

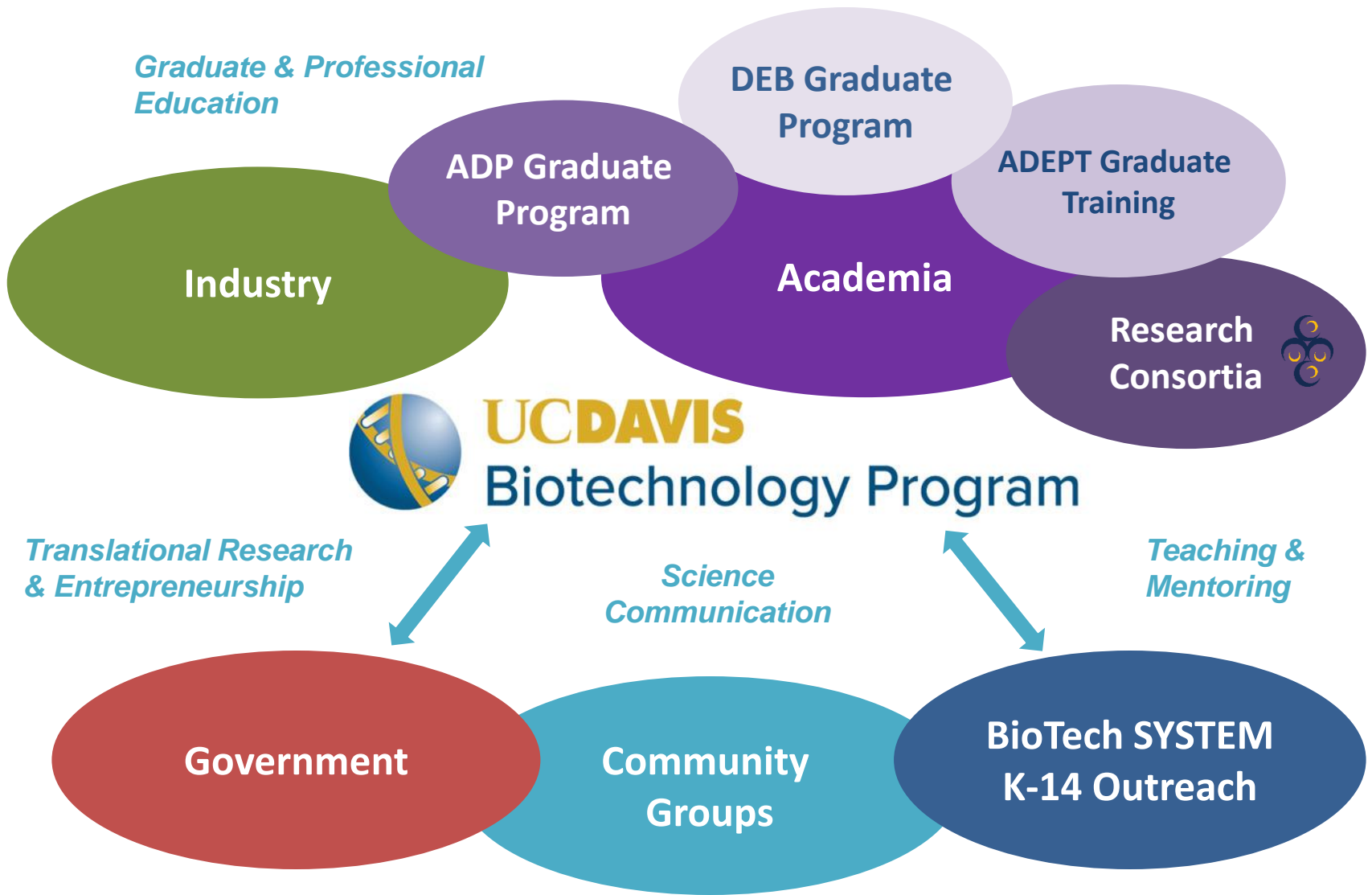


UC DAVIS

Biotechnology Program

Sustainable Protein: Building on Food, Ag and Biotech Foundations at UC Davis

Dr. Denneal Jamison-McClung
Director, UC Davis Biotechnology Program and
Co-Founder, UC Davis Cultivated Meat Consortium
October 5, 2023



Established in 1986 and reporting to the Office of Research, the UC Davis Biotech Program works to bring all members of the life science community together to promote biotechnology education and technology development. <https://biotech.ucdavis.edu/>

