BMB 961, Section 3. 3 Credits, Spring 2016

Title: ***Plant Biotechnology for Health and Sustainability***

Participating Faculty: Björn Hamberger (instructor), Christoph Benning (instructor), Tom Sharkey (instructor), invited MSU Faculty and External Participants

Coordinator: Björn Hamberger (hamberge@msu.edu)

Meeting time: Tuesdays and Thursdays 9-10:20 am

Location: Molecular Plant Sciences 1030

Description: This course is part of an interdisciplinary effort to foster opportunities for graduate students with interest in plant biotechnology. A broad overview of the state-of-the art of plant biotechnology and related fields will be provided. In addition, students are encouraged to think about concepts and ideas that can be potentially commercialized. Special emphasis will be on plant metabolic pathways that impact human health and nutrition, as well as sustainability in the production of therapeutics, food and fuels from plants and algae. Examples and case studies will be discussed that cover hosts, strategies and pitfalls in expression of foreign pathways. Examples are chosen to explain in simple terms basic metabolic engineering principles, including synthetic biology approaches to generate, analyze, and optimize transgenic plants or algae. Some of the chosen cases will be particularly suited to discuss regulatory and commercial issues related to genetically modified organisms (GMOs) and the 'share-your-parts' philosophy, as promoted for example by the international genetically modified machine (iGEM) initiative. To actively participate in the course, students need to have a basic understanding of molecular biology, genomics, or plant biochemistry, and are expected to read background and original research papers as assigned. Students will be guided to develop a 3-page brochure presenting a scientific idea for a plant biotechnology based product or process with a recognized need or new opportunity. The students will need to clearly lay out the idea, present reasonable milestones and be aware of potential technical, commercial, or societal hurdles, and articulate how the proposed technology would address the need or opportunity. A list of potential topics will be presented during the first lecture from which students can choose, or students can develop their own topic idea. Guidance and feedback will be provided by the instructor(s) to the students on an individual base as they develop a draft. During the final sessions of the semester, students will be asked to pitch their idea in a 10 min presentation, followed by feedback from the entire group.

Prerequisites: Basic knowledge in molecular biology, genomics, or plant biochemistry as demonstrated by having completed at least one of the following graduate level classes: BMB801 molecular genetics, BMB961 genomics, BMB864 plant biochemistry, BMB865 plant molecular biology.

Limitation: 15 Students

Evaluation of progress and grading:

1. Brochure, 3 pages (25% of grade)
2. Final presentation (25% of grade)
3. 1st Midterm exam, on first half of topics, take home 24 hours (25% of grade)
4. 2nd Midterm exam during finals week on second half of topics, take home 24 hours (25% of grade)

Location: 1030 Molecular Plant Sciences Building (MPS)

Topics and time line:

1. (1/12) Overview of plant biotechnology topics (targets and hosts), goals and expectations. (BH)
2. (1/14) Introduction to describe why and how transgenic plants are generated and possible ways of avoiding the generation of transgenic plants to accomplish the same goals (natural and induced mutations, TILLING, CRISPR-Cas). (BH)

Students pick topic for presentation and brochure and give notice to instructor

3. (1/19) Testimony of an entrepreneur. Explaining the basic commercial principles and hurdles of founding a plant biotechnology startup company (Bobby Bringi, Michigan Biotechnology Institute). (Confirm/possibly later date in first module, alternatively talk about IP BH).
4. (1/21) How are protein/gene targets selected for engineering? Rate limiting steps of pathways and limitations to this approach; regulation of entire pathways by targeting transcription factors. How are enzymes selected or optimized through protein engineering prior to introduction into transgenic plants. (BH)
5. (1/26) Introduction to synthetic biology. What techniques and principles are used to introduce or reorganize entire pathways in transgenic bacteria and plants? (BH)
6. (1/28) Case study for an input trait. Engineering glyphosate resistance. The science of targeting the shikimate pathway. Naturally occurring resistance in weeds. (TS/BH)
7. (2/2) Engineering resistance to insects, another input trait. BT-toxin, an example of protein engineering to maximize the production of a protein from a Gram+ bacterium in plants. (TS/BH)

