Future Agriculture Based on potato and Microalgae

基于马铃薯和微藻的未来农业

Prof. Dr. Maozhi Ren

任茂智 研究员

Institute of Urban Agriculture

Chinese Academy of Agricultural Sciences

中国农业科学院都市农业研究所

E-mail: renmaozhi01@caas.cn; Tel: 13527313471

CONTENTS

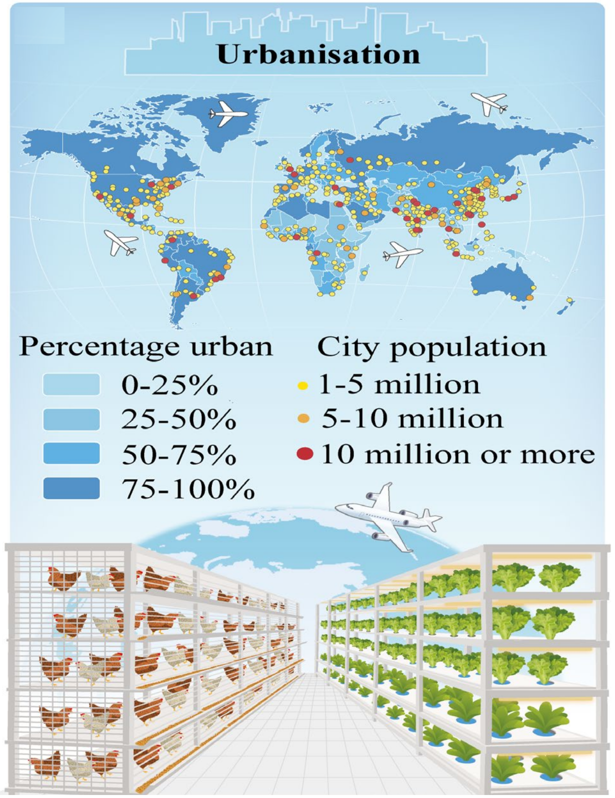
01

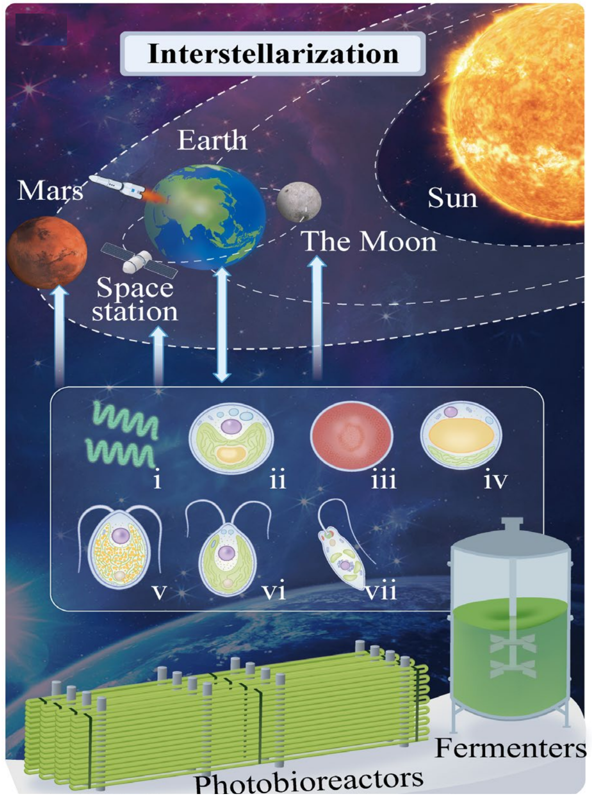
Multiplanetary Farming

星际农业

Multiplanetary Agriculture is the future 星际农业是未来

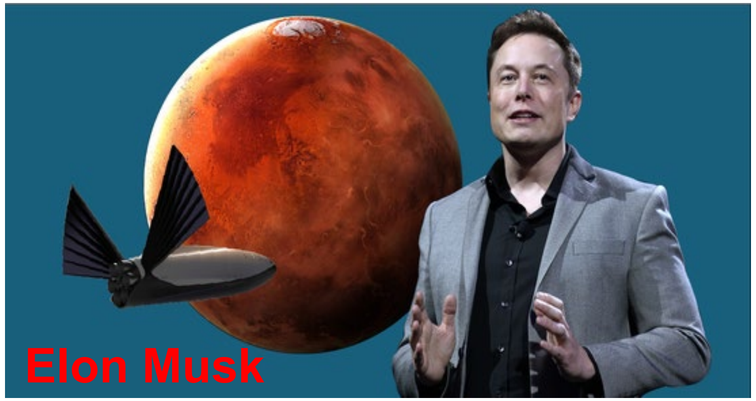
Age of Exploration 航海时代 → **Age of Aerospace 航天时代** → **Age of Space 航空时代**

