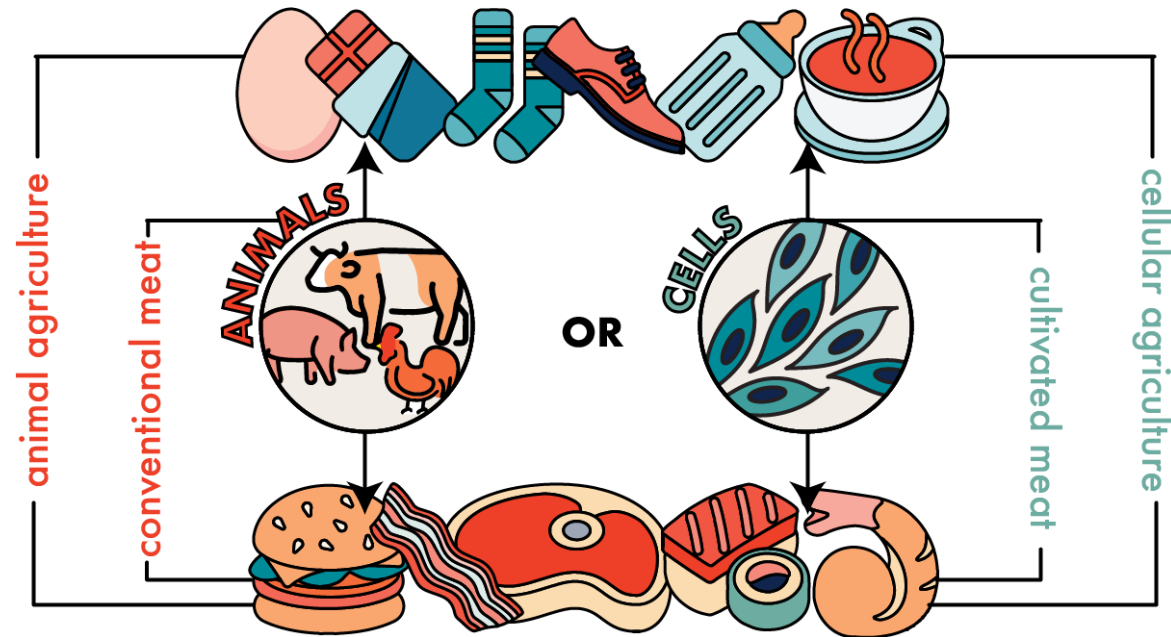



ANIMAL CELL CULTURE AS A NEW SOURCE OF PROTEIN

2024 INTERNATIONAL CONFERENCE ON ALTERNATIVE PROTEIN FOR FOOD & FEED






The **Tufts University Center for Cellular Agriculture** (TUCCA) was established in 2021 and serves as the umbrella for all cellular agriculture activities at the university




EDUCATION

-  **The Cellular Agriculture Certificate Program**
(graduate-level)
-  **The Cellular Agriculture Minor Program**
(undergraduate-level)
-  Course materials available [online](#)

RESEARCH

-  **The National Institute for Cellular Agriculture**
-  **50+** active researchers across **5+** research groups
-  **40+** peer-reviewed [publications](#)

INNOVATION

-  **The Cellular Agriculture Commercialization Laboratory**
-  **25+** intellectual patent filings; **3+** licensees; **1x** spin-out company
-  **2x** publicly-available [cell lines](#) (iBSC, Mack1)



Medford/Somerville, Boston, Grafton

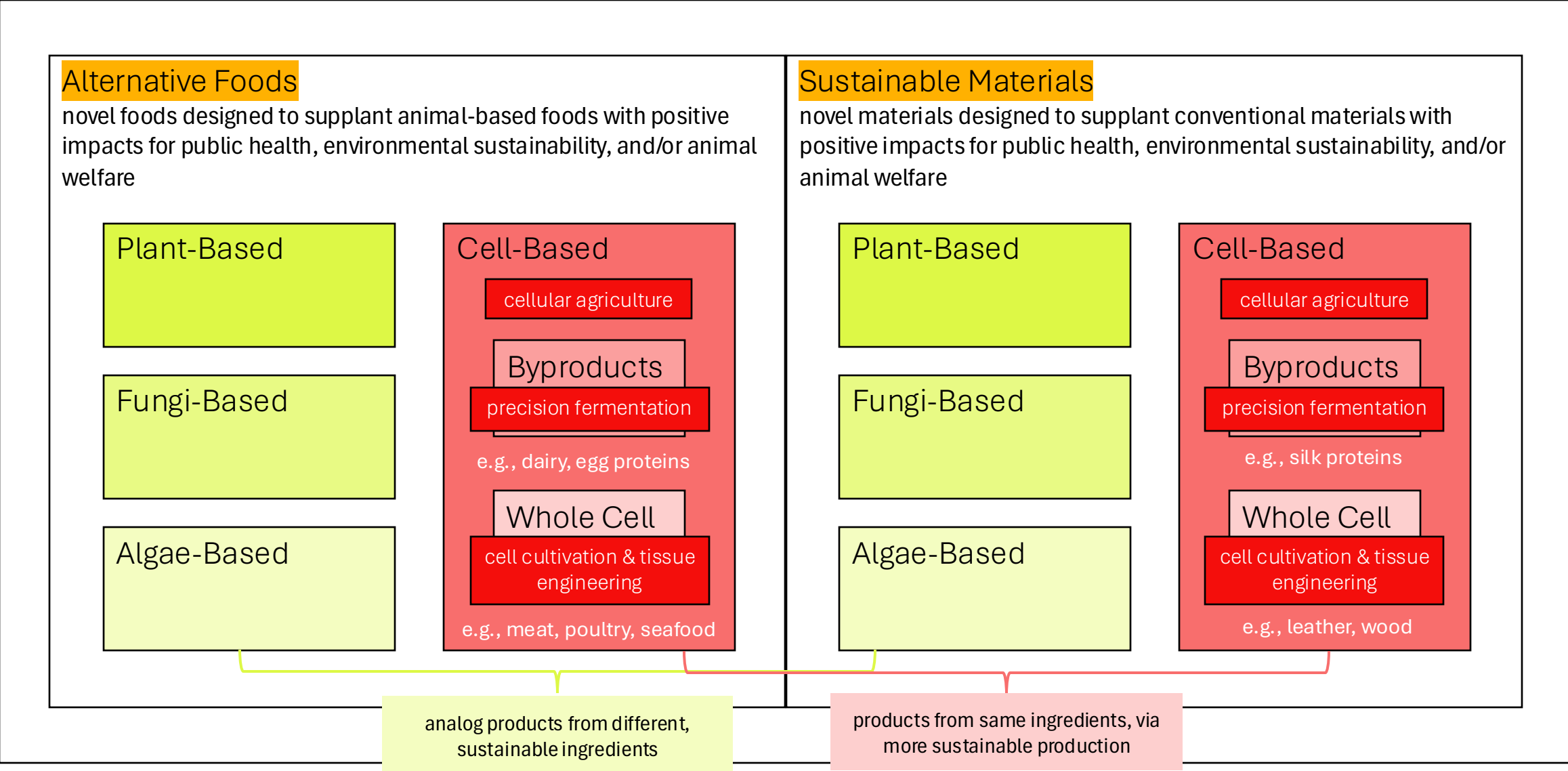
The **Industry Consortium** leverages insights from our partners to perform pre-competitive research



