

Marine Biotechnology for sustainable futures

Sergey Dobretsov

Director Centre of Excellence in Marine Biotechnology,
Sultan Qaboos University

President of European Society for Marine
Biotechnology

UNESCO Chair in Marine Biotechnology

sergey@squ.edu.om

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Outline

- SQU and CEMB
- Marine biotechnology
- Biofouling and antifouling
- Biopolymers from fish waste
- Drugs from the sea
- Conclusions and future perspectives



Sultan Qaboos University

- Opened in 1986
 - Mainly local, undergraduate students >18000
- PhD program started in 2008
- 9 Colleges College of Agricultural and Marine Sciences
- 7 departments Department of Marine Science and Fisheries

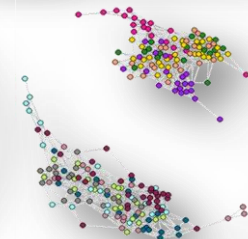
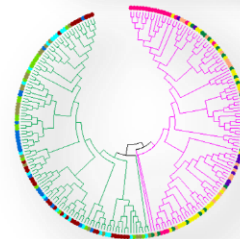


www.squ.edu.om



Center of Excellence in Marine Biotechnology. Research themes

- **Advanced aquaculture** (new species, integrated aquaculture, aquaponics, microalgae cultivation)
- **Biofouling and antifouling**
- **Marine natural products**
- **Genetics of commercial species** (spiny lobster)
- **Bioinformatics** (microbial communities, spiny lobster)

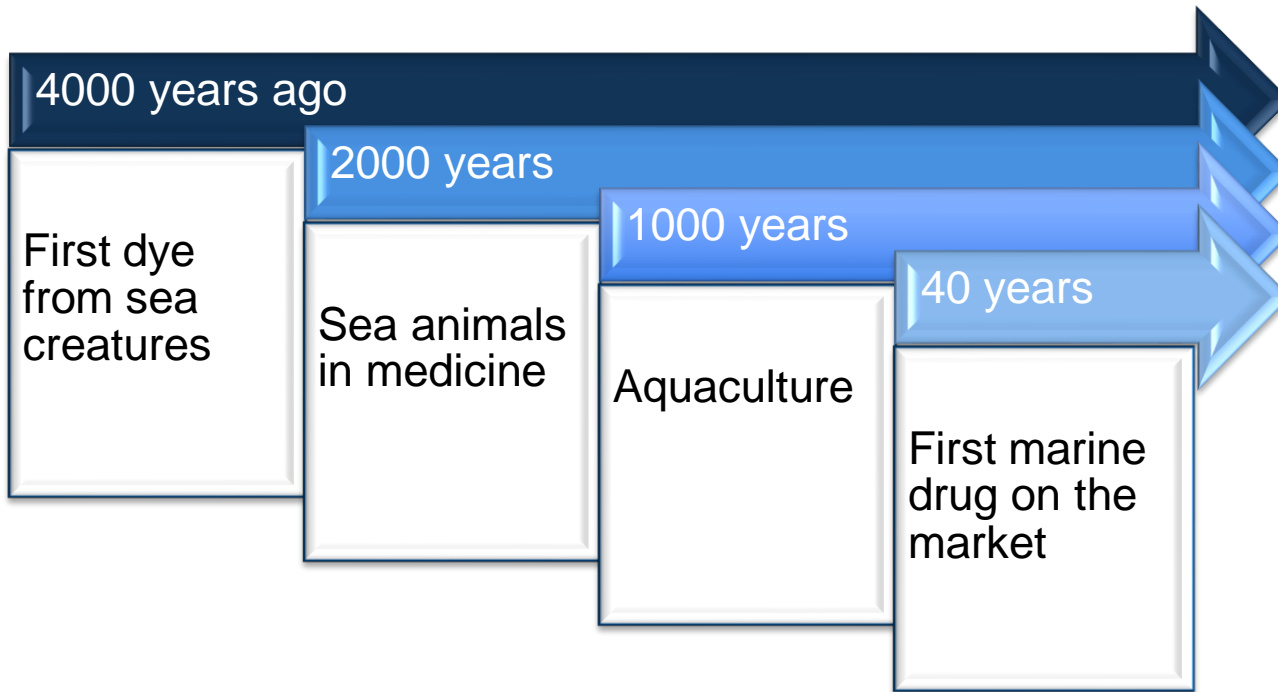


Blue biotechnology

- Marine biotechnology is the industrial, medical or environmental application of biological resources from the oceans



History of marine biotechnology



Applications of marine biotechnology

Human health

Food
(aquaculture)

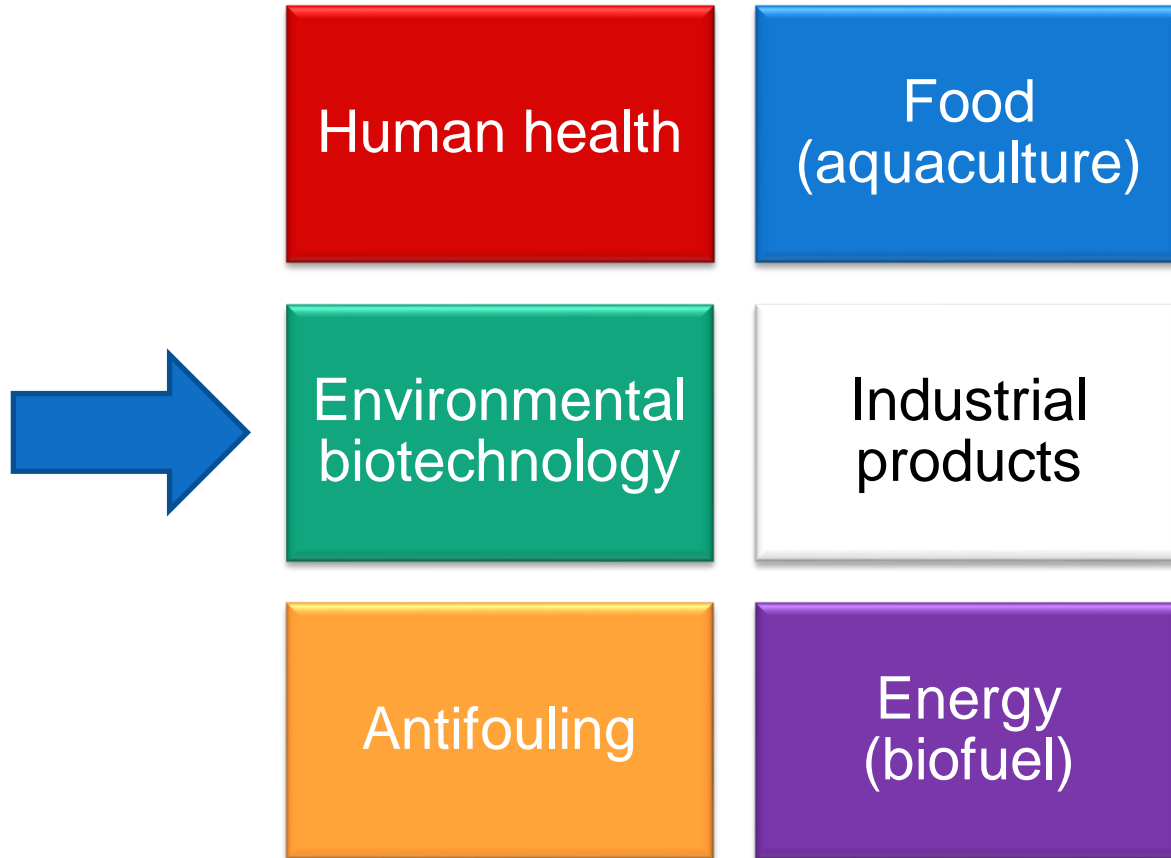
Environmental
biotechnology

Industrial
products

Antifouling

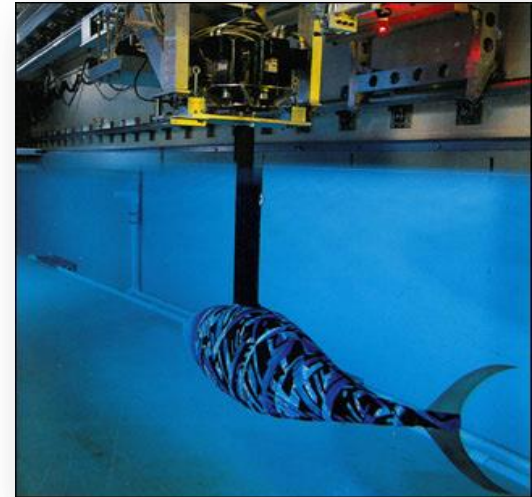
Energy
(biofuel)

Applications of marine biotechnology



Environmental biotechnology

- **Bioremediation** – degradation of pollution by marine organisms
 - Heavy metals, oil pollution, etc.
- **Biosurfactants** – “natural soap” increase availability and disperse compounds
 - Oil enhanced recover, oil degradation
- **Biosensors** – biological detectors
 - Devices for medicine, petroleum industry, and aquaculture

