Marine Algal Biotechnology in Korea: present and future perspective

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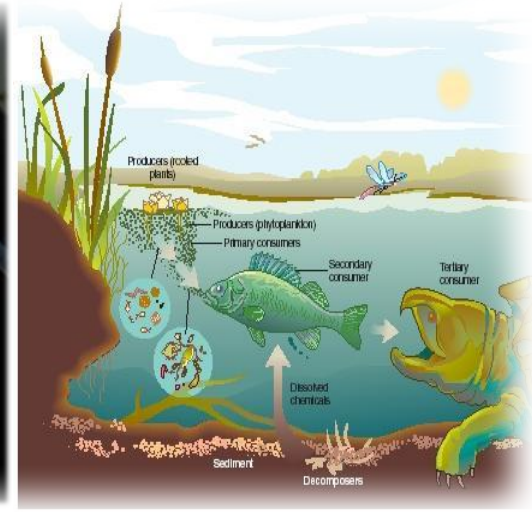

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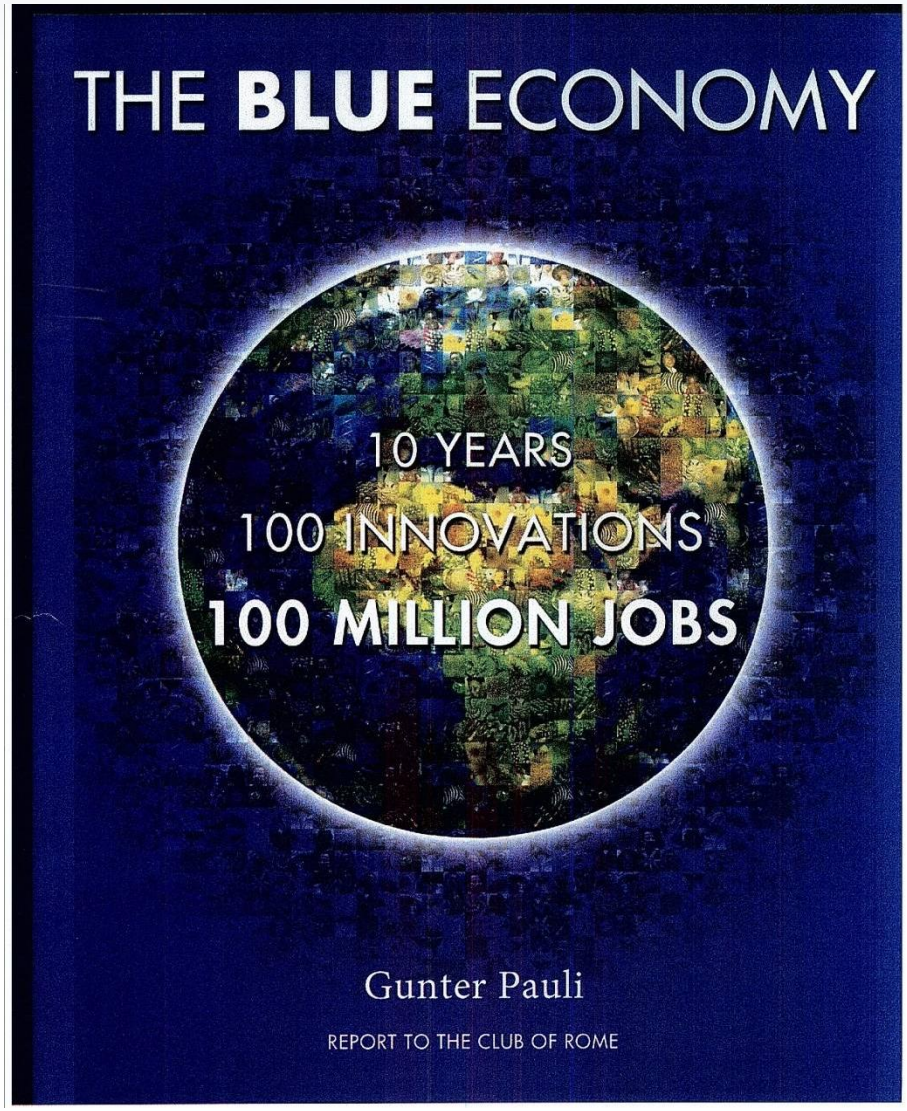
The Blue Economy



"The Blue Economy"

- ▷ Dr. Gunter Pauli
- ▷ Published in 2010

Ocean of the Earth

- ▷ 300,000 species
- ▷ 75% of the total O_2 production
- ▷ 50% of the total CO_2 storage

What is Blue Economy ?

The Red Economy

planned/based on what we do not have

The Green Economy

invest more/save some

The Blue Economy

invest less/innovate more /based on what we have

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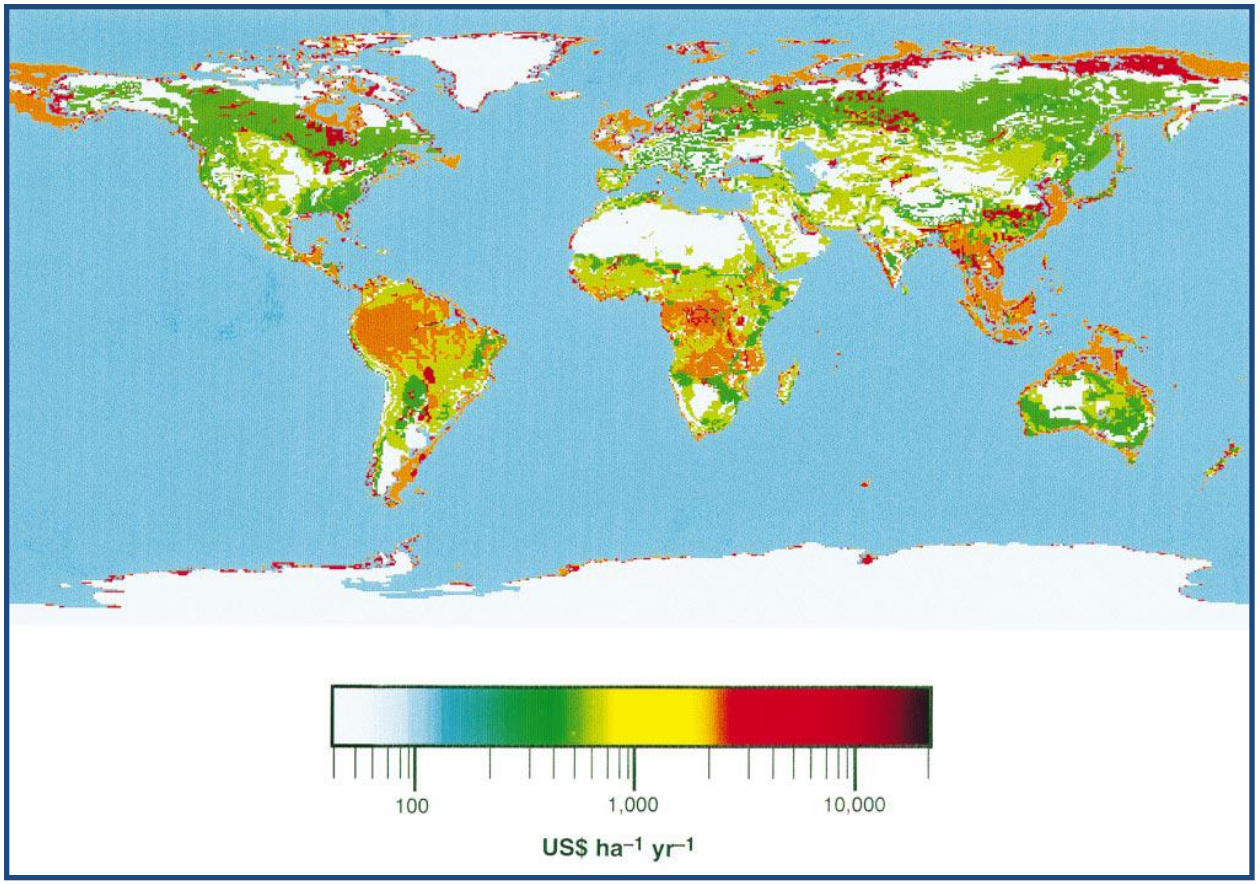
Ecosystem service

●Service market

▹ Total $33,000 billion per year in 21st century

▹ Marine ecosystem ($20,900 billion)

▹ Coastal ecosystem ($10,600 billion)



Seaweed as Waste

Seaweed as Food

Hot issues

Canary and mine field

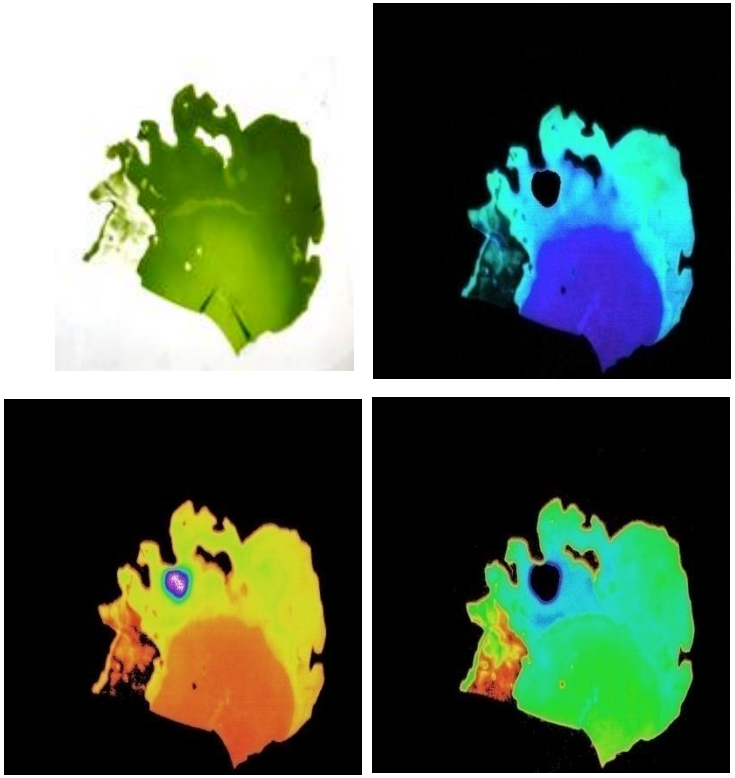
Biomonitoring of water quality

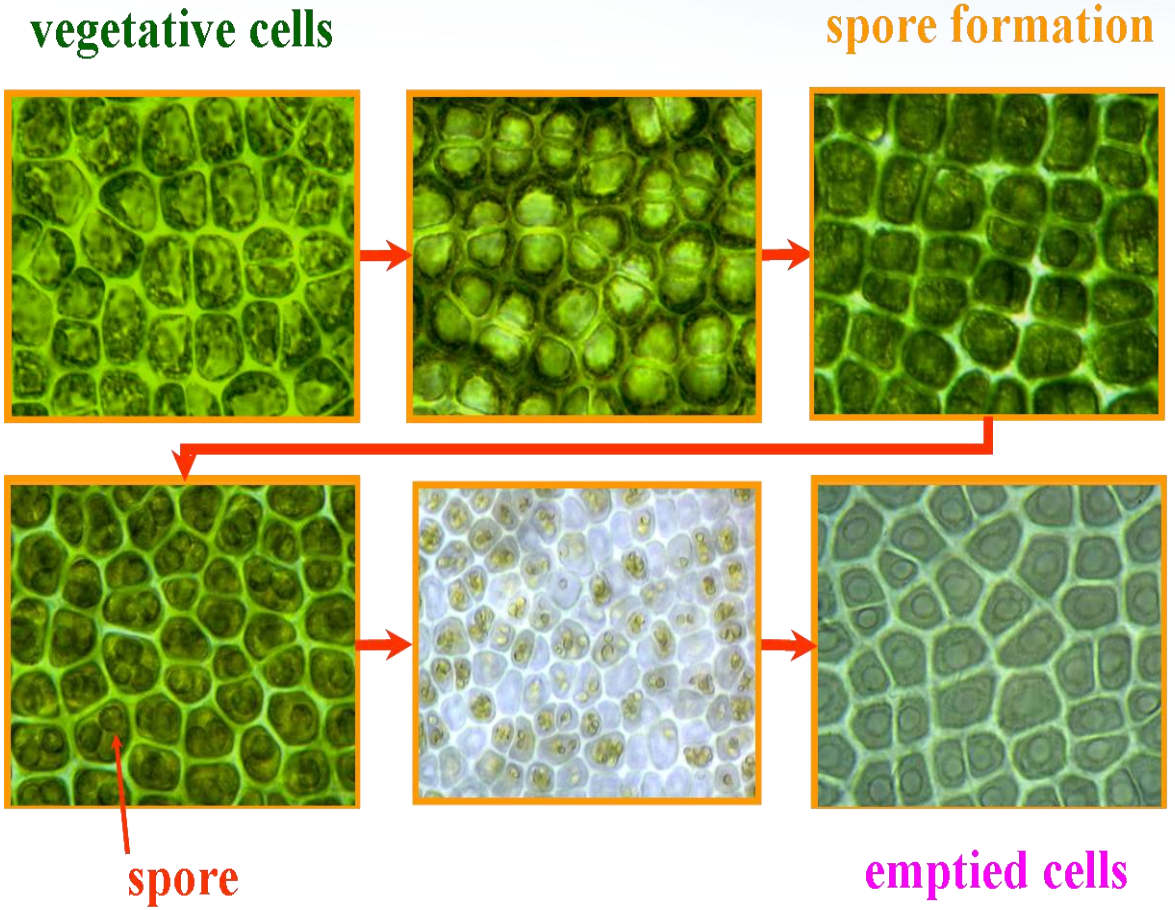
❍ *Ulva pertusa*

A principle of Ulva biotest

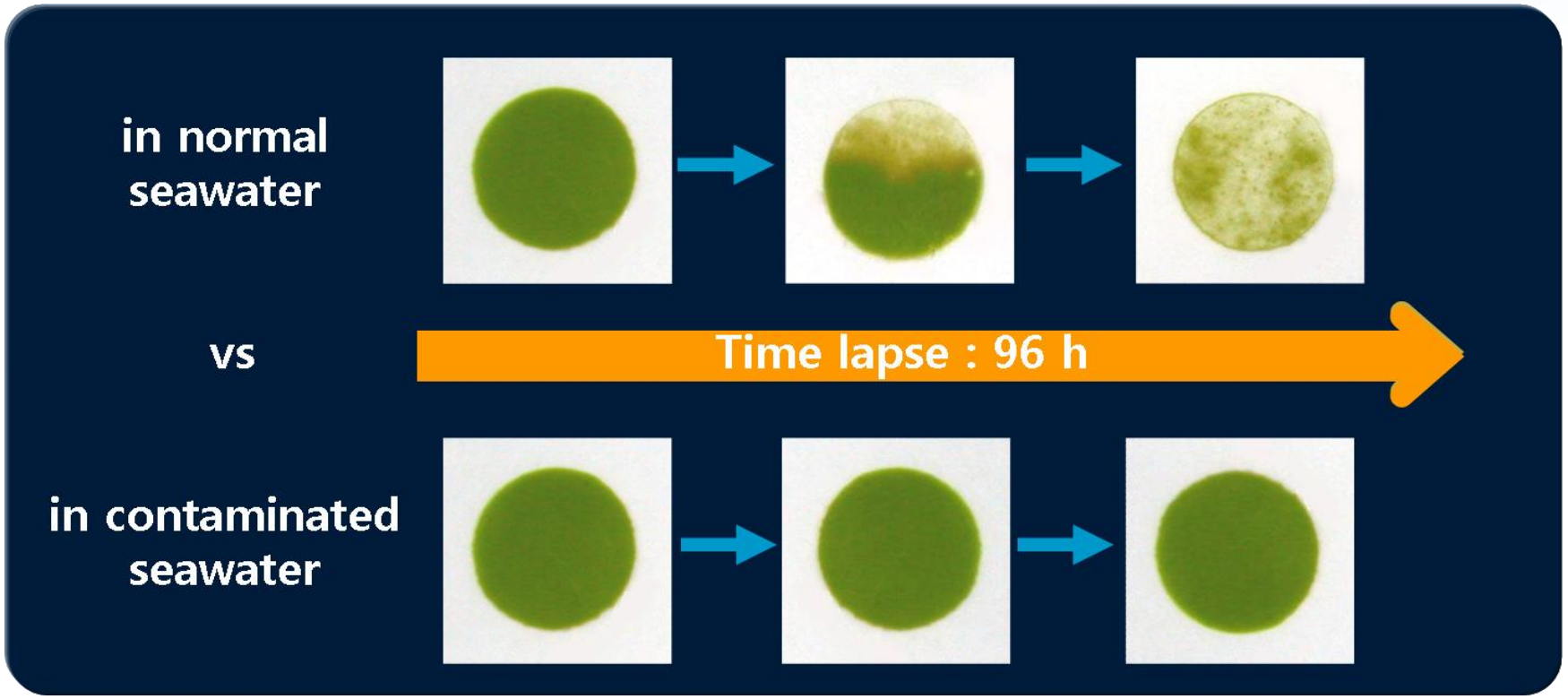
“sporulation”

A principle of Ulva biotest



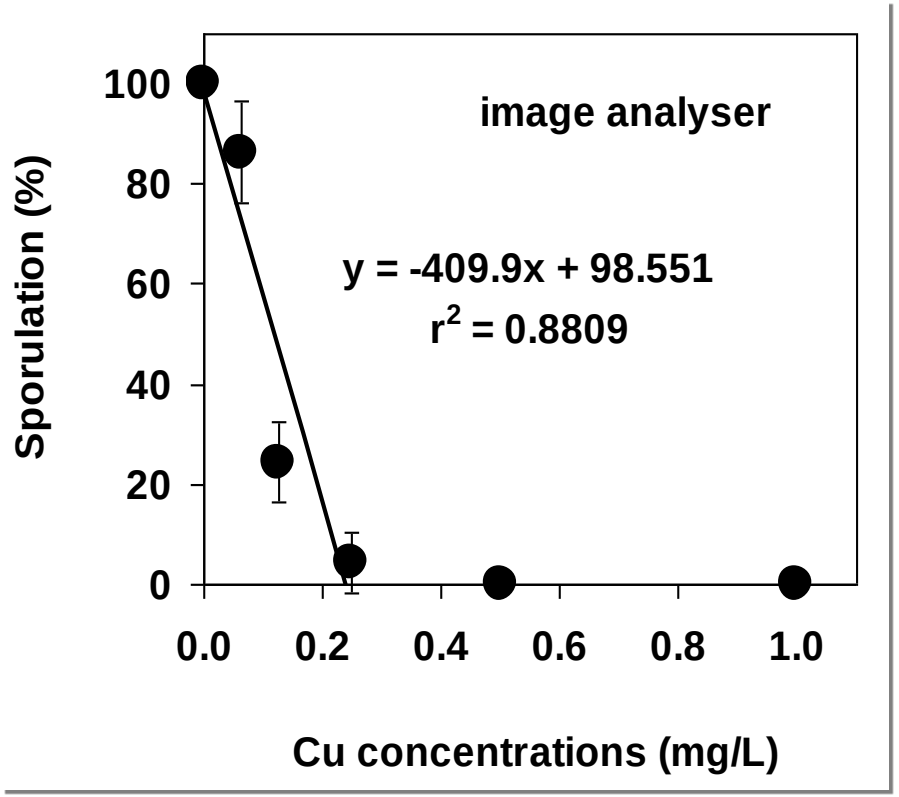


A principle of Ulva biotest



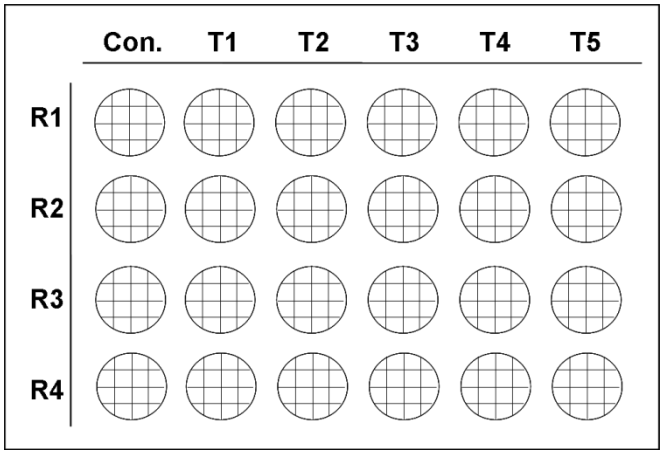
The Ulva biotest

- Image analysis method

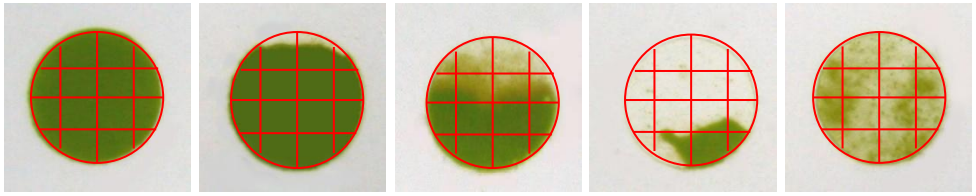


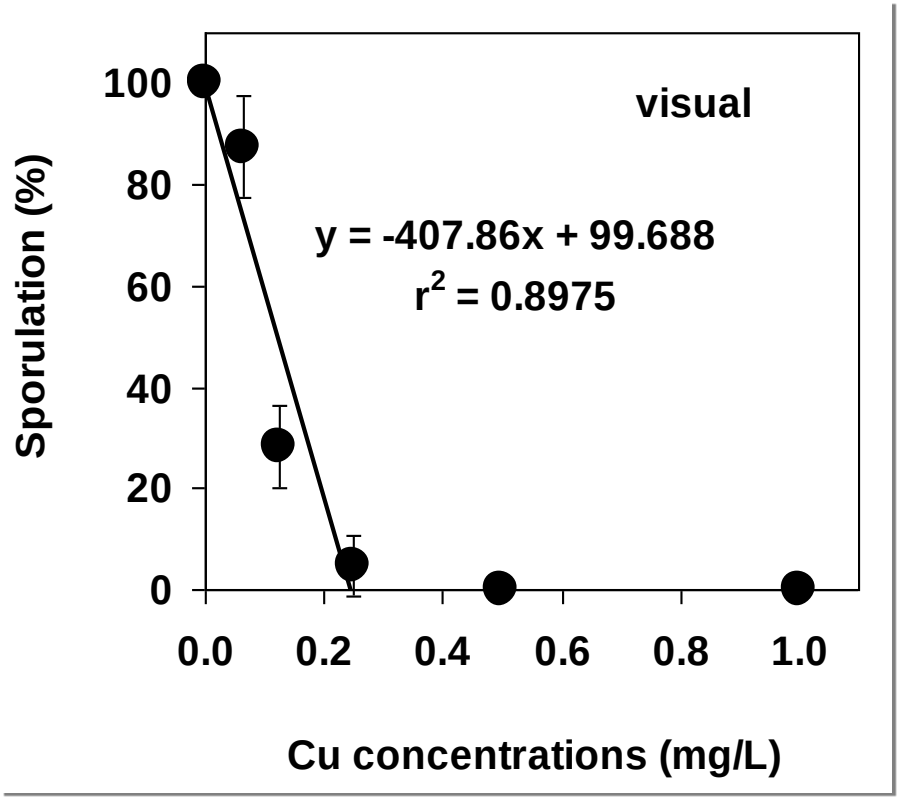
The Ulva biotest

❍ Visual observation

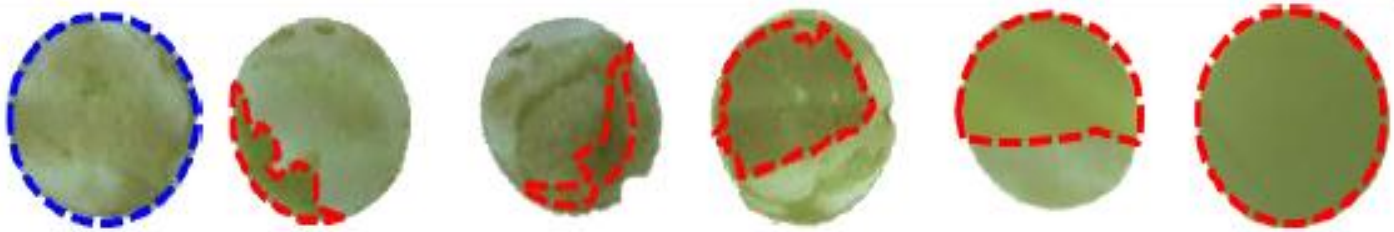


NUMBER OF OBSERVED AREAS	PERCENTAGE OF AREA WITH COLOR CHANGE(%)
0	0
1	6
2	13
3	19
4	25
5	31
6	38
7	44
8	50
9	56
10	63
11	69
12	75
13	81
14	88
15	94
16	100



