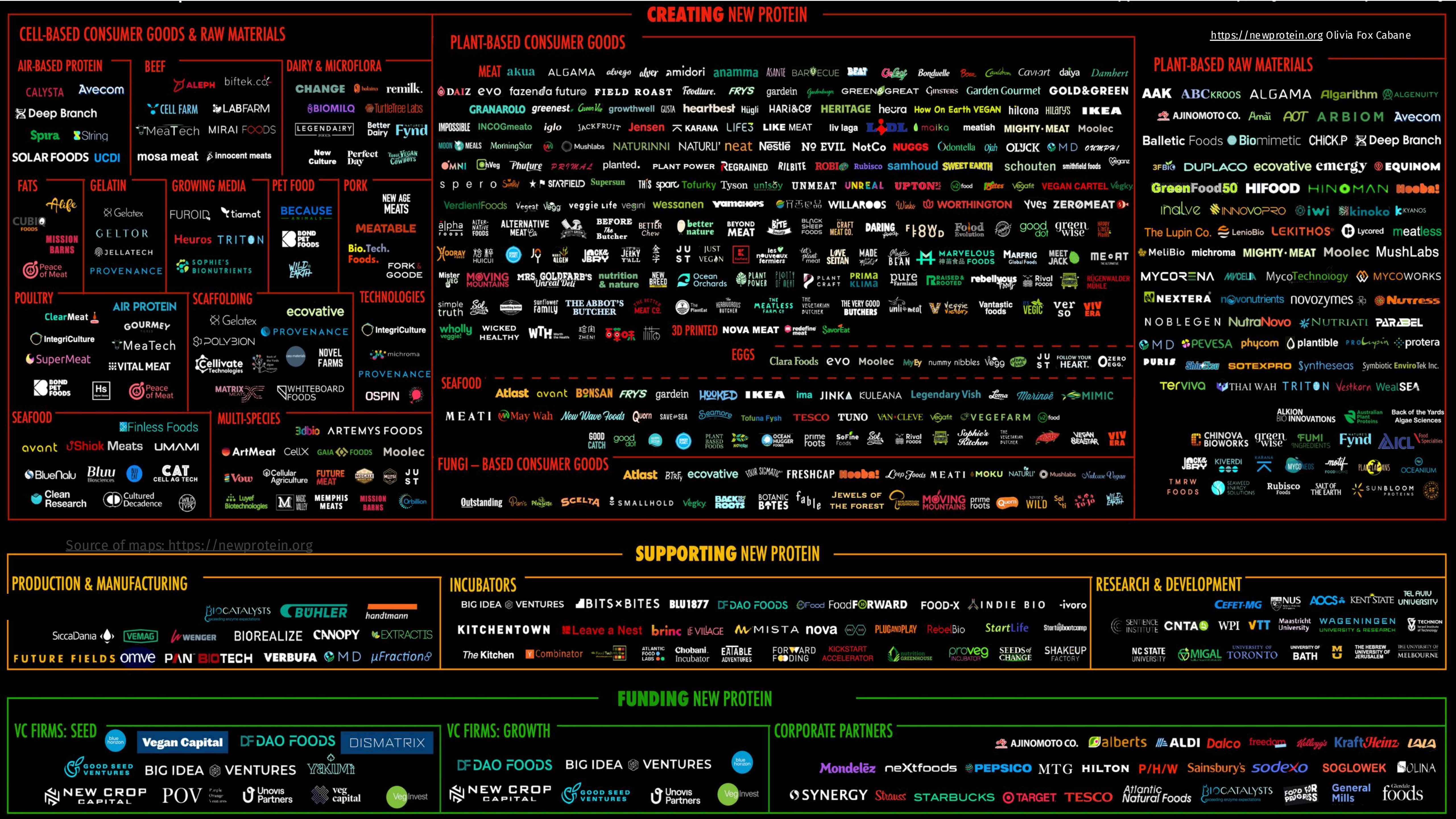

CREATING NEW PROTEIN
https://newprotein.org Olivia Fox Cabane
CELL-BASED CONSUMER GOODS & RAW MATERIALS
AIR-BASED PROTEIN
CALYSTA Avecom Deep Branch Spira String SOLAR FOODS UCDI
BEEF
ALEPH biftek.co CELL FARM LABFARM MeaTech MIRAI FOODS mosa meat innocent meats
DAIRY & MICROFLORA
CHANGE remilk. BIOMILQ TurtleTree Labs LEGENDAIRY Better Dairy Fynd New Culture Perfect Day
FATS
Alife CUBIQ FOODS MISSION BARNS Peace of Meat
GELATIN
Gelatex GELTOR JELLATECH PROVENANCE
GROWING MEDIA
FUROID tiamat Heuros TRITON SOPHIE'S BIONUTRIENTS
PET FOOD
BECAUSE ANIMALS BOND PET FOODS WILD EARTH
PORK
NEW AGE MEATS MEATABLE Bio.Tech. Foods. FORK & GOODE
POULTRY
ClearMeat AIR PROTEIN GOURMEY IntegriCulture MeaTech SuperMeat VITAL MEAT BOND PET FOODS Peace of Meat
SCAFFOLDING
Gelatex ecovative PROVENANCE POLYBION Cellivate Technologies NOVEL FARMS MATRIX MEATS WHITEBOARD FOODS
TECHNOLOGIES
IntegriCulture michroma PROVENANCE OSPIN
SEAFOOD
Finless Foods avant Shiok Meats UMAMI BlueNalu Bluu Biosciences CAT CELL AG TECH Clean Research Cultured Decadence WILD TYPE
MULTI-SPECIES
3dbio ARTEMYS FOODS ArtMeat CellX GAIA FOODS Moolec Vow Cellular Agriculture FUTURE MEAT JUST Luyef Biotechnologies MAGIC VALLEY MEMPHIS MEATS MISSION BARNS Orbillion
PLANT-BASED CONSUMER GOODS
MEAT akua ALGAMA alvego alver amidori anamma BARVECUE BEAT Bonduelle Cauldron Caviart daiya Damhert DAIZ evo fazenda futuro FIELD ROAST Foodture. FRY'S gardein GREEN&GREAT Ginsters Garden Gourmet GOLD&GREEN GRANAROLO greenest growthwell heartbest Hügli HARi&CO HERITAGE heura How On Earth VEGAN hilcona IKEA IMPOSSIBLE INCOGmeato iglo JACKFRUIT Jensen KARANA LIFE3 LIKE MEAT liv laga LIDL maika meatish MIGHTY·MEAT Moolec MOON MEALS MorningStar Mushlabs NATURINNI NATURLI' neat Nestlé NO EVIL NotCo NUGGS Odontella OLYCK MD OMNI Phuture PRIMAL planted. PLANT POWER REGRAINED Rubisco samhoud SWEET EARTH schouten smithfield foods Veganz spero STARFIELD Supersun THIS Tofurky Tyson unisoy UNMEAT UNREAL UPTON'S VEGAN CARTEL Vegky VerdientFoods Vegeat Vegg veggie life vegini wessanen WILLAROOS WORTHINGTON Yves ZERØMEAT alpha foods ALTERNATIVE MEAT Co. BEFORE The Butcher BETTER Chew better nature BEYOND MEAT BLACK SHEEP FOODS CRAFT MEAT CO. DARING FLOWD Folod Evolution good dot green wise MARVELOUS FOODS MARFRIG MEET JACK ME-AT Mister VEG MOVING MOUNTAINS MRS. GOLDFARB'S Unreal Deli nutrition & nature NEW BREED Ocean Orchards PLANT POWER PLANT CRAFT PRIMA KLIMA pure Farmland RAISED & ROOTED rebellyous Rival FOODS RÜGENWALDER MÜHLE simple truth sunflower family THE ABBOT'S BUTCHER The PlantEat THE MEATLESS FARM CO THE VEGETARIAN BUTCHER THE VERY GOOD BUTCHERS unlimeat Veggie Victory Vantastic foods VEGIC ver so VIVERA wholly veggie! WICKED HEALTHY
3D PRINTED NOVA MEAT redefine meat SavorEat
EGGS
Clara Foods evo Moolec nummy nibbles Vegg JUST FOLLOW YOUR HEART. ZERO EGG.
SEAFOOD
Atlast avant BONSAN FRY'S gardein HOOKED IKEA ima JINKA KULEANA Legendary Vish Marinoë MIMIC MEATI May Wah New Wave Foods Quorn SAVE SEA Seamore Tofuna Fysh TESCO TUNO VAN-CLEVE Vegafit VEGEFARM GOOD CATCH good dot OCEAN HUGGER FOODS prime roots SoFine Foods Rival FOODS Sophie's Kitchen VEGAN SEASTAR VIVERA
FUNGI – BASED CONSUMER GOODS
Atlast ecovative FRESHCAP Meeba! Leep Foods MEATI MOKU Mushlabs Outstanding SCELTA SMALLHOLD Vegky BACK TO THE ROOTS BOTANIC BITES fable JEWELS OF THE FOREST MOVING MOUNTAINS prime roots Quorn WILD EARTH
PLANT-BASED RAW MATERIALS
AAK ABCKROOS ALGAMA Algarithm ALGENUITY AJINOMOTO CO. Amai AOT ARBIOM Avecom Balletic Foods Biomimetic CHICK.P Deep Branch 3FBIO DUPLACO ecovative emergy EQUINOM GreenFood50 HIFOOD HINOMAN Meeba! Inalve INNOVOPRO iwi kinoko KYANOS The Lupin Co. LenioBio LEKITHOS Lycored meatless MeliBio michroma MIGHTY·MEAT Moolec MushLabs MYCORENA MYCELIA MycoTechnology MYCOWORKS NEXTERA novonutrients novozymes Nutress NOBLEGEN NutraNovo NUTRIATI PARABEL MD PEVESA phycom plantible PROlupin protera PURIS SOTEXPRO Syntheseas Symbiotic EnviroTek Inc. Terviva THAI WAH TRITON Vestkorn WealSEA ALKION BIO INNOVATIONS Australian Plant Proteins Back of the Yards Algae Sciences CHINOVA BIOWORKS green wise FUMI INGREDIENTS Fynd AICL KIVERDI KARANA MYCOTECHNOLOGY motif FOODWORKS PLANTEANS OCEANIUM TMRW FOODS SEAWEED ENERGY SOLUTIONS Rubisco Foods SALT OF THE EARTH SUNBLOOM PROTEINS
Source of maps: https://newprotein.org
SUPPORTING NEW PROTEIN
PRODUCTION & MANUFACTURING
BIOCATALYSTS BUHLER handtmann SiccaDania VEMAG WENGER BIOREALIZE CANOPY EXTRACTIS FUTURE FIELDS omve PAN BIOTECH VERBUFA MD µFraction8
INCUBATORS
BIG IDEA VENTURES BITS×BITES BLU1877 DAO FOODS FoodFORWARD FOOD-X INDIE BIO ivoro KITCHENTOWN Leave a Nest brinc EVILLAGE MISTA nova PLUGANDPLAY RebelBio StartLife Startupbootcamp The Kitchen Y Combinator ATLANTIC FOOD LABS Chobani Incubator EATABLE ADVENTURES FORWARD FOODING KICKSTART ACCELERATOR nutrition GREENHOUSE proveg INCUBATOR SEEDS of CHANGE SHAKEUP FACTORY
RESEARCH & DEVELOPMENT
CEFET-MG NUS A*STAR KENT STATE TEL AVIV UNIVERSITY SENTIENCE INSTITUTE CNTA WPI VTT Maastricht University WAGENINGEN UNIVERSITY & RESEARCH TECHNION NC STATE UNIVERSITY MIGAL UNIVERSITY OF TORONTO UNIVERSITY OF BATH THE HEBREW UNIVERSITY OF JERUSALEM THE UNIVERSITY OF MELBOURNE
FUNDING NEW PROTEIN
VC FIRMS: SEED
blue horizon Vegan Capital DAO FOODS DISMATRIX GOOD SEED VENTURES BIG IDEA VENTURES Yakumi NEW CROP CAPITAL POV Purple Orange Ventures Unovis Partners veg capital VegInvest
VC FIRMS: GROWTH
DAO FOODS BIG IDEA VENTURES blue horizon NEW CROP CAPITAL GOOD SEED VENTURES Unovis Partners VegInvest
CORPORATE PARTNERS
AJINOMOTO CO. Albertsons ALDI Dalco freedom Kellogg's KraftHeinz LALA Mondelēz neXtfoods PEPSICO MTG HILTON P/H/W Sainsbury's sodexo SOGLOWISKI SOLINA SYNERGY Strauss STARBUCKS TARGET TESCO Atlantic Natural Foods BIOCATALYSTS FOOD FOR PROGRESS General Mills Glendale foods

220+ Protein Startups to Know

We tracked over 220 companies in the space. Get to know the players working on solutions on the future of protein, and if there's someone we've missed you can quickly add them here.

Hide fields | Filter | Group | Sort | ...

