Course Archive AY2012

Degree Completion Requirements for AY2012/2013

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

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

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

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

Note 3: thesis defence is conducted before two external examiners on-site in a 3 hour oral exam. A public presentation of the thesis is recommended, but not mandatory.

Courses delivered AY2012/2013

A101 Adaptive Systems

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

Type	Elective

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

Detailed Content

1. Introduction: variety of learning and adaptation

2. Probability theory: entropy, information, Bayes theorem

3. Pattern classification

4. Function approximation

5. Kernel methods

6. Clustering, Mixture Gaussian, EM algorithm

7. Principal Component Analysis, Self-organizing map

8. Graphical models, Belief propagation

9. Sampling methods, Genetic algorithms

10. Kalman filter, Particle filter

11. Reinforcement learning, Dynamic programming

12. Decision theory, Game theory

13. Multiple agents, Evolutionary stable strategies

14. Communication and cooperation

15. Presentation and discussion

A102 Mathematical Methods of Natural Sciences

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

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

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

Detailed Content

1. Complex Analysis I: Introduction to complex analysis: analytic functions.
2. Complex Analysis II: Cauchy Theorem and contour integration.
3. Complex Analysis III: Numerical methods in complex analysis.
4. Linear algebra I: Advanced eigenvalues and eigenvectors.
5. Linear algebra II: Numerical methods.
6. Ordinary differential/difference equations (ODDE) I: Properties and exact solutions.
7. ODDE II: Approximate solutions.
8. ODDE III: Numerical solution.
9. Asymptotic expansion of sums and integrals I: elementary methods.
10. Asymptotic expansion of sums and integrals II: steepest descents.
11. Perturbation methods.
12. Boundary layer theory.
13. WKB theory.
14. Vector fields. Stokes theorem.
15. Green's functions.

A201 Quantum Mechanics

Coordinator	[Konstantinov, Denis]

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

Type	Elective
Credit	2
Assessment	Homework: 20%, Midterm Exams: 2 x 30%, Final Exam, 20%.
Text Book	Quantum Mechanics: Vol I & II, by Cohen-Tannoudji, Diu, Laloe (1977). Wiley-Interscience
Reference Book	Principles of Quantum Mechanics 2 edn, by Shankar (1994) Springer Atom-Photon Interactions, by Cohen-Tannoudji, Dupont-Roc, Grynberg (1998) Wiley-Interscience Statistical Mechanics, 3 edn, by Pathria and Beale (2011) Academic Press

Detailed Content

1. State vector and complex vector space. Measurements and operators. Uncertainty relation. Matrix representation.

2. Wave function. Translation transformation and operator of momentum. Coordinate and momentum representation. Wave packets.

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

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

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

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

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

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

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

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

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

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

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

14. Scattering theory.

15. Open systems. Density matrix formalism.

A202 Fluid Dynamics

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

Type	Elective
Credit	2
Assessment	Homework: 20%, Midterm Exams: 2 x 30%, Final Exam, 20%.
Text Book	Fundamentals of Fluid Mechanics, by Munson, Young, Okiishi and Huebsch (6th Edition)
Reference Book	Multi-Media Fluid Mechanics, by G. M. Homsy et al., Cambridge University Press. An Album of Fluid Motion by Milton van Dyke, Parabolic Press.

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

Detailed Content

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

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

3 Fluid Statics (Effects of constant acceleration or rotation)

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

5 Bernoulli Equation (Pressure and its measurement)

6 Fluid Kinematics (Description of velocity field)

7 Fluid Kinematics (Control volume, system representations)

8 Fluid Kinematics (Reynolds transport theorem)

9 Control volume Analysis (Conservation laws)

10 Control volume Analysis (Many applications)

11 Dimensional Analysis (Dynamic similarity)

12 Dimensional Analysis (Pi theorem, Applications)

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

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

A203 Advanced Optics

Coordinator	Nic Chormaic, Síle
Description	Wave properties of light; quantum properties of light; review of geometrical optics, including ray tracing, aberrations and optical instruments; wave optics, including Fresnel and Fraunhofer diffraction, transfer functions, coherence, auto and cross correlation; interaction of photons and atoms, quantum optics; applications of optics, including fibre optics, laser resonators, laser amplifiers, holography, acousto-optics, lectro-optics, non-linear optics, optical switches, and ultrafast optics.
Aim	To introduce students to fundamental and advanced topics in modern optics and photon physics.

Type	Elective
Credit	2
Assessment	Homework: 60%, Final Exam, 40%.