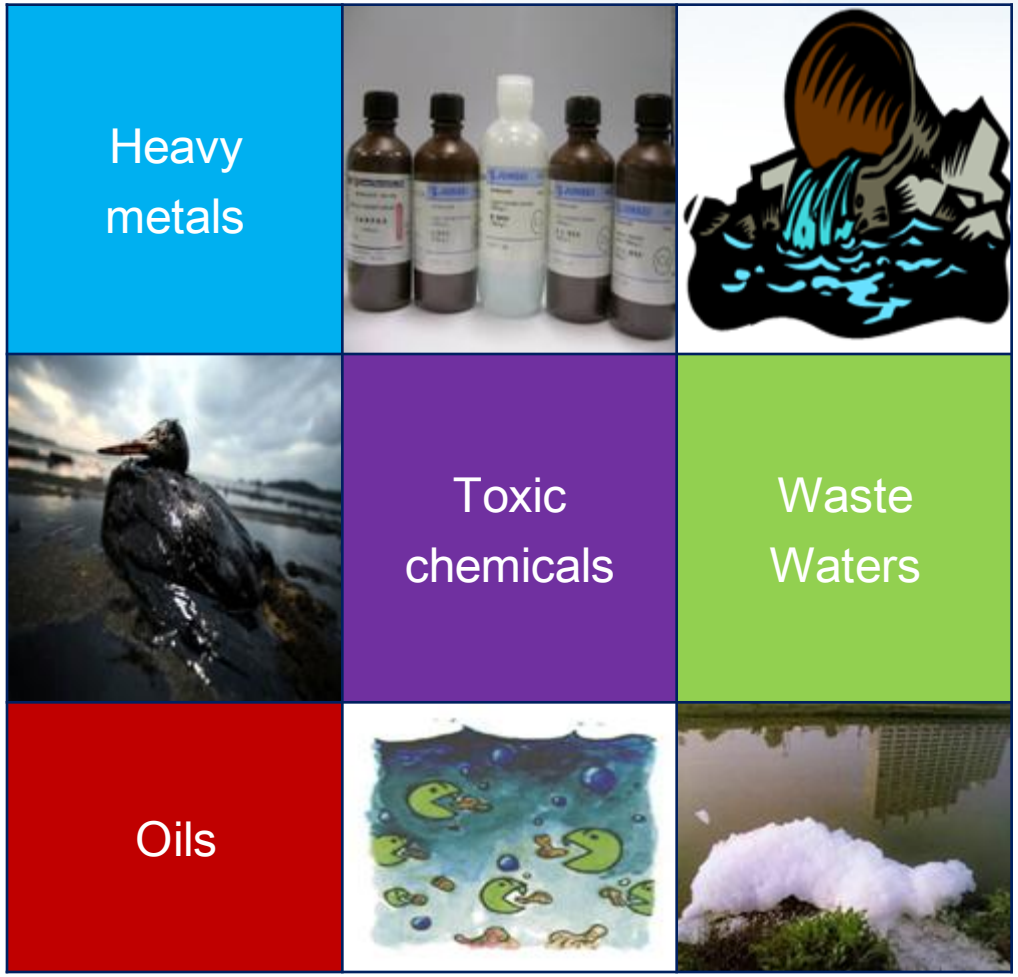


The Ulva biotest-update

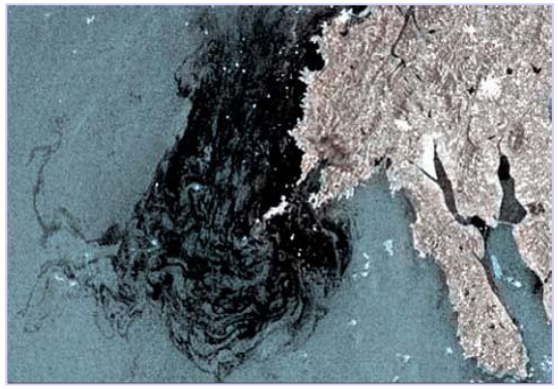
Analysis Method (Sporulation %)		Concentration of Cu (mg·L^{-1})					
		0	0.0156	0.0313	0.0625	0.125	0.250
Before Staining	Motic image analysis						
		100	84.555	84.141	49.051	32.955	0
	Image J						
		100	75.267	50.612	50.33	36.121	0

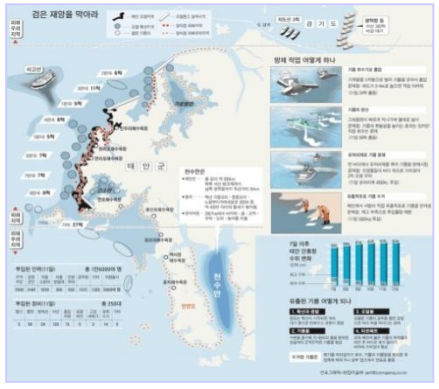
Tested samples by the Ulva biotest

Toxicants	No. of samples
Metals	13 species
VOCs	7 species
Herbicides	3 species
individual compounds	3 species
sludge elutriates	9 species
slag leaching water	4 species
Oil	1 species
Wastewater	4 species
Stream water	13 species
Sea water	17 species
Totals	74 species

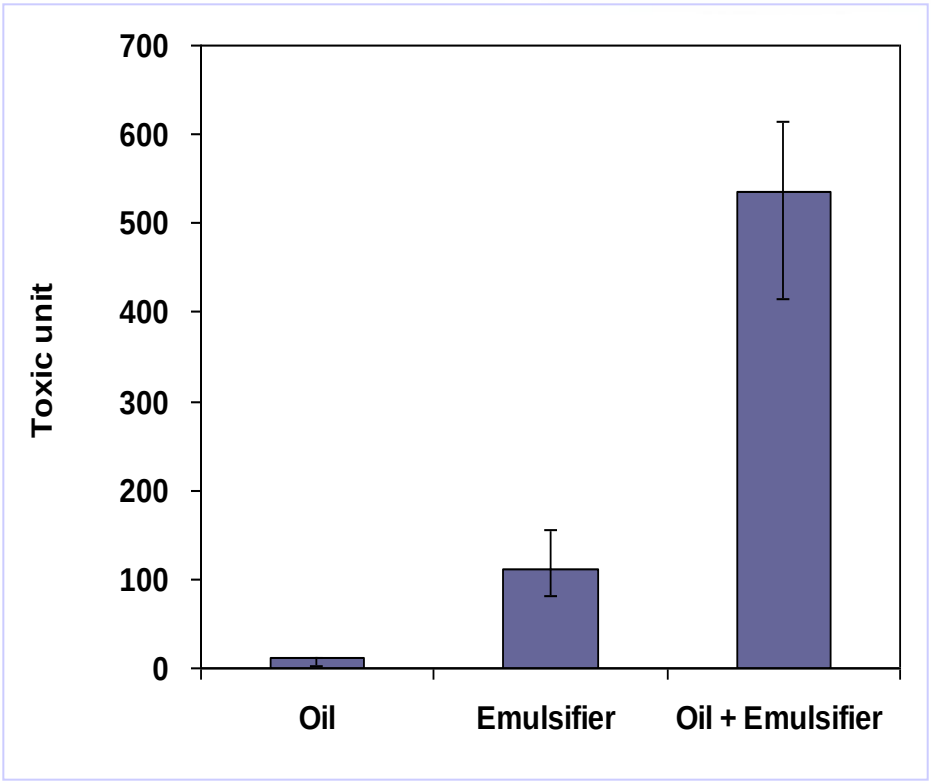


Biotesting oil pollution





	TU	Min	Max	CV(%)
Oil	10.6	8.8	18.1	9.74
Emulsifier	111.1	66.6	141.5	12.79
Oil + Emulsifier	534.6	455.2	655.1	7.57

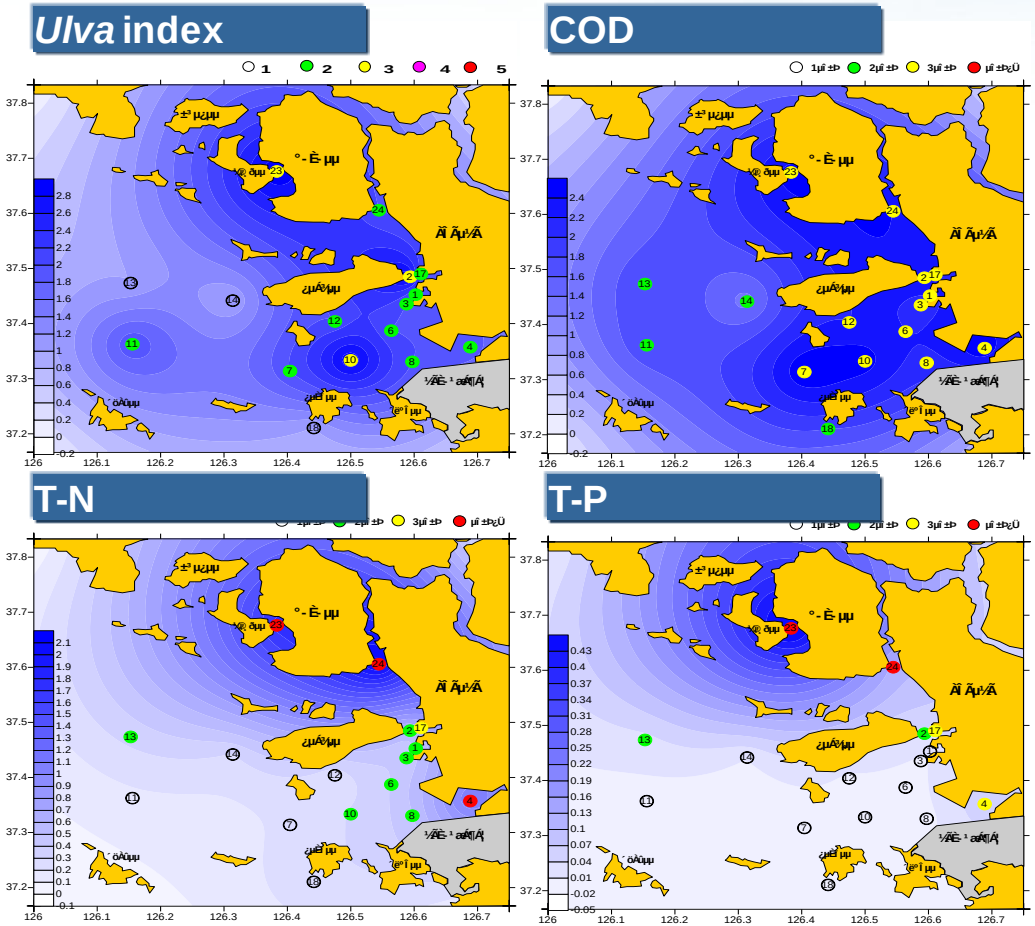


Ulva watch programme

Set point

Data input
(Surfer 7.0 program)

Mapping



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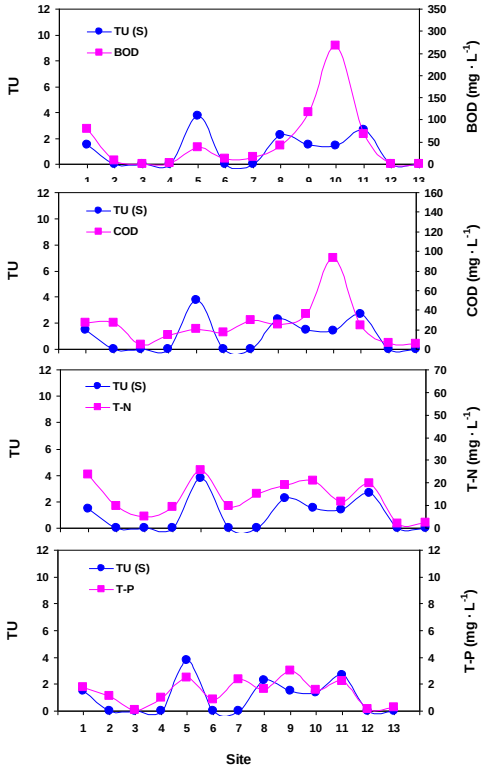
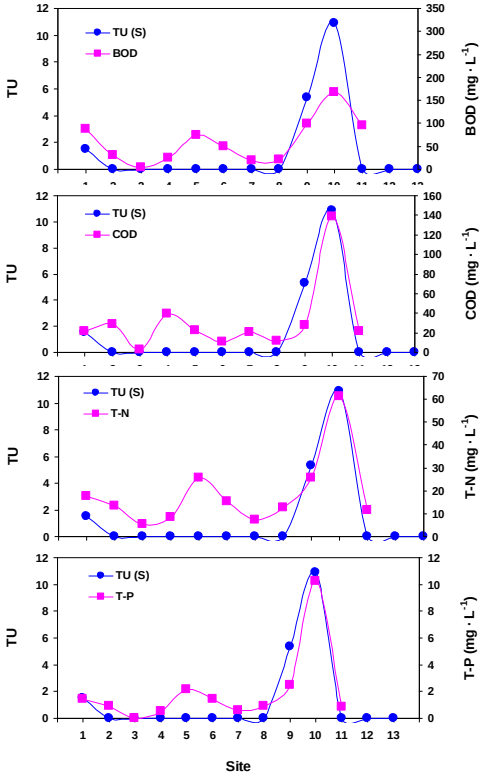
Ulva index vs BOD, COD, T-N, T-P

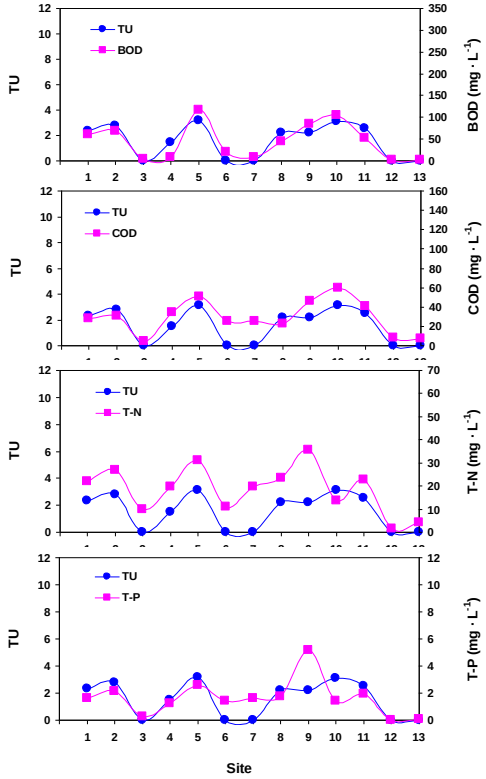
spring



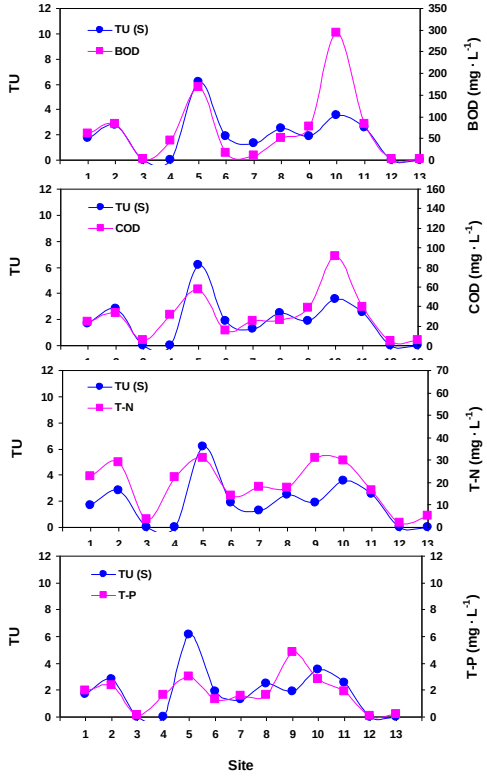
summer



autumn



winter



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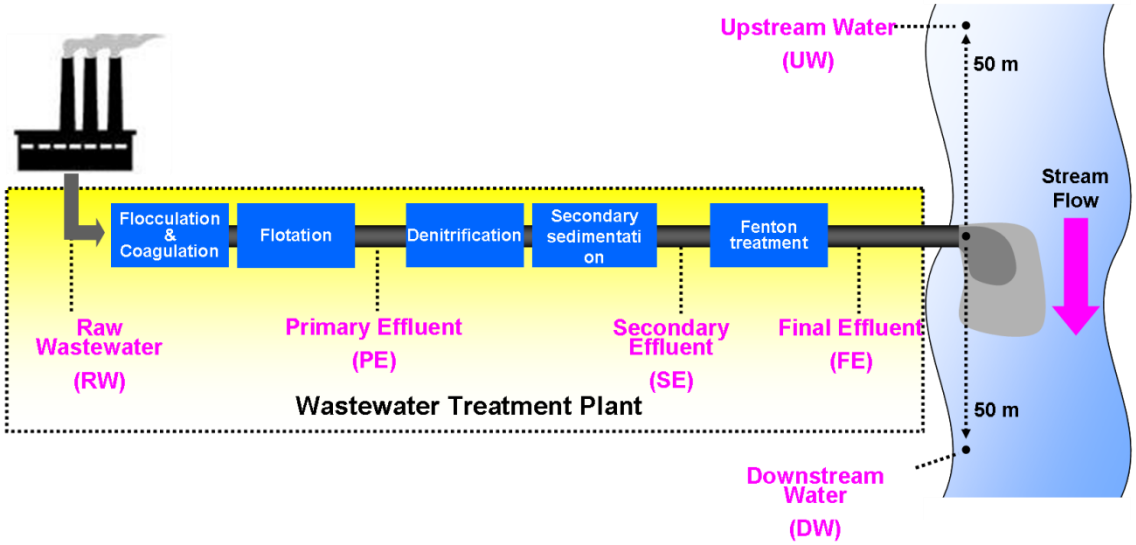
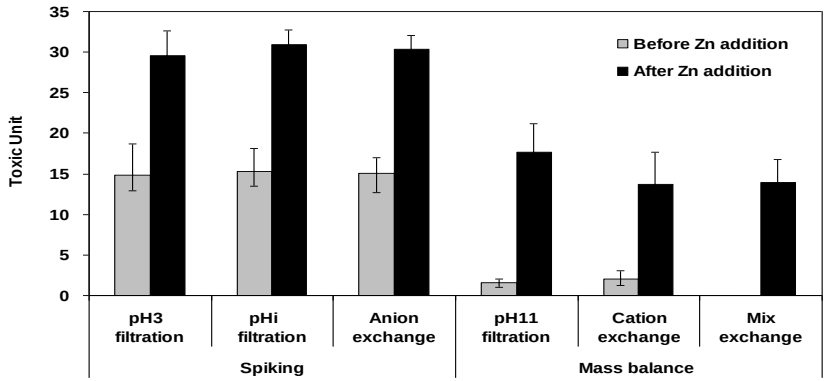
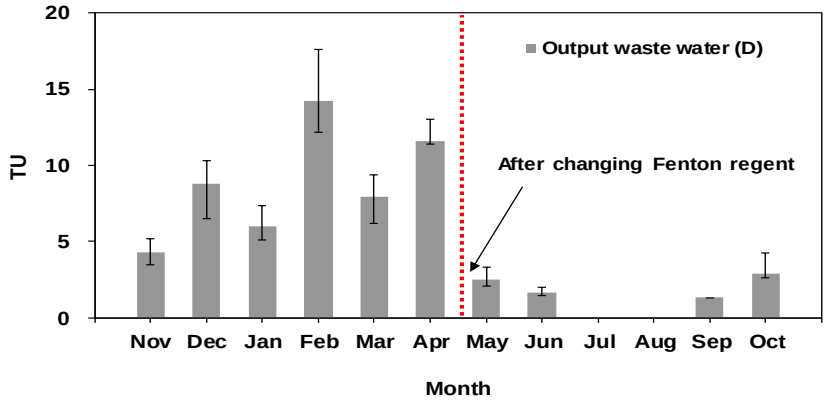
Toxicity identification by Ulva test