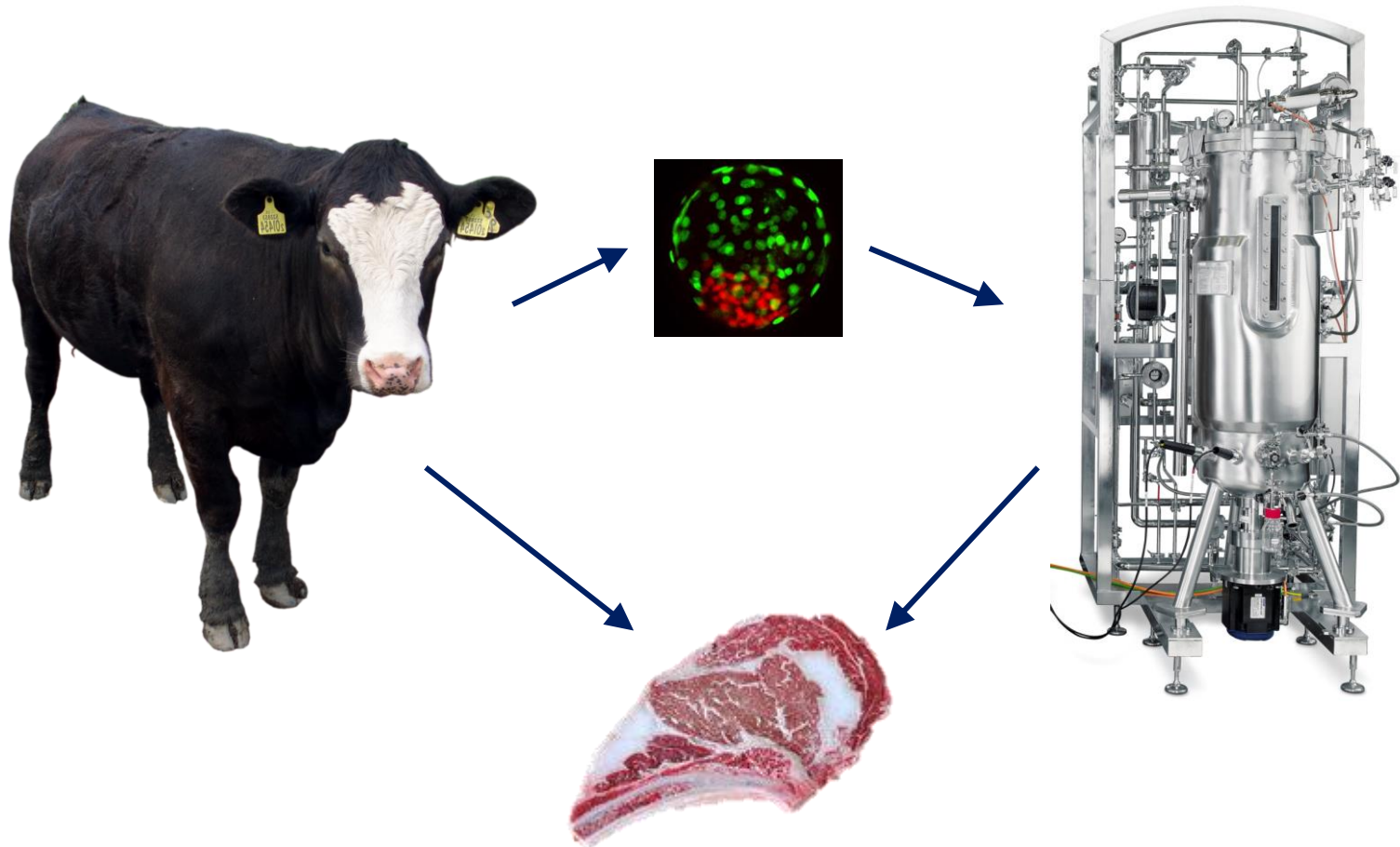


UC Davis Cultivated Meat Consortium

- Biotech Program has been actively engaged in hosting industry speakers and placing students in internships in the alt protein / cultivated meat industry since ~2015.
- CMC formed in late 2019 to bring together interested students, faculty researchers and educators at UC Davis.
- Affiliated UC Davis faculty have internal and external funding on a variety of research and education projects.
- CMC faculty teach traditional academic courses and curricular modules, as well as continuing education courses on cultivated meat and alt proteins.

<https://cultivatedmeat.ucdavis.edu/>

What is cultivated meat?