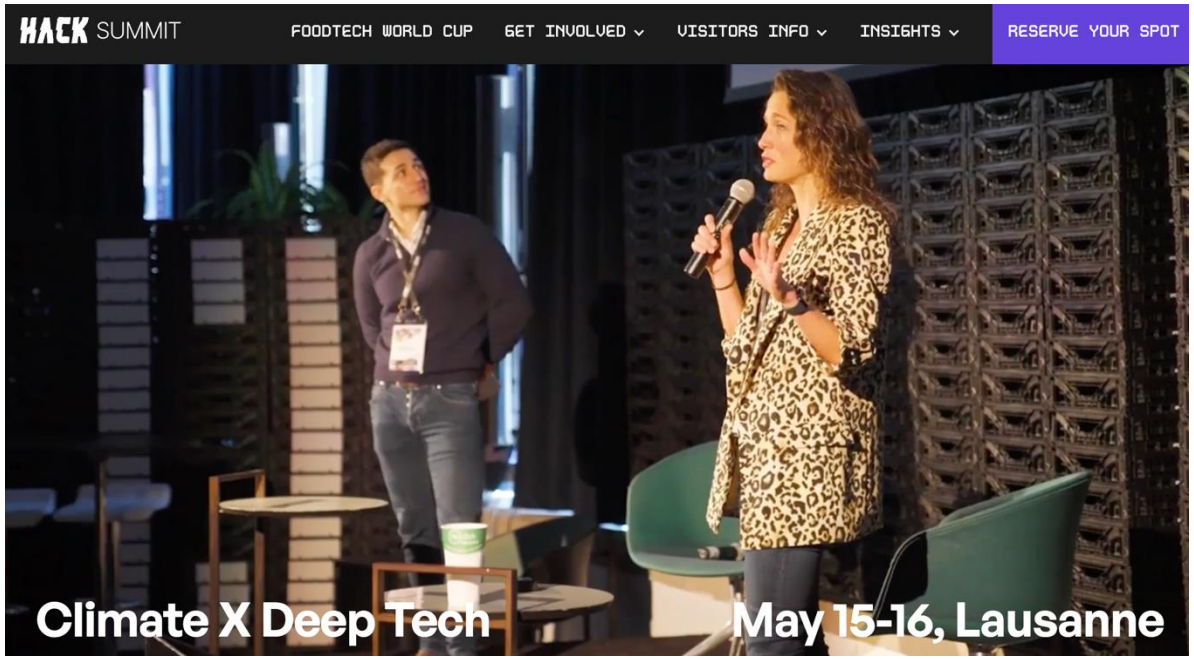
	Company Name	Technology	Website
1	3DBioFibr	Materials	https://www.linkedin.com/...
2	70/30 Food Tech	Mycoprotein	https://7030foodtech.com
3	Adaptyv Bio	Protein Discovery with AI	https://www.adaptyvbio.c...
4	AI Bobby	Protein Discovery with AI	https://www.linkedin.com/...
5	Aikium	Protein Discovery with AI	https://www.aikium.com/
6	Ailurus Bio	Platform, Protein Discove	https://www.ailurus.bio/
7	Air Protein	Protein from air	https://airprotein.com/
8	Alchemy	Protein Discovery with AI	https://www.alchemy.com/
9	Aleph Farms	Cultivated Meat	https://aleph-farms.com/
10	Algiecel	Protein from Air	https://www.linkedin.com/...
11	All G	Precision Fermentation	https://www.linkedin.com/...
12	All g	Precision Fermentation	All.com

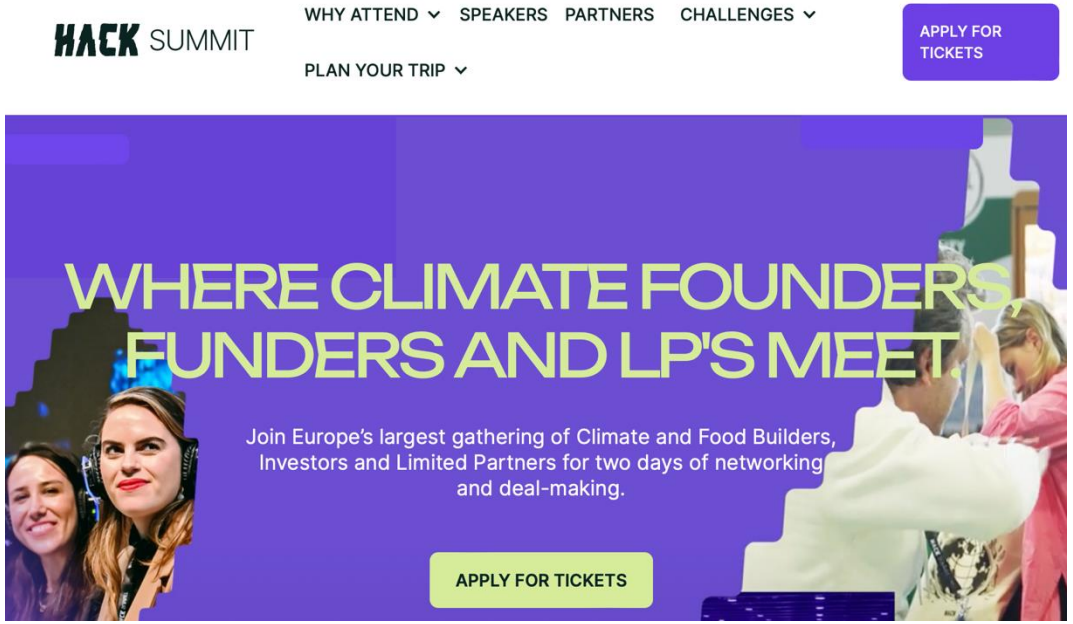
[2] https://hacksummit.beehiiv.com/p/protein-and-deeptech

FoodHack

Volunteers requested to support in the annual Food Hack Event

Fascal Hukker <fascal@hackgroup.org>





https://www.hacksummit.co

Food Biotechnology
Alternative meat & dairy protein developments

Wilbert Sybesma

EPFL Course ENG-436

Only for Teaching Purposes
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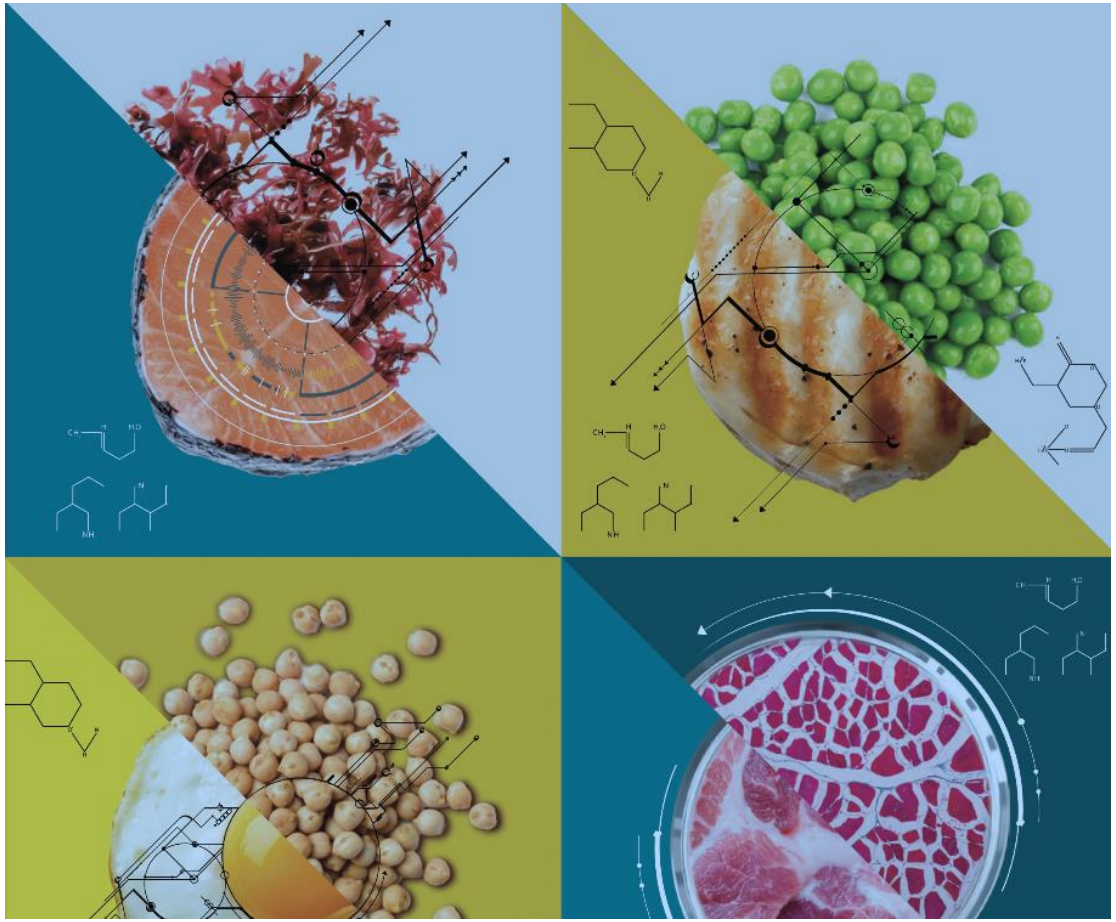
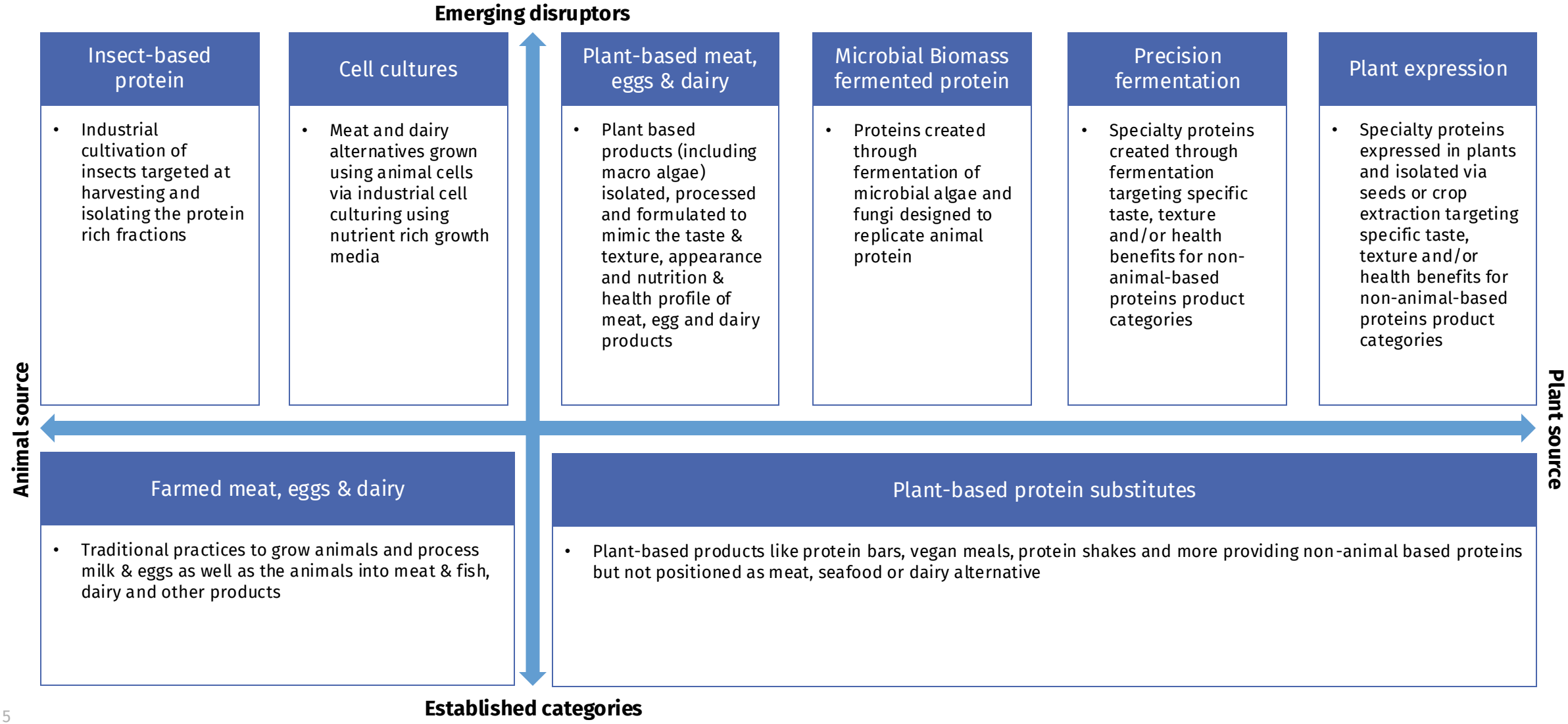
Not for external distribution



https://innovationisrael.org.il/sites/default/files/GFI%20Israel%20State%20of%20Alternative%20Protein%20Innovation%20Report%202021_0.pdf