❍ Toxicity test of wastewater effluent near Hantan river basin

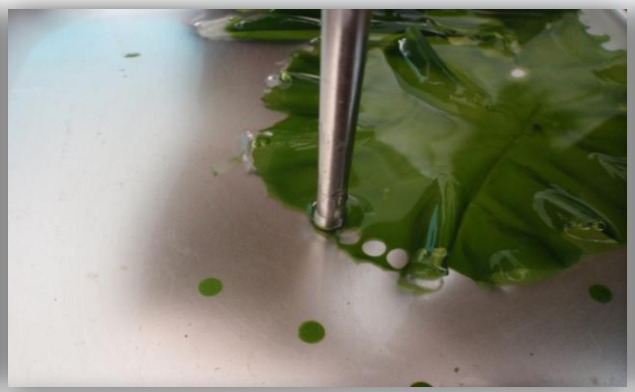


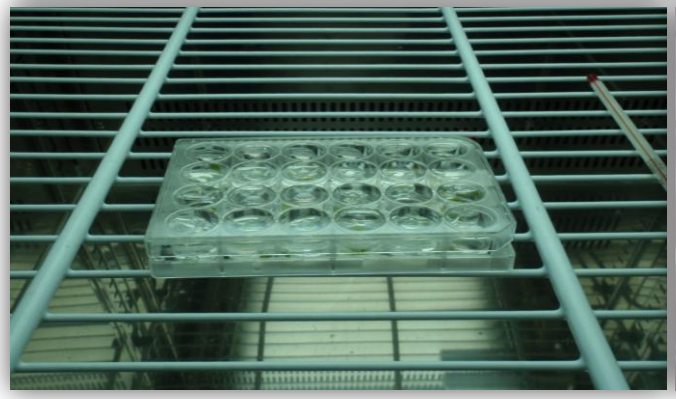
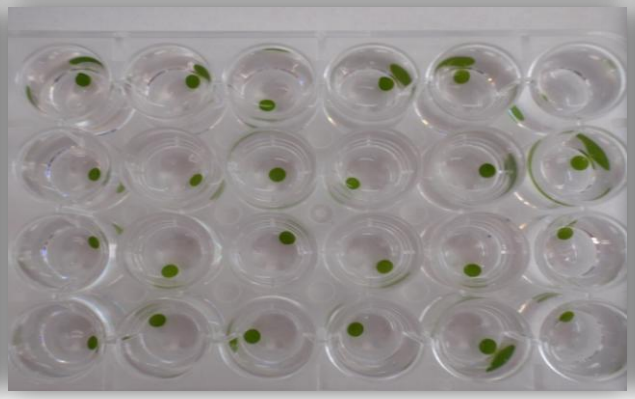
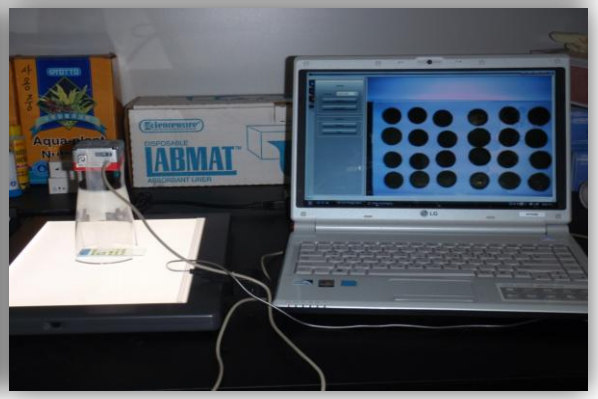


독성평가생물	RW	PE	SE	FE	US	DS
물벼룩	4.10	1.00	< 1.00	3.70	<1.00	1.50
파래	4.75	2.65	<1.00	4.30	<1.00	2.51



Operational procedure

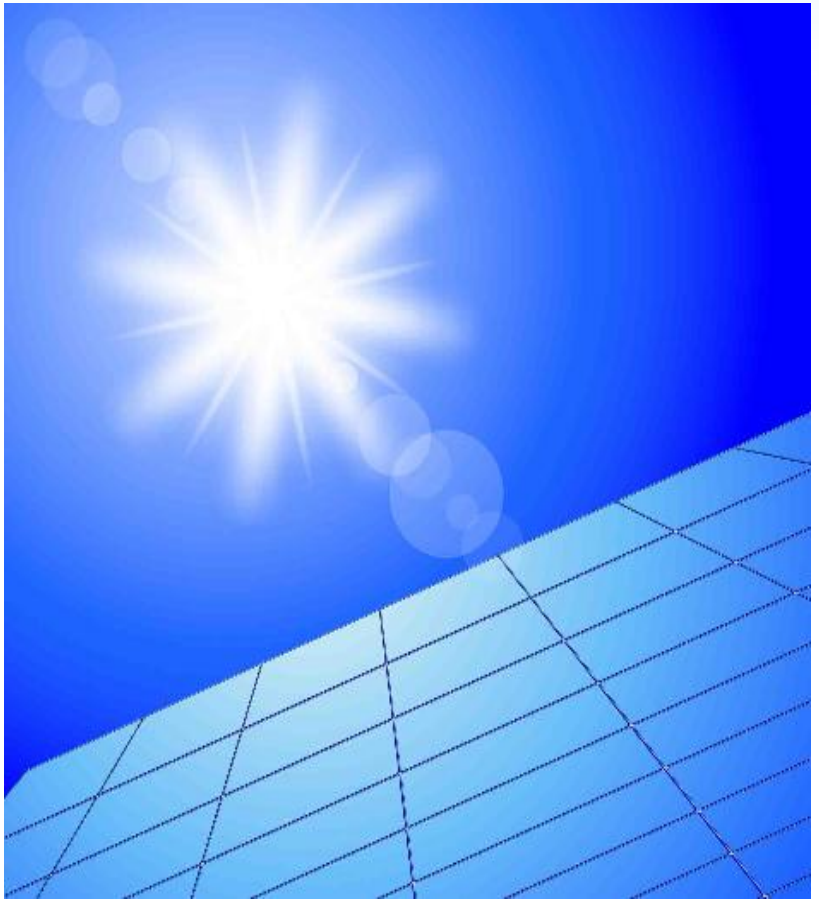
Space : <1m²
Person : 1
Time : 96 h

Facilities : temperature-controlled culture chamber, 24 well plates, pipets, tips, hole borer etc.
Measuring device : simple image analyzer

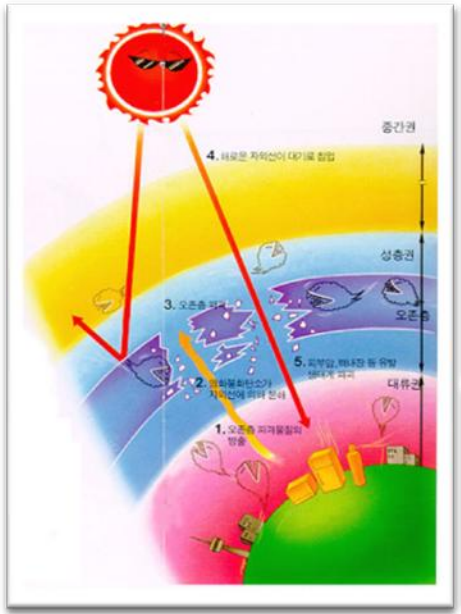
The Ulva kit

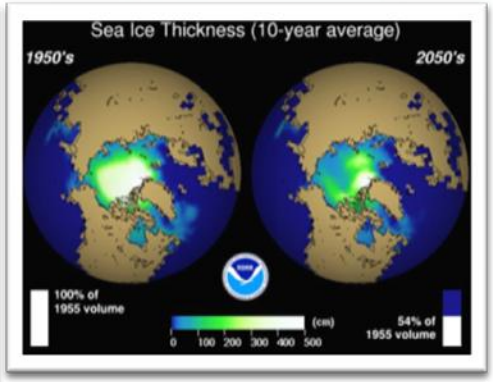
The new bioassay is simple to use, sensitive, economic, eco-relevant and has worldwide application

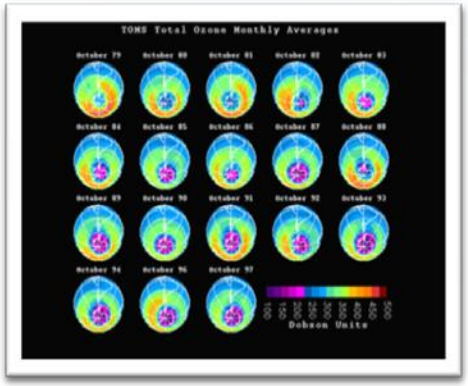
Solar UV radiation

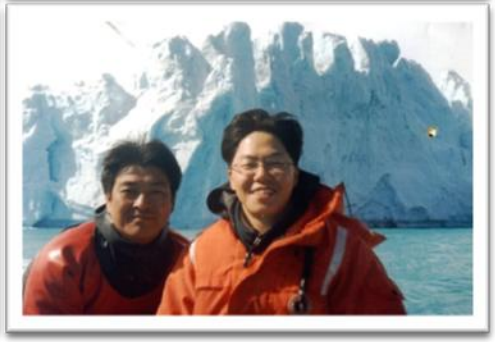


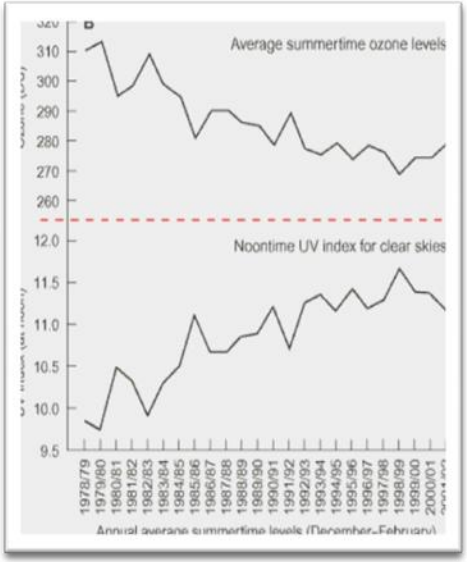
Climate change and UV radiation



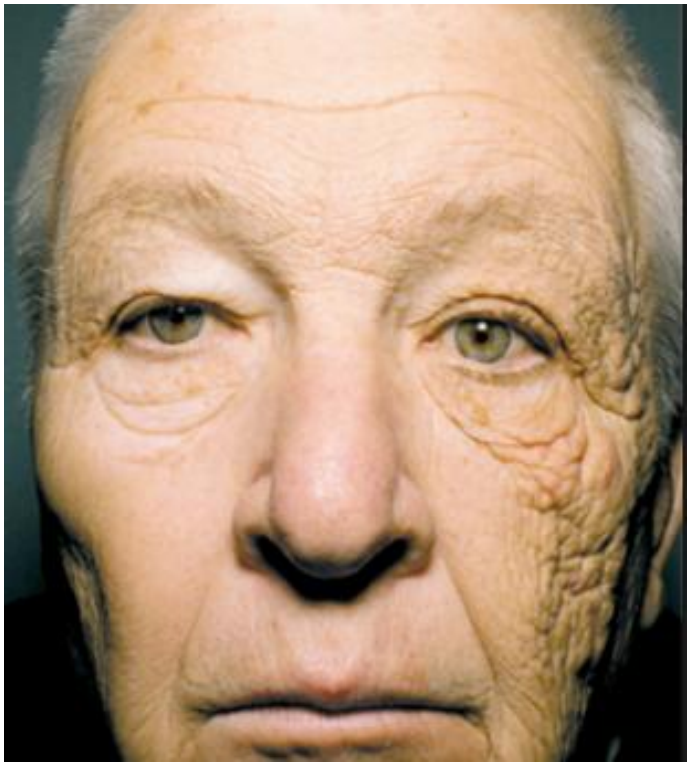




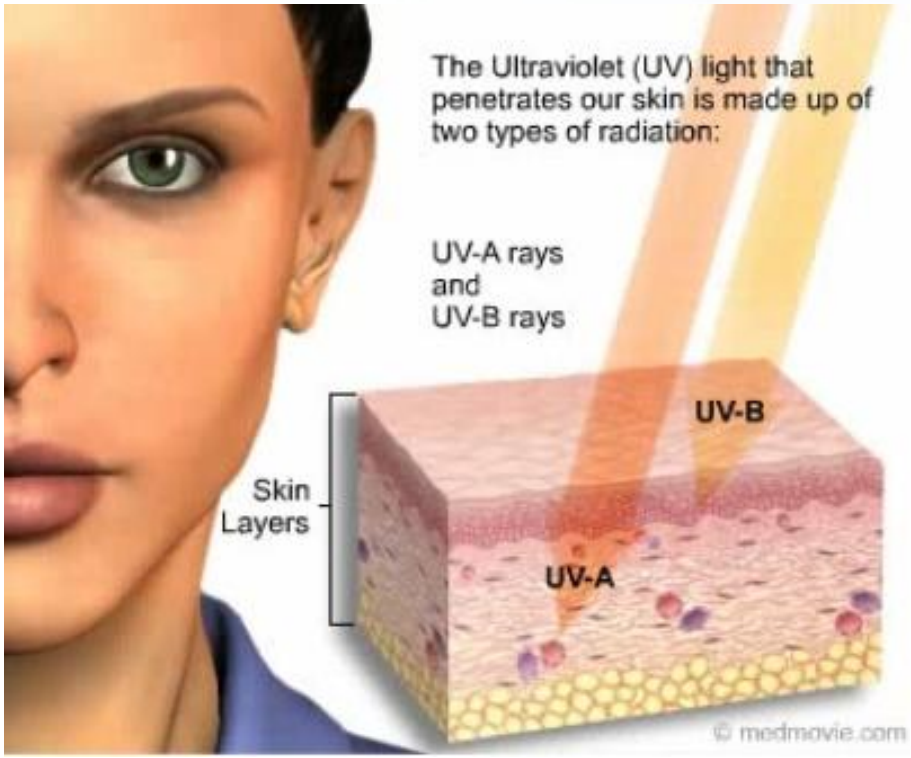




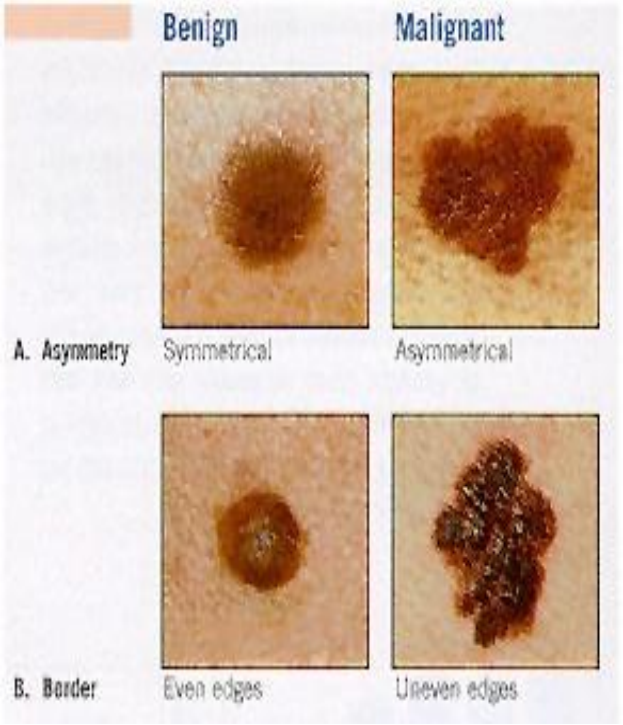
Harmful effects of UV on the skin

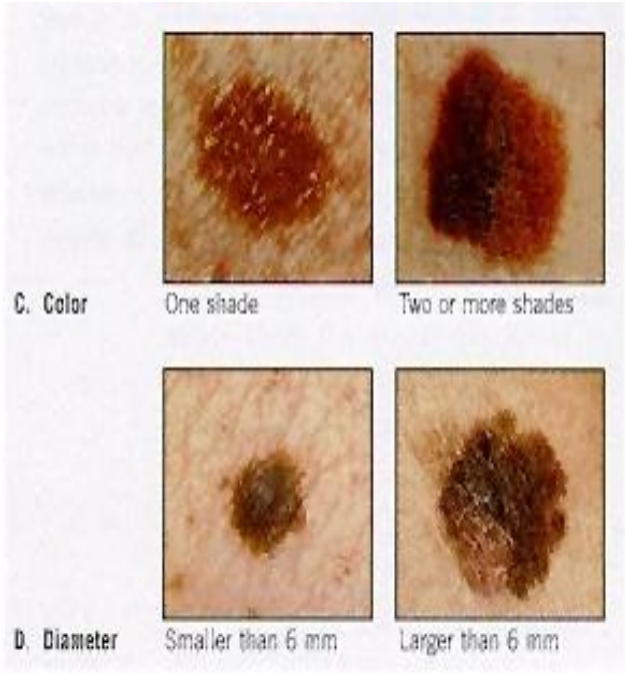


<Photo = jennifer R.S. Gordon, M.D>

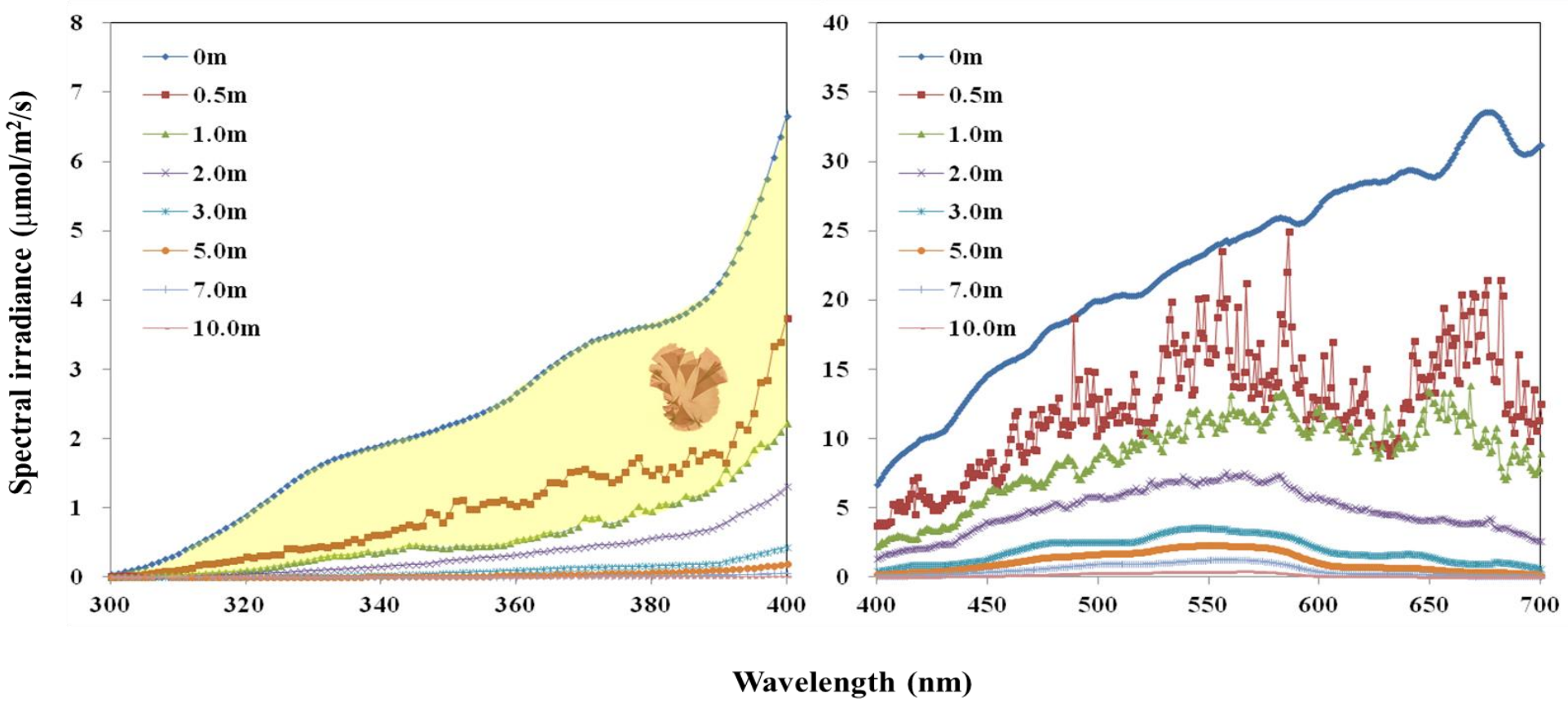


Harmful effects of UV on the skin



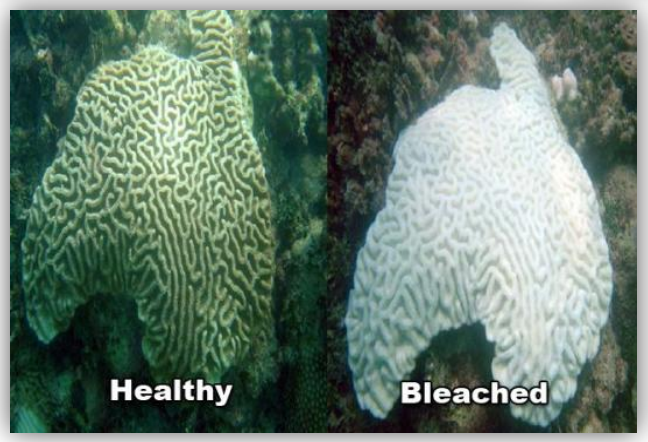


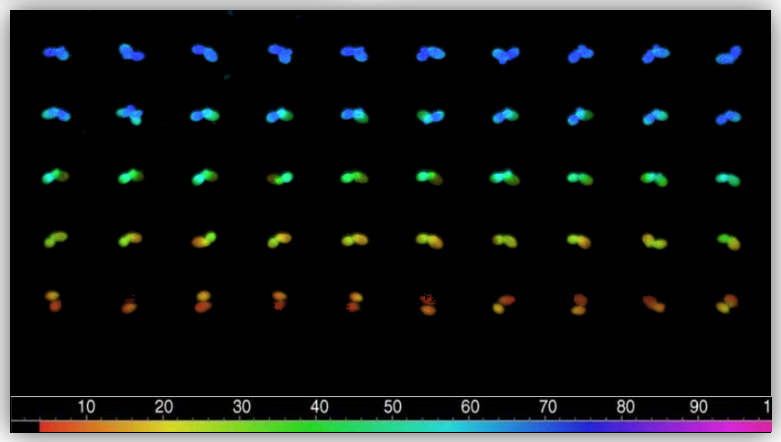
Underwater profile of solar radiation



Harmful effects of UV on marine organisms

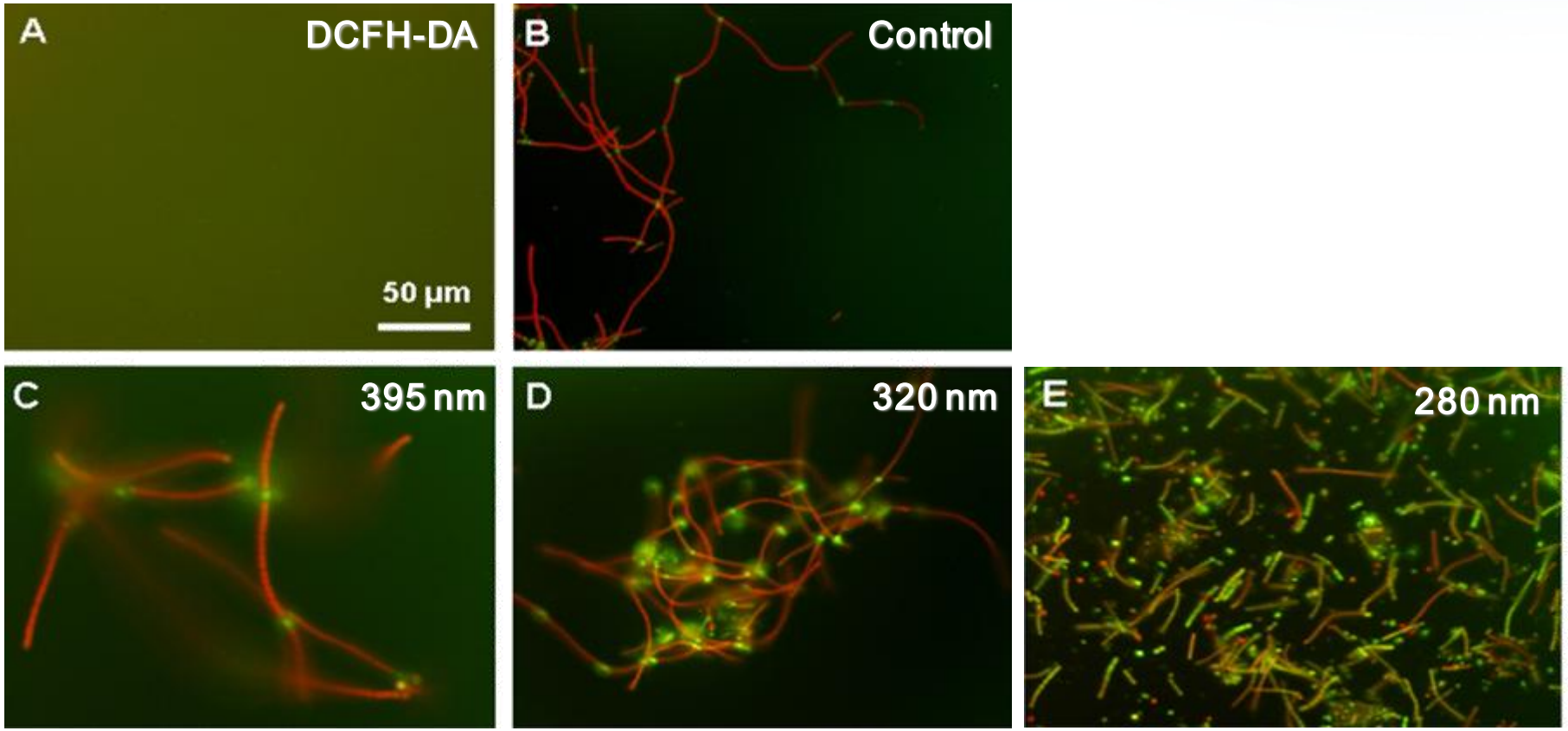
- **Physiological and biochemical damage**