<https://www.dartagnan.com/>

UC Davis/Pablo Ross

<https://www.sartorius.com>

Clipartkey.com

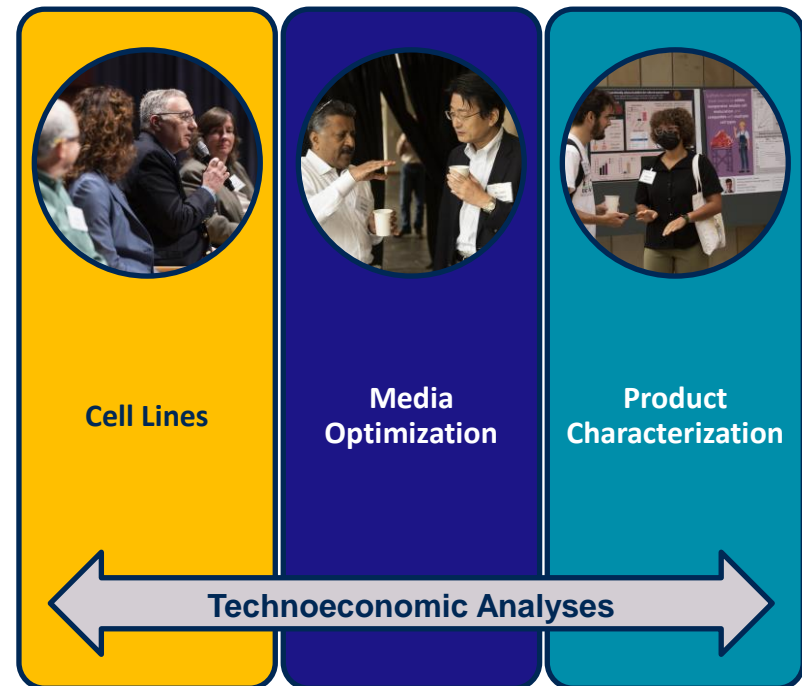
Products are on the Market in Singapore and the U.S. (Limited Distribution)

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U.S. challenges for this industry include:

- **Technical** -> cell line development, media optimization, product characteristics (form/structure, flavor, mouth-feel, shelf life, etc.)
- **Economic** -> CAPEX/OPEX, cost of media, biomanufacturing capacity, competitive workforce landscape
- **Regulatory** -> FDA worked with USDA on a regulatory process – first two approvals in June 2023.



