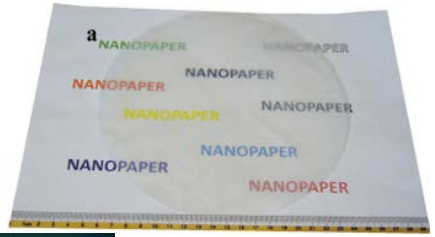
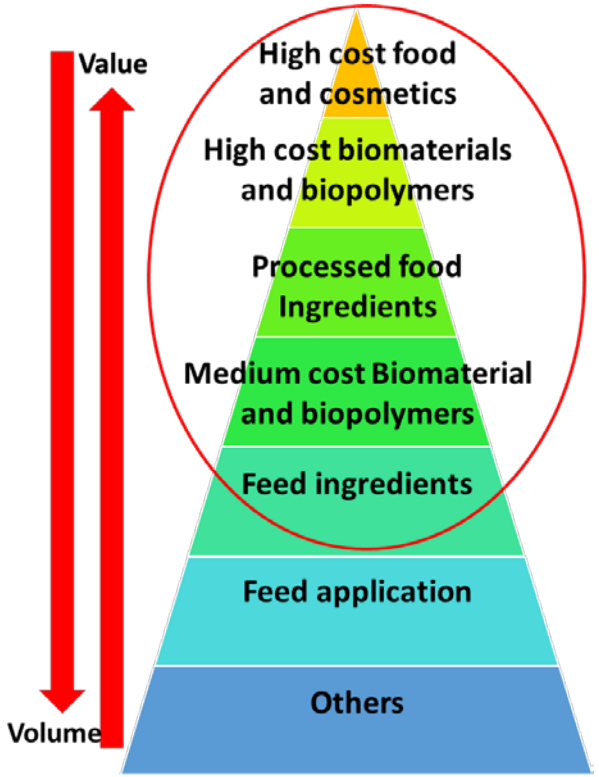
Norwegian Seaweed Biorefinery Platform (SBP-N)
Biomaterials, bioactives and enzymes



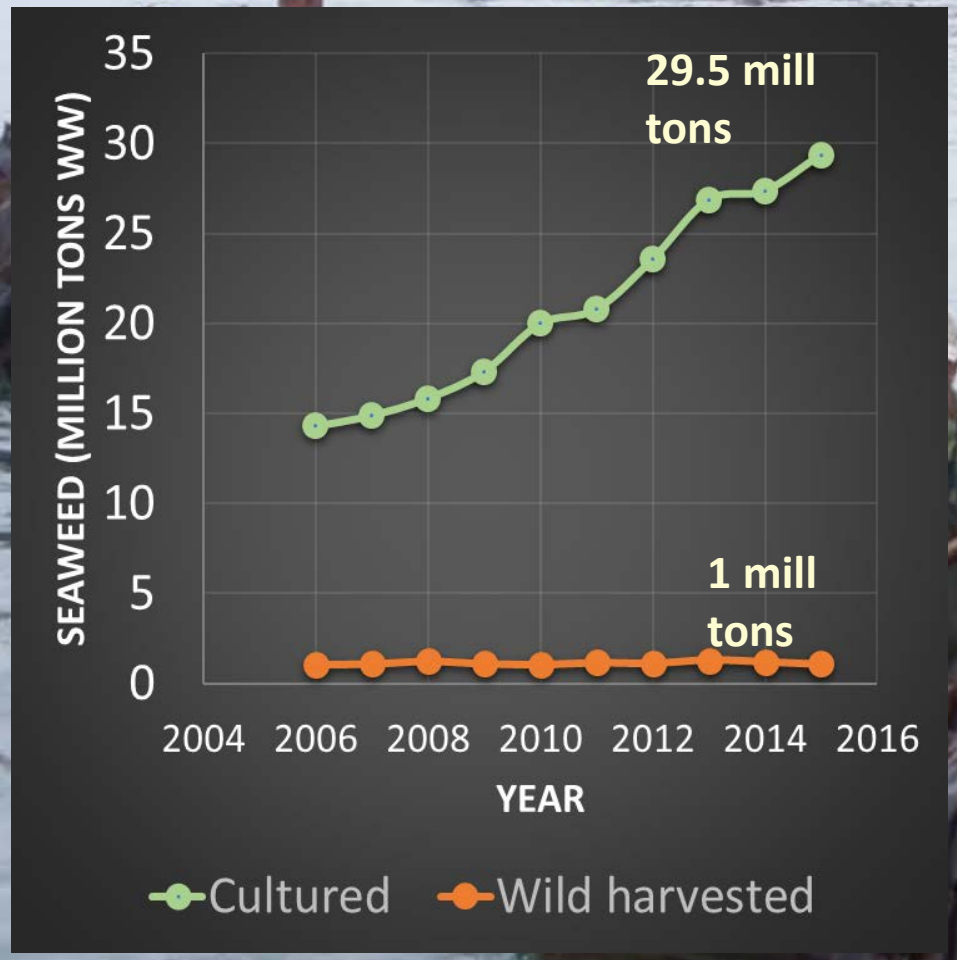


SIG Seaweed
INDUSTRIAL BIOTECH NETWORK NORWAY

Håvard Sletta
SINTEF Industry, Department of Biotechnology and nanomedicne
Trondheim, Norway