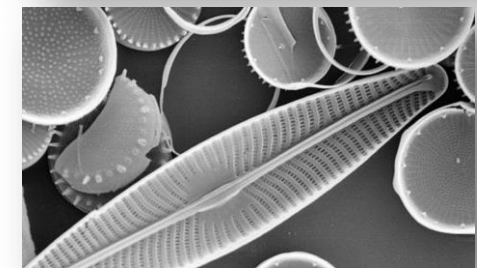
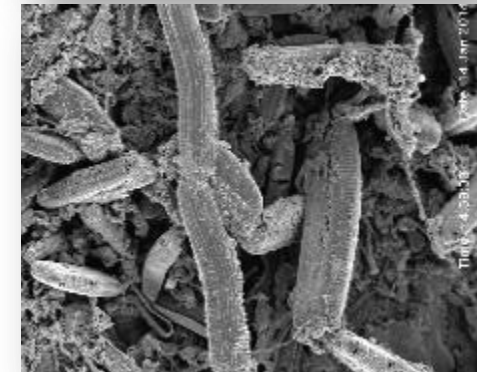


<https://www.festo.com/>

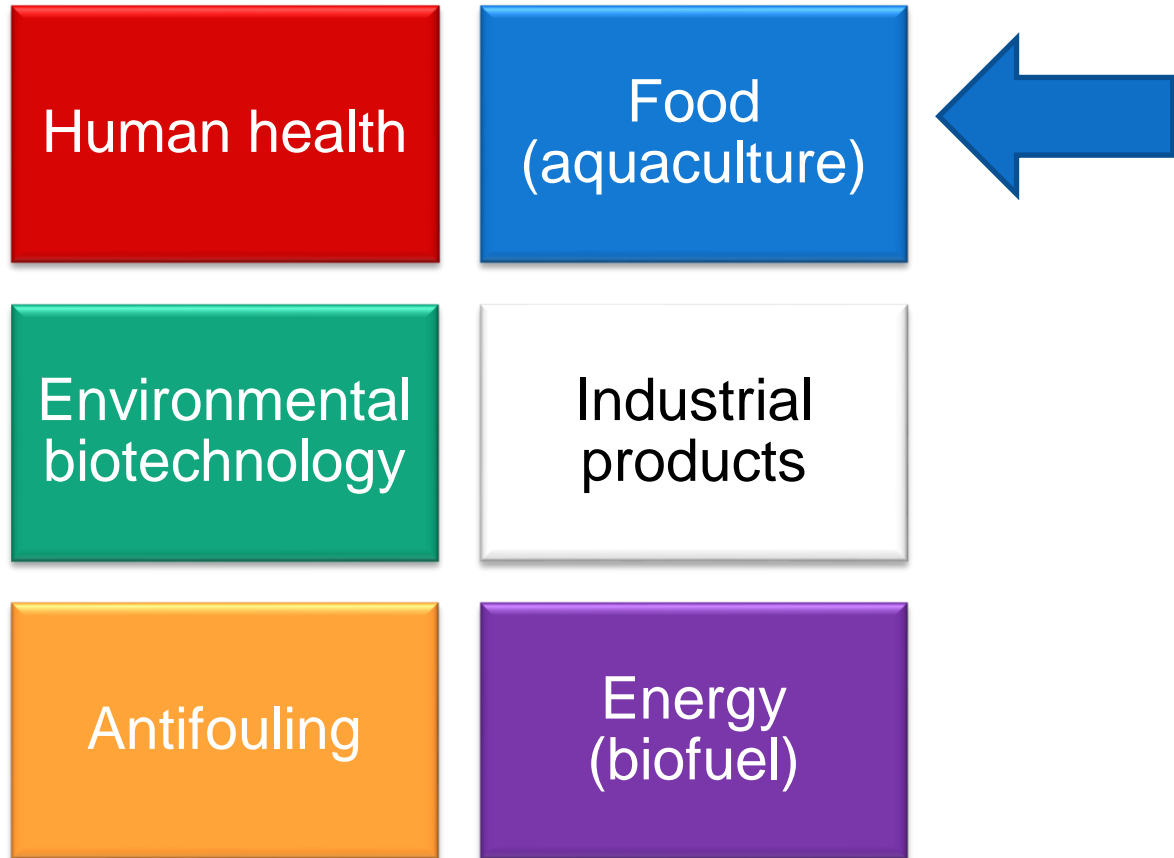


Microbes on sea turtles

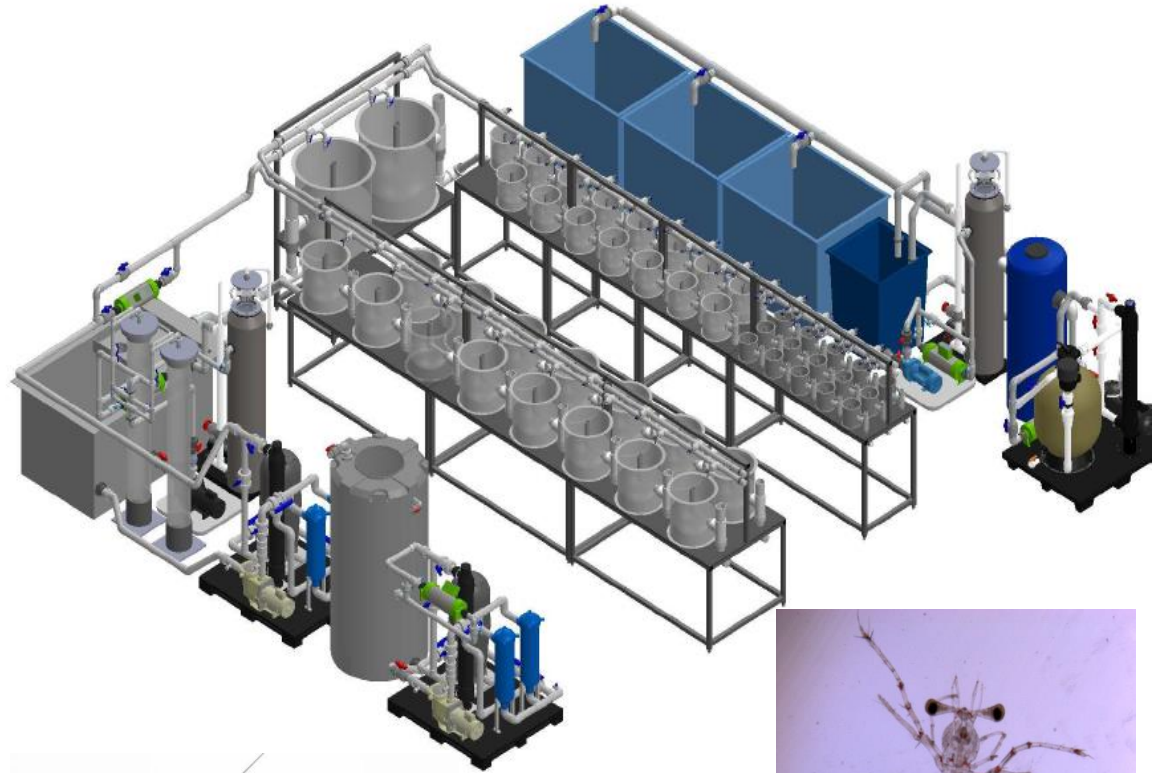
- Sea turtles (*Chelonia mydas*) have unique diatom communities
- New diatom genera *Poulinea* and *Chelonicola* composed >60%
- Investigating possibilities of using diatoms as gas biosensors and as photonic crystals.



