

State-of-the-art in precision fermentation and a potential application of models to support risk-assessment of products

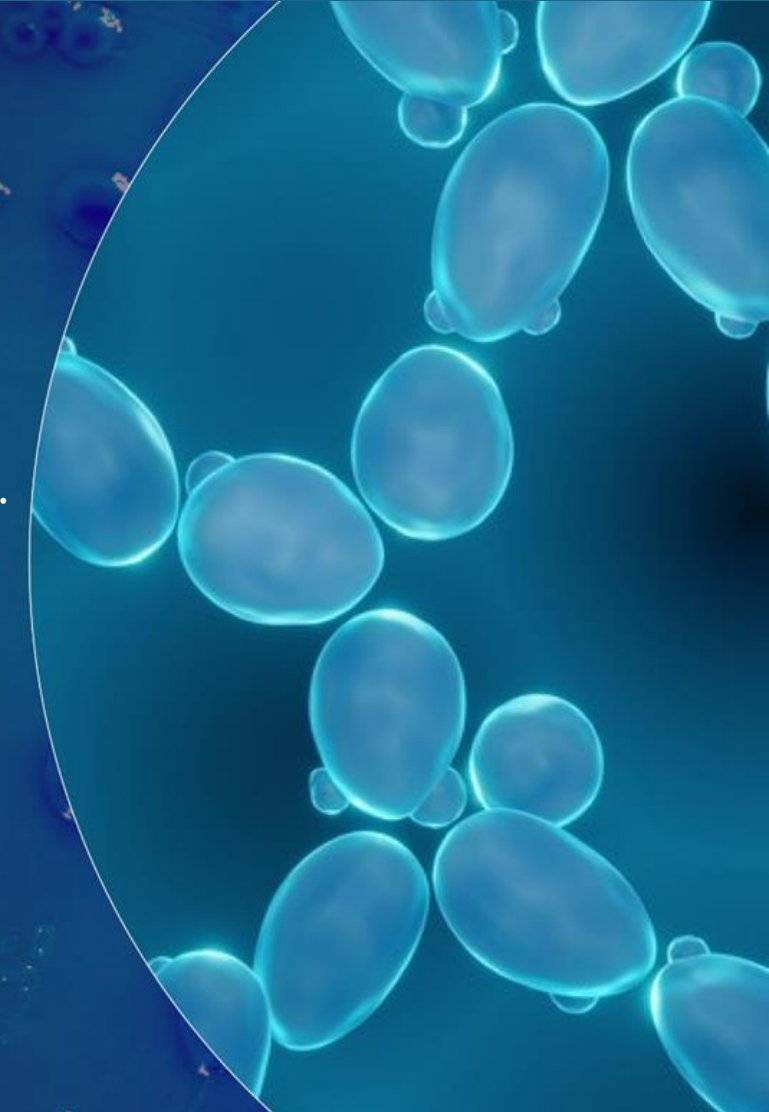


Fermentation is a logical choice for production of food ingredients, as many strains have been domesticated exactly for this purpose.



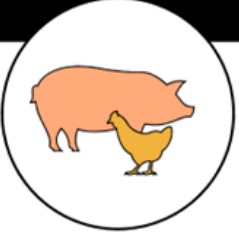



Modern Biotechnology gives us the tools to quickly train/engineer these organisms to produce food ingredients.

DSP is essential for product purification – bio-similars

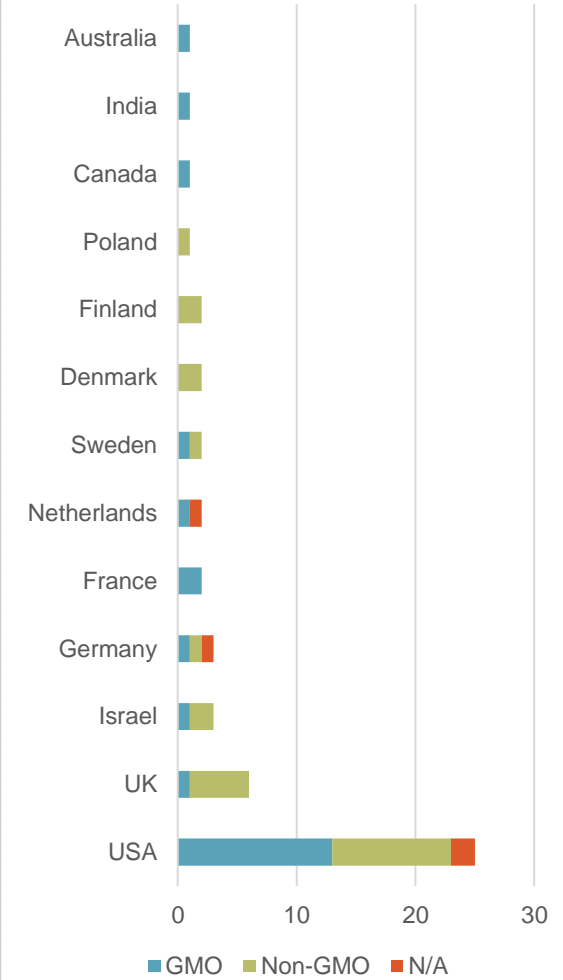
Fermentation enables carbon-footprint reduction and sustainable production of high yields of pure products.