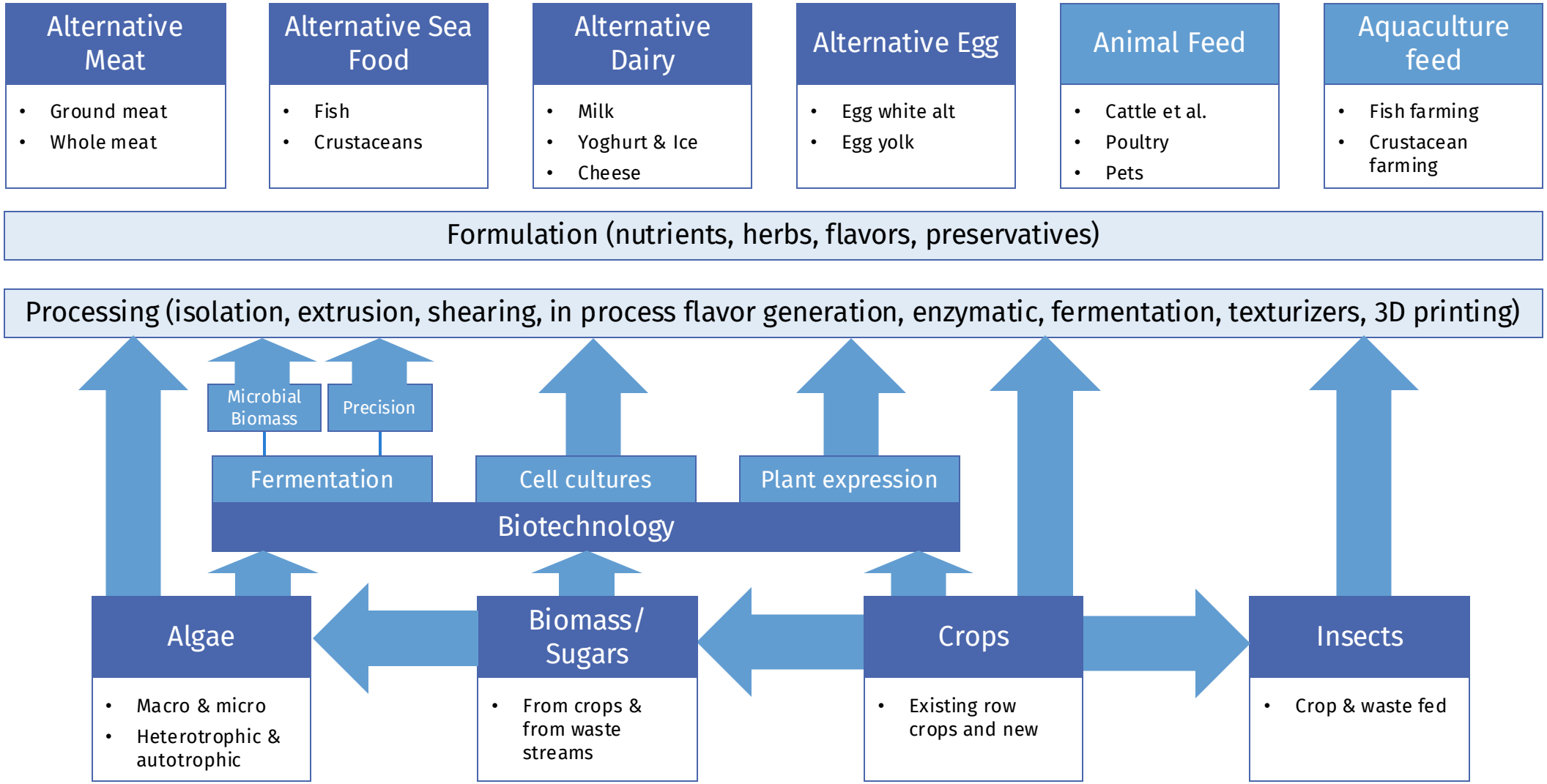
The alternative meat & dairy protein landscape is very dynamic, boundaries are shifting, hybrid offerings are created, new players are constantly emerging

The landscaping is shaped by applying multiple sources & developing and applying a wide range of technologies targeting end products competing in taste & texture, appearance and nutrition & health, with animal-based meat, eggs & dairy products

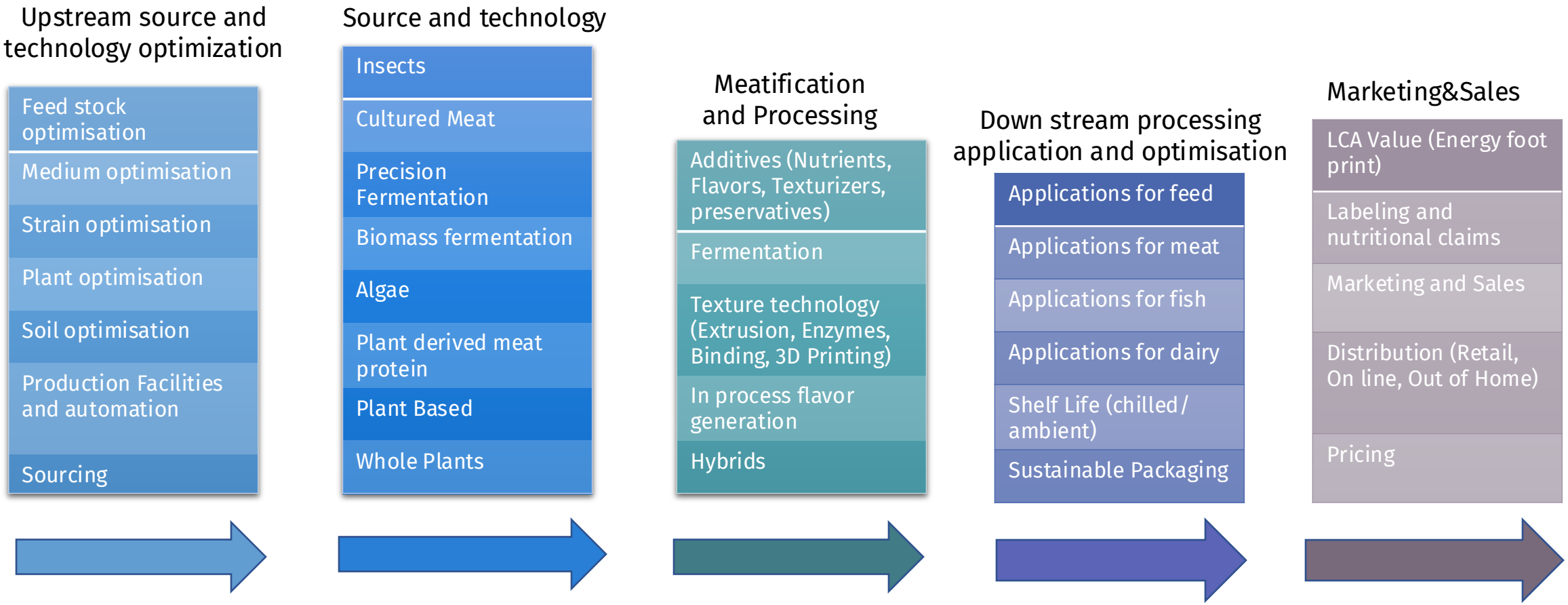


Adopted from LEK Consultancy, Nov 22nd 2021, FIE, Frankfurt

The alternative protein industry is characterized by a diverse range of sources and technologies



Sustainable Protein Value Chain



Meat & Seafood

The playing field: four source and technology-based clusters

Consumer products are in many cases hybrid products in which multiple plant-based proteins are mixed and/or specialty proteins are used to enhance taste and texture

	Plant Based Meat	Fermentation Based	Cellular / Cell based	Insects
	• Fully plant-based meat alternatives complemented by specialty proteins to enhance taste and texture • Fast growing market with broad customer acceptance	• Biomass fermentation for ground meats complemented by specialty proteins to enhance taste and texture • Expanding beyond ground meat in chicken alternatives, sausages and more	• Fully cellular based meat with the same taste and texture as traditional meat • No sizable commercial production expected before 2035	• Including the entire insect life cycle (breeding, growing, processing, and application) • Still suffering from 'yuck' factor
	• Variety of technologies applied to produce protein feedstock • Range of processing technologies applied to produce meat texture	• Biomass fermentation to produce mycoprotein or bacterial proteins • Specialty protein fermentation for taste and texture enhancements	• Cell culture-based technologies to express animal cells • Upstream innovation in growth media and growth factors is pre-requisite to significantly lower variable costs levels	• (Aqua) feed and pet food are key markets for emerging players like Protix (NL) and Ynsect (FR) • Protix and Ynsect are also targeting human food and some smaller players are selling processed insects
Nutritional value	Often too much salt and fat added. Not always balanced amino acid profile	By its nature a good intrinsic nutritional value	On par with meat	On par with meat, or even better when you consider the whole insect including fiber, fats and minerals

Algae*

*Algae can be classified in crops (sea weed cultivation) and Fermentation Based (micro algae). See separate slide for illustration.

GOOD Meat, the World's First-to-Market Cultivated Meat Company, Receives U.S. FDA Clearance

Acclaimed chef José Andrés will be first in the country to serve GOOD Meat's chicken

ALAMEDA, Calif.--(BUSINESS WIRE)--GOOD Meat, the cultivated meat division of food technology company Eat Just, Inc., announced today that it has received a "no questions" letter from the U.S. Food and Drug Administration as part of one of the agency's first pre-market consultations for a new kind of meat, poultry and seafood made from cells instead of raised and slaughtered animals. The letter means that following a careful and rigorous evaluation, the FDA has accepted the company's conclusion that its first poultry product, cultivated chicken, is safe to eat.

This clears a crucial step in bringing GOOD Meat to restaurants and retail in the U.S. more than two years after its historic approval and launch in Singapore. The company is now working with the U.S. Department of Agriculture on necessary approvals before world-renowned chef and humanitarian José Andrés becomes the first in the country to offer GOOD Meat's chicken to customers at a restaurant in Washington, D.C. Andrés is chef/owner of José Andrés Group, which operates more than 30 restaurants across the country.

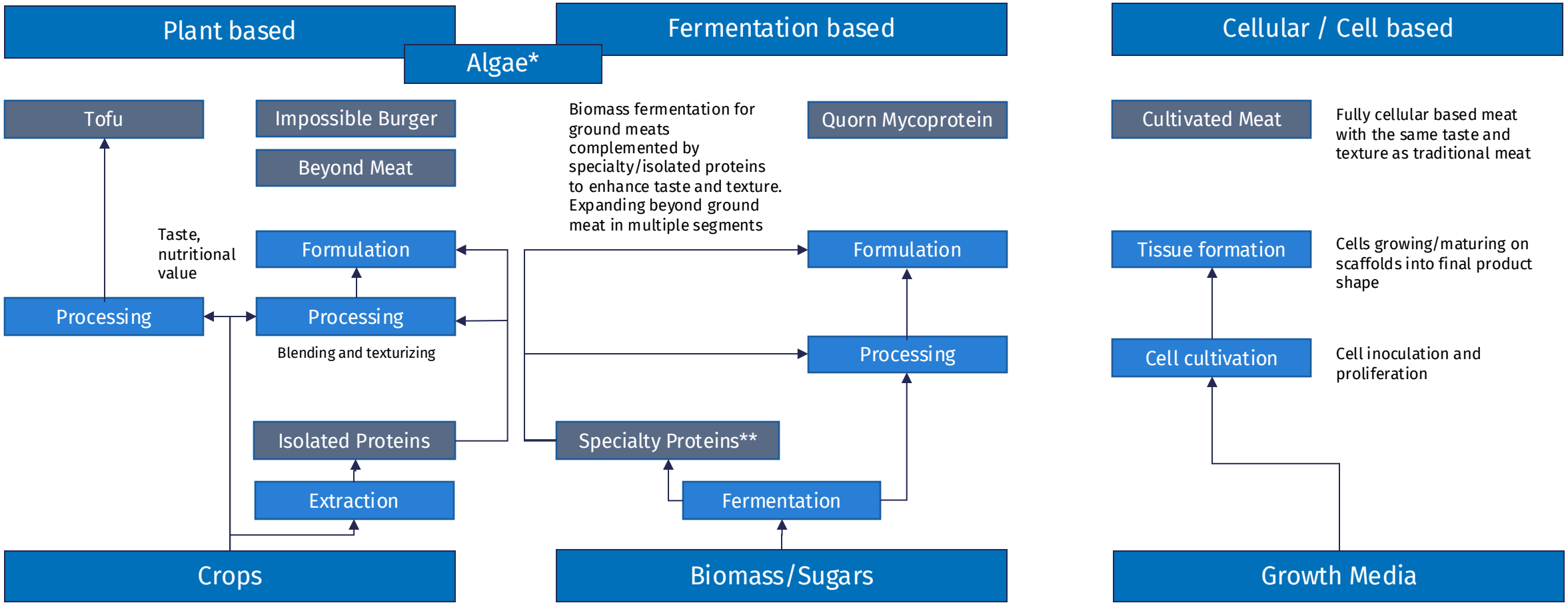
"Since Singapore approved GOOD Meat for sale, we knew this moment was next. I am so proud to bring this new way of making meat to my country and to do it with a hero of mine, Chef José Andrés," said Josh Tetrick, co-founder and CEO of GOOD Meat and Eat Just.