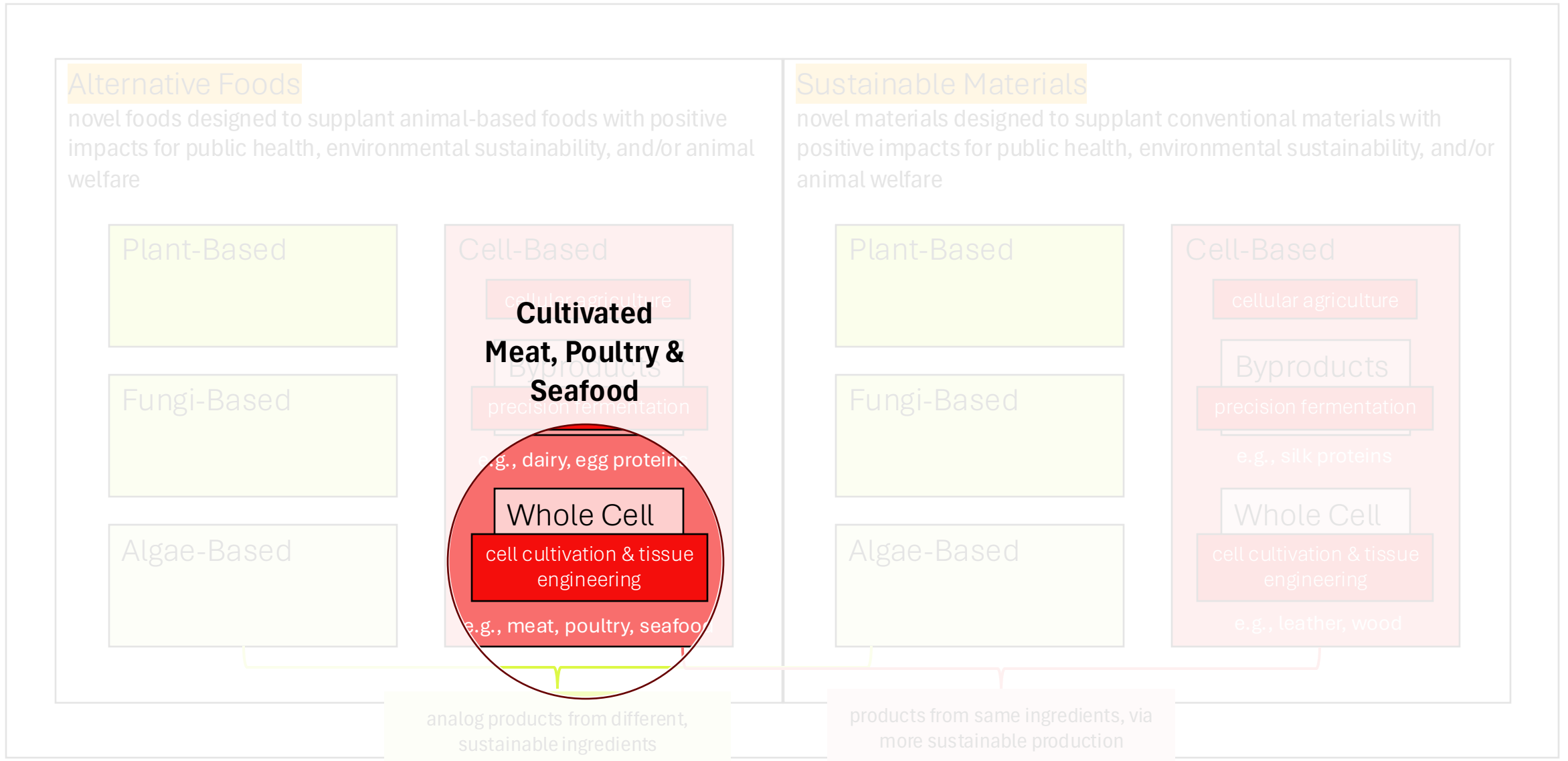
The **National Institute for Cellular Agriculture** (NICA) is a \$10M, 5-year grant funded by the United States Department of Agriculture (USDA) across 8x universities



ALTERNATIVE FOODS & MATERIALS



ALTERNATIVE FOODS & MATERIALS



HISTORICAL CONTEXT

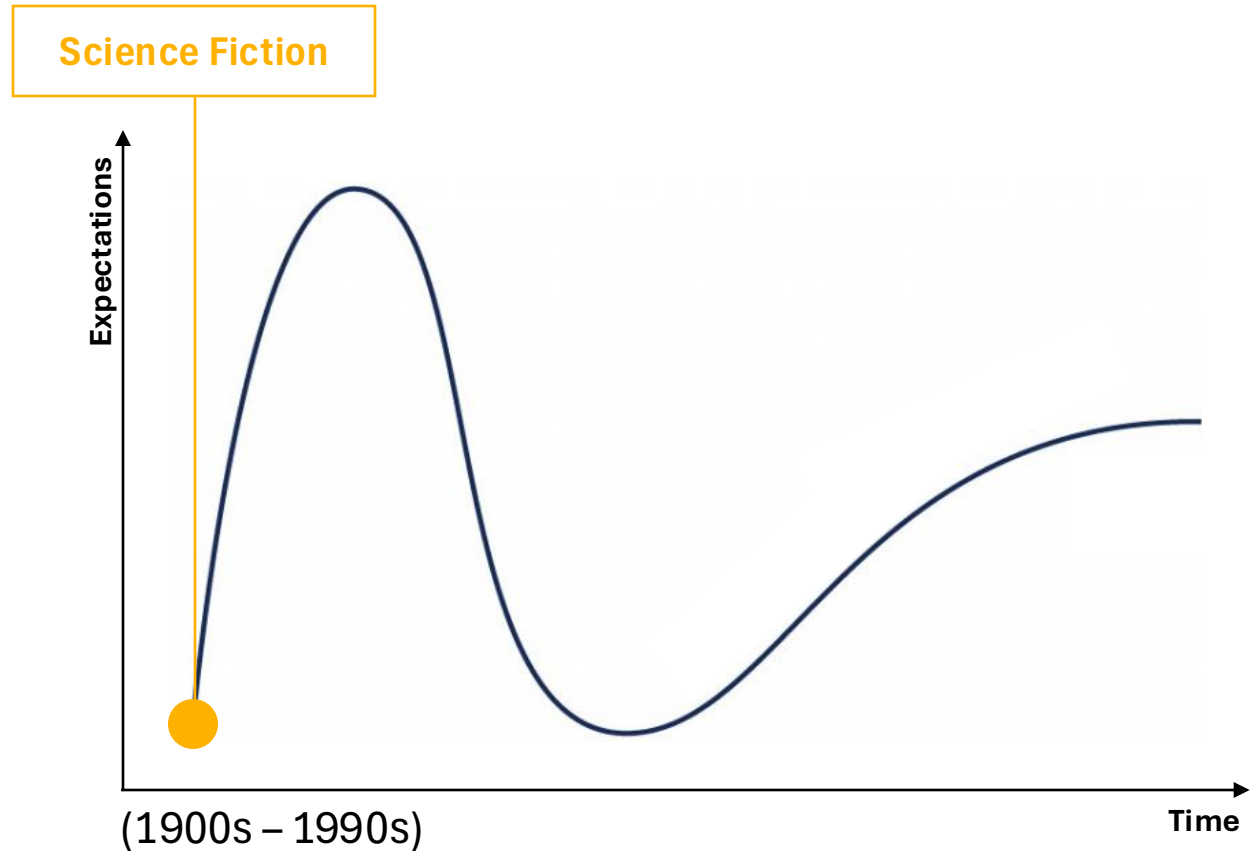
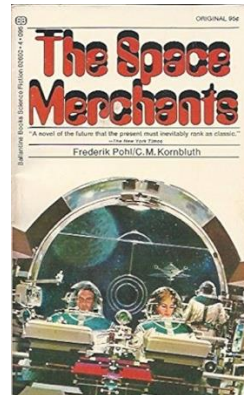
Cultivated meat first emerged as a concept of science fiction with references in novels like **The Space Merchant** (1952) and in episodes of **Star Trek** (1990). Famously, **Winston Churchill** predicted the innovation in a 1931 essay entitled “Fifty Years Hence”.



A lesser known quote –

"It will no longer be necessary to go to the extravagant length of rearing a bullock in order to eat its steak. From one 'parent' steak of choice tenderness, it will be possible to grow as large and as juicy a steak as can be desired."

