Degree Completion Requirements for AY2019/2020

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

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

Note 1: 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 Taught in AY2019/2020

Note: not all course available are offered every year. This archive shows only those courses that were taught.

A103 Stochastic Processes with Applications

Course coordinator

Simone Pigolotti

Description

This course presents a broad introduction to stochastic processes. The main focus is 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 concepts in probability theory, we introduce stochastic processes and the concept of stochastic trajectory. We 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 common stochastic processes: Markov chains, Master Equations, Langevin/Fokker-Planck equations. For each process, we present applications in physics, biology, and neuroscience, and discuss algorithms to simulate them on a computer. The course 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 are finalized as homework and constitute the main evaluation of the course.

Aim

The course is aimed at students interested in modeling systems characterized by stochastic dynamics in different branches of science. Goals of the course are: to understand the most common stochastic processes (Markov chains, Master equations, Langevin equations); to learn 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 of Langevin equations. 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.

6) Element of stochastic thermodynamics. Work, heat, and entropy production of a stochastic trajectory. Fluctuation relations, Crooks and Jarzynski relations.

Course Type

Elective

Credits

2

Assessment

Reports (numerical simulations): 60% hands-on sessions, 20% homework assignments, 20% participation in class

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 probability theory, e.g. discrete and continuous distributions, random variables, conditional probabilities, mean and variance, correlations. These concepts are briefly revised 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.

A104 Vector and Tensor Calculus

Course coordinator

Eliot Fried

Description

A geometrically oriented introduction to the calculus of vector and tensor fields on three-dimensional Euclidean point space, with applications to the kinematics of point masses, rigid bodies, and deformable bodies. Aside from conventional approaches based on working with Cartesian and curvilinear components, coordinate-free treatments of differentiation and integration will be presented. Connections with the classical differential geometry of curves and surfaces in three-dimensional Euclidean point space will also be established and discussed.

Course Content

1. Euclidean point and vector spaces

2. Geometry and algebra of vectors and tensors

3. Cartesian and curvilinear bases

4. Vector and tensor fields

5. Differentiation and integration

6. Covariant, contravariant, and physical components

7. Basis-free descriptions

8. Kinematics of point masses

9. Kinematics of rigid bodies

10. Kinematics of deformable bodies

Course Type

Elective

Credits

2

Assessment

weekly problem sets, a midterm examination, and a final examination

Text Book

none, working from personal notes

Reference Book

none

Prior Knowledge

multivariate calculus and linear (or, alternatively, matrix) algebra

A203 Advanced Optics

Course coordinator

Síle Nic Chormaic

Description

Review of geometrical optics; wave properties of light and the wave equation; Helmholtz equation; wave optics, including Fresnel and Fraunhofer diffraction, transfer functions, coherence, auto and cross-correlation; Gaussian and non-Gaussian beam profiles; quantum optics and photon statistics; spin squeezing; applications of optics including fiber optics, laser resonators, laser amplifiers, non-linear optics, and optical trapping; quantum properties of light; interaction of photons and atoms.

Aim

To introduce students to fundamental and advanced topics in modern optics and photon physics.

Course Content

1. Review of classical optics
2. Ray and wave optics
3. Laser optics and Gaussian beams
4. Non-Gaussian beam optics
5. Fourier optics
6. Electromagnetic optics
7. Nonlinear optics
8. Lasers, resonators and cavities
9. Photon optics

10. Photon statistics and squeezed light
11. Interaction of photons with atoms
12. Experimental applications: Optical trapping
13. Experimental applications: Laser resonator design
14. Experimental applications: Light propagation in optical fibers and nanofibers
15. Experimental applications: laser cooling of alkali atoms
16. Laboratory Exercises: Mach-Zehnder & Fabry-Perot Interferometry; Fraunhofer & Fresnel Diffraction; Single-mode and Multimode Fiber Optics; Polarization of Light; Optical Trapping & Optical Tweezers

Course Type

Elective

Credits

2

Assessment

Continuous Assessment: 60%, Final Exam, 40%.

Text Book

Fundamentals of Photonics, by Saleh and Teich (2007) Wiley

Reference Book

Quantum Optics, an Introduction, by Mark Fox (2006) Oxford University Press

Optics, by Eugen Hecht (2001) Addison Wesley

A205 Quantum Field Theory

Course coordinator

Shinobu Hikami

Description

This course covers quantum field theory. Due to recent developments, we organize it with emphasizing statistical field theory.
The renormalization group method, symmetry breaking, gauge field and string theory, random matrix theory are key ingredients.

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

E. Brezin, Introduction to statistical field theory (CambridgeUniversity 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

Prior Knowledge

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

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. Organocatalysis
7. Design and synthesis of functional molecules
8. Chemical mechanisms of bioactive molecules including chemistry of enzyme inhibitors
9. Molecular recognition and non-covalent bond interactions
10. Enzyme catalysis and catalytic mechanisms
11. Enzyme catalysis and small organic molecule catalysis
12. Enzyme kinetics and kinetics of non-enzymatic reactions
13. Strategies for the development of new designer catalysts
14. Methods in identification and characterization of organic molecules
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

Strategic Applications of Named Reactions in Organic Synthesis, Kurti and Czako (2005)

Reference Book

Advanced Organic Chemistry, Part B: Reactions and Synthesis, Carey and Sundberg (2007)

Advanced Organic Chemistry, Part A Structures and Mechanisms, Carey and Sundberg (2007)

Organic Chemistry, McMurry

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.).

Aim

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

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

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

A211 Advances in Atomic Physics for Quantum Technologies

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 for quantum technologies

Course Content

1. Early atomic physics
2. The hydrogen atom and atomic transitions
3. Helium and the alkali atoms
4. LS coupling
5. Hyperfine structure
6. Atom interactions with radiation
7. Laser spectroscopy
8. Laser cooling and trapping
9. Bose-Einstein condensation
10. Fermionic quantum Gases
11. Atom interferometry
12. Ion traps

13. Practical elements: Laser spectroscopy
14. Practical elements: Laser cooling of Rb
15. Applications: Quantum computing
16. 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

A good pass in B13 Fluid Mechanics is required pre-knowledge for A212. If you have taken Fluid Mechanics from your former B.S or M.S Universities, please contact Prof. Amy Shen directly to determine whether you are prepared to take A212.

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.

See course highlights at: https://groups.oist.jp/cccu/post/2016/12/16/course-highlights-inorganic-electrochemistry.

