0, 0, 0, 0, 25, 0, 0, 50
LSM4245	Advanced Epigenetics and Chromatin Biology	Yes - BMS	LSM3235	2	Biochemistry	Assoc Prof Chen Ee Sin bchces@nus.edu.sg	The aim of this course is to introduce concepts and molecular mechanism of epigenetics. Students will learn the historic discoveries of epigenetic research, DNA methylation, post-translational histone modifications, noncoding RNA, chromatin remodelling and epigenetic reprogramming. The course will focus on the role of epigenetic modifications in biological functions. The clinical applications of epigenetics will also be discussed.	Not Available	1. comprehend fundamental concepts of epigenetics, 2. master essential methods to dissect epigenetic\nphenomenon, 3. demonstrate knowledge about epigenetic mechanisms\ninvolved in diseases, 4. demonstrate knowledge about epigenetic mechanisms\ninvolved in gene regulation, 5. apply basic knowledge and methods of epigenetics for\nclinical applications, such as cancer, genomic imprinting\nand nuclear reprogramming	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	20, 0, 0, 50, 0, 0, 0, 0, 0, 30
LSM4251	Plant Growth and Development	Yes - EEB	LSM2254 or LSM3233 or LSM3258	1	Biological Sciences	Prof Yu Hao dbsyuhao@nus.edu.sg	Growth and development of higher vascular plants through their life cycles. Discussion in this course include selected topics in gamete development, fertilization, embryo development, seed germination, development of various plant organs and flowering, the role of plant growth regulators, and the cellular, physiological and molecular basis of plant morphogenesis. The molecular basis of various stages of plant development will be discussed using developmental mutant analyses.	1. Introduction 2. Flowering time control and flower development Physiological and genetic control of flowering; Floral meristem specification; Flower development 3. Fruit development and ripening Biochemistry, physiology and molecular biology of fruit growth and ripening; Role of ethylene in fruit development 4. Microsporogenesis, megasporogenesis and gametogenesis Anther differentiation; Pollen development and maturation; Male gametogenesis ; Pollen germination and growth of the pollen tube; Ovule determination and development; Megasporogenesis 5. Root development Origin and development of the root in the embryo; Postembryonic root structure and physiological function (primary root and lateral roots); Genetic control of root development (transcription factors); Root systems biology (gene regulatory network; root map) 6. Hormonal control of root development Plant hormones; Auxin control of root development; Control of root development by other hormones 7. Epigenetic regulation of plant development Histone (de)acetylation; Long non-coding RNAs 8. Embryo Development Mutants in zygotic embryogenesis 9. Growth and differentiation of the shoot Vegetative shoot apices; Tissue differentiation in the shoot; Leaf growth and development; Development of specialized cells and organs	1. Design basic molecular, genetic and physiological experiments to test molecular hypothesis associated with plant phenotypes., 2. Understand molecular genetic mechanisms underlying various stages of plant development, and apply the knowledge learned to analyze and interpret the molecular basis of various physiological phenomena.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 35, 15, 0, 0, 0, 0, 0, 0, 50
LSM4252	Reproductive Biology	Yes - BMS	LSM2233	2	Biological Sciences	Assoc Prof Christoph Winkler dbswcw@nus.edu.sg	This course covers the events and mechanisms leading to the development and differentiation of gonads and sexes in animals and humans, and eventually to the reproduction and propagation of a new generation. It describes the use of invertebrate (Drosophila, C. elegans) and vertebrate models (fish, mouse) in reproduction research, and discusses selected topics to highlight the current trends in animal and human reproduction. This includes new trends in hormonal control of human reproduction (endocrinology), cellular mechanisms and genetic control underlying gonad differentiation, and diseases of the reproductive system.	Not Available	1. Understand key concepts of ageing and how evolution contributed to the diversity of ageing mechanisms., 2. Explain the role of the brain in controlling reproductive activity., 3. Understand the role of hormones in the formation and function of reproductive organs., 4. Explain the most important morphological features of the male and female reproductive tissues., 5. Appreciate the complexity of developmental processes starting from fertilization through fetal development., 6. Understand key concepts of ageing and how evolution contributed to the diversity of ageing mechanisms., 7. Explain the links between reproductive diversity and ageing., 8. Formulate and ask questions relevant to the topic.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 0, 30, 30, 0, 30, 0, 0, 0, 0
