Course Archive AY2017

Degree Completion Requirements for AY2017/2018

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 points (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: coursework 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, in full or part. The amount of waiver due to prior relevant coursework is at the discretion of the mentor.

Note 2: a published paper or manuscript ready for publication from the research work presented in the thesis shall be submitted with the thesis to denote that the "material is worthy of publication". Students in AY2016 cohort and onwards must provide evidence that a paper has been submitted, if none has been published.

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.

Note 4: Examination and final versions of the thesis are submitted only as PDF files. All theses are published online in the OIST Institutional Repository. Partial embargo periods are available by negotiation.

Courses delivered AY2017/2018

A101 Adaptive Systems

Course Coordinator: Kenji Doya

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.

Course 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

Course Type:

Elective

Credits:

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

Prior Knowledge:

Assumes good knowledge of statistics and ability to look at biological problems in a mathematical way.

OIST courses to complete beforehand: B07 Statistical Methods

A102 Mathematical Methods of Natural Sciences

Course Coordinator: Jonathan Miller

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

Course 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 fieldsStokes theorem.
15. Green's functions.

Course Type:

Elective

Credits:

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:

Basic Training in Mathematics. R. Shankar. Plenum, 1995.

Geometrical methods of mathematical physics. B. Schutz. Cambridge, 1999.

Statistical Field Theory. G. Mussardo. Oxford, 2009.

Statistical Mechanics: Entropy, Order Parameters and Complexity J.P. Sethna. Oxford, 2008

A103 Stochastic Processes with Applications

Course Coordinator: Simone Pigolotti

Description:

This course will present a broad introduction to stochastic processes. The main focus will be on their application to a variety of modeling situations and on numerical simulations, rather than on the mathematical formalism. After a brief resume of the main concept in probability theory, we will explain what stochastic processes are and the concept of stochastic trajectory. We will then broadly classify stochastic processes (discrete/continuous time and space, Markov property, forward and backward dynamics). The rest of the course is devoted to the most commonly used types of stochastic processes: Markov chains, Master Equations, Langevin/Fokker-Planck equations. For each process, we will review the main applications in physics, biology, and neuroscience, and discuss the simplest algorithms to simulate them on a computer. The course will include “hands-on” sessions in which the students will write their own Python code (based on a template) to simulate stochastic processes, aided by the instructor. These numerical simulations will be finalized as homework and will constitute the main evaluation of the course.

Aim:

The course is aimed at students interested in modeling systems characterized by stochastic dynamics in different disciplines. Goals of the course are: to understand the most common types of stochastic processes (Markov chains, Master equations, Langevin equations); to be aware of important applications of stochastic processes in physics, biology and neuroscience; to acquire knowledge of simple analytical techniques to understand stochastic processes, and to be able to simulate discrete and continuous stochastic processes on a computer.

Course Content:

1) Basic concepts of probability theory. Discrete and continuous distributions, main properties. Moments and generating functions. Random number generators.

2) Definition of a stochastic process and classification of stochastic processes. Markov chains. Concept of ergodicity. Branching processes and Wright-Fisher model in population genetics.

3) Master equations, main properties and techniques of solution. Gillespie algorithm. Stochastic chemical kinetics.

4) Fokker-Planck equations and Langevin equations. Main methods of solution. Simulation schemes for Langevin equations. Random walks and colloidal particles in physics.

5) First passage-time problems. Concept of absorbing state and main methods of solution. First passage times in integrate-and-fire neurons.

Course Type:

Elective

Credits:

2

Assessment:

Reports (numerical simulations): 75% (3 hours/week). Homework: 25% (1 hour/ week).

Text Book:

“Random walks in Biology” by H. C. Berg (1993) Princeton University Press

“Stochastic Methods: A Handbook for the Natural and Social Sciences” by C. Gardiner (2009) Springer

Reference Book:

“An Introduction to Probability Theory and its Applications, Vol 1” by W. Feller (1968) Wiley

“The Fokker-Planck Equation”, by H. Risken (1984) Springer

Prior Knowledge:

• Basic calculus: students should be able to calculate integrals, know what a Fourier transform is, and solve simple differential equations.

• Basic probability theory: students should be familiar with basic concepts in probability theory, e.g. discrete and continuous distributions, random variables, conditional probabilities, mean and variance, correlations. A resume will be made at the beginning of the course.

• Scientific programming: the students are expected to be already able to write, for example, a program to integrate a differential equation numerically via the Euler scheme and plot the results. Python is the standard language for the course. The students are required to install the Jupiter notebook system and bring their own laptop for the hands-on sessions.

A202 Fluid Dynamics

Course Coordinator: Satoshi Mitarai

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.

Course 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)

Course Type:

Elective

Credits:

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.

A205 Quantum Field Theory

Course Coordinator: Shinobu Hikami

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.

Course 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

Course Type:

Elective

Credits:

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

Prerequisites: A216, A217 Quantum Mechanics I and II B11 Classical Electrodynamics

A206 Analog Electronics

Course Coordinator:

Yabing Qi

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

Course 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.

Course Type:

Elective

Credits:

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

A207 Nanotechnology

Course Coordinator: Mukhles Ibrahim Sowwan

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.

Course 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

Course Type:

Elective

Credits:

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

A208 Bioorganic Chemistry

Course 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.

Course 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

Course Type:

Elective

Credits:

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:

Modern Physical Organic Chemistry, Anslyn and Dougherty (2005)

The Organic Chemistry of Drug Design and Drug Action, 2nd edn, Silverman (2004)

Organic Chemistry, 7th Edition, McMurry (2008)

A209 Ultrafast Spectroscopy

Course 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.).

Course Content:

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

Aim:

This course provides an overview of the modern methods and applications in ultrafast spectroscopy.

Course Type:

Elective

Credits:

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

A210 Advanced Quantum Mechanics

Course Coordinator: Thomas Busch

Description:

Advanced course in Quantum Mechanics, based on recent theoretical and experimental advances. Evolution in Hilbert space and quantum bits; conditional quantum dynamics; quantum simulations; quantum Fourier transform and quantum search algorithms; ion-trap and NMR experiments; quantum noise and master equations; Hilbert space distances; Von Neumann entropy; Holevo bound; entanglement as a physical resource; quantum cryptography; lab: quantum eraser, interaction free measurement.

Aim:

To introduce students to advanced and recent concepts and techniques in quantum mechanics

Course Content:

1. Quantum Mechanics: Mathematical Framework
2. Quantum Mechanical Postulates
3. Quantum Measurements
4. Quantum Algorithms
5. Quantum Computing: Physical Realisations
6. Quantum Noise
7. Entropy and Information
8. Quantum Statistical Mechanics
9. Quantum Information Theory

Course Type:

Elective

Credits:

Assessment:

Homework: 20%, Midterm Exams: 2 x 20%, Journal Club: 30%, Lab: 10%

Text Book:

Quantum Computation and Quantum Information, by M.A. Nielsen and I.L. Chuang (2010). Cambridge University Press

Reference Book:

Quantum Information and Coherence, by E. Andersson and P. Ohberg (2014) Springer

Modern Quantum Mechanics, by J.J. Sakurai and J.J. Napolitano (2010) Addison-Wesley

Quantum Information Theory, by M.M. Wilde (2013) Cambridge University Press

Prior Knowledge: A201 Quantum Mechanics, companion course to A204 Condensed Matter

A211 Advances in Atomic Physics

Course Coordinator: Síle Nic Chormaic

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.