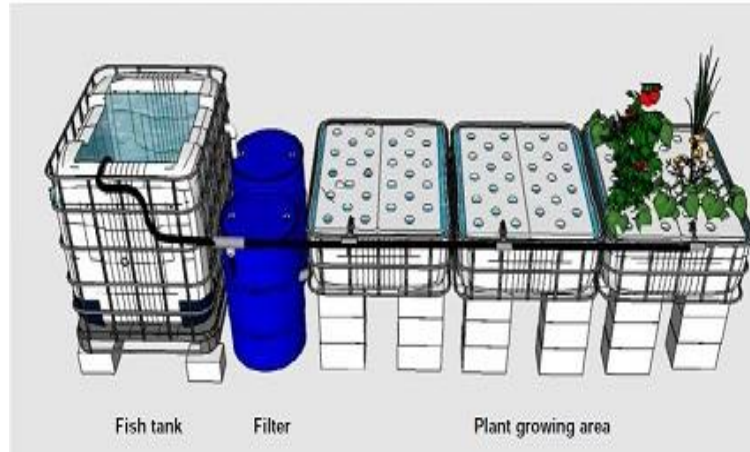
Applications of marine biotechnology



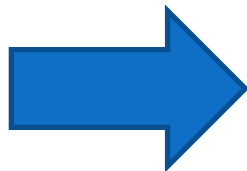
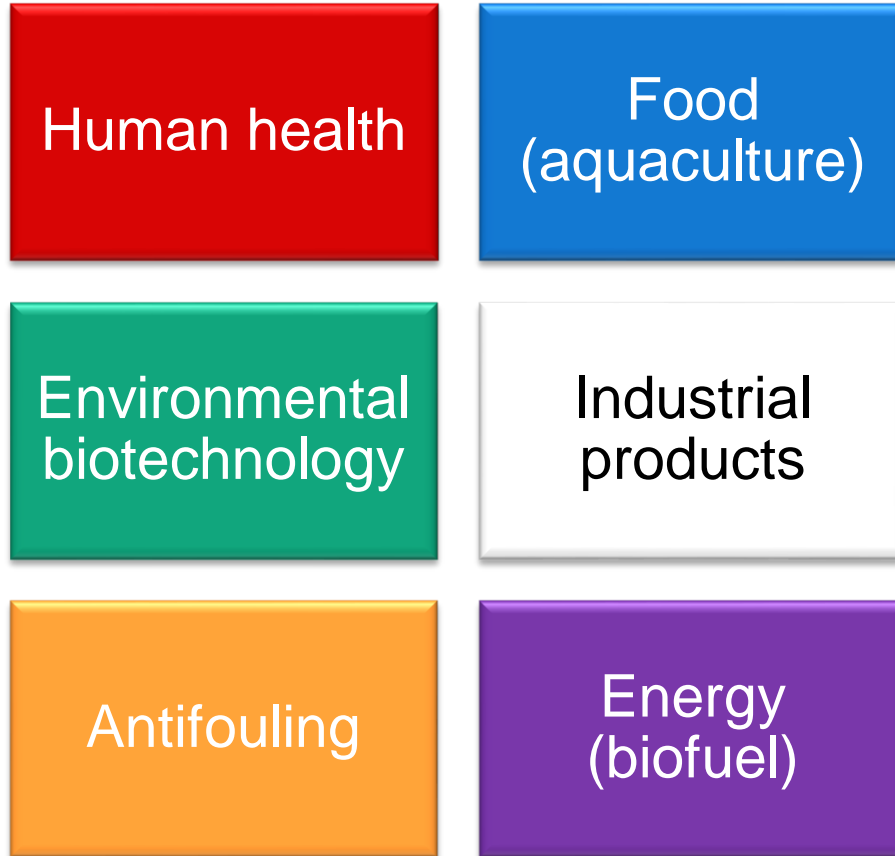
Recirculating Rearing Facility



Aquaponic facility



Applications of marine biotechnology



Marine Biofouling



Micro-fouling (bacteria, microalgae) Macro-fouling (barnacles, mussels)

Impact of biofouling

- Fouled ships hulls burn 40% more fuel. Increase emission of CO₂. Costs €7.5 mill./ year
- Control of fouling of water tanks, exchangers, power plants, costs over €15 bill./year
- Control fouling on RO membranes costs more €1 bill./ year



Impact of biofouling

- Fouled ships hulls burn 40% more fuel. Increase emission of CO₂
- Constant tank cleaning plan bill.
- Control fouling on RO membranes costs more €1 bill./ year



Marine biofouling is a costly problem



Biofouling prevention

- Antifouling coatings contains paint and biocides
- Biocides are mixed with the paint and slowly leach out
- Biocides kill non-target organisms, accumulate in the sediments, affect behavior and reproduction of organisms



<http://mfame.guru/antifouling-coatings-market>

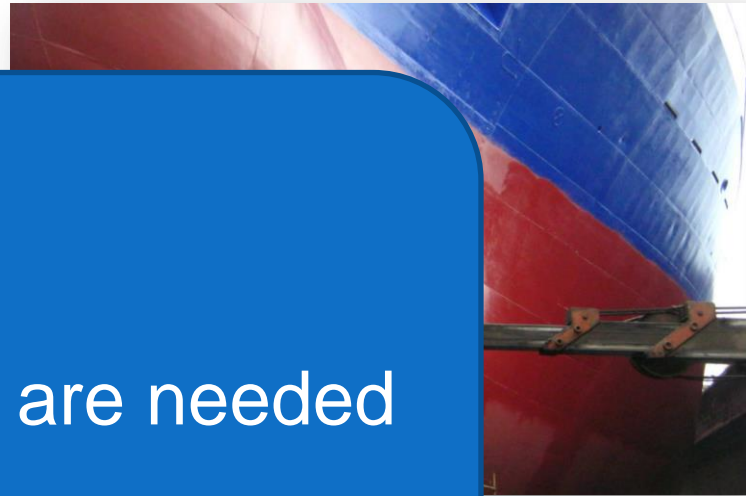
Biofouling prevention

- Antifouling coatings contains paint and biocides

- Biocides
and slow

- Biocides
accumulation
behavior
organisms

Non-toxic alternatives are needed



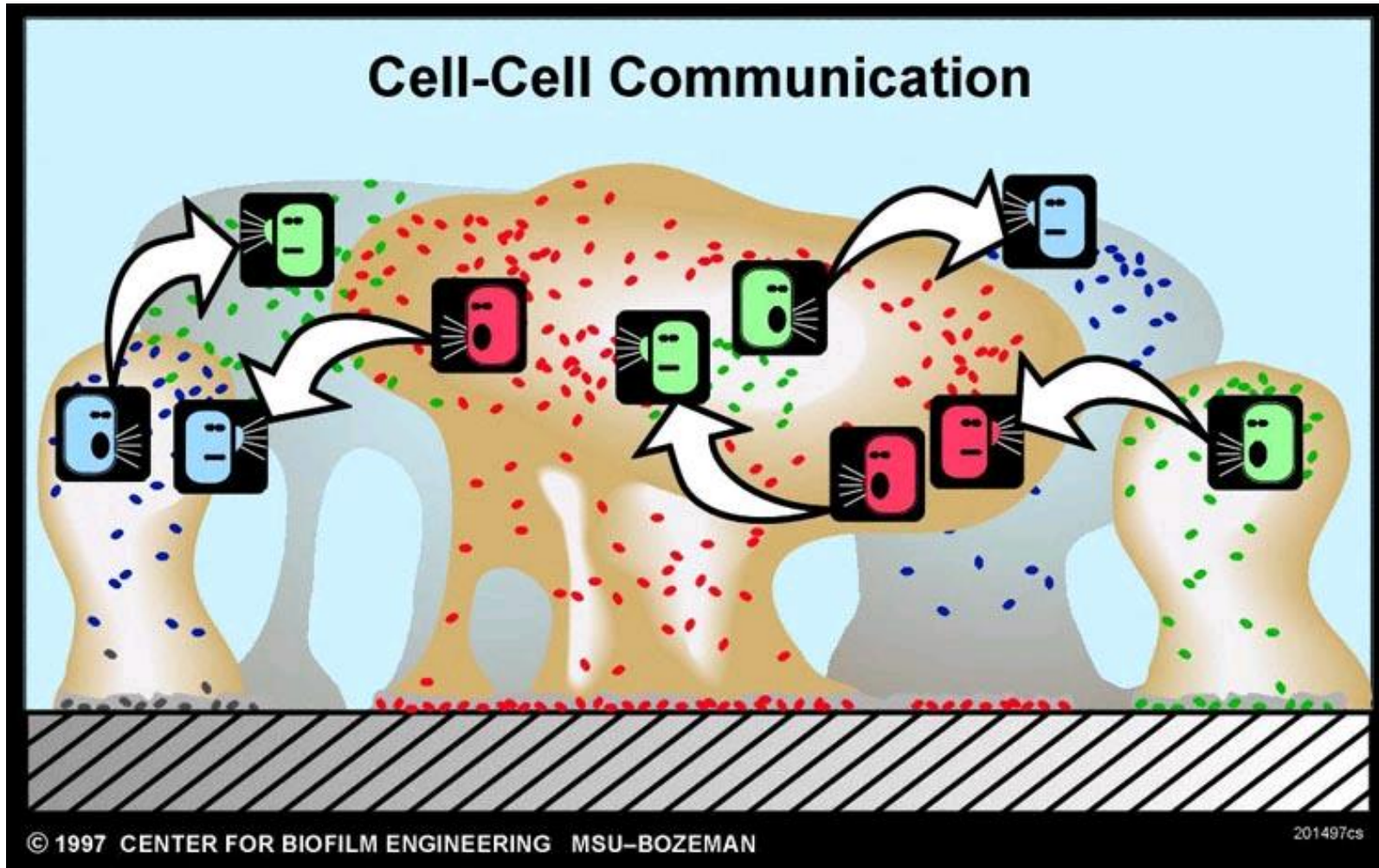
coatings-market

Non-toxic alternatives for biofouling prevention

- “Learn from nature” approach
- Some marine organisms are clean from biofouling
- Can they “teach” us?



