Course Archive AY2015

Degree Completion Requirements for AY2015/2016

The OIST Graduate School offers an integrated doctoral program leading to the degree of Doctor of Philosophy (PhD). The degree of PhD is a research postgraduate degree. Such a degree shall be awarded to a candidate who

1. meets admission requirements and receives and accepts an offer of admission, and is registered as a full-time PhD student for a minimum of three years and not more than ten years; and
2. satisfactorily completes prescribed work amounting to at least 30 credits (20 from courses, 10 from research work) or alternatively, has obtained the equivalent number of credits based on prior study; and
3. presents a successful thesis representing the result of the candidates research which should constitute an original contribution to knowledge and contain material worthy of publication; and
4. satisfies the examiners in an oral examination in matters relevant to the subject of the thesis.

Note 1: credits based on prior study can be waived up to a maximum of 10 elective credits to recognise relevant prior learning, at the advice of the mentor and with approval of the graduate school. This is not a guarantee that such waiver will be made.

Note 2: a published paper or manuscript ready for publication from the research work presented in the thesis shall be appended to the examination version of the thesis to denote that the "material is worthy of publication".

Note 3: after successful examination of the written thesis, a thesis defence is conducted before two external examiners on-site in an oral exam. A public presentation of the thesis is required, and takes place immediately preceding the closed examination.

Courses delivered AY2015/2016

A101 Adaptive Systems

Coordinator	Doya, Kenji
Description	This course aims to provide common mathematical frameworks for adaptation at different scales and to link them with biological reality of control, learning, and evolution. We will look at different classes of adaptation problems using real-world examples of robot control, web searching, gene analysis, imaging, and visual receptive fields.
Aim	Introduction to machine learning algorithms and their application to modeling and analysis of biological systems.

Type	Elective
Credit	2
Assessment	Midterm Reports 60% (2 x 30%), Final Exam 40%.
Text Book	Pattern Recognition and Machine Learning. Bishop (2006) Springer, New York
Reference Book	Matlab for Neuroscientists: An Introduction to Scientific Computing in Matlab I, by Wallisch et al. (2008) Academic Press

Detailed Content

1. Introduction: variety of learning and adaptation
2. Probability theory: entropy, information, Bayes theorem
3. Pattern classification
4. Function approximation
5. Kernel methods
6. Clustering, Mixture Gaussian, EM algorithm
7. Principal Component Analysis, Self-organizing map
8. Graphical models, Belief propagation
9. Sampling methods, Genetic algorithms
10. Kalman filter, Particle filter
11. Reinforcement learning, Dynamic programming
12. Decision theory, Game theory
13. Multiple agents, Evolutionary stable strategies
14. Communication and cooperation
15. Presentation and discussion

A102 Mathematical Methods of Natural Sciences

Coordinator	Miller, Jonathan
Description	This course develops advanced mathematical techniques for application in the natural sciences. Particular emphasis will be placed on analytical and numerical, exact and approximate methods, for calculation of physical quantities. Examples and applications will be drawn from a variety of fields. The course will stress calculational approaches rather than rigorous proofs. There will be a heavy emphasis on analytic calculation skills, which will be developed via problem sets.

Aim	To develop expertise in application of advanced mathematical methods for natural scientists

Type	Elective
Credit	2
Assessment	Homework 60%, Midterm Exam 20%, Final Exam 20%
Text Book	Advanced Mathematical Methods for Scientists and Engineers, Bender and Orszag (1999) Springer A Guided Tour of Mathematical Physics, Snieder. At: http://samizdat.mines.edu/snieder/ Mathematics for Physics: A Guided Tour for Graduate Students, Stone and Goldbart (2009) Cambridge.
Reference Book	1. Basic Training in Mathematics. R. Shankar. Plenum, 1995. 2. Geometrical methods of mathematical physics. B. Schutz. Cambridge, 1999. 3. Statistical Field Theory. G. Mussardo. Oxford, 2009. 4. Statistical Mechanics: Entropy, Order Parameters and Complexity J.P. Sethna. Oxford, 2008

Detailed Content

1. Complex Analysis I: Introduction to complex analysis: analytic functions.

2. Complex Analysis II: Cauchy Theorem and contour integration.

3. Complex Analysis III: Numerical methods in complex analysis.

4. Linear algebra I: Advanced eigenvalues and eigenvectors.

5. Linear algebra II: Numerical methods.

6. Ordinary differential/difference equations (ODDE) I: Properties and exact solutions.

7. ODDE II: Approximate solutions.

8. ODDE III: Numerical solution.

9. Asymptotic expansion of sums and integrals I: elementary methods.

10. Asymptotic expansion of sums and integrals II: steepest descents.

11. Perturbation methods.

12. Boundary layer theory.

13. WKB theory.

14. Vector fields. Stokes theorem.

15. Green's functions.

A201 Quantum Mechanics

Coordinator	Konstantinov, Denis
Description	Basic course in nonrelativistic quantum mechanics. Wave functions and the Schrödinger Equation; Hilbert space; central forces and angular momentum; one-dimensional problems including particle in box, tunneling, and harmonic oscillator; hydrogen atom; Pauli principle; scattering; electron spin; Dirac notation; matrix mechanics; the density matrix; time-independent perturbation theory; Heisenberg picture; time-dependent perturbations; degenerate harmonic oscillators; electrons in a uniform magnetic field; quantized radiation field; absorption and emission of radiation; symmetry principles, entanglement.
Aim	To introduce students to basic concepts and techniques in quantum mechanics

Type	Elective
Credit	2
Assessment	Homework: 30%, Midterm Exam: 35%, Final Exam: 35%.
Text Book	J.J. Sakurai "Modern Quantum Mechanics"; R. Shankar "Principles of Quantum Mechanics"; David J. Griffiths "Introduction to Quantum Mechanics"
Reference Book	G. Baym "Lectures on Quantum Mechanics"; Landau and Lifshitz "Course of Theoretical Physics: Vol. II, Quantum Mechanics"

Detailed Content

1. Introduction. Experimental motivations. Wave-particle duality.

2. State vector and complex vector space. Measurements and observable. Compatible and incompatible observables. Matrix representation of state vectors and operators.

3. Translation transformation and operator of momentum. Coordinate and momentum representation. Wave packets. Uncertainty relation for coordinate and momentum.

4. Time evolution of state vector. Schrodinger equation for time- evolution operator. Time-energy uncertainty relation. Heisenberg picture. Ehrenfest's theorem.

5. Wave equation. One –dimensional problems. Potential barrier. Scattering. Quasi-classical approximation. Bohr-Sommerfeld quantization rule. Tunneling through potential barrier.

6. One-dimensional harmonic oscillator. Raising and lowering operator formalism. Coherent states of quantum harmonic oscillator.

7. Charged particle in electro-magnetic fields. Gauge transformation. Aaronov-Bohm effect. Electrons in a uniform magnetic field.

8. Rotation transformation and angular momentum. Eigenvalues and eigenstates of angular momentum operators.

9. Particle in central potential and method of separation of variables. Hydrogen atom.

10. Total angular momentum. Spin-1/2 particles and Pauli matrices. Dynamics of spin in a uniform magnetic field. Addition of angular momenta. Spin-orbit interaction.

11. Systems consisting of identical particles. Spin-exchange interaction. Second quantization formalism.

12. Conservation lows in quantum mechanics. Space inversion and time reversal symmetries. Discrete translation symmetry and Bloch theorem.

13. Approximation methods in quantum mechanics. Variational method. Time-independent perturbation theory. Hydrogen atom in electrical field. Relativistic corrections to energy levels in Hydrogen atom.

14. Time-dependent perturbation theory. Interaction of particle with radiation field (semi-classical theory). Selection rules. Quantization of radiation field. Strong coupling regime and Jaynes-Cummings model.

15. Open systems. Mixed ensembles and density matrix formalism.

A202 Fluid Dynamics

Coordinator	Mitarai, Satoshi
Description	This course introduces students to the fundamental laws that characterize fluids at rest and in motion. The equations for the conservation of mass, for momentum balance, and for conservation of energy are analyzed in control volume and, to some extent, in differential form. Students will learn to select appropriate models and solution procedures for a variety of problems. Flow phenomena that occur in actual flow situations are also illustrated, so that students will learn to assess the strengths and limitations of the models and methods.
Aim	To introduce basic fluid dynamics skills that may be applied to problems in the life sciences and environmental sciences. The course is aimed at biologists rather than physicists, although physicists interested in a refresher course in basic fluid dynamis may apply.

Type	Elective
Credit	2
Assessment	Homework: 20%, Midterm Exams: 2 x 30%, Final Exam, 20%.
Text Book	Fundamentals of Fluid Mechanics, by Munson, Young, Okiishi and Huebsch (6th Edition)

Reference Book	Multi-Media Fluid Mechanics, by G. M. Homsy et al., Cambridge University Press. An Album of Fluid Motion by Milton van Dyke, Parabolic Press.

Note: This course is designed for biologists rather than physicists. Students must have completed Maths I and Maths II, or be able to demonstrate equivalent mathematical knowledge and expertise.

Detailed Content

1 Introduction (Background, Definitions, general concepts, etc)

2 Fluid Statics (Hydrostatic balance, pressure forces on objects)

3 Fluid Statics (Effects of constant acceleration or rotation)

4 Bernoulli Equation (Use of Newton's second law)

5 Bernoulli Equation (Pressure and its measurement)

6 Fluid Kinematics (Description of velocity field)

7 Fluid Kinematics (Control volume, system representations)

8 Fluid Kinematics (Reynolds transport theorem)

9 Control volume Analysis (Conservation laws)

10 Control volume Analysis (Many applications)

11 Dimensional Analysis (Dynamic similarity)

12 Dimensional Analysis (Pi theorem, Applications)

13 Flow in Pipes, Ducts, Etc. (Laminar and turbulent pipe flow, etc)

14 Flow Around Objects (Boundary layers & potential flow, etc)
15 Compressible Flow (Mach number, sound speed, etc)

A204 Condensed Matter

Coordinator	Busch, Thomas
Description	This topic explores an emerging interface involving strongly correlated systems in atomic and condensed matter physics. Topics include bosonic and fermionic Hubbard models, quantum spin systems, low dimensional systems, non-equilibrium coherent dynamics and system-bath interactions, Fermi surfaces, Bloch waves, the Ising model, and quantum computing. Special attention will be paid to the physics of ultracold atoms.
Aim	To introduce students to the modern physics of condensed matter.