Text Book	Physics of Light and Optics, by Justin Peatross and Michael Ware (download from Brigham Young University website) Quantum Optics, by Mark Fox (2006) Oxford University Press
Reference Book	Laser Cooling and Trapping, by Metcalf and van der Straten (1999) Springer-Verlag Atomic Physics, by Chris Foot (2005) Oxford University Press Optics, by Eugen Hecht (2001) Addison Wesley Fundamentals of Photonics, by Saleh and Teich (2007) Wiley

Detailed Content

1. Ray and wave optics
2. Laser optics and Gaussian beams
3. Non-Gaussian beam optics
4. Fourier optics
5. Electromagnetic optics
6. Nonlinear optics
7. Lasers, resonators and cavities
8. Photon optics
9. Photon statistics and squeezed light
10. Interaction of photons with atoms
11. Experimental applications: Optical trapping
12. Experimental applications: Laser resonator design
13. Experimental applications: Light propagation in optical fibers and nanofibers
14. Experimental applications: laser cooling of alkali atoms
15. Review of classical optics
16. Laboratory Exercises: Mach-Zehnder & Fabry-Perot Interferometry; Fraunhofer & Fresnel Diffraction; Single-mode and Multimode Fiber Optics; Polarization of Light; Optical Trapping & Optical Tweezers

A204 Condensed Matter

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

Type	Elective
Credit	2
Assessment	Homework: 60%, Project 20%, Final Exam, 20%.
Text Book	Quantum Theory of Solids, 2 edn, by Charles Kittel (1987) Wiley. Solid State Physics, 2 edn, by Ashcroft and Mermin (2002) Holt Rinehart & Winston
Reference Book	Principles of the Theory of Solids, 2 edn, by J Ziman (1979) Cambridge University Press

Detailed Content
1. Crystal structures, Bloch waves 2. Fermi surfaces 3. Low dimensional systems: Quantum wells, quantum dots 4. Quantum spin systems 5. Quantum computing 6. System bath interactions 7. Non-equilibrium coherent dynamics 8. Ultrafast spectroscopy 9. Correlated electron systems 10. Bose-Hubbard model and dynamical mean field theory 11. Semiconductors 12. Quantum Hall systems 13. Superconductors 14. Manganites and heavy fermions 15. Ultracold atoms

A205 Quantum Field Theory

Coordinator	Hikami, Shinobu

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

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

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

A206 Analog Electronics

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

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

Detailed Content

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

11. Voltage Regulators
12. Noise, noise reduction, transmission lines, grounding, shielding,
13. Lock in amplifiers.
14. Instrumentation amplifiers.
15. Analog to Digital conversion.

A207 Nanotechnology

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

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

Detailed Content
1, 2. Introduction to Nanotechnology and its applications (2 lectures) History, State of the art nanotechnology, applications in different fields 3, 4. Surface imaging and visualizations (2 lectures)

SPM, SEM, TEM 5, 6. Conventional Nanofabrication (2 lectures) Microfabrication, e-beam lithography, photolithography, micro and nanoelectronics 7, 8. Non-conventional nanofabrication (2 lectures) Nanoimprint lithography, bottom top fabrication 9 – 13. Nanomaterials: Synthesis, properties and application (5 lectures) Nanoparticles, nanorods, nanocrystals, nanobiomaterials , nanostructured thin films 14, 15. Nanosystems and self-assembly (2 lectures) Self assembly of hybrid systems, bioorganic/inorganic inspired nanodevices

A301 Signal Transduction

Coordinator	Price, Mary Ann
Description	In this course, students will develop the concepts of cell signaling first seen in Cell Biology and Genetics, by studying recent advances in the field of signal transduction, such as the roles of ubiquitination, membrane trafficking, organelle targeting, cytoskeleton, and cilia in cell signaling. Students will also learn about state-of-the-art methods for studying cell signaling. Lectures will focus on several papers from the current literature. The course will also present different special topics from year to year.
Aim	This advanced cell signalling course will describe molecules involved in cell signalling, methods of studying cell signalling, and modeling of cell signalling pathways.