LSM4254	Principles of Taxonomy and Systematics	Yes - EEB	LSM2252	2	Biological Sciences	Prof Peter Ng peterng@nus.edu.sg	This course introduces the science and practice of taxonomy and systematics. The process of grouping biodiversity into discrete categories, from species to superfamilies; and describing and naming these units, and how they may be classified in a way that reflects their evolutionary history, including the legal framework in which organisms are named and treats the various internationally recognised nomenclatural codes. The importance of this formal and codified way of identifying, naming and classifying organisms is discussed in view of the science of biodiversity, the philosophy of the discipline and the conservation and management of biological resources in human society.	Understanding of zoological nomenclature The use of scientific names in biological research The process of discovery, hypothesis-forming and describing a new taxon The concept of the species and significance in biological science Elucidation of phylogenies and a natural classification The importance of taxonomy in international initiatives (e.g., Nagoya, Law of the Sea, CITES etc.)	1. Understand zoological nomenclature, 2. Able to use of scientific names in biological research, 3. Conduct the process of discovery, hypothesis-forming and describing a new taxon, 4. Appreciate the concept of the species and significance in biological science, 5. Elucidate phylogenies and a natural classification, 6. Being aware of the importance of taxonomy in international initiatives (e.g., Nagoya, Law of the Sea, CITES etc.)	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (project), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 0, 0, 0, 20, 0, 20, 0, 0, 50

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

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For course syllabus, please refer to website LSM Courses. https://www.dbs.nus.edu.sg/lifesciences/lsm_courses/
Please note that S/U option is applicable to Level 1000 LSM courses only.

Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM4255	Methods in Mathematical Biology	Yes - EEB	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1	Biological Sciences	Assoc Prof Chisholm, Ryan Alistair dbscra@nus.edu.sg	The use of mathematics has a long history in the life sciences, allowing scientists to clearly articulate their assumptions, rigorously test their ideas about how biological systems work, and make predictions. In this course, students will explore both current and classical questions in mathematical biology, such as: What factors constrain and contribute to the species diversity of an ecosystem? Under what conditions can we expect the stable coexistence of predator and prey populations, or competitors in an ecosystem? What proportion of a human population do we have to vaccinate to prevent an epidemic?	Not Available	1. Gain familiarity with the software R and Mathematica., 2. Acquire a toolbox of essential mathematical skills that they can apply to current problems., 3. Learn the history of mathematical biology and basic concepts such as the definition and purpose of a model and of a theory.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignments), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 0, 10, 20, 30, 0, 0, 40
LSM4256	Evolution of Development	Yes - EEB	LSM3233 or LSM3252	1	Biological Sciences	Prof Antonia Monteiro antonia.monteiro@nus.edu.sg	The objective of this course is to integrate two disciplines, Evolutionary Biology and Developmental Biology into a common framework. The course explores the evolution of animal bodies, e.g., legs, segments, eyes, wings, etc., by focusing on changes at the molecular and developmental levels. This course will introduce important concepts such as hox genes, selector genes, homology, serial homology, modularity, gene regulatory networks, genetic architecture, developmental basis of sexual dimorphism, and phenotypic plasticity, and give a broad organismic-centred perspective on the evolution of novel traits.	1st class: What is Evo-Devo and what does this course cover? 2nd class: Where do we belong on the tree of animals, and what does this tree look like? 3rd class: Why do we need comparative work to make sense of how development works? Introduction to early Drosophila Development. 4th class: What are organizers, fields, morphogens and selector genes? 5th class: What is the Pax6 selector gene, and why is it so famous? 6th class: What are homeotic (hox) genes and why are they so important? 7th class: Legs, and other body appendages – how do they come about? 8th class: How does protein evolution alter body plans? 9th class: How do changes to hox gene targets alter body plans? Or how beetles get their forewings turned into elytra? 10th class: How does cis-regulatory evolution alter body plans? 11th class: What is developmental modularity, and why does it matter? 12th class: CA test 13th class: Visit to the Museum of Natural History – Can we identify what is a novel complex trait? 14thclass: What is genetic architecture and how does it impact the evolution of traits? 