Monthly Bioeconomy Webinar Series

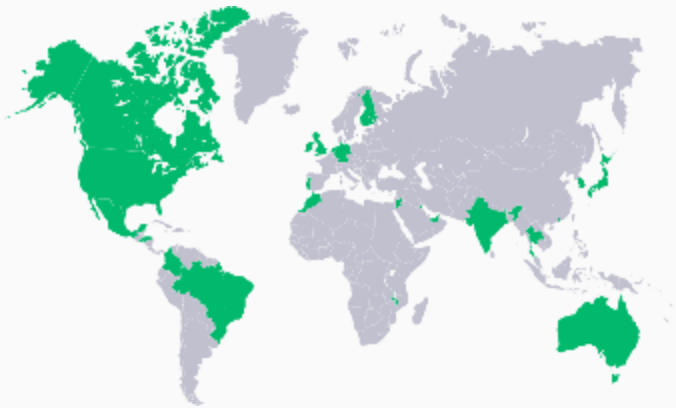
October 2024

Guiding Businesses to Align Sustainability and Success

Services
Funding Identification & Due Diligence
Engineering & Project Oversight
Project Development & Operations
Regulatory & Specialty Services
Expert Witness Services

Areas of Expertise
Biobased Materials & Chemicals
Bioenergy & Biofuels
Biotechnologies
Biopharmaceuticals
Feedstocks

Project Locations



Our experts have experience managing bioeconomy projects across geographic and cultural boundaries.

150+
Experts

30+
Average Years of Experience

50%
C-Suite Executives

97%
PhD, MBA & Advanced Degrees

$3B
Projects Evaluated

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Guest Speakers

Dr. Maya Benami Pritsker

Location:
Tennessee, USA

Dr. Greg Potter

Location:
Halifax, Canada

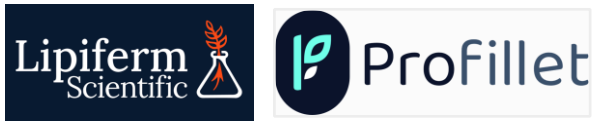
Rudy Ham-Zhu, MS MBA

Location:
California, USA

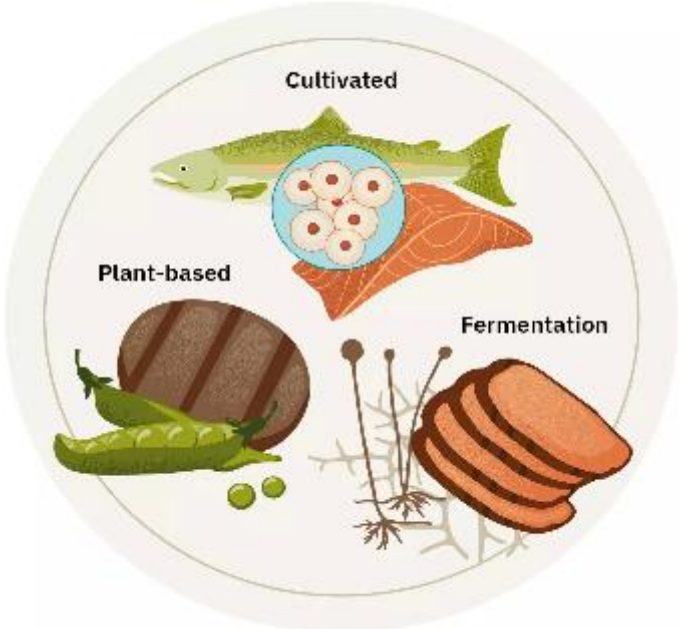
We are Founders, Scientists & Technical Due Diligence Experts

Dr. Maya Benami Pritsker

Dr. Greg Potter



Rudy Ham-Zhu, MS MBA



https://gfi.org/defining-alternative-protein/

In addition, many other LEC Experts have extensive alternative protein-related knowledge.