Type	Elective
Credit	2
Assessment	Oral presentation of paper, 40%; Research proposal, 40%; participation, 20%.
Text Book	Cellular Signal Processing: An Introduction to the Molecular Mechanisms of Signal Transduction, by Marks, Klingmüller, Müller-Decker (2008) Garland Science Molecular Biology of the Cell, 5 edn, by Alberts, Johnson, Lewis, Raff, Roberts, Walter (2007) Garland Science
Reference Book	Cell Signalling 3 edn, by John Hancock (2010) Prentice Hall Signal Transduction, 2 edn, by Gomperts, Kramer, Tatham (2009) Academic Press

Detailed Content

1. Ligands (electrophysiology as a readout of signalling)

2. Receptors (genetic dissection of signalling pathways)

3. Common pathways and components (biochemical dissection of pathways)

4. Imaging methods for studying cell signalling

5. High throughput methods for studying cell signalling

6. Regulation of transctiption by signalling pathways (Caroline)

7. The role of ubiquitin in cell signalling (Brandy)

8. The role of endocytosis and trafficking in cell signalling (Lashmi)

9. Cell signallling in plants (Nino)

10. The role of cilia in cell signalling (Yi-Jyun)

11. Axon guidance (Sakurako)

12. mRNA decay or quorum sensing (Haytham)

13. Modelling signalling pathways: a systems approach (Kitano)

14. Modelling signalling pathways: a mathematical approach (Kitano)

15. Modelling signalling pathways: a computer exercise (Kitano)

A302 Ecology and Evolution

Coordinator	Mikheyev, Alexander Economo, Evan P
Description	This course focuses on patterns in the distribution and abundance of living organisms, and on their interactions with the environment. It provides an overview of the theory and principles of evolutionary biology, with emphasis on recent advances in the field. Starting with a discussion of evolutionary genetics, including the phenomena of natural selection, drift, and population genetics, we then look at adaptation, species, and taxonomy. Systems aspects such as biodiversity and population dynamics in cosystems are then examined, before we look more specifically at animal and human evolution, and comparative evolutionary biology. Major topics in ecology include fundamental concepts such as the ecological niche, community ecology, and population ecology.
Aim	This lecture series provides an introduction to advanced evolutionary biology and ecology.

Type	Elective
Credit	2
Assessment	
Text Book	The Economy of Nature 6 edn, by Robert E. Ricklefs (2008) W H Freeman (Paperback) Evolution, by Douglas Futuyma (2005) Sinauer

Reference Book	

Detailed Content

1. Introduction / Basic evolutionary concepts
2. Biochemistry
3. Molecular Biology
4. Gene regulation
5. Development
6. Mendelian Genetics
7. Mitosis and Meiosis
8. Population Genetics
9. Evolution
10. Ecology
11. Ethology and Behavioral Biology
12. The Biosphere
13. Recombinant DNA
14. Human Genetics
15. The Future of Biology

A303 Developmental Biology

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

Type	Elective
Credit	2
Assessment	Participation 20%; Written Report 40%; Presentation 40%
Text Book	Principles of Development 2 edn, Lewis Wolpert (2010) Oxford University Press

	Developmental Biology 9 edn, Scott F. Gilbert (2010) Sinauer Development of the Nervous System 3 edn, Sanes, Reh, Harris (2011) Academic Express
Reference Book	

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

A304 Evolutionary Developmental Biology

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

Type	Elective

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

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

A305 Microbiology and Biotechnological Applications

Coordinator	Jenke-Kodama, Holger
Description	The course introduces you to modern microbiology with a focus on its applications in environmental science and biotechnology. With the availability of high-throughput sequencing technology, enormous amounts of genome data and various "omics" approaches, microbiology has entered a new era. Besides the many new insights in microbial diversity and interactions with other organisms, the new experimental and computational approaches are offering completely new applications in different fields of biotechnology. The first part of the course deals with the principles, concepts and methods necessary for understanding applied microbiology. In the second part, we concentrate on environmental and biotechnological topics with an initial overview followed by selected examples, which are discussed in detail using original research literature as much as possible.
Aim	To provide a concise overview of modern microbiology and its state-of-the-art applications in biotechnology.

Type	Elective
Credit	2
Assessment	Final Exam 100%
Text Book	Microbial Biotechnology, by Glazer and Nikaido, 2 edn, 2007, Cambridge University Press
Reference Book	

Detailed Content

1. Introduction I (overview, main terms, systematics, taxonomy, main groups of prokaryotic (archaea, bacteria) and eukaryotic (protists, fungi) microorganisms, viruses)
2. Introduction II (history of microbiological research and biotechnology, principal characteristics, evolutionary relationships, current questions and directions)
3. Biochemistry and physiology of prokaryotes
4. Biochemistry and physiology of eukaryotic microorganisms
5. Comparative biochemistry and physiology (differences between microorganisms and higher eukaryotes), genetics of microorganisms
6. Experimental and computational methods in microbiology
7. Environmental microbiology and biogeochemical cycles I
8. Environmental microbiology and biogeochemical cycles II
9. Microorganisms in symbiosis
10. Secondary metabolism, bioactive compounds, genome mining
11. Biotechnology of enzymes
12. Biodegradation and bioremediation
13. Microorganisms as energy sources: biofuels and fuel cells
14. Metabolic modeling and engineering I
15. Metabolic modeling and engineering II