8. (2/4) Discussion of risks and benefits of GMOs engineered for input traits such as glyphosate resistance or BT toxin production. What are the benefits and costs for the farmer, the consumer of agricultural products and processed foods from GMOs, the environment? (TS/BH)
9. (2/9) Engineering a complex input trait by targeting of the CBF1 transcription factor regulating cold tolerance (Mike Thomashow, DOE-Plant Research Lab, guest speaker, to be confirmed). (CB, TS)
10. (2/11) First example for a high value output trait with relevance to human nutrition and health: polyunsaturated fatty acids (fish oil) from algae. Risks/benefits to human health. Introduction to fatty acid and complex lipid biosynthesis in algae and plants. (CB)
11. (2/16) Transferring the pathway for polyunsaturated fatty acids from algae into oil crops. Engineering and optimization strategies. (CB)
12. (2/18) Genomic and genetic approaches towards identifying factors controlling oil biosynthesis in algae (Case studies from the Benning Lab, Biochemistry) (CB)
13. (2/23) Exploring algae as sustainable energy feedstock. Discussion of cultivation methods and their benefits and challenges. Net energy gain, carbon foot print, water usage, and environmental impacts. (CB)
14. (2/25) Engineering oil seeds for human nutrition. Example of commercialization hurdles for a transgenic crop (Toni Voelker, Monsanto, by video, to be confirmed)
15. (3/1) Ethanol and fuels from plants. Using corn starch or lignocellulosics as feedstock; discussion of the entire process from the farm to the gas pump. Discussion of sustainability, net energy gain, and carbon conservation (Bruce Dale, Chemical Engineering, to be confirmed, guest speaker)

Thursday , March 3 - 1st Midterm exam (covering topics 1-12)

SPRING BREAK: MARCH 7-11

Students provide draft of brochure to instructor for critique

16. (3/15) From lipids to more complex targets: Terpenoids general introduction. Discussion of the two pathways of isoprenoid biosynthesis in plants and overview of high-value products. (BH)
17. (3/17) Case study: discovery and reconstitution of biosynthetic pathways to high-value compounds using synthetic biology. Engineering principles to introduce and optimize the pathway in heterologous hosts. (BH)
18. (3/22) Jet fuel, flavors, and fragrances. (TS)
19. (3/24) Case study enhancing vitamin A content of food for the developing world. Engineering principles and challenges leading to the production of Yellow Rice and discussion of barriers to its acceptance. (TS)
20. (3/29) Case study enhancing vitamin E content of food. The role of tocopherols in plants and animal cells. Biosynthesis and engineering. (Radin Sadre, Biochemistry, guest speaker, to be determined).
21. (3/31) Other vitamins and drugs made in plastids. (TS)

22. (4/5) Sampling biodiversity for drug discovery. Genomics of medicinal plants. An overview of medicinal plants, their uses, and the underlying biochemistry is provided. The focus will be on aspects of pathway discovery. (BH)
23. (4/7) Case study for alkaloid drug production. Brewing Bad: Identifying the enzymes of morphine biosynthesis and fermentation based production. (BH)
24. (4/12) Introduce and discuss the principles and challenges of generating and analyzing genomic sequencing data on a grand scale using the medicinal plant project as an example. (Robin Buell, Plant Biology, guest speaker, to be confirmed).
25. (4/14) Plants and algae as factories for useful peptides. Overview and principles of virus-based and chloroplast transformation-based expression systems. Example: The production of human peptides (e.g. hormones) free of human pathogens using plant virus-based expression systems. (CB)

Tuesday, April 19 - 2nd Midterm exam (topics 13-23)

26. - 28. (4/21, 4/26, and 4/28) Presentations by students and discussions