Bacterial quorum sensing

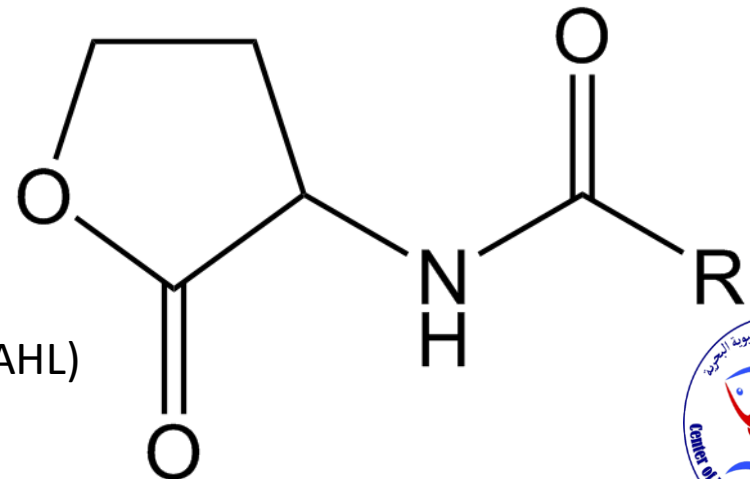


Quorum sensing in marine environment



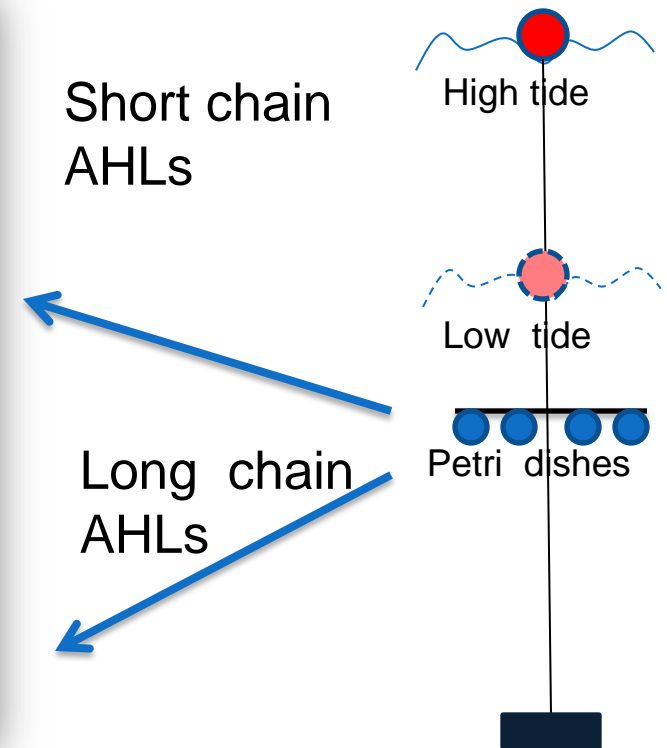
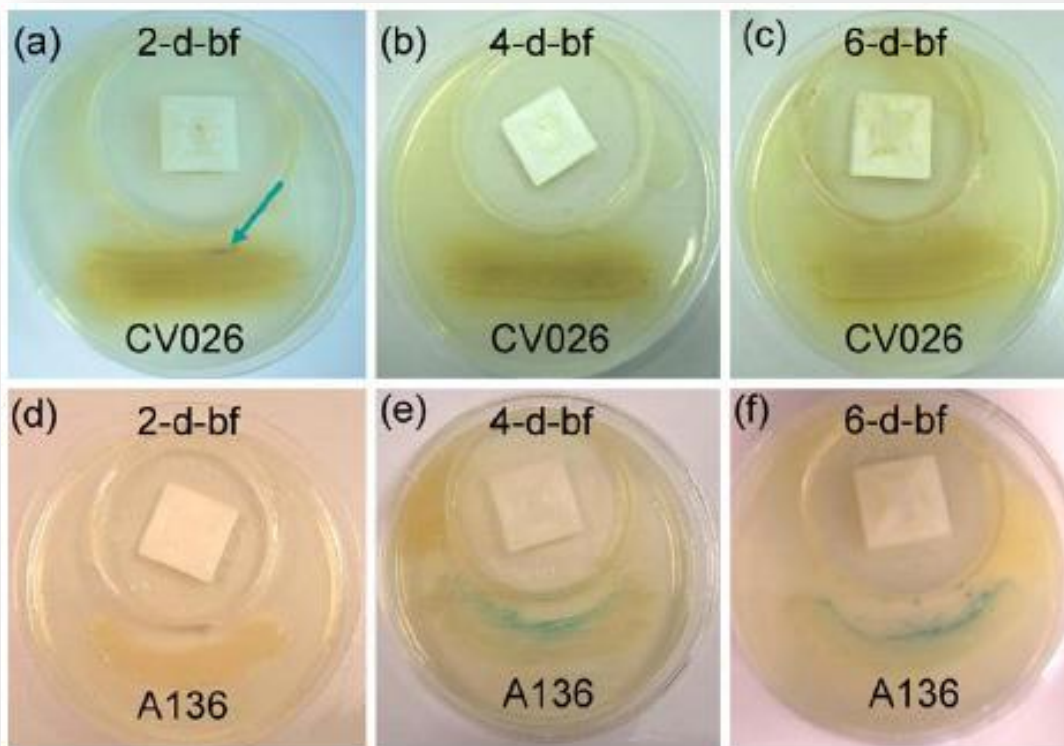
<http://www.che.caltech.edu/groups/fha/quorum.html>

Quorum sensing was first discovered in the marine luminescent bacterium *Vibrio fischeri* – a symbiont of the squid *Euprymna scolopes*



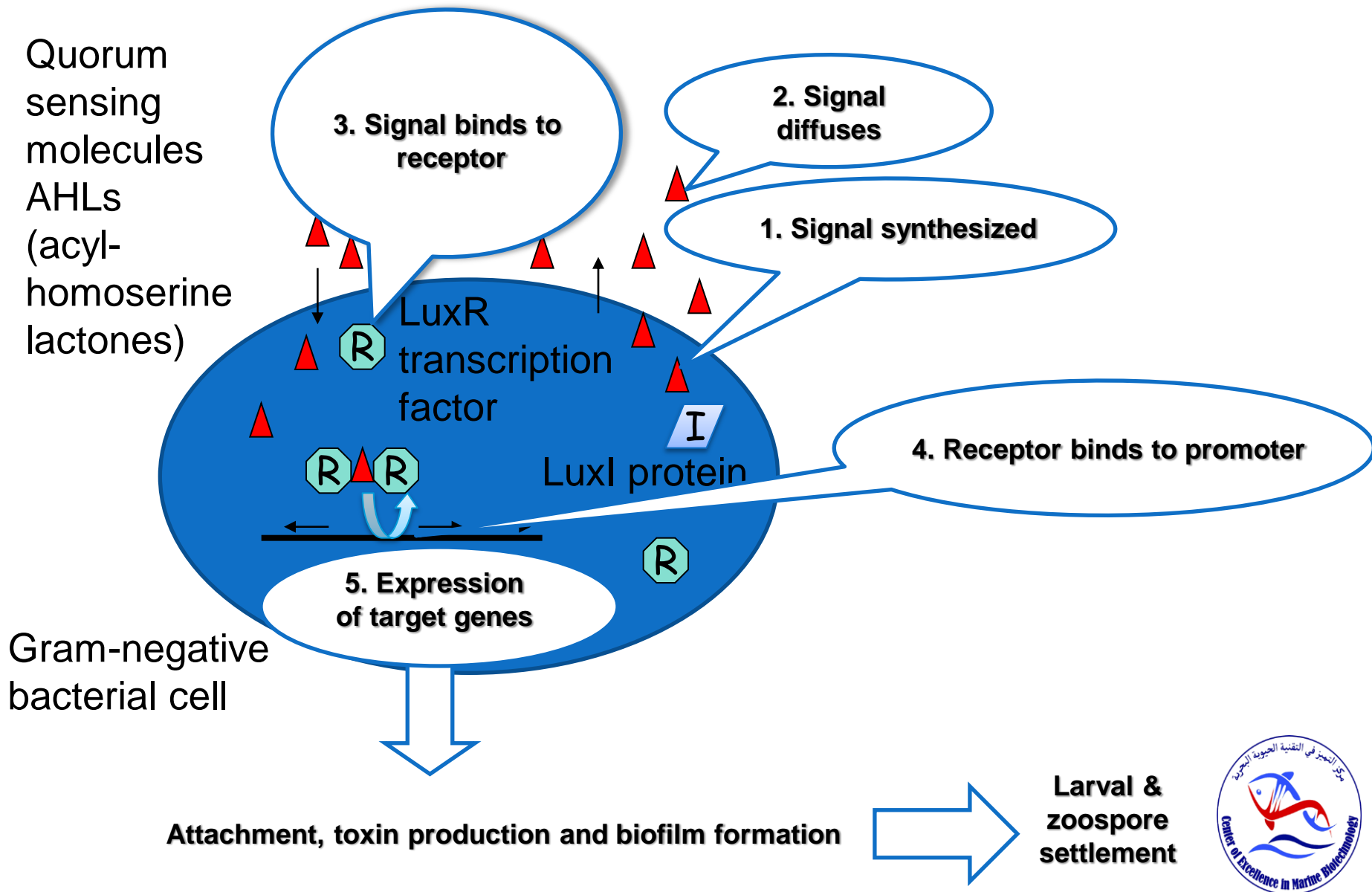
Acyl homoserine lactone (AHL)

Quorum sensing in marine biofilms



Different QS are present and produced during biofilm development

“Bacterial language”



Inhibition of quorum sensing

Quorum sensing molecules
AHLs
(acyl-homoserine lactones)