Aim:

To introduce students to recent advances in atomic physics

Course Content:

Early atomic physics

The hydrogen atom and atomic transitions

Helium and the alkali atoms

LS coupling

Hyperfine structure

Atom interactions with radiation

Laser spectroscopy

Laser cooling and trapping

Bose-Einstein condensation

Fermionic quantum Gases

Atom interferometry

Ion traps

Practical elements: Laser spectroscopy

Practical elements: Laser cooling of Rb

Applications: Quantum computing

Practical Exercises : presentations, laboratory exercises on light-matter interactions

Course Type:

Elective

Credits:

2

Assessment:

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

Text Book:

No single textbook will be used during this course.

Reference Book:

Advances in Atomic Physics: An Overview by Cl. Cohen-Tannoudji and D. Guéry-Odelin (2011) World Scientific

Atomic Physics by C.J. Foot (2013) Oxford

Introductory Quantum Optics by C.C. Gerry and P. L. Knight (2005) Cambridge

A212 Microfluidics

Course Coordinator: Amy Shen

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.

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.

Course Content:

1. Introduction to microfluidics; Scaling analysis
2. Low Reynolds number flows
3. Pressure-driven microfluidics
4. Capillary-driven microfluidics
5. Microfabrication
6. Diffusion in microfluidics
7. Mixing in microfluidics
8. Droplet microfluidics and 2-phase flows
9. Bio-MEMs

Course Type:

Elective

Credits:

2

Assessment:

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

Text Book:

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

Reference Book:

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.

Prior Knowledge: Either A202 Fluid Dynamics or B13 Fluid Mechanics

A213 Inorganic Electrochemistry

Course Coordinator: Julia Khusnutdinova

Description:

In this course, students will learn basic principles of electrochemistry with a particular focus on redox behavior of transition metals including metalloproteins. Modern research in application of transition metal complexes for renewable energy storage and production will be highlighted and discussed in detail, including metal-catalyzed water oxidation, proton reduction and CO2 reduction processes. The course will provide practical training in voltammetric techniques and spectroelectrochemistry, and analysis and simulation of cyclic voltammetry data.

Aim:

This course introduces basic principles of electrochemistry, and discusses modern research in the application of transition metal complexes in electrocatalysis for renewable energy storage and production.

Course Content:

1. Basic aspects of electrochemistry
2. Electrochemical instrumentation
3. Cyclic voltammetry: Reversible, irreversible and quasireversible processes
4. Cyclic voltammetry: Effect of coupled chemical reactions; Digital simulation of cyclic voltammograms
5. Bulk electrolysis and pulsed voltammetric techniques
6. Hydrodynamic techniques: application for studying reaction intermediates and mechanisms.
7. Electrochemical behavior of transition metal complexes.
8. Redox-active metalloproteins
9. Redox-induced structural reorganization of metal complexes
10. Electrocatalysis by transition metals for renewable energy production and storage: water splitting to O2and H2
11. Transition metal-catalyzed electroreduction of CO2 and dehydrogenation of formic acid and alcohols: application for hydrogen storage
12. Immobilization of metal catalysts on electrode surface
13. Photoelectrochemistry
14. Application of electrochemical processes in chemical industry

Course Type:

Elective

Credits:

2

Assessment:

Laboratory reports: 25%; Homework: 25%; Presentation: 25%; Final exam: 25%

Text Book:

“Inorganic Electrochemistry: Theory, Practice and Application”, Pierro Zanello (2003), RSC.

Reference Book:

Original papers and review articles will be supplied as required.

A214 Nucleic Acid Chemistry and Engineering

Course Coordinator: Yohei Yokobayashi

Description:

In this course, students will learn basic principles of nucleic acid chemistry and engineering through lectures and discussions. The students will then use the basic knowledge to deepen their understanding of the current research in the field of nucleic acid chemistry and engineering. Finally, the students will design, construct, and characterize functional nucleic acids in the laboratory while learning basic experimental skills to manipulate nucleic acids.

Aim:

This course introduces the basic principles and current research in nucleic acid chemistry and engineering through lectures, discussions and laboratory sessions.

Course Content:

Basic nucleic acid chemistry (3 hr)

1. Structure (DNA, RNA, unnatural nucleic acids, secondary/tertiary structures)
2. Thermodynamics (hybridization)

Synthesis of nucleic acids (4.5 hr)

1. Chemical synthesis (solid phase synthesis)
2. Biochemical synthesis (PCR, in vitro transcription, gene synthesis, biological synthesis, etc.)

Analysis of nucleic acids (4.5 hr)

1. Chemical analysis (UV, electrophoresis, CD, nuclease probing, SHAPE, etc.)
2. Sequence analysis (Sanger, Illumina, PacBio, nanopore, etc.)

Nucleic Acid Engineering (12 hr)

- Synthetic nucleic acids

1. Unnatural bases and backbones
2. Self-assembly, materials
3. Nucleic acid amplification and detection
4. Therapeutics
5. Aptamers
6. Catalytic nucleic acids

7. In vitro selection, in vitro evolution
8. Molecular computation

- Biological nucleic acids

1. Riboswitches
2. Ribozymes

Laboratory: Design, construction, and characterization of functional nucleic acids (12-16 hr labs)

Course Type:

Elective

Credits:

2

Assessment:

Reports 40%; Presentations 40%; Exam 20%

Text Book:

None

Reference Book:

original papers will be supplied as required

A215 Advanced Experimental Chemistry

Course Coordinator: Ye Zhang

Description:

Materials chemistry is emerging as an interdisciplinary field that involves knowledge from diverse science and engineering research fields. The recent public attention and enthusiasm on nanoscience and nanotechnology not only underscores the importance of interdisciplinary research, but also highlights the promises of materials chemistry. The development of modern chemistry allows chemists to precisely control the three-dimension arrangement of many atoms for developing novel materials. In this laboratory course, we will discuss the development and applications of five kinds of materials and synthesize them using classical chemical reactions through modern techniques. The course is a combination of basic theoretical study, and hands on experimental practice, following with further discussions on modern applications and self-designed possible applications as the after class challenge. The course is designed to be accessible to students from a wide range of educational backgrounds.

Aim:

The aim of the course is to teach students to be able to grasp the fundamental concepts of materials chemistry and gain intuition for developing novel materials for a variety of applications.

Course Content:

Experiment 1: Temperature-sensitive Polymeric Hydrogel

Experiment 2: Magnetic Nanoparticles/Ferrofluids

Experiment 3: Lyotropic Liquid Crystals

Experiment 4: Gold Nanoparticles

Experiment 5: Supramolecular Nanofibers/Hydrogels

(Each experiment runs up to 10 hours over 2 weeks)

Course Type:

Elective

Credits:

2

Assessment:

Performance on experiments 40%, Experiment reports 30%, Presentation on designed application 30%

Text Book:

Lab manual will be supplied.

Reference Book:

Nanomaterials: An Introduction to Synthesis, Properties and Applications, 2nd Edition, Dieter Vollath

Soft Condensed Matter (Oxford Mater Series in Condensed Matter Physics, Vol 6), Richard A. L. Jones

Polymer Chemistry, 2nd Edition, Paul C. Hiemenz and Timothy P. Lodge

A216 Quantum Mechanics I

A217 Quantum Mechanics 2

Course Coordinator: Denis Konstantinov

Description:

This is a two-term graduate course that covers most of the essential topics of modern nonrelativistic quantum mechanics. The course is primarily intended for graduate students with background in Physics.

Aim:

This two-term courses aims to prepare students for taking further advanced courses in Physics and Material Science offered in OIST, such as the Solid State and Condensed Matter Physics, Advanced Quantum Mechanics, Advances in Atomic Physics, Quantum Field Theory, etc.