A401 Controversies in Science

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

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

Detailed Content

1. The Scientific Method, Ockham's Razor, Basic Philosophy of Science
2. Boundaries of Science, L'Affaire Sokal, "Crackpots"
3. Science & Racism in 1940s Germany and Japan
4. Science and Capitalism: the pharmaceutical industry & biomedical science
5. Science and Communism: Lysenko
6. Scientific Misconduct I: Piltdown Man
7. Scientific Misconduct II: Recent Cases
8. Insights ahead of their time: Mendel and others
9. Paradigm shifts: the reception of evolutionary biology
10. Science and Religion: opposition to evolution
11. Science and the media: the case of the autism-vaccination link, and others
12. Science and the law: the suppression of psychedelics research
13. Science and war: the making of the nuclear bomb
14. The animal rights movement and science
15. Conclusions: science as a social enterprise

A402 Computational and Mathematical Biology

Coordinator	Kitano, Hiroaki / Goryanin, Igor
Description	Computational approaches to science in general, and particularly in biology, are an increasingly important topic. However, understanding the concepts behind such computational approaches in biology is particularly difficult due to discrepancies in the methodologies and languages that are used. This course covers basics of computational and mathematical biology with strong emphasis on understanding of computational foundation and practical modeling of metabolic networks and signal transduction

	networks. Students are expected to actively participate in hands-on modeling sessions. A series of numerical computation, statistical, and intelligent systems approaches will be shown in the context of computational biology. The course will introduce standards used in the field such as SBML, SBGN, BioPAX, and MIRIAM, and students will gain direct experience in modeling sessions using CellDesigner (http://www.celldesigner.org/) and PhysioDesigner (http://www.physiodesigner.org/).
Aim	The goal of this course is to provide basic exposure to computational and mathematical thinking about basic biological processes and learn how to construct models and analyze them for biological studies.

Type	Elective
Credit	2
Assessment	Written report, 50%; Project, 50%.
Text Book	Systems Biology: A Textbook by Klipp, Liebermeister, Wierling, Kowald, Lehrach, and Herwig (2009) An Introduction to Systems Biology: Design Principles of Biological Circuits, by Uri Alon (2006) Kinetic Modelling in Systems Biology, by Oleg Demin and Igor Goryanin (2008)
Course Dates 2013	Intensive 3-week course, 2-22 August 2013 (2 hours class time per day plus reading and exercises)

Detailed Content

1. Introduction to Computational & Systems Biology Kitano
2. Biological Networks 1 Kitano
3. Biological Networks 2 Kitano
4. Modeling and Simulation in Biology 1 Kitano
5. Modeling and Simulation in Biology 2 Kitano
6. Hands on lab. 1 (CellDesigner based modeling and simulation) Kitano
7. Hands on lab. 2 (CellDesigner based modeling and simulation) Kitano
8. Modeling Signaling Networks Kitano
9. Modeling Cell Cycle Kitano
10. Metabolite and gene product profiling Goryanin

11. Metabolic network modeling 1 Goryanin
12. Metabolic network modeling 2 Goryanin
13. Mark up languages for metabolics: SBML, SBGN Goryanin
14. Database resources and development Goryanin
15. Data exploration and automation Goryanin

A403 Structural Biology

Coordinator	Skoglund, Ulf/ Samatey, Fadel
Description	The aim of this course is to understand how to develop a 3D model of a macromolecule. The course will start by introducing the notion of "biological samples" and by explaining the different challenges in getting samples. We will continue by presenting the range of techniques currently used in structural biology, the advantage of each technique in regard to studied samples and to the desired structural goals. In-depth theory of the main techniques used in structural biology, electron microscopy, and X-ray diffraction, will be presented. To complement the theory, sample preparation and quality assessment, data collection and analysis will be done during practical sessions that will combine both wet-lab and dry-lab experiments.
Aim	This course covers structure-function analysis by biophysical techniques