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 O2 and 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. Emphasis will be placed on reviewing current and future applications of nucleic acids in diverse fields including chemistry, biology, materials, medicine, biosensors, 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 (12-16 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
9. Genome editing

- 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 50%; Presentations 50%

Text Book

None

Reference Book

Original papers will be supplied as required

A216 Quantum Mechanics I

Course coordinator

Denis Konstantinov

Description

This is a two-semester graduate course that covers most of the essential topics of modern non-relativistic quantum mechanics. The course is primarily intended for graduate students with background in Physics and aims to prepare such students for taking further advanced courses in Physics and Material Science offered in OIST, such as Solid State and Condensed Matter Physics, Advanced Quantum Mechanics, Advances in Atomic Physics, Quantum Field Theory, etc.

Students who take this course are expected to be familiar with general topics in Classical Mechanics, Electrodynamics and Calculus.

Aim

This two-term course aims to prepare students for taking further advanced courses in Physics and Material Science offered in OIST, such as 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 physics: black body radiation and the “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. The Ehrenfest theorem.

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.

9. Quantum harmonic oscillator: two approaches in solving the problem, coherent and squeezed states of the quantum harmonic oscillator.

10. The WKB approximation. Feynman’s path integral and classical limit of the quantum mechanics.

11. 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.

12. Rotations in space and operator of angular momentum. Orbital and spin angular momentums. Coordinate representation of orbital angular momentum. Spherical harmonics.

13. 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, the hydrogen atom and emission spectrum.

14. Scattering of quantum particles from 3D potentials. Green function method and the Born approximation. Expansion into partial waves and the Optical theorem.

15. Spin-1/2 particle and the Stern-Gerlach experiment. Matrix representation of spin-1/2 states and Pauli matrices. Bloch sphere representation. Motion of spin-1/2 particle in a uniform magnetic field.

Course Type

Elective

Credits

2

Assessment

Homework: 60%, Midterm Exam: 20%, Final Exam: 20%.

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.

A217 Quantum Mechanics II

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

Course Content

1. Addition of angular momentums and direct product space. Spin orbit interaction. Model problem: N non-interacting spin-1/2 particles and the Dicke states.
2. N-particle systems. Indistinguishable particles and Pauli exclusion principle. System of spin-1/2 particles and exchange interaction.
3. Introduction to second quantization methods. Operators on Hilbert space of Dirac states. Model problem: 1D chain of strongly-interacting spin-1/2 particles.
4. 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 and its consequences.
5. 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.
6. Energy spectrum of the hydrogen atom revisited: fine structure and hyperfine splitting.

7. Hydrogen atom in static electric and magnetic fields: quadratic and linear Stark effects, Zeeman splitting and Paschen-Back effect.
8. Time-dependent perturbation theory. Interaction picture and Dyson series for the time-evolution operator. Transitions under time-dependent perturbations: adiabatic and sudden perturbations.
9. Harmonic perturbation and interaction of quantum particles with electromagnetic field. The Fermi's golden rule. Stimulated emission and absorption of electro-magnetic waves by a quantum particle. Spontaneous emission and the Einstein coefficients. Exactly solvable time-dependent problem: two-level system approximation and the Rabi oscillations.
10. Introduction to the quantum electrodynamics (QED): quantization of electro-magnetic field. Operators for electric and magnetic fields. Photons and vacuum fluctuations of electro-magnetic field.
11. Interaction of a quantum particle with electromagnetic field revisited: beyond semi-classical description. Derivation of the rate of spontaneous emission. The Lamb shift and renormalization of electron mass.
12. Introduction to quantum statistical physics. Density matrix formalism and statistical ensembles. System of non-interacting quantum particles: the Boltzmann, Bose-Einstein and Fermi-Dirac distributions.
13. Description of open quantum systems. Dephasing. Density matrix approach and the master equation. Model problem: the spin-boson model and optical Bloch equations.

Course Type

Elective

Credits

2

Assessment

Homework: 100%

Text Book

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

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

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

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

Statistical Mechanics, by R.K. Parthria and P. D. Beale (2011) Elsevier

Prior Knowledge

Students who take the course are expected to be familiar with general topics in Classical Mechanics, Electrodynamics and Calculus. This course requires a pass in A216 Quantum Mechanics I.

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.

A223 Quantum Materials Science

Course coordinator

Yoshinori Okada

Description

After overviewing various interesting quantum materials and their unique functionalities, this course will introduce the concept of materials design and its realization in bulk single crystal growth and epitaxial thin film growth. Then, the principles of single particle spectroscopy will be introduced, particularly focusing on photoemission and tunneling spectroscopy. This course is ideal for students interested in both crystal growth and spectroscopy in quantum materials science.

During this course, several lectures by external scientists and engineers from R&D companies will be arranged. Also, "4. Group discussion and presentations based on recent literatures" and "6. Experiencing quantum materials growth and their characterization" will be arranged acording to circumstances and students' preference.

Aim

This course hopes to provide the student with sufficient knowledge to enjoy quantum materials growth and analysis at the frontiers of quantum materials science.

Course Content

1. Overview of recent interests in quantum materials

2. Materials design concepts and various growth methods
   2-1. bulk single crystal growth
   2-2. epitaxial thin film growth
3. Single particle spectroscopies
   3-1. electronic states in momentum space
   3-2. electronic states in real space
   3-3. heterogeneous electronic states
4. Group discussion and presentations based on recent literatures
5. Lecture by external speakers
   (Lectures will be invited from R&D companies)
6. Experiencing quantum materials growth and their characterization
   (This will be flexibly arranged depending on attendee's preference)

Course Type

Elective

Credits

2

Assessment

Presentation 50%, Report 50%

Text Book

None

Reference Book

Prior Knowledge

Undergraduate level of condensed matter physics

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.

Aim

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

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.

Aim

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

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

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.

Aim

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

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

Course Type

Elective

Credits

2

Assessment

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

Text Book

Behavioral Neurobiology, by Thomas J Carew (2000) Sinauer

Prior Knowledge

Required: B26 Introduction to Neuroscience or similar (demonstrated by passing the B26 exam)

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

Prior Knowledge

Requires at least advanced undergraduate level Cell Biology and Genetics or similar background knowledge

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 advanced undergraduate level 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 passes in OIST courses B22 Computational Methods and B26 Introduction to Neuroscience, or similar background knowledge in computational methods, programming, mathematics, and neuroscience.

