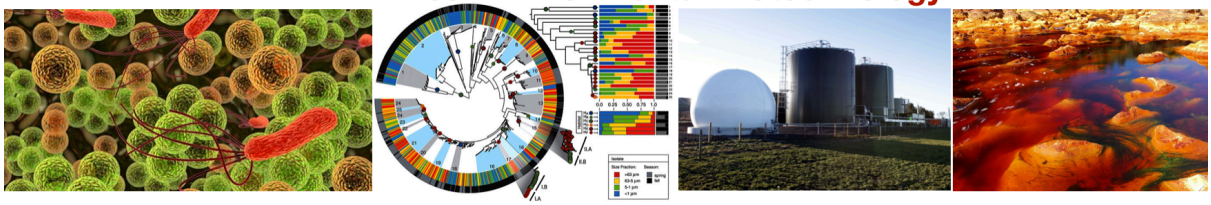
MI4103: Environmental Biotechnology



This advanced module will focus on the composition, development, dynamics, genomics, exploitation, and optimisation, of complex microbial communities in biotechnology.

The following areas will be covered:

(1) Important applications of anaerobic microbial communities, including in wastewater treatment, biorefining, and bioconversions to energy biofuels.

(2) Bioremediation of soils, sediments and oil spills.

(3) Metal-microbe interactions will be discussed in detail and will be focused on: metal removal from wastewater; biomining for metal recovery from metal ores; biooxidations for gold and silver mining; and acid mine drainage microbiology.

Learning Outcomes (LOs)
Students should be able to do the following on completing the module, and associated reading and tasks:

- **LO1:** Discuss the context for the technologies and processes covered in this module i.e. the need for environmental protection, resource recovery and achieving circular bio-economies
- **LO2:** Discuss the application of microbial communities for a range of biotechnologies, including anaerobic digestion, microbial fuel cells and in biorefineries
- **LO3:** Describe the technological and biochemical basis of the anaerobic digestion, biorefining, nutrient recovery, and bioelectrical systems covered in this module
- **LO4:** Discuss the application of microbial communities, of both bacteria and fungi, for bioremediation of soils, sediments and oil spills
- **LO5:** Describe biotechnologies used for metal removal from wastewater – including the use of metal nanoparticles in metal-resource recovery from wastewater; biomining for metal recovery from metal ores; and biooxidations for gold and silver mining
- **LO6:** Explain the microbiological basis of the biotechnologies covered by this module – including in the context of genomics and metagenomics
- **LO7:** Discuss the microbiology of acid mine drainage, and the potential of new, genome-centric approaches to study the microbial communities underpinning environmental biotechnologies

LECTURES – TIMETABLE, SCHEDULE AND DETAILS FOR 2019/2020

- Your first Environmental Biotechnology lecture will be on **Mon, 13th January 2020**.
- Your last lecture will be on 14th February.
- Lectures will start **sharply on-the-hour** and finish at ten min before the hour.
- Your attendance at lectures is absolutely expected and will be monitored using *Qwickly.*

The weekly timetable is:

- Mondays, 1pm, G2002, Áras Uí Chathail (ÁUC)
- Tuesdays, 4pm, IT125 (IT Building)
- Wednesdays, 9am, AM150 Máirtín Ó Tnuathail Theatre, Arts Millennium Building
- Fridays, 9am, IT125G (ground floor, IT Building)

Lecture Schedule (GC = Gavin Collins; VO'F = Vincent O'Flaherty)

- **1pm, Mon, 13th Jan 2020:**
  - Lecture 1: Introductory lecture GC/VO'F (joint)
    - A discussion by GC & VO'F
      - Basic concepts in Environmental Biotechnology
      - The potential of applications of microorganisms for sustainable wastewater treatment, agriculture and food production, sanitation and international development, bioremediation, and next-generation energy production and resource recovery/recycling.
      - NUI Galway and a proud tradition in this field.
    - Topics in this module.
    - Learning outcomes.
    - How much work you should do, and how you should do it.
    - Assessment; marks; expectations.

- **4pm, Tues, 14th Jan 2020:**
  - Lecture 2: Anaerobic digestion in agriculture (VO'F)
    - Applications of anaerobic digestion (AD) for biogas production from agri-food residues and biomass.

- **9am, Wed, 15th Jan 2020:**
  - Lecture 3: AD in sustainable wastewater treatment (VO'F)
    - AD for wastewater treatment.
    - Development of low-temperature AD wastewater treatment.

- **9am, Fri, 17th Jan 2020:**
  - Lecture 4: Microbial community development during low-temperature AD – Part 1 (VO'F)
    - Trophic groups in AD.
    - Microbial interactions underpinning conversion of organic matter.

- **1pm, Mon, 20th Jan 2020:**
  - Lecture 5: Microbial community development during low-temperature AD – Part 2 (VO'F)
    - Key features of microbial communities in low-temperature AD
    - Considerations for bioreactor operation under low temperatures
    - Examples from lab- and full-scale

- **4pm, Tues, 21st Jan 2020:**
  - Lecture 6: Nitrogen and phosphorus recovery linked to AD - anammox and polyphosphate (VO'F)

    - Nutrients (N & P) removal processes in wastewater treatment systems built around AD
    - Archaeal polyphosphate accumulation – is it real?