Type	Elective
Credit	2

Assessment	Homework: 40%, Journal Club: 40%, In-term Exams: 20%.
Text Book	Quantum Theory of Solids, 2 edn, by Charles Kittel (1987) Wiley. Solid State Physics, 2 edn, by Ashcroft and Mermin (2002) Holt Rinehart & Winston
Reference Book	Principles of the Theory of Solids, 2 edn, by J Ziman (1979) Cambridge University Press

Detailed Content

1. Quantum Phase Transitions
2. Bloch States, Bloch Waves, Bloch Oscillations
3. Optical Lattices
4. Quantum Simulators
5. Hubbard models (bosonic, fermionic, mixed)
6. Bogoliubov Theory
7. Numerical Methods
8. Low dimensional systems, strong correlations, Bethe Ansatz
9. Quantum Spin Systems
10. High Tc Superconductors, BCS theory
11. Artificial Gauge Fields (abelian and non-abelian)
12. Quantum Hall Effect (integer and fractional)
13. Quantum Information
14. Measurement

A205 Quantum Field Theory

Coordinator	Hikami, Shinobu
Description	This course covers quantum electrodynamics and chromodynamics. Topics include canonical quantization, Feynman diagrams, spinors, gauge invariance, path integrals, identical particles and second quantization, ultraviolet and infrared divergences, renormalization and applications to the quantum theory of the weak and gravitational forces, spontaneous symmetry breaking and Goldstone bosons, chiral anomalies, effective field theory, non-Abelian gauge theories, the Higgs mechanism, and an introduction to the standard model, quantum chromodynamics and grand unification.
Aim	To introduce students to basic concepts and techniques in relativistic quantum field theory.

Type	Elective
Credit	2
Assessment	Homework: 60%, Final Exam, 40%
Text Book	A First Book in Quantum Field Theory, by Lahiri and Pal (2005) Alpha Science International A Modern Introduction to Quantum Field Theory, by Michele Maggiore (2005) Oxford University Press.
Reference Book	Quantum Field Theory, by Michio Kaku (1993) Oxford University Press. An Introduction to Quantum Field Theory, by Peskin and Schroder (1995) Westview Press. Gauge Theories in Particle Physics, Vol. I and II, by Aitchison and Hey (2004) Institute of Physics

Detailed Content

1. An electron in a uniform electromagnetic field: Landau levels
2. Canonical Quantization
3. Antiparticles
4. Particle decay
5. Feynman rules and the S-matrix
6. Weyl and Dirac spinors
7. Gauge Theories
8. Quantization of the electromagnetic field
9. Symmetry breaking
10. Path integrals
11. Aharonov-Bohm effect
12. Renormalization
13. Quantum chromodynamics
14. Nuclear forces and Gravity
15. Field unification

A206 Analog Electronics

Coordinator	Dorfan, David / Qi, Yabing
Description	A practical course to train students in the design and construction of analog electronic circuits, based on the classic text The Art of Electronics. Conceptual understanding of the key elements of analog circuits will be reinforced by significant project work in the electronics workshop. Although very little device physics will be taught, the course provides sufficient theory to design and analyze analog electronic circuits, with extensive project work to enable students to become familiar with circuit construction.

Aim	A project-based course to provide theory and practice in design, analysis, and construction of modern analog electronic circuits

Type	Elective
Credit	2
Assessment	Projects 3 x 25% ; final exam 25%
Text Book	The Art of Electronics, 2 edn, Horowitz and Hill (1989) Cambridge University Press The Art of Electronics Laboratory Manual, Horowitz and Robinson (1981) Cambridge University Press
Reference Book	The Art of Electronics Student Manual, Hayes and Horowitz (1989) Cambridge Analysis and Design of Analog Integrated Circuits, 5 edn, Gray, Hurst, Lewis and Meyer (2009) Wiley The Electrical Engineering Handbook, 2 edn, Richard C Dorf (1997) CRC Press

Detailed Content

1. Passive components. Current and voltage sources, Thevenin and Norton equivalent circuits. Diodes. (Ebers Moll equation)
2. The bipolar transistor, transconductance and its use in making efficient current and voltage sources.
3. Common emitter, common base, amplifiers. Differential amplifiers, current mirrors.
4. Push pull and other outputs, as well as some other useful circuits. Miller effect.
5. Thermal behavior of transistors; circuit temperature stability.
6. Field effect transistors and analog switches.
7. Operational Amplifiers and basic op amp circuits.
8. Negative feedback.
9. Sample and hold, track and hold, circuits. Further applications of op amps.
10. Filters
11. Voltage Regulators
12. Noise, noise reduction, transmission lines, grounding, shielding,
13. Lock in amplifiers.
14. Instrumentation amplifiers.
15. Analog to Digital conversion.

A207 Nanotechnology

Coordinator	Sowwan, Mukhles
Description	This course covers the Nanotechnology revolution in science and engineering that is leading to novel ideas about the way materials, devices, and systems are designed, made and used in different applications. We cover the underlying principles of the multidisciplinary and very diverse field of nanotechnology, and introduce the concepts and scientific principles relevant at the nanometer scale. Then we provide a comprehensive discussion of the nanomaterials, including characterization techniques and the effect of size on their structural, physical, and chemical properties and stability. In addition we discuss the current and future applications of Nanotechnology in different fields such as materials engineering, medicine, electronics, and clean energy.
Aim	Advanced course in the science and applications of nanomaterials and nanoengineering.

Type	Elective
Credit	2
Assessment	Participation and Homework 10%; Presentations 30%; Project 60%.
Text Book	Handbook of Nanoscience Engineering and Technology, Edited by Goddard, Brenner, Lyshevski, Iafrate (2003) CRC press
Reference Book	Nanotechnology: A Gentle Introduction to the Next Big Idea, by Ratner and Ratner (2002) Prentice-Hall Nanostructures & Nanomaterials: Synthesis, Properties & Applications, Cao and Wang (2004) Imperial College Press Encyclopedia of Nanotechnology, Edited by Bhushan and Bharat (2012) Springer

Detailed Content

1, 2. Introduction to Nanotechnology and its applications (2 lectures)
History, State of the art nanotechnology, applications in different fields
3, 4. Surface imaging and visualizations (2 lectures)
SPM, SEM, TEM
5, 6. Conventional Nanofabrication (2 lectures)
Microfabrication, e-beam lithography, photolithography, micro and nanoelectronics
7, 8. Non-conventional nanofabrication (2 lectures)
Nanoimprint lithography, bottom top fabrication
9 – 13. Nanomaterials: Synthesis, properties and application (5 lectures)
Nanoparticles, nanorods, nanocrystals, nanobiomaterials , nanostructured thin films
14, 15. Nanosystems and self-assembly (2 lectures)
Self assembly of hybrid systems, bioorganic/inorganic inspired nanodevices

A208 Bioorganic Chemistry

Coordinator	Fujie Tanaka
Description	This course covers essential concepts and recent advances in the design and synthesis of functional molecules used for understanding and controlling biological systems. Topics of this course include design and synthesis of small organic molecules, organic reactions, methods for controlling reaction pathways, asymmetric synthesis, mechanisms of catalysis and molecular recognition, and creation of designer proteins and peptides.
Aim	To discuss design and synthesis of functional molecules used for understanding and controlling biological systems.

Type	Elective
Credit	2
Assessment	Exercises 50%, reports 50%
Text Book	Advanced Organic Chemistry, Part A: Structures and Mechanisms, Part B: Reactions and Synthesis, 5th edn, Carey and Sundberg (2007)
Reference Book	Lehninger Principles of Biochemistry, Nelson and Cox (2008) Modern Physical Organic Chemistry, Anslyn and Dougherty (2005) The Organic Chemistry of Drug Design and Drug Action, 2nd edn, Silverman (2004) Strategic Applications of Named Reactions in Organic Synthesis, Kurti and Czako (2005) Modern Methods of Organic Synthesis, 4th edn, Carruthers and Coldham (2004)

Detailed Content

1. Methods of chemical transformations to access designer molecules
2. Strategies for the development of new reaction methods including stereoselective reaction methods
3. Asymmetric reactions and asymmetric catalysis
4. Catalytic enantioselective reactions: Carbon-carbon bond forming reactions
5. Catalytic enantioselective reactions: hydrolysis, reduction, dynamic kinetic resolutions, etc.
6. Design and synthesis of functional molecules
7. Chemical mechanisms of bioactive molecules including chemistry of enzyme inhibitors
8. Molecular recognition and non-covalent bond interactions
9. Enzyme catalysis and catalytic mechanisms
10. Enzyme catalysis and small organic molecule catalysis
11. Enzyme kinetics and kinetics of non-enzymatic reactions
12. Strategies for the development of new designer catalysts
13. Methods in identification and characterization of organic molecules
14. Strategies for the development of designer functional proteins and peptides
15. Chemical reactions for protein labeling; chemical reactions in the presence of biomolecules

A209 Ultrafast Spectroscopy

Coordinator	Keshav Dani
Description	This course will be an introductory graduate level course to initiate students into the techniques of ultrafast spectroscopy. They will be introduced to the basic concepts underlying sub-picosecond phenomena in nature (ultrafast chemical processes, femtosecond electron dynamics in materials, etc.) and the tools used to study such phenomena (pump-probe spectroscopy, Terahertz Time Domain Spectroscopy, etc.).
Aim	This course provides an overview of the modern methods and applications in ultrafast spectroscopy.

Type	Elective
Credit	2
Assessment	Homework and Exercises, 80%; End of Class Presentation, 20%
Text Book	No text set, students will work from primary sources that will be advised
Reference Book	

Detailed Content

1. Introduction, History and Development:
2. Basic Concepts
3. Understanding Ultrafast Pulses:
4. Spectrum, Fourier Transform, Uncertainty Principle, wavelength, repetition rate
5. Understanding Ultrafast Pulses & Capabilities:
6. Time Resolution, Nonlinearities,
7. Ultrafast pulse measurement: Spectrum, Phase, Amplitude, Intensity
8. Ultrafast pulse measurement: AutoCorrelation, FROG, SPIDER
9. Ultrafast Techniques: Pump Probe, Four-Wave Mixing, or others.
10. Ultrafast Techniques: Time Resolved Fluorescence, Up-converstion, or others.
11. Ultrafast Techniques: THz-TDS, Higher Harmonic Generation, or others.
12. Ultrafast Techniques: Single Shot Measurements, etc.
13. Applications: e.g. Condensed Matter Physics
14. Applications: e.g. Chemistry and Materials Science
15. Applications: e.g. Biology

A211 Advances in Atomic Physics

Professor Sile Nic Chormaic

Assessment

Continuous Assessment: 40%, Midterm Exams: 2 x 15%, Final Exam, 30%.

Description

Advanced level course in atomic physics. Progress in laser control of atoms has led to the creation of Bose-Einstein condensates, ultrafast time and frequency standards and the ability to develop quantum technologies. In this course we will cover the essentials of atomic physics including resonance phenomena, atoms in electric and magnetic fields, and light-matter interactions. This leads to topics relevant in current research such as laser cooling and trapping.