A311 Cellular Aging and Human Longevity

Course coordinator

Mitsuhiro Yanagida

Description

Cells undergo aging and have limited lifespans. This lecture course covers the genetic, molecular, and cellular mechanisms that control cellular aging and that affect the lengths of organismal lifespans. Various strategies for investigating human longevity are also discussed.

Aim

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

Course Content

1	Gerontology	What is gerontology?
2	Measuring	How to measure aging
3	Longevity	Longevity in different organisms
4	Method 1	On human aging 1
5	Method 2	On human aging 2
6	Cellular aging	Mechanism of aging

7	Genetics	Genetics of aging
8	Plant	Plant aging
9	Human	Human aging
10	Physiology	Body, Skin, Sense, etc.
11	Diseases	Age related diseases
12	Diabetes, Frailty	Brain, Cardiovascular, Endocrine
13	Modulating aging	Modulating aging & Longevity

Course Type

Elective

Credits

2

Assessment

Requirements; Reports, Oral Discussion, Participation of Experimental demonstration using apparatus (LC-MS)

Text Book

Biology of Aging Roger McDonald 2014

https://www.amazon.co.jp/Biology-Aging-Roger-B-McDonald/dp/0815342136

Prior Knowledge

Requires at least advanced undergraduate level Cell Biology and Genetics or similar background knowledge

A313 Cognitive Neurorobotics

Course coordinator

Jun Tani

Description

The primary objective of this course is to understand the principles of embodied cognition by taking a synthetic neurorobotics modeling approach. For this purpose, the course offers an introduction of related interdisciplinary knowledge in artificial intelligence and robotics, phenomenology, cognitive neuroscience, psychology, and deep and dynamic neural network models. Special focus is given to hands-on neurorobotics experiments and related term projects.

Aim

This course aims to provide an overview of the synthetic approach to understand embodied cognition by using deep dynamic neural network models and robotics platforms.

Course Content

1. Introduction: cognitive neurorobotics study

2. Cognitism: compositionality and symbol grounding problem

3. Phenomenology: consciousness, free will and embodied minds

4. Cognitive neuroscience I: hierarchy in brains for perception and action

5. Cognitive neuroscience II: Integrating perception and action via top-down and bottom-up interaction

6. Affordance and developmental psychology

7. Nonlinear dynamical systems I: Discrete time system

8. Nonlinear dynamical systems II: Continuous time system

9. Neural network model I: 3-layered perceptron, recurrent neural network

10. Neural network model II: deep learning, variational Bayes

11. Neurorobotics I: affordance & motor schema

12. Neurorobotics II: higher-order cognition, meta-cognition, and consciousness

13. Neurorobotics III: hands-on experiments in lab

14. Paper reading for neurorobotics and embodied cognition I

15. Paper reading for neurorobotics and embodied cognition II

Course Type

Elective

Credits

2

Assessment

Mid-term exam: 40%, final term project report: 60%.

Text Book

Exploring robotic minds: actions, symbols, and consciousness as self-organizing dynamic phenomena. Jun Tani (2016) Oxford University Press.

Reference Book

Prior Knowledge

Basic mathematical knowledge for the calculus of vectors and matrices and the concept of differential equations are assumed. Programming experience in Python, C or C++ is also required.

A314 Neurobiology of Learning and Memory

Course coordinator

Jeff Wickens

Description

The aim of this course is to engage students in thinking about and discussing fundamental issues in research on neural mechanisms of learning and memory. Topics include the neural mechanisms of learning, memory, emotion, and addictive behavior. Students will be expected to read original reports including classical papers as well as recent advances. The course includes an experimental requirement in which students must design and conduct an experiment related to learning and memory mechanisms of the brain.

Aim

The aim of this course is to engage students in thinking about and discussing fundamental issues in research on neural mechanisms of learning and memory.

Course Content

1. Historical perspectives on learning and memory. Classification of learning and memory functions. Theories of memory and learning.
2. Experimental models of memory. Developmental plasticity. Anatomical plasticity. Conditioned reflexes. Imprinting. Extinction. Forgetting.
3. Synaptic plasticity: Homosynaptic and heterosynaptic plasticity, long-term potentiation, long-term depression. Spike-timing dependent plasticity.
4. Cellular mechanisms of synaptic plasticity. Intracellular messages, retrograde messages, receptor phosphorylation, protein synthesis, gene expression, synaptic tagging. Amino acid receptors. AMPA, NMDA, mGluR, nitric oxide.
5. Invertebrate models: Aplysia, honey bees, Drosophila. Sensitization of reflexes.
6. Neural circuits for reinforcement learning. Substrates of reward and punishment.
7. Neuromodulation and memory. Dopamine, acetylcholine, serotonin, other neuromodulators. Volume transmission.
8. Cellular mechanisms of reinforcement. Neurochemical basis. Habits, action-outcome learning, behavioral flexibility.
9. Memory and aging. Amnesia. Memory enhancers.
10. Neurochemistry of emotion. Drugs and mood. Addictive behavior.

Course Type

Elective

Credits

2

Assessment

Students will be required to: (i) prepare and present a lecture on the neural basis of a higher integrative function (40%); (ii) design and conduct an experiment on learning and memory (40%); (iii) participate in class discussions (20%).

Text Book

Selected original papers. Selected chapters from the online course, https://nba.uth.tmc.edu/neuroscience/s1/iend.html

Reference Book

Prior Knowledge

Students should have previously taken at least two basic courses in neuroscience: B26 Introduction to Neuroscience, and at least one other basic neuroscience course; or have completed the equivalent by documented self-directed study or skill-pill participation.

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. Neuroscience started in a disagreement
2. Scary influence at a distance
3. Paradigm shifts: the real scientific advances are not predictable
4. Some other theories of scientific knowledge and its advancement
5. 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)

A405 Emerging Technologies in Life Sciences

Course coordinator

Ichiro Maruyama

Description

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

Aim

This course introduces cutting-edge technologies in life science.