https://www.businesswire.com/news/home/20230321005793/en/GOOD-Meat-the-World's-First-to-Market-Cultivated-Meat-Company-Receives-U.S.-FDA-Clearance

https://www.goodmeat.co

The non-animal-based meat analogue revolution

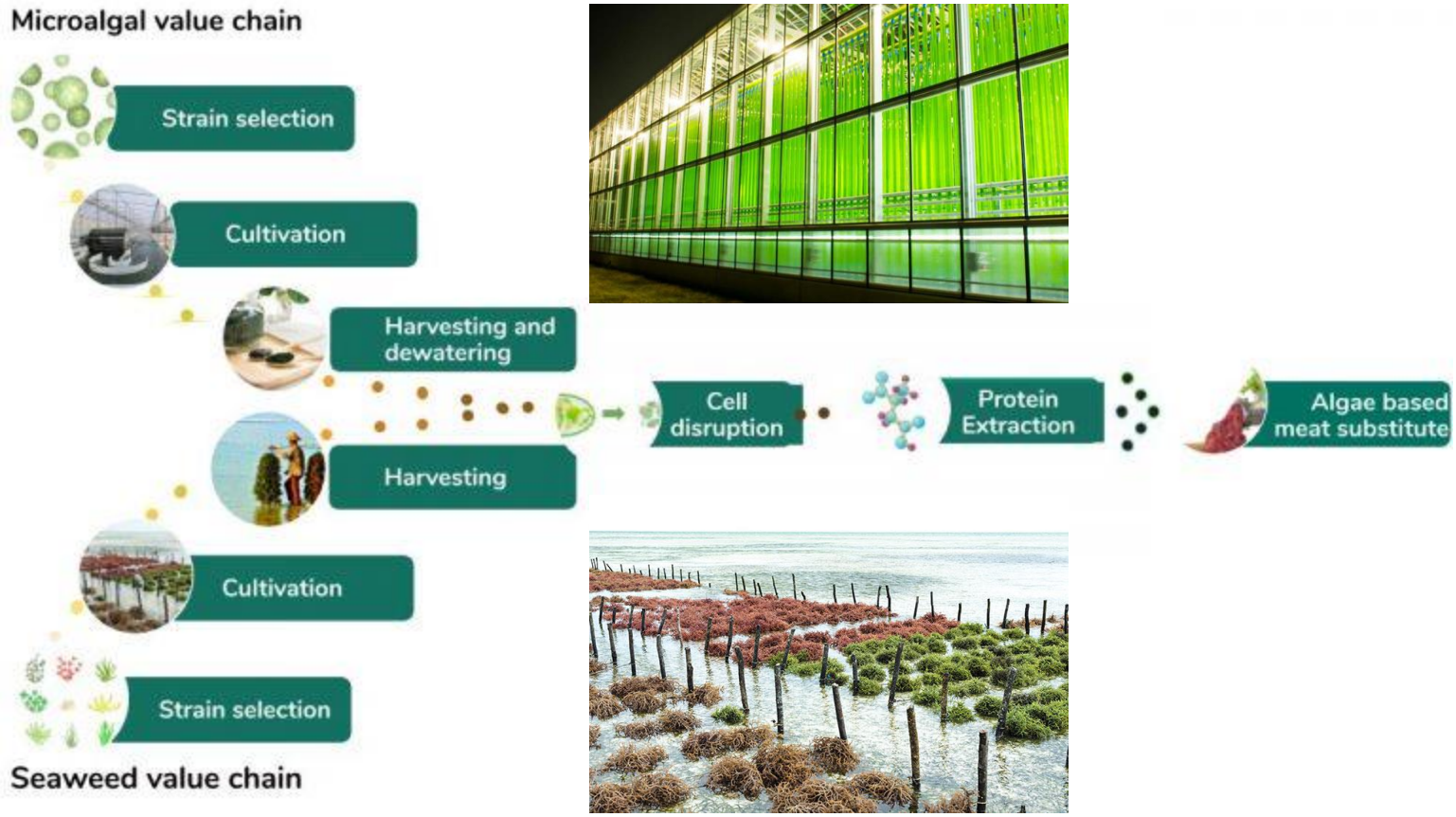
A diverse, fast emerging playing field



*Algae can be classified in crops (seaweed cultivation) and Fermentation Based (micro algae). See separate slide for illustration.
** Example: Impossible Foods - soy leghemoglobin (SLH), a vat-grown, genetically engineered form of the heme iron found in the root nodules of soya bean plants

Algae alternative proteins can be classified as plant based crops (seaweed) or fermentation based (microalgae).

Algae can be used as full protein source, or as production organisms for lipids and other nutrients



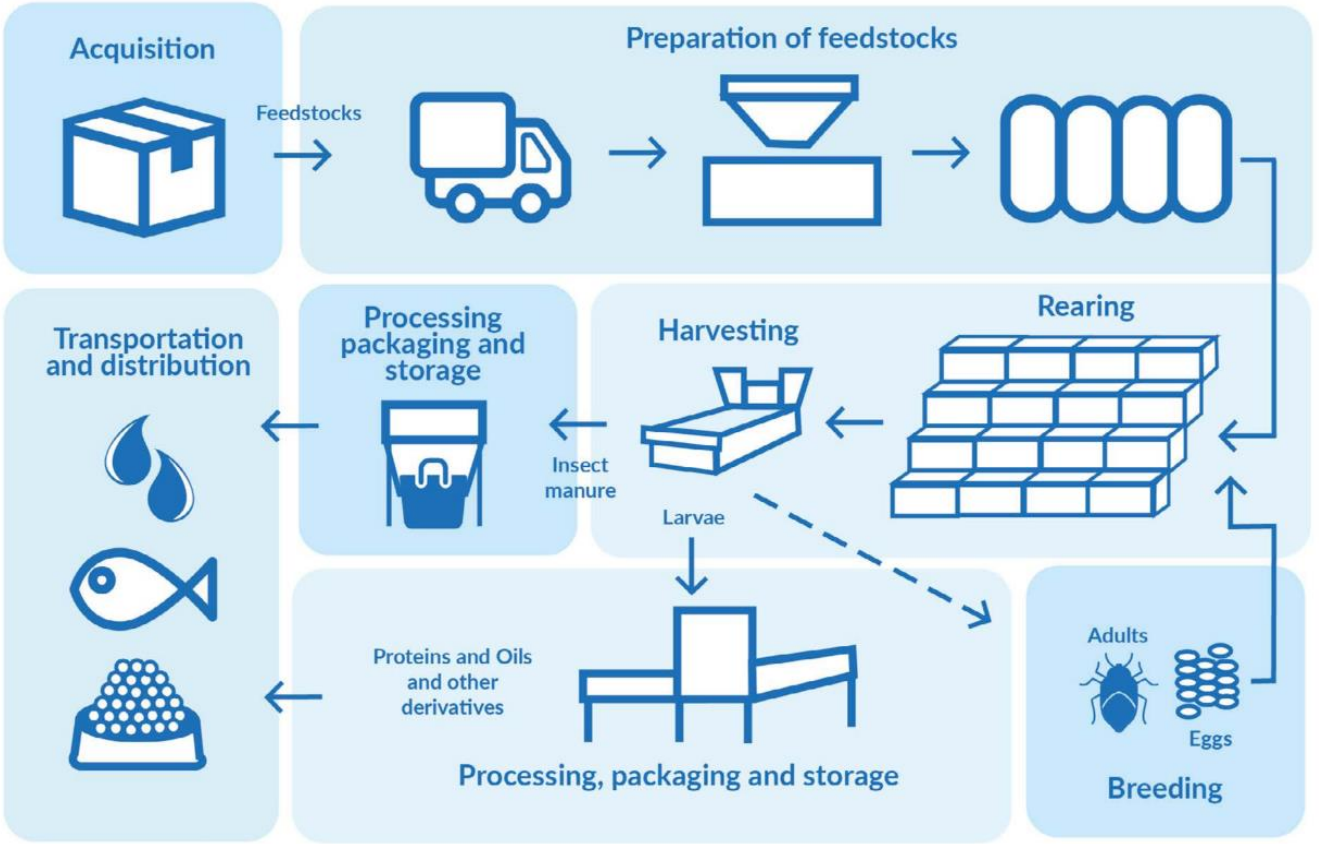
https://gfi-india.org/microalgae-and-seaweed-proteins-as-alternative-proteins/

https://youtu.be/KhgGwQGg-f0?feature=shared

The non-animal-based meat analogue revolution

Due to their specific nature, insect meat analogue production initially follows a different process compared to the other sectors[1,2]

- Even though insects are estimated to be part of the diet of about 2 Bln people, most insects consumed are harvested in the wild and hardly commercially reared[1]
- Small scale insect farms can be found in Asia but also in Europe and the US
- Entomophagy is heavily influenced by cultural and religious practices
- In most Western countries people view entomophagy with disgust and associate eating insects with primitive behavior
- The ability for insects to feed themselves with a wide variety of waste and the potential outlets in aquafeed and pet food created renewed interest in the Western world



https://vmvt.lt/sites/default/files/ipiff_guide_a4_2020_correction_red.pdf

1 – FAO, Edibel insects, 2013
2 - International Platform of Insects for Food and Feed (IPIFF) –Guide 2020

Plant based meat industrial players

Fast growing companies targeting B2C space, large group of emerging companies targeting B2C as well as new processing technologies, feedstocks and final product features

- Fully plant-based meat alternatives complemented by specialty proteins to enhance taste and texture
- In the plant-based space, Beyond Meat and Impossible Foods are the two best known examples targeting the burger/ground meat market
- A broad range of other start-ups are targeting a similar approach
- Leading food companies are actively investing as well as actively acquiring interesting start-ups
  - Vivera (NL) acquired by JBS[1]
  - Unilever acquired Dutch based Vegetarian Butcher in 2018[2]
  - Nestle acquired Sweet Earth in 2017[3]

- A smaller group of companies are actively exploring more advanced processing technologies to either produce better burgers and/or mimicking the fibrous structure of meat
  - Umiami - French based start-up with proprietary texturisation technology
  - Rebellyous Foods - US based – advanced extrusion technology
  - Revo Foods (AT) – 3D printing like technology, targeting seafood

Plant based
Beyond Meat
Impossible Foods
Eat Just
v2Food
planted
Redefine Meat
Good Catch Foods
Banza
Umiamu
Rebellyous Foods
Revo Foods

Umiami's whole-muscle chicken breast

List given is an illustration of companies active in this space. The list is not meant to be complete

1 - https://agfundernews.com/vivera-acquired-by-jbs-for-plant-based-protein-409m.html

2 - https://www.foodingredientsfirst.com/news/unilevers-the-vegetarian-butcher-expands-plant-based-whopper-roll-out-in-latin-america-the-caribbean-and-china.html

3 - https://www.livekindly.co/nestle-vegan-meat/

Fermentation based alternative protein industrial players

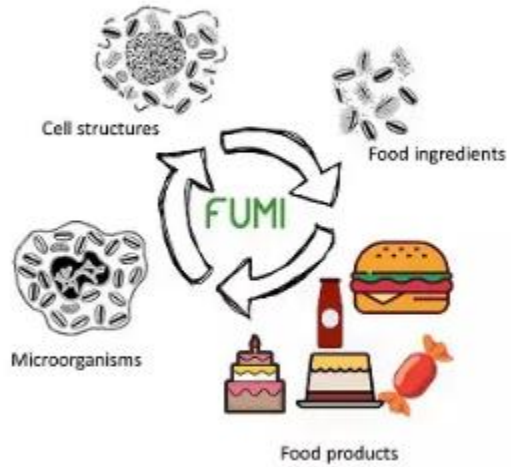
Quorn created the market, traction is growing

Biomass, bulk fermentation and high added value, specialty fermentation for specialty functional proteins

- Biomass fermentation for ground meats complemented by specialty proteins to enhance taste and texture
- Expanding beyond ground meat in chicken alternatives, sausages, sea-food and more

- Biomass fermentation to produce mycoprotein, bacterial and/or yeast-based proteins
  - Natures Fynd (US) – started with solid state fermentation to produce chicken like meat.
  - ENOUGH (UK) – former Quorn team, improving process and backed by Unilever
  - The Protein Brewery (NL) –
  - Atlast Food (US) – Targeting breakfast bacon market
- Specialty protein fermentation for taste and texture enhancements
  - FuMi Ingredients (NL) – yeast based technology
  - Myco Technology (US) – mycelium based flavor components, now becoming a more hybrid company
  - Motif (US) – Focus on flavoring (Hemami) and texture (Appetex)

Fermentation based
Quorn
Nature's Fynd
Motif
Myco Technology
ENOUGH
Atlast Food
The Protein Brewery
Mycorena
Fumi Ingredients



Cellular (cell cultured) alternative protein industrial players

Latest development in alternative protein industry. Still, long trajectory towards commercial feasible offering.

- Fully cellular based meat with the same taste and texture as traditional meat
- The tissue engineering learnings created a base for pivoting towards cultured (of cell based or…) meat and seafood
- Prototype products have been produced and were offered as sample material for product testing by Aleph Farms in Israel[1]
- Singapore is positioning itself as innovation hub for cultured meat, has given regular approval, and one product was served in one restaurant (product is not 100% cultured meat based)[2]

- Mosa Meat (NL) - Mosa Meat is the developer of a tissue cultured hamburger. The company aims to develop tissue engineering into a technology that can mass-produce affordable meat. Front runner
- Upside Foods (US) – Together with Mosa Meat paving the way for other companies. Based in California, aggressive growth trajectory
- Gourmey (FR) – focusing on foie gras, claiming to be cost competitive, benefit of 'simple' texture of foie gras as well as commercial opportunity by animal-based product ban in various US states
- Aleph Farms (IL) – Aleph's 3D technology uses the four core cell types of farmed beef to recreate a real food experience.
- Meatable (NL) – focusing on pork meat, claims to have a differentiating technology to create meat like structure.