UC Davis CMC Research Faculty on the NSF Growing Convergent Research Project

Slide courtesy of Prof. David Block, UC Davis CMC

Bioprocess /Tissue Engineering

Stem Cells/Animal Science

Muscle Physiology/ Differentiation

Technoeconomic/Life Cycle Analysis

Food Science/ Nutrition

Block

Biochemical
engineering/
Optimization

Baar

Muscle
Physiology/
Tissue Culture

Denicol

Bovine Stem
Cells

Sumner

Agricultural
Economics

Nandi

Plant Cell
Culture/
Protein
Expression

Vahmani

Animal
Science/
Nutrition

Taha

Food Science/
Meat Stability

Oberholster

Sensory
Science/
Mouthfeel

Leach

Biomedical
Engineering/
Tissue Culture

Wan

3-D Tissue
Culture/
Chemical
Engineering

Spang

Sustainable
Food
Processing

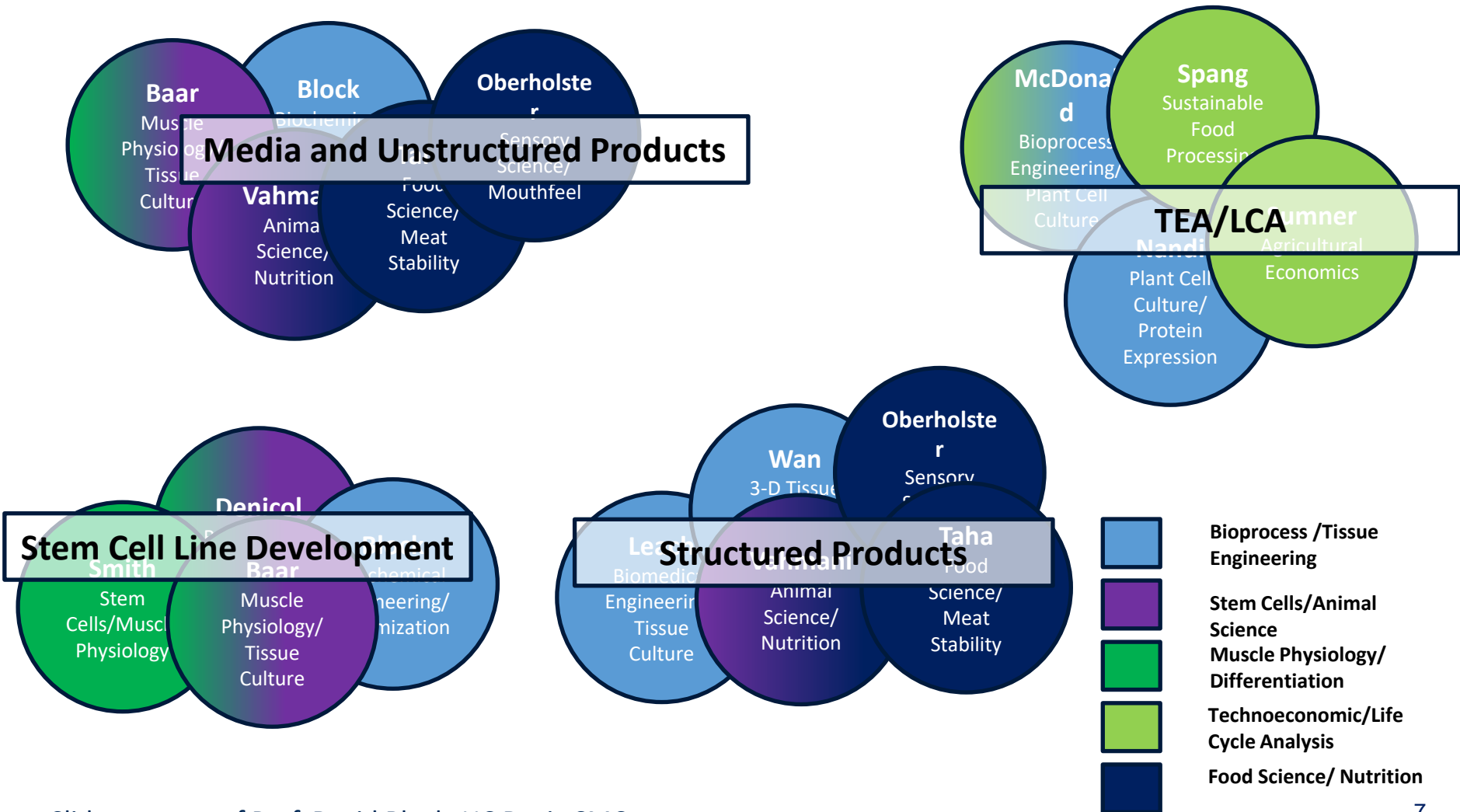
McDonald

Bioprocess
Engineering/
Plant Cell
Culture

Smith

Stem
Cells/Muscle
Physiology

Convergent Research is Multidisciplinary



UC Davis CMC's NSF GCR Project Evolution

$$\mu = \mu_{\max} \frac{G}{K_G + G} \frac{S}{K_S + S} \frac{F}{K_F + F} \frac{1}{1 + \frac{L}{K_L}} \frac{1}{1 + \frac{A}{K_A}} \left(1 - \frac{X}{X_m}\right)$$