Harmful effects of UV

- **Generation of reactive oxygen species (ROS)**



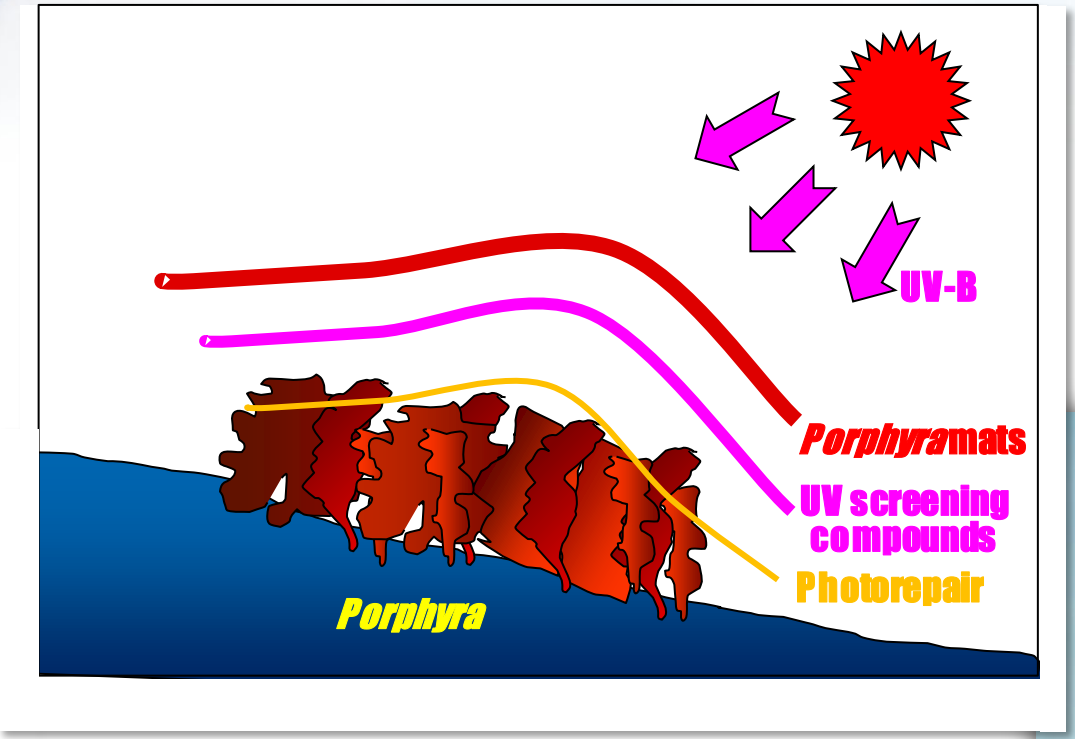
(Rastogi et al., BBRC, 2010)

UV protective mechanisms

PHOTOPROTECTIVE MECHANISMS

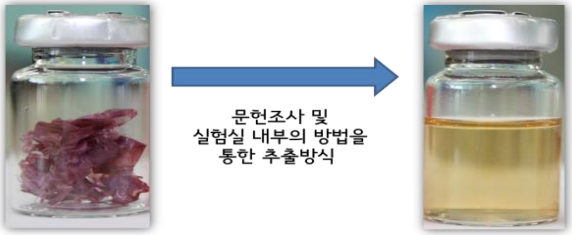
- 1st line of defense mechanisms
  - Migration
  - Mat formation
  - Changes in morphology to increase self-shading
- 2nd line of defense mechanisms
  - Production of quenching
  - Antioxidant systems
- 3rd line of defense mechanisms
  - Production of UV-absorbing compounds
- 4th line of defense mechanisms
  - Repair mechanism

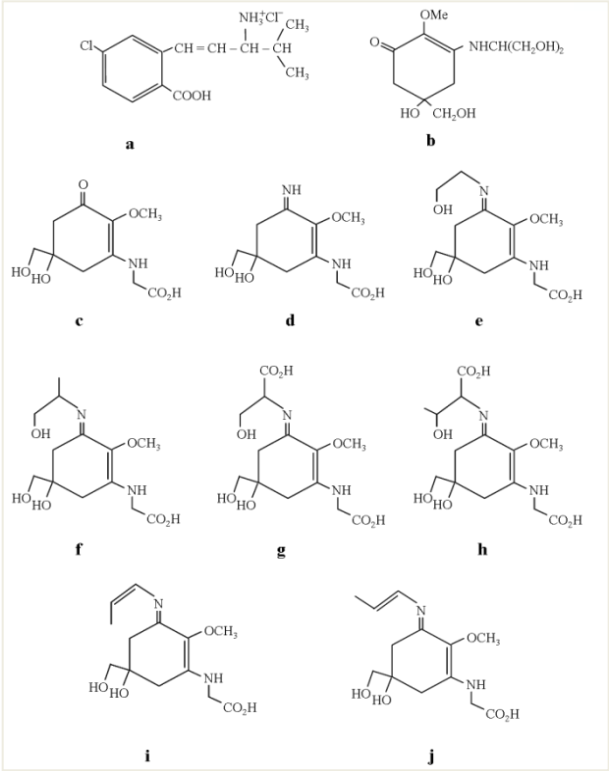
UV protection in seaweeds



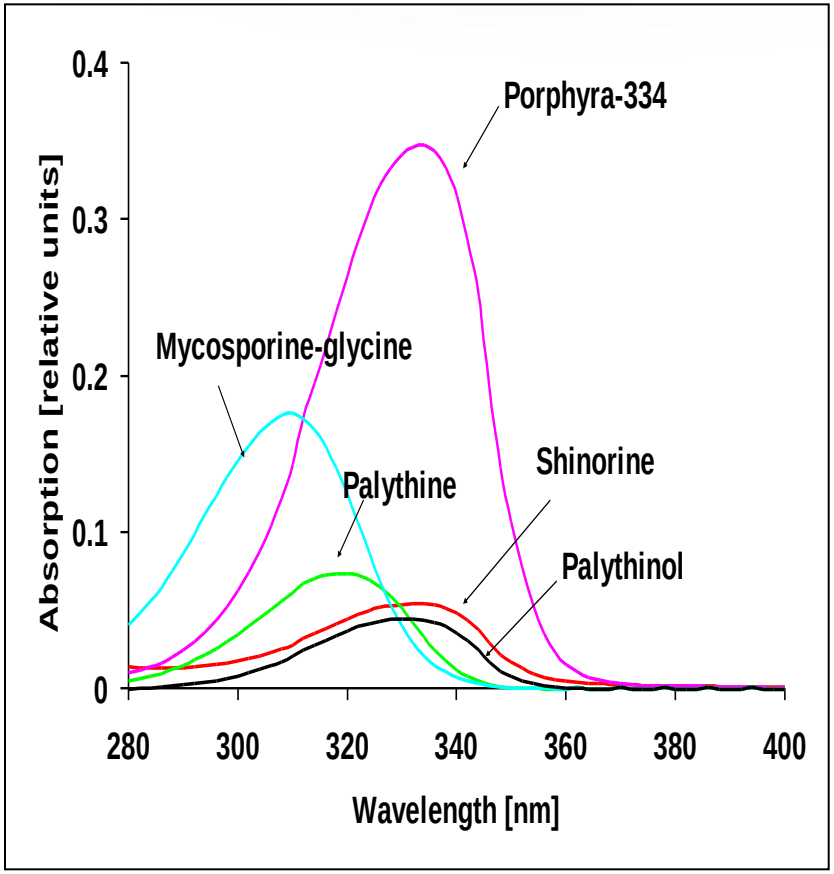
UV–Screening Compounds

Porphyra yezoensis



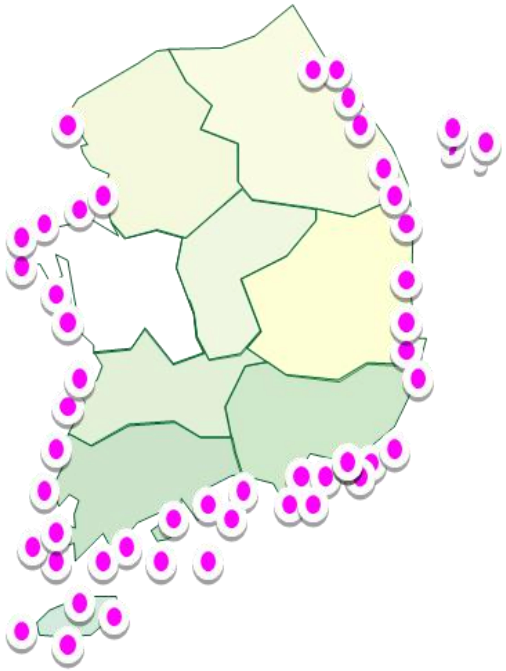


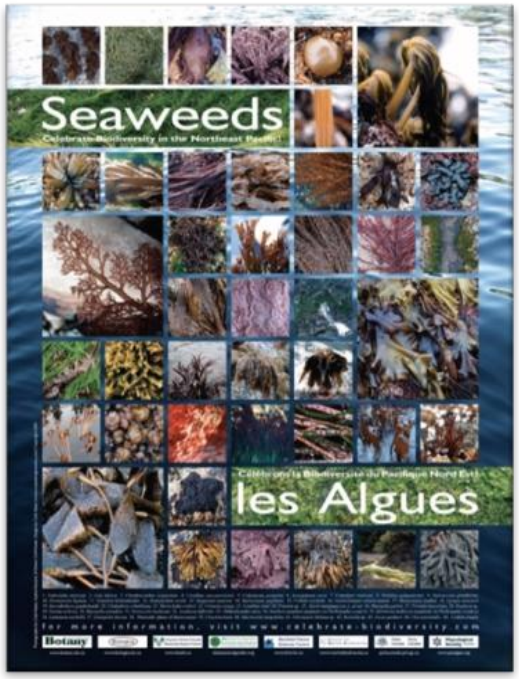
MAAs compounds



Search for MAAs in Korean macroalgae

- 133 species of domestic algae (17 of green algae, 34 of brown algae, 82 of red algae)





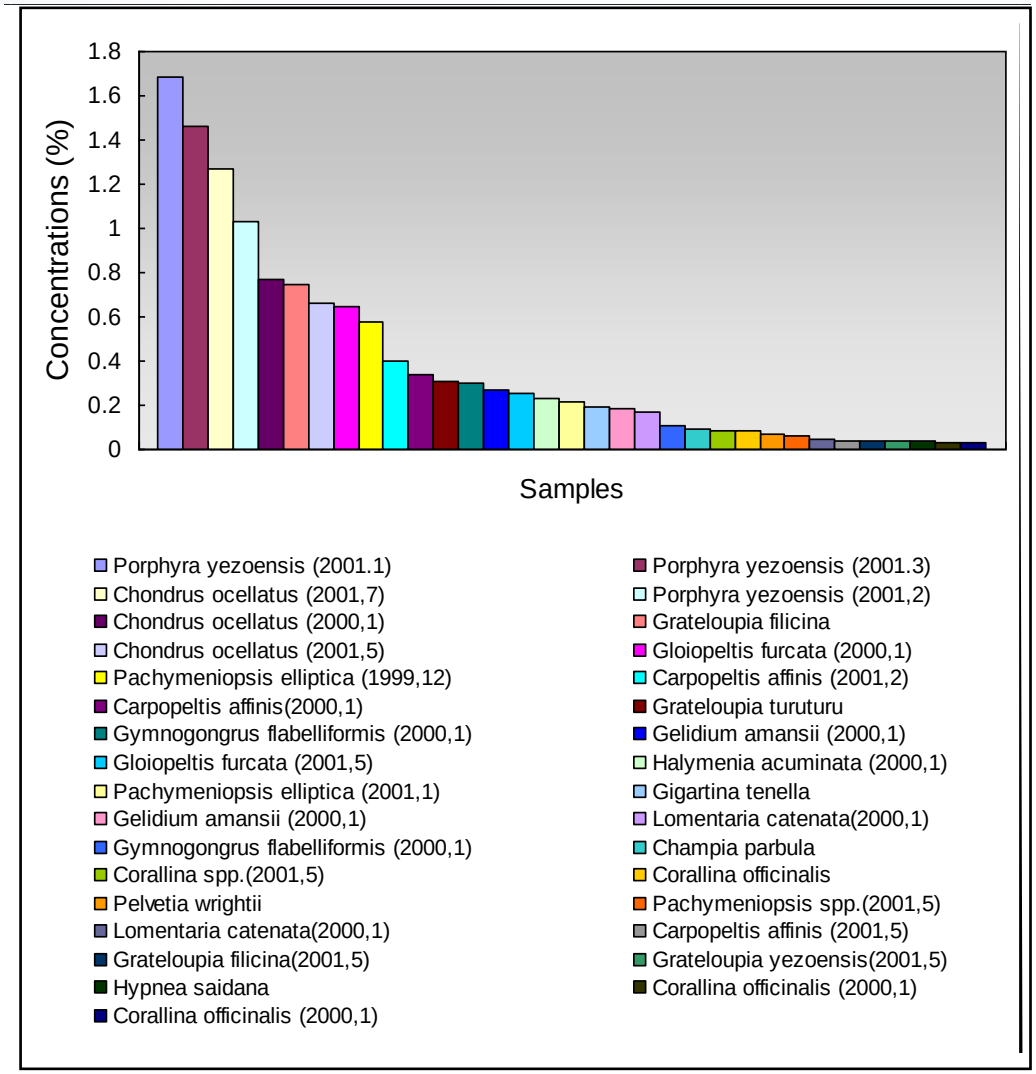
해조류의 자외선 흡수 색소에 관한 고찰

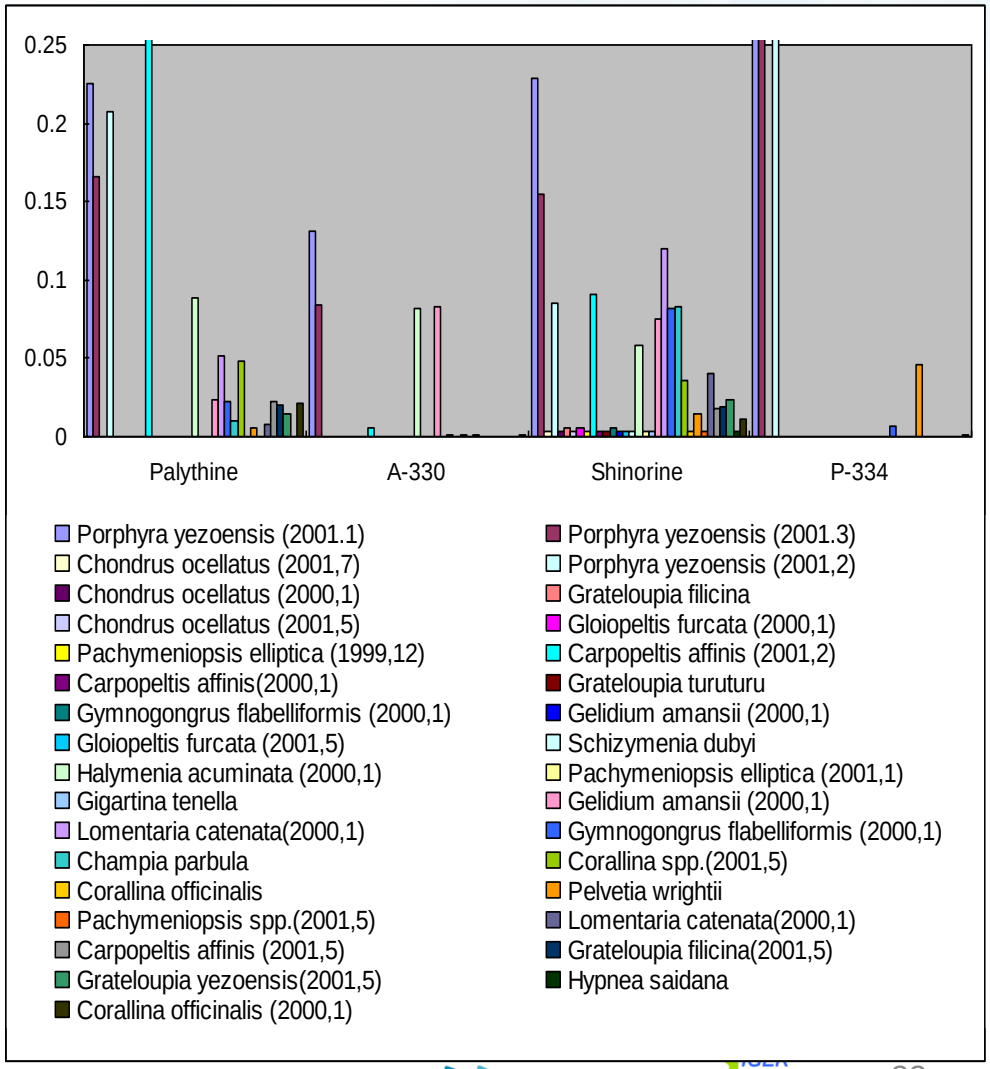
박진희 · 한태준*

Overview of UV-absorbing Pigments in Marine Algae

Jin-Hee Park and Taejun Han*

Ranking order of MAA contents in Korean seaweeds





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Introduction to *Porphyra* (or *Pyropia*)

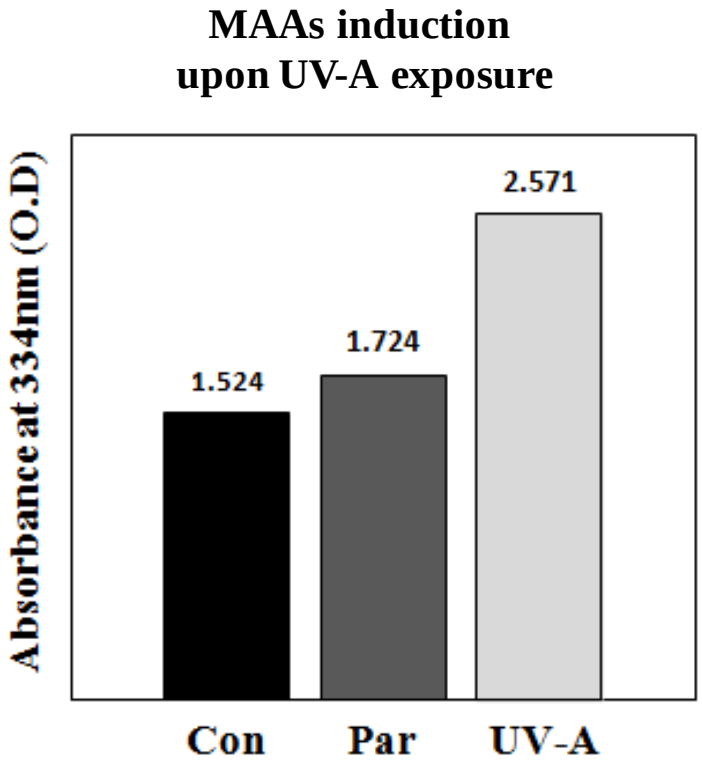
- ***Porphyra***
  - ▹ Red algae (Rhodophyceae, Bangiales, Bangiaceae)
  - ▹ Grows in the intertidal zone
  - ▹ The most commonly eaten seaweed (ex. 'Nori' in Japan, 'Gim' in Korea)
  - ▹ 60 to 70 species of *Porphyra* worldwide

Aquaculture technology of *Porphyra* (or *Pyropia*)

Habitats for *Porphyra*

Response of *Porphyra* to UV radiation

Porphyra yezoensis



in vivo amplification

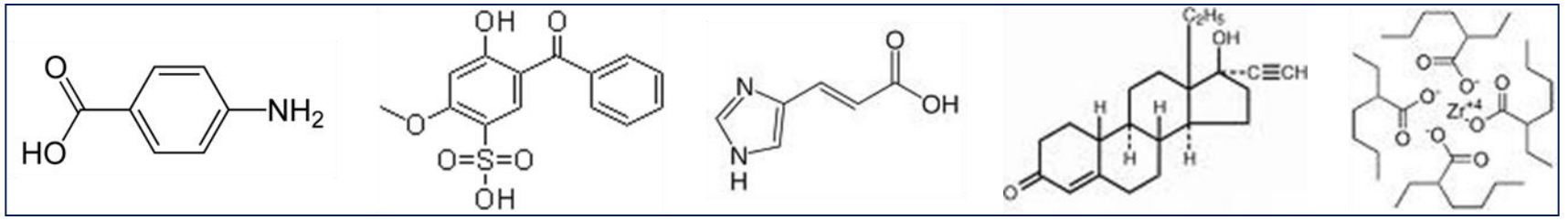
Side or negative effects of conventional sunscreens