15th class: What is homology and process homology? 16th class: How can novel traits emerge from the co-option of pre-existent gene networks? 17th class: How does development constrain or bias the evolution of novel traits? 18th class: How do gene duplications affect the evolution of novelty? 19th class: How to write and develop a grant proposal in evo-devo. 20th class: How do males and females develop different traits when they share almost the same genome? 21st class: What is phenotypic plasticity and how does it evolve? 22nd class: What is genetic assimilation and accommodation and how do these processes contribute to evolution? 23rd class: What is epigenetics and how can it contribute to evolution? 24th class: student project presentations 25th class: student project presentations 26th class: student project presentations	1. Integrate two disciplines, Evolutionary Biology and Developmental Biology, into a common framework., 2. Explore the evolution of animal bodies, e.g., legs, segments, eyes, wings, etc., by focusing on changes at the molecular and developmental levels., 3. Introduce important concepts such as hox genes, selector genes, homology, serial homology, modularity, gene regulatory networks, genetic architecture, developmental basis of sexual dimorphism, and phenotypic plasticity, and give a broad organismic-centred perspective on the evolution of novel traits.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (discussion questions), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 20, 30, 0, 0, 20, 20, 0, 0, 0
LSM4257	Aquatic Vertebrate Diversity	Yes - EEB	LSM2252	1	Biological Sciences	Dr Zeehan Jaafar jaafarz@nus.edu.sg	Aquatic vertebrates are essential components of freshwater and marine ecosystems, often occupying higher trophic/food web levels with wider ecological influence. As relatively sizeable and abundant elements of aquatic ecosystems, these organisms are also central to the ecosystem goods and services provided. Besides fishes, the most speciose extant vertebrate group, the remaining four vertebrate classes all include aquatic lineages. This course offers a firm foundation in the global diversity of aquatic vertebrates in the context of their biology, ecology, and conservation. Emphasis on Southeast Asian aquatic vertebrate biota provides a framework that informs management of regional imperiled freshwater and marine ecosystems.	Not Available	1. Ability to recognise major aquatic vertebrate lineages, with emphasis on Southeast Asian biota., 2. Identify key aquatic adaptations of vertebrate organisms through comparative anatomy, physiology, and behaviour., 3. Identify broad principles of aquatic life; and the challenges facing organisms living in freshwater and marine systems., 4. Establish a strong foundation in the recognition of fundamental roles of global aquatic vertebrate organisms in freshwater and marine ecology., 5. Exposure to a broad range of resources pertaining to Southeast Asian aquatic vertebrate biodiversity, including the use of identification keys, and conservation status reports., 6. Familiarity with relevant field techniques to assess aquatic biodiversity with emphasis on vertebrates, including methods in specimen collection and preparation for scientific analyses., 7. Application of knowledge gained in formulation of sound management practices for the conservation of freshwater and marine ecosystems based on of extant information on aquatic vertebrate organisms.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (fieldwork), Others 2 (assignment), Others 3 (if applicable & describe in notes), Final Exam	10, 0, 0, 20, 20, 0, 30, 20, 0, 0
LSM4259	Evolutionary Genetics of Reproduction	Yes - EEB	LSM2105 and LSM2107	1	Biological Sciences	Dr Nalini Puniamoorthy nalini@nus.edu.sg	Why do some species invest all their resources in securing a mate to reproduce with whilst others avoid sex altogether by cloning themselves? This course takes an integrative approach to understanding the mechanisms of inheritance and reproduction from an evolutionary perspective across plants and animals. We will adopt evidence-based learning, review both classic and current primary literature, as well as offer hands-on practicals on analysing datasets (e.g.: selection experiments, population genome data etc.). Topics covered include the evolution of sex, operation of sexual selection, the genetics of reproduction and the rapid evolution of immune function and reproduction.	This course will cover topics under four main sections across 12 weeks: (I) Evolutionary origins of recombination - Introduction - Anisogamy and gamete evolution - Evolution of breeding systems - Sexual and asexual reproduction (II) Operation of sexual selection and diversification - Sex roles and the Darwin-Bateman paradigm - Sex and speciation - Developmental plasticity and alternative reproductive strategies (III) Genetics of reproduction - Variability and its measurement - Heritability and environment - Additive and non-additive models of inheritance - Mechanisms of speciation (IV) Rapid evolution, reproduction and immunity - Reproduction and genome evolution - Host-microbe interaction - Trade-offs, immunity and reproduction Week 13 will be a review of entire syllabus, focusing on more difficult concepts (based on quiz results) and questions raised by student feedback.	1. Reconstruct the origins of reproduction., 2. Explain the mechanisms behind gamete evolution., 3. Define and apply models of sexual selection., 4. Differentiate and apply additive and non-additive models of inheritance., 5. Critically review classic and current literature on reproductive evolution in plants and animals.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	15, 20, 30, 35, 0, 0, 0, 0, 0