28th of November 2019

Seaweeds Globally: 30.5 mill tons/11.7 bill USD (FAO 2017)



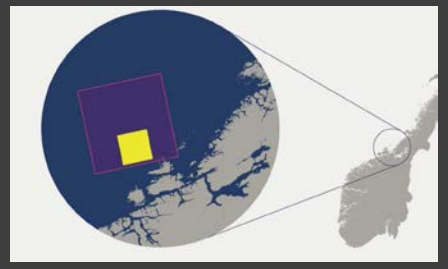
40 %: Brown algae
60%: Red algae

87 % : Used for human consumption (food or food additive (e.g. the hydrocolloids alginates, agars and carrageenans))

13 % : Used for fertilizers, animal feed additives and cosmetics, biotechnological and biomedical applications, +++)

Key marked areas of seaweed based products are increasing

"We can produce 20 mill tons of biomass, in a area at a the size of Trondheimsfjorden"



SINTEF Ocean (Ole Jacob Brock)

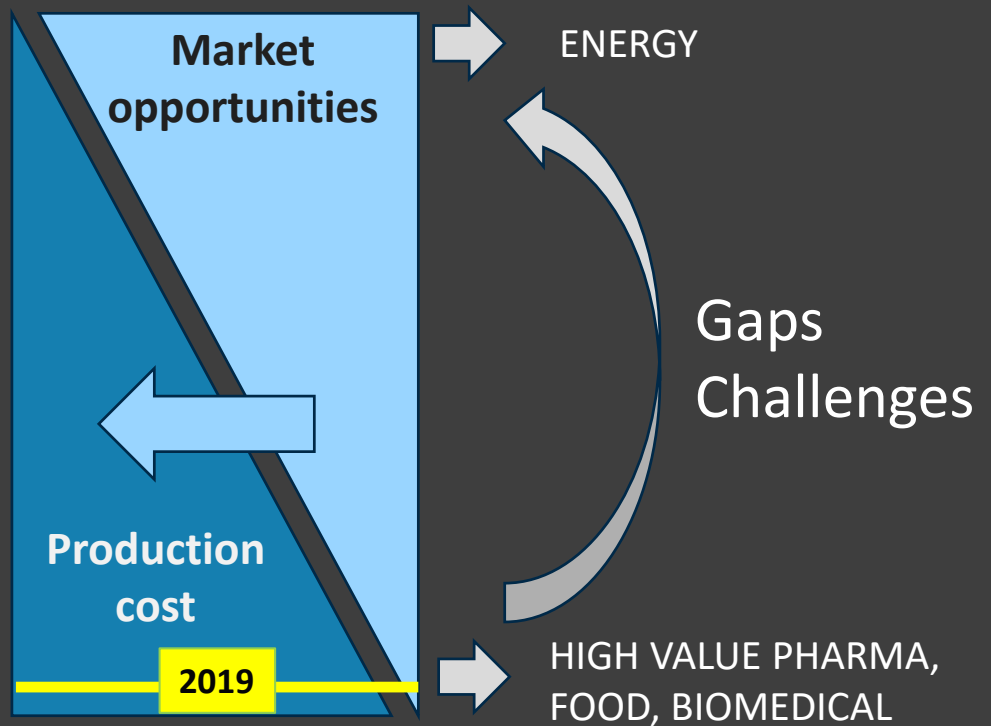
"How to develop new products and processes from the potentially big volume of biomass?"

DuPont (Trond Helgerud)

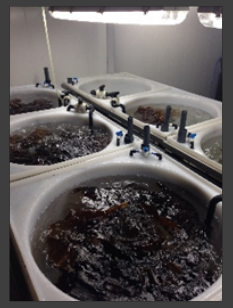
"Need standardised end products with a validated known marked"

Algaia (Frank Hennequart):

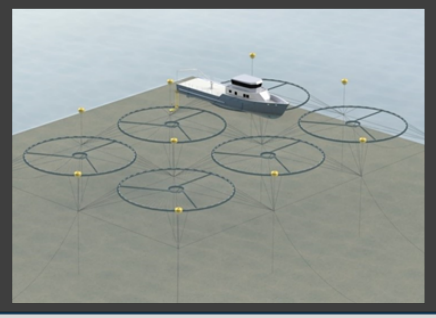
Sustainability, trends, challenges, opportunities, LCA, Industrialisation, automation, breeding, IMTA, ……