Detailed description

1 Early atomic physics
2 The hydrogen atom and atomic transitions
3 Helium and the alkali atoms
4 LS coupling
5 Hyperfine structure
6 Atom interactions with radiation
7 Laser spectroscopy
8 Laser cooling and trapping
9 Bose-Einstein condensation
10 Fermionic quantum Gases
11 Atom interferometry
12 Ion traps
13 Practical elements: Laser spectroscopy
14 Practical elements: Laser cooling of Rb
15 Applications: Quantum computing

Aim

To introduce students to recent advances in atomic physics

Resources

Advances in Atomic Physics: An Overview by Cl. Cohen-Tannoudji and D. Guery-Odelin, World Scientific (2011); Atomic Physics by C.J. Foot, Oxford (2013); Introductory Quantum Optics by C.C. Gerry and P. L. Knight, Cambridge (2005).

A212 Microfluidics

Professor Amy Shen

Assessment

Homework: 20%, Midterm Exam: 30%, Lab: 20%, Course Project: 30%

Description

The interface between engineering and miniaturization is among the most intriguing and active areas of inquiry in modern technology. The aim of this course is to illuminate and explore microfluidics as an interdisciplinary research area, with an emphasis on emerging microfluidics disciplines, including molecular assembly to bulk and device level scales, with applications in novel materials synthesis, bio-microtechnology and nanotechnology.

The course will begin by highlighting important fundamental aspects of fluid mechanics, scaling laws and flow transport at small length scales. We will examine the capillary-driven, pressure-driven, and electro-kinetic based microfluidics. We will also cover multi-phase flow, droplet-based microfluidics in microfluidics. This course will also illustrate standard microfabrication techniques, micro-mixing and pumping systems.

Detailed description

Introduction to microfluidics; Scaling analysis
Low Reynolds number flows
Pressure-driven microfluidics
Capillary-driven microfluidics
Microfabrication
Diffusion in microfluidics
Mixing in microfluidics
Droplet microfluidics and 2-phase flows
Bio-MEMs

Aim

To introduce students to fundamental fluid transport physics at the micron and nanometer scale for applications in micro/nanofluidic devices. This course will also illuminate and explore microfluidics as an interdisciplinary research area, with an emphasis on emerging microfluidics disciplines.

Other

Fundamentals and Applications of Microfluidics by Nam-Trung Nguyen and Steve Wereley, Artech House; 2002. Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, by Brian Kirby, Cambridge University Press, 2013.

Resources

Introduction to Microfluidics by Patrick Tabeling, 2010, Oxford University Press

A303 Developmental Biology

Coordinator	Masai, Ichiro
Description	This course introduces fundamental principles and key concepts in the developmental processes of animal organisms, by focusing on Drosophila embryonic development and vertebrate neural development as models, and will facilitate graduate students to reach a professional level of understanding of developmental biology. Furthermore, genetic tools for live imaging of fluorescence-labeled cells using Drosophila and zebrafish embryos will be introduced as practical exercises. The course also includes debate on specific topics in developmental biology by students and a writing exercise of mock-grant application. Some lecturers outside OIST will be invited to present particular special topics.

Aim	This lecture series will introduce fundamental principles governing development of animal organisms and current research topics

Type	Elective
Credit	2
Assessment	Participation 20%; Written Report 40%; Presentation 40%
Text Book	Principles of Development 2 edn, Lewis Wolpert (2010) Oxford University Press Developmental Biology 9 edn, Scott F. Gilbert (2010) Sinauer Development of the Nervous System 3 edn, Sanes, Reh, Harris (2011) Academic Express
Reference Book	

Detailed Content

1. Basic concepts of developmental biology, and introduction of model systems
2. Development of the Drosophila embryonic body plan
3. Organogenesis
4. Patterning of vertebrate body plan
5. Morphogenesis
6. Cell fate decision in the vertebrate nervous system
7. Current topics of neuronal specification and multipotency of neural stem cells
8. Axon guidance, target recognition
9. Synaptogenesis
10. A model for neurodegeneration in Drosophila
11. Debate of topics of developmental biology by students
12. Debate of topics of developmental biology by students
13. Debate of topics of developmental biology by students
14. Genetic tools for live imaging of fluorescence-labeled cells using Drosophila
15. Genetic tools for live imaging of fluorescence-labeled cells using zebrafish

A304 Evolutionary Developmental Biology

Coordinator	Satoh, Noriyuki
Description	The course presents the most recent theory and techniques in evolutionary and developmental biology with an emphasis on the underlying molecular genomics. Recent advances in decoding the genomes of various animals, plants and microbes will be followed, with a discussion on comparative genomics, the evolution of transcription factors and signal transaction molecules and their relation to the evolution of the various complex body plans present through history.

Aim	To introduce basic concepts of Evo-Devo that are essential to understand the diversity of animal body plans.

Type	Elective
Credit	2
Assessment	Homework (20%), Written reports (4 x 20%).
Text Book	From DNA to Diversity, 2 edn, by Carroll, Grenier and Weatherbee (2005) Blackwell.
Reference Book	

Detailed Content

1 Introduction (background, general concepts, etc)
2 History of animals (fossil records, phylogenic tree)
3 History of animals (genomics, molecular phylogeny)
4 Genetic toolkits (developmental concepts)
5 Genetic toolkits (Hox complex)
6 Genetic toolkits (genetic toolkits, animal design)
7 Building animals (lower metazoans)
8 Building animals (protostomes)
9 Building animals (deuterostome and vertebrates)
10 Evolution of toolkits (gene families)
11 Diversification of body plans (body axis)
12 Diversification of body plans (conserved and derived body plans)
13 Evolution of morphological novelties
14 Species diversification
15 Phylum diversification

A306 Neuroethology

Coordinator	Yoko Yazaki-Sugiyama
Description	The course provides an understanding of the neuronal mechanisms that underlie animal behavior. We will study the neuronal mechanisms for specialized animal behaviors such as sensory processing, motor pattern generation, and learning by reading original papers, which also provide an understanding of experimental technique. The course further discusses the evolutionary strategy and the biological ideas of animal behavior and underlying neuronal mechanisms.
Aim	To introduce an understanding of the neuronal mechanisms that control complex animal behavior.

Type	Elective
Credit	2
Assessment	Homework, 20%; Written reports, 4 x 20%.
Text Book	Behavioral Neurobiology, by Thomas J Carew (2000) Sinauer
Reference Book	

Detailed Content

1. Introduction (Basic Neurophysiology and neuronal circuits)
2. Sensory information I: Visual and Auditory (map formation, plasticity and critical period, etc.)
3. Sensory information II: Olfactory (Chemical) and other senses
4. Sensory perception and integration I (Echolocation, Sound localization, etc.)
5. Sensory perception and integration II (Sensory navigation, etc.)
6. Motor control I (Stereotyped behavior)
7. Motor control II (Central pattern generator)
8. Sexually dimorphic behavior
9. Learning I (Learning and memory)
10. Learning II (Associative learning)
11. Learning III (Sensory motor learning during development)
12. Learning VI (Spatial navigation)
13. Behavioral plasticity and the critical period
14. Recent techniques in neuroethology

A307 Molecular Oncology and Cell Signaling

Coordinator	Tadashi Yamamoto
Description	This course consists of lectures and exercises. First, students learn, through lectures, recent progress in cancer research and the mechanism of carcinogenesis based on the molecular and cellular functions of oncogenes and anti-oncogenes. Further, students will learn the relevance of signal transduction, cell cycle progression, cell adhesion, and gene regulation to tumor development and are encouraged to simulate effective methods of diagnosis and treatment of cancer. Further, through exercises, students will consider the relevance of genome sciences and systems biology to cancer research. Students are encouraged to refer to the textbook and to papers from the current literature. The course will also present special novel and important topics from year to year.

Aim	This advanced course aims to develop a deep understanding of tumor development, based on recent research developments in the molecular and cellular biology of cancer.

Type	Elective
Credit	2
Assessment	Oral presentation of paper, 50%; Research report, 50%.
Text Book	The Biology of Cancer, by Weinberg (2006) Garland Science Molecular Biology of the Cell, 5 ed, by Alberts, Johnson, Lewis, Raff, Roberts and Walter (2007) Garland Science
Reference Book	The Molecules of Life, by Kuriyan, Konforti, and Wemmer (2012) Garland Science Biochemistry, 7 ed, by Berg, Tymoczko, and Stryer (2010) WH Freeman & Company

Detailed Content

1. Historical background of molecular oncology
2. Viruses, chemical carcinogens, and tumor development
3. RNA tumor viruses and oncogenes
4. Discovery of anti-oncogenes
5. Regulation of signal transduction and cell cycle progression by oncogenes and anti-oncogenes
6. Roles of oncogenes and anti-oncogenes in normal physiology
7. Molecular mechanisms of metastasis
8. Genome, proteome, metabolome, and cancer
9. Animal models of cancer
10. Drug development for cancer treatment
11. Cancer stem cells
12. microRNA and cancer development
13. Genome sciences in cancer research
14. Systems biology in cancer research

A308 Epigenetics

Coordinator	Hidetoshi Saze
Description	Epigenetic regulation of gene activity is essential for development and response to environmental changes in living organisms. This course introduces fundamental principles and key concepts of epigenetics, and original research publications

	contributed to understanding the mechanism underlying the epigenetic phenomena will be reviewed. Lecturers from outside OIST may be invited for specific topics.
Aim	This course provides an overview of the principles of epigenetics to students with background of molecular biology and genetics.

Type	Elective
Credit	2
Assessment	Participation 50%; Presentation, 50%.
Text Book	Epigenetics, by Allis, Jenuwein, Reinberg, Caparros (2006) Cold Spring Harbor Laboratory Press
Reference Book	Molecular Biology of the Cell, 5 edn, by Alberts et al. (2007) Garland Science Introduction to Genetic Analysis, 10 edn, by Griffiths et al. (2010) W.H. Freeman and Company

Detailed Content

1. Introduction to Epigenetics
2. Histone variants and modifications
3. DNA methylation
4. RNA interference and small RNA
5. Regulation of chromosome and chromatin structure
6. Transposable elements and genome evolution I
7. Transposable elements and genome evolution II
8. Epigenetic regulation of development I
9. Epigenetic regulation of development II
10. Genome imprinting
11. Dosage compensation I
12. Dosage compensation II
13. Epigenetic reprogramming and stem cells
14. Epigenetics and disease
15. Epigenomics

A309 Quantitative Molecular Biology

Coordinator	Tatiana Márquez-Lago

Description	“What does this experiment tell us?” and “Can I actually use this data for the model I am trying to construct?” These are two prototypical questions from students who wish to conduct research associated with molecular biology, but have little or no experience with the techniques. This course will answer such questions in the context of commonly used experimental approaches. The course will not include any hands-on training with laboratory equipment. Instead, it will solely focus on what each method is useful for, enabling students to understand why and how experiments can be used to draw specific conclusions. Furthermore, students will be able to identify which experiments could be done to confirm specific hypotheses from models, facilitating their communication with experimental labs. Case studies will be chosen from the literature for each topic, and will mainly focus on gene expression and synthetic biology applications.
Aim	This course provides an overview of quantitative experimental methods commonly used in Molecular Biology, and links how experimental outputs can be used in mathematical models. The course is primarily intended for students with a background in the Mathematical, Computational or Physical Sciences who are interested in conducting research in Systems and Synthetic Biology.