Inhibitors

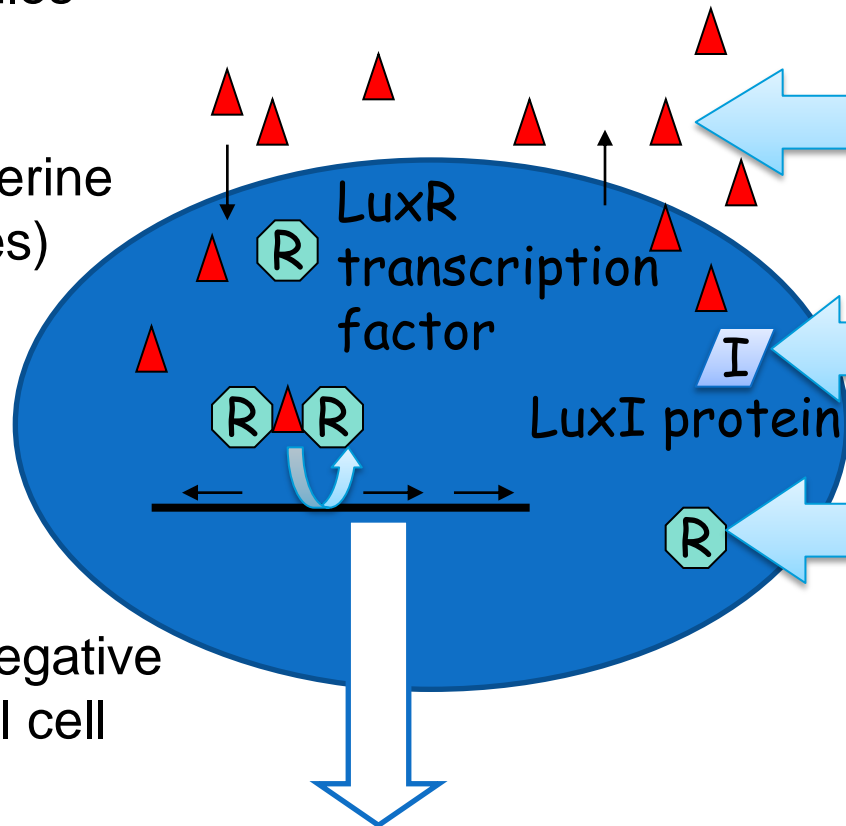
AHL signals
(AHL-acylase)

Signal generation
(triclosan)

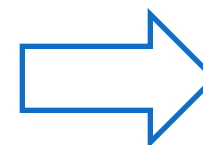
Furanones



Gram-negative bacterial cell



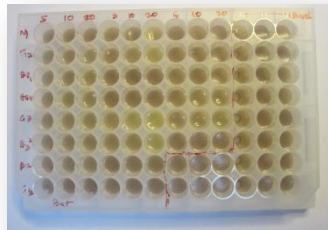
Attachment, toxin production and biofilm formation



Larval & zoospore settlement



Separation and identification of compounds



QSI
assay

Multi-well plate
antibacterial and
quorum sensing
inhibitory bioassays



Collection of
organisms and extract
preparation



Organisms are
extracted with polar
and non-polar solvents

Identificaron
of
compounds

Extracts were identified
based on GC-MS, LC-MS and
NMR

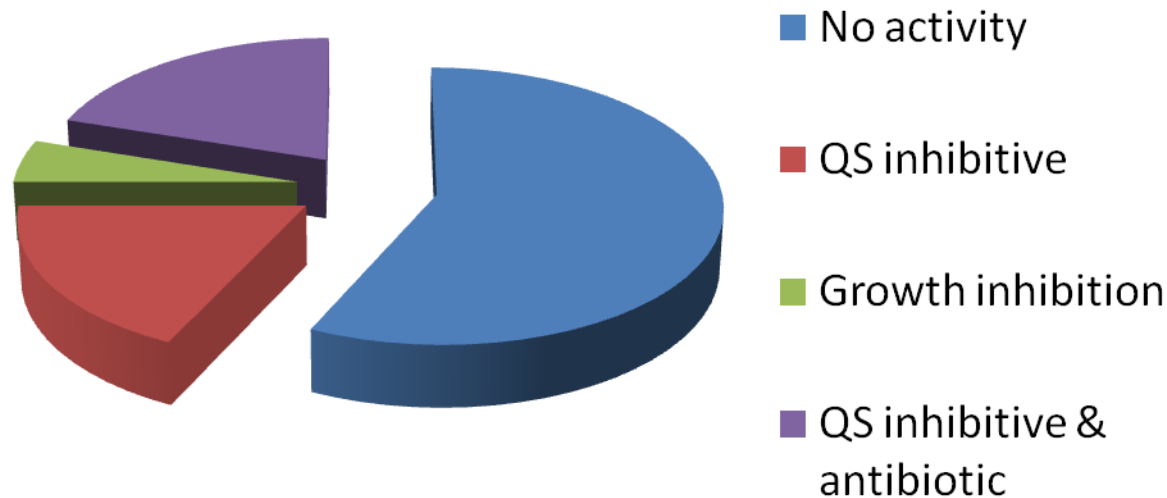
Extract
separation

Extracts separated by
chromatography



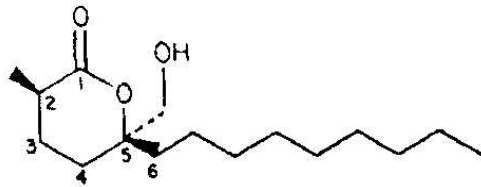
Screening of microbial natural products for QS inhibitory activity

% of compounds



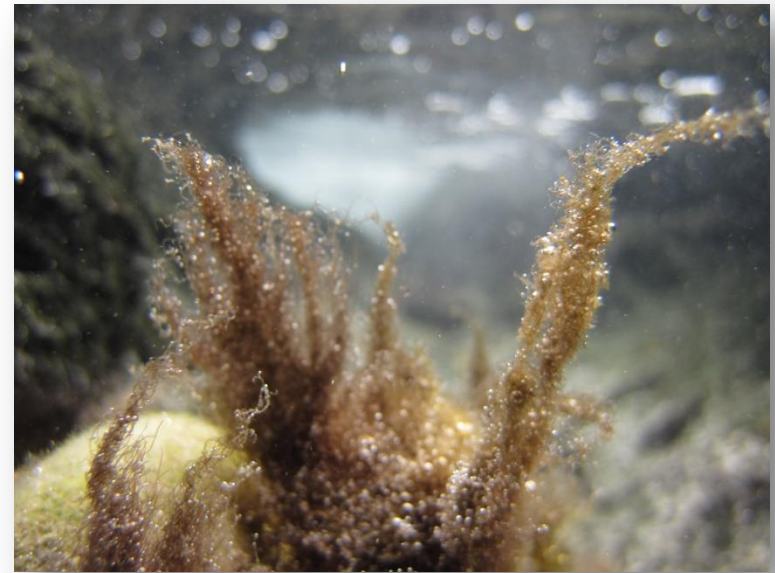
Out of 100 tested compounds about 25% has QS inhibitory activity

QS inhibitor from the cyanobacterium *Lyngbya majuscula*

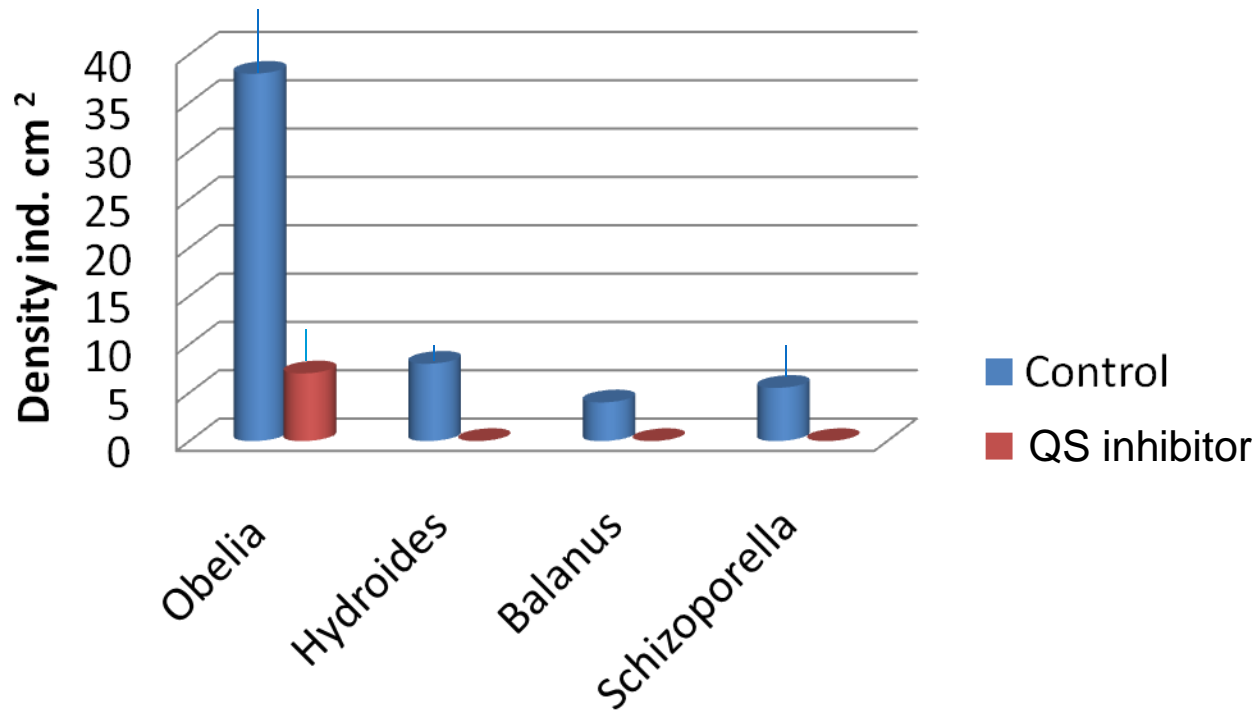


Malyngolide

$EC_{50} = 12.2 \pm 1.6 \text{ mM}$



Inhibition of biofouling



QS inhibitors reduce densities of macrofoulers

Inhibition of biofouling



It is possible to prevent biofouling using QS inhibitors

QS inhibitors reduce densities of macrofoulers

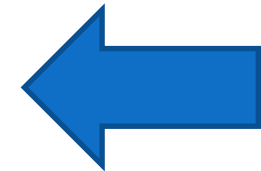
Applications of marine biotechnology

Human health

Food
(aquaculture)