Application	Traditional fermentation	Enhanced fermentation	Animal Feed	Ingredient production	Meat & Dairy alternatives	Single Cell protein
						
State-of-the-art	<p>Used historically and currently in processes such as:</p> <ul style="list-style-type: none"> • Alcohol production • Food preservation • Taste and texture development 	<p>Strain chosen, bred or engineered to improve:</p> <ul style="list-style-type: none"> •Taste •Texture •Health benefits 	<p>Biomass used in feed as:</p> <ul style="list-style-type: none"> • Nutritional supplement • Primary food source • Nutraceutical and/or therapeutic platform 	<p>Production and purification of native or recombinant food additives for:</p> <ul style="list-style-type: none"> • Nutrition • Taste/odour • Processing 	<ul style="list-style-type: none"> • Microbial meat analogues recreating nutrition, taste and texture. • Production of animal products components in cell factories. 	<ul style="list-style-type: none"> • Microbial food product including as a: <ul style="list-style-type: none"> • Primary source of protein • Complete food source • Health supplement
Engineering & future developments	<ul style="list-style-type: none"> • Active preservation of traditional techniques • Historical research into understanding early fermentation techniques in ancient cultures 	<ul style="list-style-type: none"> • Using -omics tools to select and breed optimal strains for processes • Engineered strains producing additional vitamins, PUFAs, taste, odour in fermenting strains 	<ul style="list-style-type: none"> • Strains chosen or engineered to match needs of specific animals, agricultural methods and aims. • Engineered into a therapeutic platform • Biomass growth on waste substrate to optimise sustainability. 	<ul style="list-style-type: none"> • Engineered pathways to produce non indigenous chemicals, proteins or other biological substances. • Engineered living therapeutics, drugs delivered using probiotics. 	<ul style="list-style-type: none"> • Engineered nutritional or texture elements allowing for closer resemblance to meat. • Animal flavourings produced in cells to such as haemoglobin or lactose. 	<ul style="list-style-type: none"> • Engineered to improve nutritional profiles. • Engineered into a therapeutic platform. • Growth on waste substrates to optimise sustainability. • Engineered taste compounds to improve organoleptic properties.