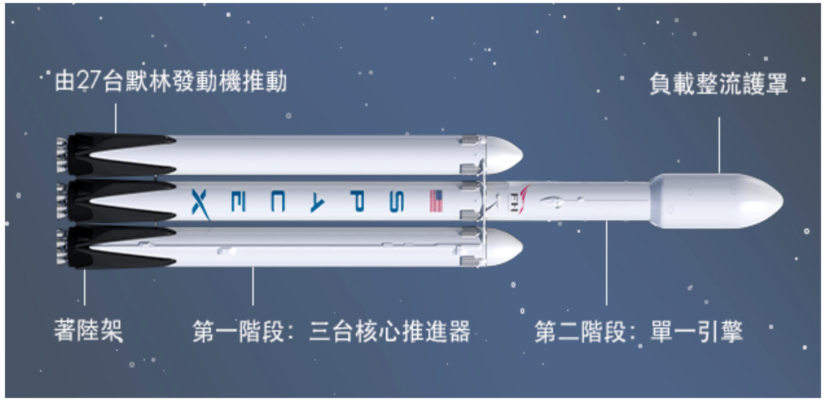




Rural Agriculture 乡村农业 → **Urban Agriculture 都市农业** → **Multiplanetary Agriculture 星际农业**

50,000 people will land on Mars by 2050 火星移民计划

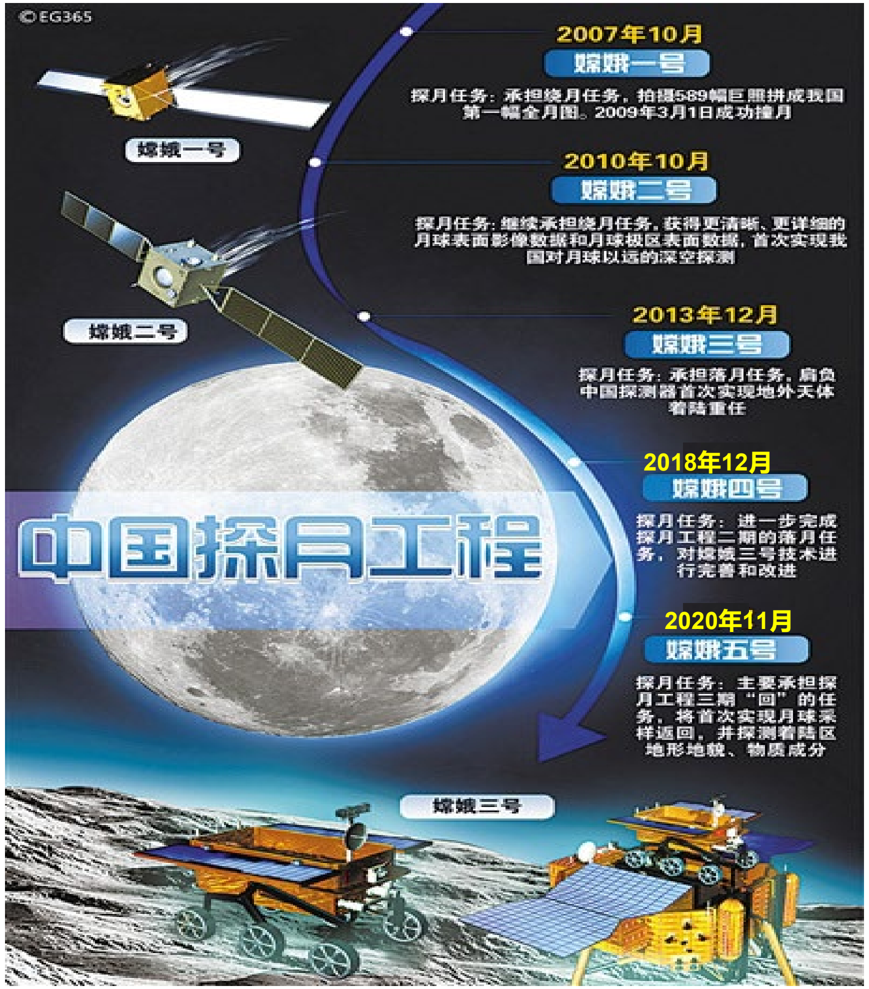




In recent years, agencies in NASA, ESA, CNSA, RAKA, and other countries have formulated a series of deep-space exploration plans, and NASA and CNSA even plan to build permanent settlements on the Moon and Mars.