Environmental
biotechnology

Industrial
products



Antifouling

Energy
(biofuel)

Fish waste

- About 50% of caught fish is wasted
- Fish waste contain many biomaterials and compounds (oil, meal, cosmetics)



<https://redoubtreporter.wordpress.com>

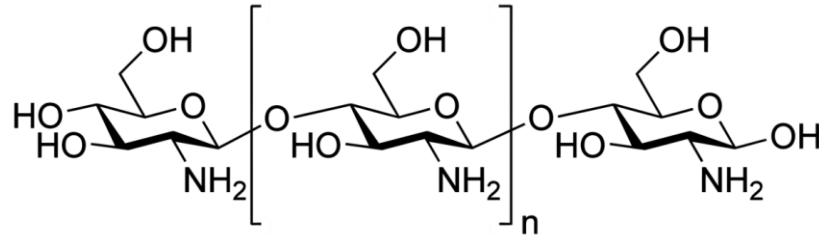


Chitosan



Shrimp waste

Chitin

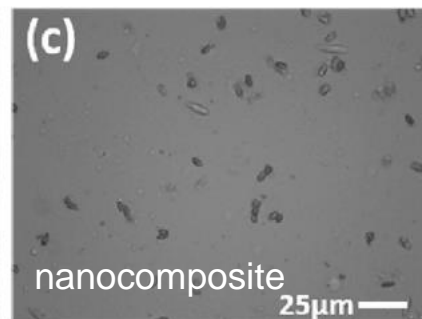
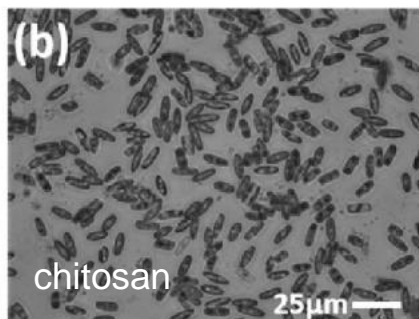
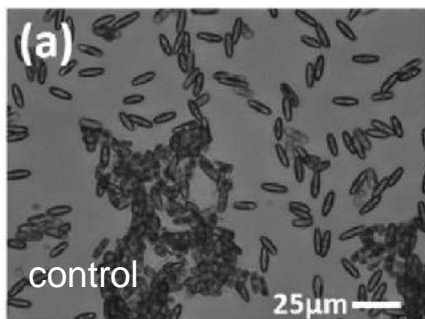
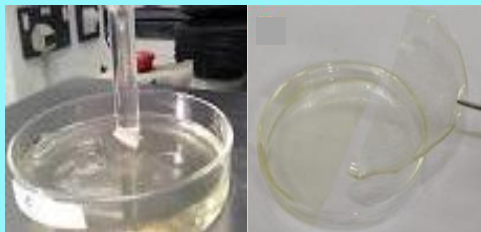


Chitosan

- Chitosan is obtained from crustacean (shrimp, crabs) shells (waste)
- It is a linear polysaccharide
- Has antimicrobial properties

Antialgal activity of chitosan-ZnO nanocomposite coatings

Chitosan Composite



Chitosan-ZnO nanocomposite was more active

Nanocomposite for food applications

- PE bags were coated with chitosan-ZnO nanocomposite



- Reduced fungal and bacterial growth



- Not affected quality of fruits and vegetables

- Extend shelf-life



Nanocomposite for food applications

- PE bags were coated with nanocomposite

- Reduces bacterial growth

- Not suitable for fruits and vegetables

- Extend shelf-life

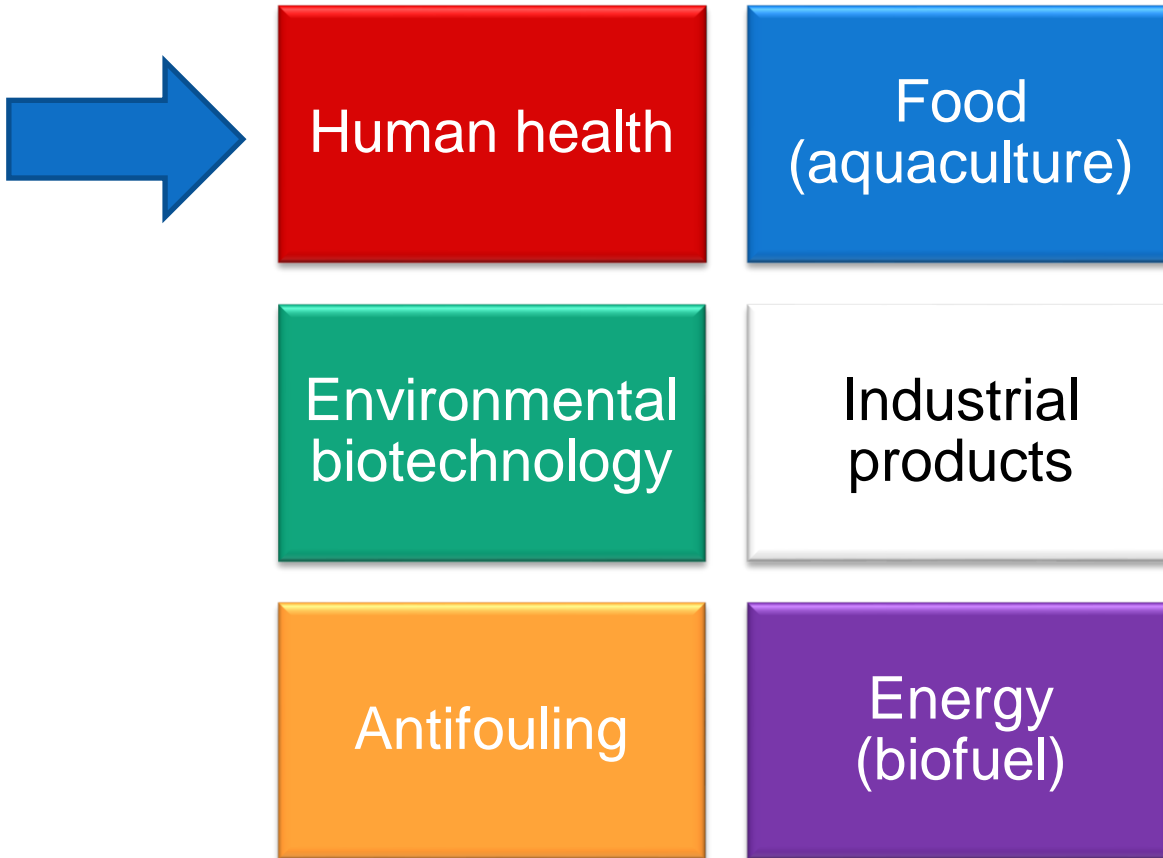
It is possible to create industrial products from fish waste