Alternative Protein Industry Categories

Fermentation

Fermentation from micro-algae, filamentous fungi, yeasts, bacteria

Genetically modified (precision fermentation) and biomass-based (gas and biomass fermentation)

Animal Based

Cultivated meat and seafood

Plant-Based

Commodity or novel plant proteins as ingredients or base proteins

Molecular farming

Plant-cell culture

Others

Insects
Macro-algae

Alternative Protein Category Overview

Category	CAGR (%)	TRL Level	Historic Ingredients	Novel Ingredients and Companies
Cultivated Meat & Seafood	13-52%	5-6 (Early Commercial Phase)	Biopharmaceutical applications (growth factors)	Beef, Chicken, Seafood (Upside Foods, Believer Meats, Mosa Meat, Blue Nalu)
Gas Fermentation	NA (part of Biomass fermentation)	4 (Novel) to 9 (Commercial)	Acetic acid, butyric acid, ethanol, butanol	Single cell proteins (Solar Foods, Air Proteins) for human and animal feed
Precision Fermentation	5.8-46%	8-9 (Commercial)	Enzymes, vitamins, insulin	Egg proteins (The Every Company), Dairy proteins (Perfect Day), Fats (Melt & Marble)
Biomass Fermentation	14-24%	8-9 (Commercial)	Yeasts, Bacteria, Algae (fermentation alcohol, baking, for yoghurt starters, etc.)	Filamentous fungi-derived meat analogues (Meati, Quorn), Omega-3 compounds
Plant-Based Proteins	7-24%	8-9 (Commercial)	Soy, Pea Protein (Beyond Meat, Impossible Foods)	Mung bean, chickpeas, duckweed
Molecular Farming	10-15%	4-5 (Pre-Commercial)	Antibodies, Vaccines, Enzymes, Vitamins	Meat Proteins (Moolec Science), Dairy proteins (Miruku), Egg proteins (Polopo)
Plant Cell Culture	8-13%	4-5 (Pre-Commercial)	Bioactives	Coffee (Pluri Coffee, Cultivated X), Chocolate (California Cultured), Vanilla (Vanilla Vida)

Fermentation

Rudy Ham-Zhu, MS MBA

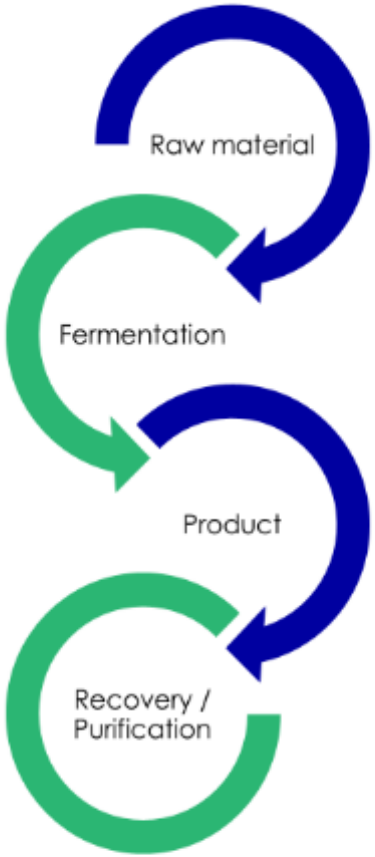
Fermentation

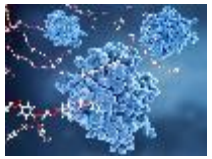
Context and Definition

- Microorganism metabolism in the absence of oxygen → "La vie sans air"
- Evidence of its use since 7000 b.C. (pre-dates the Pyramids of Giza)*
- Process that brings most joy
  - Beer & Bread
  - Wine & Cheese
- Is it really anoxic?
  - Enzymes and Proteins
  - Feed and Fuel
  - Medicines

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC539767/

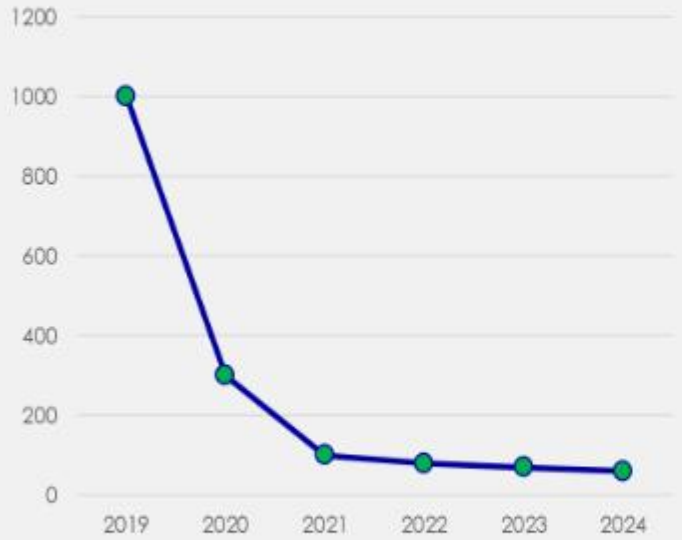
Methods of Creation



	Cheese	Wine	Food	Enzyme	Medicine
Raw Material	Milk Precipitate	Grape Juice	Soy Beans	Sugar and Raw Ag. Materials	Sugar and Refined Mat.
Fermentation	Solid	Liquid	Solid	Liquid	Liquid
Product Fraction	All the precipitate	All the wine	All the soy beans	Recovered	Purified
Process	-	-	-	Cell Sep **Concentration** Formulation	Lysis Folding Cell Sep **Chromato.** Formulation
Example	**Blue Cheese**	**Chardonnay**	**Tempeh**	**Protease**	**Insulin**
					