Frederick Smith



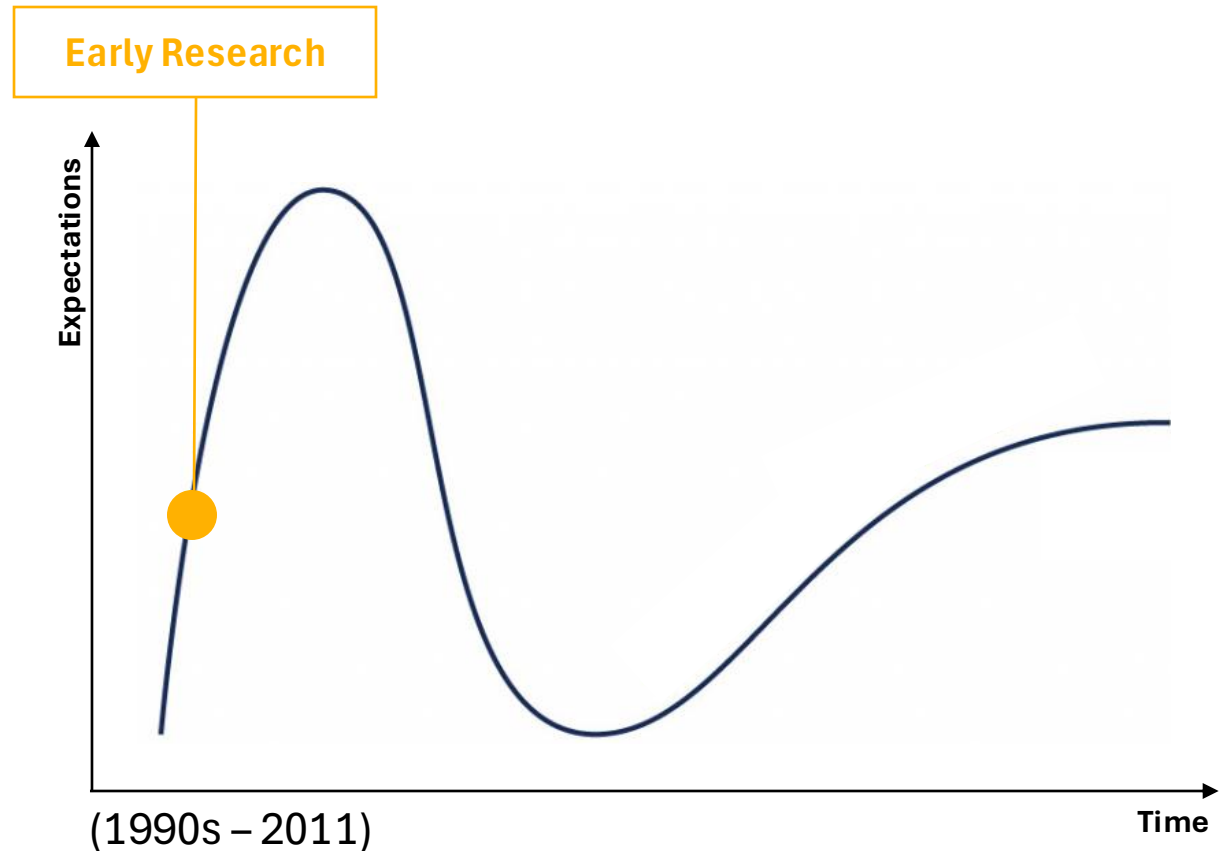
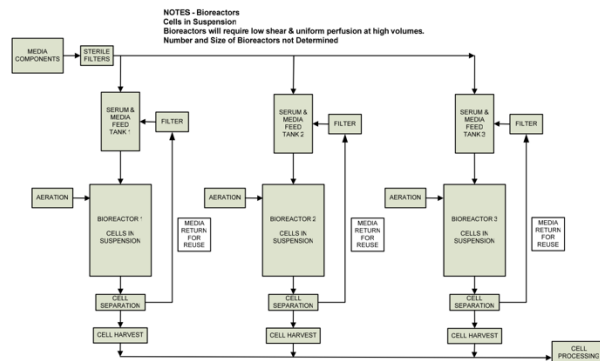
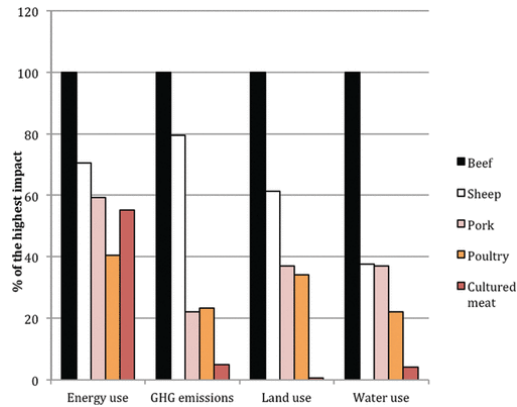
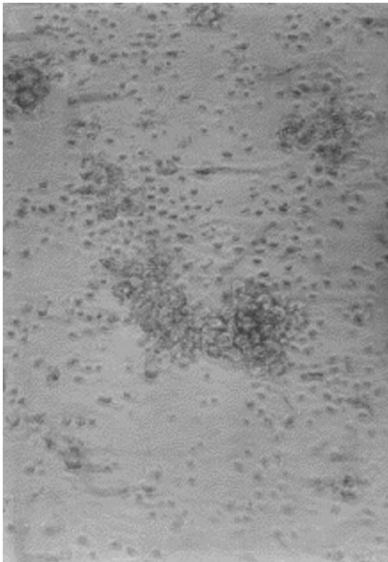
HISTORICAL CONTEXT

Before the private sector gained interest, several early research efforts laid the groundwork. The **first patents** were filed in 1991 and 1997, the National Aeronautics and Space Administration funded the **first public research** published in 2004, a **preliminary economics study** in 2008, and the **first environmental impact assessment** in 2011.

(12) **United States Patent**
Van Eelen

(54) **INDUSTRIAL PRODUCTION OF MEAT USING CELL CULTURE METHODS**

(76) Inventor: **Willem Frederik Van Eelen**,
Sumatrakade 99, Amsterdam (NL)
NL-1019 PJ



HISTORICAL CONTEXT

Between 2011 and 2023, **over 170 cultivated meat companies** were formed around the world to commercialize products. In 2020, Good Meat was the first company to obtain **regulatory approval in Singapore** and sell cultivated meat in a restaurant. In 2023, two companies obtained approval for the **sale of cultivated chicken in the United States**.

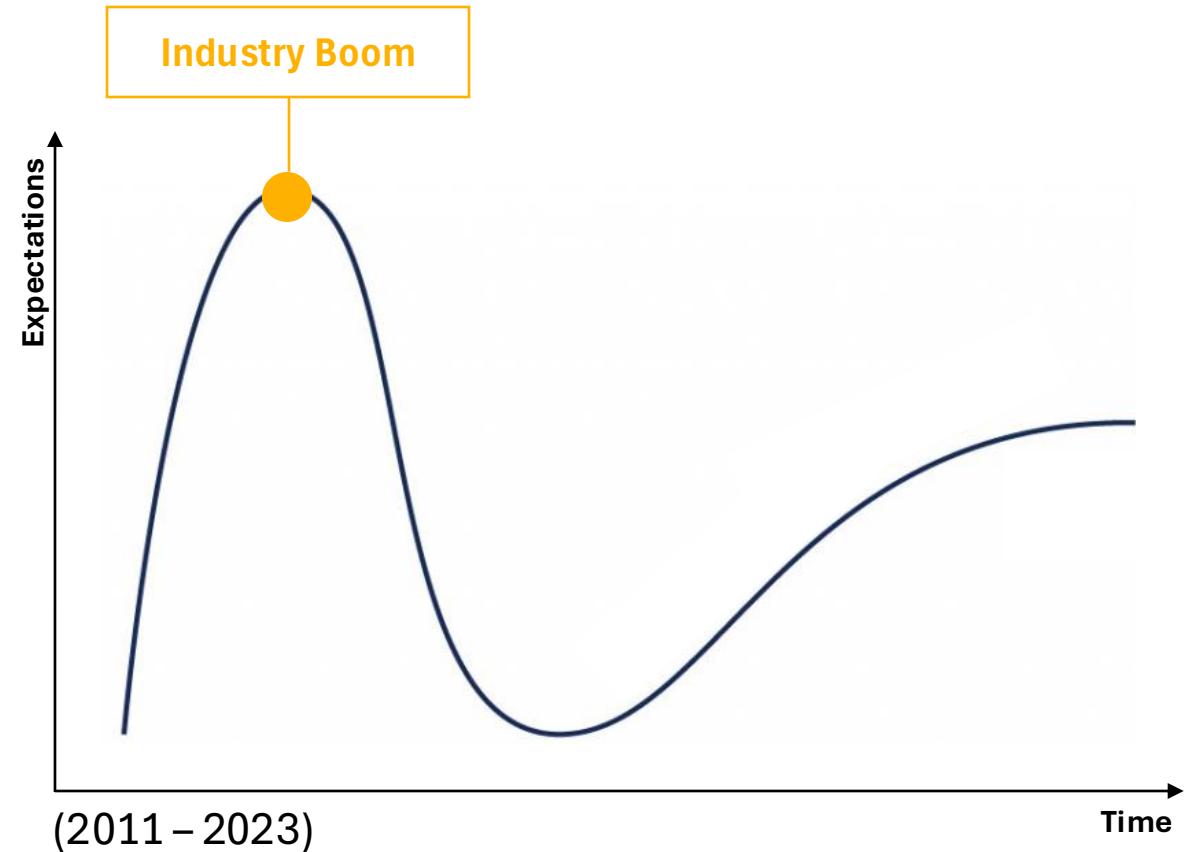
Singapore becomes first country to approve lab-grown meat

By Amy Woodyatt and Danielle Wiener-Bronner, CNN Business
2 minute read · Updated 11:14 AM EST, Wed December 2, 2020

USDA approves 1st ever 'cell-cultivated meat' for 2 American manufacturers







UPSIDE will cultivate and sell chicken grown from animal cells in bioreactors.

