

Bioengineering Opportunities in Civil and Environmental Engineering

Outline of this session:

- overview of the Civil and Environmental Engineering (CEE) major and its undergraduate requirements at MIT
- discussion of various techniques used in genomics to understand environmental microbiology
- overview of some of the biological CEE research groups at MIT

Introduction

Martin Polz is an associate professor of Civil and Environment Engineering at MIT who specializes in environmental microbiology, microbial community structure, population dynamics, environmental genomics, and the ecology of pathogens.

Overview of the CEE Major

The CEE department (Course 1) emphasizes the combination of mechanics, ecology, and mathematics in design. Classes teach students to apply learned knowledge in the creation of practical solutions to common problems.

At MIT, all students must complete the freshman general institute requirements (GIR):

8.01	Physics: Mechanics
8.02	Physics: Electricity and Magnetism
3.091/5.111/5.112	Chemistry
7.01x	Biology

along with eight humanities, arts, and social sciences (HASS) classes. The typical class requires twelve hours per week and is allotted twelve units.

The CEE program begins sophomore year with fundamental engineering classes:

18.03	Differential Equations
1.00	Intro. to Computers and Engineering Problem Solving
1.010	Uncertainty in Engineering

At the end of sophomore year, students can choose between the environmental or the civil engineering track. The environmental track teaches biology and chemistry while the civil track focuses on computation and analysis of structures. Both tracks require its both unrestricted electives and culminate in a capping design project at the end of senior year.

These are some examples of common engineering design projects undertaken during sophomore year. All projects emphasize team work, and the application of learned knowledge to solve practical problems in real life.

Environmental Microbiology

Without the presence of bacteria and other micro-organisms, there would be no life on earth. An every-day process as simple as the nitrogen cycle would not be possible without microbes.

Prokaryotic organisms such as bacteria are present everywhere in the world. The following slide shows the abundance of prokaryotic life in different types of water. The microbial biomass rivals plant biomass, but the former has much higher turnover.

Estimations of the diversity of prokaryotes have changed over the years. In 1988, Wilson believed that prokaryotes compose of approximately 3,500 of the total 1.4 million species on earth. In 1995, Hammond estimated that prokaryotes compose of 10 million of the total 11 million species. We now believe that the majority of diversity of life comes from prokaryotes. Moreover, the bulk of this diversity cannot be cultivated in the laboratory. In the example given of coastal and open ocean bacterioplankton, only two of the many species are cultured representatives.

The Role of Genomics

In the tree of life, the tip of each branch represents an organism. Polymerase chain reaction (PCR) techniques can be used to measure prokaryotic biodiversity. Gene analysis, used to trace relations between different species has shown that multi-cellular organisms have evolved relatively late in biological evolution.

In the universal phylogeny of culturable and unculturable bacteria, the place where the curve reaches an asymptote denotes where species begin to proliferate. The understanding of gene diversity through methods such as PCR can be extrapolated to understand organismal diversity and community organization.

Biological CEE Research Groups at MIT

Building 48, the Parsons Laboratory building, is a part of the CEE department and houses much of the environmental biology research groups at MIT. Much of the biological research in CEE is currently involved in the genome sequencing of single micro-organisms in order to understand their roles in community ecosystems. The following slides describe the works of individual laboratories.

Associate professor of CEE Martin F. Polz is exploring the structure-function relationships in microbial communities of coastal oceans. Through the use of evolutionary relationships and comparative genomics, his lab is building model systems of bacterial communities. These models will then be used to predict individual interactions in micro-diverse communities.

Lee & Geraldine Martin Professor of Environmental Studies Penny Chisholm's lab is currently sequencing the entire genome of a minimal phototroph called *Prochlorococcus*. Her research focuses on use of these gene sequences to understand the microbial ecology of the ocean and the role of phytoplankton in general in the global carbon cycle.

Professor of Civil and Environmental Engineering and of Biological Engineering Edward DeLong is currently analyzing the genomes of uncultured communities. His lab extracts the genes of single microbes and translates them into "environmental libraries," where they are analyzed for possible potential uses in developing biotechnologies.

In the water, the nutrients that are crucial to sustain life are consumed the fastest and not evenly distributed. Marine snow, broadly defined as consisting of all kinds of primary organic particles, is generally white and rains down from the ocean. Bacteria depend on it for food and in the process leave behind a trail of nutrient-rich water, which serve as food for other animals. The colonization of the marine snow by micro-organisms and the eventual consumption of the bacteria by other animals mark the transfer of carbon from one species to the next. Professor of Applied Mathematics Roman Stocker is interested in developing mathematical models of the chemical profile of the ocean as described above.