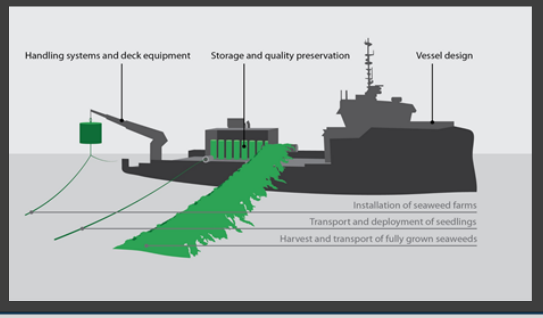
"BREEDING"



CULTIVATION



HARVESTING AND PROCESSING



BIOREFINERY

PRODUCTS

RESEARCH, INNOVATION, NEW SEAWEED BASED INDUSTRY

CHALLENGES: SEAWEED BIOREFINERIES:

- ❑ The harvesting season is short (cultured seaweed)
- ❑ Current technology for marine biomass processing is not useful for cost efficient separation/recovery of products
- ❑ The knowledge about structure and composition of marine biomass not good enough to suggest good enzyme assisted strategies for treatment and fractionation
- ❑ The enzyme toolbox for processing of marine biomass is not yet developed for industrial utilization
- ❑ Products are poorly characterized, lack of structure function data
- ❑ Some of the products lack good industrial applications

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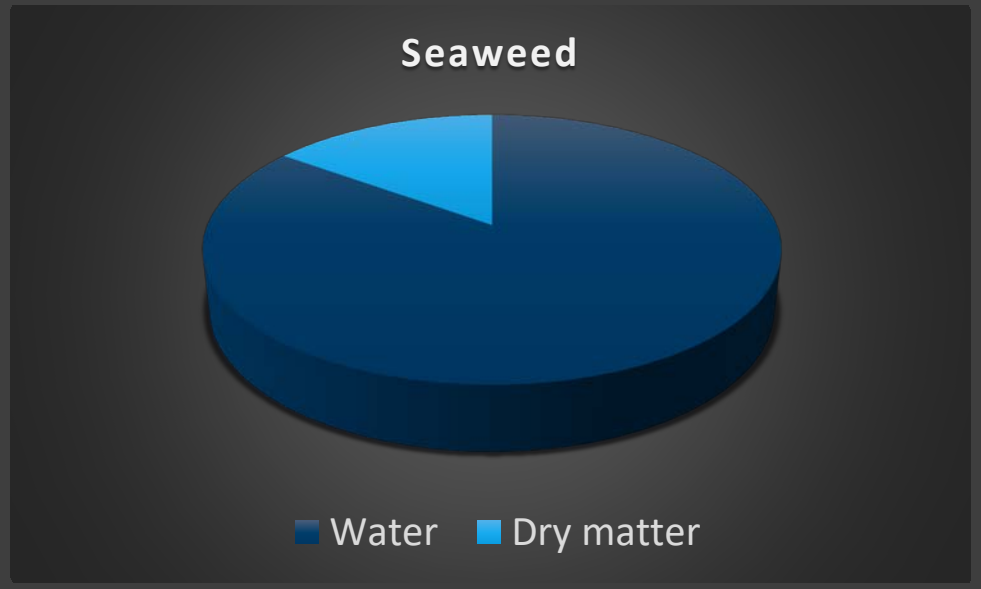
What is the components in brown algae?