Course Content:

Quantum Mechanics I

1. Early crisis of classical mechanics and motivations for a new approach in physics: black body radiation and "ultraviolet catastrophe", Plank's hypothesis. Einstein's explanation of photoelectric effect. Bohr's model of hydrogen atom.
2. Brief review of analytical mechanics: Newtonian mechanics and conservation laws, constrains and Lagrange reformulation of classical mechanics. Hamiltonian formalism. Poisson brackets and canonical transformations. The Hamilton-Jacoby equation.
3. Brief review of classical electrodynamics: Maxwell equations and boundary conditions, effect of continuous medium, propagation of electromagnetic waves. Ray optics and eikonal approximation. Charged particle in electric and magnetic fields.
4. Motivations for postulates of quantum mechanics: Young's double-slit experiment. de Broglie's hypothesis of matter waves.
5. Bra-ket formalism, Hilbert space, operators, and their matrix representation. Postulates of quantum mechanics. General uncertainty relation.
6. Canonical transformation in quantum mechanics as a main approach to describe motion of a physical system. Translation in space and operator of momentum. Coordinate and momentum representations. Coordinate-momentum uncertainty relation and the Standard Quantum Limit.
7. Time-evolution operator. Energy-time uncertainty relation. The Schrodinger equation of motion and continuity equation. The Heisenberg picture and equation of motion for operators.
8. Some exactly solvable problems in wave mechanics: particle in free space and motion of the Gaussian packet, particle in the box, linear potential, potential barriers and tunneling. Quantum harmonic oscillator: two approaches in solving the problem, coherent and squeezed states of the quantum harmonic oscillator.
9. The WKB approximation. Feynman's path integral and classical limit of the quantum mechanics.
10. Quantum particle in static electric and magnetic fields. Gauge transformation and the Aharonov-Bohm effect. Macroscopic quantum coherence and the Josephson effect. Charged particle in the uniform magnetic field: Landau states and their degeneracy. The Quantum Hall effect.
11. Rotations in space and operator of angular momentum. Orbital and spin angular momentums. Coordinate representation of orbital angular momentum. Spherical harmonics.
12. The Schrodinger equation of motion in 2D and 3D. Particle in central potential: 2D and 3D rigid rotators, particle in a spherical box, 3D quantum harmonic oscillator, Hydrogen atom and emission spectrum.
13. Scattering and diffraction of a quantum particle: Born approximation, expansion into the partial waves.

14. Spin-1/2 particle. Stern-Gerlach experiment. Matrix representation of spin-1/2 states and Pauli matrices. Spin-1/2 particle in the uniform magnetic field.

15. Spinor. Addition of angular momentums. Spin-orbit interaction.

Quantum Mechanics 2

1. N-particle systems. Indistinguishable particles and Pauli exclusion principle. System of spin-1/2 particles and exchange interaction. Introduction to second quatization methods.
2. Symmetries in quantum mechanics. Invariance under unitary transformations and conservation laws. Space inversion symmetry and parity. Lattice symmetry: Bloch waves and energy bands. Time reversal symmetry.
3. Approximation methods in quantum mechanics: variational methods, time-independent perturbation theory. Time-independent perturbation theory in case of degenerate states. Selection rules for orbital angular momentum.
4. Hydrogen atom revisited: fine structure and hyperfine splitting.
5. Hydrogen atom in static electric and magnetic fields: quadratic and linear Stark effects, Zeeman splitting and Paschen-Back effect.
6. Time-dependent perturbation theory. Dyson series for the time-evolution operator. Transitions under time-dependent perturbations: adiabatic and sudden perturbations.
7. Harmonic perturbation and interaction of quantum particle with electromagnetic field. The Fermi's golden rule. Stimulated emission and absorption of electro-magnetic waves by a quantum particle.
8. Exactly solvable time-dependent problem: two-level system approximation and the Rabi oscillations.
9. Introduction to the quantum electrodynamics: quantization of electro-magnetic field. Photons and vacuum fluctuations of electro-magnetic field.
10. Hydrogen atom revisited (again): the Lamb shift.
11. Interaction of quantum particle with electromagnetic field revisited: beyond semi-classical description. Spontaneous emission. The Einstein coefficients.
12. Some topics of modern quantum mechanics: cavity QED and Janes-Cummings Hamiltonian. Implications for qubits.
13. Introduction to quantum mechanical statistics. Density matrix formalism. Pure and mixed ensembles of particles. Description of a system of noninteracting particles.
14. Dynamics of an open quantum system and dephasing. Density matrix approach and the master equation. Von Neumann's postulate of quantum measurements.

Course Type: Elective

Credits: 2 per course

Assessment:

Homework: 30%, Midterm Exam: 30%, Final Exam: 40%.

Text Book:

Modern Quantum Mechanics, by J. J. Sakurai (1994) Addison-Wesley

Principles of Quantum Mechanics, 2nd edition, by Shankar (1994) Springer

Introduction to Quantum Mechanics, 2nd edition, by David J. Griffiths (1995) Pearson Education

Reference Book:

Quantum Mechanics: Vol I & II, by Cohen-Tannoudji, Diu, Laloe (1977). Wiley-Interscience

Quantum Mechanics, Vol. 3, and Quantum Electrodynamics, Vol. 4, 2nd edition, by Landau and Lifshitz (1982) Elsevier

Lectures on Quantum Mechanics, by Gordon Baym (1969) Westview Press

Prior Knowledge: Students who take the course are expected to be familiar with general topics in Classical Mechanics, Electrodynamics and Calculus. Entry to the second part requires a pass in the first part.

A218 Condensed Matter

Course Coordinator: Yejun Feng

Description:

Condensed matter physics is both old-fashioned (originating from solid state physics in 1950's or even metal physics in 1920's) and also new style (with emphasis on collective behaviour, symmetry, and topological conditions). Over the past century, this sub-field of physics has grown to a monstrous size with various ramifications such that any perspective offered would always be partial and biased. Here this class will be served at the introduction level, and at a few places, I will try to demonstrate how to evolve from fundamental concepts to perspectives of advanced topics. Nevertheless, the first half of this course is built on the single particle picture and is of mean field nature. The second half starts to introduce a few examples of electron correlation. More specialized fields, such as spintronics and topological states and excitations, will not be covered here.

Aim:

This is a class designed for beginner students who would pursue a Ph.D. in fields related to physics, materials science, device engineering, and chemistry. The course covers major concepts and topics in condensed matter, with an emphasis on the shifting new perspective and paradigms in this evolving field. During the weekly three-hour lecture, I will try to split the time with half on theory and half on experimental demonstration of those theoretical concepts.

Course Content:

1. Introduction: the change of perspective and paradigms in condensed matter physics.
2. Phase transitions, critical phenomena, and mean field approach.
3. Renormalization approach, universality classes, quantum phase transition.
4. Crystals, symmetry, space groups.
5. Phonons. X-ray and neutron diffuse scattering.
6. Amorphous materials, glass, correlation function, quasi-crystals.
7. Itinerant electrons, band structure, Fermiology, dHvA techniques, resistivity.
8. Electronic excitations, dynamic form factor, inelastic scattering.
9. Superconductivity, BCS vs BEC in solids.
10. Exchange interaction, static magnetic orders magnetic space group.

11. Magnetism: dimension, geometry, and frustration. Disordered spin states.
12. Soft condensed matter: liquids, liquid crystals, and mesoscopic physics.
13. Perspective of advanced topics.

Course Type:

Elective

Credits:

2

Assessment:

Essays (4-6) 70%, final presentation, 30%.

Text Book:

Ashcroft & Mermin, Solid State Physics (1967).

Chaikin & Lubensky, Principles of condensed matter physics (1995).

Reference Book:

D. Pines, Elementary excitations in solids (1963).

L. P. Levy, Magnetism and superconductivity (1997).

J. R. Schrieffer, Theory of superconductivity (1964).

S.K. Ma, Modern theory of critical phenomena (1976).

A.B. Pippard, Magnetoresistance in metals (1989).

Prior Knowledge:

Students are required to have basic understanding of quantum mechanics (e.g., A216 QM I and A217 QM II), and basic concepts of statistics.