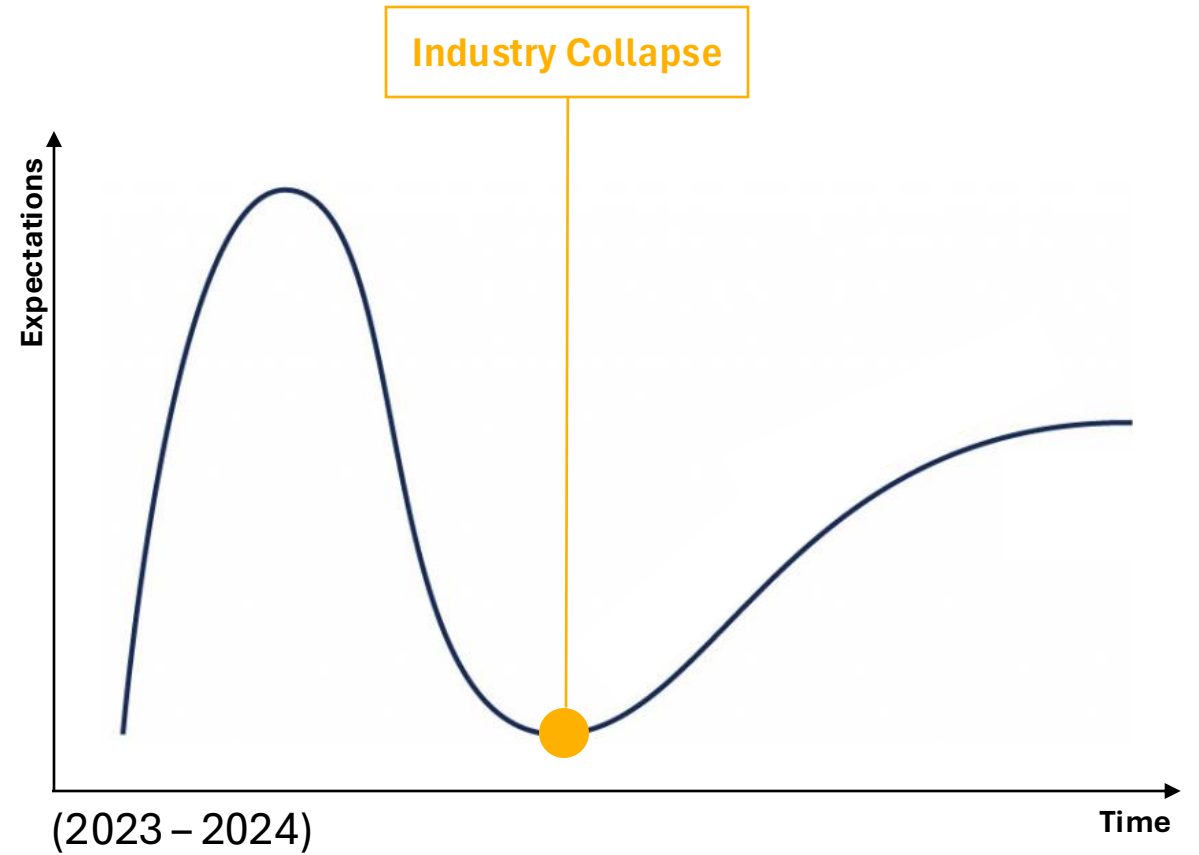
By Kelly McCarthy, GMA
June 22, 2023, 11:04 AM



HISTORICAL CONTEXT

The landmark regulatory approvals were followed by less positive signals such as **negative media** articles and **cultivated meat bans** passing in Florida and Alabama. In 2023, **new company formation and investments declined by 75%+**. In 2024, multiple companies have **shut down** or announced **major lay-offs**.

<p>AgFunderNews</p> <p>Cultivated meat funding nosedives in 2023</p> <p>Preliminary data shows that funding for cultivated meat startups peaked at \$989 million in 2021, dipped slightly to \$807 million in 2022.</p> <p>Feb 7, 2024</p>	
<p>Florida Phoenix</p> <p>Florida now poised to become the first state in the nation to ban lab-grown meat</p> <p>By: Mitch Perry - March 6, 2024 2:29 pm ... The GOP-controlled House of Representatives on Wednesday approved legislation that would prohibit the manufacturing...</p> <p>Mar 6, 2024</p>	
<p>AgFunderNews</p> <p>Crunch time for cultivated meat: 'Probably 70-90% of players will fail in the next year'</p> <p>70-90% of companies in this space are going to fail over the next year, but those that survive will build real businesses and will scale.</p> <p>Nov 20, 2023</p>	
<p>AP-NORC</p> <p>Few adults are interested in trying "lab-grown" meat</p> <p>Half of the public is not interested in eating cell-based meat grown in labs, citing strangeness and food safety concerns.</p> <p>Aug 21, 2023</p>	
<p>TechCrunch</p> <p>Even after \$1.6B in VC money, the lab-grown meat industry is facing 'massive' issues</p> <p>200 startups worldwide remain hopeful that growing meat from cells, rather than slaughtering animals, will one day be a major portion of our food supply.</p> <p>Aug 4, 2024</p>	
<p>UC Davis</p> <p>Lab-Grown Meat's Carbon Footprint Potentially Worse Than Retail Beef</p> <p>UC Davis researchers find cultivated meat is likely worse for the climate than retail beef under current production methods.</p> <p>May 22, 2023</p>	



HISTORICAL CONTEXT

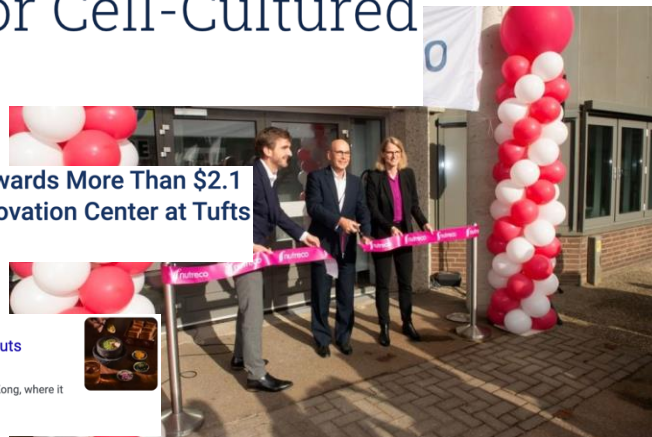
The next decade of cultivated meat will be characterized by building ecosystems to enable a more mature industry. Early examples include **\$100M** in funding from The Bezos Earth Fund to establish **Sustainable Protein Centers**, the publication of **regulatory guidelines in South Korea**, and the launch of the **Nutreco cell feed production facility**.