Name	Focus	Country	GMO	Organism	Product
Shiru	Ingredients	USA	✓	Yeast and fungi	Flourish™: protein discovery platform for food ingredients (currently: gelling agents.)
Oobli (formerly Joywell)	Ingredients	USA	✓	Yeast: <i>Pichia pastoris</i>	Sweet proteins
EVERY company (formerly Clara Foods)	Ingredients	USA	✓	Undisclosed	Eggs: EVERY EggWhite™, EVERY Protein™, Pepsin: EVERY Pepsin
Geltor	Ingredients	USA	✓	E.coli	Collagen: PrimaColl®
Melibio	Ingredients	USA	✓	Undisclosed	Honey
Impossible foods	Ingredients	USA	✓	<i>Pichia pastoris</i>	Animal alternative processed meats
Perfect day	Ingredients	USA	✓	Yeast	Dairy: Whey
Better Dairy	Ingredients	UK	✓	Undisclosed	Dairy: Casein
Change Foods	Ingredients	Australia/ USA	✓	Undisclosed	Dairy: Casein
New Culture Food	Ingredients	USA	✓	Undisclosed	Dairy: Casein
Nutropy	Ingredients	France	✓	Yeast	Dairy: Casein
Standing ovation	Ingredients	France	✓	Undisclosed	Dairy: Casein
Formo (formerly LegenDairy)	Ingredients	Germany	✓	Undisclosed	Dairy :'bioidentical milk protein'
Remilk	Ingredients	Israel	✓	Yeast	Dairy: Milk proteins
Mycotechnology	Ingredients	USA	✗	Filamentous Fungi: multiple	Fermented plant proteins: FermentIQ™, Bitter blocking and flavour modulating: ClearIQ™
Motif foodworks	Ingredients	USA	✓	Yeast	Animal free ingredients: Haem: HEMAMI™,
Planet A Foods	Ingredients	Germany	✓	Yeast	Cocoa butter
C16 Bioscience	Ingredients	USA	✓	Coculture: oleaginous yeast +	Palm oil
Melt&Marble	Ingredients	Sweden	✓	Yeast	Animal Fats: beef fat
Nourish ingredients	Ingredients	Australia	✓	Yeast	Animal Fats
Corbion	Ingredients	Netherlands	✓	Microalgae: <i>Chlorella</i> spp., <i>Prototheca</i>	Lactic Acid and its derivatives/ Algal oil SCO and SCP
Manus Bio	Ingredients	USA	✓	Multiple	Food ingredients: diverse
Skotan	Feedstock/aquaculture / Ingredients	Poland	✗	<i>Yarrowia lipolytica</i>	Animal Feed: Equinox Horse food, Caniflow dog and cat food,
Lallemand	Feedstock/aquaculture / Ingredients	Canada	✓	Multiple	Bacteria and yeast speciality products in many areas.
Unibio	Feedstock/aquaculture	Denmark	✗	<i>Methylococcus capsulatus</i>	Animal Feed: Uniprotein®
Novus International	Feedstock/aquaculture	USA	✗	B.licheniformis	Animal Feed Supplement: Cibenza®, protease from B.licheniformis
Kiverdi	Feedstock/aquaculture	USA	✓	Undisclosed	Fish feed: CO2 AQUAFEED , Palm oil
Novonutrients	Feedstock/aquaculture	USA	✗	Bacterial	Fish feed
Nutrisinc (acquired by iCell)	Feedstock/aquaculture	USA	✗	Bacterial	Fish feed
KnipBio	Feedstock/aquaculture	USA	✓	<i>Methylobacterium extorquens</i>	Fish feed: KnipBio Meal (Taurine and Carotenoid enriched)
Deep branch	Feedstock/aquaculture	UK	✗	Undisclosed	Fish Feed: Proton™
Calysta	Feedstock/aquaculture / SCP	UK	✗	Methane oxidizing bacteria	Animal and Fish feed: FeedKind®, SCP: Positive Protein
String Bio	Feedstock/aquaculture/ SCP	India	✓	Bacterial methanotroph	Animal and Fish feed: aquaculture and poultry, SCP: human food
Enifer	Feedstock/aquaculture / SCP	Finland	✗	Filamentous Fungi : <i>Paecilomyces</i>	Mycoprotein SCP and feed: PEKILO®
Solar foods	SCP for humans	Finland	✗	Chemoautotrophic bacteria	Bacterial SCP food
Quorn (Marlow Foods)	SCP for humans	UK	✗	<i>Fusarium venenatum</i>	Quorn® meat-alternative products: various
Air protein	SCP for humans	USA	✓	Undisclosed	Air Protein: protein powder
MyForest Foods (formerly Atlast Food Co)	SCP for humans	USA	✗	Filamentous Fungi	MyBacon® Strips
The protein brewery	SCP for humans	Netherlands	✗	Filamentous Fungi	Mycoprotein SCP
Natures Fynd	SCP for humans	USA	✗	<i>Fusarium yellowstonensis</i>	Fy Protein™: Meat Patties and cream cheese substitute
Marmite (Unilever)	SCP for humans	UK	✗	Brewers yeast	Marmite
Meati™ Foods	SCP for humans	USA	✗	Undisclosed	Mycoprotein SCP: Meati™, Whole Cuts substitute
Prime roots	SCP for humans	USA	✗	<i>Aspergillus oryzae</i>	Mycoprotein SCP: charcuterie, ham, bacon substitute
Brevel	SCP for humans	Israel	✗	Microalgae	Microalgae protein supplement
Superbrewed Food	SCP for humans	USA	✗	Gut Bacterium	Fortified protein milk and cream
Bosque Foods™	SCP for humans	Germany	✗	Undisclosed	Mycoprotein SCP: Whole cuts
Mycorena	SCP for humans	Sweden	✗	Filamentous Fungi	Mycoprotein B2B SCP: Promyc®
Enough	SCP for humans	UK	✗	<i>Fusarium venenatum</i>	ABUNDA B2B mycoprotein seafood alternative ingredient
The Mediterranean Food Lab	Fermented animal product alternative	Israel	✗	Multiple	Meat alternatives: Fermented Plant protein
Miyoko Creamery	Fermented animal product alternative	USA	✗	Multiple	Fermented plant milk cheese products
MATR Foods	Fermented animal product alternative	Denmark	✗	Fungi	Meat alternatives: Fermented Plant protein