Fermentation Challenges

COGS



Cost of Goods Sold has been a struggle for a lot of applications

Public Acceptance

*Mycoprotein™: Mycoprotein is a mold (member of the fungi family). There have

What is Blue Cheese made from?

Fluff

Lack of Product Market Fit, Financial Margins, Technical Feasibility

COGS Solutions

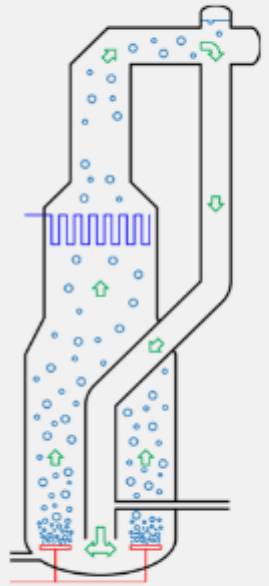
Maximize Price

- Medical Need
  - Medicine
  - Vaccine (RNA)
- Health Benefits
  - Lactoferrin
- Food
  - Quorn
  - Rhiza

Increase price

Decrease cost

Decrease Cost



Fermentation Companies

Quorn

NEWLIGHT

CPKelco
A HUBER COMPANY

novozymes
Rethink Tomorrow

Cultivated Meat & Seafood

Dr. Greg Potter

Close-up of BlueNalu's whole-muscle, cell-based yellow-tail fish, beer-battered and deep-fried

What is Cultivated Meat/Seafood, and Why Does it Exist?

WHAT IS IT?

- Real, genuine animal protein made directly from cells vs. slaughtering animals

WHY DOES IT EXIST?

- More humane and (likely) sustainable option vs. conventional meat / seafood
- More reliable source of protein-rich foods (post-COVID supply disruptions)

OTHER KEY BENEFITS

- Cleaner production: reduced likelihood of contamination/foodborne illness
- Tunable nutrition: potential to modify or tune nutritional attributes (e.g. saturated fat; omega-3s)
- Less zoonotic infections: lower density farming operations prevent avian, swine flu; COVD-19
- Economic stimulus: as emerging technology, could require new industries and support from existing ones (e.g. raw materials, manufacturing)

Getty/Forbes

Cell-Based: Main Challenges

TECHNICAL

- Scaling up production
- Differentiation efficiency
- Cost of growth medium
- Texture recapitulation

ECONOMIC

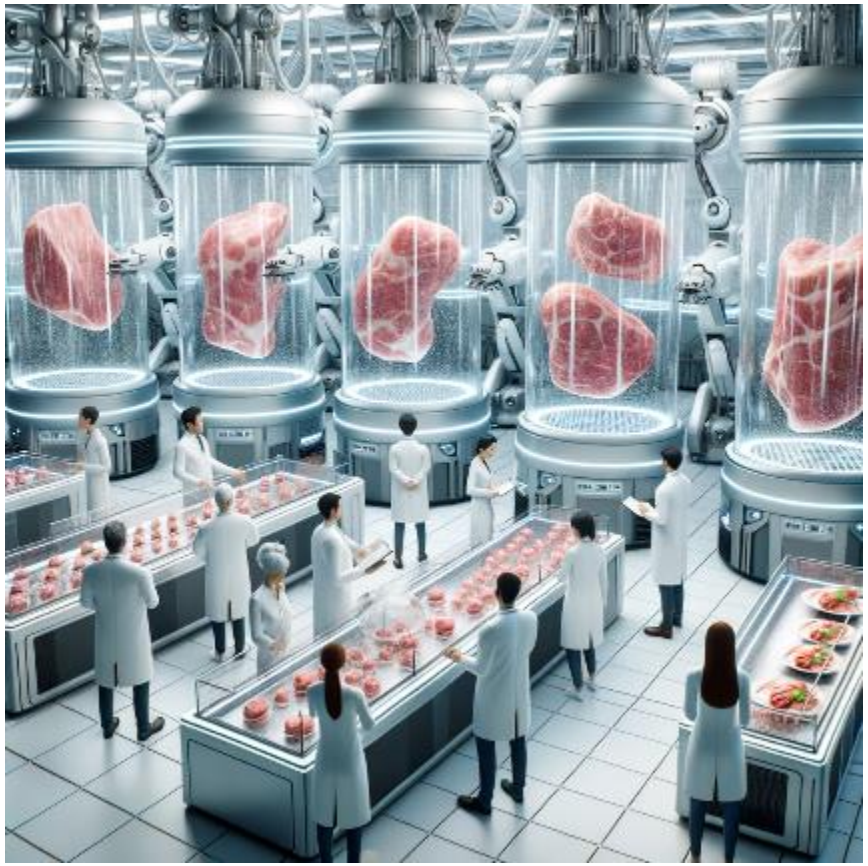
- Production cost and capital investment
- Economies of scale of conventional meat