Type	Elective
Credit	2
Assessment	Midterm Report 50%; Final Essay 50%
Text Book	Principles of Protein X-Ray Crystallography, 3 edn, by Jan Drenth (2006) Springer
Reference Book	Biomolecular Crystallography: Principles, Practice, and Application to Structural Biology, by Rupp (2009) Garland Science Membrane Structural Biology: With Biochemical and Biophysical Foundations, by Luckey (2008) Cambridge University Press Computational Structural Biology: Methods and Applications, by Schwede and Peitsch (2008) World Scientific Introduction to Protein Architecture: The Structural Biology of Proteins, by Lesk (2001) Oxford University Press

Detailed Content
1. Introduction to Protein Structure and Protein Folding Samatey 2. Biophysical Methods in Structural Biology I Samatey

3. Biophysical Methods in Structural Biology II Skoglund 4. Diffraction: X-ray, Electron, Neutron Samatey 5. Methods in Protein Crystallography Samatey 6. Electron Tomography: 3D Reconstruction Skoglund 7. Practical Aspects of 3D Reconstruction: High Contrast Material Skoglund 8. Introduction to the TEM Skoglund 9. Optics and Image Formation in the TEM Skoglund 10. Practical Aspects of 3D Reconstruction: Low Contrast Material Skoglund 11. From Structure to Function (and vise-versa) Skoglund and Samatey 12. Electron Microscopy Sample Preparation Skoglund 13. Protein Crystal Preparation Samatey 14. When EM Meets X-ray crystallography: Combined techniques Skoglund 15. Structure Docking Methods Skoglund

A405 Emerging Technologies in Life Sciences

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

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

Detailed Content

1. Course Introduction & Nucleotide sequencing I (Background, Basics, PCR & qPCR, etc)
2. Nucleotide sequencing II (Next generation, Genome analysis, etc)

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

B03 Mathematics I

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

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

Detailed Content

1 History of mathematics and relation to natural sciences.
2 Geometry: Distance, Euclidean and other spaces.
3 Geometry: Vectors, dot and cross products.
4 Geometry: Computation of angles and distance from a point to a line segment and a plane.
5 Geometry: Volume of a tetrahedron. Application to concept of rank.
6 Probability: Concepts (frequentist and Bayesian), independence, conditional probability, Bayes' Theorem.
7 Probability: Random walk, Bernoulli processes, Stirling's formula, normal distribution.
8 Probability: Nearest-neighbour distance distribution for randomly distributed points in a plane.

9 Calculus: Concepts of limit and slope. Application to biology.
10 Calculus: Taylor expansions. Exponential decay.
11 Calculus: Harmonic oscillator. Diffusion.
12 Numerical Methods: Roots of a quadratic polynomial.
13 Numerical Methods: Least squares curve fitting. Bisection.
14 Numerical Methods: Approximation of functions by polynomials.
15 Student presentations.

B04 Mathematics II

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

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

Detailed Content
1. Linear Algebra: Rotations in the plane and space. Matrix representation. Matrix multiplication. 2. Linear Algebra: Solution of linear systems. Eigenproblems. Hardy-Weinberg equilibrium. 3. Linear Algebra: Change of basis, discrete Fourier transform. 4. Continuous flows: Vector fields, conservation of mass, compressibility and divergence. 5. Exercises (individual) 6. Systems of differential equations: Reduction to systems of first order. Euler's method. 7. Systems of differential equations: Reaction-diffusion equations. Heun's method. 8. Systems of differential equations: Hodgkin-Huxley equations. 9. Dynamical Systems: Linear systems, fixed points. 10. Dynamical Systems: Linearization of nonlinear systems. 11. Dynamical Systems: Predator-prey systems. Bifurcation. Chaos. 12. Stochastic differential equations: Euler-Maruyama method. 13. Student presentations: Preparation.

14. Student presentations: Preparation. 15. Student presentations: Presentation.

B05 Neurobiology

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

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

Detailed Content

1. May-13 Introduction to the course and its subject Arbuthnott
2. May-20 Ionic basis of excitability and voltage-gated ion channels Arbuthnott
3. May-27 Action potential generation and propagation Baughman
4. Jun-03 Synaptic transmission, neurotransmitters, neuromodulators Arbuthnott
5. Jun-10 Synaptic ion channels and receptors Arbuthnott

6. Jun-17 Synaptic plasticity, intracellular signaling, retrograde messengers Arbuthnott
7. Jun-24 Neural morphology, cytoskeleton, and implications for function Baughman
8. Jul-01 Neural networks, cerebral cortex, basal ganglia, cerebellum Arbuthnott
9. Jul-08 Motor system; movement Arbuthnott
10. Jul-15 Somatosensory systems; Whiskers Arbuthnott
11. Jul-22 Mechanism of sensory transduction Baughman
12. Jul-29 Sensory systems Vision and hearing Baughman
13. Aug-5 Discussion of neurophysiology of brain systems with methods in the awake animal Arbuthnott