nanocomposite coating

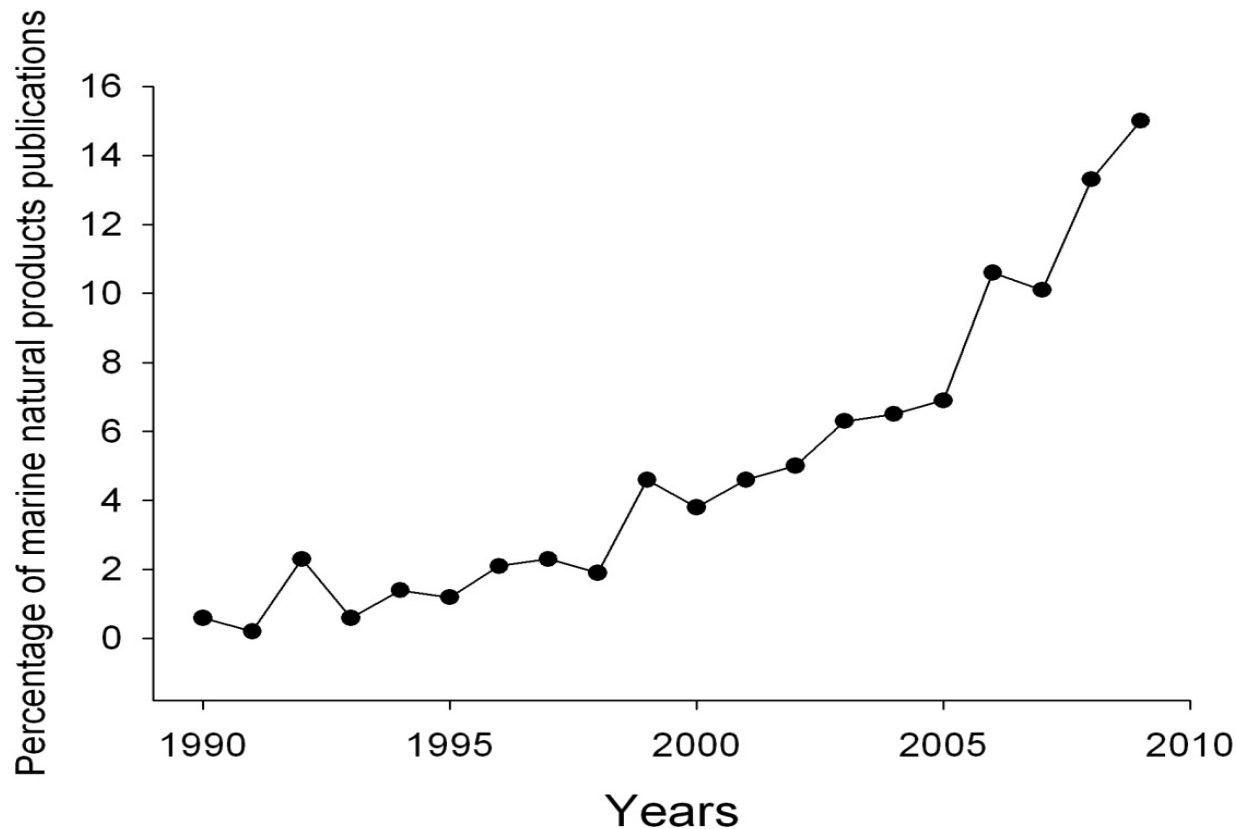
nanocomposite coating



Applications of marine biotechnology



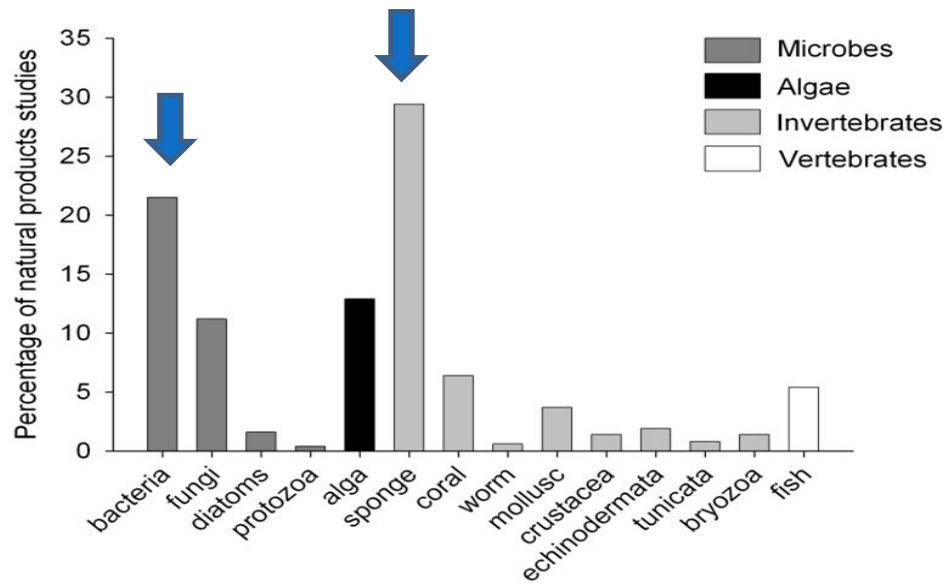
Marine natural product publications



The number of published marine natural products are increasing
> 6,500 publications > 42,000 patents, 16% of all NP



Marine organisms producing natural products



Mostly natural products are reported from bacteria and sponges



Some marine natural products on the market

- Anticancer Ecteinascidin or Yondelis® originally from the tunicate *Ecteinascidia turbinata* synthesized now by PharmaMar
- Pain relief drug Ziconotide derived from venom of the snail *Conus mardus*.
- Vent DNA polymerase from the marine thermophile *Pyrococcus furiosus* for PCR

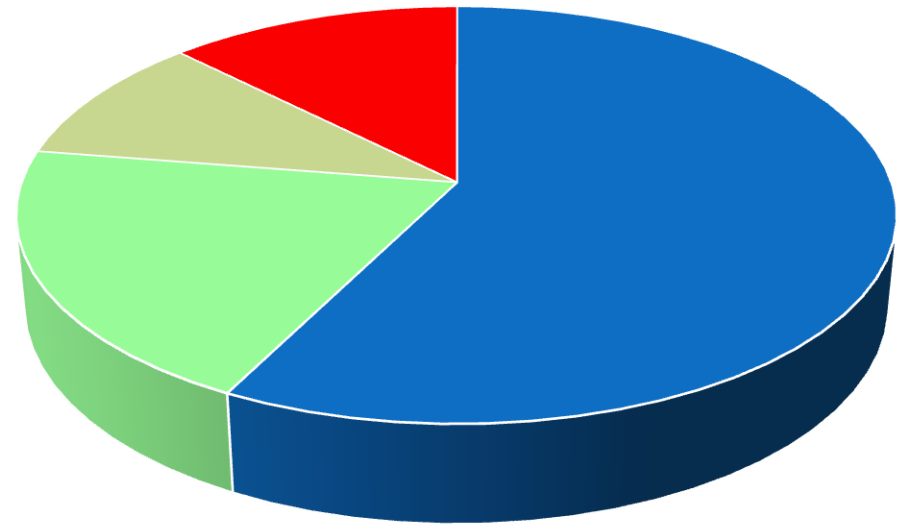


<http://www.underwaterkwaj.com>



Anticancer compounds from Omani marine organisms

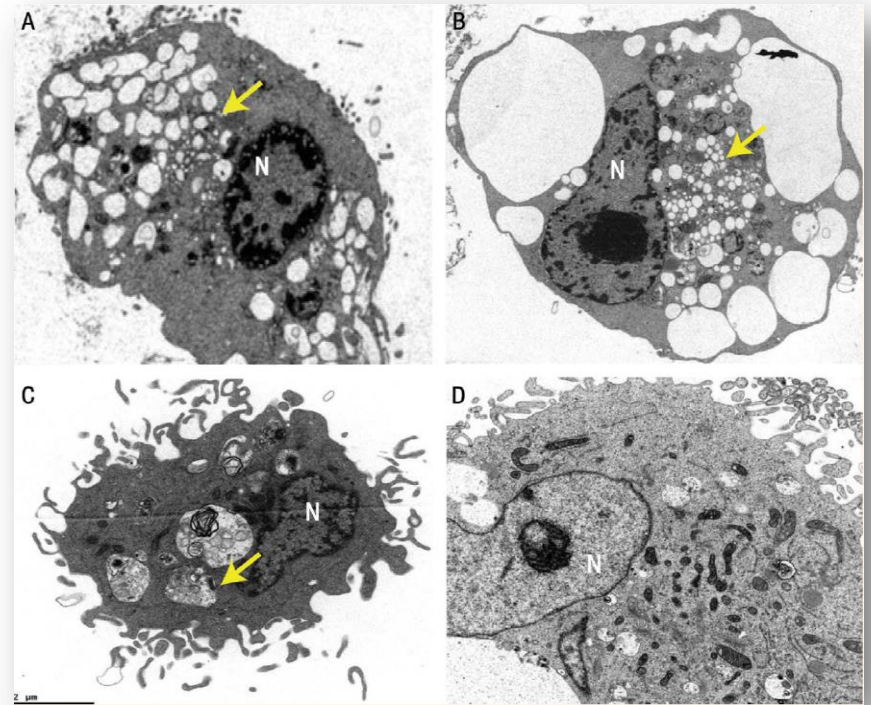
- 40 natural products from marine organisms were screened
- 22.5% showed anticancer activity to MCF-7 breast cancer cell line
- EC₅₀ range from 1000-50µg/ml



■ no activity ■ weak
■ medium ■ strong activity

Anticancer activity of malformin

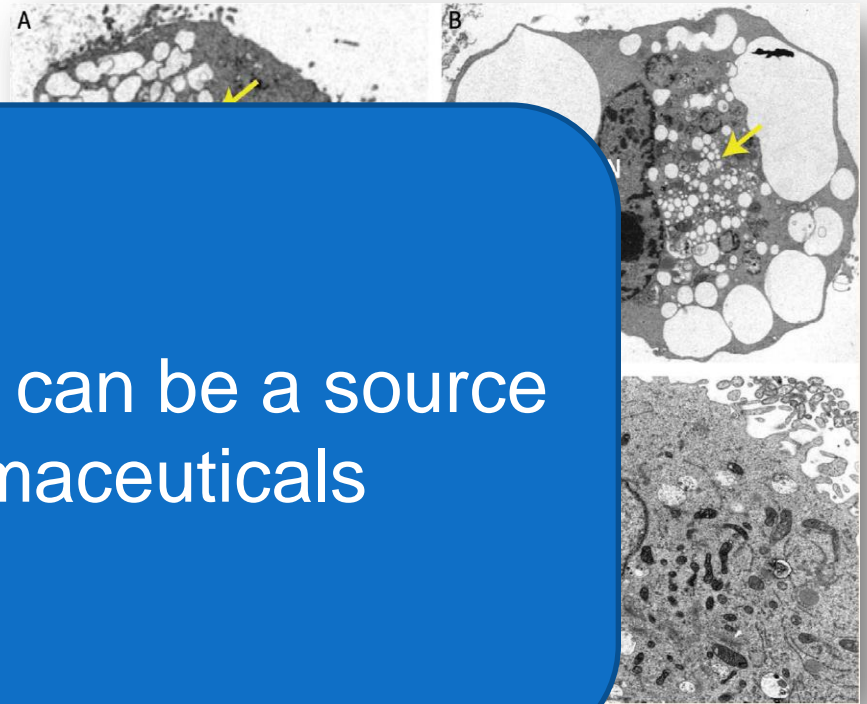
- Apoptosis of MCF-7 breast cancer cells after treatment with malformin at $50\mu\text{g/ml}$ for 24h