Plant-based Whole organism

Interesting for:

consumptions of whole or part of the biomass of the organism itself

Less effective for single molecule products



Cell-based meat Special functionality

Interesting for:

specific replacements of mammalian consumption products where the tissue is the actual product

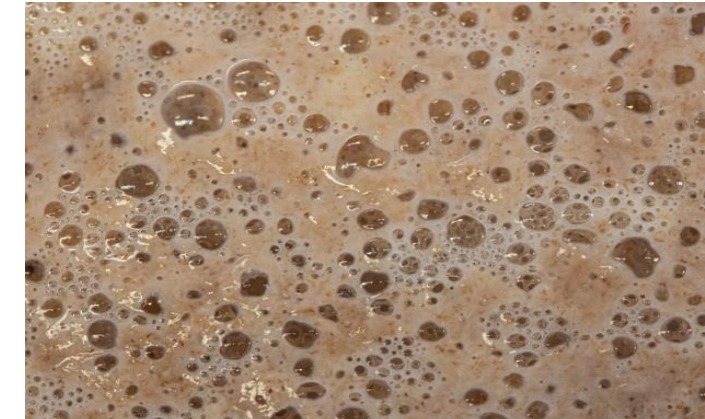


Fermentation Product specific

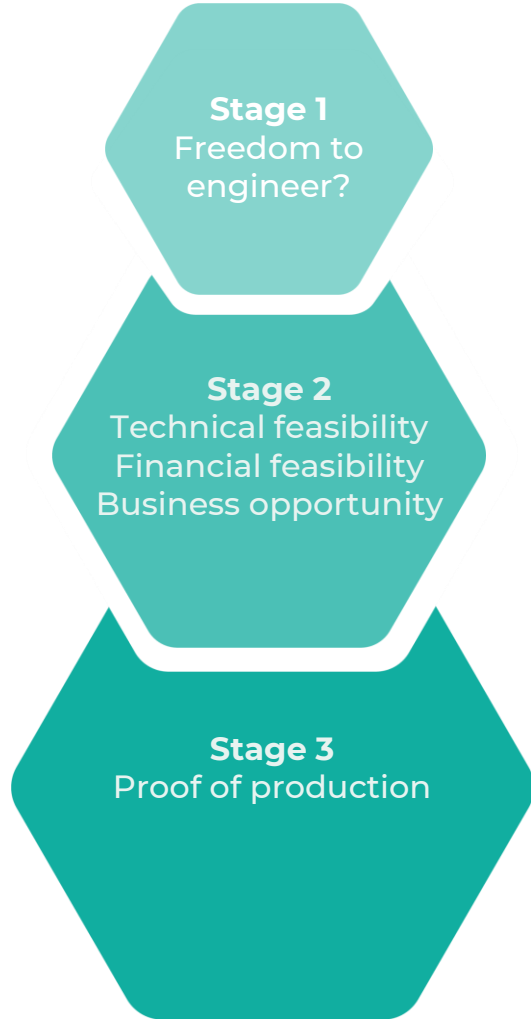
Interesting for:

single molecule products, biomass

E.g. nutritional proteins, lipids, flavor molecules, vitamins

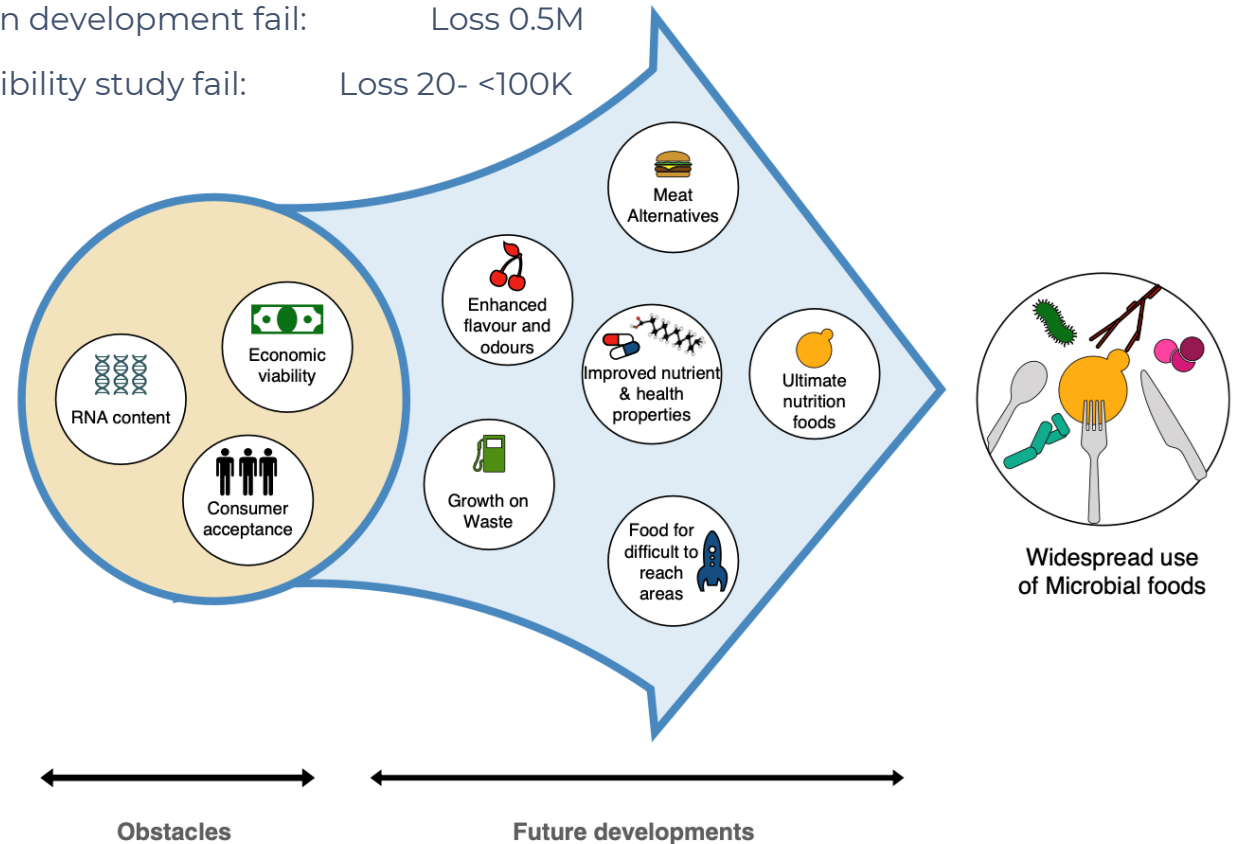


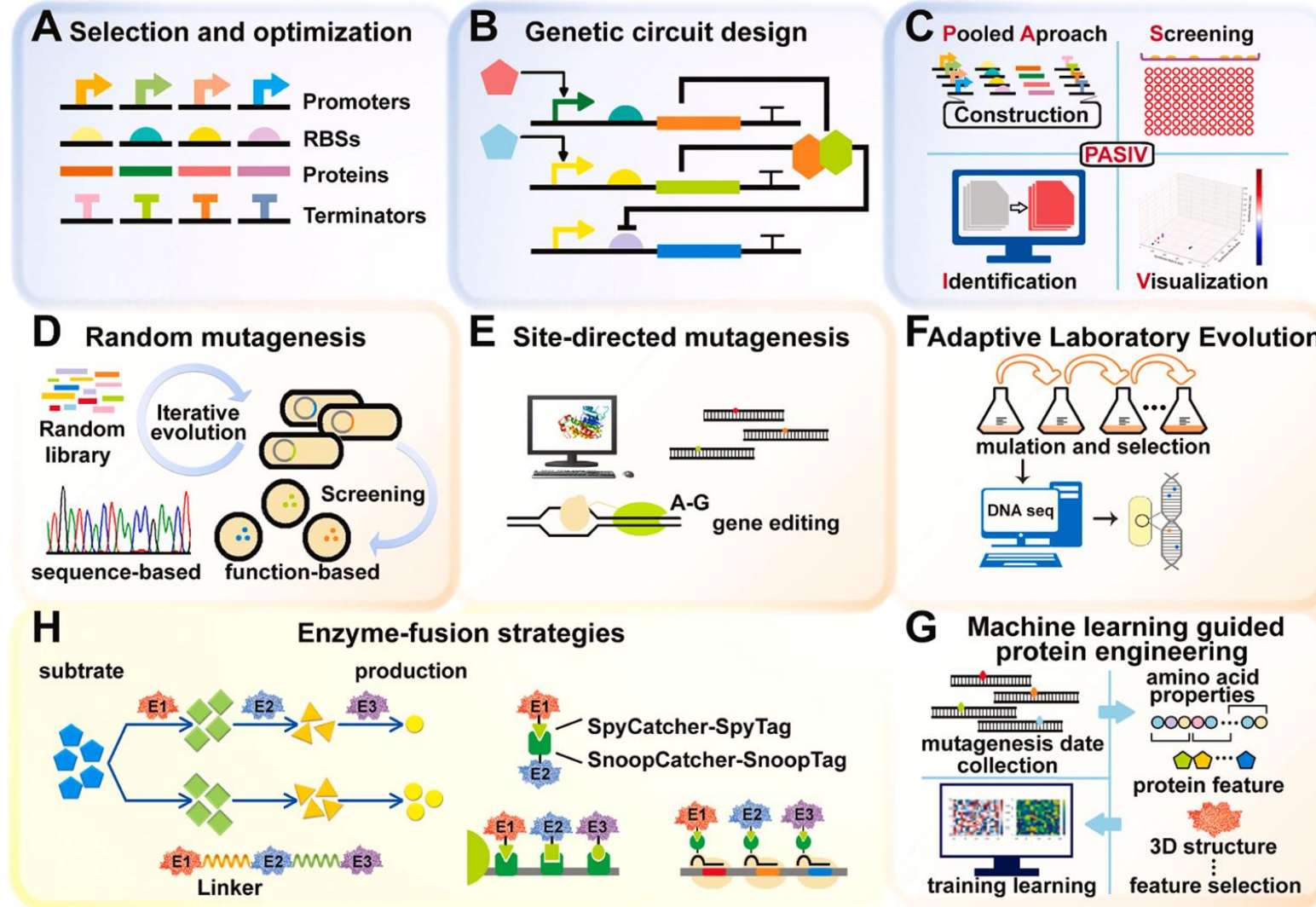
De-risk a project at earliest possible stage

