MICB 301: Microbial Ecophysiology

Calendar description.
Dynamics and control of prokaryotic cellular processes in response to the biotic and abiotic environment including metabolic interactions and metabolic cooperation between microorganisms.
[3-0-1] Prerequisite: BIOL 201 and MICB 201.

General course learning outcomes

1. Students will have a broad knowledge of microbiology that can serve as a foundation for advanced studies and careers in diverse fields
2. Students will be fluent in usage of terms and concepts in microbial physiology and ecology; they will be able to read, write and speak about this field.
3. Students will be able to critically analyze real-world issues involving microbial systems in areas such as health, environment and biotechnology.
4. Students will be able to identify and explain the microbial processes at the foundation of nearly all environmental issues.
5. Students will be able to explain examples of how microbial ecophysiology is important to their personal well-being.

Starting on the next page, is a detailed course outline.

Section 1. Prokaryotic cell growth & division – a closer look

Learning objectives – Students will be able to

1. Recognize structures of peptidoglycan and its components (you do not need to be able to draw them)
2. Explain how peptidoglycan is synthesized, relating this process to its functions
3. Describe the function and regulation of the replisome
4. Describe the structure and functioning of the divisome
5. Discuss what is and is not known about coordination of growth, DNA replication and cell division

Major Concepts – be able to identify, explain or give examples of these

Complex molecular machines
Prokaryotic cell organization
Prokaryotic cytokinesis
Regulation & coordination of complex cellular processes

Outline

1.1 Peptidoglycan synthesis
    Cell envelope
    Structure
    Growth
1.2 DNA replication
    Regulation
1.3 Cell division
    Cytokinesis
    Divisome
    Protein localization
    KaiAB hourglass – a simple circadian clock

Continued

Section 2. Respiration: a broad view

Learning objectives – Students will be able to

1. Within respiratory processes, recognize or give specific examples of major concepts, including energy coupling, energy conservation, energy transduction, redox reactions, electron transport, redox gradients.
2. Identify electron donors and acceptors in redox reactions.
3. Be able to use the electron tower to explain or predict energetic aspects of respiration.
4. For the various types of respiration discussed, describe and compare the environments where they occur and the impacts they have on those environments.
5. Be able to use the names and formulae of the chemical species discussed to recognize and describe respiratory processes.
6. Explain the environmental significance and applications of types of respiration discussed.

Major Concepts – be able to identify, explain or give examples of these

Anabolism	Hydrogen carrier	Dissimilation
Catabolism	Mineralization	Fuel cell
Electron acceptor	Oxidative phosphorylation	Subsurface environment
Electron carrier	Redox gradient	Bioremediation
Electron donor	Energy conservation	Symbiosis
Electron transport chain	Energy transduction	Dehalorespiration
Water activity	Electron tower	Proton translocation
Oxygen relationships	Microgradient	Energy coupling
Redox reaction	Rhizosphere	Denitrification
Terminal electron acceptor (TEA)		

Outline

2.1 Overview
2.2 The big picture of metabolism, a review
- Catabolism
- Anabolism

2.3 Respiration, the basics & diversity
- Essential process
- Electron tower
- Redox gradients
- The soil environment

2.4 Denitrification
- Mechanism
- Applied & environmental significance

2.5 Dissimilatory metal reduction
- Acquisition of ferric iron
- Environmental significance
- Microbial fuel cells

2.6 Dehalorespiration
- Perchloroethene
- PCBs
- *Dehalococcoides* genome – bioinformatic ecology

Section 3. Sensing & responding to the environment

Learning objectives – Students will be able to

1. Recognize, describe, draw and compare different transporters
2. Identify the force(s) driving different transport processes
3. Describe two-component systems and how they generally function
4. Compare phosphorelay and two-component systems
5. Explain the mechanism by which OmpF and OmpC synthesis is regulated and how mutants in the system lead to particular phenotypes
6. Predict and explain phenotypes of mutants with defective chemotaxis sensors or signal transducers
7. Explain the significance and mechanism of adaptation in chemotaxis

Major Concepts – be able to identify, explain or give examples of these

Adaptation to chemoeffectors
Active transport
DNA binding affinity
Energy transduction
Kinase
Phosphorylase
Protein-protein interaction
Proton-motive force
Signal amplification
Signal integration
Signal transduction

Outline

3.1 Transport
- Facilitated diffusion & porins
- ABC transporters
- MFS transporters
- Rhodopsins
- Secondary transport: symport, antiport, uniport

3.2 Signal transduction
- Two-component systems, EnvZ-OmpR
- Phosphorelay systems, Spo system

3.3 Chemotaxis
- Sensors & transducers
- Mechanisms of sensing and adaptation

Section 4. Organic compound degradation

Learning objectives – Students will be able to

1. Recognize and distinguish the reactions of the types of oxygenases discussed.
2. Explain how aerobic hydrocarbon biodegradation relates to total metabolism, including energy conservation, anabolism, reductant and the fate of carbon.
3. Discuss factors potentially limiting hydrocarbon biodegradation in natural environments and explain how those limitations can be overcome in engineered systems.
4. Be able to recognize structures of lignin and cellulose as well as to compare and contrast mechanisms for degradation of these two polymers.
5. Name and describe groups of organisms that degrade wood and describe their adaptations permitting wood degradation.
6. Describe how any of the processes of organic compound metabolism covered in this course affect the carbon cycle.