Cultured meat
Future Meat Technolog
Upside Foods
Aleph Farms
Mosa Meat
BlueNalu
Meatable
Gourmey
New Age Meats
Mission Barns
Others

1 - https://www.jpost.com/health-science/worlds-first-lab-grown-meat-restaurant-opens-near-tel-aviv-649762
2 - https://www.cnbc.com/2020/12/18/singapore-restaurant-first-ever-to-serve-eat-just-lab-grown-chicken.html

Insect alternative protein industrial players

Targeting feed and exploring potential in food

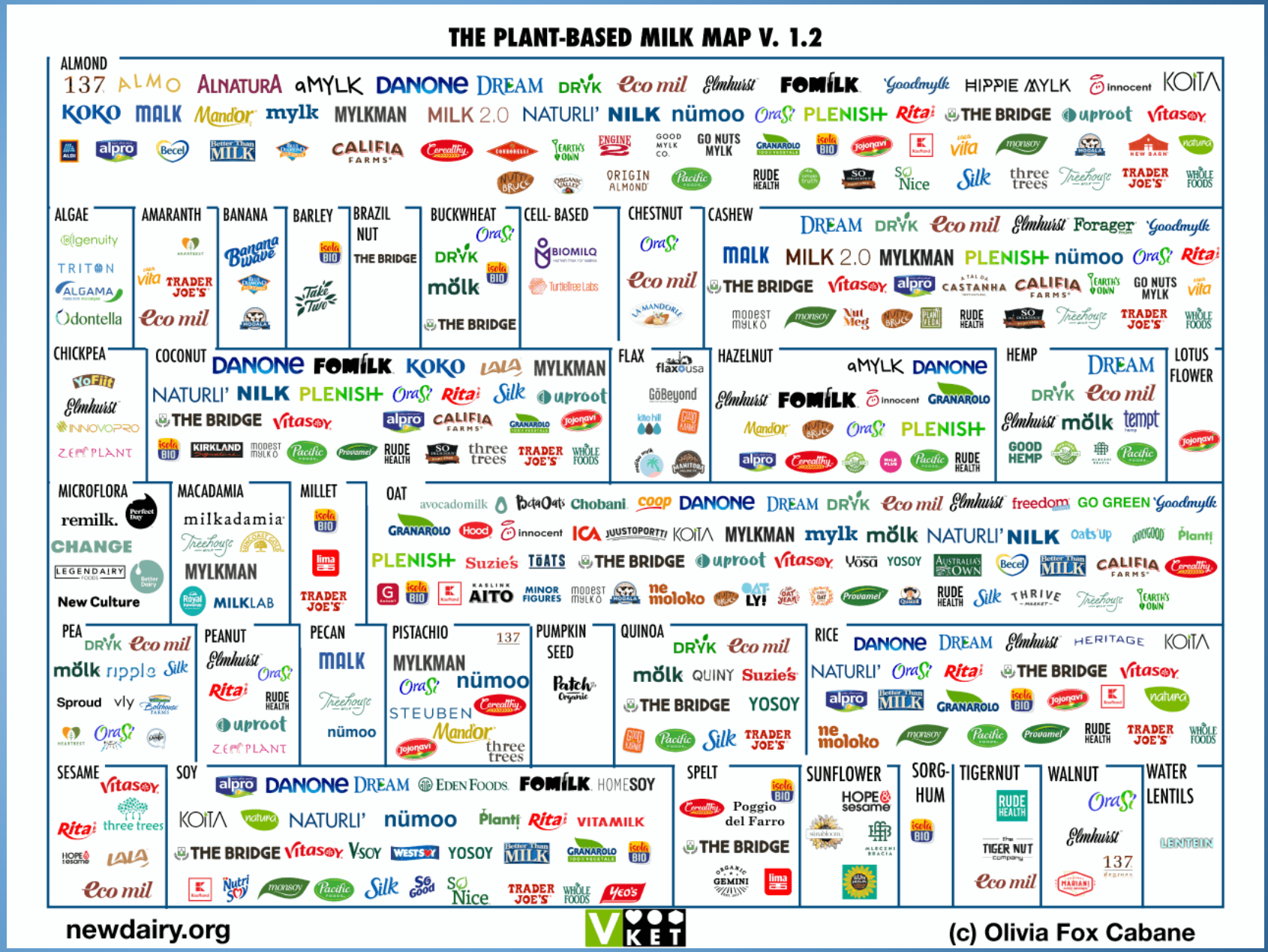
- Agronutris, Ynsect and Protix are the industry frontrunners
- EU gave greenlight for yellow mealworm-based food products in 2021[1] creating options to enter the food market
- Bühler is selling (Protix) technology for companies interested in emerging in the insect growing business

- Feed
  - Key outlet for all insect breeders with a focus on aquaculture and pet-food (higher added value)
- Food
  - Protein powders are the most likely candidates to enter the food space targeting to improve the nutritional profile of products
  - Insect based products can be found in some consumer products ranging from bars to burgers
  - Crickets are farmed small scale in various countries and cricket flour as well as whole crickets can be purchased in some shops and on-line[3]

Insects	Species
Ynsect	Yellow mealworm beetles
AgriProtein	Black soldier fly
Agronutris	Yellow mealworm beetles
Protix	Black soldier fly
Better Origin	Black soldier fly
Entocycle	Black soldier fly
Enterra	Black soldier fly

1 - https://www.foodingredientsfirst.com/news/eu-greenlights-authorization-of-the-first-insect-food-products-made-from-yellow-mealworm.html
2 - https://www.feednavigator.com/Article/2021/05/21/Insect-Technology-Group-UK-in-administration
3 - https://ca.entomofarms.com/ - https://exoprotein.com/collections/all-products

Dairy



The dairy alternative protein industrial players

Lifestyle and/or health driven in dairy and yoghurt. Taste and texture driven in cheese

- The dairy market space is dominated by milk-based alternatives as well as the search for solutions to mimic the unique cheese texture
- Oatly is *the* example of a fast-growing company fully benefitting from lifestyle driven consumer choices
- Health benefits driven growth based on specific ingredients (i.e. specialty peptides as well as HMO's) will always be slower but can be more sustainable/profitable in the long run

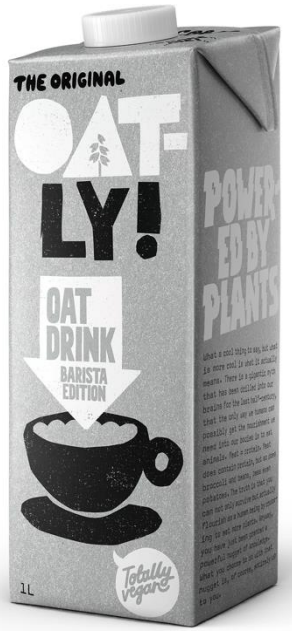
Dairy technology	Key companies
Fermentative	Motif, Perfect Day, Those Vegan Cowboys*, Remilk
Plant based	NotCo, Ripple, Eclipse Foods, Good Planet Foods
Cultured milk	BioMilq, Turtle Tree Labs
Other	
Total	

Dairy segment	Key companies
Milk	NotCo, Perfect Day, Ripple, Turtle Tree Labs,
Cheese	Good Planet Foods, New Culture, Those Vegan Cowboys
Yogurt/Frozen	Eclipse, The Coconut Collaborative
Other	Motif Foodworks
Total	

- "Casein - The key component that gives dairy cheese the traits we love – the texture, stretchiness and mouthfeel – doesn't have a good alternative in the plant-based world."[1]
- Mimicking the taste and texture of cheese is a true specialty protein challenge
- Large scale casein protein production at cost levels < 5-7€/kg must be achieved to produce cheese at market competitive prices

THE ORIGINAL OAT-LY!

Oatly Group AB



1 - https://www.wired.co.uk/article/vegan-cheese-uk-recipe-taste - July 2019
2 - https://plantbasednews.org/lifestyle/food/people-looking-at-buying-vegan-cheese-this-christmas/ - Dec 2020

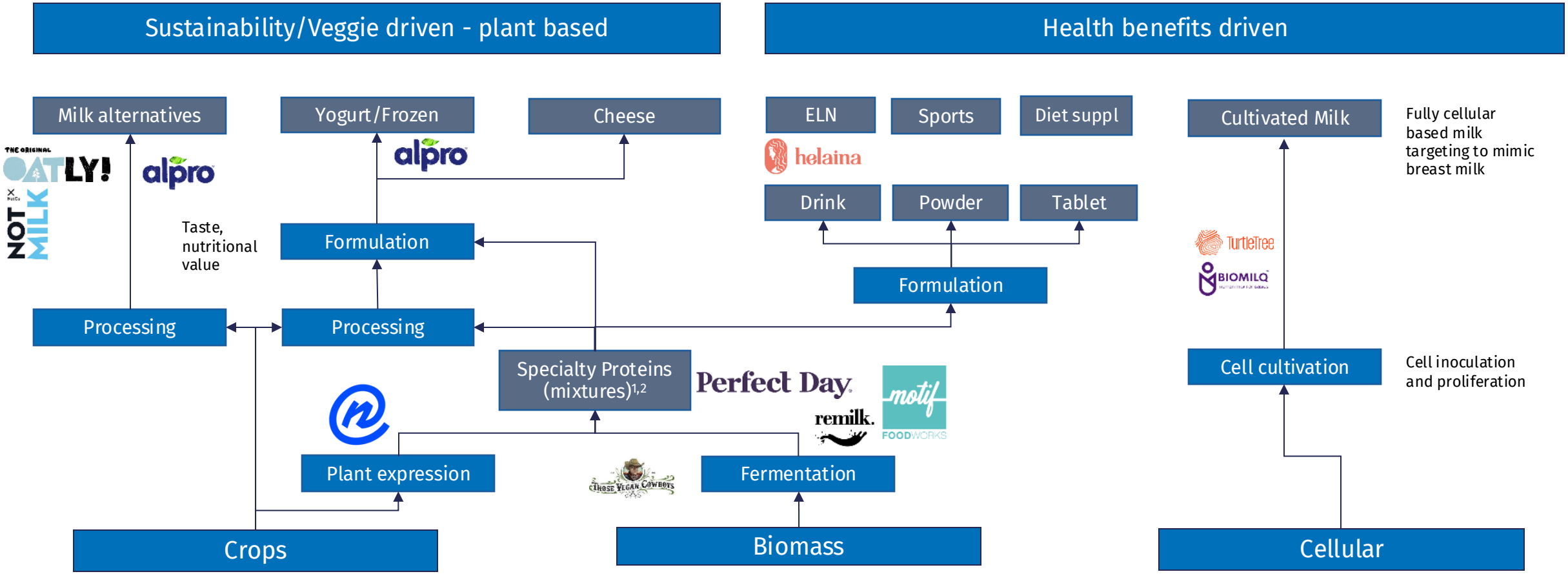
The dairy market – well established for milk alternatives, cheese is the next target

	Crops	Biomass/Fermentation	Cultured
	• Straight crop procession was the base for many dairy drinks and for part of the vegan cheese varieties • Proven track record and established market position	• Strong focus on production of specialty proteins with either specific health benefits (i.e. lactoferrin) or texture properties (casein like proteins for cheese)	• Mammary cells to produce real, full milk in clean food production facilities. Next to producing cow milk, breast milk is also targeted
	• Protein expression in plants is an emerging area targeting both special health benefits as well as casein proteins to solve the cheese challenge • Nobell Foods recently raised 75 Mln$	• As multiple casein proteins are present in cheese the key challenge is to produce more than one variety as well as create the right formulation(s)	• Companies like TurtleTree and BioMilq are exploring the technology • BioMilq is aiming to for human milk for babies (and even personalizing it)
Nutritional value	Many dairy alternatives have low protein content, lacking micronutrients and contain too much sugar	For milk like products, this is the differentiator	High. As in the real situation

1 - https://www.foodnavigator-usa.com/Article/2021/08/19/From-cows-to-microbes-to-plants-the-brave-new-world-of-animal-free-dairy-In-conversation-with-Nobell-Foods

The non-animal-based dairy revolution,

A diverse, fast emerging playing field in which specialty proteins can create a differentiating play in cheese (texture) as well as in health benefits driven segments



1 –Helaina makes nature-equivalent breast milk components. Bovine colostrum-based powders have an established market position, focusing on specific proteins/peptides would be new . Due to the nature of the feedstock, supply is capped and requires strict product management.
2 – Single protein production or mixtures of proteins are produced. Perfect Day claims to produce a mixture whereas others are focusing on specific proteins to mimic casein, lactoglobulin or other milk proteins

Eggs

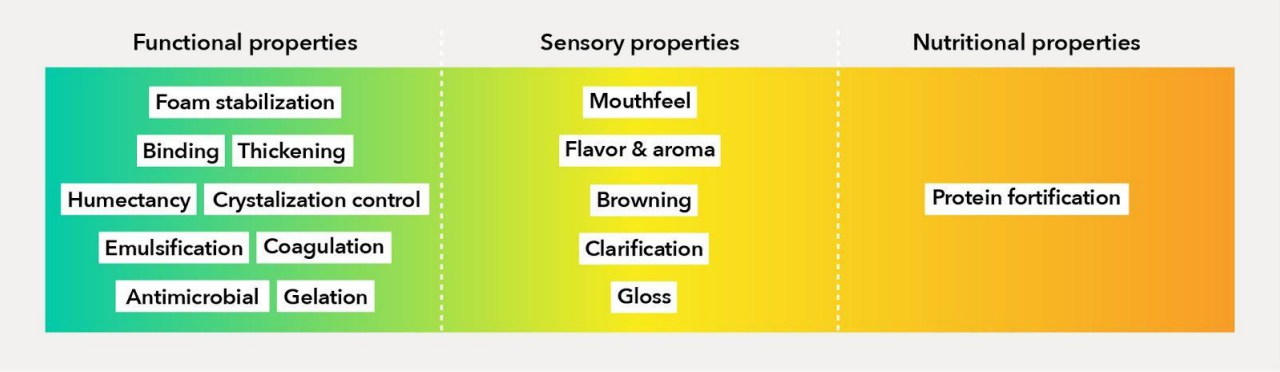
- Alternative egg proteins – Diverse functionality and application scope

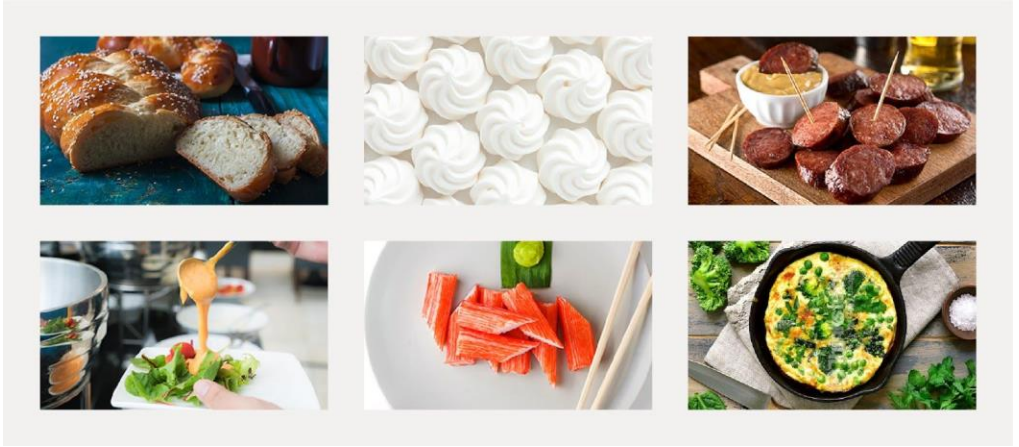
- Examples of companies
  - Whole egg substitutes for baking and scramble
  - Precision fermentation for selected proteins

Alternative egg proteins – Diverse functionality and application scope

The egg alternative protein space is characterized by a range of different individual ingredients as well as ingredient blends, which facilitate a broader range of functional properties

- The technology source ranges from precision fermentation for selected egg proteins towards developing stand-alone egg alternatives by blends of plant based protein, fats and carbs for simulation of scrambles and omelettes. See next slide





Functionalities and applications of eggs

Eggs impact many distinct attributes to food applications as a result of their molecular properties. These attributes contribute in varying degrees to many aspects of the consumer experience of the final product, including the nutritional attributes of the product, the functional properties it exhibits, and sensory qualities, such as taste, texture, and appearance.