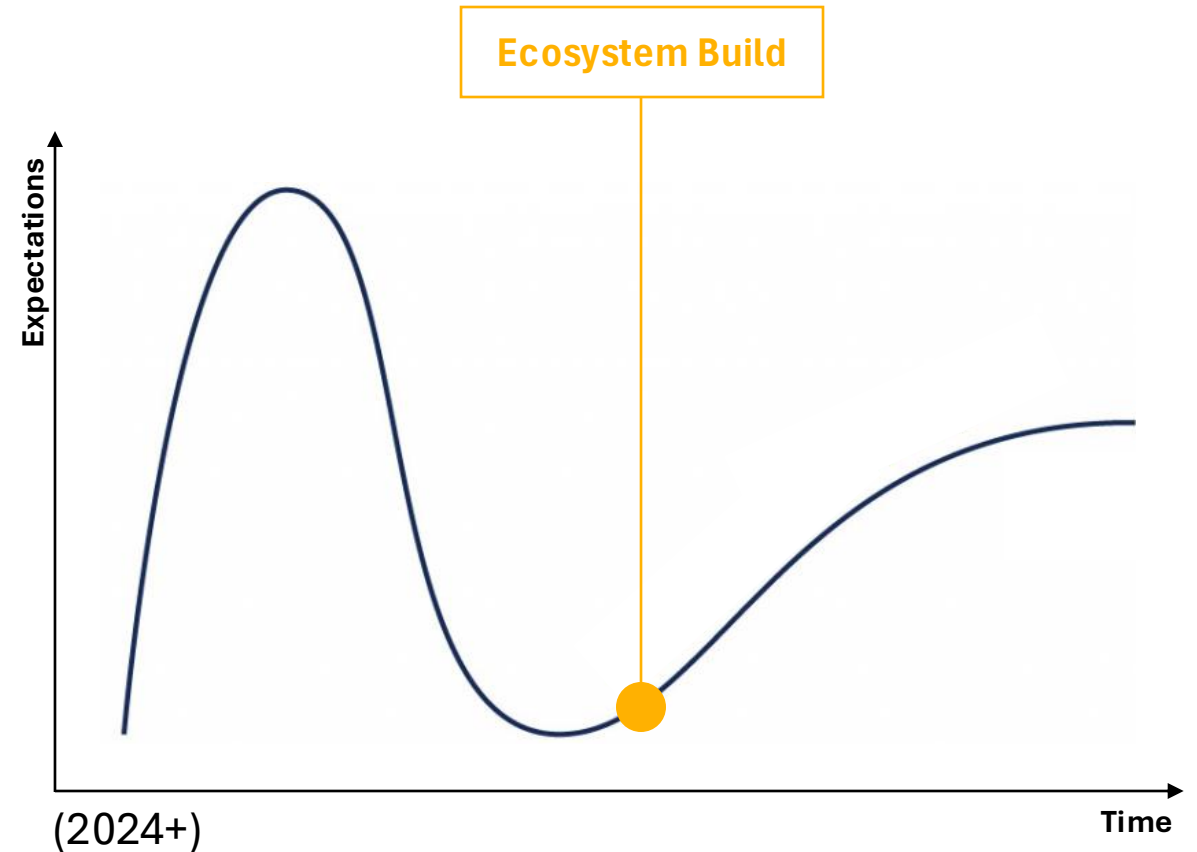
PUBLICATION 11.08.2024

Korea Releases Application Guidelines for Cell-Cultured Food

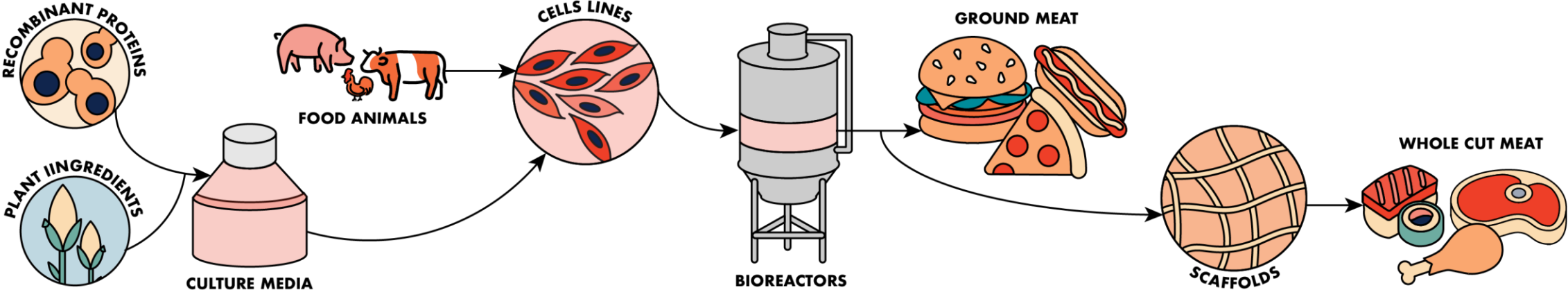
Healey-Driscoll Administration Awards More Than \$2.1 Million to Cellular Agriculture Innovation Center at Tufts University



Green Queen
Vow Forges Regulatory Success in Hong Kong, Debuts Cultured Foie Gras
Australian cultivated meat startup Vow has been cleared to sell in Hong Kong, where it will debut cultured foie gras at the Mandarin Oriental.
2 weeks ago

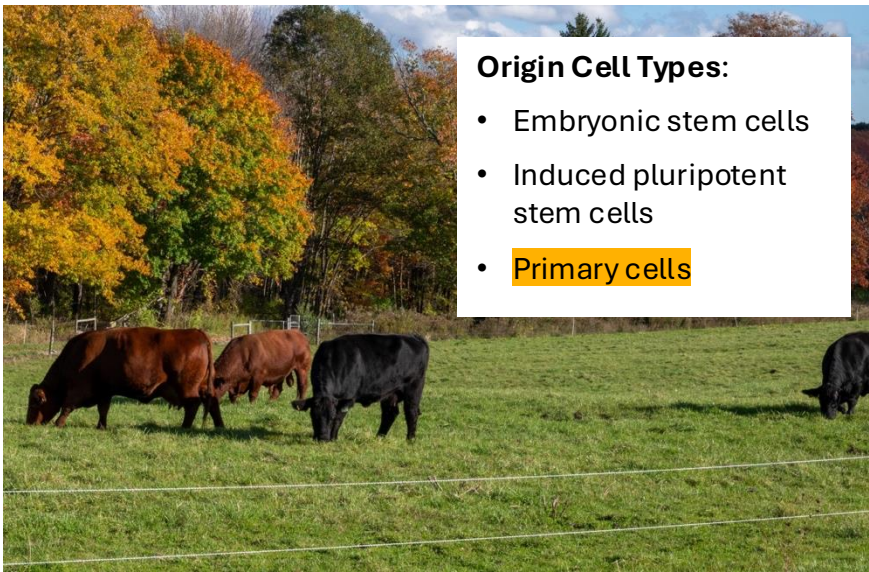
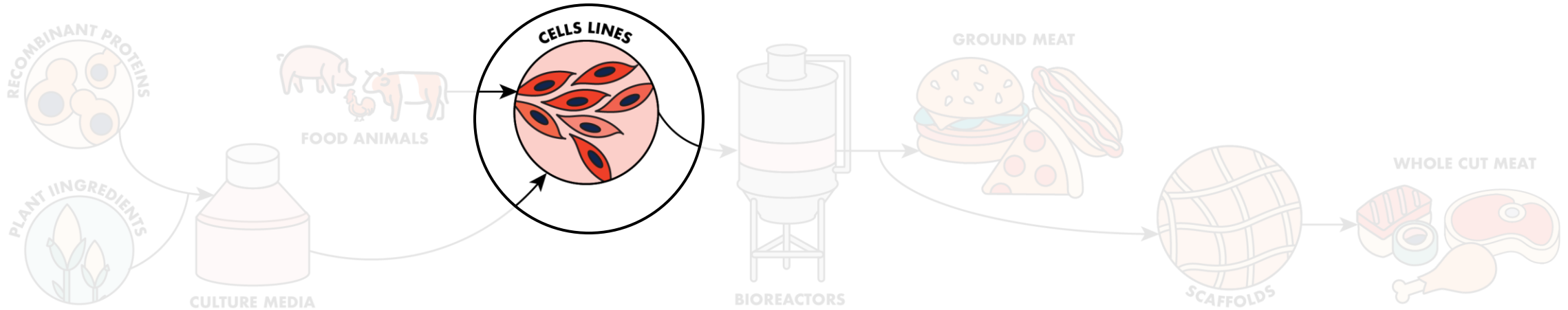


TECHNOLOGY Making cultivated meat entails propagating animal cells by mimicking *in vivo* conditions *in vitro* – via bioreactors and culture media tuned to recapitulate temperature, nutrients, stimuli, etc.

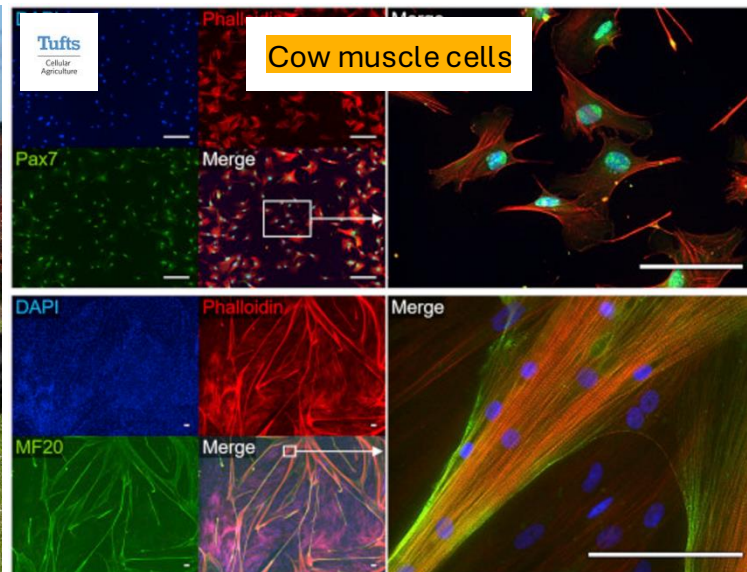


TECHNOLOGY – CELL LINES

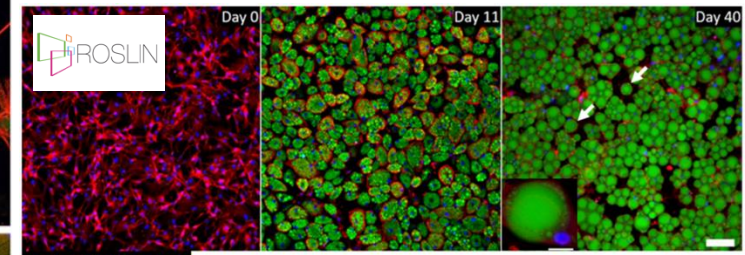
Animal cells are the primary ingredients of cultivated meat – dictating much of the texture, taste, and nutritional properties of the product.