Type	Elective
Credit	2
Assessment	Participation 30%; Presentations, 40%; Final exam/project (30%).
Text Book	Working from primary sources, students will be advised on specific readings
Reference Book	

Detailed Content

1. Introduction and general aims. Classic study organisms (pros and cons for quantitative analysis)
2. Basic lexicon and laboratory navigator I
3. Laboratory navigator II
4. Extraction / purification techniques. Gel electrophoresis and detection.
5. Hybridization techniques
6. Immunostaining and immunoprecipitation techniques
7. Sequencing techniques
8. Microarrays
9. Mass spectrometry
10. Microscopy essentials
11. Flow cytometry and cell sorting
12. Topics in gene expression
13. Inducible systems vs. repressible systems. Construction of gene circuits
14. Synthetic Biology topics I and II.

Requires B06 Cell Biology (or knowledge of gene regulation processes, cell division and recombinant DNA) and B03 Mathematics I (or higher, preferably).

Ideally taken with A301 Signal Transduction

A310 Computational Neuroscience

Coordinator	Erik De Schutter
Description	Computational neuroscience has a rich history going back to the original Hodgkin-Huxley model of the action potential and the work of Wilfrid Rall on cable theory and passive dendrites. Nowadays standard simulator software exists to apply these modeling methods, which can then be used to interpret and predict experimental findings. This course introduces the standard modeling methods with an emphasis on simulation of single neurons and synapses and of small circuit and networks. Each theoretical topic is linked to one or more seminal papers that will be discussed in class. The corresponding models are made available in the NEURON simulator together with simple exercises to solve with the model.
Aim	This course introduces basic concepts and methods of computational neuroscience based on theory and a sampling of important scientific papers.

Type	Elective
Credit	2
Assessment	Discussions in class, 40%; Written exercises, 20%; Report on a student-selected modeling paper, 40%.
Text Book	Biophysics of Computation, by Christof Koch (1999) Oxford Press Computational Modeling Methods for Neuroscientists, edited by Erik De Schutter (2010) MIT Press
Reference Book	

Detailed Content

1. Introduction and the NEURON simulator
2. Basic concepts and the membrane equation
3. Linear cable theory and passive dendrites
4. Synapses and passive synaptic integration
5. Ion channels and the Hodgkin-Huxley model
6. Neuronal excitability and phase space analysis
7. Exercise evaluations and discussion of student selected modeling papers
8. Reaction-diffusion modeling and calcium dynamics
9. Active dendrite modeling and parameter searching

10. Integrate-and-fire neurons and network modeling
11. Oscillations and microcircuit modeling
12. Large-scale network modeling
13. Exercise evaluations and discussion of student selected modeling papers

Requires prior B03 Mathematics I, B04 Mathematics II and B05 Neurobiology or similar background knowledge

A401 Controversies in Science

Coordinator	Arbuthnott, Gordon
Description	The course Controversies in Science aims to develop critical thinking and argument, essential skills for effective independent scientists. The course will be flexible in content and presentation. Invited lecturers will present topics of some controversy or recent interest in science and lead debates by the students. We will also look at some historical controversies in different fields such as neuroscience and genetics, in which we will assign students to take sides by reading only one side of a specific argument, and encourage them to discuss the issue and arrive at a resolution in class.
Aim	This course aims to develop the argument and critical powers of scientists by examining the scientific process and its relation to knowledge, and looking at a wide range of topics of moral controversies in science.

Type	Elective
Credit	2
Assessment	Participation and contribution to discussion and debate.
Text Book	Scientific Controversies: Case Studies in the Resolution and Closure of Disputes in Science and Technology, by Engelhardt and Caplan (1987) Cambridge University Press
Reference Book	Doubt: A History: The Great Doubters and Their Legacy of Innovation from Socrates and Jesus to Thomas Jefferson and Emily Dickinson, by JW Hecht (2004)

Detailed Content

1. The Scientific Method, Ockham's Razor, Basic Philosophy of Science

2. Boundaries of Science, L'Affaire Sokal, "Crackpots"

3. Science & Racism in 1940s Germany and Japan

4. Science and Capitalism: the pharmaceutical industry & biomedical science

5. Science and Communism: Lysenko

6. Scientific Misconduct I: Piltdown Man

7. Scientific Misconduct II: Recent Cases

8. Insights ahead of their time: Mendel and others

9. Paradigm shifts: the reception of evolutionary biology

10. Science and Religion: opposition to evolution

11. Science and the media: the case of the autism-vaccination link, and others

12. Science and the law: the suppression of psychedelics research

13. Science and war: the making of the nuclear bomb

14. The animal rights movement and science

15. Conclusions: science as a social enterprise

A402 Computational and Mathematical Biology

Coordinator	Kitano, Hiroaki / Goryanin, Igor
Description	Computational approaches to science in general, and particularly in biology, are an increasingly important topic. However, understanding the concepts behind such computational approaches in biology is particularly difficult due to discrepancies in the methodologies and languages that are used. This course covers basics of computational and mathematical biology with strong emphasis on understanding of computational foundation and practical modeling of metabolic networks and signal transduction networks. Students are expected to actively participate in hands-on modeling sessions. A series of numerical computation, statistical, and intelligent systems approaches will be shown in the context of computational biology. The course will introduce standards used in the field such as SBML, SBGN, BioPAX, and MIRIAM, and students will gain direct experience in modeling sessions using CellDesigner (http://www.celldesigner.org/) and PhysioDesigner (http://www.physiodesigner.org/).
Aim	The goal of this course is to provide basic exposure to computational and mathematical thinking about basic biological processes and learn how to construct models and analyze them for biological studies.

Type	Elective
Credit	2
Assessment	Written report, 50%; Project, 50%.
Text Book	Systems Biology: A Textbook by Klipp, Liebermeister, Wierling, Kowald, Lehrach, and Herwig (2009) An Introduction to Systems Biology: Design Principles of Biological Circuits, by Uri Alon (2006)

	Kinetic Modelling in Systems Biology, by Oleg Demin and Igor Goryanin (2008)
Course Dates 2016	Intensive 2-week course, August 2016 (3-4 hours class time per day plus reading and exercises)

Detailed Content

Day 1: Course Overview and Introduction of Computational Biology (Kitano)
Day 2: Computational Foundation of Metabolomics (Goryanin)
Day 3: Metabolic network reconstruction (Goryanin)
Day 4: Metabolic network modeling (Goryanin)
Day 5: Mark up languages: SBML, SBGN (Goryanin)
Day 6: Metabolic Database Resources and development (Goryanin)
Day 7: Metabolic Modeling and Practical applications (Goryanin)
Day 8: Metabolic Pathways Reconstruction and Modeling: Practical Session (Goryanin)
Day 9: Metabolic Pathways Reconstruction and Modeling: Practical Session (Goryanin)
Day 10: Signal Transduction & Metabolic Modeling: Practical Session (Kitano & Groyanin)
Day 11: Signal Transduction Modeling: Practical Session (Kitano)
Day 12: Computational Foundation of Signaling (Kitano)
Day 13: Computational Foundation of Cell Cycle (Kitano)
Day 14: Practical applications of signal transduction modeling (Kitano)
Day 15: Advanced topics in computational biology (Kitano)

A403 Structural Biology: Protein X-ray Crystallography

Coordinator	Samatey, Fadel,
Description	To understand the function of protein at the molecular level, it is always very helpful, if not necessary, to have the 3D structure of proteins. Protein X-ray crystallography is one of the most powerful methods to obtain high-resolution 3D structures of proteins. A successful use of this method requires a good knowledge of the sample (i.e. the protein). This implies using few biophysical and biochemical methods. Prior to starting a project in structural biology, there are many bioinformatics tools that would help to assess the feasibility of the project. Is the protein available? Is the protein soluble? Is the protein stable? These are some of the questions a protein crystallographer asks themself at the start of a project. And the answers come in the form of results of experiments done in biophysics, in biochemistry or in bioinformatics. During the lectures we will look into some of these methods that are very important tools in the field of protein structure.
Aim	This course provides an overview of modern structural biology, with a focus on protein Xray crystallography.

Type	Elective
Credit	2

Assessment	Participation 40%; Regular short reports 30%, Presentation 30%.
Text Book	Methods in Molecular Biophysics, by Serdyuk, Zaccai, Zaccai (2007) Cambridge University Press Protein Crystallography, by Blundell & Johnson (1976) Academic Press
Reference Book	Biomolecular Crystallography: Principles, Practice, and Application to Structural Biology, by Rupp (2009) Garland Science Membrane Structural Biology: With Biochemical and Biophysical Foundations, by Luckey (2008) Cambridge University Press Computational Structural Biology: Methods and Applications, by Schwede and Peitsch (2008) World Scientific Introduction to Protein Architecture: The Structural Biology of Proteins, by Lesk (2001) Oxford University Press

Detailed Content

1. Introduction to protein folding
2. Principles of protein purification
3. Principles of protein crystallization
4. Protein characterization
5. Principles of X-ray crystallography
6. Bioinformatics tools

A404 Measurement

Coordinator	Konstantinov, Denis
Description	Measurement is fundamental to scientists in all disciplines. This course will look at ways to make measurements and to avoid many of the pitfalls encountered in common and unusual measurements. A sound theoretical basis will be provided to allow students to go on to make their own choices with confidence and experience. Topics will include instrumentation, physical noise processes, signal transduction, models of small signal amplification, as well as modulation, detection, synchronous and lock-in detection, signal sampling techniques, digitization, signal transforms, Fourier analysis. Theoretical techniques to be presented will be centered around probability, probability theory, probability distributions, statistical inference, information theory, exact cases, and Gaussians.
Aim	This course describes fundamental problems in measurement and cutting-edge solutions to them.