REGULATORY

- Multiple governing bodies across jurisdictions
- Defined labeling standards; nomenclature

CONSUMER ACCEPTANCE

- Public perception (e.g. Franken-meat)
- Cultural and ethical concerns
- Price sensitivity



Medium

Cell-Based TRL Levels

Current TRL Levels

- Some disagreement as to current TRL level
- Well-known analyst suggests not yet out of the lab (TRL 1-3)
- European Parliament Guide for Alternative proteins suggests otherwise
    - Cultured meat has advanced beyond the initial R&D phase (TRL 1-3)
    - A number of companies have produced edible products in a lab (TRL - 5)
    - Some companies moved into to a preliminary commercial scale facility (TRL 6)
    - Small number of companies have prototypes for what will be sold commercially (TRL-7)

TWI Global

Cell-Based Companies

Ye et al., 2023

Top companies in 2024

Aleph Farms - Israel
Avant - Singapore, Hong Kong
GOOD Meat (Eat Just, Inc.) - USA
Biftek.co - USA
Mosa Meat - Netherlands
BlueNalu - USA
Believer Meats - Israel, USA
Shiok Meats - Singapore

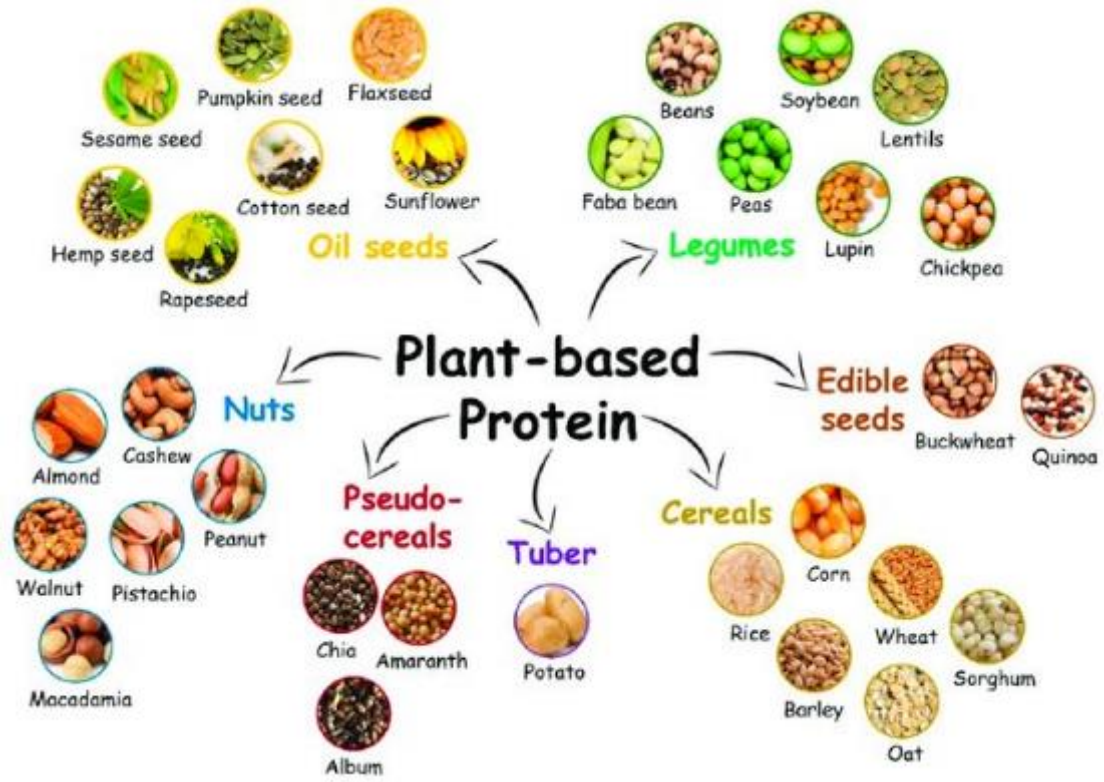
Emergen Research

Plant Based

Dr. Maya Benami Pritsker

Plant Based Types and Categories

- Largest and most diverse category of alternative proteins - TRL level 9
- Used in dairy, meat, cheese, egg, seafood, and pet food analogues to replace conventional animal-based ingredients and CPG products