UV absor-bent

- **Function**: Absorb UV to inactive or intoxify
- **Type**: PABA (P-aminobenzoic 2 hydroxy-4 methoxurocanic acid, urocanic acid & benzophenone derivatives)
- **Weakness**: Severe side effects
  Strictly regulated in most countries

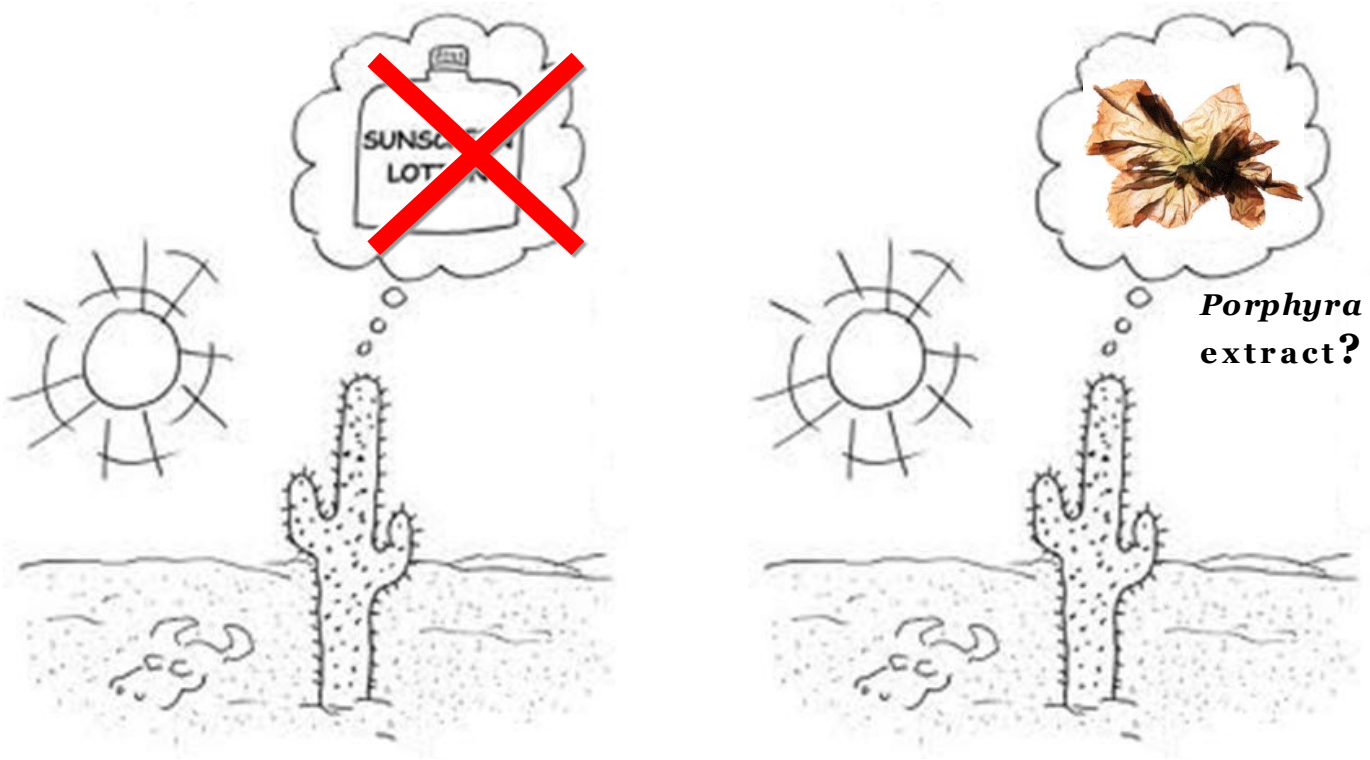
UV scatter

- **Function**: Reflect or scatter UV
- **Type**: Titanium oxide | zirconia oxide | zinc oxide
- **Weakness**: Little side effects
  Less comfortable to apply on the skin



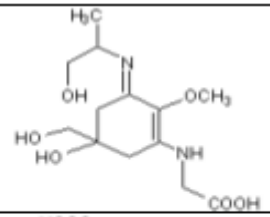
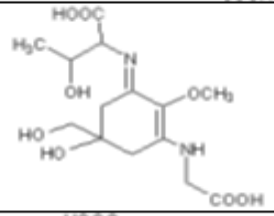
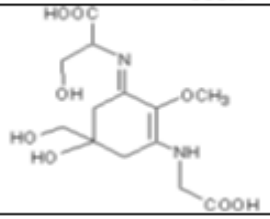
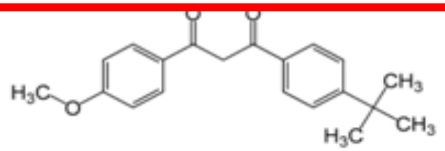
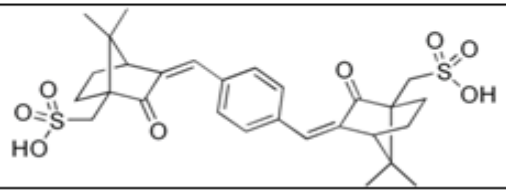
Question 1

- Are *Porphyra* extracts strong UV absorbers?



MAAs in *Porphyra* extracts

- Structure and extinction coefficients of MAAs and synthetic filters

MAAs	Structure	extinction coefficient ε (M^{-1} cm^{-1})
Palythinol		43,500
Porphyra-334		42,300
Shinorine		44,700
Parsol 1789		40,000
Mexoryl SX		45,000

Commercially available MAA products

HELIONORI®

For a natural bioprotection against UVA

Ecocert Approved

Patent FR 9 916 785

Gelyma

UVA rays are the main producers of free radicals which damage tissues as well as their components such as cellular membranes and DNA.

To prevent deteriorating, the answer has been found in the ocean, especially in certain macroalgae which contains powerful UVA-absorbing compounds, acting as natural sunscreens and known as "mycosporine-like amino acids" (MAAs).

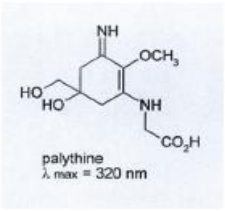
PRESENTATION

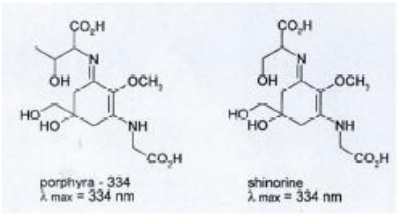
HELIONORI® is a patented water and concentrated active ingredient prepared from the red seaweed *Porphyra umbilicalis* (L.) Kützing known as "nori" in Japan.

Porphyra umbilicalis (in situ)

Three different MAAs are extracted selectively from *Porphyra umbilicalis* :

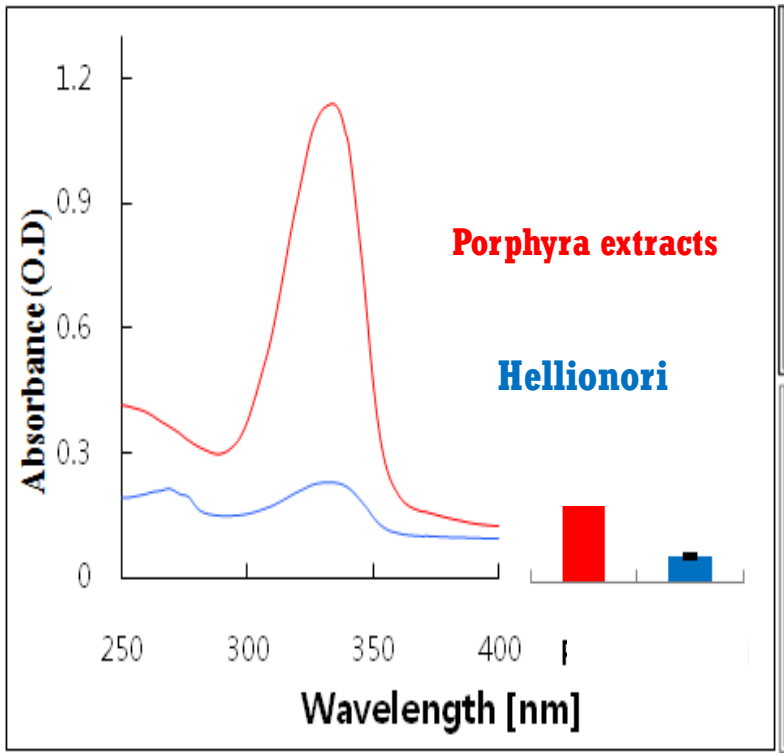
- palythine
- porphyra 334
- shinorine.

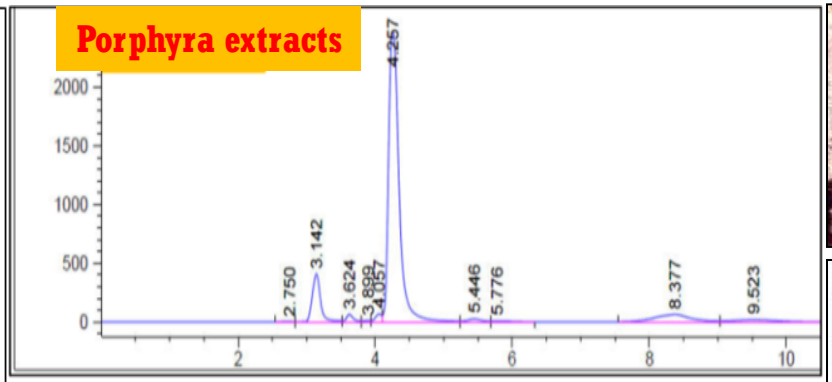


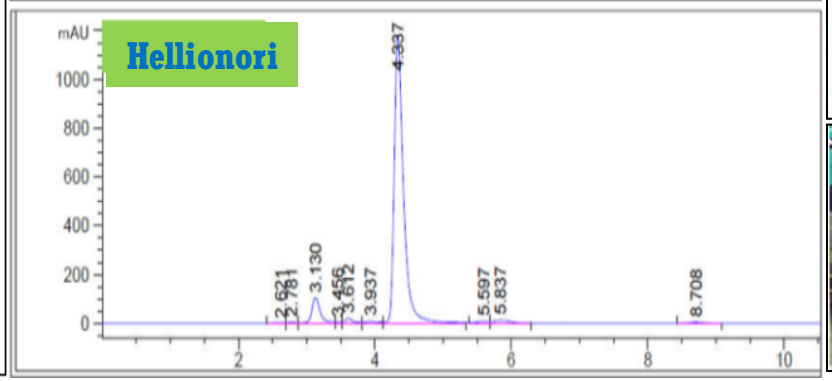


UV–absorbing capacity

- Comparative analysis of MAAs in between *Porphyra* extracts and Helionori

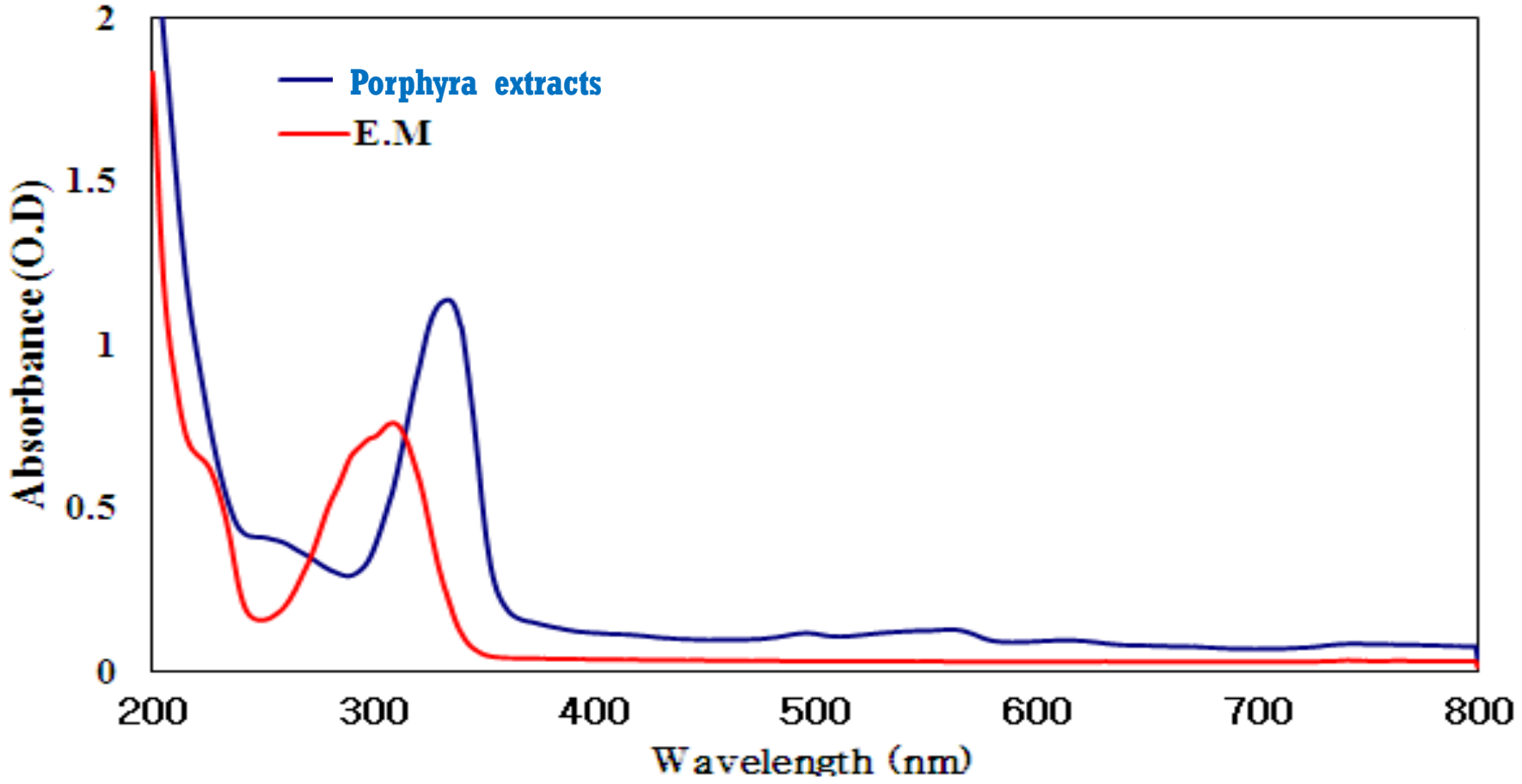






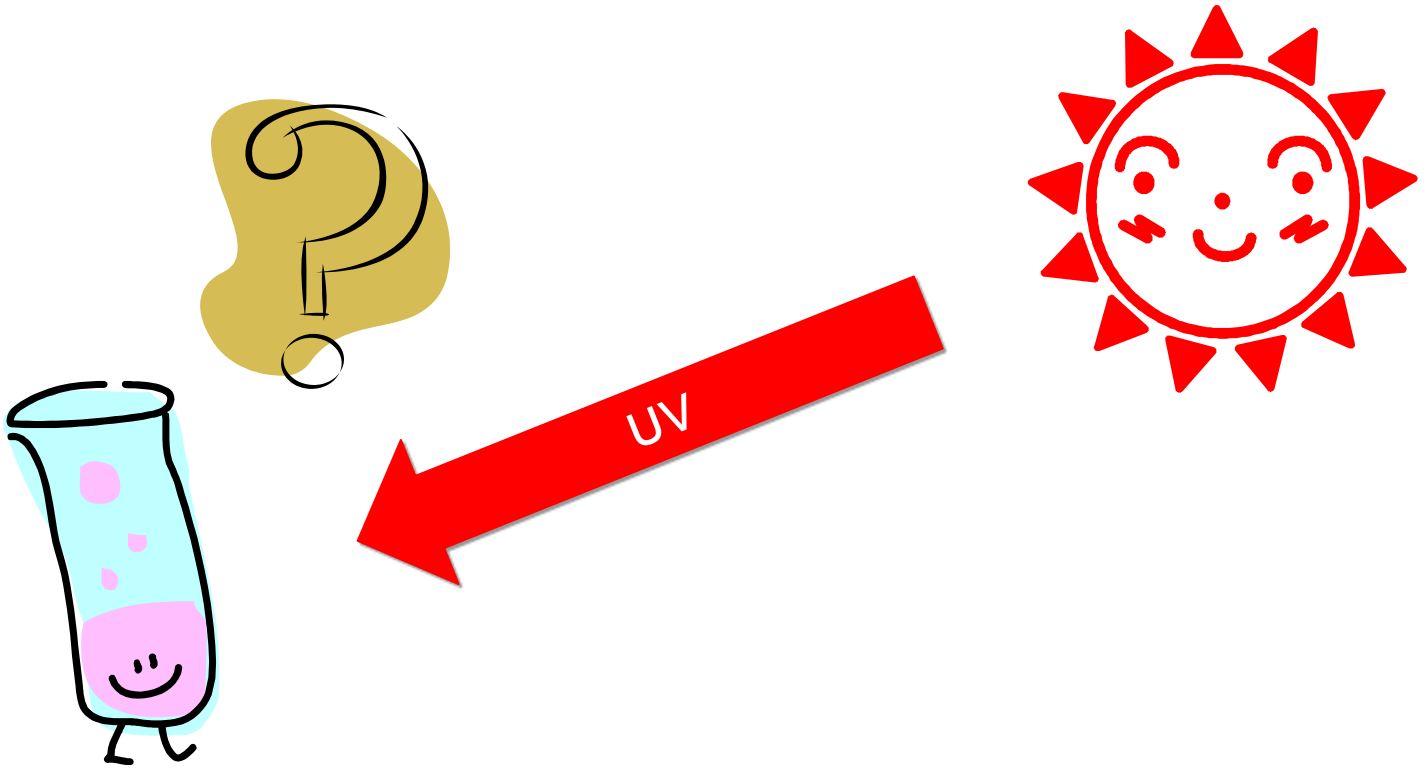
UV-absorbing characteristics

- Comparison of UV absorbance between *Porphyra* extracts and ethylhexyl methoxycinamate

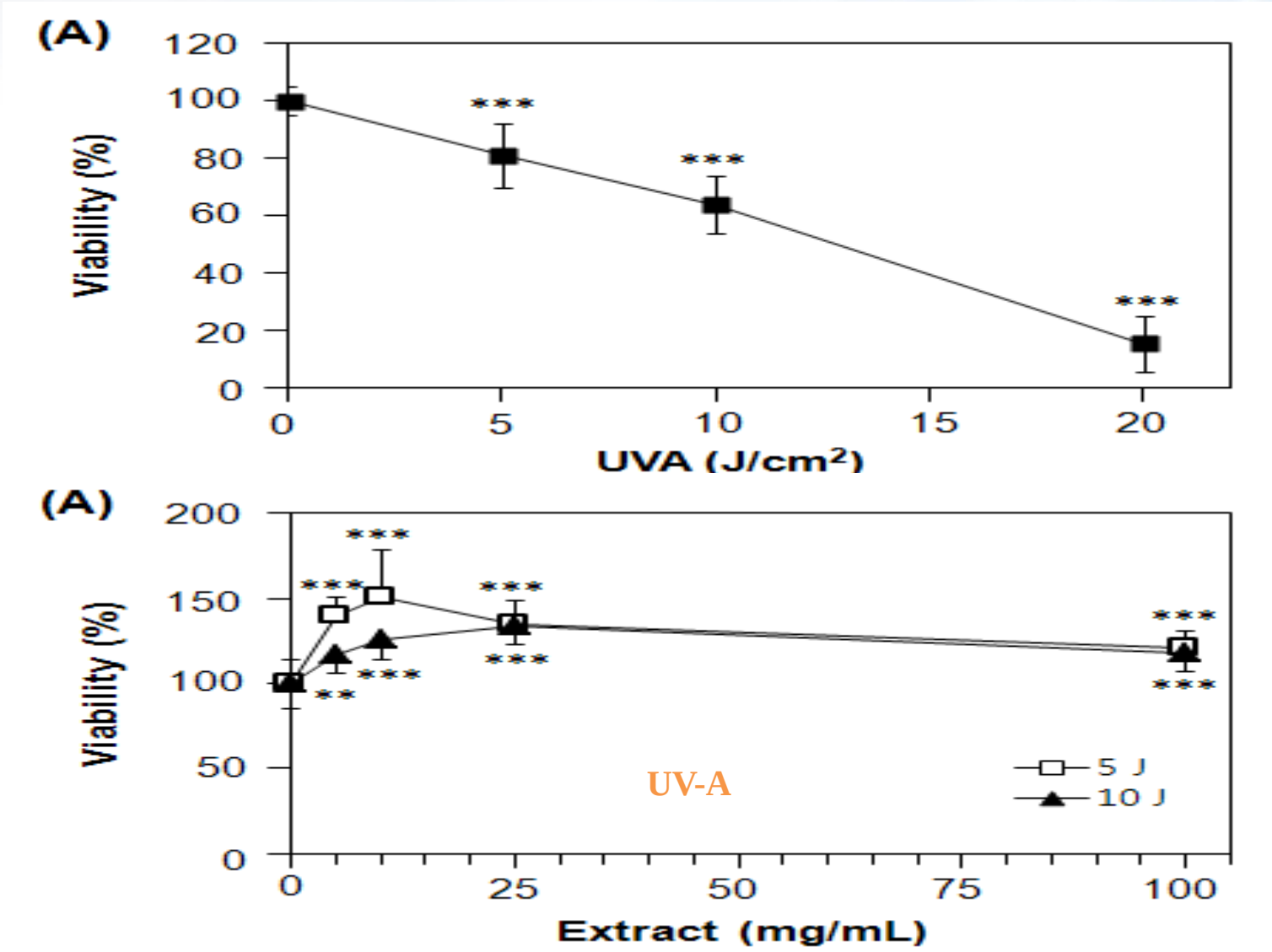


Question 2

- Do *Porphyra* extracts provide UV protection?