LSM4260	Plankton Ecology	Yes - EEB	LSM3254 or LSM3257	1	Biological Sciences	Dr Maxine Mowe dbsmadm@nus.edu.sg	Phytoplankton and zooplankton are a vital part of aquatic ecosystems and form the basis of aquatic food webs. Understanding the role of plankton in aquatic ecosystems will help in advancing the solutions to problems facing today's water resources (harmful algal blooms, eutrophication and pollution). This course focuses on the biodiversity and ecology of phytoplankton and zooplankton, the roles they play in marine and freshwater ecosystems, their potential uses as biofuel and in aquaculture. The course will consist of lectures, practicals and a hands-on application of modelling on phytoplankton datasets.	1. Plankton diversity - Introduction - Freshwater phytoplankton and zooplankton diversity - Marine phytoplankton and zooplankton diversity - Sampling methods 2. Plankton ecology - Planktonic food webs - Interactions with higher trophic levels 3. Plankton linked environmental and water quality issues - Marine algal blooms - Freshwater algal blooms - Invasive zooplankton - Microplastics and impact on plankton - Climate change and impact on plankton 4. Uses of plankton - Phytoplankton as biofuel/aquaculture feed 5. Monitoring and management of planktonic blooms - Monitoring of planktonic blooms - Understanding bloom models for management - On-site management of blooms 6. Overall review of topics	1. Explain the role of phytoplankton and zooplankton in aquatic environments., 2. Learn and apply methods to evaluate plankton diversity and biomass in a water body., 3. Compare and contrast plankton diversity in temperate and tropical water bodies., 4. Analyse the effects of environmental variables on phytoplankton growth in marine and freshwater environments., 5. Predict how climate change may impact phytoplankton and zooplankton ecology in the future, 6. Collaborative learning using statistical modelling in the field of phytoplankton ecology	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 30, 20, 0, 20, 0, 0, 0, 20
LSM4261	Marine Biology	Yes - EEB	LSM3254	2	Biological Sciences	Assoc Prof Huang Danwei huangdanwei@nus.edu.sg	Main focus on the understanding and appreciation of marine environment, the diversity of marine life, and the constant interaction between man and the sea. Marine biology as the scientific study of marine animals and the marine environment. Fundamentals of oceanography. The range of marine environments and variety of organisms inhabiting them. Benefits of the marine environment and its resources to humans. The impact of exploitation and human activities on the oceans.	Introduction to marine biology: An overview of the course structure and content. Recap of basic oceanography, marine ecology, key marine environments, resources from the sea, human impacts, and marine environment management. Patterns, processes, ecosystems and organisms: Estimating marine biodiversity; inferring marine biogeography and connectivity. Overview of oceanographic processes, productivity and drivers of fisheries. Selected ecosystems: deep sea, tropical coral reefs, seagrass meadows and mangrove forests. Focus on corals: intra- and interspecific variations and their drivers. Human-ocean interactions: Living (renewable) and non-living (non-renewable) resources and their rates and patterns of exploitation will be examined. Impacts of human activities, both localized and global, assessed. The state of the marine environment, management of endangered species and critical habitats, urban marine ecology, and restoration techniques, will be critically discussed.	1. Explain oceans, their biodiversity and functioning as ecological systems., 2. Learn and practice skills for observing and surveying the marine environment., 3. Discuss impacts by human activities and interactions with wildlife in the oceans., 4. Familiarise with principal marine habitats, especially those relevant to Singapore.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 30, 35, 10, 25, 0, 0, 0, 0, 0

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

For course scheduling information, please refer to NUSMODS. https://nusmods.com/timetable/
For course syllabus, please refer to website LSM Courses. https://www.dbs.nus.edu.sg/lifesciences/lsm_courses/
Please note that S/U option is applicable to Level 1000 LSM courses only.

Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM4262	Tropical Conservation Biology	Yes - EEB	LSM2251 and either LSM3272 or ENV1101	1	Biological Sciences	Dr Ian Chan ianchan@nus.edu.sg	Conservation and the loss of biodiversity and natural ecosystems are currently regarded as one of the most pressing problems facing mankind. The course will highlight the impact of habitat loss on biodiversity and the basis for formulation of effective conservation management strategies. The course will also introduce students to the theory of current conservation biology as illustrated by applications in tropical areas, species conservation issues, ecological challenges, role of zoological gardens, legal challenges etc. Conservation of tropical biota, management of local and regional environmental problems, appreciation and consideration of the socio-economic issues will also be treated.	1. Extinction 2. Habitat loss and protection 3. Overexploitation and sustainable use of biological resources 4. Invasive species impacts and management 5. Conservation decision science 6. Biodiversity and ecosystem services 7. Socioeconomic development, governance, and biodiversity conservation 8. Human-nature relationships	1. Familiar with the main drivers and effects of the tropical biodiversity crisis., 2. Familiar with the solutions that have been proposed as a response to this crisis, and able to critically evaluate their shortcomings and ongoing improvements., 3. Aware of the complex reality of biodiversity conservation problems, especially in the tropics with their accompanying social, political, economic, and cultural contexts., 4. Able to analyse such complex problems in a holistic manner, form their own opinions/suggestions on the issues involved and present/defend these ideas in discussions with others.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (reflections), Others 2 (debate), Others 3 (roundtable discussion), Final Exam	0, 0, 25, 0, 0, 0, 25, 25, 25, 0
LSM4263	Field Studies in Biodiversity	Yes - EEB	LSM2251 and LSM2252	4	Biological Sciences	Dr Tan Yen Yi yenyi.tan@nus.edu.sg	This course introduces students to field biology - the basic techniques involved, sampling design and basic data gathering and data management. Through field study sessions, students will experience and encounter tropical environs and habitats, namely coastal, mangrove, primary and secondary forests. This is to gain an understanding of the various field methods in biodiversity research, and to achieve an appreciation and a broader perspective on the types or sub-fields of biodiversity research and what they entail. A week-long field project is incorporated and will be conducted in Pulau Tioman, Malaysia.	1) Importance and relevance of biodiversity - Important issues in biodiversity and conservation 2) Overview of field techniques - An introduction to different field methods employed to study a variety of taxonomic groups 3) Biodiversity Research - An in-depth look into the various sub-fields in biodiversity research and what they entail (vertebrates and invertebrates) 4) Research Design - How to formulate, design, and write a research proposal within a hypothesis-testing framework. This will mostly be done through group-based tutorials 5) Data Analysis - Fundamentals in data analysis including statistics and data visualization in R.	1. Understand various field methods in biodiversity research., 2. Have a broader perspective on the types/sub-fields of biodiversity research and what they entail., 3. Have first-hand and hands-on experience in formulating, designing, planning, managing, executing, analyzing, and completing a field-based research project of their own.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (group presentation), Others 2 (individual performance in group work), Others 3 (if applicable & describe in notes), Final Exam	0, 20, 45, 5, 0, 0, 20, 10, 0, 0
LSM4264	Freshwater Biology	Yes - EEB	LSM3254	2	Biological Sciences	Dr Maxine Mowe dbsmadm@nus.edu.sg	Freshwater is essential to life, yet constitutes less than 3% of Earth's total water. With many freshwater ecosystems under threat, understanding the biology of freshwaters is fundamentally important to their management, conservation and restoration. This course introduces the study of inland waters, with emphasis on aquatic ecology, structure and function, and aquatic conservation. Topics discussed will include diversity and ecology of freshwater habitats and aquatic organisms, and aquatic conservation issues including policies, regulation and management of freshwater resources in local and international contexts.	1a. course introduction o Course overview 1b. Limnology o Introduction to limnology o Limnological techniques 1c. Freshwater habitats o Classification of freshwater habitats o Singapore's freshwater habitats 1d. Freshwater wetlands o Types of wetlands, tropical vs. temperate wetlands, hydrology, ecology 2. Freshwater biodiversity o Classifying limnological diversity o Examples of diversity: Freshwater crabs, phytoplankton, zooplankton 3. Freshwater ecology o Trophic cascades, biomanipulation alternate stable state, food web studies, electrofishing methods 4a. Threats to fresh waters: pollution and climate change o Eutrophication, Pollution (metals, plastics), climate change impacts on freshwater systems 4b. Threats to fresh waters: aquatic invasive species o Introducing invasive species, invasion process and pathways, management of invasive species, aquatic invasive species in Singapore 5a. Aquatic conservation and human water use o Conceptual framework, freshwater ecosystem services, human water use, sustainable water use in Singapore 5b. Freshwater biodiversity conservation o Focusing conservation efforts o Effective conservation strategies o Future of freshwater biodiversity conservation	1. Recognise and explain the scope and relevance of freshwater biology., 2. Identify, compare and contrast the structure and function freshwater habitats., 3. Appreciate and discuss key issues in aquatic conservation of topical and/or local interest., 4. Appreciate and discuss various freshwater ecological processes of topical and/or local interest., 5. Synthesise information to analyse and understand the role of science in informing aquatic conservation policy and management., 6. Identify and discuss the diversity and ecological roles of major groups of freshwater organisms, and be aware of techniques for sampling them., 7. Critically and constructively evaluate scientific papers and oral presentations; and better communicate ideas and information verbally and through writing.