Anticancer activity of malformin

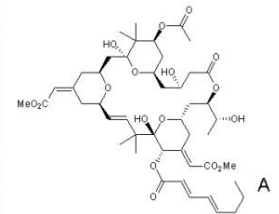
- Apoptosis
breast
treatment
malformin
for 2

Marine organisms can be a source
of new pharmaceuticals



Problems associated with marine natural products

- **High cost & long time.** >\$ 1 mil
>10 years
- **Source?** Who is producing the host or the microbial symbionts?
- **Supply?** Not sufficient
14 metric tons (wet weight) of bryozoan = 18 g of Bryostatin



Bugula neritina does not produce anticancer compound - bryostatin

Solutions

- **Problem:** Not sufficient supply
- **Solutions:** microbial fermentation, algal aquaculture, synthesis of natural products

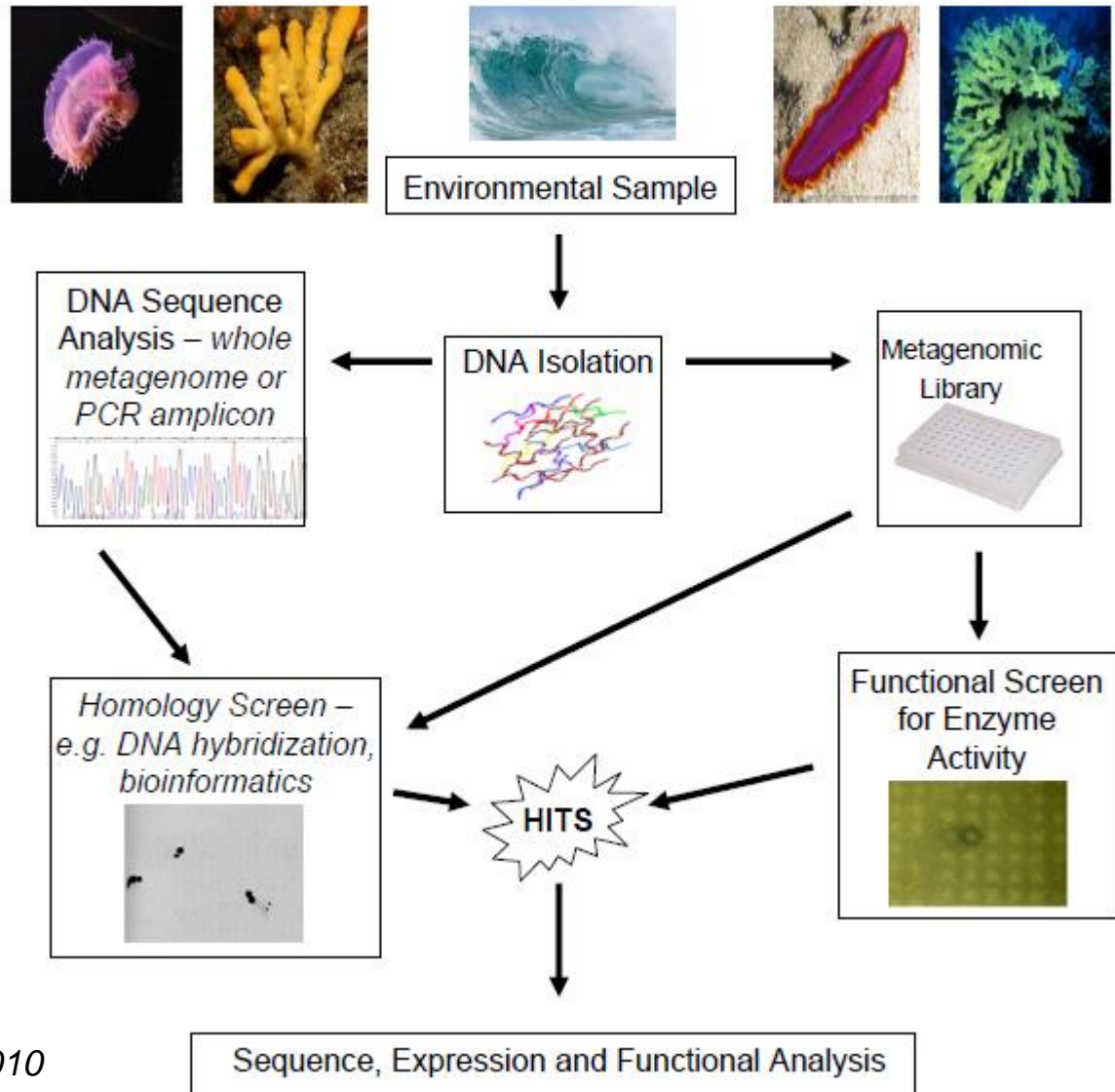


Exporebiotech.com

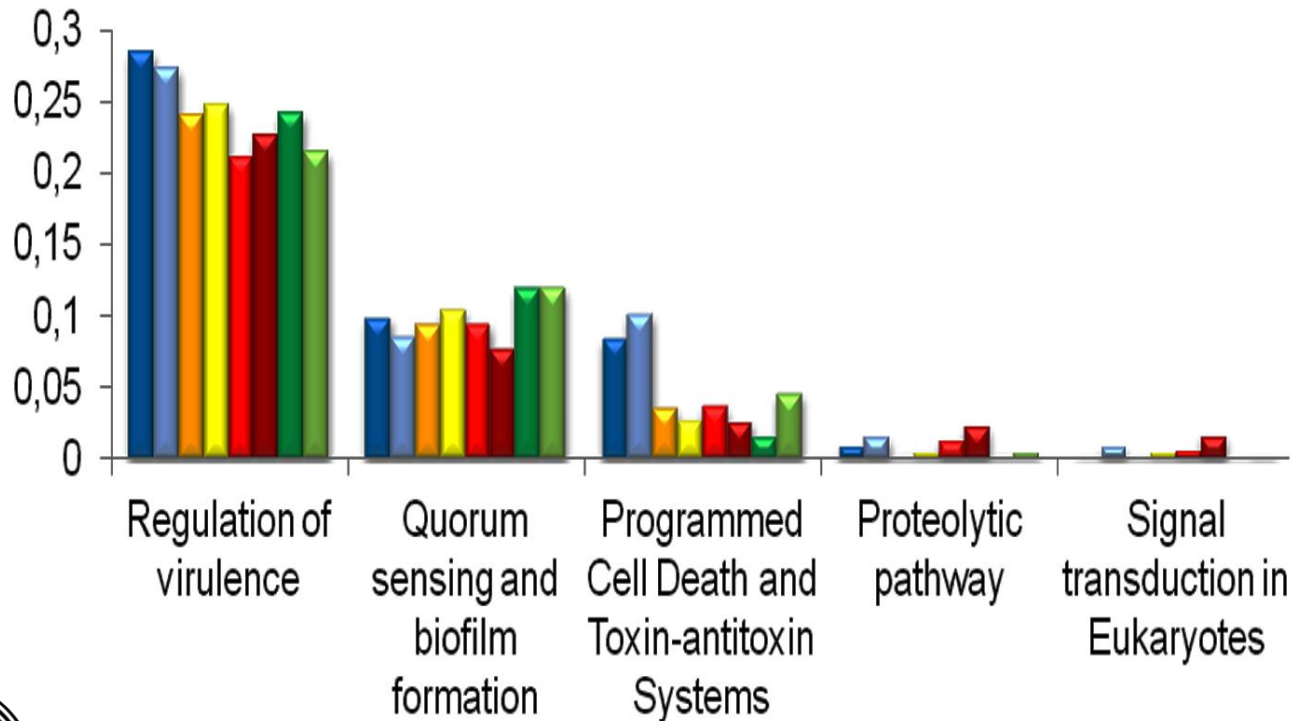


Functional metagenomics

- Screening DNA for certain activity
- Look for new genes and new functions
- Can identify genes from uncultivable organisms



Bioactive genes in Brazil sponges



UFRJ

■ Ti-out ■ Hh-out ■ Da-in ■ De-in
■ Ti-in ■ Hh-in ■ Da-out ■ De-out

Batista et al. Mar Env Res 2018



Conclusions

- Marine organisms provide food, bioactive compounds and high tech products for different applications.
- Chitosan from fish waste can be used in industrial applications (food packaging, antifouling)
- QS exist in marine biofilms and inhibitors can be used for the prevention of biofouling



Future perspectives

- **Investigate** biotechnological potential of marine organisms
- **Interdisciplinary** research
- **Development** of start-ups companies that translate scientific discoveries into products



Gracias!

THANK YOU