B06 Cell Biology and Genetics

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

Type	Elective
Credit	2
Assessment	Essay 50%; Final Exam, 50%.
Text Book	Molecular Biology of the Cell 5 edn Alberts, Johnson, Lewis, Raff, Roberts, and Walter. (2007) Garland Molecular Biology of the Gene 6 edn Watson Baker Bell Gann (2007) Benjamin Cummings
Reference Book	Molecular Cell Biology 6 edn, Lodish et al., (2007) WH Freeman Lewin's Genes X, Krebs, Goldstein, Kilpatrick (2009) Jones & Bartlett Recombinant DNA: Genes and Genomes, 3 edn, Watson, Myers, Caudy, Witkowski (2007) WH Freeman

Detailed Content

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

B07 Statistical Methods

Coordinator	Doya, Kenji
Description	This course introduces basic principles and practical methods in statistical testing, inference, validation, and experimental design. The lectures cover the following topics: What is probability: frequentist and Bayesian views; probability distributions; Statistical measures; Statistical dependence and independence; Stochastic processes; Information theory; Statistical testing; Statistical inference: maximum likelihood estimate and Bayesian inference; Model validation and selection; Experimental design. Emphasis is put on the assumptions behind standard statistical methods and the mathematical basis for finding the right one.
Aim	This basic course will equip students with the necessary understanding and experience in statistical methods essential to modern scientific research.

Type	Elective
Credit	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

Detailed Content
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

B08 Physics for Life Sciences

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

Type	Elective
Credit	2
Assessment	Midterm test, 35%, Final test, 65%
Text Book	Atkins Physical Chemistry, by P. Atkins & J. de Paula (2006) Oxford University Press Introduction to Biophotonics by P.N. Prasad, (2003) J. Wiley & Sons Foundations of Cellular Neurophysiology by D. Johnston & S.M-S. Wu (1994) The MIT Press
Reference Book	

Detailed Content

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

B09 Learning and Behavior

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

Type	Elective
Credit	2
Assessment	Article reviews and critiques (4) each worth 5% (Total 20%) Class presentation (Total 30%) Participation in class discussions (Total 10%) Research/grant proposal (Total 40%)
Text Book	Throughout the course readings will be assigned (original articles and textbook chapters) together with recommended reading.
Reference Books	

Detailed Content

- Research methods (I)
- Ethics
- Hypothesis testing
- Dependent and independent variables
- Reliability and validity
- Bias, blinding
- Research methods (II)
- Data collection methods
- Observation
- Surveys
- Experimental and quasi experimental designs
- Data analysis
- Learning and behavior (I)
- Classical, Pavlovian, respondent conditioning (elicited responses)
- Operant, instrumental conditioning (instrumental responses)
- Learning and behavior (II)
- Reinforcement and punishment
- Operant schedules
- Learning and behavior (III)
- Behavior modification
- Applications
- Motivation and reward
- Drug addiction
- ADHD
- Memory and cognition (I)
- Memory and cognition (II)
- Perception and attention
- Behavioral neuroscience (I)
- Behavioral neuroscience (II)
- Genes and behaviour
- Animal models
- Life span

B10 Analytical Mechanics

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

Type	Elective
Credit	2
Assessment	Homework Assignments 20%, Midterm written tests, 2 x 25%; Final written test, 30%.
Text Book	Classical Mechanics 3 edn, by Goldstein, Poole, and Safko, Pearson
Reference Book	Mechanics, 3 edn, by Landau and Lifshitz (1976) Butterworth-Heinemann

Detailed Content

1. The Principle of Least Action

2. Equations of Motion: Galileo and Lagrange

3. Equations of Motion: Newton

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

5. Integration of Equations of Motion

6. Breakup, Collision, and Scattering of Particles

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

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

9. Equations of Motion for Rigid Body

10. Euler's Equations

11. Dynamics of Rigid Bodies in Contact

12. Hamilton's Equations

13. Maupertuis' Principle

14. Canonical Transformations and Liouville's Theorem

15. Hamilton-Jacobi Equations

B11 Classical Electrodynamics

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

Type	Elective
Credit	2
Assessment	Midterm tests, 2 x 30%; Final written test, 40%.
Text Book	Electrodynamics of Continuous Media, 2 edn, by Landau, Pitaevskii, Lifshitz (1984)
Reference Book	Electricity and Magnetism (Berkeley Physics Course, Vol.2) 2 edn by Edward M. Purcell (1986) Waves (Berkeley Physics Course, Vol.3) 2 edn by Frank S. Crawford (1968) Butterworth-Heinemann The Classical Theory of Fields, 4 edn, by DL Landau (1980) Butterworth-Heinemann Classical Electrodynamics, 3 edn, by JD Jackson (1998) Wiley