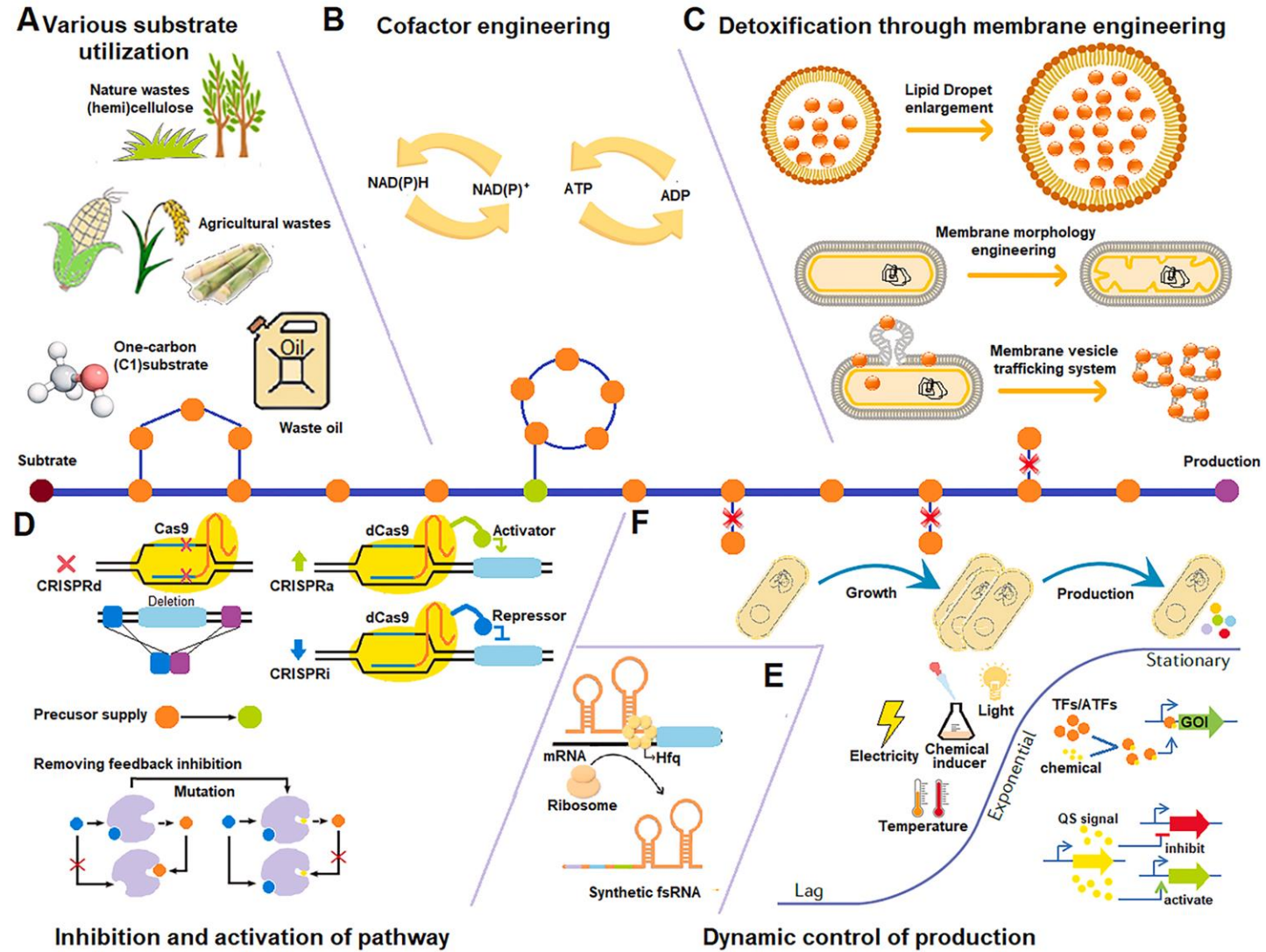


Fail fast to reduce loss of resources

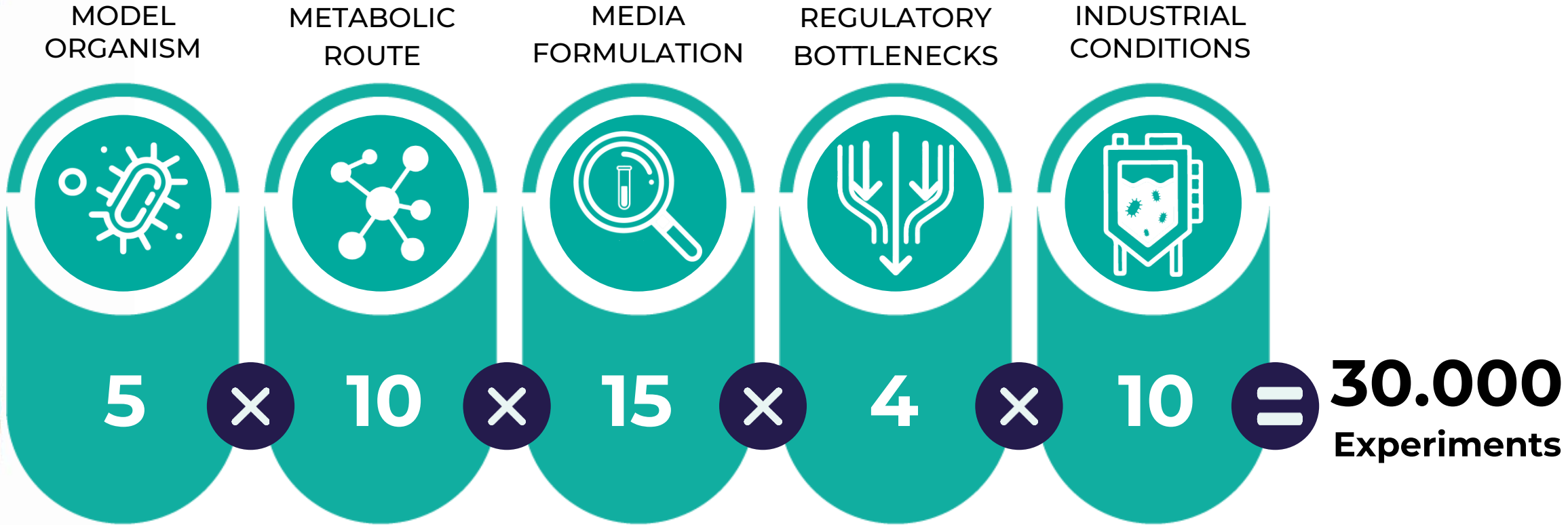
- Commercialisation fail: Loss 100M
- Upscaling fail: Loss 1 - 2M
- Strain development fail: Loss 0.5M
- Feasibility study fail: Loss 20- <100K