Course Content

1. Course Introduction & Genetic engineering
2. Classical nucleotide sequencing
3. Next-generation nucleotide sequencing
4. Fluorescent proteins
5. Microfluidics
6. Fluorescence light microscopy (confocal, TIRF, spinning disk, etc)
7. Mass spectroscopy
8. CRSPR/Cas9
9. Super resolution microscopy
10. PCR & Isothermal amplification
11. etc

Course Type

Elective

Credits

2

Assessment

Final grades will be determined by listed criteria described below. Scores will be converted to letter grades, where A: 100-90%, B: 89-80%, C: 79-60%, and F: below 60%

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 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 Cellular 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

Principles of Neural Science, 5 edn, Kandel, Schwartz, Messel, Siegelbaum and Hudspeth (2012) McGraw-Hill

Ion Channels of Excitable Membranes, 3 edn, Bertil Hille (2001) Sinauer

Neuroscience, 5 edn, by Dale Purves, George J. Augustine, David Fitzpatrick, William C. Hall, Anthony-Samuel LaMantia, and Leonard E. White (2012) Sinauer

Fundamental Neuroscience 3 edn, Larry Squire, (2008) Elsevier (Academic Press)

Reference Book

Prior Knowledge

Required: B26 Introduction to Neuroscience or similar (demonstrated by passing the B26 exam)

B07 Statistical Methods

Course coordinator

Tomoki Fukai

Description

(Course under review)

Aim

(Course under review)

Course Content

(Course under review)

1. What is probability: frequentist and Bayesian views
2. Statistical measures and Information theory
3. Statistical dependence and independence
4. Statistical testing
5. Random numbers, random walks, and stochastic processes
6. Regression and correlation analysis
7. Analysis of variance I
8. Analysis of variance II
9. Statistical inference: maximum likelihood estimate and Bayesian inference
10. Model validation and selection
11. Experimental design

12. Experimental design II
13. Conditional probability
14. Special probability densities and distributions
15. Revision and conclusions

Course Type

Elective

Credits

2

Assessment

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

Text Book

All of Statistics - A Concise Course in Statistical Inference, by Larry Wasserman (2003) Springer

All of Nonparametric Statistics, by Larry Wasserman (2005) Springer

Reference Book

Pattern Recognition, 4 edn, by S. Theodoridis and K. Koutroumbas (2008) Academic Press

Neural Networks for Pattern Recognition, by Christopher Bishop (1996) Oxford University Press

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.

Aim

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

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 Part 1
6. Fluorescence and its applications Part 2 - Solvatochromism and Electrochromism

7. Biophotonics
8. Photosynthesis
9. The physics of optogenetics
10. Linear optics
11. Microscopy
12. Non-linear optics, lasers, two-photon microscopy, super resolution microscopy
13. The physics of DNA, lipid membranes, and proteins
14. Bioelectricity
15. Electronics for electrophysiology
16. Magnetic resonance

Course Type

Elective

Credits

2

Assessment

Midterm presentation 25%, Final presentation 25%, participation + homework 25%, 30 minutes oral examination 1-2 weeks after the last lecture 25%

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

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

Assessment

Text Book

No textbook is set.

Reference Book

Fluid Mechanics by L. D. Landau and E. M. Lifshitz, 2 edn (1987) Butterworth-Heinemann

Vectors, Tensors and the Basic Equations of Fluid Mechanics by Rutherford Aris (1990) Dover

General Continuum Mechanics by T. J. Chung (2007) Cambridge University Press

Fluid Dynamics for Physicists by T. E. Faber (1995) Cambridge University Press

An Introduction to Fluid Dynamics by G. Batchelor (2000) Cambridge

Scaling by G. I. Barenblatt (2003)

Fluid Mechanics by P. K. Kundu and I. M. Cohen, 5 edn (2011) Academic Press

Prior Knowledge

Prerequisite is A104 Vector and Tensor Calculus

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

Assessment

Text Book

No textbook is set. Students are expected to take good notes in class. The Professor will from time to time distribute essential readings, as needed.

Reference Book

General Continuum Mechanics by T. J. Chung (2007) Cambridge University Press

Scaling by G. I. Barenblatt (2003)

Prior Knowledge

Prerequisite is A104 Vector and Tensor Calculus

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.

Aim

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

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

Course Type

Elective

Credits

2

Assessment

Report 50%; Final exam 50%

Text Book

Reference Book

Immunobiology 9th edition, by Kenneth Murphy (2016) 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.

Aim

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

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

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 I
2. Animal phylogeny II
3. Gene homology
4. Practice: Molecular Phylogeny
5. Gene expression
6. Signaling pathways I
7. Signaling pathways II
8. Research tools for EvoDevo I
9. Research tools for EvoDevo II
10. New Animal Models

Course Type

Elective

Credits

2

Assessment

Midterm Reports 70% (2 x 35%), Presentation 30%

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

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

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

Reference Book

Prior Knowledge

Biology, chemistry, or physics at undergraduate levels

B22 Computational Methods

Course coordinator

Tom Froese

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

Prerequisite courses and assumed 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

Reference Book

Prior Knowledge

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

B24 Neural Dynamics of Movement

Course coordinator

Marylka Yoe Uusisaari

Description

The course will start from the mechanisms of animal movement, including the evolutionary, ecological and energetic aspects; we will explore the anatomical and mechanical features of the body machinery (such as muscles, bones and tendons) before investigating the structure and dynamic function of the neuronal circuits driving and controlling movements. We will thus examine neuronal function at various levels, allowing the students to familiarize themselves with many fundamental concepts of neuroscience; the theoretical lectures will be complemented by practical exercises where the students will study movement in themselves and their peers in the motion capture laboratory environment as well as with more classical approaches.

Aim

This course aims to provide an introductory-level overview of the structures and mechanisms underlying brain function in the context of generating and modulating physical movement of the body.

Course Content

BLOCK 1 (4 weeks): The physical reality of movement

- Environments, evolution and fitness
- Movement styles - running, flying, swimming
- Mechanics of movement - forces, angles, timing
- Body mechanics - muscles, bones, tendons

BLOCK 2 (5 weeks): Movement generation

- Reflexes and drive in neuromuscular control
- Principles of neuronal circuit function
- Pattern generation in spinal systems
- Ascending brainstem pathways - reflex modulation
- Descending brainstem pathways - drive and modulation of locomotion

BLOCK 3 (4 weeks): Moving with purpose

- Motor cortex - commanding descending pathways
- Somatosensory cortex - monitoring movement
- Adjusting movements - sensory feedback, cerebellar systems
- Motor learning
- Linking motor behavior to cognitive function

Course Type

Elective

Credits

2

Assessment

Participation and Discussion 40%; In-term exams 30%; Project work 30%

Text Book

Animal Locomotion (English Edition) 2nd Edition by Andrew Biewener Sheila Patek ISBN-13: 978-0198743163

Reference Book

Principles of Neural Science, by Kandel, Schwartz, Jessell, Siegelbaum, Hudspeth (2012) MIT Press

Handbook of Brain Microcircuits, by Shepherd & Grillner (2010) Oxford University Press

Prior Knowledge

This is a basic level course, which will be adjusted according to the interests of enrolled students. No prior knowledge assumed, and suitable for out-of-field students.
However, the course B26 Introductory Neuroscience is required if you intend to continue with additional Neuroscience courses.