Detailed Content
1. Charge and Gauss's Law 2. Current and Ampere's Law

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

B12 Statistical Physics

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

Type	Elective
Credit	2
Assessment	Weekly problem sheets 75%. Final presentation 25%
Text Book	K. Huang, "Introduction to Statistical Physics" 2nd Edition - (2009) Chapman & Hall F. Mandl, "Statistical Physics", 2nd Edition (1988) Wiley M. Plischke and B. Bergersen, "Equilibrium Statistical Mechanics" 3rd edition (2006) World Scientific
Reference Book	L. D. Landau and E. M. Lifshitz, "Statistical Physics" (1996) Butterworth-Heinermann

	P. Chaikin and T. Lubensky, “Principles of Condensed Matter Physics” (2003) Cambridge University Press

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

B13 Theoretical and Applied Fluid Mechanics

Coordinator	Pinaki Chakraborty
Description	We will introduce basic concepts of flow of fluids. We will discuss conservation laws and constitutive equations. We will derive the Navier-Stokes equations, and study its exact and approximate solutions. Last, we will introduce the theory of hydrodynamic stability and then discuss turbulent flows. Throughout the course we will discuss a wide spectrum of flows from nature and engineering.
Aim	To introduce basic concepts, equations, and methods of the mechanics of fluids.

Type	Elective

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

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

B14 Theoretical and Applied Solid Mechanics

Coordinator	Gustavo Gioia

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

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

Detailed Content

(1) Mathematical Preliminaries:

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

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

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

(3) Elasticity and the Mechanics of Plastic Deformation:

- Navier equations, problems with spherical symmetry and problems with cylindrical symmetry (tunnels, cavities, centers of dilatation).
- Anti-plane shear. Plane stress, plane strain.
- The Airy stress-function method in polar and Cartesian coordinates.
- Superposition and Green's functions.
- Problems without a characteristic lengthscale.
- Flamant's problem, Cerruti's problem, Hertz's problem.

- Load-induced versus geometry-induced singularities (unbounded versus bounded energies).
- Problems with an axis of symmetry.
- Disclinations, dislocations, Burgers vector, energetics; relation to plastic deformation in crystalline solids.

(4) Fracture Mechanics:

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

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

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

Other Courses: Special Topics

Matter - States & Properties (Mahesh Bandi)

Informally, we will refer to them as The Shtuff Lectures. (inspired by Daffy Duck, the Looney Tunes character).

This is a set of informal lectures organized for my research group. However, attendance is open to anyone interested.
Please note, this is not a formal course offered by the Graduate School; ergo students attending these lectures get no credit for participation. You attend if you want to.

1) Some topics are covered in other formal OIST courses. However, the approach will be quite different, more on that below.
2) Some topics currently not offered at OIST will be covered; in particular Colloids and Polymers.
3) Where possible, scientific facts will be connected to the seminal experiments that established those facts.
4) Theoretical rigor is not our goal. Emphasis is on physical intuition and the simplest models that illuminate the concept.

5) Mathematics is unsophisticated. Real experimental values will be plugged in to provide order of magnitude estimates. The art of back-of-the-envelope calculations has a rich history in experimental physical sciences, and it is my view that this beloved art is slowly dying away, which it should not. I hope to resurrect that culture in my limited capacity in this lecture series.

We will take a bare minimum of fundamental facts concerning the atomic/molecular structure and inter-atomic/molecular interactions. From there, we will construct a simple (but not simplistic) picture of how the various states of matter emerge, and how and why they come to have the various properties that we know them to exhibit.

Lecture Timeline: We will proceed at our natural pace (approx. 2-3 hour lecture each week). We'll start in January and cover as much as we can by end summer and stop. I have formal teaching responsibilities Sep - Dec. I also have some travel in between when we will not meet for lectures.

Expected Background: High School Physics & Math. Calculus knowledge useful, but not necessary. The low entry bar for this lecture series should not be construed as a low quality bar for the material. The concepts are sophisticated, but they need not be presented with sophisticated math. One is expected to be reasonably smart enough to think, reason, and arrive at the conclusions based on available facts. Mathematics only serves the role of offering that information in a condensed format.