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (field trip), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	15, 20, 25, 20, 0, 0, 20, 0, 0, 0
LSM4266	Aquatic Invertebrate Diversity	Yes - EEB	LSM2252	2	Biological Sciences	Dr Theresa Su theresasu@nus.edu.sg	Invertebrate biodiversity is an important component of aquatic environments and ecosystems. Its study is essential for conservation and management of such environments. This course aims to enhance students' knowledge of tropical aquatic biodiversity through directed studiesin freshwater and marine invertebrates. Biota in Singapore will be highlighted. Emphasis is on organismal diversity, taxonomy and classification. Other topics such as structure and function, ecology, conservation, and economic importance will be covered within the context of selected organismal groups. Appreciation of the importance of aquatic biodiversity as well as knowledge, familiarity, and understanding of selected groups of aquatic biodiversity are the learning outcomes.	A) Introduction to aquatic invertebrate biodiversity: main groups; classification; importance; threats, conservation, and management. B) Processing and preservation of aquatic invertebrate organisms; practical identification skills. C) Advanced topics (e.g., in diversity, taxonomy and classification, structure and function, ecology, conservation, economic importance, etc.) on selected groups of aquatic organisms (may be taxonomic or functional groupings): - Bivalve molluscs / Echidoderms / Corals / Sponges - Crustaceans Common areas to be covered for all groups will include, at least: - Classification (including bases for classification) - Singapore biota and their relevance in Singapore context etc.	1. Exploit relevant resources to identify/comment on less familiar aquatic organisms., 2. Recognise, and be able to compare and contrast major groups of aquatic biodiversity across a wide range of criteria., 3. Be familiar with relevant field sampling techniques and preservation methods needed for ecological assessment of aquatic biodiversity., 4. Be familiar with their systematics and understand the reason behind biological classification of selected groups of aquatic organisms., 5. Be able to identify and are knowledgable with common/prominent local aquatic species (at least 10 species from selected groups) and their habitats., 6. Apply knowledge and understanding of selected groups of aquatic biodiversity in relation to formulation of conservation/rehabilitation policy and management decisions., 7. Have a broad understanding of the relevance and importance of aquatic biodiversity in environmental/ecological terms as well as in human terms (ecosystem goods and services).	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (reflections), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 20, 0, 30, 30, 20, 0, 0, 0
LSM4267	Light & Vision in Animal Communication	Yes - EEB	LSM3267	1	Biological Sciences	Dr Lim Lek Min, Matthew matlim@nus.edu.sg	Animals rely on various sensory systems to detect environmental information; a common mode involves light detection. Many rely on visual stimuli for numerous behavioural activities; humans often fail to understand these light signals. This course will introduce: (i) the fundamentals of light detection, (ii) the instrumentation and software involved in accurate detection, quantification/characterisation of animal/plant light signals, (iii) the formulation of hypotheses in animal-animal and animal-plant visual communication from interdisciplinary sciences (e.g., behaviour, conservation, optics), and (iv) relevant industrial applications. This course will also visit some other systems beyond the visible light spectrum, for example: infrared reception and thermoreception.	1. Diversity of light signals; questions on animal/plant light signals 2. Mechanisms of light signal production, propagation and reception 3. Ultraviolet, visible light, and near-infrared vision: Adaptive functions 4. Instrumentation: Reflectance, transmission & absorbance spectrometry 5. Colour vision: Colourspace 6. Polarized light reflection and polarization vision: Mechanisms 7. Adaptive functions of polarization vision 8. Applications of UV, IR and polarization photography 9. Sensing far-infrared: Introduction to thermoreception 10. Industrial applications	1. Use a spectrophotometer for various light-related applications and experiments (depending on the type of individual project chosen by student)., 2. Take ultraviolet and infrared photographs for research purposes., 3. How colours and light signals should be characterized (i.e. via spectrophotometry).	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (report), Others 2 (narration), Others 3 (documentary), Final Exam	0, 0, 40, 0, 0, 0, 20, 40, 0, 0

LSM Courses - For Academic Year AY2024/2025 (Updating 4 October 2024)

For course scheduling information, please refer to NUSMODS. https://nusmods.com/timetable/
For course syllabus, please refer to website LSM Courses. https://www.dbs.nus.edu.sg/lifesciences/lsm_courses/
Please note that S/U option is applicable to Level 1000 LSM courses only.

