Syllabus for ESE/BI 168 – MICROBIAL METABOLIC DIVERSITY

Winter Term 2020/2021; MWF 9am-10am
Zoom Link: https://caltech.zoom.us/j/86870121749

	OFFICE HOURS
Professor: Dianne K. Newman; dkn@caltech.edu	by appointment
TAs: John Ciemniecki; jciemnie@caltech.edu	by appointment
Shaelyn Silverman; ssilverman@caltech.edu	by appointment

Week	Monday	Wednesday	Friday	Topic
1	Jan. 4 *lecture*	Jan. 6 *paper 1A*	Jan. 8 *paper 1B*	Foundations of Metabolism
2*	Jan. 11 *lecture*	Jan. 13 *lecture*	Jan. 15 *paper 2A*	ΔG
3*	Jan. 18 *MLK Day*	Jan. 20 *paper 3A*	Jan. 22 *paper 3B*	Fermentation
4*	Jan. 25 *lecture*	Jan. 27 *paper 4A*	Jan. 29 *paper 4B*	PMF/ATPase
5	Feb. 1 *lecture*	Feb. 3 *paper 5A* **MIDTERM OUT**	Feb. 5 *paper 5B*	Respiration
6*	Feb. 8 *lecture* **MIDTERM DUE**	Feb. 10 *paper 6A*	Feb. 12 *paper 6B*	Photosynthesis
7	Feb. 15 *President's Day*	Feb. 17 *lecture*	Feb. 19 *paper 7A*	Electron Bifurcation
8	Feb. 22 *lecture*	Feb. 24 *papers 8A*	Feb. 26 *paper 8B*	Syntrophy
9	Mar. 1 *lecture*	Mar. 3 *paper 9A*	Mar. 5 *paper 9B*	Redox Homeostasis
10	Mar. 8 *paper 10A*	Mar. 10 *paper 10B,* *re-read paper 1A*		Growth in Context
11	**ORAL FINALS (TIMES TBD)**			

* recitations w/ TAs will be offered these weeks, time TBD

Format. For two thirds of the class meetings, 1-2 original research papers will be assigned as required readings. During class, the papers will be discussed critically and in detail. The emphasis here is on discussion—apart from the lectures I give to introduce the topics, this will not be a lecture course. I expect each student to participate actively and often. To insure this participation, I will call on students at random either to summarize the major points in a paper, or to comment specifically on a particular experiment or conclusion. My goal is to ensure that everyone participates equally and that students become comfortable engaging in constructively critical discussions. Accordingly, it is essential that you read and think about the assigned papers. If you have not done so, then don't come to class.

Zoom Format. Due to Covid-19, this course will be conducted virtually through Zoom. Lectures will require real-time note taking but will be recorded. The Zoom format for paper discussions will depend on the class size.

Grades. One third of your grade will be based on the quality and quantity of your classroom participation. Another third will come from a take-home midterm examination. The final third will come from a 30 minutes oral final examination. The midterm exam will not come from the assigned reading. Rather, it will test your overall understanding of the material we have covered until that point. In the final, we'll try to determine how much you have synthesized the key concepts presented throughout the course.

Readings

The course reader contains the papers we will discuss in class. In addition, I will assign specific sections from D. White's The Physiology and Biochemistry of Prokaryotes, 4th edition, or review articles as background reading to complement the week's theme.

Week 1: Foundations of Metabolism

Required background reading: From Harold F.M. *The Vital Force: A Study of Bioenergetics,* Chapter 2, The Metabolic Web: "The Logic of Metabolism", "ATP and Energy Coupling", "Functional Organization of Metabolism".

1A: Kluyver, A.J. 1924. Unity and diversity in the metabolism of microorganisms. *Chemisch Weekblad*, 21:266-.

1B: Chapman, A.G. *et al.* 1971 Adenylate energy charge in *Escherichia coli* during growth and starvation. *J Bact*, 108:1072-1086.

Week 2: ΔG

Required background reading: D. Canfield, Ch. 3 – Thermodynamics and Microbial Metabolism; Aquatic Chemistry Tables, Morel and Hering

2A: Jackson, B. and McInerney, M.J. 2002. Anaerobic microbial metabolism can proceed close to thermodynamic limits. *Nature*, 415:454-456.

Week 3: Fermentation

Textbook reading: White: Chapter 8, 15

3A: Benz, M. *et al.* 1998. Humic acid reduction by *Proprionibacterium freudenreichii* and other fermenting bacteria. *Appl Env Microbiol,* 64:4507-4512.

3B: Hunt, K.A. *et al.* 2010. Substrate-level phosphorylation is the primary source of energy conservation during anaerobic respiration of *Shewanella oneidensis* strain MR-1. *J Bacteriol*, 192:3345-3351.

Week 4: PMF/ATPase

Textbook reading: White: Chapter 4
Optional background reading: P. Mitchell Nobel Prize lecture
Required background reading: Harold, F.M. Gleanings of a chemiosmotic eye. 2001. *BioEssays*, 23: 848-855.