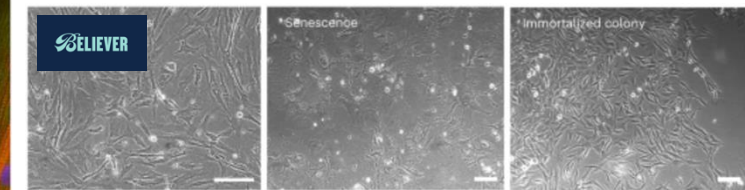
- Origin Cell Types:**
- Embryonic stem cells
 - Induced pluripotent stem cells
 - **Primary cells**



Pig fat cells



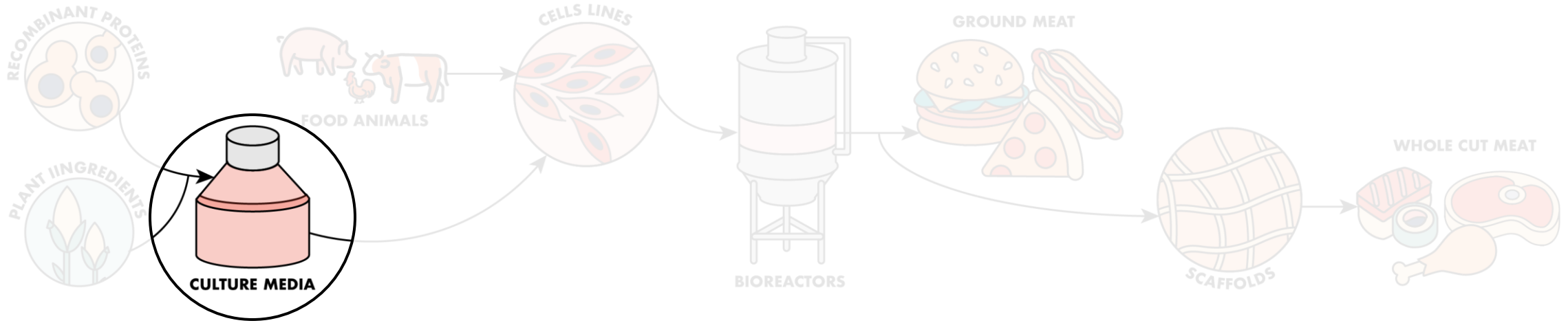
Chicken fibroblast cells



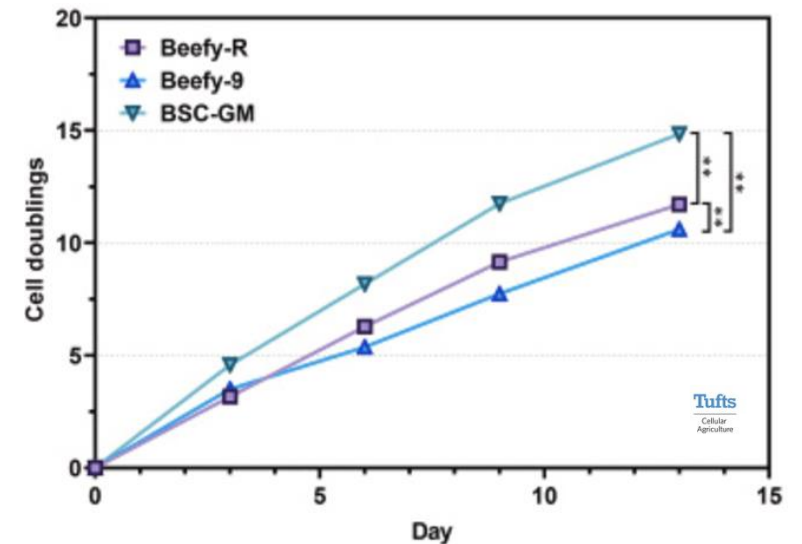
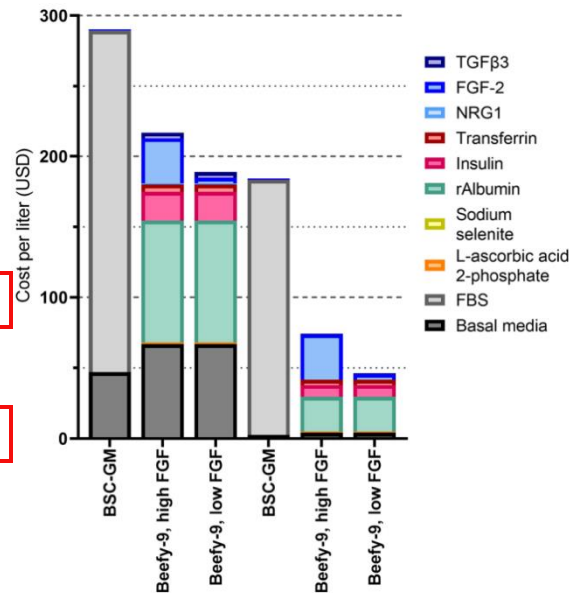
[Cummings 2023; Stout et al., 2020; Thrower et al., 2024; Pasitka et al., 2023]

TECHNOLOGY – CULTURE MEDIA

Culture media is the feedstock for cultivated meat, supplying nutrients and signaling factors, regulating pH, and retaining waste products.

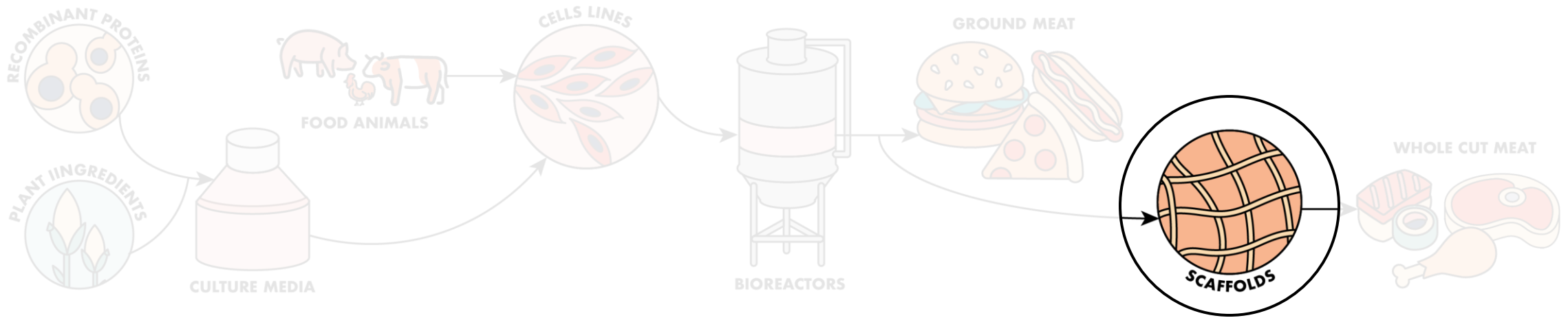


Ingredient	Weight g/kg CM	Prices \$/kg ingredient	Total costs \$/kg CM
Amino acids (total)	316.2	4.78	1.51
Amino acids from hydrolysate	237.2	2.65	0.63
Amino acids from conventional production	79.1	11.18	0.88
Sugars (total)	77.5	2.91	0.06
Sugars: Glucose	75.5	0.53	0.04
Sugars: Pyruvate	2.0	10.00	0.02
Recombinant proteins	7.1	198,919.58	1,406.57
Salts	80.0	0.46	0.04
Buffering agent	31.6	35.57	1.12
Vitamins	2.0	20.49	0.04
Growth factors	0.000	890,151,808.52	281.49
Water	12,649.1	0.01	0.13
			Total:
Total (g)	13,163.49		1,691
Total (L)	13.4		



TECHNOLOGY – SCAFFOLD MATERIALS

Scaffold materials are an optional component; providing texture and mechanical cues for structured tissue formation.