Laminaria Hyperborea (stipe, leaf) % dry matter

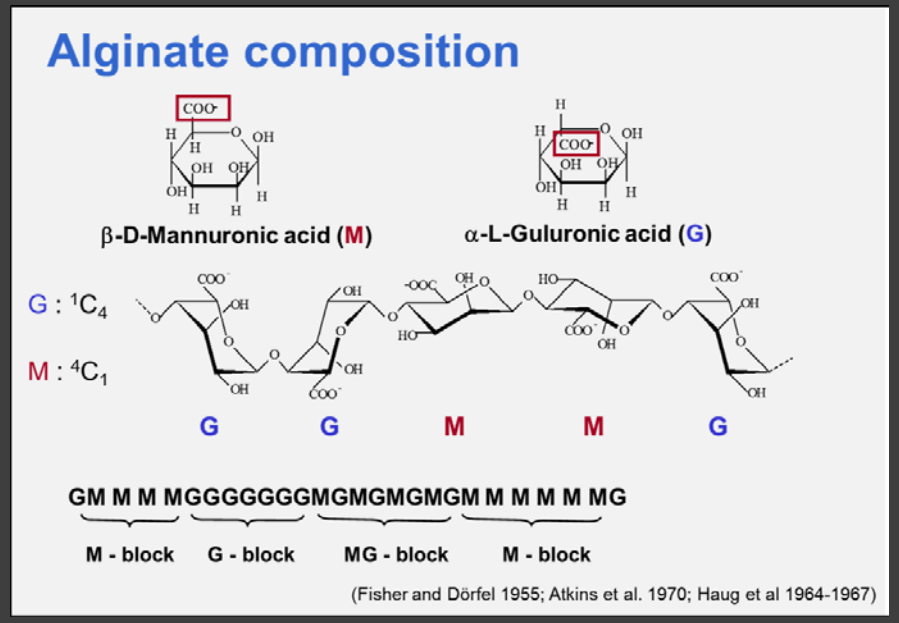
Component	% Dry matter Stem [Leaf]	"Bioactivity"
Alginic acid	33% [17-34%]	+
Laminaran	0.5-1% [0-30%]	+
Fucoidan	2-4% [-]	++
Cellulose	10-12% [-]	-
Mannitol	3-7% [4-25%]	-
Protein	7-10% [4-14%]	+
Polyphenols	1 % [-]	++
Fat	0.5-1% [-]	-
K>Na>Ca>S>Iodine>Mg>P	17-19%	
Pigments ++	Traces	+

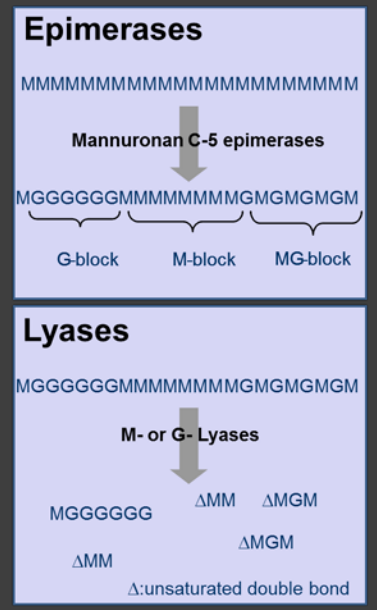
Bioactivity?

Bioactivities of seaweed derived molecules

Litterature:
anticancer, antiobesity, antidiabetic, antihypertensive, antihyperlipidemic, antioxidant, anticoagulant, anti-inflammatory, immunomodulatory, antiestrogenic, thyroid stimulating, neuroprotective, antiviral, antifungal, antibacterial and tissue healing properties.

"A macromolecule from seaweed is not a defined product, but a product class, thus understanding the "true" bioactivity is dependent of understanding structure function relationships"





Bioactivity?

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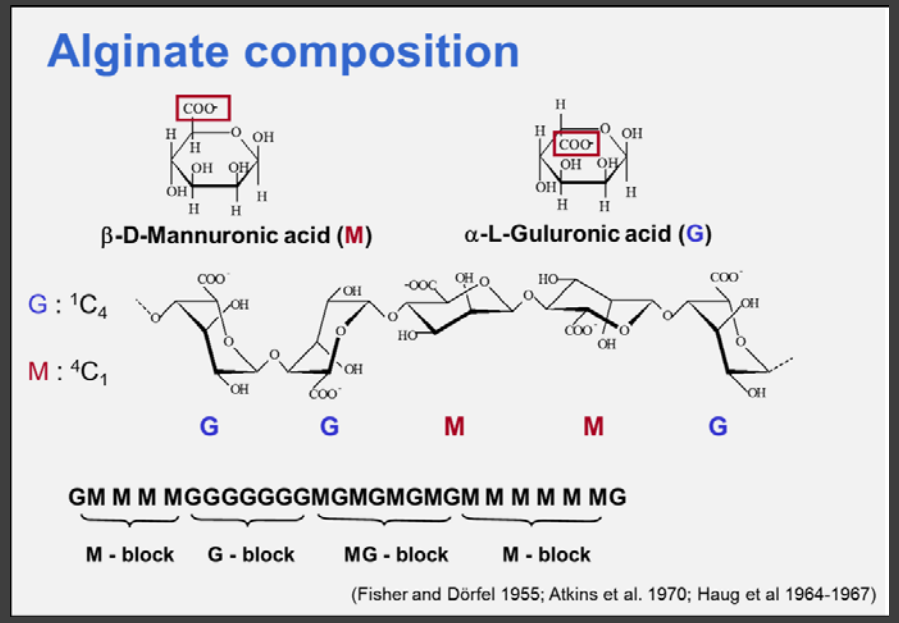