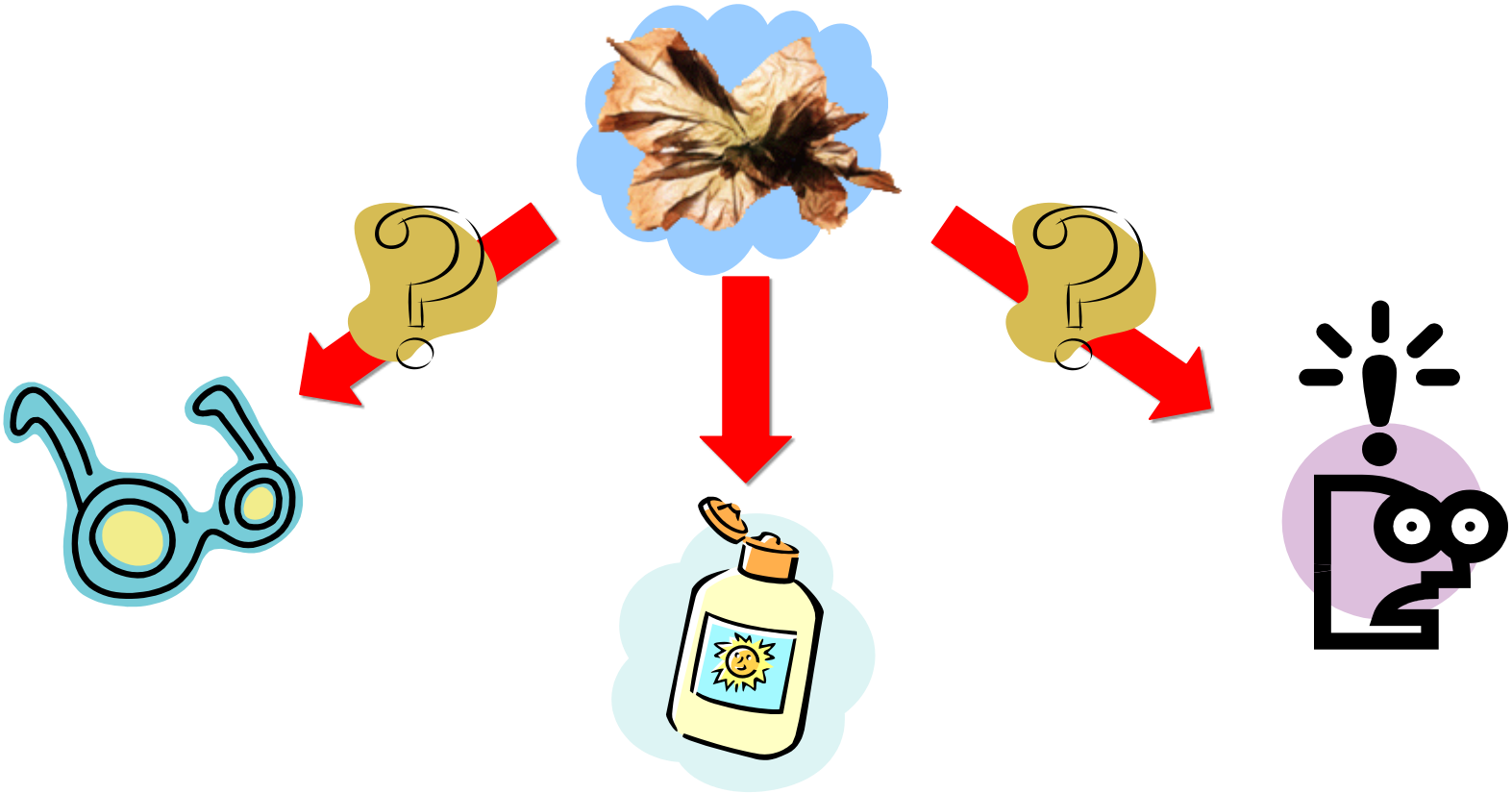


UV-protective effects



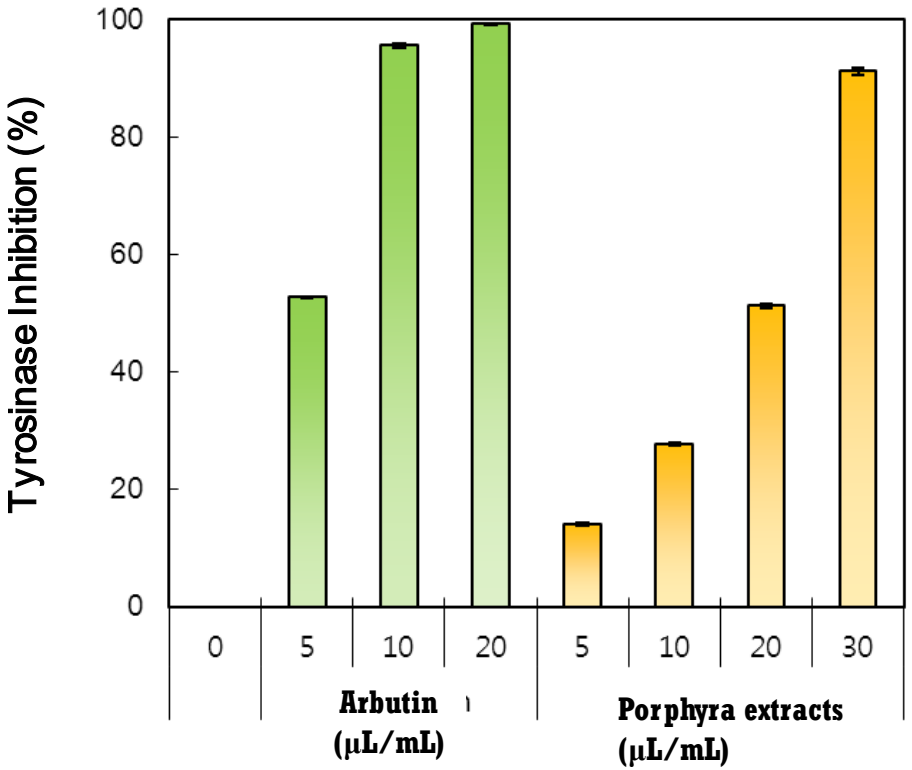
Question 3

- Are there any other novel functions in *Porphyra* extracts?

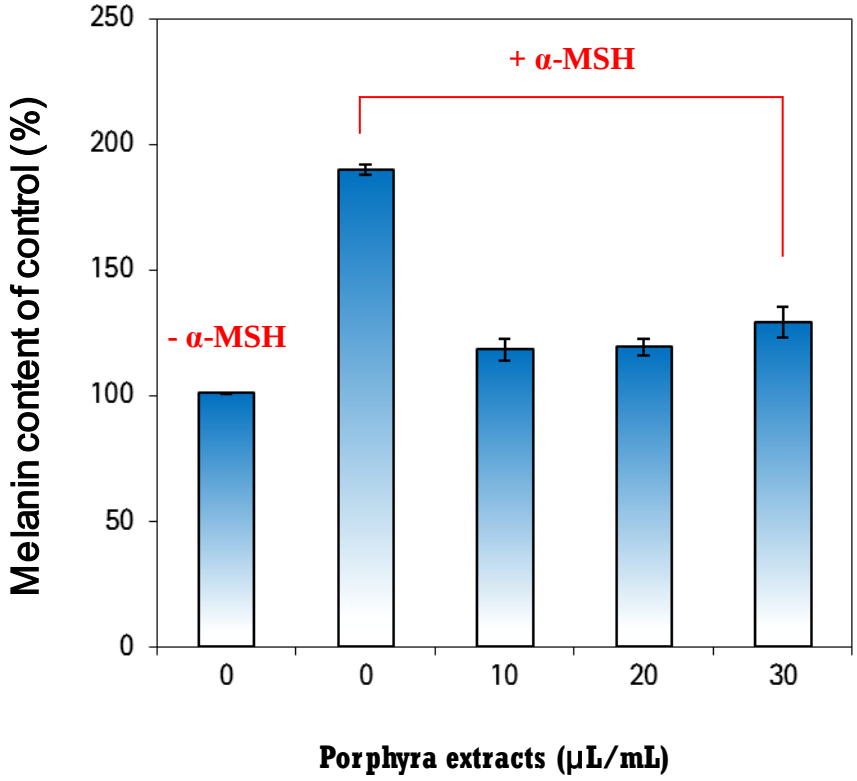


Whitening effects

● Tyrosinase inhibition assay

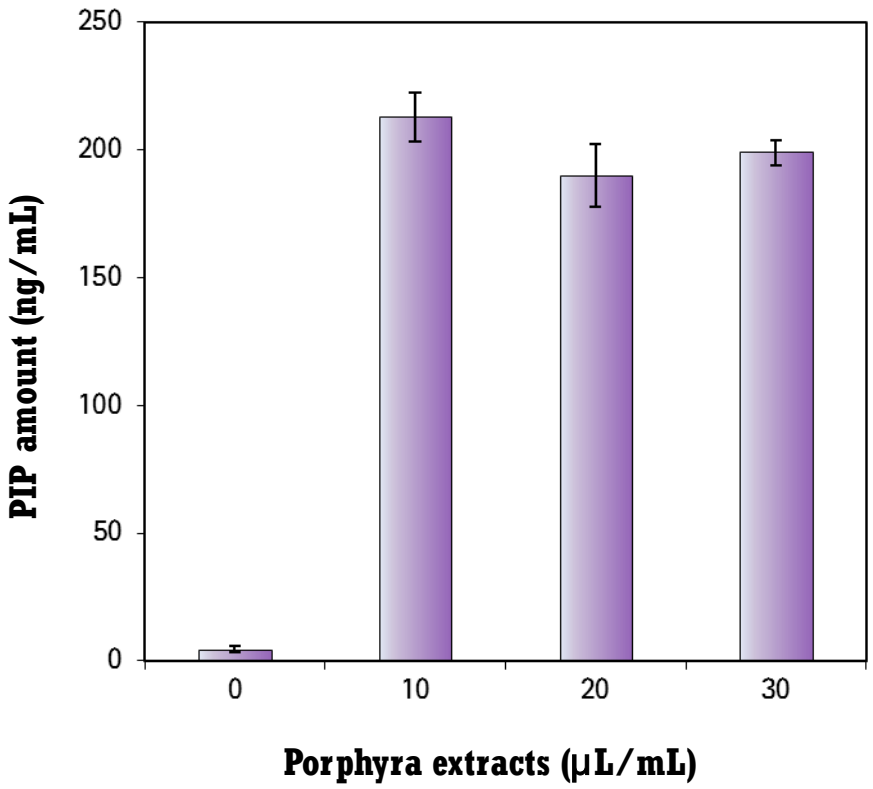


● Melanin synthesis

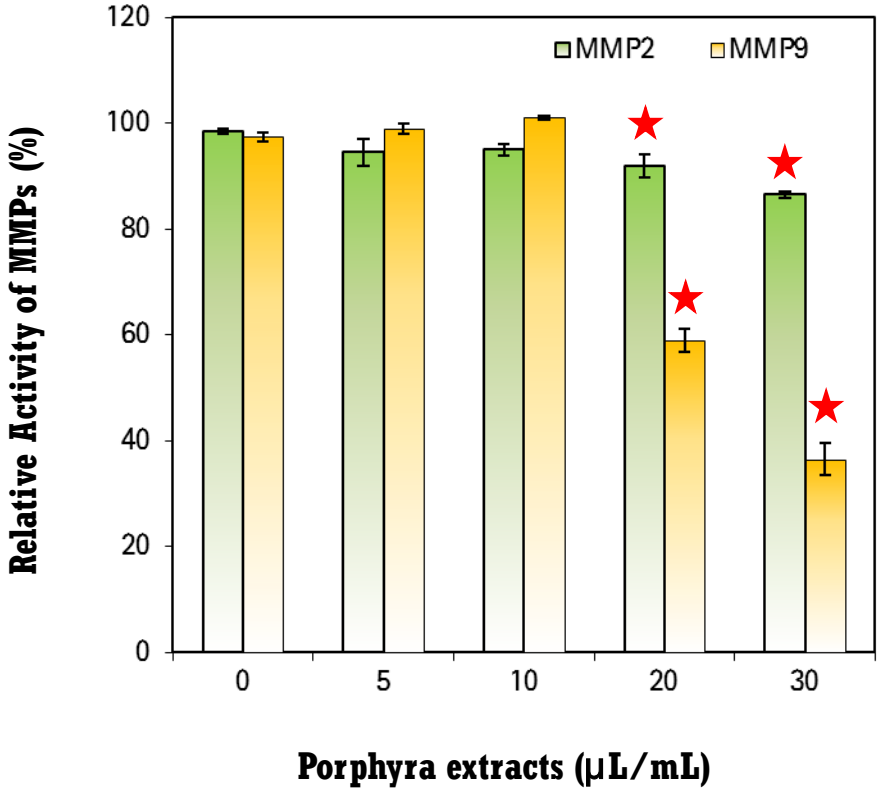


Anti-aging effects

● Collagen synthesis

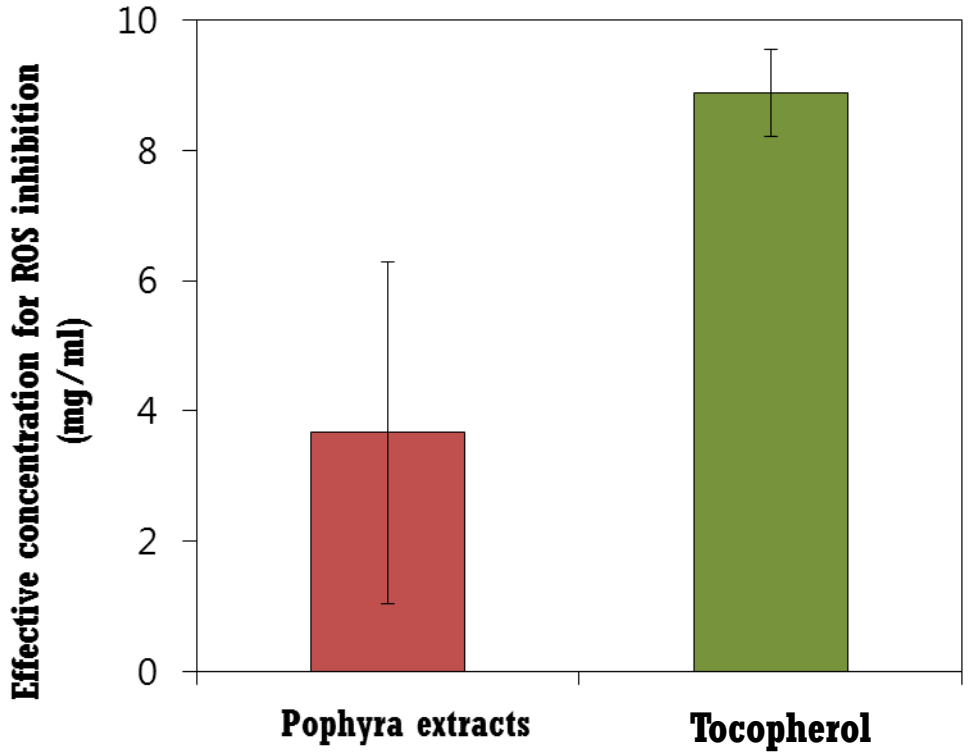


● Zymography for MMP2 & MMP9



Antioxidant activity

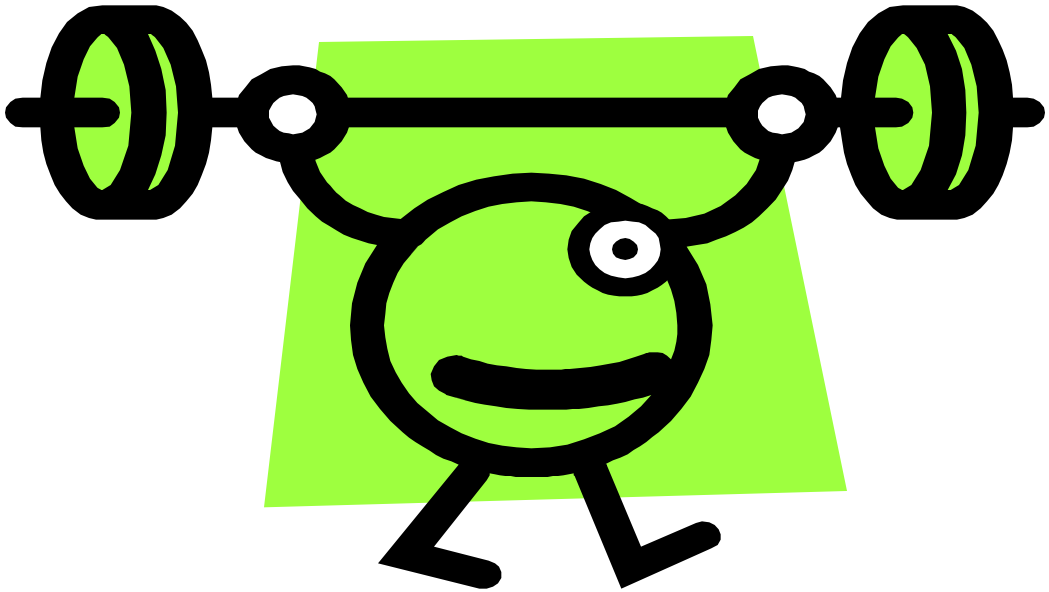
- Comparison of ROS reducing power between *Porphyra* extracts and tocopherol



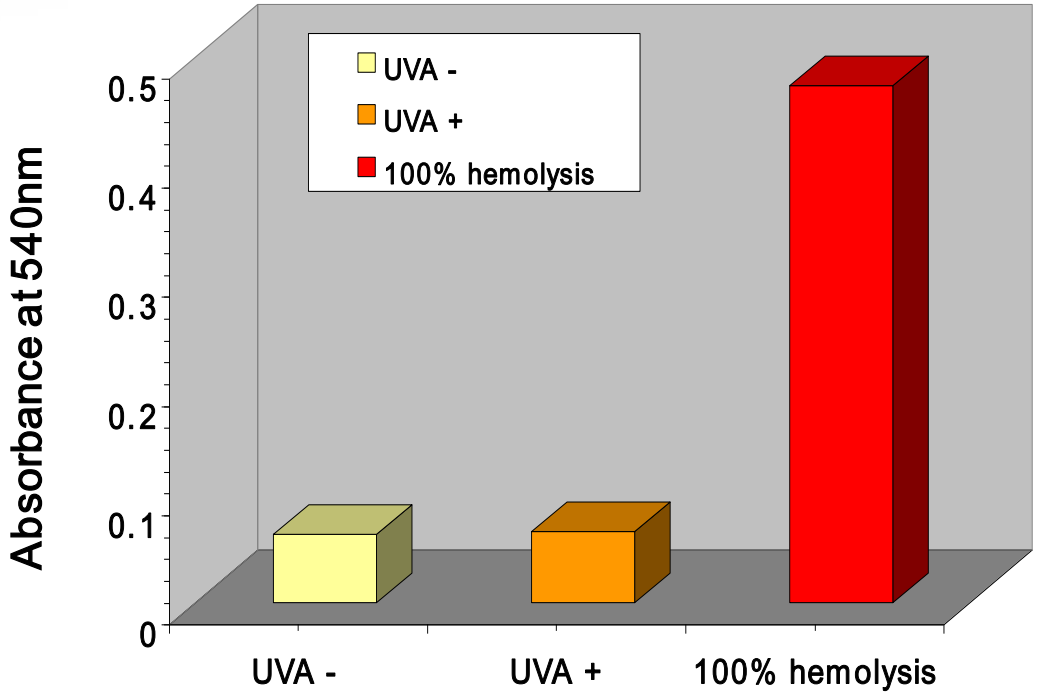
Product	EC_{50} (mg/mL)	EC_{50} CV (%)
Porphyra extracts	3.662	2.628
Tocopherol	8.879	0.663

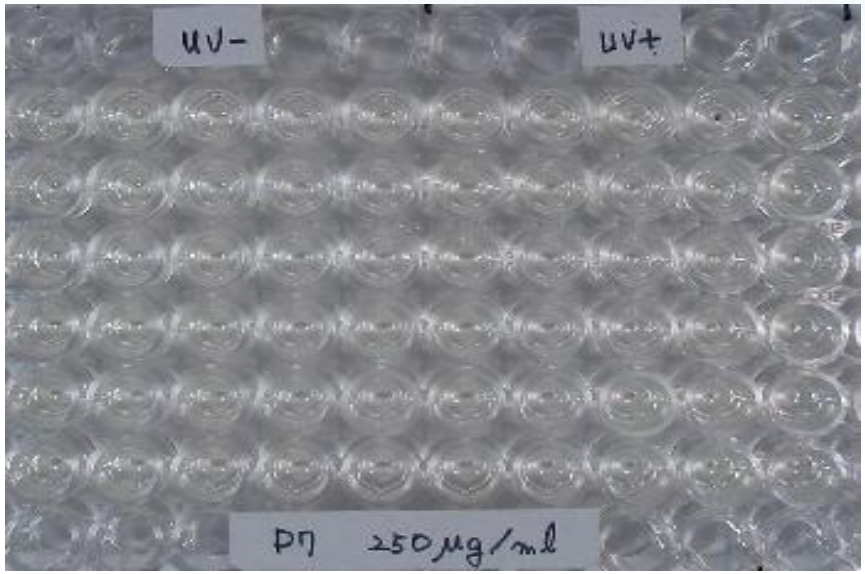
Question 4

- Are *Phrphyra* extracts safe?