- **9am, Wed, 22nd Jan 2020:**
    - Lecture 7: AD as a biorefining platform - volatile and medium chain-length carboxylate fatty acids (VO'F)
        - Biological conversion of wastes and other organic residues in the 'bioeconomy'
        - High-value products from valorisation of residues in biorefineries

- **9am, Fri, 24th Jan 2020:**
    - Lecture 8: The carboxylate platform for biodegradable plastic production (VO'F)
        - The 'Carboxylate Platform': use of mixed-species microbial consortia to produce carboxylates
        - Chain elongation of carboxylates
        - Production of 'bio-plastics'

- **1pm, Mon, 27th Jan 2020:**
    - Lecture 9: Bioelectrochemical systems for AD-based biorefining (VO'F)
        - Electrogenic microbial processes – how microbes make electricity
        - (Micro)Bioelectrochemical technologies and microbial fuel cells (MFCs)
        - Bioelectrochemistry and biorefining

- **4pm, Tues, 28th Jan 2020:**
    - Lecture 10: Sustainable sanitation in international development (GC)
        - The great, global challenge, and opportunity, for Biotechnology: sustainable sanitation in developing countries and poor communities
        - On-site sanitation; collection/transport/treatment/valorisation of faecal solids (FS)
        - Sustainable FS management (FSM). Sanitation 'value chains'. The FSM Bioeconomy.
        - Emerging topics: genome-centric monitoring of pathogen transmission routes in low-and-middle-income-countries (LMICs)

- **9am, Wed, 29th Jan 2020:**
    - Lecture 11: Bacterial bioremediation of soils, sediments, groundwater, and oil spills (GC)
        - Legacy of historical environmental contamination. Trends in contamination.
        - Bioaugmentation, and nutrients supplementation, to remediate environmental contamination.
        - Factors affecting success of bioaugmenting indigenous microbial communities.
        - Factors affecting rates of bioremediation.
        - Examples of full-scale *in situ* and *ex situ* applications of bioremediation.
        - Microbial ecology of – and new trends in – bacterial bioremediation.

- **9am, Fri, 31st Jan 2020:**
    - Lecture 12: Mycoremediation (fungal bioremediation) – an untapped biotech (GC)

- Lignin: abundance; structure; polymerisation; depolymerisation.
- Biochemistry of ligninolytic white-rot fungi.
- Potential application of fungi for degradation of environmental pollutants – why so difficult? And, what's the potential?

- **1pm, Mon, 3rd Feb 2020:**
  - Lecture 13: Applications, microbial ecology, and genomics of fungal bioremediation (GC)
    - Lessons from real mycoremediation applications.
    - Genetics and genomics of mycoremediation.

- **4pm, Tues, 4th Feb:**
  - Lecture 14: Microbial enhancement of oil recovery. Microbiology of oil reservoir souring (GC)
    - Use of microbes, and microbial products, to enhance oil recovery.
    - Microbiology of sulfur-cycling, and souring, in oil reservoirs
    - Examples: mitigating souring of BP oil reservoirs

- **9am, Wed, 5th Feb:**
  - Lecture 15: Metal removal and recovery from wastewater (GC)
    - Mechanisms for application of microorganisms for removal/recovery of metals from wastewaters
    - Microbes and metal nanoparticles

- **9am, Fri, 7th Feb:**
  - Lecture 16: Biomining: fundamentals and applications – Part 1 (GC)
    - Microbial interactions with metals in Nature
    - Roles of microbes in mining. Solubilisation of metals, and the production of 'acid mine drainage'.
    - The 'ferrous/ferric cycle'. The 'sulfur/sulfuric-acid cycle'.

- **1pm, Mon, 10th Feb:**
  - Lecture 17: Biomining: fundamentals and applications – Part 2 (GC)
    - Versatile bio-miners: the flexible autotrophs that eat rocks
    - Biooxidation; recovery of precious metals from ores
    - Applications of biomining

- **4pm, Tues, 11thFeb:**
  - Lecture 18: Biomining: Microbiology, genomics, & legacy management (GC)
    - Genome-centric ecology, of acid mine drainage
    - *Legacy-planning case study:* treatment of alkaline, zinc-, lead- and sulfur-containing mine-influenced water (MIW) at Tara Mines, Navan, Co Meath (Europe's largest zinc mine) using sulfur-reducing bacteria in bioreactors and constructed wetlands

- **9am, Wed, 12th Feb:**
  - Lecture 19: *Special lecture* (Guest: Dr Paolo Dessì)

- **9am, Fri, 14th Feb:**
  - Lecture 20: Tutorial; Q&A/Discussion (GC & VO'F)
    - You come with questions and we lead a discussion.

EXAM:

- You will have a conventional exam at the end of Semester 2.
- You will see past/sample papers on Blackboard.

- You are expected to study material covered by both GC and VO'F.
    - Material covered by Dr Dessì will not be examined on the exam paper, but:
        - It will likely be of use in answering questions from GC and/or VO'F
        - You **are** expected to attend the guest lecture and your attendance will be monitored.
- Exam duration: 2 hours
- There will be two sections on the exam paper:
    - Section A (answer one from two Qs)
    - Section B (answer one from two Qs)
    - You'll be asked to answer a question from Section A AND Section B.