B25 Statistical Mechanics

Course coordinator

Reiko Toriumi

Description

Statistical physics deals with large collections of particles, typically about 10^23. Anything big enough to see with our eyes (daily experience) has enough particles in it to qualify as a subject of statistical physics. Within physics, statistical physics is widely used in condensed matter physics, cosmology, and furthermore it shares a lot of techniques with Quantum Field Theory, which successfully describes at least three fundamental forces in nature: the Strong, Weak, and Electromagnetic forces. Many physical systems, as they constitute many degrees of freedom, exhibit phase transitions which statistical mechanics lets us explore. At the critical point where phase transitions happen, seemingly different systems exhibit the same universal behavior. This is really an observer's dream. Statistical mechanics bridges the microscopic world with the macroscopic world, i.e., makes the connection between one particle and 10^23 particles. It is a way to let the different scales talk to each other. Our course will strive to demonstrate the unity of these perspectives.

Aim

The course is designed as an introduction to the methods of Statistical Mechanics. Statistical physics is a thrilling intersection of physical and mathematical ideas which can describe experiences ranging from our daily life to very non-daily ones, possibly including quantum gravity.

Course Content

We plan to cover the following material from the textbook
- Chap 1: The Statistical Basis of Thermodynamics
- Chap 2: Elements of Ensemble Theory
- Chap 3: The Canonical Ensemble
- Chap 4: The Grand Canonical Ensemble
- Chap 5: Formulation of Quantum Statistics
- Chap 6: The Theory of Simple Gases
- Chap 7: Ideal Bose Systems
- Chap 8: Ideal Fermi Systems
- Chap 9: Statistical Mechanics of Interacting Systems: Cluster Expansions Method

The instructor reserves the right to make minor changes in the syllabus, as needed.

Note: homework asignments are due every Wednesday, before the class. There will be no late homework submission accepted, unless it is discussed with the instructor beforehand.

Lecture meets with Toriumi: Wed:10-12 Fri: 10-11
Discussion meets with Toriumi: Mon: 10-11

The exams will be closed book, but you can bring a single sheet of paper on which you can write what you want to refer to during the exam on both sides. Note that I will decide how many midterms we will do shortly after we start the course. Depending on the number of midterms, there will be adjustments on the distribution for the weights of each element (i.e., homework and exams).

Expectations: Students are expected to attend every lecture and discussion. Students are responsible for the materials that are covered in lectures. Note that in lectures, we will cover additional materials that are not discussed in the textbooks. Discussion sessions are designed for you to practice solving problems.
One of the important things in your scientific career is good communication. You will have collaborators, peers, students and public for you to communicate your scientific results with. Without you communicating well about your results, your results may well be equal to nothing. Students are therefore expected to practice good communication with the instructor. Your homework, and your exams for example, are ways to communicate with the instructor. Keep in mind that it is not just about showing that you solved the problems, but it is about showing and demonstrating that your work is legitimate. You are expected to work toward this goal.

Course Type

Elective

Credits

2

Assessment

Weekly assignments (40%); midterm exam (30%); final exam or project (30%)

Text Book

Statistical Mechanics, by Pathria and Beale (2011) Elsevier

Reference Book

An introduction to Thermal Physics, by Schroeder (2000) Addison Wesley

David Tong, online lectures on Statistical Mechanics

Prior Knowledge

Students should have knowledge of Classical Mechanics and Quantum Mechanics to advanced undergraduate level.

B26 Introduction to Neuroscience

Course coordinator

Izumi Fukunaga

Description

This is a basic course targeted to those without neuroscience background, or those who need to refresh knowledge of key concepts to prepare for more advanced courses in Neuroscience.

This will serve as a pre-requisite for several Neuroscience courses. All neuroscience students need to pass this course before going on to other courses, unless they can demonstrate that they have already mastered the topics by passing the exam.

Assessment will be in the form of an exam at the end. This is not meant to be a stressful experience, but an opportunity for all students to demonstrate the understanding of the materials in their own words. In the exam, each lecturer will submit a short question based on the lecture content and the reading materials indicated in the course description. Each answer should be about 100 words long. Some questions may bridge lecture materials from two or more lectures. Students will be expected to answer all questions. A pass is 50%.

Students with prior knowledge but wishing to attend a part of the course will be allowed to audit.

Aim

An introduction to neuroscience, from cellular to systems, and brief introduction to several areas of specialization available at OIST. This course is co-taught by neuroscience faculty on a rotating basis.

Course Content

Week	Topic	Suggested textbook ref	Lecturer	Week starting on	Keywords / concepts to cover
1	Cell biology basics		Ichiro Maruyama	17-Sep	• Fundamentals of cell biology in the context of neuroscience • Brain ->nervous system -> neurons, cells -> constituents of cells: cell surface including sugars, cell membranes including lipids, organelles, nucleus, proteins, RNA and DNA.
2	Neurobiology concepts (building blocks - neurons, morphology)	Purves pg 1-10, Ch. 4	Gordon Arbuthnott	23-Sep	• Neurons are cells too; They just don't divide • Cajal and the neuron doctrine • Varieties shapes and connection types • Modern methods to see them.

					• They need support from glial cells • They work together in dynamic teams • The layout of the architecture is the next lecture
3	Organisation of the nervous system/neuroanatomy	Purves pg 13-23; other neuroanatomy textbook	Izumi Fukunaga	30-Sep	• Peripheral, central, autonomic and enteric nervous systems • Forebrain, midbrain, hindbrain • Cranial nerves • Cortex, subcortical regions, brainstem, Spinal cord • Sulci and gyri, layers, Brodmann areas • Special organs (eyes, ears etc)
4	Bioelectricity	Purves Ch. 2, 3	Jeff Wickens	07-Oct	• Passive electrical properties of neurons • Electrical current flow in neurons • Electrochemical origin of membrane potential • Voltage-dependent Ion channels • Ionic basis of action potentials • Action potential propagation in axons and dendrites