Type	Elective
Credit	2
Assessment	Projects (2 x 30%) 60%; Final Exam 40%.
Text Book	Modern Instrumentation for Scientists and Engineers, by John Blackburn (2000) Springer Essentials of Mathematical Methods in Science and Engineering, by Selcuk Bayin (2008) Wiley-Interscience
Reference Book	The Art of Electronics 2 edn, by Horowitz and Hill (1989) Cambridge University Press The Electrical Engineering Handbook 2 edn, by Richard C Dorf (1997) CRC Press

Detailed Content

1. Information theory: signals, background and noise.
2. Probability, distributions, Gaussians, Boltzmanns
3. Sample size and Power of analysis
4. Signal sampling techniques
5. Frequency and digitization
6. Fourier and other transforms
7. Instrumentation
8. Amplifiers
9. Modulation
10. Time-locked measurements, synchronous and asynchronous events
11. Analog instruments
12. Noise reduction
13. Small signals
14. Projects
15. Projects

A405 Emerging Technologies in Life Sciences

Coordinator	Maruyama, Ichiro
Description	This course is designed to provide a broad, advanced-level coverage of modern technologies in life sciences for first year PhD students. Topics include recombinant DNA technologies, polymerase chain reactions, DNA sequencing, microfluidics, fluorescent proteins, optical microscopy, and mass spectrometry, among others. Lectures will draw from historical and current research literature with emphasis on development of technologies as life sciences develop. A major goal of this course is to help graduate students accustomed to inventing novel technologies or improving existing technologies in the field of life sciences.
Aim	This course introduces cutting-edge technologies in life science.

Type	Elective
Credit	2
Assessment	Midterm Reports (3 x 20%) 60%; Final Essay 40%
Text Book	An Introduction to Genetic Analysis, 8 edn, by Lewontin, Miler, Suzuki, Gelbart, Griffiths (2004) WH Freeman
Reference Book	Handbook of Biological Confocal Microscopy, 3 edn, Edited by JB Pawley (2006) Springer Principles of Fluorescence Spectroscopy, 3 edn, by JR Lakowicz (2006) Springer

Detailed Content

1. Course Introduction & Nucleotide sequencing I (Background, Basics, PCR & qPCR, etc)
2. Nucleotide sequencing II (Next generation, Genome analysis, etc)
3. Nucleotide sequencing III (RNA sequencing, ChIP, Applications, etc)
4. Microarray I (Background, Basics, DNA chips, etc)
5. Microarray II (Protein chips, Applications, Future development, etc)
6. Confocal laser scanning microscopy I (Basics, Live cell imaging, probes, etc)
7. Confocal laser scanning microscopy II (Multi-color imaging, Multi-photon, etc)
8. Confocal laser scanning microscopy III (Spectral imaging, FRAP, FRET, etc)
9. Confocal laser scanning microscopy IV (PALM, SHIM, STED, etc)
10. Microfluidics I (Background, Basics, Microfabrication, etc)
11. Microfluidics II (Applications, Devices, Future development, etc)
12. Single molecule imaging I (FCS, FCCS, etc)
13. Single molecule imaging II (TIRF、 FLIM, etc)
14. Neuroimaging I (Optical, PET/CT, etc)
15. Neuroimaging II (MRI/fMRI, SPECT, etc)

A409 Electron Microscopy

Coordinator	Matthias Wolf
Description	The course is designed as a mix of introductions into selected topics in the theory of transmission electron microscopy followed by practical demonstrations and hands-on exercises, which provide an opportunity to comprehend the concepts by experimenting with commonly-used image processing software. Students will be required to read and digest scientific papers for a subset of lecture topics on their own, which will subsequently be discussed jointly during student presentations with the goal to immerse them into the subject without passive consumption. The lectures cover several important concepts of the physics of image formation and analysis, which require a basic level of mathematics. An emphasis will be given to highlighting common properties between diffraction and image data and how to take advantage of tools from both techniques during the final image processing projects.
Aim	This course provides an introduction into electron microscopy techniques and applications in biology. Participants will obtain the background knowledge for critical

	reading of current literature and will be exposed to practical exercises in image processing.

Type	Elective
Credit	2
Assessment	Participation 30%; Presentation, 30%; Practical Exercises 30%.
Text Book	Transmission Electron Microscopy: A Textbook for Materials Science (4-vol set), by Williams and Carter (2009) Springer Three-Dimensional Electron Microscopy of Macromolecular Assemblies, 2 edn, by J Frank (2006) Oxford University Press
Reference Book	Transmission Electron Microscopy: Physics of Image Formation and Microanalysis, 4th edn, by L. Reimer (1997) Springer Introduction to Fourier Optics, 3 edn, by J Goodman (2004) Roberts & Co.

Detailed Content

1. History of the TEM / Design of a TEM - Lecture
2. Design of a TEM (cont'd) - Lecture
3. Design of a TEM (cont'd) - Lecture
4. Demonstration of a TEM - Demo
5. Math refresher / Electron waves - Lecture
6. Fourier transforms - Lecture
7. Intro to image processing software in SBGRID - Practical
8. Image alignment - Practical
9. Contrast formation and transfer - Lecture
10. Image recording and sampling - Student presentation
11. Applications in biology - Lecture
12. Preparation of biological samples - Demo
13. Low-dose cryo-EM - Student presentation
14. 2D crystallography - Student presentation
15. Overview of the single particle technique - Lecture
16. Review of theory - Lecture
17. Electron tomography (guest lecture) - Lecture
18. Physical limits to cryo-EM - Student presentation
19. Particle picking - Practical
20. Classification techniques - Student presentation

21. 3D reconstruction - Student presentation
22. Image processing project 1 - Practical
23. Resolution-limiting factors - Student presentation
24. Refinement and sources of artifacts - Student presentation
25. Image processing project 2 - Practical
26. A sampling of original literature - Discussion

A410 Molecular Electron Tomography

Coordinator	Ulf Skoglund
Description	The course will show through theoretical and practical work how the 3D structure of a protein can be determined to about 2nm resolution directly in a buffer solution or in tissue. The students will get a direct hands-on experience of the processes involved in the practical and theoretical aspects of molecular electron tomography (MET). The students will be aware of how to carry out their own MET reconstruction and understand the limitations of the method and how to optimize its use.
Aim	This course provides an overview of structure-function analysis of individual macromolecules.

Type	Elective
Credit	2
Assessment	Oral presentation of analyzed (cryo-)EM tomography article The major assessment is an oral presentation of a selected article in tomography. The students also have to pass the practical sessions in specimen preparations and data processing using computers.
Text Book	Basic papers will be used. There is no published book yet on low-dose cryo-electron tomography on normal sized proteins.
Reference Book	Electron Tomography (Three-dimensional imaging with the transmission electron microscope) edited by Joachim Frank (1992) Plenum Press New York. One edition is from 1992.

Detailed Content

1. Learning the computer 1
2. Learning the computer 2
3. Practical Aspect of sample preparation for cryo-TEM
4. Sample preparation for cryo-TEM
5. Sample preparation for cryo-TEM; data collection

6. 3D reconstruction 1
7. 3D reconstruction 2
8. 3D reconstruction 3
9. Generating simulation-data
10. 3D reconstruction from simulation-data 1
11. 3D reconstruction from simulation-data 2
12. Electron Microscopy: Sample Preparation

B02 Biology

Coordinator	Alexander Mikheyev
Description	This course will provide a practical hands-on introduction to biology for students without any background in biology, focusing on computational methods. The scope of this course will range from biological molecules, to genomes, to populations. Our goal will be to understand how computational tools may be used to answer fundamental biological problems, and, in the process of doing so, to learn what these problems might be. Although the course will aim to provide a general introduction to biology for student from other disciplines, students with an undergraduate background in biology are also welcome to attend this course for its computational aspect. The course will have a lecture component, but students will be expected to invest a significant amount of time in homework assignments, and the final research-based project.
Aim	This lecture series provides an introduction to the study of life and to the biology of living organisms, using computational techniques familiar to physics background students.

Type	Elective
Credit	2
Assessment	Participation and attendance 1/3; homework 1/3; final project 1/3.
Text Book	none
Reference Book	to be notified

Detailed Content

1. Gene and genome structure
2. Biological databases
3. Sequence alignment and BLAST
4. Phylogeny

5. Population genetics

6. Hidden Markov Models

7. Structural bioinformatics

8. Gene expression

9. Biological networks

10. Next-generation sequencing

11. Genome assembly

12. SNPs and the human genome

13. Final presentations

B03 Mathematics I

Coordinator	Sinclair, Robert
Description	This course introduces necessary background and fundamental mathematics for graduate biologists. The course emphasizes relevant topics calculus, probability, and numerical methods with their applications in biology.
Aim	Survey of basic mathematics for application to life/environmental sciences.

Type	Elective
Credit	2
Assessment	Weekly written exercises, Student presentation in final week.
Text Book	none
Reference Book	none

Detailed Content

1 History of mathematics and relation to natural sciences.

2 Geometry: Distance, Euclidean and other spaces.

3 Geometry: Vectors, dot and cross products.

4 Geometry: Computation of angles and distance from a point to a line segment and a plane.

5 Geometry: Volume of a tetrahedron. Application to concept of rank.

6 Probability: Concepts (frequentist and Bayesian), independence, conditional probability, Bayes' Theorem.

7 Probability: Random walk, Bernoulli processes, Stirling's formula, normal distribution.

8 Probability: Nearest-neighbour distance distribution for randomly distributed points in a plane.

9 Calculus: Concepts of limit and slope. Application to biology.

10 Calculus: Taylor expansions. Exponential decay.

11 Calculus: Harmonic oscillator. Diffusion.

12 Numerical Methods: Roots of a quadratic polynomial.

13 Numerical Methods: Least squares curve fitting. Bisection.

14 Numerical Methods: Approximation of functions by polynomials.

15 Student presentations.

B04 Mathematics II

Coordinator	Sinclair, Robert
Description	The students will be introduced to some more advanced mathematical topics, but without proofs. Linear algebra, vector fields, dynamical systems, stochastic differential equations and numerical methods for these will be covered. Vector fields will be discussed with a view to motivating fluid dynamics, meaning conservation of mass, compressibility and divergence will be discussed. Systems of differential equations and their solution using Euler's and Heun's methods will be introduced. Dynamical systems will include fixed points, their stability, and bifurcation. The meaning of stochastic differential equations and their solutions will be discussed.
Aim	An extension of the course Mathematics I for graduate biologists.