A219 General Relativity

Course Coordinator: Yasha Neiman

Description:

We begin by introducing tensors in non-relativistic physics. We then give an overview of Special Relativity, and discuss the special nature of gravity as an “inertial force”. With this motivation, we develop the differential geometry necessary to describe curved spacetime and the geodesic motion of free-falling particles. We then proceed to Einstein’s field equations, which we analyze in the Newtonian limit and in the linearized limit (gravitational waves). Finally, we study two iconic solutions to the field equations: the Schwarzschild black hole and Friedman-Robertson-Walker cosmology. We will use Sean Carroll’s textbook as the main reference, but we will not follow it strictly.

This is an alternating years course.

Aim:

An introduction to General Relativity, from geometry to applications.

Course Content:

1. Tensors in 3d: moment of inertia and magnetic field
2. Special Relativity in 3d language
3. Special Relativity in 4d language: Minkowski spacetime
4. Gravity as an inertial force: the equivalence principle
5. Curved spacetime: metric and Christoffel symbols
6. Geodesic motion: Newtonian limit, redshift, deflection of light
7. Curved spacetime: The Riemann tensor and its components
8. The Einstein field equations and their Newtonian limit
9. Linearized limit and gravitational waves
10. The Schwarzschild black hole
11. More on the Schwarzschild metric: precession of planets, black hole thermodynamics
12. Friedmann-Robertson-Walker cosmology

Course Type:

Elective

Credits:

2

Assessment:

Midterm exam 25% (only if helps the final grade); Final exam 75%

Text Book:

"Spacetime and Geometry – an introduction to General Relativity", Sean Carroll (2003) Addison Wesley

Reference Book:

Landau & Lifshitz vol. 2 ("Classical Theory of Fields").

"Relativity, Gravitation and Cosmology: A Basic Introduction", Ta-Pei Cheng.

"General Relativity", Robert M. Wald.

Prior Knowledge:

Prerequisites: Maxwell's equations in differential form. Solving Maxwell's equations to obtain electromagnetic waves. Linear algebra of vectors and matrices.

A273 Ultracold Quantum Gases

Course Coordinator: Thomas Busch

Description:

The course will start out by introducing the fundamental ideas for cooling and trapping ultracold atoms and review the quantum mechanical framework that underlies the description of interacting matter waves in the ultracold regime. This will introduce the idea of degenerate Bose and Fermi gases, and in particular the concept of Bose-Einstein condensation.

After this the main properties of Bose-Einstein condensates will be discussed, including coherence and superfluidity, and for Fermi gases the physics of the BCS transition will be introduced. Conceptually important developments such as optical lattices, Feshbach resonances, artificial gauge fields and others will be explained in detail as well. New developments in the area of strongly correlated gases will be introduced and applications of cold atoms in quantum information or quantum metrology provide the final part of the course.

The course will mostly focus on the theoretical description of ultracold quantum gases, but regularly discuss experimental developments, which go with these.

Aim:

The course introduces the students to the field of ultracold quantum gases. The lectures are combined with a weekly journal club, where original publications related to the lecture are discussed. Students will learn some fundamental concepts and techniques used in ultracold atoms research and obtain an overview over the many directions this diverse field is developing into. At the end of the course the students should be able to read current scientific literature and discuss work with researchers in the area. Since the area of ultracold quantum gases has connections to many other fields of physics, especially condensed matter and optics, students will be able to pick up aspects of these as well.

Course Content:

1. Ultracold atomic gases: cooling and trapping
2. Bose-Einstein condensation and Fermi degeneracy in ideal gases
3. Interacting Bose-Einstein condensates: Gross-Pitaevskii equation.
4. Dynamics of Bose-Einstein condensates. Expanding and oscillating condensates.
5. Elementary excitations. Bogoliubov-De Gennes equations.
6. Two-dimensional Bose gases. Kosterlitz-Thouless transition.
7. Vortices and Superfluidity
8. One-dimensional systems: quasi-condensates and solitons
9. Strongly interacting 1D Bose gases. Impenetrable bosons.
10. Degenerate Fermi gases: BEC and BCS transitions
11. Optical lattices
12. Artificial Gauge fields
13. Applications in quantum information and metrology

Course Type:

Elective

Credits:

2

Assessment:

Homework: 50%, Project 25%, In-term tests, 25%.

Text Book:

Bose-Einstein Condensation in Dilute Gases C.J. Pethick and H. Smith (2002) Cambridge University Press

Bose-Einstein Condensation L.P. Pitaevskii and S. Stringari (2003) Oxford University Press

Fundamentals and New Frontiers of Bose--Einstein Condensation M. Ueda (2010) World Scientific

Reference Book:

Modern Quantum Mechanics, by J. J. Sakurai (1994) Addison-Wesley

Quantum Mechanics, by J.-L. Basdevant and J. Dalibard (2002) Springer

Prior Knowledge:

While the fundamental concepts of atomic physics and quantum mechanics that are required will be reviewed in the beginning of the course, basic prior knowledge of quantum mechanics is required (e.g. A216 & A217).

Companion course to A211 Advances in Atomic Physics

A303 Developmental Biology

Course Coordinator: Ichiro Masai

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.

Course 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

Aim:

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

Course Type:

Elective

Credits:

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

A304 Evolutionary Developmental Biology

Course Coordinator: Noriyuki Satoh

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.

Course 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

Aim:

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

Course Type:

Elective

Credits:

2

Assessment:

Homework (20%), Written reports (4 x 20%).

Text Book:

From DNA to Diversity, 2 edn, by Carroll, Grenier and Weatherbee (2005) Blackwell.

A306 Neuroethology

Course 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.

Course 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

Aim:

To introduce an understanding of the neuronal mechanisms that control complex animal behavior.

Course Type:

Elective

Credits:

2

Assessment:

Homework, 20%; Written reports, 4 x 20%.

Text Book:

Behavioral Neurobiology, by Thomas J Carew (2000) Sinauer

A307 Molecular Oncology and Cell Signalling

Course 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.

Course 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

Course Type:

Elective

Credits:

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

A308 Epigenetics

Course 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.

Course 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

Course Type:

Elective

Credits:

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

Prior Knowledge:

Requires at least B06 Cell Biology and Genetics or similar background knowledge

A310 Computational Neuroscience

Course 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. More recently networks consisting of simple integrate-and-fire neurons have become popular. Nowadays standard simulator software exists to apply these modeling methods, which can then be used to interpret and predict experimental findings.

This course introduces some standard modeling methods with an emphasis on simulation of single neurons and synapses and an introduction to integrate-and-fire networks. Each theoretical topic is linked to one or more seminal papers that will be discussed in class. A number of simple exercises using the NEURON simulator will demonstrate single neuron and synapse modeling.

Aim:

This course introduces basic concepts and methods of computational neuroscience based on theory and a sampling of important scientific papers.

Course Content:

1. Introduction and the NEURON simulator

2. Basic concepts and the membrane equation
3. Linear cable theory
4. Passive dendrites
5. Modeling exercises 1
6. Synapses and passive synaptic integration
7. Ion channels and the Hodgkin-Huxley model
8. Neuronal excitability and phase space analysis
9. Other ion channels
10. Modeling exercises 2
11. Reaction-diffusion modeling and calcium dynamics
12. Nonlinear and adaptive integrate-and-fire neurons
13. Neuronal populations and network modeling
14. Synaptic plasticity and learning

Course Type:

Elective

Credits:

2

Assessment:

Active participation to textbook discussions in class (40%), reports on modeling papers (40%), written exercises (20%).