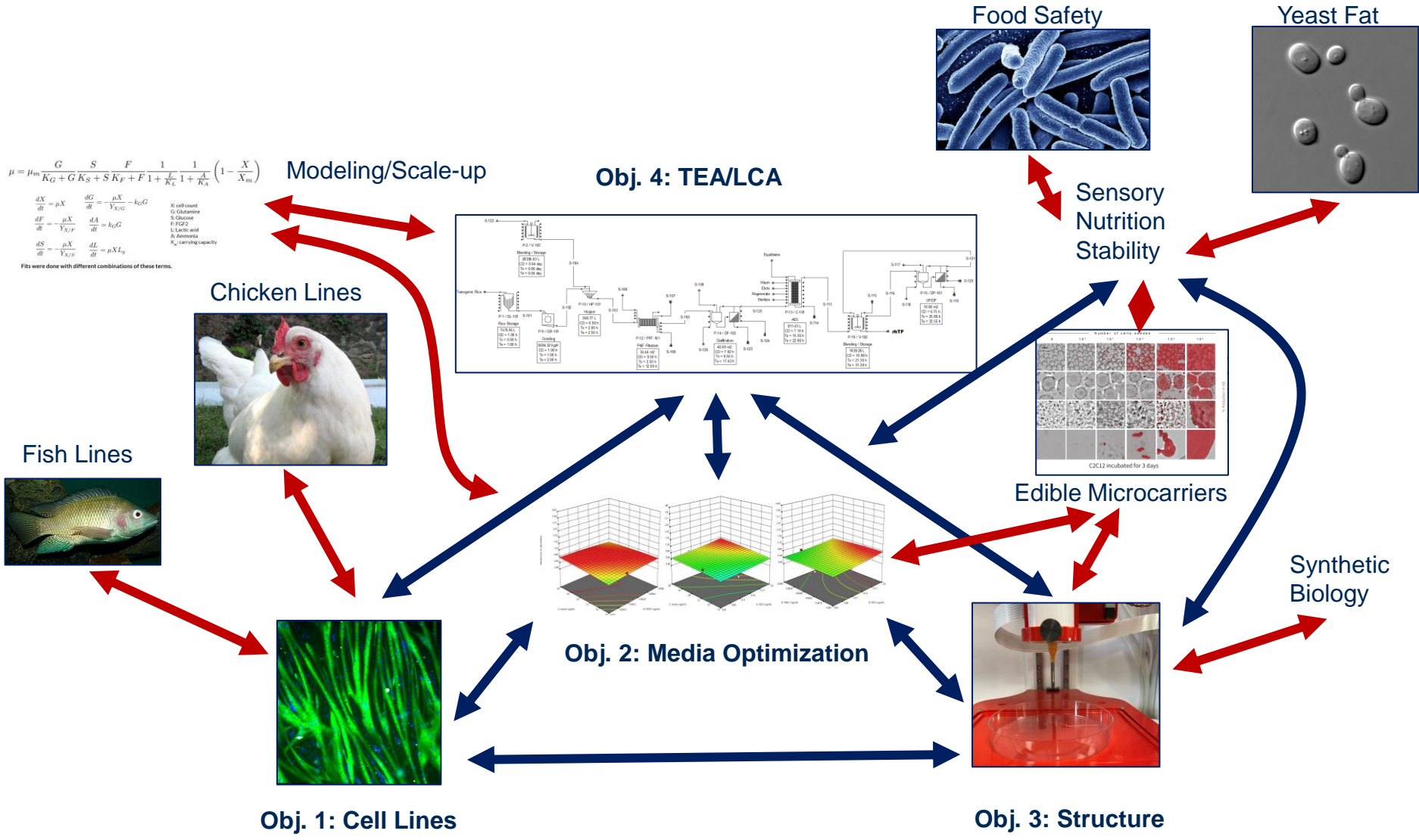
$$\frac{dX}{dt} = \mu X \quad \frac{dG}{dt} = -\frac{\mu X}{Y_{X/G}} - k_G G$$

$$\frac{dF}{dt} = -\frac{\mu X}{Y_{X/F}} \quad \frac{dA}{dt} = k_G G$$

$$\frac{dS}{dt} = -\frac{\mu X}{Y_{X/S}} \quad \frac{dL}{dt} = \mu X L_p$$

Fits were done with different combinations of these terms.

K_G : coefficient
 G : Glutamine
 F : FGF2
 L : Lactic acid
 A : Ammonia
 X_m : carrying capacity



Cell Lines for Cultivated Meat

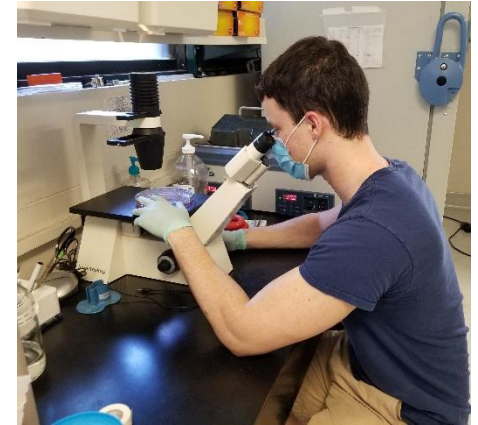
- Smith Lab (Neurobiology, Physiology and Behavior)
 - Specializes in growing skeletal muscle for repairing muscles -> applying knowledge to cell culture and structure products
 - Role for alginates or other microcarriers/matrices for promoting cell division and growth

- Denicol Lab (Animal Science)
 - Specializes in reproductive biology -> investigating age and type of cells best for starting cell cultures
 - Possible role for embryonic stem cells (can tolerate more divisions before differentiation)