Type	Elective
Credit	2
Assessment	Weekly written exercises.
Text Book	none
Reference Book	none

Detailed Content

1. Linear Algebra: Rotations in the plane and space. Matrix representation. Matrix multiplication.
2. Linear Algebra: Solution of linear systems. Eigenproblems. Hardy-Weinberg equilibrium.
3. Linear Algebra: Change of basis, discrete Fourier transform.
4. Continuous flows: Vector fields, conservation of mass, compressibility and divergence.
5. Exercises (individual)

6. Systems of differential equations: Reduction to systems of first order. Euler's method.
7. Systems of differential equations: Reaction-diffusion equations. Heun's method.
8. Systems of differential equations: Hodgkin-Huxley equations.
9. Dynamical Systems: Linear systems, fixed points.
10. Dynamical Systems: Linearization of nonlinear systems.
11. Dynamical Systems: Predator-prey systems. Bifurcation. Chaos.
12. Stochastic differential equations: Euler-Maruyama method.
13. Student presentations: Preparation.
14. Student presentations: Preparation.
15. Student presentations: Presentation.

B05 Neurobiology

Coordinator	Arbuthnott, Gordon / Takahashi, Tomoyuki
Description	In this course students learn about the cellular and molecular basis of neuronal functions, and how individual electrical signals are integrated into physiological functions. The course will stress connections between information, computations, and biological mechanisms in processes underlying motivated behavior, and will be taught by discussion of physiological mechanisms that contribute to such behaviors. Students will learn how to evaluate evidence obtained in laboratory studies conducted with animals.
Aim	This course provides an overview of cellular neurophysiology and how neuronal circuits produce behavior.

Type	Elective
Credit	2
Assessment	Essay 80%, Lab reports, 20%.
Text Book	Neuroscience, 5 edn, by Dale Purves, George J. Augustine, David Fitzpatrick, William C. Hall, Anthony-Samuel LaMantia, and Leonard E. White (2012) Sinauer
Reference Book	The Synaptic Organization of the Brain, 5 edn, Gordon M. Shepherd (2003) OUP Fine Structure of the Nervous System, 3 edn, Peters Parlay Webster (1991) OUP The Human Central Nervous System, 4 edn, Nieuwenhuys, Voogd, van Huijzen (2008) Springer The Central Nervous System, 4 edn, Per Brodal (2010) Encyclopaedia of Neuroscience, 5 edn, Kandel, Schwartz, Jessel (2012) McGraw-Hill Fundamental Neuroscience 3 edn, Larry Squire, (2008) Elsevier (Academic Press) Ion Channels of Excitable Membranes, 3 edn, Bertil Hille (2001) Sinauer

Detailed Content

1. Introduction to the course and its subject
2. Ionic basis of excitability and voltage-gated ion channels
3. Action potential generation and propagation
4. Synaptic transmission, neurotransmitters, neuromodulators
5. Synaptic ion channels and receptors
6. Synaptic plasticity, intracellular signaling, retrograde messengers
7. Neural morphology, cytoskeleton, and implications for function
8. Neural networks, cerebral cortex, basal ganglia, cerebellum
9. Motor system; movement
10. Somatosensory systems; Whiskers
11. Mechanism of sensory transduction
12. Sensory systems Vision and hearing
13. Discussion of neurophysiology of brain systems with methods in the awake animal

B06 Cell Biology and Genetics

Coordinator	Professor Mitsuhiro Yanagida
Description	Molecular cell biology is a vast and growing field, and this course covers the essential principles required to understand the regulation and functioning of the living and dying cell, the fundamental unit of life. Lectures cover classical and molecular genetics, including genetic regulation and mRNA, before moving on to describe the physical and chemical organization of the cell, and the way these various domains interact in the normal cell.
Aim	This course provides an overview of the principles of genetics, molecular and cell biology to students

Type	Elective
Credit	2
Assessment	Essay 50%; Final Exam, 50%.
Text Book	Molecular Biology of the Cell 5 edn Alberts, Johnson, Lewis, Raff, Roberts, and Walter. (2007) Garland Molecular Biology of the Gene 6 edn Watson Baker Bell Gann (2007) Benjamin Cummings
Reference Book	Molecular Cell Biology 6 edn, Lodish et al., (2007) WH Freeman Lewin's Genes X, Krebs, Goldstein, Kilpatrick (2009) Jones & Bartlett

	Recombinant DNA: Genes and Genomes, 3 edn, Watson, Myers, Caudy, Witkowski (2007) WH Freeman

Detailed Content

1. Mendelian genetics
2. Recombination, linkage and mapping
3. Gene interaction, complementation, and epistasis
4. Nucleic acids and chromosome structure
5. Protein structure and function
6. DNA replication
7. Transcription and its regulation
8. mRNA splicing and translation
9. Maintenance of genomic integrity
10. Cellular structures and organelles
11. Intracellular membrane trafficking
12. Cell cycle and cell division
13. Cellular cytoskeleton and cell movement
14. Cell-cell communication
15. Apoptosis

B07 Statistical Methods

Coordinator	Doya, Kenji
Description	This course introduces basic principles and practical methods in statistical testing and inference. The lectures cover the following topics: Confidence Interval, P Values, Error bars, t Test, Multiple testing, ANOVA, Nonparametric tests, Joint and conditional distribution, Statistical dependence, Probability distributions, Maximum likelihood, Linear Regression, Multiple regression, Logistic regression, ROC, Regularization, Bayesian methods, Clustering, Mixture models, Entropy, Information theory, PCA, ICA, and Stochastic process.
Aim	This basic course will equip students with the necessary understanding and experience in statistical methods essential to modern scientific research.

Type	Elective
Credit	2
Assessment	Problem sets, 50%; Final written report, 50%.
Text Book	Intuitive Biostatistics - A Nonmathematical Guide to Statistical Thinking, by Harvey Motulsky (2014) Oxford University Press All of Statistics - A Concise Course in Statistical Inference, by Larry Wasserman (2003) Springer

	All of Nonparametric Statistics, by Larry Wasserman (2005) Springer
Reference Book	Pattern Recognition and Machine Learning, by Christopher Bishop (2006) Springer

Detailed Content

learning_method

Hands-on exercises using R language is included. Please bring your laptop.

1. Introduction
2. Confidence Interval of proportion
3. Confidence Interval of mean
4. P Values, Error bars, t Test
5. Multiple testing, ANOVA
6. Nonparametric tests
7. Joint and conditional distribution, Statistical dependence
8. Linear Regression
9. Probability distributions, Maximum likelihood
10. Multiple regression, Logistic regression, ROC
11. Regularization, Bayesian methods
12. Clustering, Mixture models
13. Entropy, Information theory
14. PCA, ICA
15. Stochastic process

B08 Physics for Life Sciences

Coordinator	Kuhn, Bernd
Description	Principles of physics of central relevance to modern biological analysis and instrumentation are introduced with an emphasis on application in practical research areas such as electrophysiology, optogenetics, electromagnetics, the interaction of light and matter, and brain recording, stimulation, and imaging.
Aim	This basic course aims to introduce physical principles that are necessary in modern life sciences, such as biophysical modeling and electromagnetic and optical measurements.

Type	Elective
Credit	2
Assessment	Midterm presentation 35%, final presentation 35%, participation in class 30%

Text Book	Atkins Physical Chemistry, by P. Atkins & J. de Paula (2006) Oxford University Press Introduction to Biophotonics by P.N. Prasad, (2003) J. Wiley & Sons Foundations of Cellular Neurophysiology by D. Johnston & S.M-S. Wu (1994) The MIT Press
Reference Book	

Detailed Content
1 Physics in Biology: How physics contributes to life sciences. 2 Fundamentals on light and matter 3 Fundamentals on light and matter interaction 4 Luminescence with special focus on fluorescence 5 The physics of photobiology with special focus on photosynthesis 6 The physics of optogenetics 7 Linear optics with special focus on microscopy 8 Non-linear optics with special focus on imaging and lasers 9 The physics of electron microscopy and mass spectrometry 10 Nuclear magnetic resonance and its applications in biology 11 The physics of DNA 12 The physics of lipid membranes 13 The physics of proteins 14 Diffusion and enzyme kinetics 15 Basic electric circuits and electrophysiology

B09 Learning and Behavior

Coordinator	Tripp, Eileen Gail
Description	This course aims to introduce the function of the brain at the macroscopic level, namely, the control of behaviors and the cognitive and adaptive mechanisms behind it. The topics include the following: Reflex, classical and operant conditioning. Perception, adaptation, and attention. Feedback and predictive control. Procedural and declarative memory. Motivation and emotion. Thinking and reasoning. Communication and language. Psychological disorders. Clinical and experimental neuropsychology.
Aim	This course aims to introduce the function of the brain at the macroscopic level, namely the control of behavior and the cognitive and adaptive mechanisms behind it.

Type	Elective
Credit	2

Assessment	Article reviews and critiques (4) each worth 5% (Total 20%) Class presentation (Total 30%) Participation in class discussions (Total 10%) Research/grant proposal (Total 40%)
Text Book	Throughout the course readings will be assigned (original articles and textbook chapters) together with recommended reading.
Reference Books	

Detailed Content

1. Research methods (I)
2. Ethics
3. Hypothesis testing
4. Dependent and independent variables
5. Reliability and validity
6. Bias, blinding
7. Research methods (II)
8. Data collection methods
9. Observation
10. Surveys
11. Experimental and quasi experimental designs
12. Data analysis
13. Learning and behavior (I)
14. Classical, Pavlovian, respondent conditioning (elicited responses)
15. Operant, instrumental conditioning (instrumental responses)
16. Learning and behavior (II)
17. Reinforcement and punishment
18. Operant schedules
19. Learning and behavior (III)
20. Behavior modification
21. Applications
22. Motivation and reward
23. Drug addiction
24. ADHD

25. Memory and cognition (I)
26. Memory and cognition (II)
27. Perception and attention
28. Behavioral neuroscience (I)
29. Behavioral neuroscience (II)
30. Genes and behaviour
31. Animal models
32. Life span

B10 Analytical Mechanics

Coordinator	Bandi, Mahesh
Description	Mastery of the concepts and techniques of analytical mechanics is essential to a deep understanding of physics. This course begins with basic principles and proceeds to the Newtonian equations of motion and laws of conservation. We use the Lagrange formalism to describe particle motion in multiple modes, before covering the equations of Euler and Hamilton, and canonical transformations. The calculus of variation is used to develop Maupertuis's principle and the Hamilton-Jacobi equations, providing a starting point for the consideration of waves in later courses. This course is taught from the unifying principles of symmetry and least action.
Aim	Covers the fundamental theories of classical mechanics, and provides a firm grounding for later studies of fluid dynamics and quantum physics.