Examples of ‘Mix and fix’ whole egg substitutes for baking and scramble

- VeganEgg (Follow Your Heart, USA). https://followyourheart.com - whole algal flour, whole algal protein, modified cellulose, cellulose, gellan gum, calcium lactate, carrageenan, nutritional yeast, black salt
- The Neat Egg (Atlantic Natural Foods). https://atlanticnaturalfoods.com - chia seeds, garbanzo beans
- No Egg Egg Replacer (Orgran, AU). https://www.orgran.com - potato starch, tapioca starch, raising agent (calcium carbonate), citric acid, methylcellulose
- Egg Replacer (Ener-G Foods, USA). https://www.ener-g.com/products/egg-replacer - potato starch, tapioca flour, leavening (calcium lactate, calcium carbonate, cream of tartar), cellulose gum, modified cellulose
- Egg Replacer (Namaste Foods, USA). https://namastefoods.com/products/gluten-free-egg-replacer - tapioca starch, arrowroot starch, citrus fiber, cream of tartar, sodium bicarbonate
- Egg Replacer (Bob’s Red Mill). https://www.bobsredmill.com/gluten-free-vegan-egg-replacer.html - whole soy flour, wheat gluten, corn syrup solids, algin (from algae)
- Baking Mix (The Vegg, USA). https://thevegg.com/product/uncaged-baking-mix/ - pea protein isolate, fortified nutritional yeast, xanthan gum, sodium alginate, guar gum, black sea salt, beta carotene
- Not Your Parents’ Tofu Scramble (The Vegg,). https://thevegg.com - soy protein, whole algal protein, whole algal flour, fortified nutritional yeast, magnesium chloride, black sea salt
- Vegan Egg Yolk (The Vegg). https://thevegg.com - fortified nutritional yeast, sodium alginate, black salt, beta carotene
- Just Egg (Eat Just, USA). https://www.ju.st/eat/just-egg - Mung bean protein isolate, rapeseed oil, onion, gellan gum, carrot extract (color), flavors turmeric extract (color), potassium citrate, salt, soy lecithin, sugar, tapioca syrup, sodium diphosphate, transglutaminase, nisin (preservative).
- Start-Up: Perfeggt (DE). https://www.perfeggt.co - Flavabean based.
- Start-Up: Nomelet (The very Company, FR/CH). https://nomelet.ch - Pea protein and chickpea protein (formulation is free of soy and gluten).

No need to remember all these companies

Examples of specific egg protein production by precision fermentation

- The Every Company (USA). https://theeverycompany.com - Formerly known as Clara Foods. Produces pepsin, egg white (ovalbumine), December 2021: Oversubscribed $175 Million Series C Round as it drives scale-up of its B2B animal-free protein platform. Partnership with Ingredion.
- Start up: Fumi Ingredients (NL)* - https://www.fumiingredients.com – egg white replacers, emulsifiers, heat set gels
- Start up: Paleo (BE)*. https://www.paleo-taste.com - Production process of six key proteins in meat and fish and is expanding its portfolio. Undefined proteins. Probably includes egg protein.

Remarks:
- Announced on Jan 7 2022: Researchers in Finland, VTT, have created ovalbumin, the primary protein in egg white, out of the fungus *Trichoderma reesei*.
https://www.greenqueen.com.hk/fungi-based-egg-white/

*Proposed as potential investment target. See slides 35-38.

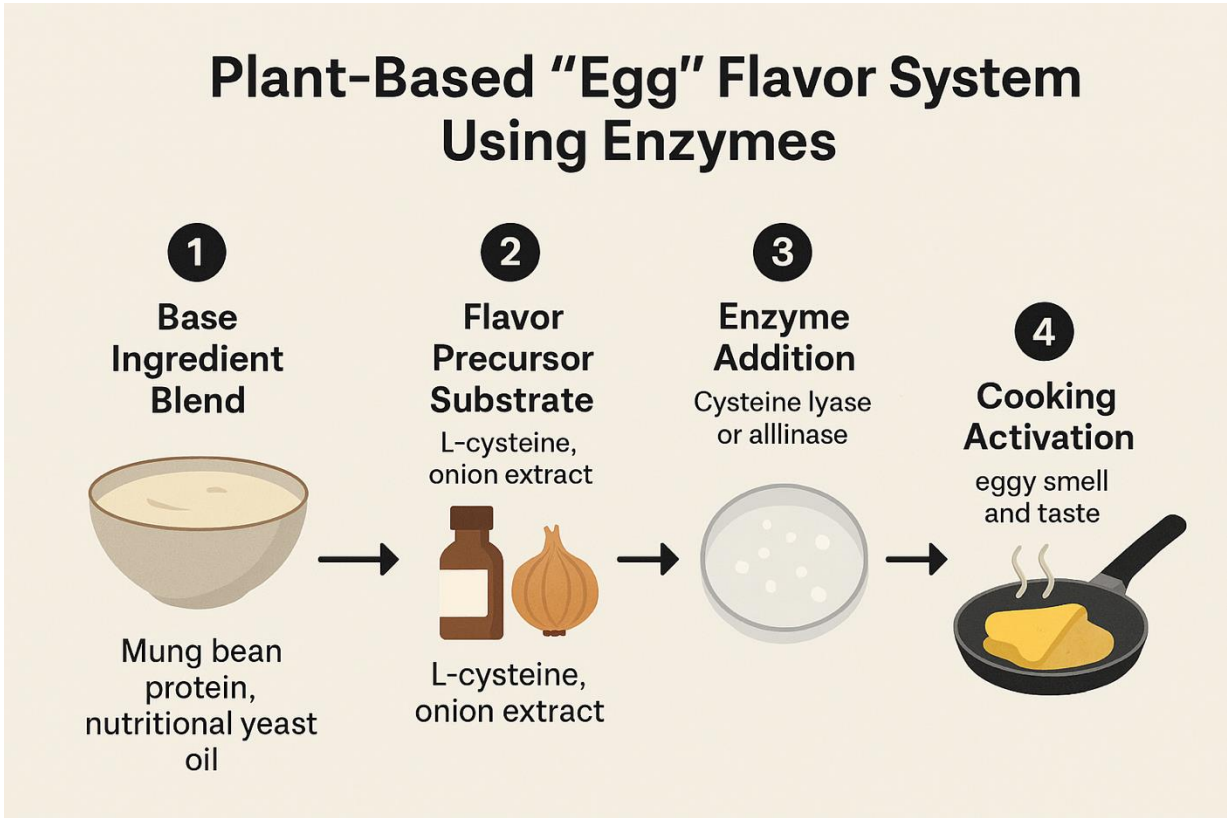
1. Base Ingredient Blend
•**Mung bean protein** (or other legume protein) — provides structure & natural sulfur amino acids (e.g. cysteine, methionine).
•**Nutritional yeast** — adds umami and some additional sulfur precursors.
•**Oil or emulsifier** — for mouthfeel.

2. Flavor Precursor Substrate
•Add natural sulfur precursors:
•**L-cysteine** (plant-derived or fermented)
•**Onion or garlic extract** (rich in **alliin**)
•Small amounts of **methionine** (optional)

3. Enzyme Addition (encapsulated or heat-activated)
•**Cysteine lyase** or **alliinase**:
•These convert sulfur precursors into:
•**Hydrogen sulfide**
•**Methanethiol**
•**Dimethyl disulfide**
•Enzyme may be **microbially derived**, and either:
•Pre-activated before packaging
•**Encapsulated** and activated by **heat during cooking**

4. Cooking Activation
•When the consumer cooks the product (e.g., scrambles it), the **heat activates** the enzyme:
•Sulfurous volatiles are released.
•The result is the **authentic cooked egg aroma**.

Result:
•Scrambled, folded, or poured product with:
•Soft texture
•Bright yellow color (often from turmeric or carrot extract)
•And that signature **eggy smell and taste**, entirely from **plant sources and enzymatic flavor reactions**.



Miscellaneous

- Digestible Indispensable Amino Acid Score (DIAAS) score
- Emerging technologies and trends
  3D Bioprinting, Hot Moisture Extrusion and Shear Cell Technology, Genetic Engineering, Probiotic and prebiotic fermented food
- Options for ‘probiotization’
- Brief comments about the regulatory framework
- How can we grow the alternative protein market?

https://www.un.org/en/food-systems-summit/good-food-for-all

Watch out: Single plant based alternative protein solutions may have a lower Digestible Indispensable Amino Acid Score (DIAAS), which can be compensated by combinations of different protein sources

Today the nutritional aspects of the plant based food are not yet broadly addressed, although some companies start mentioning it

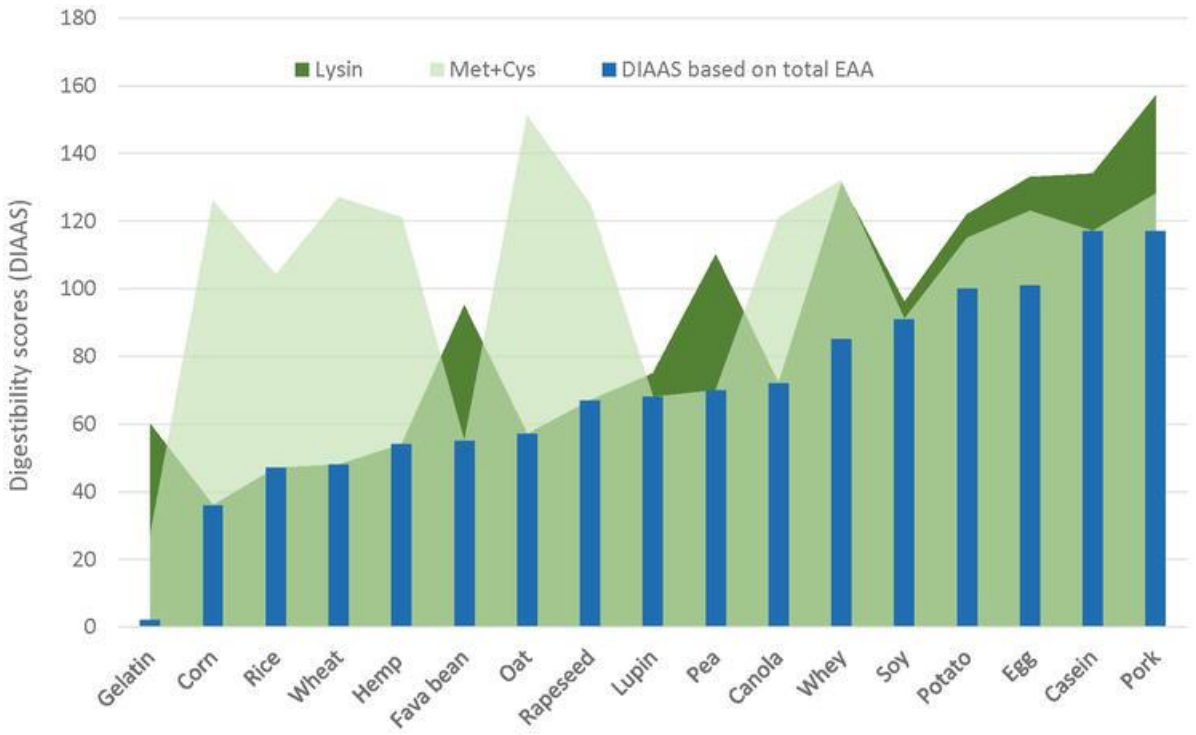
DIAAS
A protein source reaching a DIAAS of 100 or above indicates that none of its amino acids is limiting and this sole protein source should be able to meet physiological requirements. For instance, potato protein, egg protein, casein, and pork meat reach the 100 score

For a protein source with a DIAAS lower than 100, strategies are possible to ensure an adequate protein intake based on such protein:

a) increase the protein intake of the limiting protein until the physiological requirement is reached.

b) combine protein sources and ensure complementarity of their amino acids to reach a higher DIAAS.

Phuture Foods (MY) has developed a plant-based alternative to pork for the Chinese consumer market including several different crops/mushrooms providing a complete amino acid profile, https://phuturemeat.



Digestibility scores (DIAAS) of limiting EAAs (lysine and methionine+cysteine) and DIAAS of 17 dietary protein sources according to the 0.5-to 3-year-old reference pattern score.

Herreman L, et al. Comprehensive overview of the quality of plant- And animal-sourced proteins based on the digestible indispensable amino acid score. Food Sci Nutr. 2020 Aug 25;8(10):5379-5391. doi: 10.1002/fsn3.1809.
Hertzler SR, et al. C. Plant Proteins: Assessing Their Nutritional Quality and Effects on Health and Physical Function. Nutrients. 2020 Nov 30;12(12):3704. doi: 10.3390/nu12123704. PMID: 33266120;

Selected emerging technologies - 3D Bioprinting Serves Up Meat Alternatives

The 3D printing process can recreate a muscle-like matrix through micro-extruding filaments using a plant-based paste or cultured cells. Several start-ups have adapted 3D printing technology used in the manufacture of durable goods for use with biological food inputs to build slabs of protein with the desired appearance .