No photo- and cyto-toxicity of *Porphyra* extracts





Samples	3T3 NRU phototoxicity			
	Mean IC_{50}(UV-) (mg/mL)	Mean IC_{50}(UV+) (mg/mL)	PIF IC_{50}(UV-)/ IC_{50}(UV+)	Result
Porphyra extract	> 1,000	> 1,000	1	Non-phototoxic

Samples	IC_{50}	Result
Porphyra extracts	>5,000μg/mL	Non-cytotoxic

Biochemical composition of *Porphyra*

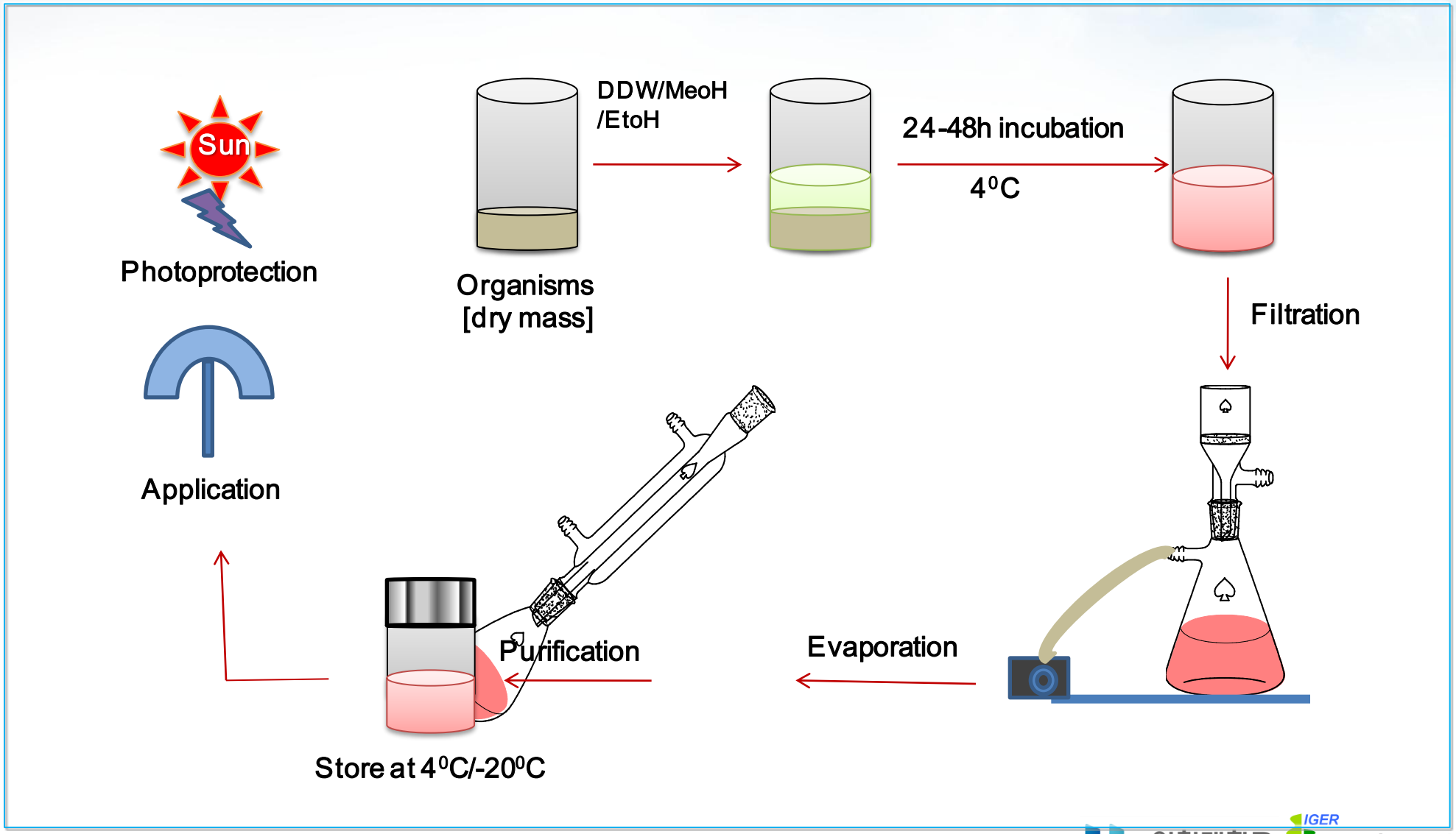
● Per 100g *Porphyra*

Component	Contents	Component	Contents	Component	Contents
Moisture	11.1g	Fiber	1.8g	Vitamin B2	3.4mg
Protein	38.8g	Potassium	2.1g	Vitamin C	100mg
Non-fibrous	39.5g	Calcium	390mg	Vitamin E	4.3mg
Ash	6.9g	Iron	12mg	Niacin	9.8mg
Lipid	1.9g	Vitamin B1	1.15mg	Carotene	25mg

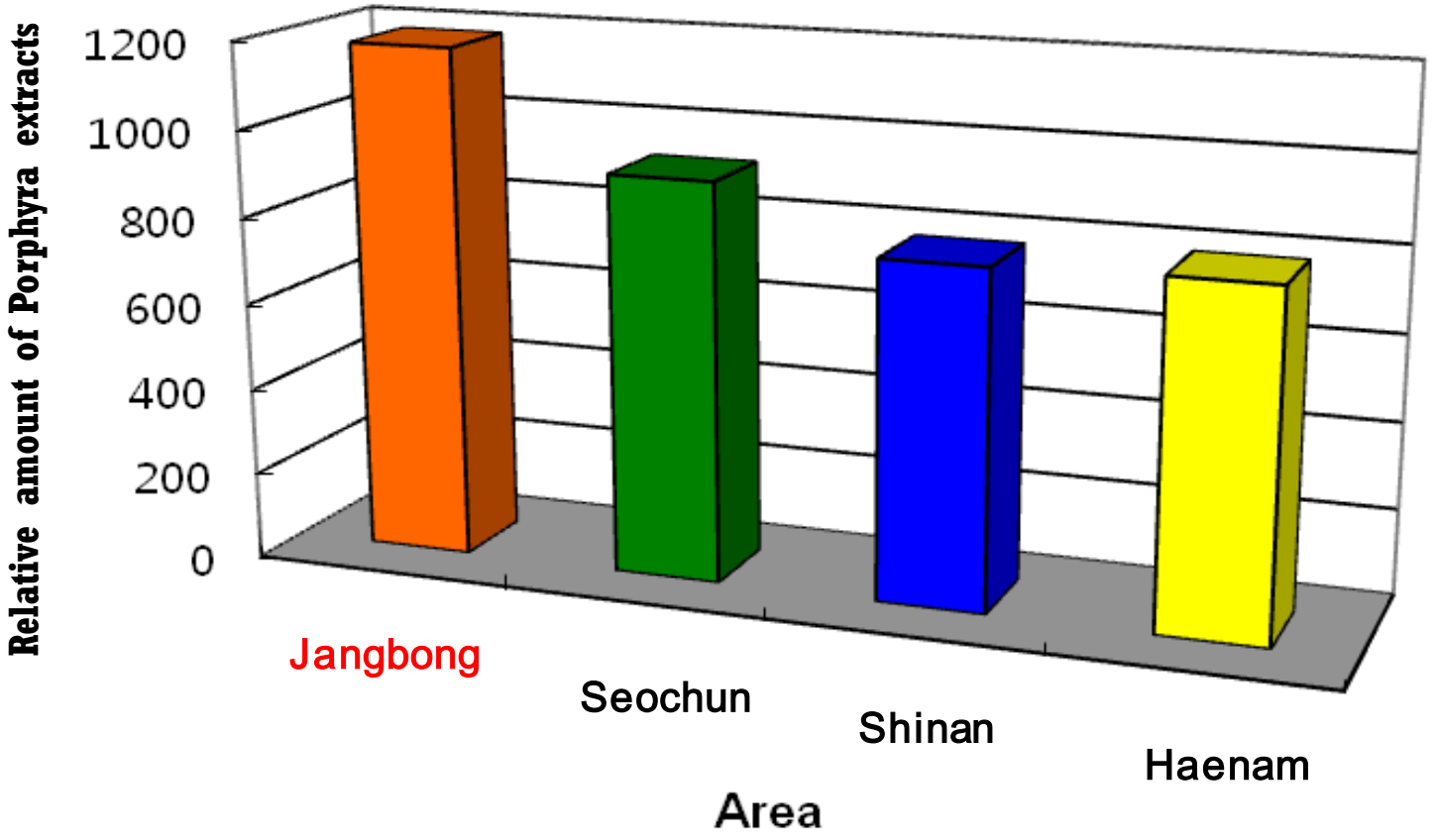
Question 5

● Is it economic and sustainable to obtain *Porphyra* extracts containing MAAs?

Simple extraction procedure



Relative amounts of *Porphyra* extracts



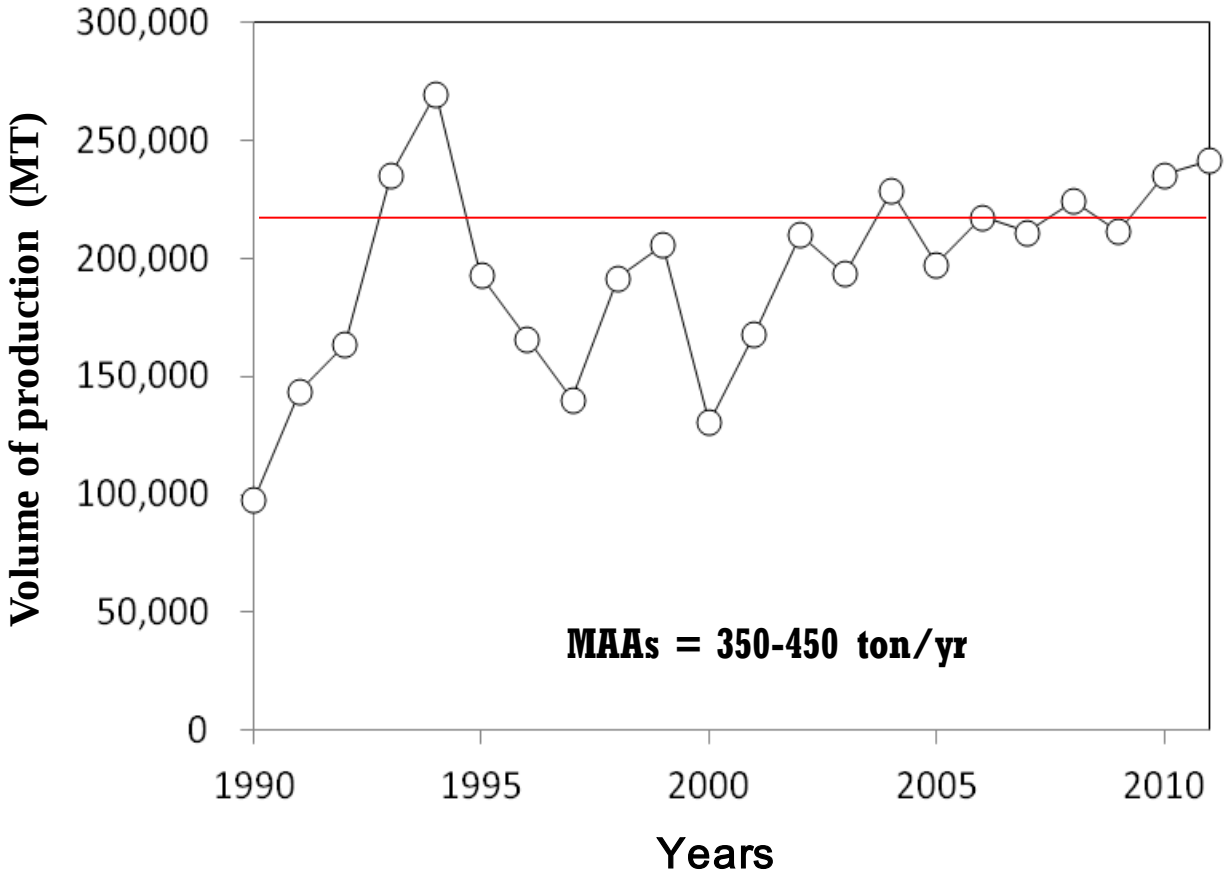
Seaweed cultivation technology

- **Floating-rafts method & Pole-type farming method**

VS

Porphyra production

- **Jangbong island**



Seaweed cosmetic brands

2010	2011	2012	2013	2015
REVE	SEALGAE	M·ROSE ALIVE SEAWEED COSMETIC	Sikia COSMETIQUE MARINE	해숨 HAESUM
	 			MarineZip Cosmetique Marine 

Seaweed cosmetics

Sikia COSMETIQUE MARINE

M·ROSE ALIVE SEAWEED COSMETIC

BeautyLine

Off-line shops

평화의 숨결, 아시아의 미래
제17회 인천아시아경기대회
17th Asian Games Incheon 2014

인천광역시

인천대학교
University of Incheon

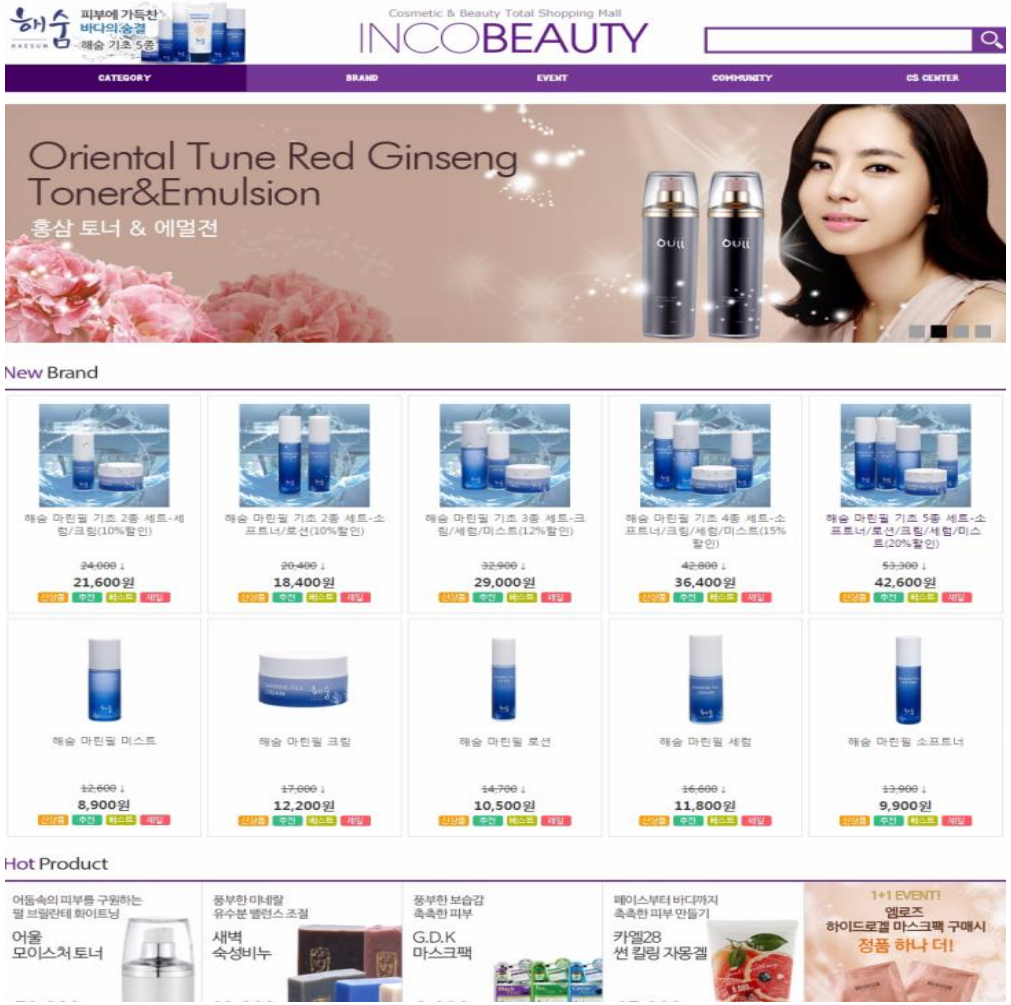
K water

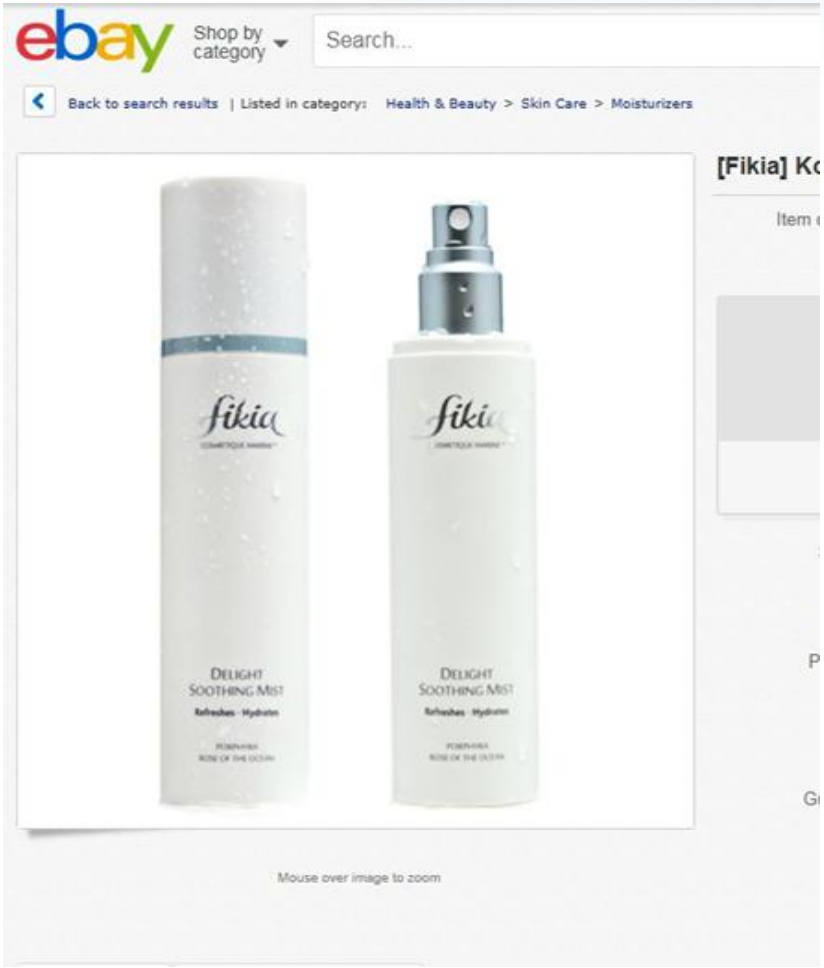
Sbirds
SHINHAN BANK

신한은행 에스버드 여자농구단
Shinhan Bank S-Birds Women's Basketball Team

E-marketing place

INcheon + COsmetic + BEAUTY; url : www.incobeauty.com connected to e-bay, Amazon, Yahoo, Rakuten, Taobao





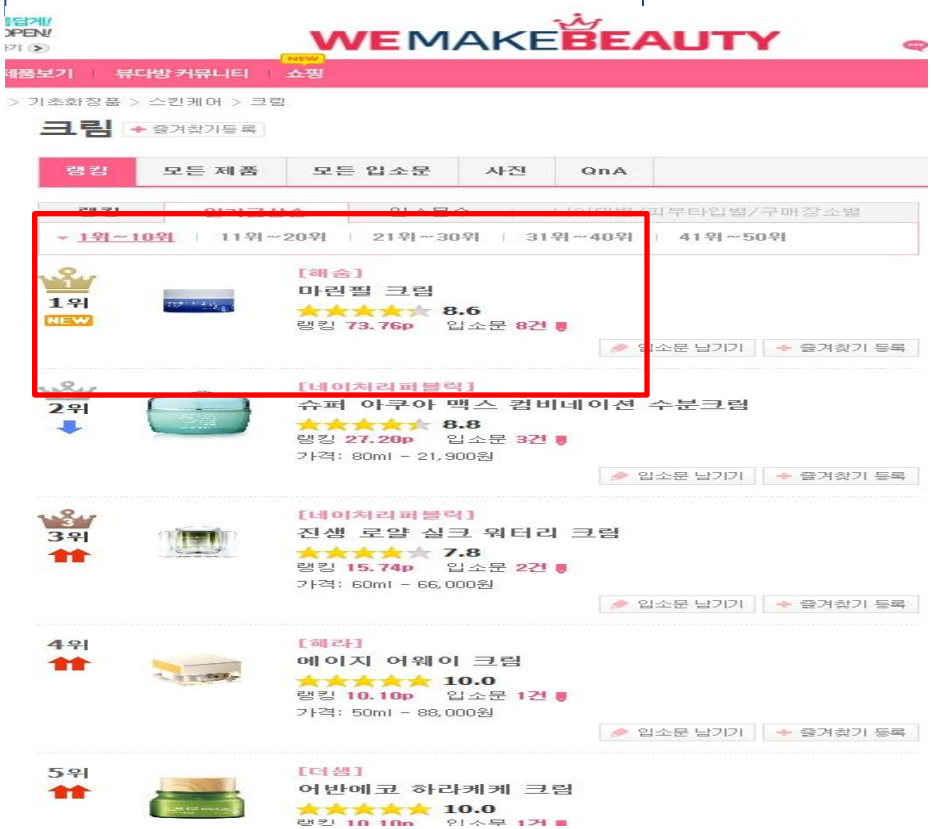
인천대학교 University of Incheon
IGER 녹색환경과학센터 Institute of Green Environmental Research

PR marketing

Viral marketing

SNS(Facebook)

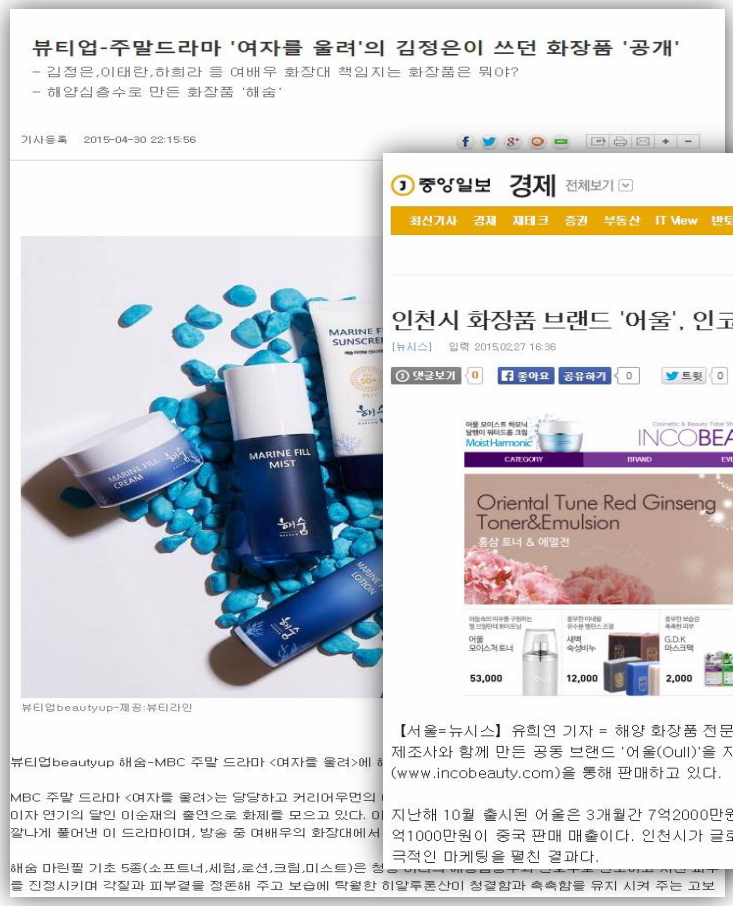
Beauty community network



PR marketing

Mass media

Major news papers (on-line and paper)



PR marketing

Mass media

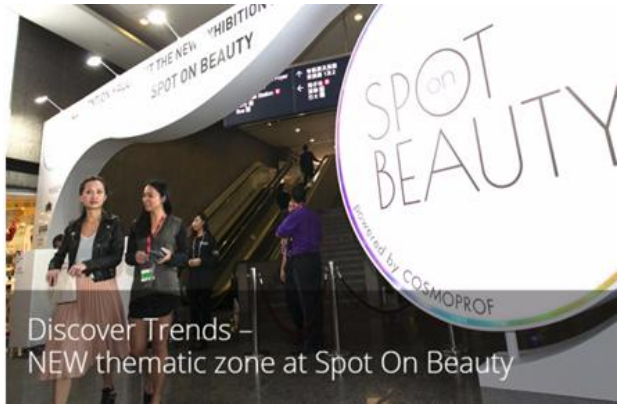
Arirang TV and famous drama

Radio

CBS 박승화의 가요 속으로

SBS 이세준, 최재훈의 도시락 쇼

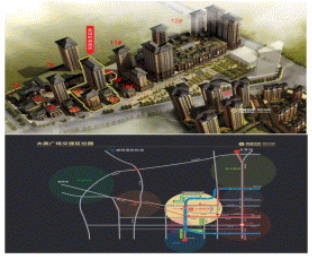
Exhibition



중국·산시 제1회 신 실크로드 패션주 상품전시회

2015. 5.16 ~ 6.19 / 중국 서안·태오국제광장

시진평 주석의 '신 실크로드 경제벨트' 과 '21세기 바다 위의 실크로드' 전략 정책, 박근혜 대통령의 '유라시아 중시' 계획을 호응하기 위해 산시성인민정부외사사무실,중국세계민족문화교류협회, 산시성상무청, 산시성 문화청은 올해 5-6월 간에 서안에서 '중국·산시 제1회 신 실크로드 패션주 상품 전시 판매월' 활동을 하기로 했다.