Type	Elective
Credit	2
Assessment	Homework Assignments, 20%. Midterm written tests, 2 x 25%; Final written test, 30%.
Text Book	Mechanics, 4 edn, by Landau and Lifshitz (1976) Butterworth-Heinemann Classical Mechanics, 3 edn, by Goldstein, Poole, and Safko (2001) Addison Wesley
Reference Book	The Variational Principles of Mechanics, 4 edn, Cornelius Lancoz (1970) Dover The Feynman Lectures on Physics including Feynman's Tips on Physics: The Definitive and Extended Edition, 2 edn, by RP Feynman with Robert B. Leighton et al., editors (2005) Addison Wesley

Detailed Content

1. The Principle of Least Action

2. Equations of Motion: Galileo and Lagrange

3. Equations of Motion: Newton

4. Conservation Laws: Energy, Momentum, and Angular Momentum

5. Integration of Equations of Motion

6. Breakup, Collision, and Scattering of Particles

7. Harmonic Oscillations: Free, Forced, and Damped Oscillations, Resonance

8. Rigid Body Dynamics: Angular Velocity, Inertia Tensor, Angular Momentum

9. Equations of Motion for Rigid Body

10. Euler's Equations

11. Dynamics of Rigid Bodies in Contact

12. Hamilton's Equations

13. Maupertuis' Principle

14. Canonical Transformations and Liouville's Theorem

15. Hamilton-Jacobi Equations

B11 Classical Electrodynamics

Coordinator	Shintake, Tsumoru
Description	This course assumes undergraduate level knowledge of mechanics and a firm grasp of calculus and vector mathematics. An understanding of static electromagnetic fields is extended through Maxwell's equations to a discussion of dynamic vector fields and electromagnetic waves. Along the way, numerous physical and technical applications of these equations are used to illustrate the concepts, including dielectrics and conductors, wave guides, and microwave engineering. Special relativity is introduced with discussion of relativistic and non-relativistic motion and radiation, using linear accelerators and synchrotron radiation as illustrative applications.
Aim	Covers the theory and application of classical electrodynamics and special relativity, and provides a firm grounding for later studies of quantum physics.

Type	Elective
Credit	2
Assessment	Midterm tests, 2 x 30%; Final written test, 40%.
Text Book	Electrodynamics of Continuous Media, 2 edn, by Landau, Pitaevskii, Lifshitz (1984)
Reference Book	Electricity and Magnetism (Berkeley Physics Course, Vol.2) 2 edn by Edward M. Purcell (1986)

	Waves (Berkeley Physics Course, Vol.3) 2 edn by Frank S. Crawford (1968) Butterworth-Heinemann The Classical Theory of Fields, 4 edn, by DL Landau (1980) Butterworth-Heinemann Classical Electrodynamics, 3 edn, by JD Jackson (1998) Wiley

Detailed Content

1. Charge and Gauss's Law
2. Current and Ampere's Law
3. Divergence and Rotation
4. Induction
5. Capacitance and Inductance
6. Maxwell's Equation 1
7. Maxwell's Equation 2
8. Vector and Scalar Potentials
9. Electromagnetic Waves
10. Energy, Dispersion
11. Impedance Concept
12. Reflection and Matching Condition
13. Relativistic Equation of Motion
14. Radiation from a Moving Charge
15. Synchrotron Radiation

B12 Statistical Physics

Coordinator	Nic Shannon
Description	Matter can exist in many different phases. The aim of this course is to explain why, and how one phase can transform into another. Starting from the question "what is temperature?", the ideas of entropy, free energy, and thermal equilibrium are introduced, first in the context of thermodynamics, and then as natural consequences of a statistical description of matter. From this starting point, a simple physical picture of phase transitions is developed, with emphasis on the unifying concept of broken symmetry. The course is designed to be accessible to students from a wide range of educational backgrounds. It will be assessed through weekly problem sets, and a final presentation on a modern example of the application of statistical physics ideas, chosen by the student.
Aim	This course introduces the fundamental concepts and mathematical techniques of equilibrium statistical mechanics in the context of two simple questions: Why does matter exist in different phases ? And how does it change from one phase to another?

Type	Elective

Credit	2
Assessment	Weekly problem sheets 75%. Final presentation 25%
Text Book	K. Huang, “Introduction to Statistical Physics” 2nd Edition - (2009) Chapman & Hall F. Mandl, “Statistical Physics”, 2nd Edition (1988) Wiley M. Plischke and B. Bergersen, “Equilibrium Statistical Mechanics” 3rd edition (2006) World Scientific
Reference Book	L. D. Landau and E. M. Lifshitz, “Statistical Physics” (1996) Butterworth-Heinermann P. Chaikin and T. Lubensky, “Principles of Condensed Matter Physics” (2003) Cambridge University Press

Detailed Content
1. General overview of phase transitions - what are they, and where do they happen? 2. Introduction to the basic concepts of thermodynamics - temperature, entropy, thermodynamic variables and free energy - through the example of an ideal gas. 3. Introduction to the basic concepts and techniques of statistical mechanics - phase space, partition functions and free energies. How can we calculate the properties of an ideal gas from a statistical description of atoms? 4. Introduction to the idea of a phase transition. How does an non-ideal gas transform into a liquid? 5. The idea of an order parameter, distinction between continuous and first order phase transitions and critical end points. How do we determine whether a phase transition has taken place? 6. Magnetism as a paradigm for phase transitions in the solid state - the idea of a broken symmetry and the Landau theory of the Ising model. 7. Universality - why do phase transitions in fluids mimic those in magnets? An exploration of phase transitions in other universality classes, including superconductors and liquid crystals. 8. Alternative approaches to understanding phase transitions: Monte Carlo simulation and exact solutions. 9. How does one phase transform into another? Critical opalescence and critical fluctuations. The idea of a correlation function. 10. The modern theory of phase transitions - scaling and renormalization. 11.To be developed through student presentations: modern applications of statistical mechanics, with examples taken from life-sciences, sociology, and stock markets.

B13 Theoretical and Applied Fluid Mechanics

Coordinator	Pinaki Chakraborty
Description	We will introduce basic concepts of flow of fluids. We will discuss conservation laws and constitutive equations. We will derive the Navier-Stokes equations, and study its exact and approximate solutions. Last, we will introduce the theory of hydrodynamic

	stability and then discuss turbulent flows. Throughout the course we will discuss a wide spectrum of flows from nature and engineering.
Aim	To introduce basic concepts, equations, and methods of the mechanics of fluids.

Type	Elective
Credit	2
Assessment	
Text Book	No textbook is set.
Reference Book	Fluid Mechanics by L. D. Landau and E. M. Lifshitz, 2 edn (1987) Butterworth-Heinemann Vectors, Tensors and the Basic Equations of Fluid Mechanics by Rutherford Aris (1990) Dover General Continuum Mechanics by T. J. Chung (2007) Cambridge University Press Fluid Dynamics for Physicists by T. E. Faber (1995) Cambridge University Press An Introduction to Fluid Dynamics by G. Batchelor (2000) Cambridge Scaling by G. I. Barenblatt (2003) Fluid Mechanics by P. K. Kundu and I. M. Cohen, 5 edn (2011) Academic Press

Detailed Content

1. Overview of fluid mechanics
2. Kinematics of flow
3. Review of Tensors and the Stress Tensor
4. Conservation Laws: Mass, Momentum, and Energy
5. Constitutive Equations: the Navier-Stokes Equations, Boundary Conditions.
6. Potential Flows
7. Vortex motion
8. Dimensional analysis and similarity
9. Exact solutions of viscous flows
10. Creeping Flows
11. Boundary Layers
12. Hydrodynamic Stability
13. Turbulent flows

B14 Theoretical and Applied Solid Mechanics

Coordinator	Gustavo Gioia
Description	Students are introduced to the concepts of stress and strain, and discuss conservation laws and constitutive equations. We derive the Navier equations of linear elasticity, introduce the Airy stress-function method, and solve problems to illustrate the behavior of cracks, dislocations, and force-induced singularities in applications relating to materials science, structural engineering, geophysics and other disciplines.
Aim	To introduce basic concepts, equations, and methods of the mechanics of solids, including solutions of representative problems in linear elasticity..

Type	Elective
Credit	2
Assessment	
Text Book	No textbook is set. Students are expected to take good notes in class. The Professor will from time to time distribute essential readings, as needed.
Reference Book	General Continuum Mechanics by T. J. Chung (2007) Cambridge University Press Scaling by G. I. Barenblatt (2003)

Detailed Content

(1) Mathematical Preliminaries:

- Summation convention, Cartesian, spherical, and cylindrical coordinates.
- Vectors, tensors, linear operators, functionals.
- Eigenvalues and eigenvectors of second-order symmetric tensors, eigenvalues as extrema of the quadratic form.
- Fields, vector and tensor calculus.

(2) Stress, Strain, Energy, and Constitutive Relations:

- Cauchy stress tensor, traction, small strain tensor, compatibility.
- Strain energy, strain energy function, symmetries, elastic modulii.

(3) Elasticity and the Mechanics of Plastic Deformation:

- Navier equations, problems with spherical symmetry and problems with cylindrical symmetry (tunnels, cavities, centers of dilatation).
- Anti-plane shear. Plane stress, plane strain.
- The Airy stress-function method in polar and Cartesian coordinates.
- Superposition and Green's functions.

- Problems without a characteristic lengthscale.
- Flamant's problem, Cerruti's problem, Hertz's problem.
- Load-induced versus geometry-induced singularities (unbounded versus bounded energies).
- Problems with an axis of symmetry.
- Disclinations, dislocations, Burgers vector, energetics; relation to plastic deformation in crystalline solids.

(4) Fracture Mechanics:

- The Williams expansion, crack-tip fields and opening displacements via the Airy stress-function method (modes I, II) and via the Navier equations (mode III), crack-tip-field exponents as eigenvalues, stress intensity factors.
- Energy principles in fracture mechanics, load control and displacement control.
- Energy release rate and its relation to the stress intensity factors, specific fracture energy, size effect, stability. The Griffith crack and the Zener-Stroh crack. Anticracks.

(5) Possible Additional Topics (if time allows):

- Elasticity and variational calculus, nonconvex potentials, two-phase strain fields, frustration, microstructures.
- Stress waves in solids, P, S, and R waves, waveguides, dispersion relations, geophysical applications.
- Dislocation-based fracture mechanics, the Bilby-Cotterell-Swindon solution, small- and large-scale yielding, T-stress effects, crack-tip dislocation emission, the elastic enclave model.
- Deterministic versus statistical size effects in quasibrittle materials.
- Vlasov beam theory, coupled bending-torsional instabilities.
- Dynamic forms of instability, nonconservative forces, fluttering (Hopf bifurcation).

B15 Immunology

Coordinator	Hiroki Ishikawa
Description	In this course, students will learn basic principles of immunology including the cellular and molecular mechanism of innate and adaptive immunity. The course also provides the clinical importance of immunology in various diseases such as HIV/AIDS, autoimmunity and allergy. Then, students will learn how the immune response can be manipulated by vaccination to combat infectious diseases and cancer.
Aim	This lecture series introduces the basic principles and current research in immunology.