Cell Culture Media Optimization

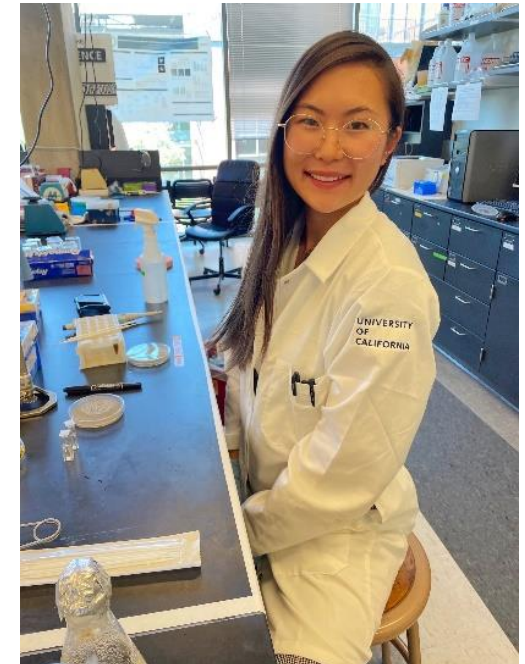
- Block and Baar Labs working on media that is:
 - Serum-free
 - Antibiotic-free
 - Less costly
 - Reduce/optimize required basic components
 - Piloting use of complex ag residues (cheaper, less refined)



- Recent Publications
 - Cosenza, Z., Astudillo, R., Frazier, P. I., Baar, K., & Block, D. E. (2022). Multi-information source Bayesian optimization of culture media for cellular agriculture. *Biotechnology and Bioengineering*, 119(9), 2447–2458.
 - Cosenza, Z., Block, D. E., & Baar, K. (2021). Optimization of muscle cell culture media using nonlinear design of experiments. *Biotechnology Journal*, 16(11), 2100228.
 - O'Neill, E. N., Cosenza, Z. A., Baar, K., & Block, D. E. (2020). Considerations for the Development of Cost-Effective Cell Culture Media for Cultivated Meat Production.

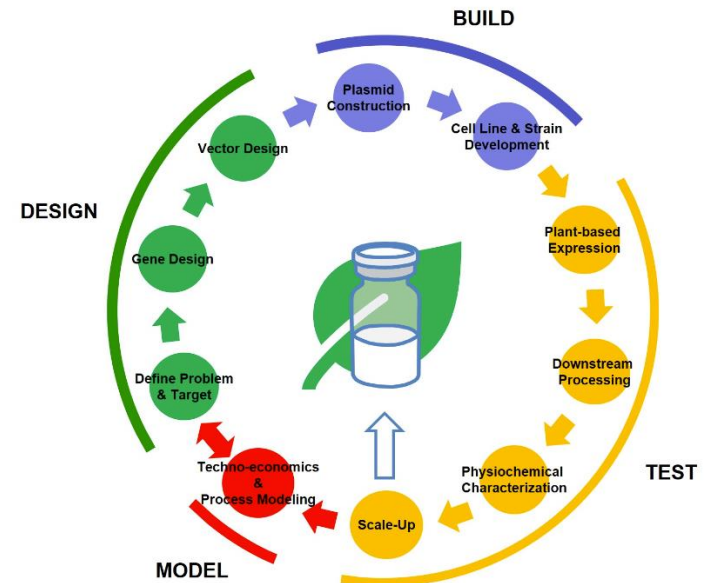
Edible Microcarriers

- Block and McDonald Labs working on microcarriers:
 - Fungal and plant cells
 - Promote / compatible with cell culture
 - Edible / add flavor
 - Inexpensive
- Provisional Patent
 - Ogawa, M., & Block, D. E. (provisional). *Compositions including filamentous fungal biomass and cultured animal cells, and methods of forming and using.* (Patent No. 0652.000004US60).
- Recent Publications
 - Ogawa, M.; Moreno García, J.; Nitin, N.; Baar, K.; Block, D.E. Assessing Edible Filamentous Fungal Carriers as Cell Supports for Growth of Yeast and Cultivated Meat. *Foods* 2022, 11, 3142.