중국 첫천째 한국 패션 문화 체험식 불목

중국·산시 제1회 신 실크로드 뷰티패션상품전

한국보세상품판매예술전시오락체험음식체험문화교류

■ 기간/장소

- 2015. 5.16~ 6.19 / 중국 서안·태오 국제광장

■ 추진기구

- 주최: 산시성인민정부외사사무실
  중국세계민족문화교류협회
  산시성 상무청

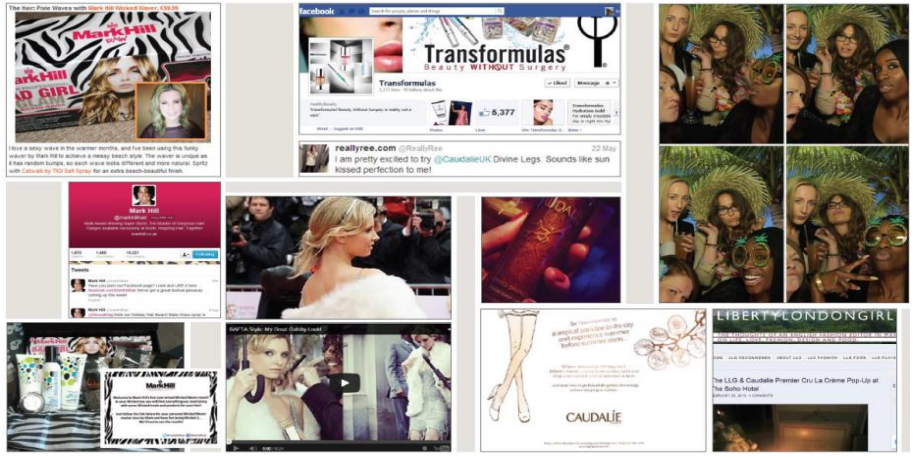
PR marketing

Working with British company (Kilpatrick) for global marketing

Magazine (COSMOPOLITAN, PRIMA)

AWARD WINNING

Social Media



Export to China and Hong-Kong

Opening brand shops in China and entrance to Sasa in Hong Kong

Export to the USA

The 5th Avenue in New York and Korean on-line mall in the USA

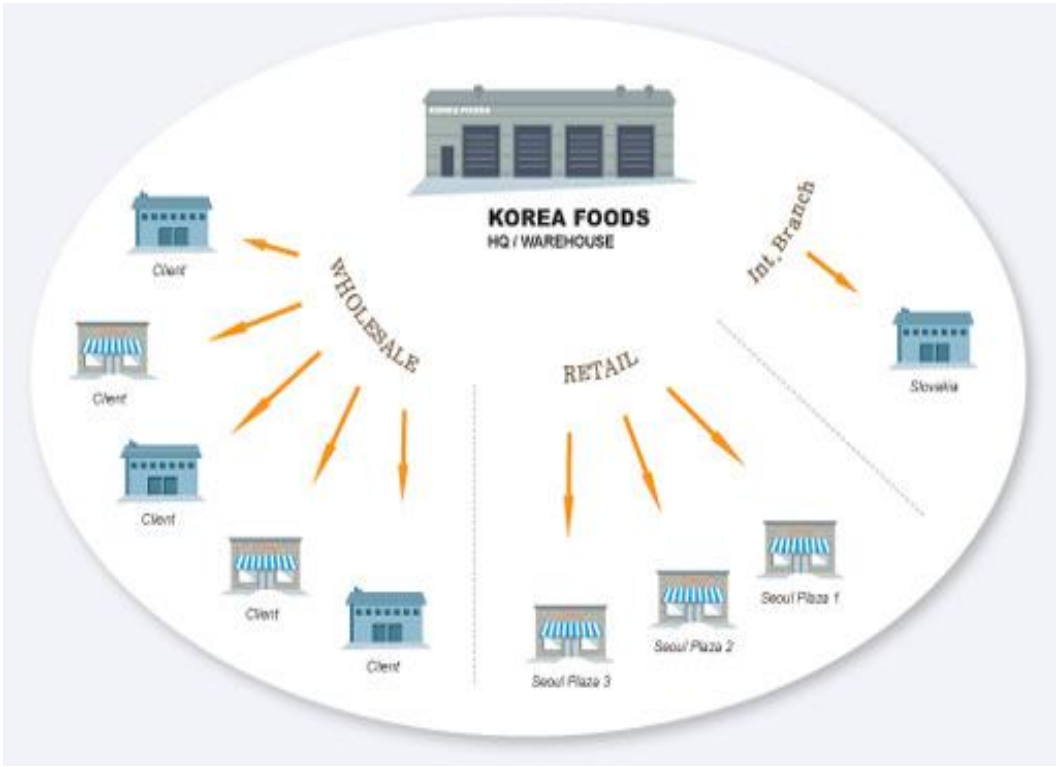
영송 마틴 (Youngsong Martin | 송영숙) 파티플래너, 패션디자이너

소속 와일드플라워 린넨 (대표, 수석디자이너)

경력 2001~ 와일드플라워 린넨 대표, 수석디자이너
미국 파슨스 디자인 스쿨 오티스미술대학 수석강사

Export to the UK

Department stores, Drugstores



International licensing

China

CFDA 国家食品药品监督管理总局
China Food and Drug Administration

UK

Delphic HSE Solutions Ltd

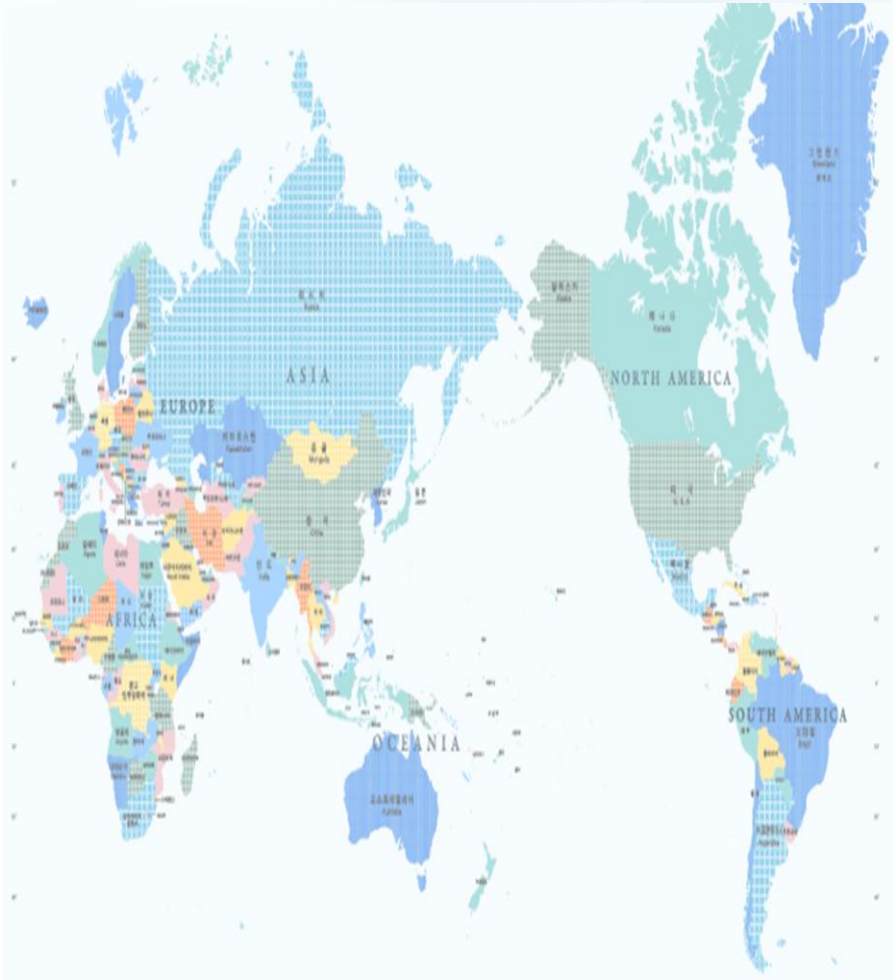
EU Cosmetic Regulation 1223/2009 services and support
Toxicological Risk Assessment
Effective health, safety and environmental management systems

Halal

MALAYSIA حلال HALAL مليزيا

MAJELIS ULAMA INDONESIA حلال HALAL مجلس علماء اندونيسيا

حلال HALAL



New product developments

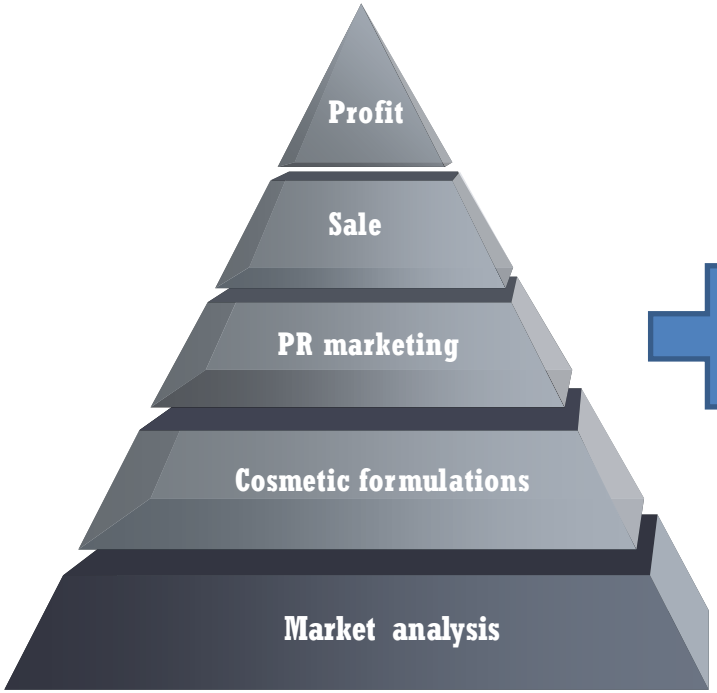
Anti-acme

After-care

Upgrading the existing brands

International cooperation

BeautyLine



GREEN PIONEER 그린파이오니아

Compound library

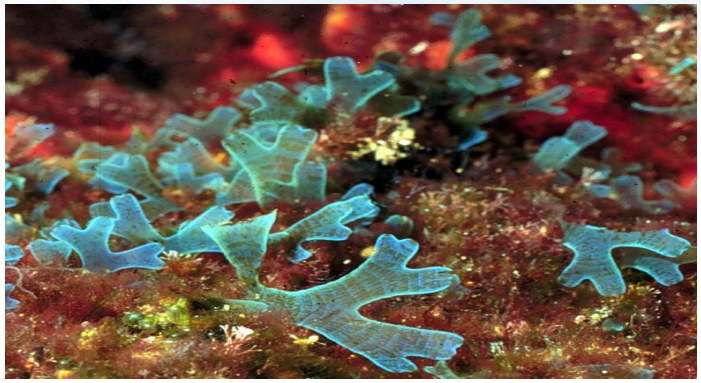
- Malaga Univ. (Spain)
- Ghent Univ. (Belgium)
- Incheon Nat'l Univ. (Korea)
- SAG Gottingen Univ. (Germany)

Functional compounds in green algae

Chlorophyta	Bioactivity
Order Bryopsidales	
Avrainvillea	Anticancer
Bryopsis	Antimicrobial
Caulerpa	Anti-hepatotoxicity[1]; antitumor[2,3]; antinociceptive[4]; anti-inflammatory[5]; antiherpetic;[6] antiviral[7]
Codium	Antioxidative and antigenotoxic[1]; antiviral[2]; anticoagulant[3]
Derbesia	Proliferation of thymus cells
Halimeda	Anticoagulant[1]; antimicrobial[2]; antioxidant[3];
Penicillus	Antimicrobial
Tydemania	Anticancer
Order Cladophorales	
Chaetomorpha	Anti-atherosclerotic
Cladophora	Antiprotozoal
Cladophoropsis	Cytotoxicity
Order Dasycladales	
Cymopolia	Antimicrobial[1]; antimutagenic[2]
Order Ulotrichales	
Acrosiphonia	Antimicrobial
Order Ulvales	
Ulva/Enteromorpha	Antioxidant[1]; antiviral[2]; anti-inflammatory[3,10]; antihyperlipidemic[5]; antitumor[6,12]; antimicrobial[7,8]; antiprotozoal[9]; antibacterial[11]; immunomodulating[12];
Monostroma	Antithrombin[1]; antiherpetic[2]; anticoagulant[3];

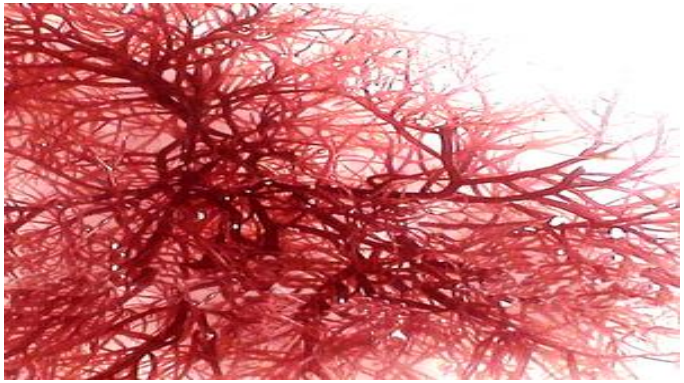
Functional compounds in brown algae

Ochrophyta	Bioactivity
Order Dictyotales	
Canistrocarpus	Antivenom
Dictyopteris	Antimicrobial
Dictyota/Dilophus	Antivenom[1]; anticoagulant[2]; antiviral[3]; antibacterial[4]; antifungal[3,4]; antioxidant[6]
Lobophora	Anti-inflamatory
Padina	Antimicrobial[1]; antioxidant[2]; cytotoxicity[3]; anticoagulant[4]; anti-cancer[5]
Spatoglossum	Antifungal[1]; antithrombotic[2]; hypoglycemic[3]
Stoechospermum	Antiviral
Stypopodium	Antivenom[1]; antiproliferative[2]; antimitotic[2]; cytotoxic[3]; antimicrobial[4]
Zonaria	Antimicrobial
Order Ectocarpales	
Adenocystis	Antiviral
Cladosiphon	Induces apoptosis[1]; anticancer[2]; gastric mucosal protection[3]
Colpomenia	Antimicrobial[1]; induction of apoptosis[2]
Dictyosiphon	Antiviral
Leathesia	Antiviral
Nemacystus	Anticoagulant
Punctaria	Antitumor
Order Fucales	
Ascophyllum	Anti-inflammatory[1]; antithrombotic[2]; anticoagulant[3]
Bifurcaria	Antifouling activity[1]; anti-proliferative effect[2]; antimitotic[3]
Caulocystis	Anti-inflammatory
Cystoseira	Antimicrobial[1,6]; antibacterial[2]; antifungal[3]; antioxidant[4]; antiviral[5]
Durvillaea	Anticoagulant
Fucus	antioxidant[1]; antitumor; antimetastatic[2]; antivenom;[3] anticoagulant[4]; antithrombin[5]
Himanthalia	Analgesic activity
Hizikia	Anticoagulant[2]; antioxidant[2]; immunomodulating[3]
Myagropsis	Hepatoprotective
Notheia	Anti-parasitic
Pelvetia	Anticoagulant[1]; antioxidant[2]; anti-diabetic[3]
Sargassum	Anticancer[1]; antiviral[2]; antioxidant[3,5,10]; antibacterial[4]; anti-inflammatory[6]; antiangiogenic[7]; antitumoral[8,9]; antiviral[10]; antiherpetic[11]
Turbinaria	Antioxidant[1]; anti-inflammatory[1]; cytotoxic[2]
Order Ishigeales	
Ishige	Antiviral
Order Laminariales	
Alaria	Antiviral
Ecklonia	Antioxidant[1,6]; antiviral[2]; antibacterial[3,6]; anticoagulant[4]; anti-tumor[5]
Egregia	Antiviral
Eisenia	Antioxidant[1]; antiviral[2]; anti-allergic[3]
Kjellmaniella	Antimicrobial
Laminaria	Anticancer[1]; anti-oxidative; anti-inflammatory[2]; anticoagulant[3]; antithrombin[4]; neuroprotective[5]; antioxidant[6]; antiproliferative[6]
Landsburgia	Antifungal; cytotoxic
Lessonia	Anticoagulant activity
Macrocystis	Anticolesterol[1]; antioxidant[2]; antiproliferative[2]
Nereocystis	Antioxidant[1]; antiproliferative[1]
Undaria	Anti-aging[1]; antiviral[2,3]; antioxidant[4]; anti-inflammatory[5]; antitumor[6]
Order Ralfsiales	
Ralfsia	Antiviral
Order Scytosiphonales	
Analipus	Antiviral
Endarachne	Antiviral
Hydroclathrus	Anti-cancer[1]; antiviral[2]

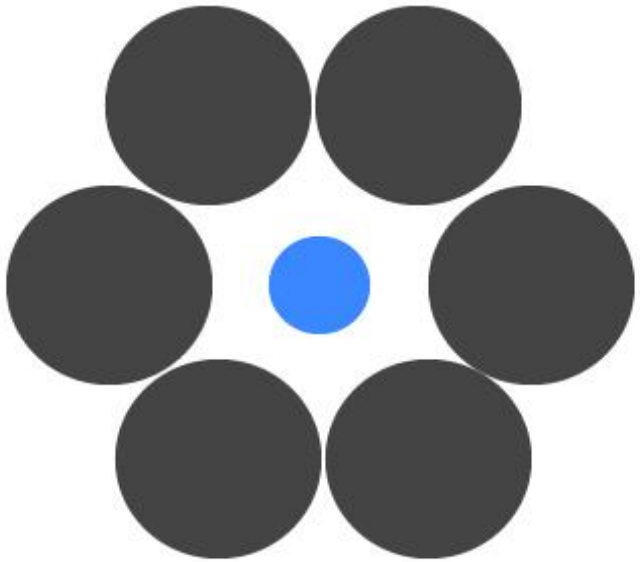


Functional compounds in red algae

Rhodophyta	Bioactivity
Order Bangiales	
Porphyra	Anti-inflammatory[1]; anticancer[2]; induction of apoptosis[3]; macrophage stimulation[4]; antioxidant[5]
Order Bonnemaisoniales	
Asparagopsis	Antiviral[1]; antibacterial[2]; antimicrobial[3]; anti-HIV[4];
Bonnemaisonia	Angiotensin-I-converting enzyme (ACE) inhibitory activities
Delisea	Anti-phytopathogenic
Order Ceramiales	
Acanthophora	Antiviral
Aglaothamnion	Antioxidant
Amansia	Lymphocyte transformation[1]; antinociceptive[2]
Boergeseniella	Antiviral
Bostrychia	Antiprotozoal[1]; antifungal[2]; antiviral[3]
Bryothamnion	Antioxidant[1]; antinociceptive[2]
Ceramium	Antiviral[1]; antiprotozoal[2]; antibacterial[3]
Centroceras	Antibacterial; anticancer
Chondria	Anthelmintic
Cottoniella	Mammalian insulin release modulator
Cryptopleura	Antiviral
Delesseria	Inhibit the release of inflammatory cytokines[2]; anticoagulant[3]
Drachiella	Antibacterial
Lithophyllum	Angiotensin-I-converting enzyme (ACE) inhibitory activities
Lithothamnion	
Marginisporum	Antitumor
Order Gelidiales	
Gelidiella	Contraceptive
Gelidium	Antiviral[1]; growth-inhibitory effects of cells[2]; anticoagulant[3]
Pterocladia/Pterocladiella	Antiviral[1]; antiherpetic[2]
Order Gigartinales	
Agardhiella	Anti-HIV[1]; antiviral[2]
Ahnfeltiopsis	Angiotensin-I-converting enzyme (ACE) inhibitory activities
(Callophycus)	Antineoplastic
Callophyllis	Anti-HIV
Chondrus	Immunomodulatory[1]; antitumor[1]
Dilsea	Antifungal
Eucheuma	Anti-tumor
Furcellaria	Antioxidant
Gigartina	Antiviral[1]; anticoagulant[2]
Gloiopeltis	Therapeutic potential in hepatoma cancer[1]; anti-tumor[2]; antiviral[3];
Gymnogongrus	Antiviral
Hyalosiphonia	Antiviral
Hypnea	Antiviral[1]; PPE elastase inhibition[2]
Kappaphycus	Anti-tumor
Meristiella	Antiviral
Meristotheca	Cell stimulating activity
Portieria	Anti-tumor[1]; antimicrobial[2];



Frame effects



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Potential applications of nuisance microalgae blooms

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Abstract Algal blooms have become a major concern in coastal areas and the great lakes of the world. Because of their various consequences for aquatic ecosystems and resources, algal blooms are called "harmful algal blooms" (HABs). HABs often become severely detrimental when they involve one or more toxin-producing microalgae of various taxonomic origins. The accumulation of algal biomass also has deleterious effects on the ecological status of water. However, appropriate management strategies can allow the beneficial utilization of these events by consuming the biomass feedstock in the production of valuable biocommodities, including biofuels, functional food ingredients, UV-absorbing compounds, pharmaceutical products, etc. However, if the algal biomass can be harvested prior to the onset of their death phase, nutrients (carbon, nitrogen, and phosphorus) can also be removed from the ecosystem by harvesting the algal blooms. Great progress has been made in the last decade in monitoring and predicting HABs, and a demand is emerging for persuasive postevent management policies that focus on the potential utilization of these blooms as natural renewable bioresources. This review summarizes various potential applications of nuisance algal blooms and the need for scientific research into their economic and industrial potential. Major algal products with great ecological and economic significance and their contemporary global utilization are analyzed.

Keywords Algal blooms · HABs · Renewable bioresources · Biomass

Introduction

Algal blooms have become a global epidemic, and the nature and frequency of harmful algal bloom (HAB) outbreaks has changed considerably over the last several decades (Anderson et al. 2012; Ferreira et al. 2011; O'Neil et al. 2012). Recently, countries including the USA, Canada, Greece, Norway, Spain, Portugal, Ireland, China, Japan, and Korea have invested

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There is hope from the sea,
but none from the grave

(Irish Proverb)

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Thank you for your attention.