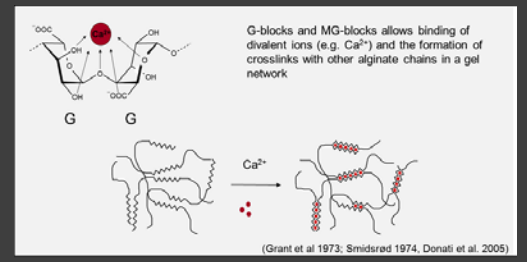

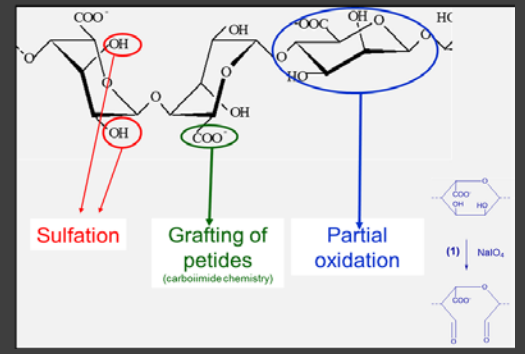

Alginates not alginate

SBP-N -Characterisation

Chemical characterisation → Functional properties → Biological activity

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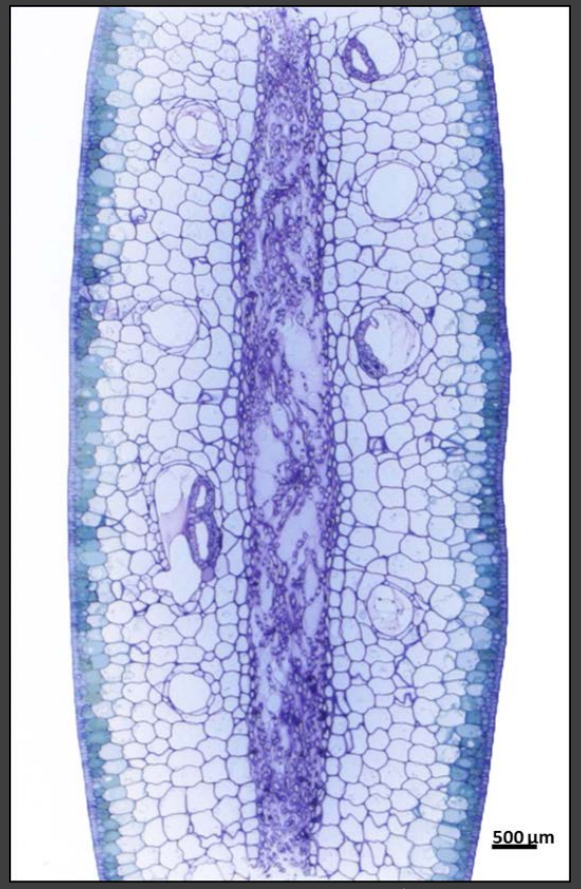
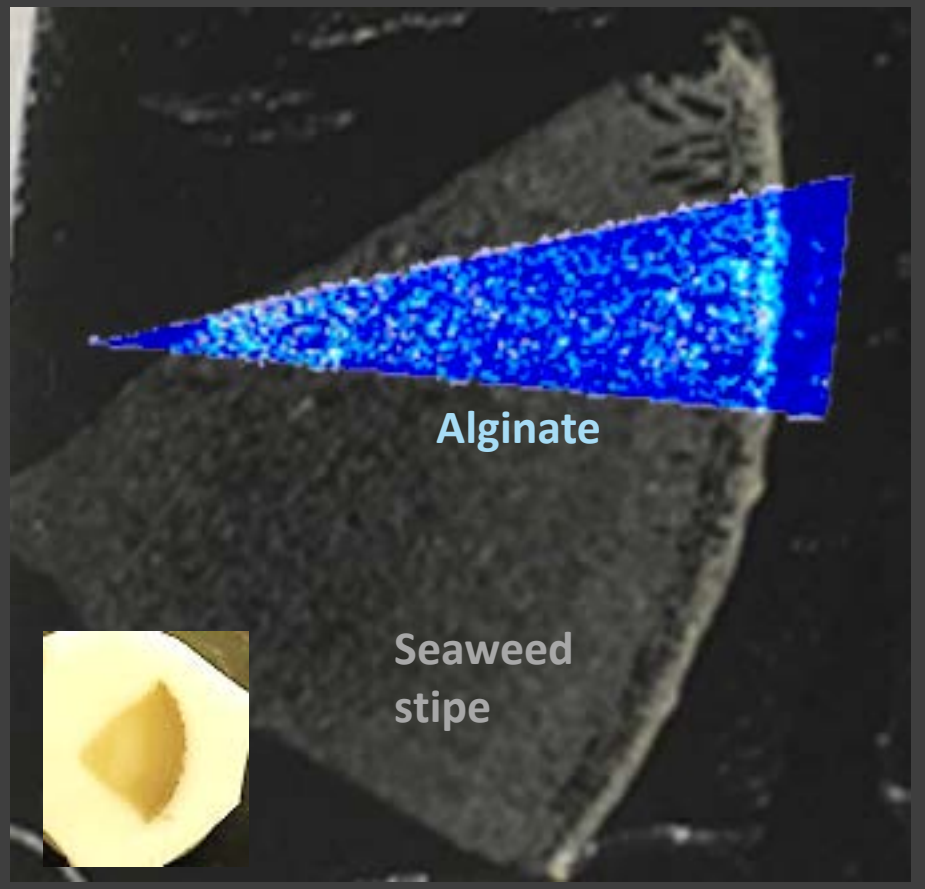
Understanding the structure of seaweed