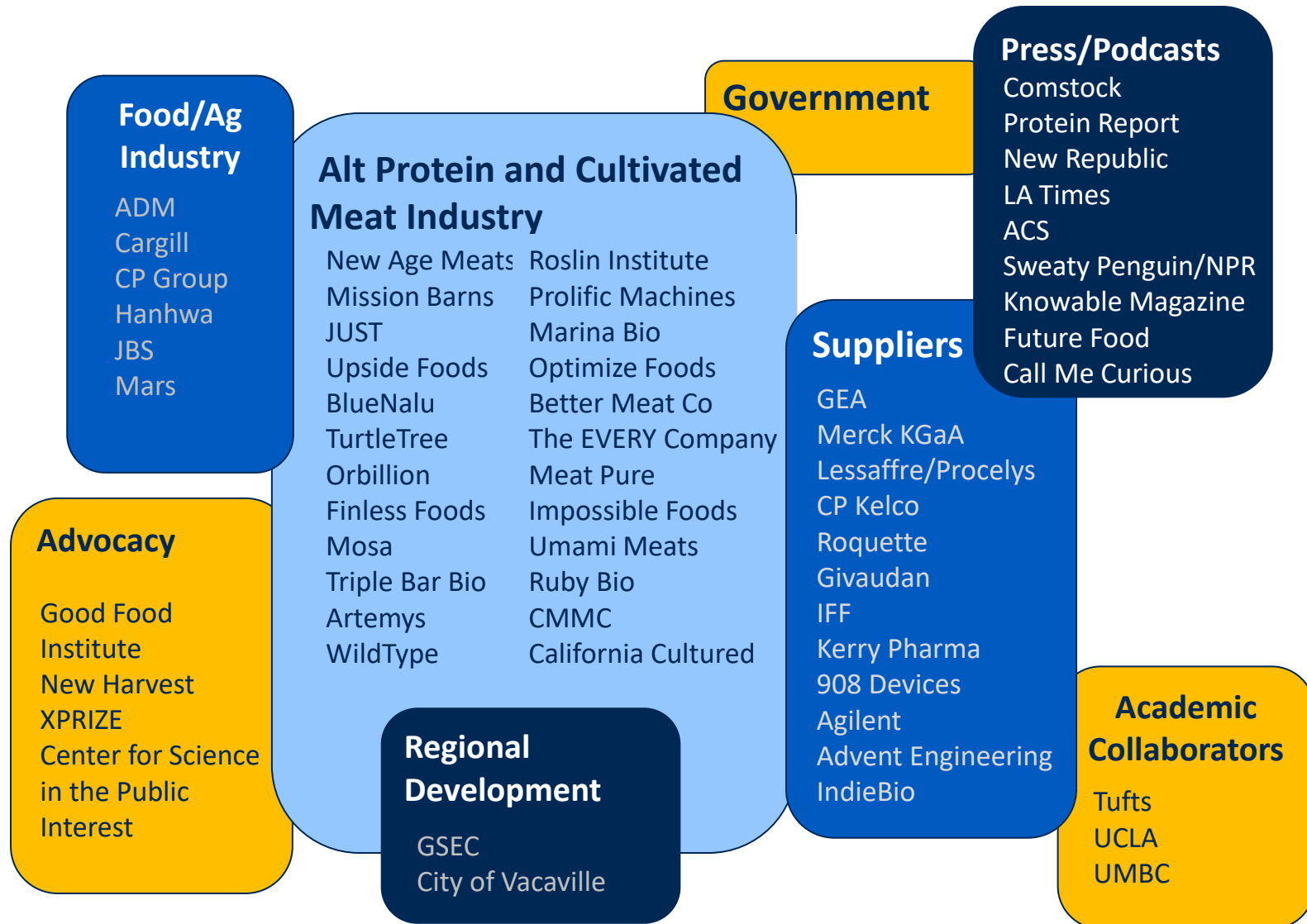


TEA for Cultivated Meat

- McDonald / Nandi Lab Group
 - Lab specializes in plant-based cell culture and is looking at TEA models and plant-based microcarriers for cultivated meat
 - TEA modeling supports use of 260,000L or larger air lift bioreactors for a “cost of goods” COGS of \$13.0/kg.
- **Recent Publications**
 - Risner, D.; Li, F.; Fell, J.S.; Pace, S.A.; Siegel, J.B.; Tagkopoulos, I.; Spang, E.S. (2021). Preliminary Techno-Economic Assessment of Animal Cell-Based Meat. *Foods*, 10, 3.
 - Negulescu, P. G., Risner, D., Spang, E. S., Sumner, D., Block, D., Nandi, S., & McDonald, K. A. (2022). Techno-Economic Modelling and Assessment of Cultivated Meat: Impact of Production Bioreactor Scale. *Biotechnol Bioeng.* 2023;120:1055–1067.



Convergence of the wider ecosystem... expanding into alt proteins (fungal, plant, other)



Two main goals...



“FDA and USDA-FSIS are using their distinct statutory authorities and unique areas of expertise to ensure that these new products are **safe** and **truthfully labeled**.”