Text Book:

Biophysics of Computation, by Christof Koch (1999) Oxford Press

Neural Dynamics: From Single Neurons to Networks and Models of Cognition, by Wulram Gerstner, Werner M. Kistler, Richard Naud and Liam Paninski (Cambridge University Press 2014)

Reference Book:

Computational Modeling Methods for Neuroscientists, edited by Erik De Schutter (MIT Press 2010)

Prior Knowledge:

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

A311 Cellular Aging and Human Longevity

Course Coordinator: Mitsuhiro Yanagida

Description:

A series of lectures and seminar (for invited lecturers) will provide basic concepts how contemporary scientists challenge the enigma of longevity and lifespan through diverse methodology. The subjects have greatly attracted mankind for thousand years. But rigorous scientific approach has been conducted for only a few decades after molecular, cellular, genetic and genome approaches to understand life mechanisms become possible. In addition, proper introduction of model organisms and detailed experimental analysis greatly helped the establishment of basic concepts on longevity and lifespan of organisms. In addition, after the entry into 21st century, developed countries have increased senior populations over 65 yr old and the financial burden for medical care and welfare is increasingly felt. Hence human longevity and lifespan have become important research themes in many countries. Healthy longevity is now the keyword for human welfare. In this series of lectures, I plan to invite a few more experts on human gerontology. It is quite important for every person to know basics of human aging and how we adapt and/or confront it.

Aim:

This course provides a current overview of cellular aging and human longevity.

Course Content:

1. (Yanagida) Introduction on cellular life span and human longevity: How I was interested in cellular and organisms lifespan after years of chromosome research.

2. Professor Hiroshi Kondoh (Kyoto University, School of Medicine, Gerontology) Introduction of human longevity part 1.

3. (Yanagida) How I started to study human aging through blood metabolites

4. Professor Hiroshi Kondoh (Kyoto University, School of Medicine) Human longevity part 2.

Seminar for OIST researchers and students after lecture.

5. (Yanagida). Measuring biological aging

6. Professor Takehiko Kobayashi (Univ Tokyo), Seminar, afternoon for OIST students and researchers

7. (Yanagida) Cellular aging

8. (Yanagida) Genetics of aging

9. (Yanagida) Genetics of aging through the study of fission yeast G0 cells

10. (Yanagida) Human longevity and agin.

11. Professor Yoichi Nabeshima (Kyoto Univ) The role of Klotho for human longevity, Seminar, afternoon for OIST students and researchers

12. March 30 Invited speaker (not decided)

13. Professor Eisuke Nishida (Kyoto Univ, School of Biostudy) Lifespan of model organisms, Seminar, afternoon for OIST students and researchers

14. (reserved) a possible topic: Age-related human diseases

Course Type:

Elective

Credits:

2

Assessment:

TBC

Text Book:

Biology of Aging by Roger B. McDonald. Garland Science 2014

A312 Sensory Systems

Course Coordinator: Izumi Fukunaga

Description:

The course will cover general concepts and specific modalities as detailed in the table below. Classes alternate between a lecture-style teaching and a journal club. Each lecture will be based on a textbook chapter (Kandel et al's Principles of Neural Sciences, in combination with other, specialised books described in the "Textbooks" section) to cover basic and broad topics, but will also serve as an opportunity to introduce concepts required to understand the research article associated with the lecture.

Aim:

The course is structured for students who would like to know about sensory systems in the brain at an advanced level. The overall aim is expose students to research-level materials, but starting from basic concepts. Topics will include specialisations as well as common principles found in the mechanisms of sensory perception, and will cover the somatosensory, visual, auditory, olfactory systems from transduction to higher cognitive functions. In parallel, the course aims to develop students' ability to read and discuss primary research articles, to give students an exposure to some of the latest techniques and developments.

Course Content:

1 (wk1) Overview lecture/intro Motivation; Modality, basic organisation: transduction, pathways, maps, integration, perception

2 (wk1) Sensory coding lecture/intro Relationship between a physical stimulus and sensation; intensity, threshold, adaptation, effect of background, discriminability

3 (wk2) Somatosensory system I lecture/intro

4(wk2) Somatosensory system I Journal club "Robust temporal coding in the trigeminal system" by Jones, Depireuz, Simons & Keller 2004

5(wk3) Somatosensory system II lecture/intro

6(wk3) Somatosensory system II Journal club "Active spatial perception in the vibrissa scanning sensorimotor system" by Mehta, Whitmer, Figueroa, Williams & Kleinfeld 2007

7(wk4) Hearing I lecture/intro

8(wk4) Hearing I Journal club "Ca^{2+} current-driven nonlinear amplification by the mammalian cochlea in vitro" by Chan & Hudspeth 2005

9(wk5) Hearing II lecture/intro

10(wk5) Hearing II Journal club "In vivo coincidence detection in mammalian sound localization generates phase delays" by Franken, Roberts, Wei, Golding & Joris 2015

11(wk6) Vision I lecture/intro

12(wk6) Vision I Journal club "Wiring specificity in the direction-selectivity circuit of the retina" by Briggman, Helmstaedter & Denk, 2011

13(wk7) Vision II lecture/intro

14(wk7) Vision II Journal club "Functional specificity of local synaptic connections in neocortical networks" by Ko, Hofer, Pichler, Buchanan Sjostrom & Mrsic-Flogel, 2011

15(wk8) Vision III lecture/intro

16(wk8) Vision III Journal club "Explicit information for category-orthogonal object properties increases along the ventral stream" by Hong, Yamins, Majaj & DiCarlo 2016

17(wk9) Chemical Senses I lecture/intro olfaction

18(wk9) Chemical Senses I Journal club "Random convergence of olfactory inputs in the Drosophila mushroom body" by Caron, Ruta, Abbott & Axel, 2013

19(wk10) Chemical Senses II lecture/intro gustation

20(wk10) Chemical Senses II Journal club "A chemosensory gene family encoding candidate gustatory and olfactory receptors in Drosophila", by Scott, Brady, Cravchik, Morozov, Rzhetsky, Zucker and Axel, 2001.

Assessment: Careful reading of the research article set for each journal club; Each student is asked to write a 1-page summary of the paper in their own words (Homework: 70%). The summary should include the context/rationale for the experiments, methods, results and the significance of the work. The summary will be assessed on clarity, balance, and whether or not student has understood the work. Class participation, 30%.

Course Type:

Elective

Credits:

2

Assessment:

Homework: 70%; Class participation, 30%.

Text Book:

1. Principles of Neural Science (MIT Press) by Kandel, Schwartz, Jessell, Siegelbaum, Hudspeth

2. Auditory Neuroscience (MIT Press) by Schnupp, Nelken and King

3. Principles of Neural Design (MIT Press) by Peter Sterling and Simon Laughlin

Reference Book:

1. Vision by David Marr

Prior Knowledge:

The course is aimed at students with a background in neuroscience (either at the BSc/MSc level or having successfully completed some of the basic neuroscience course offered at OIST). It assumes knowledge in cellular neurophysiology and neuroanatomy. Most relevant courses at OIST will include: B05 (Neurobiology; requirement), A405 (Emerging technologies in life sciences; desirable), B09 (Learning and behaviour; desirable), A310 (Computational neuroscience; highly desirable). B05 is the most important (in terms of subject matters listed on the course's website), so a pass in this course will be a pre-requisite.

A401 Controversies in Science

Course Coordinator:

Gordon Arbuthnott

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.

Course 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

Course Type:

Elective

Credits:

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)

A404 Measurement

Course Coordinator: Denis Konstantinov

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.