Code	Title	For SPN?	Prerequisite(s)	Semester	Department	Course Coordinators (NUS email contacts)	Course Description	Syllabus	Learning Outcomes	Assessment [CA Component]	Assessment [% Weightage]
LSM4268	Environmental Bioacoustics	Yes - EEB	LSM3267 or LSM3272	1	Biological Sciences	Dr Lim Lek Min, Matthew matlim@nus.edu.sg	Although animals sense their physical and biotic environments via various modalities, how they sense the environment acoustically is still poorly understood. From low frequency minute vibrations to infrasonic and ultrasonic frequencies, from waterborne to air-transmitted sounds, this course will introduce what sound is (i.e. fundamentals of sound, how sound travels etc.), how and why it matters to animals (i.e. mechanisms and adaptive functions of sound production and reception) in both terrestrial and marine habitats, bioacoustic instrumentation and software, industrial applications, and how environmental issues involving sounds such as terrestrial and ocean noise pollution are affecting animals and humans.	(1) Fundamentals of Sound; (2) Mechanisms of Sound Production; (3) Instrumentation and Data Collection; and (4) Environmental Change, Behavioural Change. Key topics covered during lectures and hands-on practical sessions are: (1) Introduction to Bioacoustics. What is sound? Why study bioacoustics? Importance of studying sound in natural and urban landscapes. (2) Fundamentals of sound: how to quantify sound? What are the units of sound? (3) Animal sounds and mechanisms: diversity of sound producing mechanisms (e.g. vocalisation, stridulation) (4) Bioacoustics and Instrumentation: diversity of sound recording devices (e.g. digital recorders, data logging acoustic devices, etc) and peripheral instruments (e.g. microphones, hydrophones, contact microphones, parabolic sound dish, etc.) and software (e.g. RavenLite) (5) Ecological and behavioural applications of bioacoustics; ecological case studies of animal sounds (e.g. birds, whales, bats and moths) and sounds of the natural world (e.g. sounds of waves against rocks and sand) used in behavioural aspects (navigation, social interaction, foraging, predator-avoidance). How bioacoustics can be used to identify species (e.g. in bats). (6) Environmental applications of bioacoustics; case studies involving how noise pollution in terrestrial and aquatic habitats have interferred with animal sounds and caused behavioural change.	1. Know about different types of microphones and how to use them for various sound-related applications and experiments (depending on the type of individual project chosen by student)., 2. Develop an understanding of environmental impacts of sound pollution on animals and humans in an anthropogenic world (eg. effects of urban & shipping noise on terrestrial & marine animals, respectively)., 3. Be familiar with key bioacoustic studies of animal models & habitats (eg. birds, bats, cateceans, snapping shrimps, intertidal zone, etc) and role of bioacoustiscs in their behaviour., 4. Measure environmental (air, substrate-based, water) sounds on a short and long term basis (data loggers).	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignments), Others 2 (peer reviews), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 40, 0, 0, 0, 20, 40, 0, 0
ZB2101	Introductory Bioinformatics	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1 and 2	Biological Sciences	Prof Greg Tucker-Kellogg greg_t-k@nus.edu.sg	Students will be introduced to the concepts, tools and techniques of bioinformatics, a field of immense importance for understanding molecular evolution, individualized medicine, and data intensive biology. The course includes a conceptual framework for modern bioinformatics, an introduction to key bioinformatics topics such as databases and software, sequence analysis, pairwise alignment, multiple sequence alignment, sequence database searches, and profile-based methods, molecular phylogenetics, visualization and basic homology modelling of molecular structure, pathway analysis and personal genomics. Concepts emphasized in the lectures are complemented by hands-on use of bioinformatics tools in the practicals.	1. Bioinformatics databases (finding information, finding links between information sources, data integrity, genomic annotation, etc.) Fundamental concepts in biological information are covered here 2. Pairwise sequence alignment. Here we cover the most fundamental algorithms of bioinformatics, as well as introduce concepts in probability and statistics that will be used throughout the course. 3. BLAST. This learning unit is named after the most widely used algorithm for sequence database search. We cover BLAST and its variants as well as more advanced methods for sequence database search, using a variety of problems and applications. 4. Multiple Sequence Alignment. This learning unit provides the bridge between previous topics and phylogenetics, and brings in more quantitative thinking and data literacy concepts. 5. Phylogenetics. Here we use all of the topics above to consider the history of life, and how biological sequence information can be used to infer evolutionary history. We cover applications in species history and forensic science. 6. Genome-wide analysis. We return to genome browsers, introduced in topic 1, with the tools covered through the semester, and take a deeper dive into the power of genomic information.	1. Be able to find, access, and use biological data from public databases for their own projects., 2. Be able to describe and distinguish algorithms for global and local pairwise sequence alignment and multiple sequence alignment., 3. Integrate and analyse data from multiple bioinformatics databases and genome browsers., 4. Be able to describe how genomic information intersects with privacy issues in modern society.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (2 Problem sets, each 15%), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	10, 0, 0, 60, 0, 0, 30, 0, 0, 0