Redefine Meat (Israel, https://www.redefinemeat.com)
Redefine Meat is on a mission to introduce a technological platform to develop, launch and scale the next generation of Alt-Meat. Redefine Meat is applying proprietary 3D printing technology, meat digital modelling, and advanced food formulations to produce animal-free meat with the appearance, texture and flavor of whole muscle meat. (IP on their 3D printers).

Novameat (Spain, https://www.novameat.com)
Novameat is the world's first developer of plant-based micro-extruded fibrous meat. Plant-based meat reinvented. Nova Meat's bioprinting-based tech gives planted-based meat manufacturers a wider array of tools to create different textures from a wide variety of ingredients, to mimic all types of meat and seafood.
This technology is able to use bioprinting strategies and adapt them to generate a meat substitute.

Aleph Farms (Israel, https://www.aleph-farms.com)
Aleph Farms is growing real beef steaks from the cells of cows and applying proprietary 3D printing technology.

Revo Foods (Austria, https://revo-foods.com)
The Austrian startup created a new technology based on food 3D printing that relies on plant-based ingredients, like pea proteins and algae extracts, that recreate the texture, color, and taste of authentic seafood.

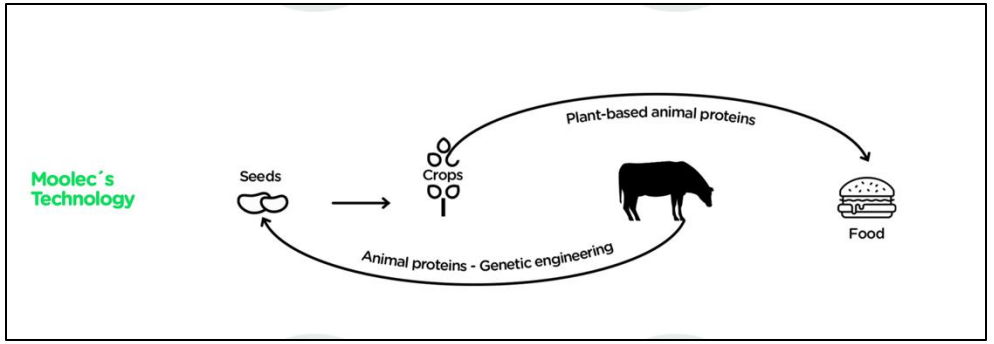
https://www.magoda.com/food/3d-bioprinting-serves-up-meat-alternatives/

Selected emerging technologies – Genetic engineering of plants and microorganisms

Application of genetic engineering (GE) in alternative meat protein is not new. Already for decades GE soy and maize are produced and have found their way to the consumer, especially in USA.

Also precision fermentation is often using genetically engineered micro-organisms (yeast, bacteria, or algae) for the sustainable production of valuable ingredients (flavors, fats and protein) for the alternative meat and dairy industry. Well-known companies applying this technology are Impossible Foods, Perfect Day and The EVERY Company, but also more recently founded companies such as New Culture, Change Foods, Cultivated Food Labs, and Formo, are all developing and using genetically engineered micro-organisms to serve their purpose.

One step further goes USA based **Nobell** Iceland based **ORF Genetics** and UK based start-up **Moolec**, who produce animal like protein by genetic engineering of plants. It remains to be seen how more cost-effective and complete these plant factories will be compared to algae and yeast based precision fermentation.



Moolec's products are based on the genetic engineering of plants to include animal genetic information in order to enable them produce proteins the way animals doMoolec: https://www.moolecscience.com

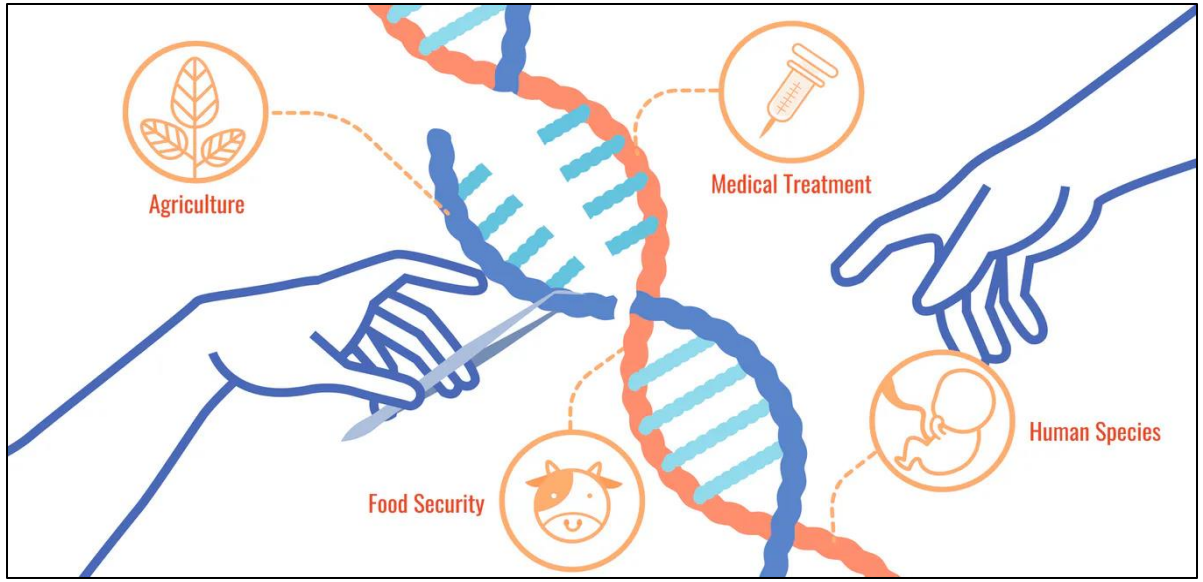
Animal growth factors for the cell cultured meat and other related industries https://www.orfgenetics.com

Selected emerging technologies – Genetic engineering of plants and microorganisms

A genetic engineering technology that is likely to accelerate the development in strain, cell and crop improvement is CRISPR. This gene editing tool has already facilitated the shelf life extension of mushrooms, and can also be applied for reduction of bitterness in crops like pea, as has been explored by University of Berkely spin-off company CRISPea. Where the application of CRISPR to knock out genes for elimination of undesired traits can be seen as a relatively low barrier application, the incorporation of new genes that bring in new traits will certainly require more regulatory approval and consumer acceptance.

In theory GE options for better and more sustainable food are endless. From faster growing and more resistant crops, to plant-based dairy with intrinsic strawberry or chocolate flavor, to fermented food delivering immune factors to your body. Experts expect that consumer acceptance will grow if purpose and benefits of the GE crops can be well explained and deliver meaningful improvements over the non GE alternative.

Also in the area of cell culture development, GE is expected to make cells which are capable to proliferate faster and better on less expensive growth media.

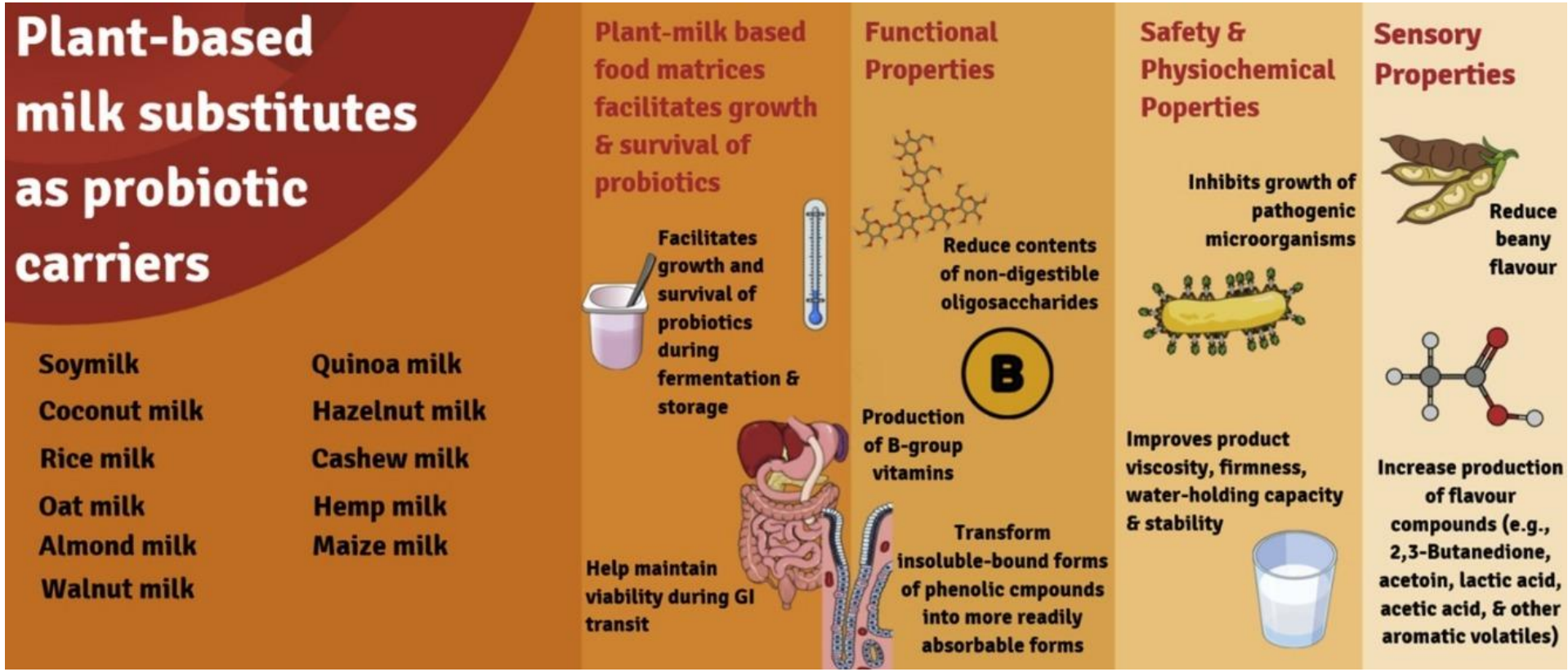


Impression of CRISPR GE technology

Probiotic and prebiotic fermented food

Food and nutrients play an integral role in maintaining overall mental and cognitive health. After almost two years of COVID-19 limitations, mental and physical wellbeing -including gut health- is receiving massive attention and awareness in the society.

The nutritional and health opportunity exploration of plant based dairy and meat alternatives has been relatively low. One of the companies entering this area is Israelian start-up Yofix Probiotics*. Its formulations are marketed as clean labelled, and include a proprietary blend of oats, lentils and sunflower seeds. In addition to being soy-free, the company's range of plant-based dairy substitutes contains gut-healthy prebiotics and probiotics.



Dissanayake, et al. Current Opinion in Food Science. 2021, 38, 8-20. https://doi.org/10.1016/j.cofs.2020.10.025.

"Probiotization"
Leveraging the gut microbiome white space in the alternative protein industry

The Reason Why
→ Results from a 2021 study

Cell

CellPress

Article

Gut-microbiota-targeted diets modulate human immune status

Hannah C. Wastyk,[2,7] Gabriela K. Fragiadakis,[1,7] Dalia Perelman,[3] Dylan Dahan,[1] Bryan D. Merrill,[1] Feiqiao B. Yu,[5] Madeline Topf,[1] Carlos G. Gonzalez,[4] William Van Treuren,[1] Shuo Han,[1] Jennifer L. Robinson,[3] Joshua E. Elias,[5] Erica D. Sonnenburg,[1,6,*] Christopher D. Gardner,[3,*] and Justin L. Sonnenburg[1,6,8,*]

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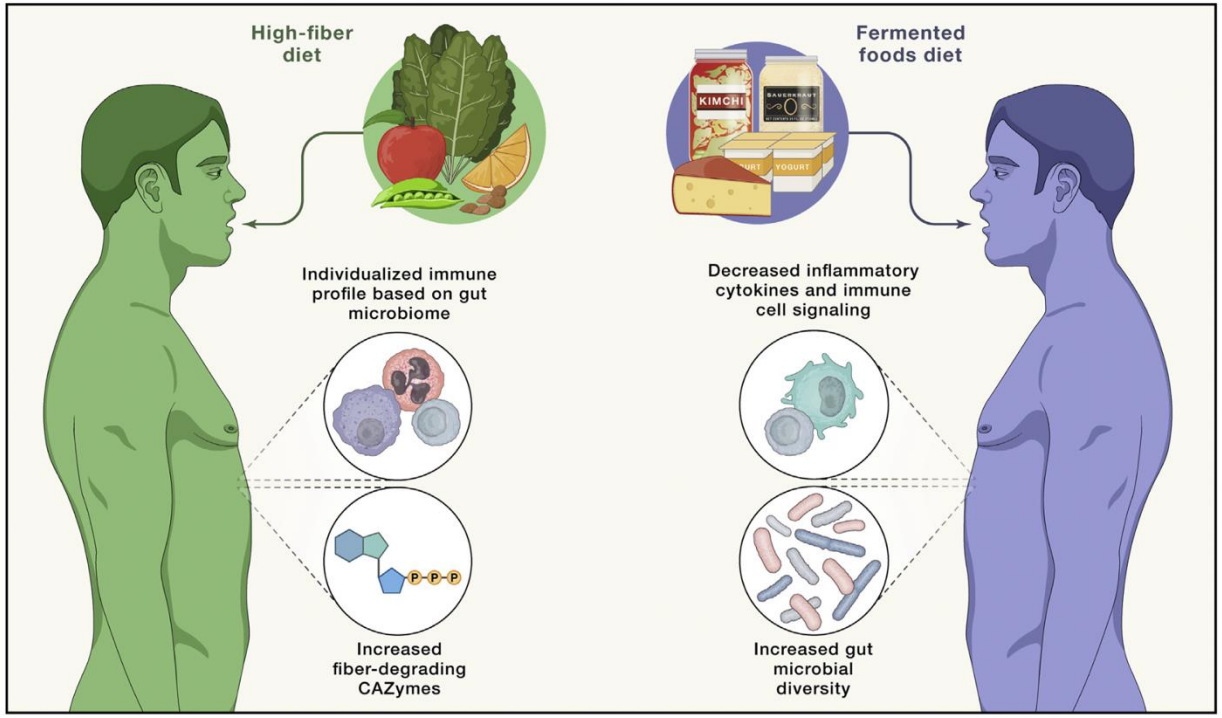
https://doi.org/10.1016/j.cell.2021.06.019