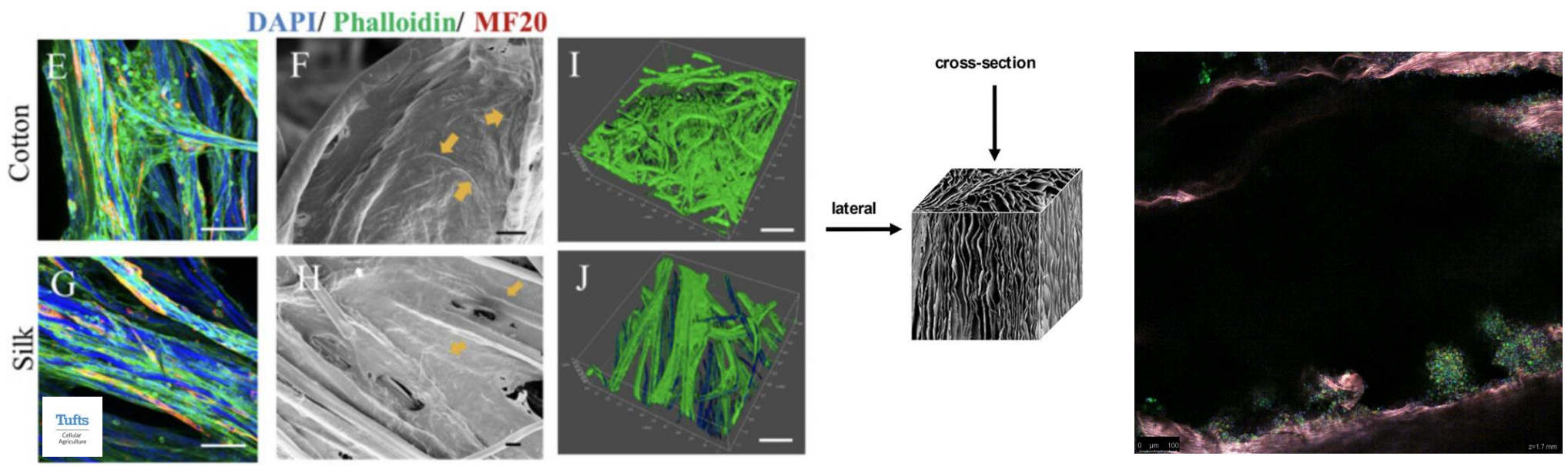


Common Materials:

- Cellulose
- Chitosan
- Alginate
- Glutenin
- Gelatin

Common Formats:

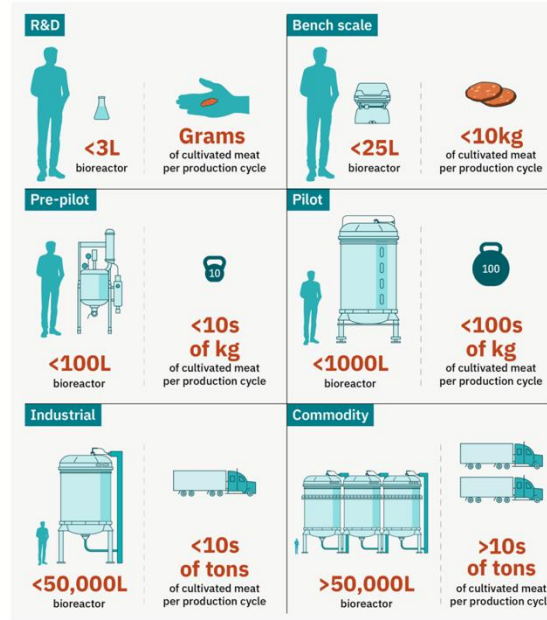
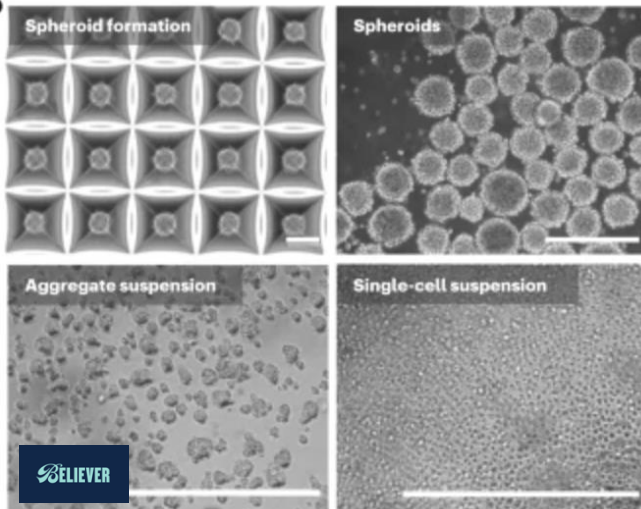
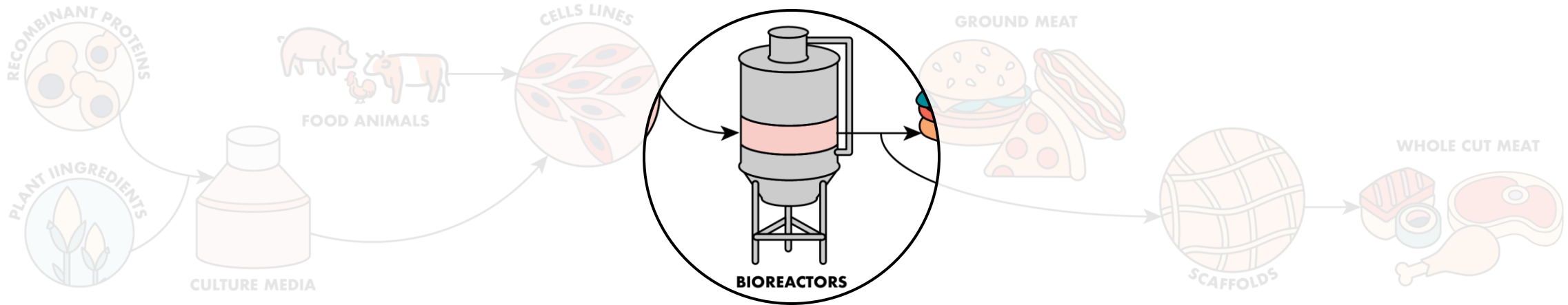
- Film
- Sponge
- Fiber
- Hydrogel
- Microcarrier



[Liet al., 2024; Rubio et al., 2019]

TECHNOLOGY – BIOPROCESS DESIGN

Bioprocessing incorporates the equipment and procedures used to propagate, differentiate, and harvest cultivated meat.



Estimated cultivated meat production

By the end of 2026; the production of 19 cultivated meat companies

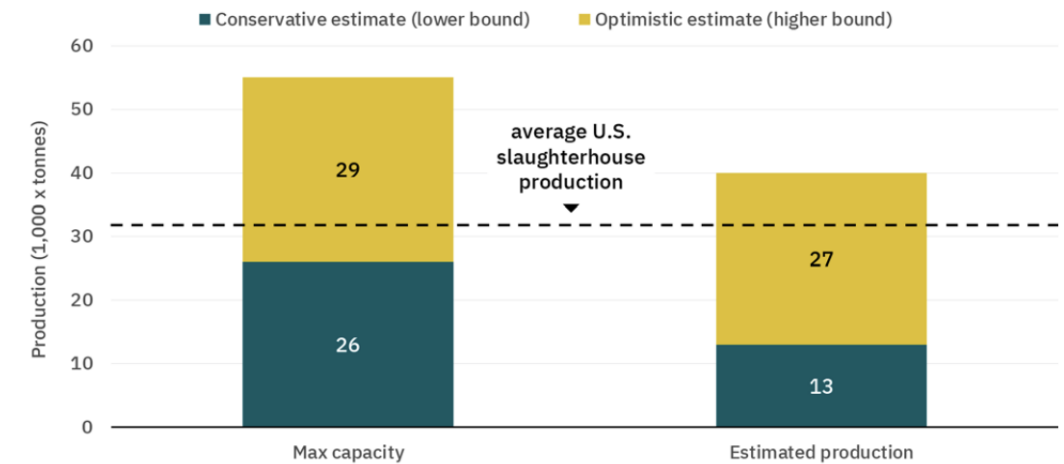


Fig. 7: The estimated cumulative cultivated meat production of 19 cultivated meat companies by the end of 2026 compared to an average U.S. slaughterhouse.

ORGANOLEPTIC PROPERTIES

Def. The sensory characteristics of a substance; such as properties related to appearance, aroma, taste, and texture.