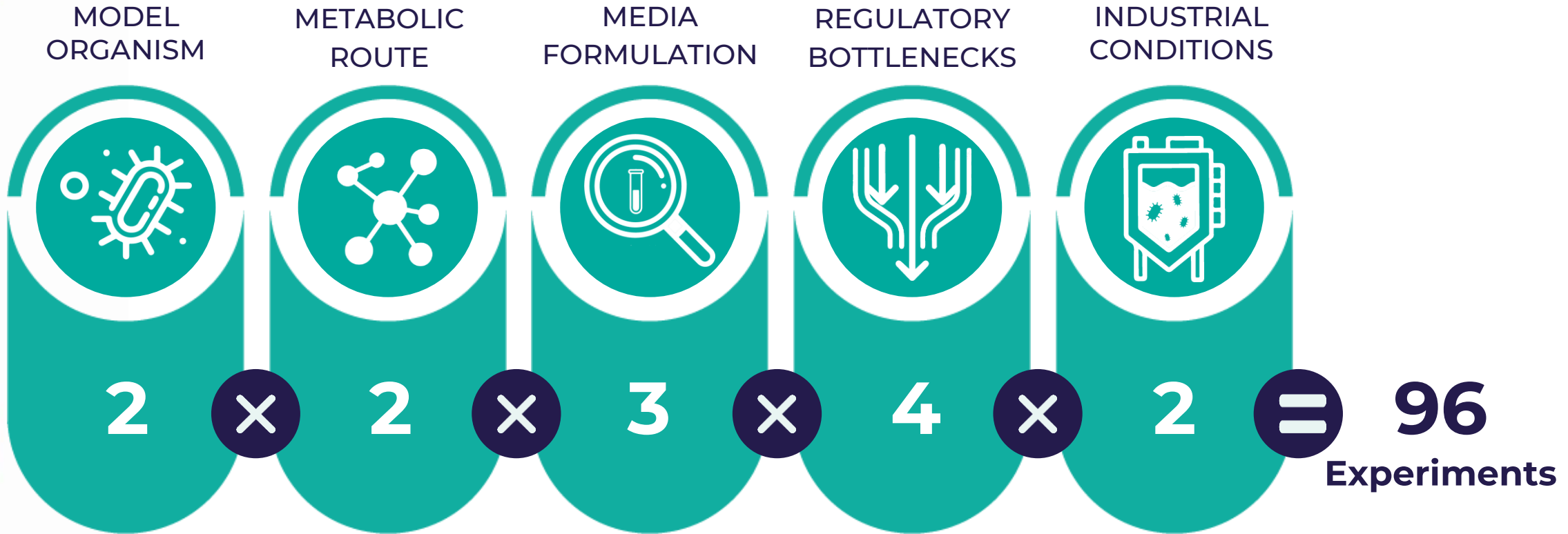




How many possibilities are there?



Selecting relevant experiments





Selecting top 10% of best performers

Laboratory solutions



Genetic engineering



Protein engineering



Fed batch strain selection already on milliliter scale



Lab-scale fermentation: Proof of performance, & validation of predictions.



x100.000 +

Results in large data sets on all -omics levels



Mechanism-driven models:

(GSM, dynamic metabolic or bioprocess models, molecular dynamics of proteins)

- Protein-ligand binding
- Metabolic response to modifications/stress
- Secretion profile predictions
- Media and process optimization simulations

Data-driven models:

(AI/ML/linear regression etc.)

- Predictions of protein stability
- Predictions of protein folding
- Generation of proprietary protein specific solubility tags
- Generation of proprietary host specific secretion tags
- Codon optimization
- Estimate risks based on phylogenetic/homology similarities





Thank you for listening!
What questions do you have for me?