- Better understanding of distribution and interactions between seaweed macromolecules necessary
- Important for design of chemoenzymatic processing strategies

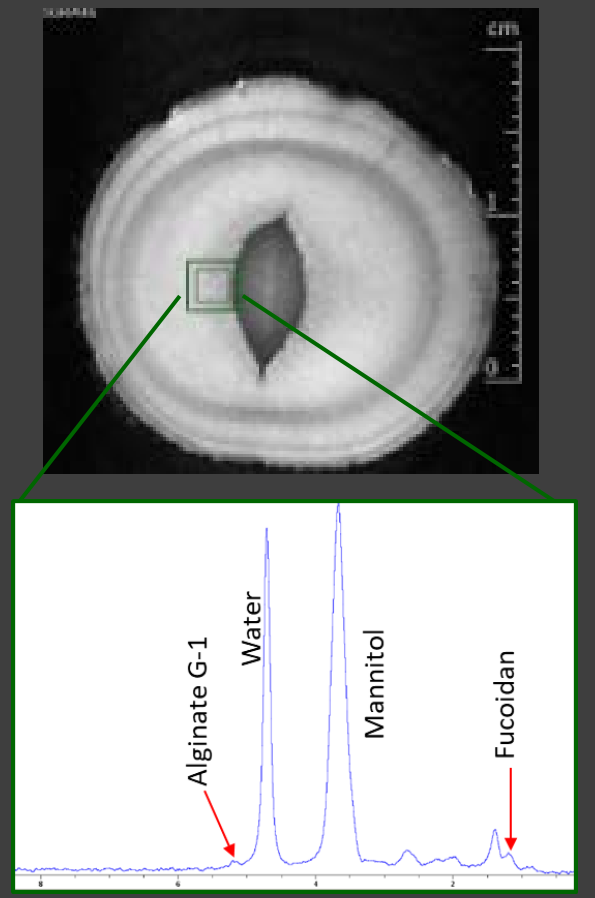
Mar3Bio



EM-picture leaf *of L. hyperborea*



FT-ICR-Maldi imaging of biopolymers in seaweed (Stipe *of L. hyperborea*)



MRI – analyses of stipe *of L. digitata*

The enzyme toolbox for processing of marine biomass and tailoring of marine biopolymers

Seaweed (pre-processed)

"Waste" fractions - Seaweed factory

Chemistry

Commercial and novel enzymes

Food ingredients

Enable fractionation and isolation of biopolymers and other compounds

Biopolymers

Chemistry

Novel enzymes

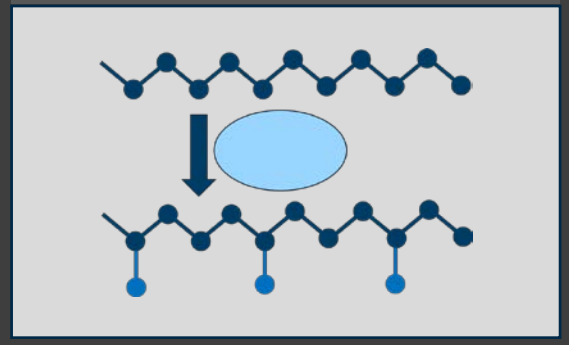
Tailored biopolymers Oligomers/monomers

BIOPROSPECTING

SCREENING ENZYME EVOLUTION

EXPRESSION

BIOPOLYMER ENGINEERING



SBP-N: Examples of relevant enzymes (novel (N) – commercial available (C))

Biomass treatment / opening /depolymerisation/modifications (>30 enzymes):

- Cellulases (C)
- Proteases (C, N)
- Laminarases (C, N)
- Alginate lyases (N)
- Carragenases (C, N)
- Alginate epimerases (N)
- Fucoidan modifying enzymes (?)