Course 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

Course Type:

Elective

Credits:

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

A405 Emerging Technologies in Life Sciences

Course Coordinator: Ichiro Maruyama

Description:

This course is intended to provide an introduction to cutting-edge techniques that might be useful for research projects by graduate students at OIST. Such techniques include nucleotide sequencing, microarray, confocal laser scanning microscopy, microfluidics and neuroimaging. Each session will be composed of a lecture relevant to the technique. Where possible, hands-on training or research laboratory visits will also be provided, and technical presentations will be invited from leading experts. This course is intended to provide an introduction to cutting-edge techniques that might be useful for research projects by graduate students at OIST. Such techniques include nucleotide sequencing, microarray, confocal laser scanning microscopy, microfluidics and neuroimaging. Each session will be composed of a lecture relevant to the technique. Where possible, hands-on training or research laboratory visits will also be provided, and technical presentations will be invited from leading experts.

Aim:

This course introduces cutting-edge technologies in life science.

Course 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)

Course Type:

Elective

Credits:

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

A409 Electron Microscopy

Course 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.

Course 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

Course Type:

Elective

Credits:

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.

Prior Knowledge:

Ideally combined with A403 Strucutral Biology: Protein Xray Crystallography (Samatey) and A410 Molecular Electron Tomography (Skoglund)

A410 Molecular Electron Tomography

Course 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.

Course Content:

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

Course Type:

Elective

Credits:

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.

B05 Neurobiology

Course Coordinator: Tomoyuki Takahashi

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 is a combination of student-led presentations on each of the key topics, and also student presentations of several classic papers, and a series of laboratory explorations of the topics covered in class.

Aim:
This course provides an overview of cellular neurophysiology and looks closely at the fundamental aspects of action potentials and synaptic signalling, in preparation for other advanced courses in neuroscience.

Course Content:
Theory Classes
Membrane potential (I)
Methods for recording electrical signals
Cell membrane compositions
Intracellular and extracellular ionic compositions
Membrane potential, polarization, depolarization, hyperpolarization
Membrane capacitance
Electrical properties of cell membrane
Nernst equation
Calculation: Equilibrium potentials of Na+ and K+, based on extracellular and intracellular ionic compositions.

Membrane potential (II)
Selective permeability of Na and K ions
Resting membrane potential described by Goldman-Hodgkin-Katz equation
Hodgkin-Huxley membrane model circuit
Active transport
Na-K ATPase

Action potential (I)
Voltage-clamp recording; principle and practice
Cable properties of axonal membrane
Molecular structure of voltage-gated Na channels
Relationship between single Na channel currents vs whole cell Na currents
Channel activation, channel deactivation vs channel inactivation
Na current-voltage relationship
Voltage dependence of Na channel conductance

Mechanism of channel inactivation: the ball-and-chain model

Action potential (II)
Voltage-gated K channels: molecular structure
Single K channel vs whole cell K currents
K current-voltage relationship
Voltage dependence of K channel conductance
Mechanism of action potential generation and repolarization
Refractory period
Calculation: Amount of Na influx in response to a single action potential, and its impact on intracellular Na concentration (assuming cell size).

Synaptic transmission (I)
Structural organization of synapses
Equilibrium potential for Ca ion.
Voltage-gated Ca channels: molecular structure and subtype classification
Ca current-voltage relationship and conductance
Non-linear relationship between Ca and transmitter release.

Synaptic transmission (II)
Roles of Ca channels and K channels in transmitter release
Quantal nature of transmitter release; from binomial to Poisson theorem

Synaptic transmission (III)
Exocytosis, endocytosis, vesicle recycling
Molecular mechanisms of transmitter release
Ca domain in the nerve terminal: how to estimate its size?
Synaptic vesicle recycling and reuse
Vesicular transmitter refilling mechanism
Synaptic transmission (IV)
Ligand-gated ion channels: molecular structure
Nicotinic acetylcholine receptor, AMPA receptor, NMDA receptor,
Glycine receptor, GABA(A) receptor
EPSP/EPSC, IPSP/IPSC; Equilibrium potentials: calculation
Regulatory mechanisms for intracellular Cl concentration

Sensory transduction mechanisms
G protein-coupled receptors
Second messengers and targets
Muscle spindle, stretch-activated channels
Auditory transduction, from sound to action potentials
Visual transduction, from light to action potentials
Olfactory transduction, from odor to action potentials

Synaptic integration & modulation
Patellar-tendon reflex
Reciprocal inhibition
Postsynaptic inhibition, presynaptic inhibition
Feedback and feedforward inhibition
Lateral inhibition
Retrograde inhibition

Autoreceptor
Short-term facilitation and depression
Long-term potentiation (LTP) and depression (LTD)
Long-lasting LTP (LLTP)
Role of NMDAR in LTP
Role of glia in LTP

Laboratory Sessions (Takahashi Unit)
Membrane Potential
Action Potential
Synaptic Transmission
Synaptic integration & modulation

Course Type: Elective
Credits: 2
Assessment:
Student presentations on classic papers, class discussion, and a final report summarising what the student learned in the course.
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
Ion Channels of Excitable Membranes, 3 edn, Bertil Hille (2001) Sinauer
Principles of Neural Science, 5 edn, Kandel, Schwartz, Messel, Siegelbaum and Hudspeth (2012) McGraw-Hill
Reference Book:
Fundamental Neuroscience 3 edn, Larry Squire, (2008) Elsevier (Academic Press)
The Synaptic Organization of the Brain, 5 edn, Gordon M. Shepherd (2003) OUP
Encyclopaedia of Neuroscience (5 volumes) (2009) Springer
From Neuron to Brain (Nicholls et al eds), Sinauer

B07 Statistical Methods

Course Coordinator: Kenji Doya

Description:

This course introduces basic principles and practical methods in statistical testing, inference, validation, and experimental design. The lectures cover the following topics: What is probability: frequentist and Bayesian views; probability distributions; Statistical measures; Statistical dependence and independence; Stochastic processes; Information theory; Statistical testing; Statistical inference: maximum likelihood estimate and Bayesian inference; Model validation and selection; Experimental design. Emphasis is put on the assumptions behind standard statistical methods and the mathematical basis for finding the right one.

Aim:

This basic course will equip students with the necessary understanding and experience in statistical methods essential to modern scientific research.

Course Content:

1. Introduction: Probability and Statistics
2. Probability distributions, Expectation, Variance
3. Joint and conditional distribution, Statistical independence, Correlation
4. Confidence intervals
5. P Values, t Test
6. Multiple testing, ANOVA
7. Nonparametric methods
8. Linear regression, Maximum likelihood
9. Multiple regression, Logistic regression, ROC
10. Regularization, Bayesian methods
11. PCA, ICA, Entropy, Mutual information
12. Clustering, Mixture models

Course Type:

Elective

Credits:

2

Assessment:

Problem sets, 60%; Final written test, 40%.

Text Book:

Harvey Motulsky (2014) Intuitive Biostatistics. Oxford University Press.

Larry Wassermann (2005) All of Statistics. Springer.

https://link.springer.com/book/10.1007/978-0-387-21736-9

Reference Book:

Sarah Stowell (2015) Using R for Statistics. Springer

https://link.springer.com/book/10.1007/978-1-4842-0139-8

Roger D. Peng (2015) R Programming for Data Science

https://leanpub.com/rprogramming

B08 Physics for Life Sciences

Course Coordinator: Bernd Kuhn

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.

Course Content:

1. Introduction - Physics in Biology: How physics contributes to life sciences.
2. Nature of light
3. Nature of matter
4. Fundamentals on light and matter interaction
5. Fluorescence and its applications
6. Biophotonics
7. Photosynthesis
8. The physics of optogenetics
9. Linear optics
10. Microscopy
11. Non-linear optics, lasers, two-photon microscopy, super resolution microscopy
12. The physics of electron microscopy
13. The physics of DNA, lipid membranes, and proteins
14. Bioelectricity
15. Electronics for electrophysiology
16. Magnetic resonance

Aim:

This basic course aims to introduce physical principles that are necessary in modern life sciences.

Course Type:

Elective

Credits:

2

Assessment:

Midterm presentation 35%, Final presentation 35%, participation + homework 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

B09 Learning and Behavior

Course Coordinator: Gail Tripp

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.