Appearance

e.g., color, structure, size, shape

Some products (ground meat, chicken) are indistinguishable from conventional meat; while others have notable differences



Similarities:

- Color
- Structure

Differences:

- None?

ORGANOLEPTIC PROPERTIES

Def. The sensory characteristics of a substance; such as properties related to appearance, aroma, taste, and texture.

Appearance

e.g., color, structure, size, shape

Some products (ground meat, chicken) are indistinguishable from conventional meat; while others have notable differences



Similarities:

- Color
- Structure

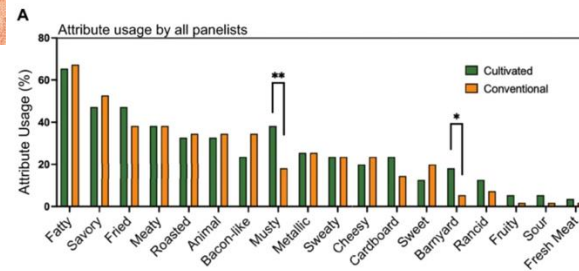
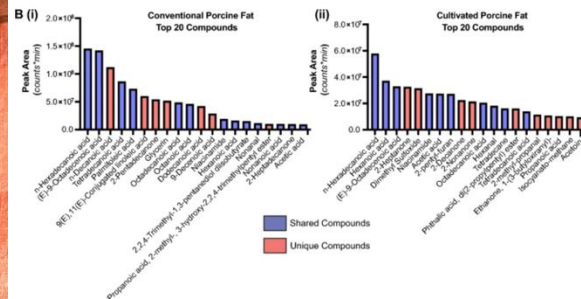
Differences:

- None?

Aroma

e.g., color, structure, size, shape

Studies on aroma are limited and show some alignment in compounds and good alignment in sensory panel data



ORGANOLEPTIC PROPERTIES

Def. The sensory characteristics of a substance; such as properties related to appearance, aroma, taste, and texture.

Appearance

e.g., color, structure, size, shape

Some products (ground meat, chicken) are indistinguishable from conventional meat; while others have notable differences



Similarities:

- Color
- Structure

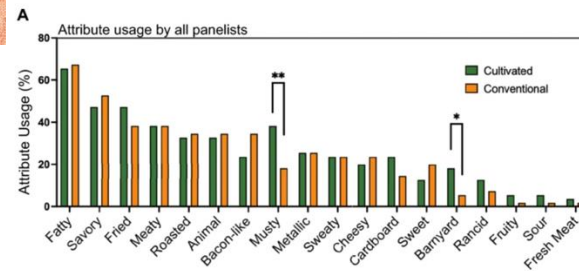
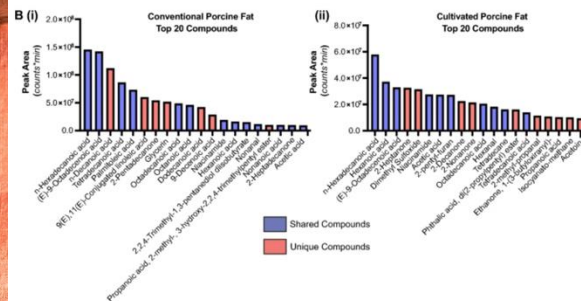
Differences:

- None?

Aroma

e.g., color, structure, size, shape

Studies on aroma are limited and show some alignment in compounds and good alignment in sensory panel data



Tufts
Cellular
Agriculture

Taste

e.g., specific flavor notes, likeability

Two studies have been performed on the taste of cultivated chicken; each receiving good evaluation (4.21/5; 8/10)

Section	Score (Mean)	SD
Pre-consumption section		
Composite score (Mean)	3.70	(0.91)
Familiarity with cultivated meat	3.58	(1.26)
Knowledge about production of cultivated meat	3.50	(1.16)
Knowledge about benefits of cultivated meat	3.53	(1.20)
Acceptance of cultivated meat	4.19	(0.90)
Post-consumption section		
Composite score (Mean)	4.18	(0.64)
Tastiness of cultivated chicken dish	4.21	(0.72)
Willingness to eat cultivated chicken in a restaurant again	4.41	(0.85)
Willingness to recommend cultivated chicken to friends or families	4.45	(0.83)
Perception of likelihood of other customers ordering cultivated chicken at restaurants	3.67	(0.84)

SMU
Lee Kong Chan
School of
Business

ORGANOLEPTIC PROPERTIES

Def. The sensory characteristics of a substance; such as properties related to appearance, aroma, taste, and texture.

Appearance

e.g., color, structure, size, shape

Some products (ground meat, chicken) are indistinguishable from conventional meat; while others have notable differences



Similarities:

- Color
- Structure

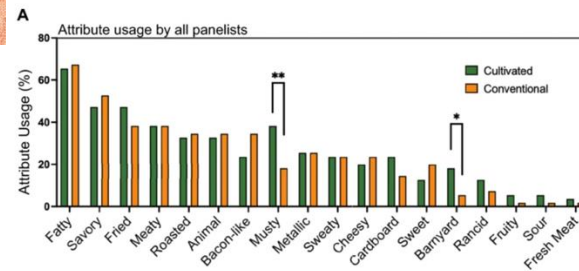
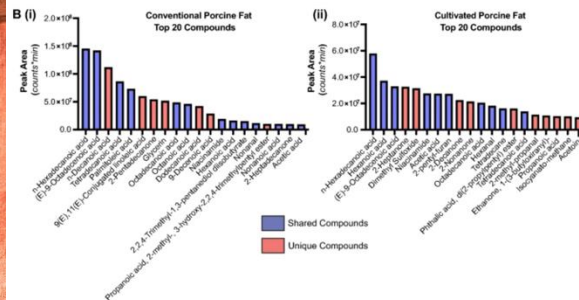
Differences:

- None?

Aroma

e.g., color, structure, size, shape

Studies on aroma are limited and show some alignment in compounds and good alignment in sensory panel data



Taste

e.g., specific flavor notes, likeability

Two studies have been performed on the taste of cultivated chicken; each receiving good evaluation (4.21/5; 8/10)

Pre-consumption section

Composite score (Mean)

Familiarity with cultivated meat

Knowledge about production of cultivated meat

Knowledge about benefits of cultivated meat

Acceptance of cultivated meat

Post-consumption section

Composite score (Mean)

Tastiness of cultivated chicken dish

Willingness to eat cultivated chicken in a restaurant again

Willingness to recommend cultivated chicken to friends or families

Perception of likelihood of other customers ordering cultivated chicken at restaurants



Texture

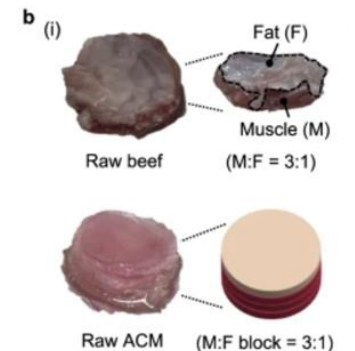
e.g., tenderness, juiciness

Many studies have been performed on texture; due to the ease of collecting mechanical data in lab

1-5



1-5





CHALLENGES & OPPORTUNITIES

CELL LINES

-  Resource-intensive cell line development (\$2-20M)
-  Insufficient cell differentiation (i.e., muscle, fat maturation)

CULTURE MEDIA

-  Costly media ingredients (i.e., growth factors, recombinant proteins, amino acids)
-  Food safety validation of media ingredients

SCAFFOLD MATERIALS

-  Matching the mechanical properties of conventional meat
-  Integration of scaffolding with bioreactors

BIOPROCESS DESIGN

-  Improving cell yield
-  Achieving economies of scale

ACKNOWLEDGEMENTS

Deco Labs

Dr. Andrew Stout
Dr. John Yuen Jr

The Cellular Agriculture Commercialization Laboratory

Ruben Torres-Sanchez
William Shaw
Frannie Shechter
Olivia Calkins

New Harvest

Isha Datar
Breanna Duffy
Dwayne Holmes
Yadira Tejeda-Saldana

The Tufts University Center for Cellular Agriculture

Dr. David Kaplan
Dr. Matt McNulty
Meera Zassenhaus
Dr. Scott Frost
Dr. Kyongbum Lee
Dr. Ayse Asatekin
Dr. Barry Trimmer
Dr. Eugene White
Dr. Sean Cash
Dr. Nicole Tichenor
Blackstone
Katie Stebbins
Dr. Xinxin Li
Dr. Taehwan Lim
Dr. Amin Nikkhah
Sophie Letcher
Michael Saad
Kirsten Trinidad
James Dolgin
Ellie Contreras