5	Synapses	Purves Ch. 5,6	Erik De Schutte r	14-Oct	• electrical versus chemical synapses • neurotransmission and the vesicle cycle • neurotransmitter receptors: excitation and inhibition synaptic integration
	Study week (SfN annual meeting)				
6	Circuits	Purves pg. 11-13	Yoe Uusisaari	28-Oct	• inhibitory vs excitatory neurons (GABA / glutamate) • interneurons vs projection neurons • scales of circuitry: local microcircuit, mesoscale circuit, systemic circuit • convergence, divergence feed-forward, feedback, recurrent signalling
	Learning and memory, Mechanisms	Purves Ch 23, 24, 30	Yoko Sugiyama	04-Nov	• Synaptic plasticity (for learning), short-term and long-term potentiation and depression • Studies of synaptic plasticity using Aplysia, and the hippocampus in mammals
7	Learning and memory, Behavioural aspects		Gail Tripp	11-Nov	• Behavioural aspects of learning • Pavlovian and instrumental learning

					• Schedules of reinforcement
8	Evolution and Developmental neurobiology	Purves Ch 22, 23, 25	Ichiro Masai	18-Nov	Genetic program for regional patterning in the brain Neurogenesis Neuronal polarity • Axon guidance • Neuronal degeneration and regeneration
9	Methodology 101	Carter, Shieh	Bernd Kuhn	25-Nov	• Electrophysiology • Optical imaging • Interaction of light and tissue • Indicators • Microscopes • Optical stimulation • fMRI
10	Introduction to theoretical and computational neuroscience	Dayan/Abbott	L1: Tomoki Fukai L2: Jun Tani	02-Dec	• models of spiking neurons (e.g., conductance-based neuron models to leaky-integrate-fire and Poisson neuron models), the fundamental conce pts of neural coding (rate, population, temporal codes) • feedforward network models for pattern recognition such as perceptron and error back-propagation (the • basis of deep learning) as well as some recurrent network possibly including long-

					short term memory (LSTM, used in various • AI applications)
11	Machine learning basics	Dayan/Abbott	L1: Tomoki Fukai L2: Kenji Doya	09-Dec	• attractor network models including Hopfield-type associative memory and working memory circuits • fundamentals of reinforcement learning and the classical models of self-organizing cognitive maps through Hebbian learning and lateral inhibition •
12	Exam				

Course Type

Elective

Credits

2

Assessment

Final exam, 100% (the exam may be taken at the start of the term to opt out of the course.)

Text Book

Purves, Augustine, Fitzpatrick, Hall, Lamantia and White: Neuroscience, 5th edition

Carter, Shieh: Guide to Research Techniques in Neuroscience, 2nd edition

Dayan and Abbott: Computational Neuroscience

Reference Book

Bertil Hille: Ion Channels of Excitable Membranes

Prior Knowledge

no prerequisites

B27 Molecular Biology of the Cell

Course coordinator

Keiko Kono

Description

We will read through the textbook "Molecular Biology of the Cell", one chapter per class.

Students will work through the Problems workbook on their own as needed, but Professor Kono offers Office hours every Friday for student help.

Three small examinations will be required during the term, weighted 25%, 25%, and 50%.

The first two exams cover material up to that time. The final exam covers all material of the term.

Grade expectations are
A corresponds to scores of 85-100%

B corresponds to scores of 70-84%

C corresponds to scores of 60-69%

Scores less than 60% receive a fail grade.

Aim

This course aims to revisit the basic knowledge of molecular and cell biology at the undergraduate level. Target students are 1) those who who did not major in molecular or cell biology, or 2) molecular/cell biology student who wants to review the basic knowledge of the field.

Course Content

1. Cells and Genomes
2. Cell Chemistry and Bioenergetics
3. Proteins
4. DNA, Chromosomes, and Genomes
5. DNA Replication, Repair, and Recombination
6. How Cells Read the Genome: From DNA to Protein
7. Control of Gene Expression
8. Examination 1
9. Analyzing Cells, Molecules, and Systems
10. Visualizing Cells
11. Membrane Structure
12. Membrane Transport of Small Molecules and the Electrical Properties of Membranes
13. Intracellular Compartments and Protein Sorting
14. Intracellular Membrane Traffic

15. Energy Conversion: Mitochondria and Chloroplasts
16. Cell Signaling
17. The Cytoskeleton
18. The Cell Cycle
19. Cell Death
20. Examination 2
21. Cell Junctions and the Extracellular Matrix
22. Cancer
23. Development of Multicellular Organisms
24. Stem Cells and Tissue Renewal
25. Pathogens and Infection
26. The Innate and Adaptive Immune Systems
27. Examination 3

Course Type

Elective

Credits

2

Assessment

Three small examinations during the term, weighted 25%, 25%, and 50%.

Text Book

Molecular Biology of the Cell, 6th Edition, by Bruce Alberts et al.

Reference Book

The Problems Book: for Molecular Biology of the Cell 6th Edition, by Tim Hunt and John Wilson

Prior Knowledge

The course is very basic. Non-biology students are welcome.

Independent Study

Course coordinator

Description

The course Independent Study will foster the development of independent study and research skills such as reading and critiquing the scientific literature, formulating scientific questions, and integrating knowledge into a coherent synthesis. Students will undertake a self-directed program of reading and synthesis of ideas. This course option must be conducted under the guidance of a faculty member acquainted with such work, and will follow common guidelines to ensure academic standards are maintained. Students should, in consultation with the faculty member, prepare a plan of the study, carry out the appropriate reading, and then describe the results of their study in a substantial report or essay. This course may be taken in any one term, and should be completed within the period of that term. The due date for all work, including online course completion, will be at the end of the current term.

The source material for Independent Study is now expanded to include online courses from a variety of educational sources, including Udacity, edX, and Coursera, subject to those courses being approved as relevant to the student's study and of sufficient educational merit. Seek approval before enrolling if credit is required. Total of external course credits permitted (online courses and international workshops) must be less than 50% of degree requirements. Your online course proposal must be approved by GS before you enroll in the online course, and the course fee can only be reimbursed if you purchase AFTER approval. Please contact Academic Affairs for assistance with online course purchase after we tell you that the course has been approved.

Student and tutor should agree on the extent of supervision provided, such as timing and format of face-to-face meetings, progress checks, and so on, especially for online courses. This should be detailed in the proposal, and the student should commit to this undertaking.

Aim

The aim of this course is to provide an opportunity for independent learning on a topic that a particular student may wish to study individually, with appropriate guidance. Online courses allow formal structured tuition in areas not covered by the existing OIST course offerings.

Course Content

Tutorial style under supervision of an OIST faculty member.
As each topic will be a unique project with its own requirements, there is no fixed schedule.

Please submit your request for Independent Study using the form. This request can come from either teacher or student.