- Current plant protein replacements: Soy, pea, oats, lentils, wheat, tubers, some seeds & nuts - commodity crops
- Move towards using more seeds (pumpkin, sunflower), legume types (cowpeas, chickpeas), hemp, native or local crops (millet), microbes (yeasts, bacteria, filamentous fungi), and lesser-known crops but with high functionality (mung bean)



Gomes, A., & Sobral, P. J. D. A. (2021). Plant protein-based delivery systems: An emerging approach for increasing the efficacy of lipophilic bioactive compounds. *Molecules*, *27*(1), 60.

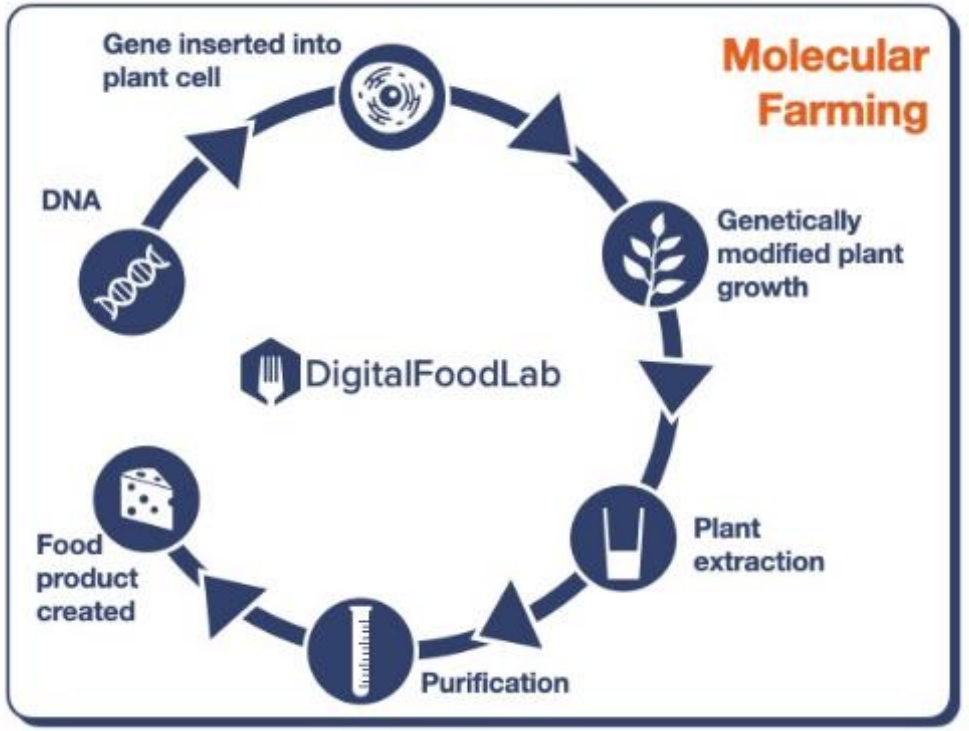
Plant Based Trends and White Spaces

- Upcycle waste-streams from processing
- Explore new plants, plant blends, and ingredients
- Enhance nutrition, functionality, flavors, and textures via technology or ingredients
- To mimic or not mimic conventional analogues?
- Reduce frozen cold chain requirements but also extend shelf life
- Encapsulation and bioavailability of ingredients to enhance nutrition and texture
- Blend with conventional meat
- Create animal feed, pet food, and seafood analogues

Image: Getty/Aamulya

Next-Gen Plant-Based Food Technologies (i)

- Molecular Farming / “Pharming”
  - Uses genetically engineered plants like soy, tobacco, or potatoes as bioreactors to produce specific molecules.
  - These plants are grown and processed using established extraction techniques, yielding either solid or liquid substances that can be used in food products