4A: Maloney, P.C. 1977. Obligatory coupling between proton entry and the synthesis of adenosine 5'-triphosphate in *Streptococcus lactis*. *J Bacteriol,* 132:5 64-575.

4B: Anantharam, V., Allison, M.J. and Maloney, P.C. 1989. Oxalate: formate exchange. The basis for energy coupling in *Oxalobacter*. *J Biol Chem*, *264*: 7244-7250.

Week 5: Respiration

Textbook reading: White: Chapter 5

5A: Calhoun, M.W. *et al.* 1993. Energetic efficiency of *Escherichia coli*: effects of mutations in components of the aerobic respiratory chain. *J Bacteriol*, 175:3020-3025.

5B: Newman, D.K. *et al.* 1997. Dissimilatory arsenate and sulfate reduction in *Desulfotomaculum auripigmentum* sp. nov. *Arch Microbiol,* 168:380-388.

Week 6: Photosynthesis

Textbook reading: White: Chapter 6
Optional background reading: M. Calvin Nobel Prize lecture

6A: Cohen, Y., Padan, E. and Shilo, M. 1975. Facultative anoxygenic photosynthesis in the cyanobacterium *Oscillatoria limnetica*. *J Bacteriol,* 123: 855-861.

6B: Ehrenreich, A. and Widdel, F. 1994. Anaerobic oxidation of ferrous iron by purple bacteria, a new type of phototrophic metabolism. *App Env Microbiol,* 60: 4517-4526.

<u>Week 7: Electron Bifurcation</u>

<u>Required background reading</u>: Muller, V. *et al.* 2018. Electron bifurcation: a long-hidden energy-coupling mechanism, *Ann. Rev. Microbiol.*, 72:331–53; Peters, J.W. *et al*. 2018. A new era for electron bifurcation. *Curr. Opin. Chem. Biol.*, 47:32-38.
<u>Textbook reading</u>: White: Chapter 5 (section 5.2)

7A: Li, F. *et al*. 2008. Coupled ferredoxin and crotonyl coenzyme A (CoA) reduction with NADH catalyzed by the butyryl-CoA dehydrogenase/Etf complex from *Clostridium kluyveri*. *J Bacteriol,* 190: 843-850.

<u>Week 8: Syntrophy</u>

<u>Required background reading</u>: Schink, B. Synergistic interactions in the microbial world. 2002. *Antonie van Leeuwenhoek*, 81: 257-261.

8A: Bryant, M.P., Wolin, E.A., Wolin, M.J., and Wolfe, R.S. (1967) *Methanobacillus omelianskii*, a symbiotic association of two species of bacteria. *Archiv Microbiol,* 59:20-31.

8B: Fröstl, J.M. and Overmann, J. (1998) Physiology and tactic response of the phototrophic consortium "*Chlorochromatium aggregatium*". *Arch Microbiol,* 169:129-135.

<u>Week 9: Redox Homeostasis</u>

<u>Required background reading</u>: Ciemniecki, J.A. and Newman, D.K. 2020. The Potential for redox-active metabolites to enhance or unlock anaerobic survival metabolisms in aerobes. *J Bact*, 202: e00797-19.

9A: Richardson, D.J. *et al*. 1988. The role of auxiliary oxidants in maintaining redox balance during phototrophic growth of *Rhodobacter capsulatus* on propionate or butyrate. *Arch Microbiol,* 150: 131-137.

9B: Glasser, N.R., Kern, S.E. and Newman, D.K. 2014. Phenazine redox cycling enhances anaerobic survival in *Pseudomonas aeruginosa* by facilitating generation of ATP and a proton-motive force. *Mol Microbiol, 92*: 399-412.

<u>Week 10: Growth in Context</u>

<u>Optional background reading</u>: Pinhassi J. *et al.* 2016. Marine bacterial and archaeal ion-pumping rhodopsins: genetic diversity, physiology, and ecology. *Microbiol Mol Biol Rev,* 80(4):929-54.

10A: Béjà O. *et al*. 2000. Bacterial rhodopsin: evidence for a new type of phototrophy in the sea. *Science*, 289(5486):1902-1906.

10B: Meylan, S. *et al*. 2017. Carbon sources tune antibiotic susceptibility in *Pseudomonas aeruginosa* via tricarboxylic acid cycle control. *Cell Chem Biol*, 24(2):195-206

1A: Kluyver, A.J. 1924. Unity and diversity in the metabolism of microorganisms. *Chemisch Weekblad*, 21:266-. NOTE: Re-read (this was assigned the 1st week of class).

Appendix

I. Aquatic Chemistry Tables from Morel and Hering
II. Four fun articles (these papers will give you some impressive and fun facts to share with your family and friends):

- → Microbiology by numbers (2011) *Nature Rev. Microbiol*., 9:628.
- → Sender et al. (2016) Revised estimates for the number of human and bacterial cells in the body, *PLoS Biol*, DOI:10.1371/journal.pbio.1002533.
- → Whitman, W.B. *et al.* (1998) Prokaryotes, the unseen majority, *PNAS*, 95:6578-6583.
- → Bar-On, Y.M. *et al.* (2018) The biomass distribution on Earth, *PNAS*, 115:6506-6511.