The proposal for independent study should outline the material to be covered, and describe assessment items and tasks. Material that is delivered by set readings, exercises, and discussions at OIST are regarded as 'taught components', and must be assessed by some form of written assessment. Externally-provided material (such as online courses) may be included as all or part of the independent study content, and such material should not be assessed by the tutor, even where the tutor provides support and discussion.

After completion, the tutor (an OIST Professor) will be asked to provide an evaluation of the assessment item set for any component taught by the OIST Professor. If the course content is entirely online, other evidence of successful completion must be provided by the student for credit to be given, and no evaluation from the Professor is necessary.

Grades for this course are only Pass or Fail. If you enrol (after the proposal is approved, enrolment is automatic), you must complete or a Fail grade will be awarded. If not approved, you will be notified.

After completion, a student may be asked to provide a brief report on online course material, conditions, support, etc., to the Graduate School to assist in quality control.

Course Type

Elective

Credits

1

Assessment

Written assessment of some form, or certificate of completion of online course, are required. Graded as Pass/Fail.

International Workshop Participation

Description

Workshops, defined as residential short courses in particular topics in a specific scientific or mathematical discipline, and sometimes referred to as Summer Schools, or Winter Schools, etc., are a recognized means of undergoing intensive training in a specific topic or technique. In such workshops, some of the leading scientists in an area gather to share ideas, to keep each other up-to-date in the latest techniques and developments, and to teach senior students. Approved workshops for award of credit should comprise an intense two - three week period of lectures and exercise sessions, with at least 40 hours of instruction, and be at a level that is accessible to doctoral students.

International workshops (which may be held in OIST, in Japan, or overseas) must be approved by the CEC as meeting criteria including sufficient content, quality of instruction and instructors, duration, and other criteria as may be deemed necessary. Preference for approval is given to workshops that include assessment and provide a transcript or report from the organisers to OIST.

Students who wish to receive credit for attending such a workshop should first seek approval (before booking travel and registration) from the Graduate School, who will check that the workshop meets approval criteria. The workshop must be appropriate and relevant to the student's intended thesis research, and be endorsed by the thesis supervisor and academic mentor.

Please use the form at THIS LINK to apply.

Aim

Students will gain a deeper understanding of their research area by learning new techniques and the most recent knowledge, and will have the opportunity to make contacts and establish networks with other students and with leading researchers in their field.

Course Content

With the approval of the Thesis Supervisor and Mentor, OIST students who have been accepted into their research lab (not those doing rotations) may participate in international workshops relevant to their research.

Satisfactory workshop participation with evidence of completion (certificate, transcript, report) is awarded 1 OIST credit only, even if a workshop suggests a higher ECTS equivalent credit. A maximum of 2 credits is permitted under the course IWS towards fulfillment of the degree requirements for total credit. However, the course may be taken more than twice, after degree requirements have been met, and will be entered into your transcript.

Criteria for approval of workshops (CEC approval is required before enrolment):

- minimum of 10 working days duration
- minimum of 40 hours of instruction time
- must be a recurring workshop from a reputable provider

- must include structured instruction from qualified instructors
- approval must be sought from GS before registering for credit
- endorsed by the thesis supervisor and academic mentor

Course Type

Elective

Credits

1

Assessment

Suitable assessment tasks, or a report or certificate of completion, are required. In addition, students may be required to report on their experience of the event: whether it meets advertised quality and content, and overall impression.

Laboratory Rotations

Course number

LRO

Course coordinator

Description

Course Requirements

1. Prepare a written summary of the aims of the rotation. Students will study original publications and discuss with the Professor in charge of the research unit to prepare the aims. The summary should be no more than one page including references and illustrations. The proposal should be submitted to the graduate school as a PDF file via Sakai. Due date 30 days after first day of term.
2. Undertake the activities in the research unit to fulfill the aims of the rotation. The activities should be completed during the term of the rotation.
3. Participate in research unit meetings and seminars during the rotation. The student is expected to attend and as appropriate, ask questions, and join discussions.
4. Present the results of the rotation activity as an oral presentation to the laboratory members. One of the three rotations will be presented as an oral presentation to the entire class as a part of Professional Development.
5. Submit a written report on the rotation. It is understood that results cannot be expected in so short a time, but the background, including a short literature review, methods used, and activity carried out in the research unit should be described using the scientific language of the field. The report is due 14 days after the end of term. The Professor of the research unit will grade the report.
6. Each student will do a minimum of three laboratory rotations, one per term.

Selection of Rotations

All students will undertake at least three rotations. Assignment of rotations is made by the Graduate School, following information provided by the student in the pre-enrollment survey and from discussions during interview. Final approval of the selection of rotations will be given by the Dean, taking into account the availability of supervision and the overall program of the student. At least one of the rotations shall be outside the specific field of the student's studies at OIST.

Aim

To be able to discuss the scientific questions addressed in the research unit using the appropriate scientific language of the field, and to be aware of and able to explain the methods used in the research unit. The experience gained in these lab rotations will guide the student in their later choice of thesis laboratory.

Course Content

Course Type

Mandatory

Credits

Assessment

Based on written report, participation in the laboratory, and oral presentation. The supervisor (Professor of the Unit) will report to the Dean on the student's attendance and participation in the laboratory meetings.

Thesis Proposal

Course number

LTP

Course coordinator

All OIST and affiliate faculty able to take students for thesis research are able to supervise a student's thesis proposal.

Description

Students work in the laboratory of the Professor under whom they wish to conduct their thesis research. They undertake and write up preliminary research work, complete an in-depth literature review and prepare a research plan. The preliminary research work should include methods the students will use in their thesis research. The literature review should be in the area of their thesis topic and be of publishable quality. The research plan should comprise a projected plan of experiments to answer a specific question(s) and place the expected outcomes against the current state of knowledge, and should take into account the resources and techniques available at OIST. The research data generated in this proposal may be included in the subsequent doctoral thesis, if appropriate.

Aim

Students prepare a proposal for the research they wish to pursue toward the submission of an independent, novel doctoral thesis.

Course Type

Mandatory

Credits

Assessment

Dean and Thesis Committee Evaluation

Professional Development I

Course number

PD1

Course coordinator

The Dean of the Graduate School

Description

This course aims to develop knowledge and skills important for leadership in scientific research and education. The three main components of the course are (1) weekly seminars covering basic principles of research conduct and ethics, scientific communication, and aspects of science in society, (2) a cross-disciplinary group project, and (3) practical experience to develop presentation and teaching skills.