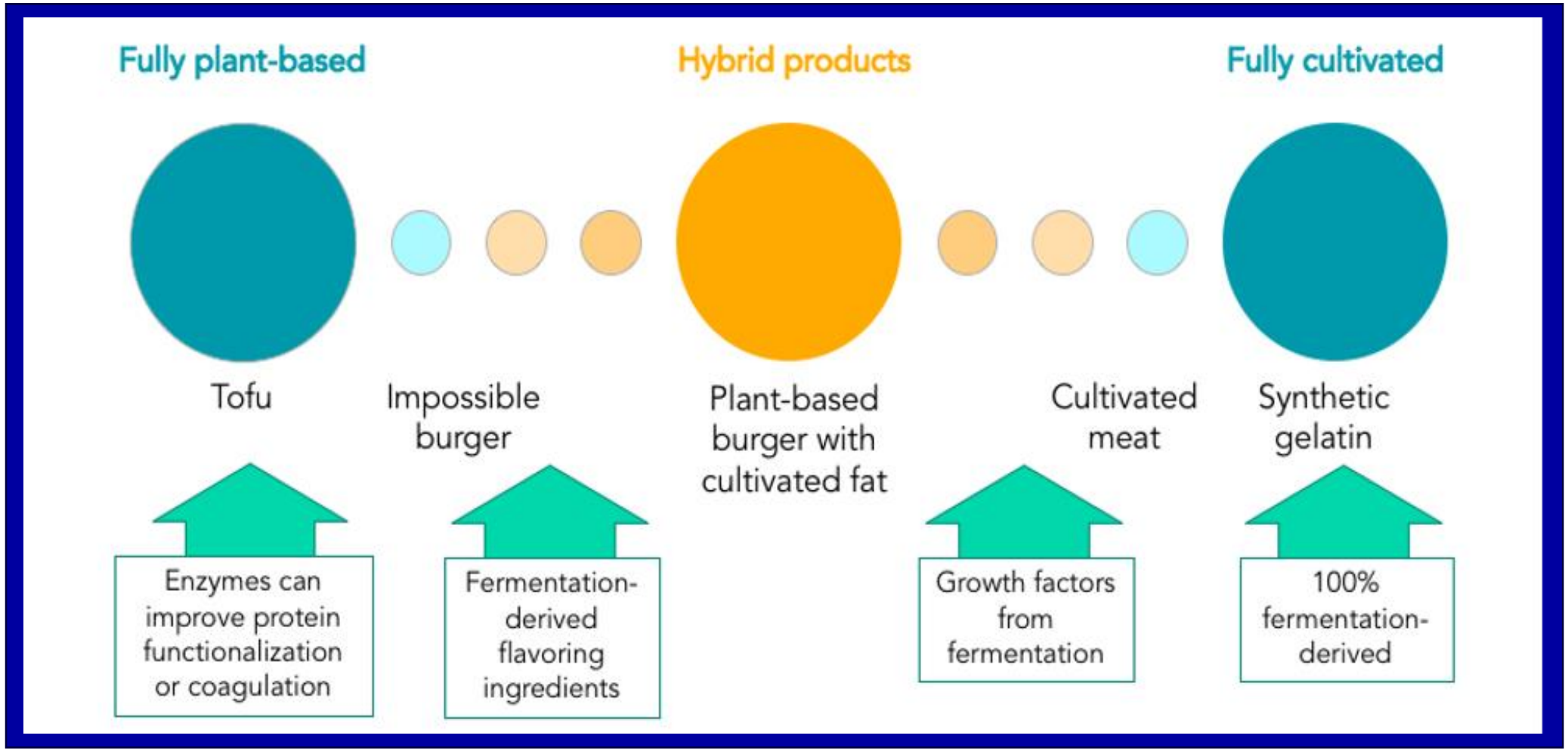
Next-Gen Plant-Based Food Technologies (ii)

Plant cell culture: involves growing plant cells in **sterile**, **controlled** environments to generate agriculturally important products.

The world's first plant cell customization assembly line. Source: Chi Botanic

Source: FoodTech Data Navigator

Future Foods will Incorporate all Alternative Protein Categories…



World Economic Forum (2020) https://www.weforum.org/agenda/2020/11/fermentation-can-help-build-a-more-efficient-and-sustainable-food-system-here-s-how/

Q&A

Dr. Maya Benami Pritsker

Dr. Greg Potter

Rudy Ham-Zhu, MS MBA

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