Course Content:

Research methods (I)

- Ethics
- Hypothesis testing
- Dependent and independent variables
- Reliability and validity
- Bias, blinding

Research methods (II)

- Data collection methods
- Observation
- Surveys
- Experimental and quasi experimental designs
- Data analysis

Learning and behavior (I)

- Classical, Pavlovian, respondent conditioning (elicited responses)
- Operant, instrumental conditioning (instrumental responses)

Learning and behavior (II)

- Reinforcement and punishment

- Operant schedules

Learning and behavior (III)

- Behavior modification
- Applications

Motivation and reward

- Drug addiction
- ADHD

Memory and cognition (I)

Memory and cognition (II)

Perception and attention

Behavioral neuroscience (I)

Behavioral neuroscience (II)

Genes and behaviour

Animal models

Life span

Course Type:

Elective

Credits:

2

Assessment:

Article reviews and critiques (5) each worth 5% (Total 25%), Student presentation (2) each worth 15% (Total 30%), Participation in class discussions 5%, Research grant proposal 40%

Text Book:

To be announced

Reference Book:

Attention and Associative Learning: From Brain to Behaviour, by Mitchell and Le Pelley (2010)

Handbook of Neuroscience for the Behavioral Sciences 4 edn, by Bernston and Cacioppo (2009) Wiley

Physiology of Behavior 10 edn, by Carlson (2009) Allyn and Bacon

B10 Analytical Mechanics

Course Coordinator: Mahesh Bandi

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.

Course 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

Course Type:

Elective

Credits:

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

B11 Classical Electrodynamics

Course Coordinator: Tsumoru Shintake

Description:

A graduate course in analytical mechanics, covering the essential equations and their applications, to prepare for later courses in electrodynamics and quantum physics. 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.

Course 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

Course Type:

Elective

Credits:

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

B12 Statistical Physics

Course 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?

Course 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. 11.To be developed through student presentations: modern applications of statistical mechanics, with examples taken from life-sciences, sociology, and stock markets.

Course Type:

Elective

Credits:

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

B13 Theoretical and Applied Fluid Mechanics

Course 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.

Course 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

Course Type:

Elective

Credits:

2

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

B14 Theoretical and Applied Solid Mechanics

Course 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.

Course 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).

Course Type:

Elective

Credits:

2

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)

B15 Immunology

Course 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.

Course 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

Aim:

This lecture series introduces the basic principles and current research in immunology.

Course Type:

Elective

Credits:

2

Assessment:

Report 50%; Final exam 50%

Reference Book:

Immunobiology 8 edn, by Kenneth Murphy (2012) Garland Science

B16 Ecology and Evolution

Course Coordinator: Evan Economo

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.

Course 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

Aim:

This course provides a basic overview of modern concepts in ecology and evolution.

Course Type:

Elective

Credits:

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, 3 edn, by Douglas Futuyma (2013) Sinauer

B20 Introductory Evolutionary Developmental Biology

Course Coordinator: Hiroshi Watanabe

Description:

This course will provide an introduction to Evolutionary Biology focusing on the developmental process of multicellular organisms for students with and without an undergraduate background in this field. Two major goals in this course will be to understand evolutionary changes in development and to learn modern creatures and technologies employed for addressing issues in evolutionary developmental biology.This course presents the basic principles and recent findings in evolutionary developmental biology.

Aim:

This course presents the basic principles and recent findings in evolutionary developmental biology.

Course Content:

1. Animal phylogeny
2. Gain and loss in evolution
3. Gene homology
4. Cell homology
5. Gene expression
6. Basic body plan I: Embryogenesis
7. Basic body plan II: Main body axes
8. Basic body plan III: Main body axes
9. Signaling pathways and gene regulatory networks
10. Body axes in basal metazoans
11. Multicellularity
12. Research tools I: Genome/transcriptome analysis and molecular phylogeny
13. Research tools II: New animal models
14. Research tools III: Gene function analysis

Course Type:

Elective

Credits:

2

Assessment:

Midterm Reports 60% (2 x 30%), Final Exam 40%

Text Book:

None

original papers will be supplied as required

Reference Book:

Animal Evolution Interrelationships of the Living Phyla, 3 Edn, by Nielsen (2011) Oxford University Press

Developmental Biology, 11 Edn, by Gilbert and Barresi (2016) Sinauer

The Evolution of Organ Systems, by Schmidt-Rhaesa (2007) Oxford University Press

Evolutionary Transitions to Multicellular Life Principles and mechanisms, by Ruiz-Trillo and Nedelcu (2015) Springer

Prior Knowledge:

No prior knowledge assumed

B21 Biophysics of Cellular Membranes

Course Coordinator: Akihiro Kusumi

Description:

Description: Students will learn several basic concepts of biophysics including thermal conformational fluctuation and thermal diffusion, and how cells might take advantage of these physical processes to enable their functions. As a biological paradigm, the cellular membrane system (and their functions), with a special attention paid to signal transduction in the plasma membrane, will be extensively covered. This is because the membranes are critically important for a variety of cellular processes, in the fields of cancer biology, immunology, neuroscience etc., and also because the membrane system provides us with an interesting and useful biological paradigm to learn how the life processes are made possible by thermal-physical processes. As a way of directly "seeing" the thermal, stochastic processes exhibited by receptors and downstream signaling molecules undergoing signaling in live cells, the methods of single-molecule imaging-tracking and manipulation will be discussed quite extensively. Through this course, students will better understand the interdisciplinary field of biology, chemistry, physics, and mathematical science.

Aim:

Aims: This lecture series introduces the basic concepts and current research in cellular biophysics of biological membrane systems.Aims: This lecture series introduces the basic concepts and current research in cellular biophysics of biological membrane systems.

Course Content:

1. Introduction to Biophysics

2. Biological Membrane Structure and Molecular Dynamics

3. Signaling in the Plasma Membrane I

4. Single-molecule Imaging and Manipulation of Plasma Membrane Molecules

5. Interaction between the Plasma Membrane and the Cytoskeleton

6. Force Involved in Organizing Membrane Molecules

7. Domain Structures of the Plasma Membrane

8. Signaling in the Plasma Membrane Enabled by Its Meso-Scale Domain Organization

9. 3D-Organization of the Plasma Membrane: Endocytosis and Exocytosis

10. Membrane Deformation

11. Interaction between the Cytoplasmic Membranes and the Cytoskeleton

12. Tubulovesicular Network in Cells

13. Signaling in the Plasma Membrane II

14. Biological Meso-scale Mechanisms

Course Type: Elective

Credits: 2

Assessment:

Report 50%; Final exam 50%

Text Book:

Mary Luckey, Membrane Structural Biology 2nd Ed. Cambridge University Press

Prior Knowledge: Biology, chemistry, or physics at undergraduate levels

B22 Computational Methods

Course Coordinator: Kenji Doya

Description:

The course starts with basic programming using Python, with some notes on other computing frameworks. Students then get acquainted with data manipulation and visualization using “numpy” and “matplotlib.” After learning how to define one’s own function, students learn iterative methods for solving algebraic equations and dynamic simulation of differential equations. The course also covers basic concepts in stochastic sampling, distributed computing, and software management. Toward the end of the course, each student will pick a problem of one’s interest and apply any of the methods covered in the course to get hands-on knowledge about how they work or do not work.

Aim:

This course aims to provide students from non-computational backgrounds with the basic knowledge and practical skills for computational methods required today in almost all fields of science. Python is used as the standard programming language, but the concepts covered can be helpful also in using other computing tools for data analysis and simulation.