Type	Elective

Credit	2
Assessment	Report 50%; Final exam 50%
Text Book	Immunobiology 8 edn, by Kenneth Murphy (2012) Garland Science
Reference Book	

Detailed Content

1. Basic concepts in immunology
2. Innate immunity
3. Antigen recognition by B-cell and T-cell receptors
4. The generation of lymphocyte antigen receptors
5. Antigen presentation to T lymphocytes
6. Signaling through immune system receptors
7. The development and survival of lymphocytes
8. T cell-mediated immunity
9. The humoral immune response
10. Dynamics of adaptive immunity
11. The mucosal immune system
12. Failures of host defense mechanism
13. Allergy and Hypersensitivity
14. Autoimmunity and Transplantation
15. Manipulation of the immune response

B16 Ecology and Evolution

Coordinator	Economo, Evan P
Description	This course covers biological phenomena at or above the scale of a single organism. We will broadly cover topics in evolutionary biology and ecology including but not limited to population genetics, animal behavior, adaptation and natural selection, speciation, phylogenetics, population biology, community ecology, ecosystem ecology, and macroecology.
Aim	This course provides a basic overview of modern concepts in ecology and evolution.

Type	Elective
Credit	2

Assessment	Participation and Discussion 50%; Midterm exam 20%; Final Exam 30%
Text Book	The Economy of Nature 6 edn, by Robert E. Ricklefs (2008) W H Freeman (Paperback) Evolution, by Douglas Futuyma (2005) Sinauer
Reference Book	

Detailed Content

1. Introduction, levels of organization in biological systems.
2. Taxonomy, systematics, phylogenetics.
3. Biodiversity
4. Energy flows and transformations in biological systems.
5. Genomics and Genetics of Adaptation
6. Physiological ecology.
7. Population dynamics and regulation
8. Life histories
9. The evolution of sex and the evolution of cooperation
10. Community Ecology
11. Ecosystem Ecology
12. Global Climate system and Climate change
13. Conservation Biology

PD1 Professional Development I for 2015 Students

Coordinator	Wickens, Jeffery
Description	This course aims to develop knowledge and skills important for leadership in scientific research and education. The three main components of the course are (1) weekly seminars covering basic principles of research conduct and ethics, scientific communication, and aspects of science in society, including a visiting speaker program (2) a cross-disciplinary group project, (3) practical experience to develop presentation and teaching skills. Seminars Seminars are held every Friday afternoon throughout the year. It is imperative that you not only attend the seminars but that you also engage by participating in

	discussion and asking questions. Visiting speakers will be invited each month to give seminars and lead interactive discussions. Visiting speakers will include leaders from major corporations, research institutes and scientific laboratories and internationally leading researchers from different fields. This is an opportunity to learn what the leaders see as important during their successful careers, and also a chance to learn how to interact and present yourself in ways that may lead to valuable connections for your future. Group Project. The group project component aims to develop skills required for effective teamwork, including leadership, project management, cooperation and creative interaction, cross-disciplinary communication, and coordination of group activity. Group project work is timetabled on Friday afternoons for two hours every second week, alternating with presentation and teaching skills training. Timing of project activity is flexible and different times may be decided by the group. The project component will require involvement in a student led group project. Projects will not be directly supervised by a faculty member, but there will be opportunities for consultation where certain expertise is required. The nature of possible projects will be explained in class but they may include development of new research tools and applications, inventions to solve problems, field studies, or creation of resources for research and learning. There will be a self-assessment requirement by group members to recognize the contributions of different members, and an overall grade based on a final presentation. A prize will be awarded for the best project. Scientific Communication Skills Being able to deliver a clear message about your research is a valuable skill. Competition for jobs both in and out of academia is fierce. Researchers, whether in academia or industry, need to develop their personal skill sets not only to do outstanding research, but also to write papers, teach and demonstrate the impact and relevance of their work. The scientific communication skills component of PD1 comprises a set of opportunities for students to improve academic presentation and scientific writing skills.
Aim	The aim of this course is to provide information essential to beginning one's career as a professional scientist, and to develop skills fundamental to modern scientific practice.

Type	Mandatory
Credit	1
Assessment	Attendance and participation
Text Book	
Reference Book	

Detailed Content

Term 1 Module: Research conduct and ethics

- laboratory procedures, conduct and safety
- record keeping and data management
- plagiarism
- research misconduct
- authorship
- peer review
- conflicts of interest
- research with animals
- research with human subjects

Other Courses: Special Topics

States and Properties of Matter
Professor Mahesh Bandi

Assessment
There will be regular assignments that include traditional problem sets and the study and critique of seminal scientific articles. There is no exam for the course. All Assessment is based on homework assignments.

Description
This is a series of four special topics courses presented over two terms (two courses per term). It treats the standard (gases, liquids and solids) and few exotic (polymers and colloids) classical states of matter, and explains how these states and their bulk properties emerge from the few interatomic and intermolecular forces at play. The emphasis is on developing strong physical intuition for microscopic mechanics using the simplest models that illuminate the concept. In doing so, we explain both the strengths and shortcomings of these simple models, and in particular, analyse the limiting conditions where they fail. Therefore, rather than theoretical rigour, the focus of the treatment is on performing quick order-of-magnitude calculations. As a result, although the mathematics is unsophisticated, Calculus is a pre-requisite. Wherever possible, scientific facts will be connected with the seminal experiments that established them.

Aim
An interdisciplinary course that explains emergence of bulk properties/behavior in materials from the few attractive and repulsive interatomic/molecular forces.

Resources
Text Book:
There is no prescribed textbook for this course. Lectures will be based on notes developed from diverse sources.

Reference Book:
There is no prescribed textbook for this course. Lectures will be based on notes developed from diverse sources.

Advanced Statistical Mechanics

Dr Ludovic Jaubert (Shannon Unit Group Leader)

Assessment

written exams (midterm 30%, final 70%).

Description

It took centuries to explain the "simple" movement of a planet around the sun, so how can we expect to understand the behaviour of a gas or a crystal, where billions of billions of atoms interact? This is where Statistical Mechanics kicks in: if an exact knowledge of each particle is impossible, their global trend can nonetheless be predicted "on average", which is what matters macroscopically. Making use of statistical and quantum mechanics, we shall learn advanced methods to explain complex phenomena such as superconductivity, superfluidity, and phase transitions. This will illustrate one of the key concepts of pysics; namely, how correlations can discard details to make macroscopic physics emerge.

Detailed description

Advanced Statistical Mechanics

1. Renormalisation Theory
a. From scaling laws to universality
b. Correlation functions
c. Renormalisation methods
i. Decimation method on lattices
ii. Fixed points

2. Quantum Statistical Mechanics
a. Quantum Bose and Fermi statistics
b. Black body radiation
c. Superconductivity
i. Phenomenology
ii. Lattice theory
d. Superfluidity

3. A glimpse of non-equilibrium statistical physics

Aim

Understand the complex collective behaviour of particles responsible for phase transitions, superconductivity, superfluidity, and other phenomena.
This course follows on from Prof Nic Shannon's B12 Statistical Physics course and is open to all students and staff of OIST with equivalent background knowledge.

Resources

Textbook: Equilibrium Statistical Mechanics, 3 edn, by Plischke and Bergersen (2006) World Scientific

Basic Computing for Life Sciences
Coordinator: Professor Alexander Mikheyev

Aim: Introduce fundamentals of programming, databases and statistical analysis to students with minimal computational background.

Description: This is a basic introduction to programming, data storage and analysis for students with no prior computational experience. The course will be largely self-paced with 'lectures' in the form of ipython notebooks. The students will ultimately write a program to mine data from online databases, store it in a local SQL database and perform a large-scale statistical analysis, presenting the final data in an easy to read report. In the course of getting there, student will learn how to write computer programs in python, how to handle various data structures, and the basics of statistical analysis. Most of the course will involve the students in solving problems posed by the instructor, instead of actual lectures. The instructor's role will be to guide students when they are stuck and to provide feedback on solutions. Students should expect about five to eight hours of week of work at a pace of their own choosing, although it can take more time.

Course contents:

1. Getting everything installed, working with the command line, file and directory structure
2. Introduction to python
   - Variables, and memory
   - Data structures, loops, control statements
   - Commenting and storing code
3. Debugging code
4. Efficiency of computer code
   - Parallelizing your code
   - Basics of cluster computing
5. Introduction to biopython
   - Working with sequence data
   - Mining data from on-line databases
6. Storing data
   - Introduction to SQL
   - Indexing databases
   - Interfacing between SQL and other languages
7. Introduction to the R package
8. Visualizing data using ggplot
9. Linear models
10. Bootstrap and simulation
11. Putting it all together into one pipeline: Making reports in knitR

Skill Pills AY2015-2016

Skill Pill: LabVIEW July 19, 20, 26, 27, August 9, 10, from 5PM to 7PM (Tuesdays and Wednesdays)

Skill Pill: Inkscape July 25th and August 1st, from 1PM to 3PM

Skill Pill: Data Structures and Algorithms with Python July 23rd and 30th (consecutive Saturdays)

Skill Pill: Database Manipulation June 21st, 23rd, 28th, 30th from 5PM to 7PM

Skill Pill: Intro to Cellular Biology May 14th and 21st, 2016 (Consecutive Saturdays)

Skill Pill: Git June 1st (Wed.) and 2nd (Thur.) from 5PM to 7PM

Skill Pill: Arduino April 16th, from 10AM to 5:30PM (Saturday)

Skill Pill: Presentation Skills April 14th, from 10AM to 5:30 PM (Thursday during Final Fortnight)

Skill Pill: CAD with SOLIDWORKS March 30th, 31st, April 6th, 7th from 1PM to 3PM (weekdays)

Skill Pill: Differential Equations March 26th and 27th, 2016 (Saturday and Sunday)

Skill Pill: Terminal March 16th, 17th, 23rd, 24th from 5PM to 7PM (weekdays)

Skill Pill: Gravitational Waves March 7th, 8th and 10th, 2016, from 4:30PM.

Skill Pill: Statistics February 27th and 28th, 2016 (Saturday and Sunday)

Skill Pill: Programming with Python February 13th and 20th, 2016 (Consecutive Saturdays)

Skill Pill: Matrix Algebra January 30th and 31st, 2016 (Saturday and Sunday)

Skill Pill: LaTeX January 18, 21, 25 and 28, 2016 (From 5PM to 7PM)

Skill Pill: Group Theory January 16th and 23rd, 2016 (Consecutive Saturdays)

Skill Pill: MATLAB November 28-29th, 2015 (Saturday-Sunday)