Seminars

Seminars are held every Friday afternoon throughout the year. Seminars last 1 hour. It is imperative that you not only attend the seminars but that you also engage by participating in discussion and asking questions. You may be assigned specific responsibilities to facilitate discussion. In order to participate in discussion well, you'll need to prepare. This means more than simply reading the required articles. You'll need to reflect on them as well. You will be informed how to obtain the required articles one week ahead of the seminar they will be used in.

Group Project

The group project component aims to develop skills required for effective teamwork, including leadership, project management, cooperation and creative interaction, cross-disciplinary communication, and coordination of group activity. Group project work is timetabled on Friday afternoons for two hours every second week, alternating with presentation and teaching skills training. Timing of project activity is flexible and different times may be decided by the group. The project component will require involvement in a student led group project. Projects will not be directly supervised by a faculty member, but there will be opportunities for consultation where certain expertise is required. The nature of possible projects will be explained in class but they may include development of new research tools and applications, inventions to solve problems, field studies, or creation of resources for research and learning. There will be a self-assessment requirement by group members to recognize the contributions of different members, and an overall grade based on a final presentation. A prize will be awarded for the best project.

Presentation and Teaching Skills

The presentation skill component comprises a set of opportunities for students to gain experience in giving presentations to various groups and teaching at different levels. It is timetabled on Friday afternoons for two hours every second week, alternating with group project activity, but may be arranged flexibly. Students develop skills by a range of different assignments including: acting as teaching assistants; assisting with visiting student programs; contributing to outreach activities;

presenting and participating in journal clubs; and giving a presentation based on research rotations. There will be a self-assessment requirement including a report documenting activities and evaluation of the research presentation.

Aim

The aim of this course is to provide information essential to beginning one's career as a professional scientist, and to develop skills fundamental to modern scientific practice.

Course Content

Term 1 Module: Research conduct and ethics

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

Term 2 Module: Scientific communication

- scientific writing
- poster presentations
- scientific talks
- communicating science to the non-specialist
- teaching science
- grant applications

Term 3 Module: Life in science and science in society

- science and the law
- intellectual property and patents
- working in science
- reputation/visibility/personal profile
- funding of science
- research and social responsibility
- leadership in research and education
- This course continues in the 2nd year. Students in second year are expected to attend seminars presented by guest speakers. Students in second year may also participate in

additional specific training if there is a need, such as further developing presentation and writing skills.

Course Type

Mandatory

Credits

1

Assessment

Attendance and participation

Professional Development II

Course number

PD2

Course coordinator

Description

This course will comprise a series of seminars and workshops designed to prepare OIST graduates to function effectively and responsibly in their scientific career. Beyond the initial focus of research, a responsible scientist should be able to communicate their research to the informed public, to make the most effective use of the public and private funds entrusted to them, and to understand the place of their science in its social and ethical context. Communication, media, and presentation techniques will be developed beyond the level of Professional Development I, including the tools to present and manage one's profile online and in person. Ethical considerations of life as a scientist will be addressed by discussion, debate and case studies. Invited experts from industry, science, patent and contract law, funding bodies, and so on will share their experience in generating and securing funding, typical intellectual property and industrial cooperation concerns, the business of running a research laboratory, and working in industry. Students will work in small groups or individually to complete relevant exercises to develop the skills to manage people and money. Students will be required to attend such seminars and workshops throughout their thesis research period.

Aim

This course develops further the many competencies and values that underpin a successful career as a professional scientist.

Course Content

A recurring series of seminars and workshops that extends PD1 to more appropriate topics for research management and career development.

Course Type

Mandatory

Credits

1

Assessment

Participation in and contribution to the structured activities and exercises.

Special Topics

Course number

SPT

Course coordinator

Description

The course Special Topics will provide an opportunity for students to study topics concerning recent scientific breakthroughs, cutting edge research of topical interest, novel, state of the art technologies, and techniques not otherwise available, with leading international experts in those topics or technologies.

This course option must be conducted in collaboration with a faculty member to provide internal academic oversight and guidance, and will follow common guidelines to ensure the required academic standards are maintained.

Each Special Topics course will require the approval of the Dean before being offered.

Students will be required to obtain the approval of the Academic Mentor or Thesis Supervisor before taking the course, and complete a defined piece of work as part of the course.

Aim

The aim of the Special Topics category is to permit students to benefit from courses that are not usually available at OIST but that may be offered from time to time, for example by visiting part-time faculty, OIST scientific staff, or external professors.

Course Content

Tutorial style under supervision of a faculty member.
As each topic will be a unique project with its own requirements, there is no fixed schedule.

A Special Topic will normally comprise a minimum of 15 hours class time.

Course Type

Elective

Credits

1

Assessment

Written Project 100%

NOTE: the number of special topics availble for 2019/2020 was severely curtailed due to COVID-19 travel restrictions.

AY2019/2020 Term 1 (September - December 2019)

Biological Networks. Bioinformatics and modelling.

Professor Igor Goryanin (OIST adjunct professor)
Professor Anatoly Sorokin (Moscow Physical Technical Institute)

18 hours
2019 October 21 onwards

PART I

Day 1: Oct 21 (Mon), 3 – 5pm
Theory: introduction, Enzymes kinetics (Goryanin)

Day 2: Oct 23 (Wed), 3 – 5 pm
Theory: Metabolic Pathways, Graph analysis of Biological networks. Standards in Systems Biology (Goryanin)

Day 3: Oct 24 (Thurs), 3 – 5 pm
Theory: Stoichiometric matrix and its properties. Flux Balance Analysis. Extreme pathways (Goryanin)

Day 4: Oct 25 (Fri), 3 – 5 pm
Theory: Metabolic Engineering and synthetic biology (Goryanin)

Part II

Day 5: Oct 28 (Mon), 3 – 5pm
Theory: Applications in Systems Biology (Goryanin)

Day 5: Oct 29 (Tue), 3 – 5pm
Theory: Introduction, installing software (Goryanin/Sorokin)

Day 6: Oct 30 (Wed), 3 – 5pm
Theory: Cytoscape, SBGN. Analysis and reconstruction of metabolic networks (Goryanin/Sorokin)

Day 7: Oct 31 (Thurs), 3 – 5pm
Theory: Flux Balance Analysis. Stoichiometric matrix and its properties. Extreme pathways. Practical. FBA with pyCOBRA/Sybi. Modeling of mutations and environment changes (Goryanin/Sorokin)

Day 8: Nov 1 (Fri), 3 – 5pm
Theory and Practical: Metagenomes analysis (Goryanin/Boerner)