Course Content:

1. Introduction to Python
2. Vectors, matrices and other data types
3. Visualization
4. Functions and classes
5. Iterative computation
6. Ordinary differential equation
7. Partial differential equation
8. Optimization
9. Sampling methods
10. Distributed computing
11. Software management
12. Project presentation

For each week, there will be homework to get hands-on understanding of the methods presented.

Course Type: Elective

Credits: 2

Assessment:

Homework: 75% (2 hours per week), Project 25%.

Text Book:

Valentin Haenel, Emmanuelle Gouillart, Gaël Varoquaux: Python Scientific Lecture Notes. (http://scipy-lectures.github.com/)

Reference Book:

Python Documentation. (https://docs.python.org/)

Prior Knowledge: Basic computer skill with Windows, MacOS, or Linux is assumed. Each student will bring in a laptop provided by the Graduate School. Knowledge of basic mathematics, such as the calculus of vectors and matrices and the concept of differential equations, is assumed, but pointers for self-study are given if necessary.

B23 Molecular Evolution

Course Coordinator:

Tom Bourguignon

Description:

Life sciences have been greatly influenced by the progress of DNA sequencing technologies. The field of Evolutionary Biology is no exception, and increasingly relies upon fast generation of DNA sequences, that are analysed using fast evolving bioinformatics tools. The aim of this course is to introduce the basic concepts of molecular evolution to students of all scientific backgrounds. We will explore some important questions in Biology, and through concrete examples, determine how molecular evolution theory help answering them. The students will also learn how to use a number of widely used bioinformatics tools.

Aim:

Understanding the theoretical concepts of molecular evolution and their application to solve biological questions.

Course Content:

1. DNA, RNA and protein
2. Replication and mutation
3. Building a genome
4. Gene
5. Selection
6. Drift and population genetics
7. Evolution of species
8. Using DNA to build phylogenies
9. Putting dates on trees
10. High throughput sequencing: the rise of genomics and transcriptomics
11. Working with genome-scale data: Annotation, gene orthology, RNAseq…
12. Genomics of symbiosis
13. Amplicon metagenomics and environmental DNA
14. Ancient DNA and protein

Course Type:

Elective

Credits:

2

Assessment:

1/4 participation, 1/4 presentation, 1/2 homework and essay.

Text Book:

An Introduction to Molecular Evolution and Phylogenetics, by Lindell Bromham (2015) Oxford University Press

Prior Knowledge:

Assumes general knowledge in biology; ideally follow-on course from B16 Ecology and Evolution

PD1 Professional Development I for 2017 Students

Coordinator	Ulf Skoglund
Description	This course aims to develop knowledge and skills important for leadership in scientific research and e main components of the course are (1) weekly seminars covering basic principles of research conduc communication, and aspects of science in society, including a visiting speaker program (2) a cross-dis (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 atte that you also engage by participating in discussion and asking questions. Visiting speakers will be invi seminars and lead interactive discussions. Visiting speakers will include leaders from major corporati and scientific laboratories and internationally leading researchers from different fields. This is an opp the leaders see as important during their successful careers, and also a chance to learn how to intera 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 leade management, cooperation and creative interaction, cross-disciplinary communication, and coordinat Group project work is timetabled on Friday afternoons for two hours every second week, alternating teaching skills training. Timing of project activity is flexible and different times may be decided by the component will require involvement in a student led group project. Projects will not be directly supe member, but there will be opportunities for consultation where certain expertise is required. The nat will be explained in class but they may include development of new research tools and applications, i problems, field studies, or creation of resources for research and learning. There will be a self-assess group members to recognize the contributions of different members, and an overall grade based on 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 bot academia is fierce. Researchers, whether in academia or industry, need to develop their personal ski outstanding research, but also to write papers, teach and demonstrate the impact and relevance of t communication skills component of PD1 comprises a set of opportunities for students to improve aca and scientific writing skills.
Aim	The aim of this course is to provide information essential to beginning one's career as a professional develop skills fundamental to modern scientific practice.

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 Offered

Special Topics

Biological Networks: Bioinformatics and Modelling

Professor Igor Goryanin

Day 1 Introduction / Theory. Enzyme kinetics (Goryanin)/ Practicals.
Introduction, installing software (Goryanin)

Day 2 Theory: Metabolic Pathways. Graph analysis of Biological networks. Standards in Systems Biology(Goryanin)

Day 3 Theory: Flux Balance Analysis. Stoichiometric matrix and its properties. Extreme pathways (Goryanin)

Day 4 Theory: Applications in Systems Biology. (Goryanin). Practicals. Tests (Goryanin/Sorokin)
Two Lectures and four practicals from 25th of July till 18th of August.

Computational Biology: Artificial Intelligence for Bioinformatics

Professor Hiroaki Kitano (OIST adjunct professor)
with other presenters

7/22 (Mon) 09:00-13:00: Kitano & Asai (Intro /Hands-on I Physiological Modeling)

7/23 (Tue) 09:00-13:00: Kitano (Signal Transaction/Cell Cycle)

7/24 (Wed) 09:00-13:00: Funahashi (Hands-on Ⅱ CellDesigner Modeling)

7/25 (Thu) 09:00-13:00: Kitano (AI for Life Science/Wrap-up)

Geometry and Topology

Professor Anastasiia Tsvietkova

Select seminar topics in Geometry and in Topology, over two terms.

Holography and Anti de Sitter space

Professor Yasha Neiman
with Lecturer Linqing Chen

Skill Pills AY2017-2018

Skill Pill: Regular Expressions August 28 and 30, 1PM to 3PM

Skill Pill: Hands-on Electronics August 23, 27 and 29, from 1PM to 4 or 5PM

Skill Pill: Git July 10 and 12, 10AM - 12PM

Skill Pill: GIMP June 25 and 28, 1PM - 3PM

Skill Pill: BLAST July 17 and 18, 10AM - 12PM

Skill Pill: Building and Maintaining a CV July 3 and 5, 10AM - 12PM

Skill Pill: Terminal May 22, 24, 28, 10AM to 12PM

Skill Pill: Filmmaking for Scientists May 30, 31, June 6, AM

Skill Pill: 3D Printing May 14, 16, 10AM to 12PM

Skill Pill: Calculus of Variations April 23. 25, 27, 10AM to 12PM

Skill Pill: Teaching Techniques April 17, 19, 10AM to 12PM

Skill Pill: Phylogenetic Reconstruction April 10 (1PM to 3PM) and 12 (1PM to 4PM)

Skill Pill: Intro to Programming March 26, 29, April 2, 5, 1PM to 3PM

Skill Pill: Skill Pill: Android Development April 4, 1PM to 5PM

Skill Pill: LabVIEW March 20, 23, 27, 30, 10AM to 12PM

Skill Pill: Philosophy of Mind Feb 27, Mar 2, 6, 9, 10AM and 11AM to 12PM

Skill Pill: Bayesian statistics January 18, 19, 25 and 26, 10AM to 12PM

Skill Pill: Visualizing Tomography Data February 6, 8 and 13, 10AM to 12PM

Skill Pill+: Nanoparticles by Design December 9 (Saturday) 10AM to 6PM

Skill Pill: Super-resolution Microscopy December 6, 7 or 8, 10AM to 12PM

Skill Pill: Electronics for Computational Neuroscience November 18 and 25 (Saturdays)

Skill Pill: Planning Your Scientific Journey Every Wednesday from October 4th to November 1st, 12PM to 1PM

Skill Pill: LaTeX November 6, 7, 13 and 14, 1PM to 3PM

Skill Pill: GPU November 7, 9 and 14, 10AM to 12PM

Skill Pill: Digital Marketing Wednesday October 11, from 10AM to 12PM

Skill Pill: MATLAB October 3, 5, 10 and 12, 10AM~12PM

Skill Pill: Keynote September 27 and 28, 10AM~12PM

Skill Pill: Raspberry Pi Saturday September 9, 10AM to 6PM