Aim: to further develop the seaweed enzymatic toolbox, and establishment of enzyme assisted processes for improved fractionation of biomass and tailoring of seaweed derived macromolecules

SBP-N Processing Platforms

Norbiolab (NTNU, NMBU, SINTEF I)
Bioprocess lab (SINTEF Ocean)
Fermentation lab (SINTEF I)
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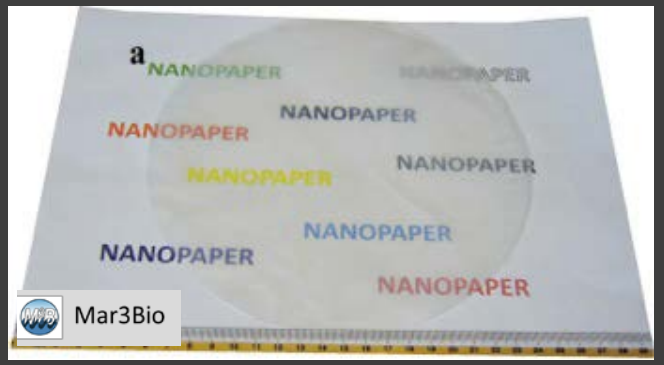
Biomaterials based on seaweed biopolymers – examples

Seaweed based plastics and packaging

Seaweed based textiles

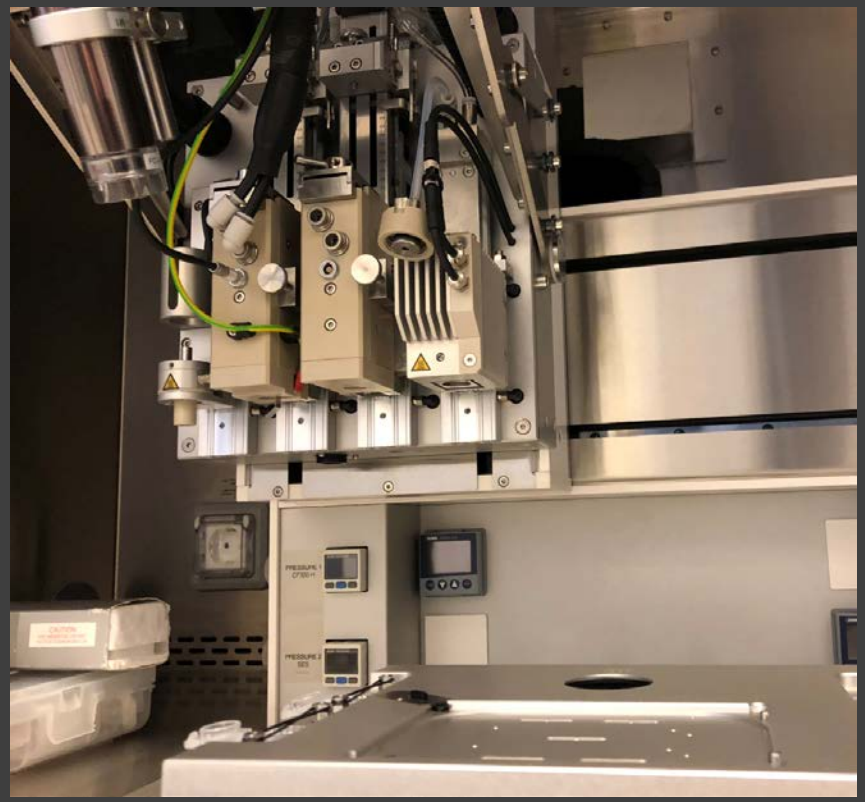
Composites, films, foams

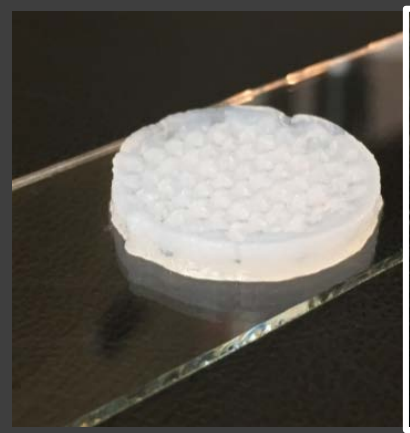


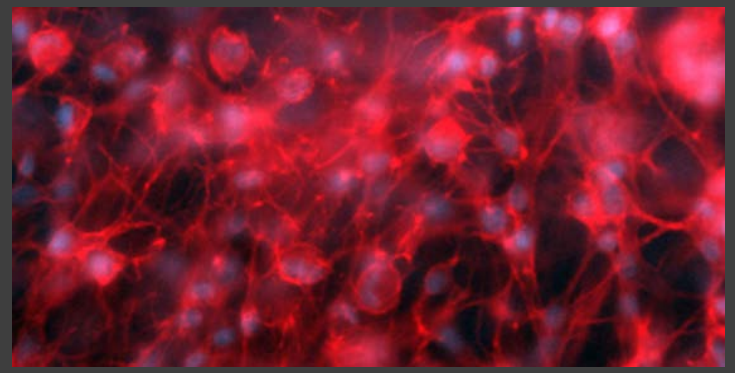
Chassis for cell cultivation

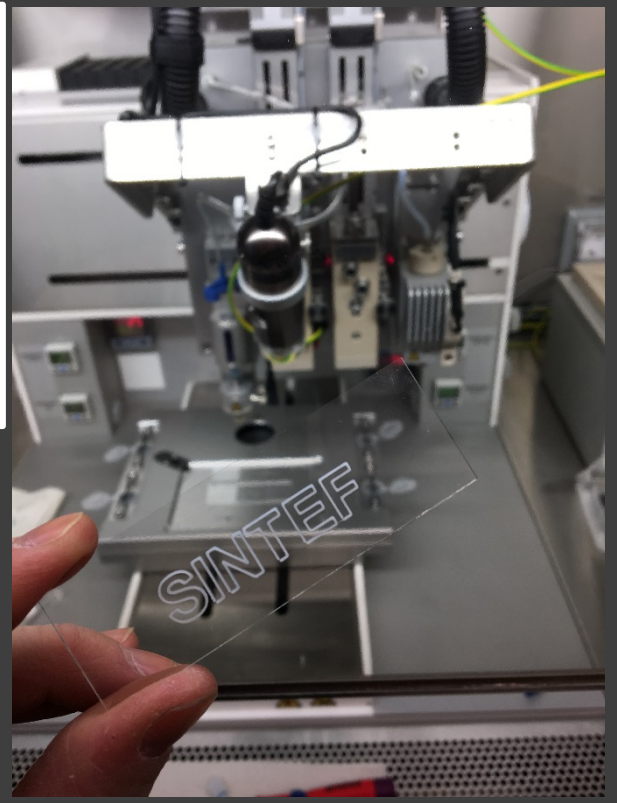
SINTEF

3D bioprinting of cells and seaweed biopolymers