ZB2201	Computational Thinking for Life Sciences	No	GCE 'A' Level or H2 Biology or equivalent, or LSM1301	1	Biological Sciences	Assoc Prof Chisholm, Ryan Alistair dbscra@nus.edu.sg	Computational thinking is becoming increasingly important across the life sciences, from molecular and cell biology to evolution and ecology. This course will introduce students to computational thinking and will focus on how to solve biological problems using computational approaches. How can you become a computational thinker? How do computers represent and solve problems? How can computers and computational thinking be used to solve problems of relevance to biology? The applied component of the course will teach the basics of programming in R and will focus on biological problems including population growth modelling, epidemic modelling, and analysis of biological data.	Specific computational skills to teach: - Algorithmic thinking - Simple variables, data types - Basic arithmetic and computation - Logic: if, then, else; Boolean logic - Loops: for, while - Functions - Specific algorithms: sorting, searching - Algorithms: abstraction, recursion, modularisation - Representation: binary and hexadecimal number systems - Strings, arrays, matrices, multidimensional data types - Matrix operations - Pseudorandom number generation and Monte Carlo simulation Examples of biologically relevant problems to be used as applications: - Simple discrete-time population growth models: exponential, logistic - Age-structured population model - Individual-based model, e.g., of an epidemic - Data processing: computing simple properties of a data set such as means, standard deviations, and quantiles, and breaking these down by groups, application of linear regression, correlation - Randomisation tests to assess statistical significance in data analyses - Analysis of protein sequences as text strings using searching and sorting algorithms	1. Perform basic data management and analysis (in R)., 2. Read computer programs (in R) and understand them., 3. Understand what it means to think computationally., 4. Know and explain how standard algorithms work (search, sort, etc.)., 5. Understand what algorithms are and how they can be used to solve problems relevant to biology, 6. Write computer programs (in R) to solve simple problems, with a focus on problems relevant to the biological sciences.	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (assignments), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 0, 10, 30, 0, 20, 0, 0, 40
ZB3101	Genomic Data Analysis	No	ZB2101 or LSM2241	2	Biological Sciences	Prof Greg Tucker-Kellogg greg_t-k@nus.edu.sg	This course introduces practical, real-world genomic data analysis: when a genomic experiment is performed, and bioinformatics analysis is required, how is it done? In "Data Access and Integration", students will learn how to distinguish databases and integrate data. In "Genomics and NGS", students will learn practical analysis of microarray and next-generation sequencing (NGS) data. Students will learn how to map sequencing data to genomes in a variety of problem settings and interpret results. In "Integrative Analysis", students will learn how approaches including pathway analysis and analysis of gene regulatory networks can add power to interpretation of genomic experiments.	1. Bioinformatics Resource Solving Biological Problems with Bioinformatics Software Implementation. Concepts in databases. Knowledge discovery: Ontologies and Data grammar (XML) 2. Basic Bioinformatics Scripting Concepts in programming. Introduction to Algorithms in Bioinformatics. 3. Machine Learning techniques in biological data analysis Machine learning I (SVM). Machine learning II (RF). 4. Molecular Modeling and Rational Drug Discovery and Design Advanced Computational Structural Biology: Structural Modeling and Molecular Dynamics; Computational Drug Design 5. Protein Interactions, Biological Pathways and Simulation Modelling of biological pathways; Analyzing Protein-Protein Interactions 6. Development of Bioinformatics Discussion: Journal Paper Classic	1. Demonstrate the ability to access, distinguish, and use public genomic data for their own analyses, 2. Design and execute basic genomic analysis projects using state-of-the-art tools, 3. Explain, compare, and critique genomic analysis papers in the scientific literature	Class Participation, Essays, Project/Group Project, Quizzes/Tests, Laboratory Tests, Mid-term Tests, Others 1 (if applicable & describe in notes), Others 2 (if applicable & describe in notes), Others 3 (if applicable & describe in notes), Final Exam	0, 0, 50, 50, 0, 0, 0, 0, 0