A new study (November 2021), carried out by researchers at Stanford University, shows that fermented-food diet may increase microbiome diversity and decrease markers of inflammation. In the same study high-fiber diet shows potential in altering gut microbiome functions and modulating immune responses.
https://doi.org/10.1016/j.cell.2021.06.019



→ *This study contributes well to earlier insights that fermented food and fiber rich foods are central elements for creating a resilient and diverse microbiome and essential for human health*
→ *The study also shows that fibers have less impact, potentially due to the already reduced concentration of essential fiber degrading bacteria in the 'urbanized' human microbiome*

"Probiotization"
Leveraging the gut microbiome white space in the alternative protein industry

The Reason Why

→ Results from a remarkable 2015 study

nature COMMUNICATIONS

ARTICLE

Received 23 May 2014 | Accepted 20 Jan 2015 | Published 28 Apr 2015 DOI: 10.1038/ncomms7342

Fat, fibre and cancer risk in African Americans and rural Africans

Stephen J.D. O'Keefe[1], Jia V. Li[2], Leo Lahti[3,4], Junhai Ou[1], Franck Carbonero[5,†], Khaled Mohammed[1], Joram M. Posma[2], James Kinross[2], Elaine Wahl[1], Elizabeth Ruder[6], Kishore Vipperla[1], Vasudevan Naidoo[7], Lungile Mtshali[7], Sebastian Tims[3], Philippe G.B. Puylaert[3], James DeLany[8], Alyssa Krasinskas[9], Ann C. Benefiel[5], Hatem O. Kaseb[1], Keith Newton[7], Jeremy K. Nicholson[2], Willem M. de Vos[3,4,10], H. Rex Gaskins[5] & Erwin G. Zoetendal[3]

In 2015 scientists already have found dramatic effects on risk factors for colon cancer when American and African volunteers swapped diets for just two weeks. Western diets, high in protein and fat but low in fibre, are thought to raise colon cancer risk compared with African diets high in fibre and low in fat and protein.

The study, published in Nature Communications, confirms that a high fibre diet can substantially reduce risk, and shows that bacteria living in the gut play an important role in this effect. DOI: 10.1038/ncomms7342

- → *This study contributes well to earlier insights, indicating that fiber-rich foods are central elements for creating a resilient and diverse microbiome and associate with human health factors.*
- → *This study confirms once more that a diet rich in animal protein associates with increased risks for colon cancer*

Selected emerging technologies – Extrusion and Shear Cell Technology

Extrusion
Extrusion is a common practice and extensively used to convert 50–70% protein-containing plant-based materials to fibrous products. It is a thermomechanical process that uses a combination of pressure, heat, and mechanical shear

In the extruder, proteins are subjected to high temperatures and pressures that cause the proteins to melt and denature, losing their tertiary or even secondary structure.

New cross-linking is what texturizes the proteins and transforms globular plant proteins into structures that more closely resemble the fibrous and laminar construction of meat. As the material exits the die at the end of the extruder, the water in the mixture rapidly evaporates due to the high temperatures and release of pressure, causing the material to expand and creating the final puffed format.

In addition to creating a meat-like structure, extrusion can also modify the color and flavor of protein components. Many undesirable flavors are volatile and will flash off along with moisture at the release of pressure at the end of the extruder.

Research and application example:
Public Private Partnership PlantPromise coordinated by Wageningen
Partners: AVEBE, Brabender, Firmenich, FujiOil, Marel, Nomad Foods, Ojah and Unilever

Shear cell technology
The shear cell technology was introduced by a group of researchers at Wageningen University, Netherlands, around 2005. It is another technique where a combination of shear and heat are used to form plant-based meat analogues, with layered fibrous structures, that resemble the mouthfeel and texture of real meat steak.

The shearing device used in this technology is called shear cell, where intensive shear can be applied. Protein deformation in the shear cell is well defined and constant, mechanical energy input in structuring is low; therefore, the shear cell technology has less variation in product quality compared to extrusion.

Research and application example:
Public Private Partnership Plant Meat Matters coordinated by Wageningen Food & Biobased Research and Wageningen University.
Partners: Meyn, Avril, Givaudan, Saturn petcare, Nutrition & Santé, The Vegetarian Butcher, Unilever, Ingredion, Rival Foods

Brief comments about the regulatory framework

- **Plant based meat alternatives** (PBM) are regulated in a similar manner as other non-animal foods. In the United States, the Food and Drug Administration (FDA), and specifically the Center for Food Safety and Applied Nutrition (CFSAN), oversees food inspection, labelling, packaging, imports, and facility safety. Most PBM products contain simple ingredients that have previously been approved for human consumption.

- In the European Union (EU), current policy and regulation are supportive for alternative proteins innovation and investment. In 2018, the European Commission presented a "**EU Protein Plan**", which encourages the production of alternative proteins for human consumption, and listed existing EU policy instruments that "provide options for strengthening the development of EU-grown plant proteins".

- **Cell based meat** faces the hardest regulatory approval challenges. So far only Singapore has approved commercialisation Eat Just chicken cell cultured products. USDA, FDA, as well as EU and other countries, including Japan, South Korea and China are working on regulatory frame works. Opposition from farming lobby is delaying the process. A new association called Cellular Agriculture Europe has been formed to represent the interests of the cultivated products industry. In USA the Alliance for Meat, Poultry and Seafood Innovation (AMPS Innovation) serves a similar purpose.

- **Fermented biomass** regulatory approval is seen as more complicated than PBM, but less complicated than cultured meat cells. For instance, following the largely marketed quorn fungal protein, in June 20201 Nature's Fynd has been given the go-ahead from the U.S. Food and Drug Administration to use its fungi-based protein Fy in food applications. The company has also sought for regulatory approval for selling Fy in Hong Kong and in mainland China.

- Regulatory approval for **precision fermentation-derived products** is seen as less complicated compared to cultured meat cells. For instance precision fermentation-derived rennet for dairy cheese production has globally been widely approved. Also market leader Impossible Foods secured approval for its precision fermentation-derived leghemoglobin in several global markets, including its home market US. However, Impossible Foods is still waiting for approval of its in 2019 filed request in EU. Therefore, for many new molecules several markets will present regulatory challenges, that take time to be navigated due to the fact that the precision fermentation process can involve gene editing or gene modification. Where as many of the newly produced ingredients in EU can follow the novel food approval process, more complicated in this category is mainland China, where any food that includes these steps in its production has a very challenging regulatory pathway to approval.

How can we grow the alternative protein market?

Reflection on which impact factors will grow the sector and drive consumers towards this market

What can authorities do:

The (EU) political framework needs to change and push further for animal-free alternatives.

- Consider installation of energy foot print taxes (as with sugar taxes)
- Stop subsidizing meat industry, start subsidizing crop conversion (from feed to alternative proteins)
- Consider subsidizing plant based or biomass based food

What can the sector collectively do:

- Agree on CO2 foot print or life cycle assessment score label (see back up slide with example from meat industry on animal well fare)
- Collectively contribute xx % or purchase price to funds and applications of common public interest
- Invest in science and fact based public education on meat vs alternative protein solutions
- Support/initiate initiatives such as www.abillion.com

What can general public / NGOs do?

- Supporting campaigns around climate and animal well fare
- Demand for initiatives like*: "Carnivoor? Geef het door!" (Carnivore?Llet us know)*
- Raise their voice at formal and informal occasions in their private and professional environment

NYC Expands Meatless Monday to All Public Schools

https://www.mondaycampaigns.org/meatless-monday

What can multinationals and investors do?

- Invest in food systems, communities and/or platforms
- Introduce crowd funding initiatives that offer clear results and benefits for public
- For Food retail: Set standards for sustainably produced alternative protein food. (See example German retail sector on animal well fare. Back up slide).
- Invest in vegan-only out of home/restaurant chains

Back up slides

Alternative Protein News Sources

Great weekly newsletter
From: FoodTech Weekly <foodtechweekly@mail.beehiiv.com>
Reply to: FoodTech Weekly <ds1337@georgetown.edu>
Date: Friday, 15 March 2024 at 09:00
To: Wilbert Sybesma <wilbert.sybesma@microbiome-solutions.com>
Subject: FoodTech Weekly #188 by Daniel S. Ruben

https://www.greenqueen.com.hk

https://vegconomist.com/all-news/

https://www.foodhack.global

https://innovationisrael.org.il/sites/default/files/GFI%20Israel%20State%20of%20Alternative%20Protein%20Innovation%20Report%202021_0.pdf

https://gfi.org/wp-content/uploads/2021/04/COR-SOTIR-Fermentation-2021-10-01-1.pdf

https://www.luxresearchinc.com/blog/plant-proteins-key-players

https://www.greenqueen.com.hk/apac-food-tech-report-2021/

Alternative Protein Databases

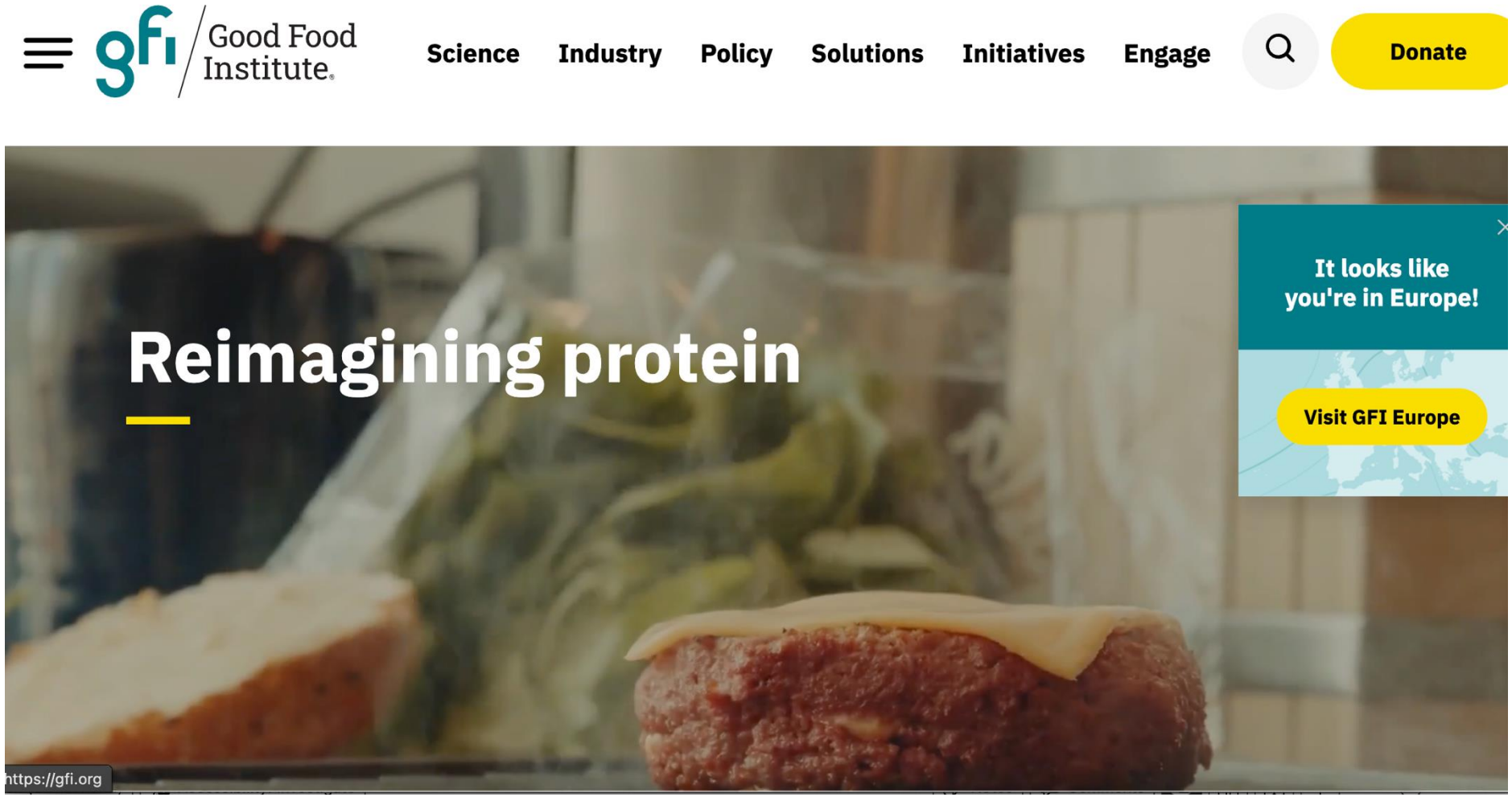
https://www.crunchbase.com

https://gfi.org/resource/alternative-protein-company-database/

https://proteindirectory.com

Critical reflection on (in)feasibility of cultured meat

https://thecounter.org/lab-grown-cultivated-meat-cost-at-scale/



https://gfi.org/

Example: German classification for animal derived products, based on quality of animal treatment

Aldi Germany will only sell products level 3 and 4 as of 2030

How can this be expanded to alternative protein products?

https://www.verbraucherzentrale.de/wissen/lebensmittel/lebensmittelproduktion/haltungsformkennzeichnung-im-handel-die-auswahl-bleibt-mangelhaft-25484