Functionalizing of alginate to promote cell interaction or allow UV crosslinking

Use of nanofibrillar seaweed cellulose to maintain the printed structures until cross-linking of alginates

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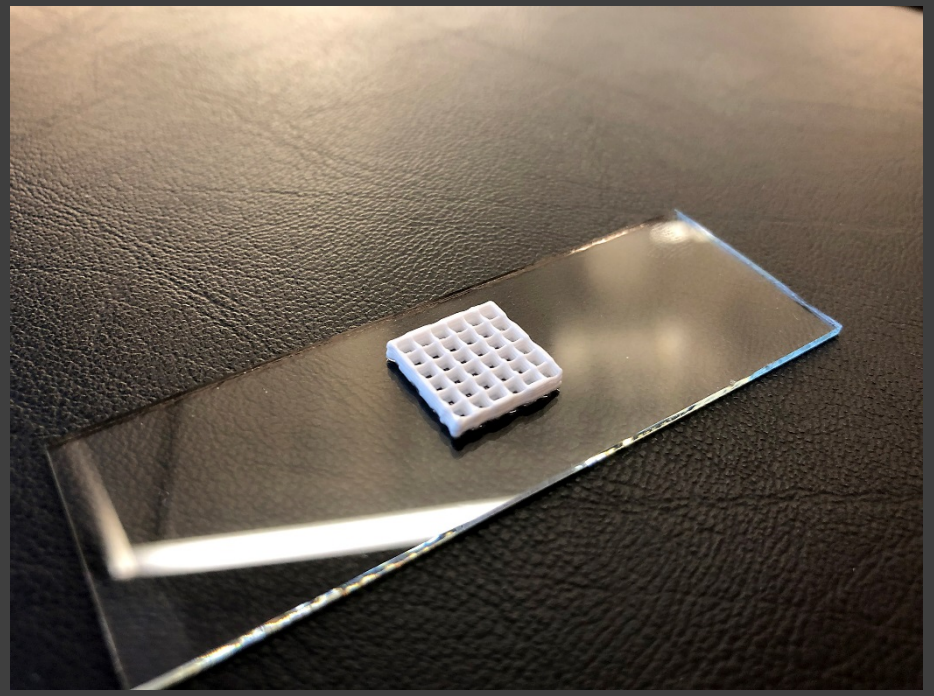

Demonstration of bioprinting methods:

1. **Assembly of scaffold (e.g. functionalized alginate+cellulose)**
2. **Ink-jetting of liquids in compartments (e.g. cells)**
3. **UV cross-linking of scaffolds**

SBP-N contributions

Cultivation
Harvesting

Seaweed biorefineries

Industry based on seaweed derived products

Support the devlopment of a large seaweed based industry in Norway/Europe

Access to infrastructure and knowledge
Education and generic research
Hub for innovation and communication

http://seaweedplatform.no/