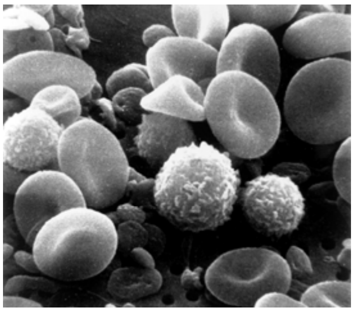

MSc in Quantitative Biology

Introduction

Over the past 10-20 years, biology has become increasingly quantitative, and mathematical sciences have in turn been increasingly influenced by biology. It has been said that “mathematics is biology's next microscope, only better” (Cohen, J.E., PloS Biology, 2004) because mathematical, statistical, and computational sciences will continue to reveal unsuspected and entirely new worlds within biology, just as the microscope revealed previously unseen worlds following its invention. It has also been said that “biology is mathematics' next physics, only better” (Cohen, J.E., PloS Biology, 2004) because biology will in turn continue to spur major new developments in computation, mathematics and statistics, just as physics has done in the past several hundred years.

Recognizing this integration, the MSc in Quantitative Biology provides students of life sciences with the quantitative skills they will need to thrive in the modern discipline of biology, and provides students from a more quantitative background with the biological insight they need to apply their technical skills. The course is unique in integrating important current research questions in biology with data from ecosystems down to cells and state-of-the-art quantitative methods. Graduates will be highly trained scientists prepared for employment in any of several settings, including as PhD students in universities and institutes worldwide; in the research departments of multinational industries concerned with the environment (e.g., pharmaceuticals, biotechnology); in conservation, management and agricultural agencies; and in local and national governments.

The course will be taught jointly by internationally renowned faculty from the Department of Life Sciences and the Department of Mathematics. It will be based at Silwood Park, an attractive postgraduate campus near the historic towns of Windsor and Ascot, one hour from central London. Silwood has top-rank scientific and computing facilities and unrivalled opportunities for fieldwork afforded by its extensive grounds. Students will be exposed to a world-class research environment, will attend lectures and seminars by leading international scientists, and will be trained in state-of-the-art techniques. Students will be part of a large and diverse community of MSc, MRes and PhD students and postdoctoral researchers with a variety of research foci. The course comprises lectures, practicals, group workshops and other exercises, and a long research project.

Taught course structure

The course will be offered as a full-time, one-year course comprising 50 weeks of study: 18 taught weeks, revision periods, and the research project. Illustrating the modern, interdisciplinary, and integrated approach of the course, taught components include the following:

A primer in mathematical methods (3 weeks). Basic mathematical tools are introduced in this primer, and further elaborated as needed in the problem-focused biological case studies.

The evolution of genetic and ecological systems (2 weeks): Population models dealing with evolution usually either focus on ecological interactions at the expense of genetic detail or consider detailed genetics while assuming constant population size. But organisms evolve in the context of their environments, so it is crucial to consider interactions between ecological and evolutionary processes. In this module, we present the two disparate approaches and discuss modern ways of bringing them together.

A quantitative approach to co-evolutionary host-pathogen systems (2 weeks): Genetic and phenotypic polymorphisms are pervasive and dynamic across environments, and recent work demonstrates that much of this diversity is generated and maintained by co-evolutionary interactions. This course introduces co-evolutionary dynamics through host-pathogen interactions, using microbes and their viral bacteriophage as model organisms. A typical question we will answer is do energetically richer environments necessarily support more diverse ecosystems?

Models of cooperation (2 weeks): Understanding the conditions favouring co-operation is central in evolutionary, ecological, social and economic theory. Classical models based on Hamilton's kin selection and game theory capture potential general trends of when cooperation might be favoured, but the weakness of these approaches is that it is difficult to estimate core model parameters, and therefore difficult to predict co-operative or non-co-operative outcomes in natural systems. A recent novel approach uses systems-biological methods in a population genetics framework and accurately and quantitatively predicts cooperator fitness in a public goods game. We introduce the classical methods and this and other modern improvements in the context of experimental data.

A primer in statistical methods (3 weeks). Basic statistical tools are introduced in this primer, and further elaborated as needed in the problem-focused biological case studies.

Stochastic population dynamics (2 weeks): Stochastic demographic methods provide powerful tools to explore a diverse array of ecological, evolutionary and conservation questions in variable environments. Much cutting edge population ecology and evolutionary biology uses these methods to understand questions including what generates dynamics of populations, quantitative traits, and alleles or genotypes, and what changes in these dynamics are likely with an anthropogenically modified climate.

Confronting mechanistic biological models with data (2 weeks): Global change increases the urgency of making ecology into a predictive discipline so that we can develop a more rational basis for mitigation policy. One way of making predictions in population and community ecology is to fit several competing, nonlinear and often complex models with available data, using the best-fitting model for predictions. Myriad new and existing methods of fitting are finding increased application in population ecology and epidemiology. We will introduce methods and apply them to models and data from several systems to draw concrete biological conclusions, possibly including measles dynamics and forest insect pest dynamics.

Food webs: From static-empirical to dynamic-theoretical approaches, and integration (2 weeks): Because data are difficult to obtain, many food web studies are broadly in one of two categories: 1) empirically based analyses of average or snapshot community structure; and 2) theoretical analyses of community dynamics. We will characterize these frameworks and discuss modern methods of integrating them using tools from the metabolic theory of ecology. The long-term goal of the modern studies is to produce an empirically grounded and predictive understanding of multi-species dynamics.

Research projects

Project can be completed at Imperial's Silwood Park or South Kensington Campuses under supervisors from the Mathematics or Biology faculties or both, or at a range of co-operating institutions in the UK and abroad. For instance, members of the Imperial Ecology and Evolution Section have links to the Durell Wildlife Conservation Trust; the Institute of Zoology; the Centre for Environment, Fisheries, and Aquaculture Science; Kew Botanical Gardens, and a variety of others.

Teaching staff

Teaching staff include:
Daniel Reuman (course Director)
Ivana Gudelj (course Director)
Tim Coulson (course Co-director)
Robert Beardmore (course Co-director)
Additional lecturers include: Mick Crawley, E.J. Milner-Gulland, Tim Barraclough, Russ Lande, Austin Burt, David Orme, Robert Ewers
Diverse other members of the mathematics and biology faculty may be included, as well as external guest lecturers.

How to apply

Candidates from life science and physical sciences backgrounds are very welcome to apply. Life scientists must have a strong interest in the quantitative approach to biology and normally must have at least an A-level or equivalent in mathematics. Physical scientists must demonstrate an abiding interest in biology. English language requirements are the same as for other Biology Division taught masters courses. Application forms will be available from the Admissions Office. For additional information please contact Dr. Daniel Reuman, Section of Ecology and Evolution, email d.reuman@imperial.ac.uk, or Dr. Ivana Gudelj, Department of Mathematics, email i.gudelj@imperial.ac.uk.

Key contacts and links

Department: www.imperial.ac.uk/lifesciences

Masters courses: www.imperial.ac.uk/lifesciences/postgraduate/courselist

Admissions: www.imperial.ac.uk/lifesciences/admissions

Course Director, Biology: Dr. Daniel Reuman, d.reuman@imperial.ac.uk

Course Director, Mathematics: Dr. Ivana Gudelj, i.gudelj@imperial.ac.uk