Major Concepts – be able to identify, explain or give examples of these

Bioremediation
Brown rot
Carbon cycle
Dioxygenase
Engineered bioremediation systems
Exoenzyme
Flux
Gliding motility
Persistence
Recalcitrance
Reservoir
White rot
Xenobiotic

Outline

4.1 The C cycle
4.2 Wood decomposition
    Wood degraders – diversity
    Lignin biodegradation, white rot
    Cellulose biodegradation, secreted cellulases, cellulosome
    Forest fungi – relationship of niche and lignocellulose degradation capacity
4.3 Concepts in biodegradation
    Oxygenases
4.4 Alkane biodegradation
4.5 Aromatic biodegradation
4.6 Methylotrophy
4.7 Bioremediation
    Limiting factors
    Engineered systems

Section 5. Anaerobic food web

Learning objectives – Students will be able to

1. Identify, explain or give specific examples of major concepts in fermentation and syntrophy listed below
2. Give examples of how fermentations are used by humans, explaining the process and the benefits
3. For the metabolic groups discussed in the notes, describe their niches and habitats
4. Describe nutritional interactions discussed in the notes and explain their consequences
5. Explain differences in aerobic and anaerobic organic decomposition that relate to energetics and to nutritional interactions between populations
6. Given a particular environment, indicate what you think would be the primary mechanism of hydrogen consumption and provide your rationale
7. Predict how disruption of particular processes would affect the overall process of anaerobic organic decomposition or the carbon cycle in a particular environment

Major Concepts – be able to identify, explain or give examples of these

Anaerbic mineralization	Disproportionation
Energy coupling	Eutrophic
Fermentation	Food web
Guild	High-energy compounds
Interspecies H_2 transfer	Redox balance
Substrate-level phosphorylation (SLP)	Syntrophy

Outline

5.1 What is fermentation
5.2 Review of glycolysis
5.3 Alcohol fermentation: ecology, applications, pathway
5.4 Homolactic fermentation: ecology, applications, pathway
    Lactic acid as an uncoupler
    Lactate/proton symport
5.5 Mixed acid fermentation: ecology, pathway
5.6 Anaerobic food webs
    Syntrophy
    Guilds
5.7 Obligate syntrophs
    Significance
    Interspecies hydrogen transfer
    Thermodynamics
    Human gut mutualism
5.8 Homoacetogens
    Acetyl-CoA pathway
5.9 Methanogens
    Significance & habitats
    Methanogenesis from CO_2
    Methanogenesis from acetate
5.10 The rumen food web
    Metagenomic discovery of biomass degrading genes of the rumen

Section 6. Phototrophy

Learning objectives – Students will be able to

1. Recognize, explain or give specific examples of major concepts listed below
2. For the groups of phototrophs discussed in the notes, state their distinguishing characteristics and discuss their niches and adaptations
3. Identify and explain interactions in the marine microbial food web
4. Suggest appropriate applications of research methods discussed in the notes and readings to address ecological questions

Major Concepts – be able to identify, explain or give examples of these

Anoxygenic phototrophy
Antenna
Cyclic electron flow
Non-cyclic electron flow
Oxygenic phototrophy
Rhodopsin
Photosynthesis
Photophosphorylation
Proton pump
Reaction center
Reverse electron flow

Outline

6.1 Overview: photosynthesis, energy transduction
6.2 Proteobacterial phototrophs
- Purple sulfur bacteria; stratified aquatic systems
- Purple nonsulfur bacteria
- Aerobic anoxygenic phototrophs
- Purple bacterial phototrophic apparatus (mechanism)

6.3 Green sulfur bacteria
- reverse TCA cycle
- GSB phototrophic apparatus (mechanism)
- Chlorosomes
- GSB in consortia w/ heterotrophs

6.4 Cyanobacteria
- Gas vesicles, gliding motility, heterocycsts, desiccation resistance, spores, lichen
- Environmental significance: oxygen atmosphere, chloroplasts, chem cycling, blooms
- Phototrophy mechanism, ETC
- Marine environment: picoplankton, ecotypes, microbial loop, viruses

6.5 Rhodopsins
- *Halobacterium*, halophily, compatible solvents
- Metagenomics and the discovery of proteorhodopsin
- *Pelagibacter*