Detailed Content

Atoms, Molecules and forces

- Atoms.
- Molecules.
- Interatomic and Intermolecular forces.

Thermodynamics Lite

- Temperature.
- Heat.
- Laws of thermodynamics.

Ideal gases - properties & simple theory

- Bulk properties.
- Elementary kinetic theory of the ideal gas.
- Ether theory of the ideal gas.
- Transport phenomena.
- Sound waves in a gas.

Further theory of ideal gases

- A better kinetic theory.
- Sedimentation.
- Temperature variation of reaction rates.
- Velocity distribution of ideal gas.
- Thermal energy of molecules.
- Macroscopic examples of Equipartition of energy.

Real (imperfect) gases

- Deviations from ideal behavior.
- Kinetic theory of real gas: The van der Waals equation.
- Some properties of the critical point.

- Law of corresponding states.
- Internal energy, specific heat capacity of van der Waals gas.
- Expansion of gases.

The Solid State
- Types of solids.
- Solid-liquid transitions: surface & bulk melting.
- Consequences of interatomic forces on solids.
- Amorphous solids (glasses).

Solids: Elastic properties
- Basic elastic properties.
- Propagation of longitudinal waves along an elastic bar.
- Bulk modulii.
- Elastic properties of rubber molecule.
- Elastic properties of bulk rubber.

Solids: Strength
- Deformation.
- Dislocations.
- Vacancies, diffusion and creep.
- Brittle solids.

Solids: Thermal & Electrical properties
- Specific heat capacity.
- Thermal expansion: Gruneisen's law.
- Thermal conductivity.
- Electrical conductivity of metals.

The Liquid State
- Liquid as a modified gas.
- Structure: The radial distribution function.
- Liquid as modified solid.
- Liquid state sui generis.
- Ice & Water.
- Latent heat of fusion.
- Melting point: The Lindemann model.
- Vapor pressure.
- Dilute ideal solutions.
- Surface tension.
- Nucleation in condensation: Wilson cloud chamber.
- Superheating.
- Energy for capillary rise.
- Liquid Crystals.

Liquids: flow properties
- Ideal liquids: Bernoulli's equation.
- Real liquids: viscosity.
- Rigidity of liquids.
- Non-Newtonian flows.

Colloids

- van der Waals forces between macroscopic bodies.
- Principles of stabilization.
- Stabilization by diffuse electrically charged double layer.
- Stabilization by adsorbed polymers: entropic repulsion.

Polymers

- Polyethylene molecule: Conformations.
- Polyethylene chain: Effective size & radius of gyration.
- Dilute polymers: chain configurations - Zimm theory.
- Molten polymer: Conformations - Neutron scattering by deuterated polymers.
- Molten polymer: Viscosity - Rouse theory.
- Molten polymer: Entanglements & reptation.
- Molten polymer: Diffusion.
- Molten polymer: Effect of shear rate on flow.
- Four main states of polymers.
- Factors affecting Glass transition temperature.
- Time-temperature superposition: stress relaxation.
- The linear viscoleastic model.
- Morphology of the glassy state.
- Elastic properties of polymers in glassy state.
- Yield properties and deformation mechanisms.
- Morphological changes in shear and rupture.
- Thermal conductivity, diffusivity & adiabatic deformation.
- Brittle behavior.
- Cross-linked polymers.
- Polymer composites.

Dielectric properties of matter

- Basic dielectric relations.
- Polarization of gases.
- Polarization of polar molecules.
- Optical dispersion and anomalous dispersion.
- Dielectric properties of liquids and solids.

Magnetic properties of matter

- Magnetic Equations.
- Diamagnetism: Langevin's treatment.
- Paramagnetism: Langevin function.
- Ferromagnetism.
- Quantum treatment of magnetic properties.
- Ferromagnetic domains.
- Magnetic hysteresis.

Advanced Statistical Mechanics

Dr Ludovic Jaubert (Shannon Unit Group Leader)

Assessment

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

Description

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

Detailed description

Advanced Statistical Mechanics

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

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

3. A glimpse of non-equilibrium statistical physics

Aim

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

Resources

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

PD1 Professional Development I for OIST PhD Students (2012 entry)

Coordinator	Wickens, Jeffery
Description	This course aims to develop knowledge and skills important for leadership in scientific research and education. The three main components of the course are (1) weekly seminars covering basic principles of research conduct and ethics, scientific communication, and aspects of science in society, (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.

Type	Mandatory
Credit	1
Assessment	Attendance and participation
Text Book	

Reference Book	

Course Content

Term 1 Module: Research conduct and ethics

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