[Animal Cell-Culture Food Technology: A New Regulatory Frontier by Dr. Jeremiah Fasano and Matthew Michael, \(Feb 20, 2020\), Food Safety Magazine.](#)

Food & Drug Administration (FDA)

- ▶ **Will be responsible for cultivated meat “pre-market” safety**
 - ▶ Cell collection, cell line banking, cell proliferation and cell differentiation
 - ▶ Fermentation processes operating at food grade cGMP (media inputs, culture conditions, bioreactors)
- ▶ **Federal Laws that FDA Enforces**
 - ▶ Federal Food, Drug, and Cosmetic Act (FFDCA; 21 U.S.C. 301 et seq.)
 - ▶ Food Safety Modernization Act (FSMA; 21 U.S.C. 2201 et seq.) ([21 C.F.R. 117] cGMP standards, hazard analysis, risk-based preventative controls)
 - ▶ Public Health Service Act (42 U.S.C. 201 et seq.)
 - ▶ Fair Packaging and Labeling Act (15 U.S.C. 1451 et seq.)
 - ▶ Egg Products Inspection Act (EPIA; 21 U.S.C. 1031 et seq.) (parts related to shell eggs)

FDA



U.S. Department of Food & Agriculture (USDA): Food Safety Inspection Service (FSIS)



- **Will be responsible for “post-harvest” cultivated meat handling and labeling (meat and poultry)**
 - Meat production
 - Labeling
- **Federal Laws that USDA-FSIS Enforces**
 - Federal Meat Inspection Act (FMIA; 21 U.S.C. 601 et seq.)
 - Poultry Products Inspection Act (21 U.S.C. 451 et seq.)
 - Egg Products Inspection Act (EPIA; 21 U.S.C. 1031 et seq.)
 - Human Methods of Slaughter Act (7 U.S.C. 1901-1906 et seq.)
 - Agriculture Marketing Act (7 U.S.C. 1621 et seq.)




Three Regulatory Work Groups...

FDA-Led Work Group on Pre-Market Consultation Process



FDA-USDA-FSIS Co-Led Group on Transfer of Jurisdiction at Cell Harvest



USDA-FSIS-Led Work Group on Coordinated Principles for Product Labeling and Claims



What's in a Name?

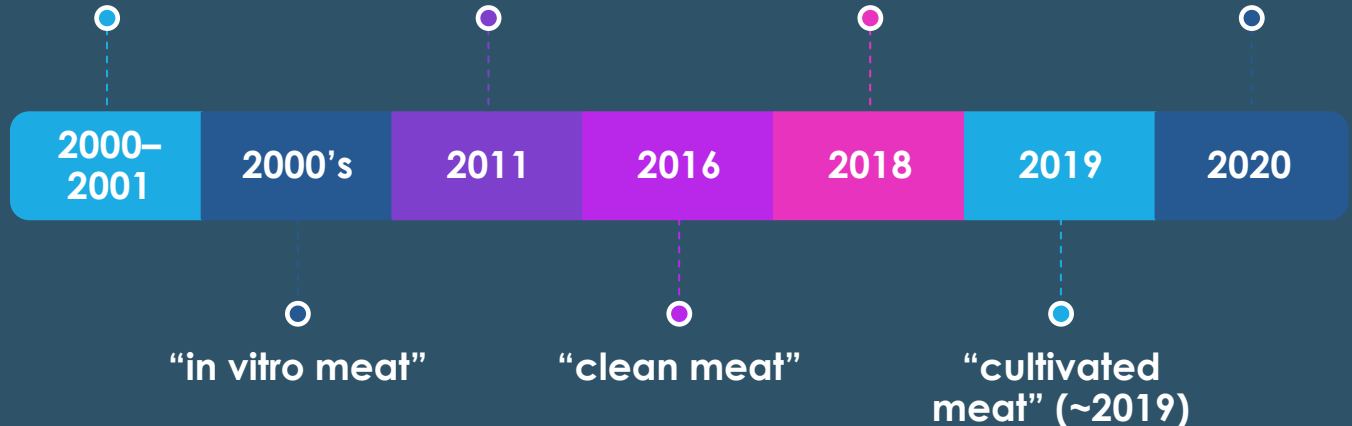
Food Product Nomenclature Influences Perceptions of Food Safety, Nutritional Value, Taste/Quality, Etc.

“in vitro edible muscle protein” (NASA nomenclature - ~2000-2001)

“cultured meat” and “lab-grown meat” (~2011)

“cell-based meat” and “cell-cultured meat” (~2018)

“animal cell-culture food products” (2020 – FDA/USDA)



- Key Regulatory and Labeling Concept - “Standard of Identity”

- Basis of Labeling Laws -> Transparency regarding product content and origin, preventing consumer confusion

Two U.S. Regulatory Approvals for Cultivated Chicken in 2023

- ▶ First approvals on June 21, 2023
 - ▶ UPSIDE Foods
 - ▶ GOOD Meat
- ▶ First commercial sales in the U.S. on July 1, 2023



<https://upsidefoods.com/blog/breaking-new-ground-upside-foods-makes-history-with-first-cultivated-meat-serving-in-the-us>

Future Workforce