近年来，NASA、ESA、CNSA、RAKA等国家机构制定了一系列深空探测计划，NASA和CNSA甚至计划在月球和火星上建立永久定居点。

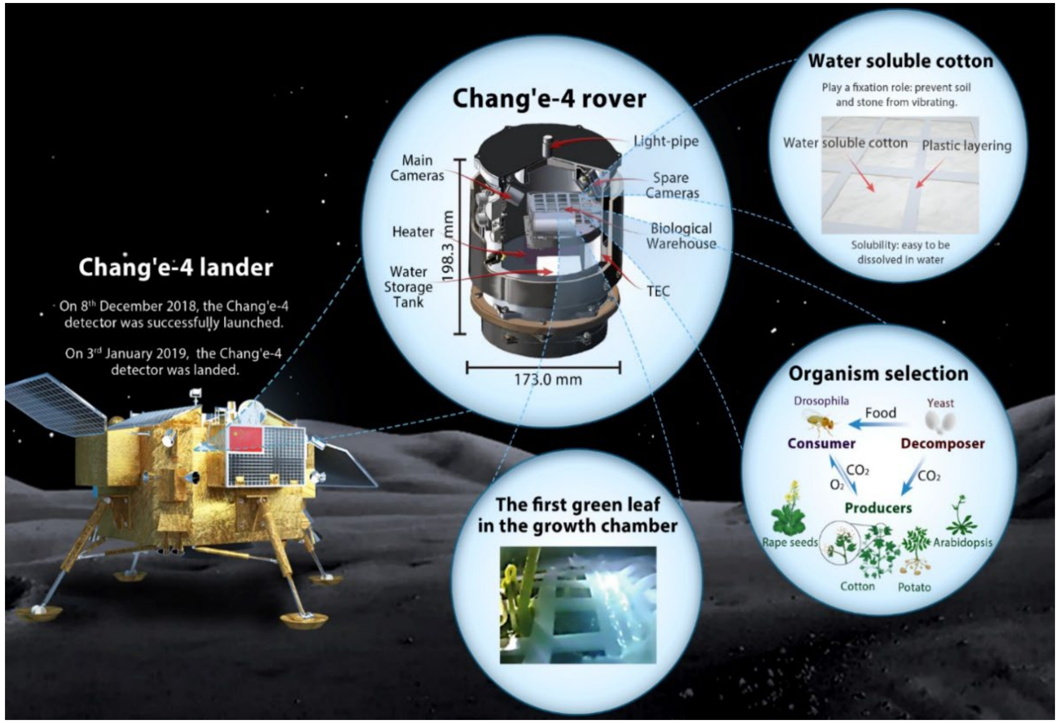
The Chinese Lunar Exploration Program opens a pathway for multiplanetary farming 载人登月国家战略，开启星际农业新赛道



China is Planning to Land Humans on the Moon by 2030.

中国计划到2030年将人类送上月球。

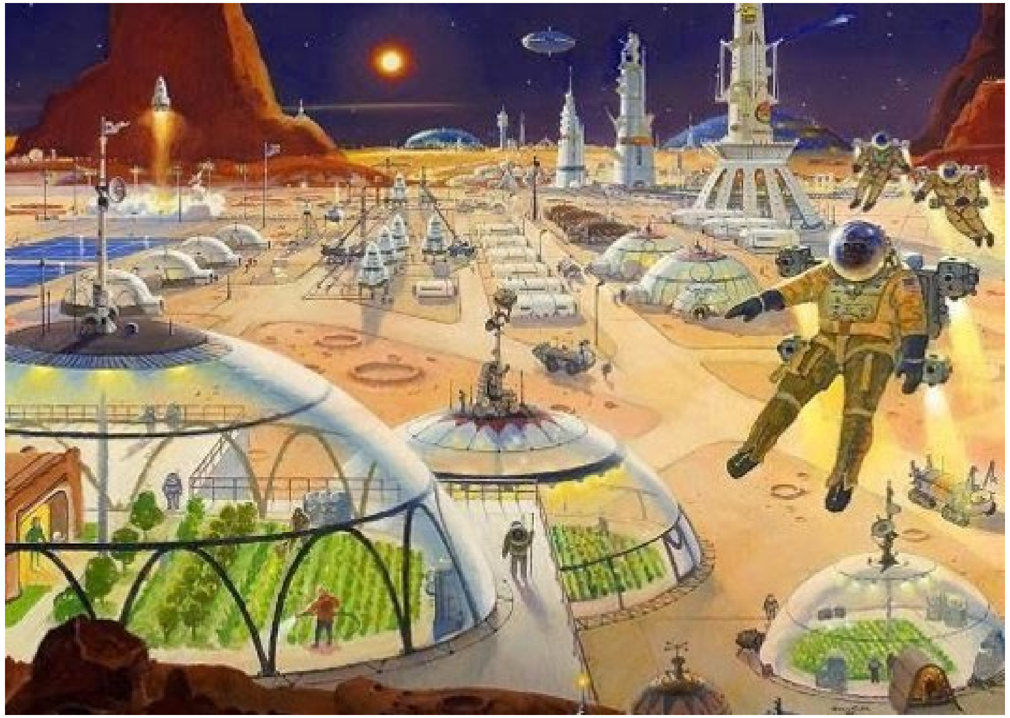
Plant sprouts on the Moon for first time ever “月球第一绿”

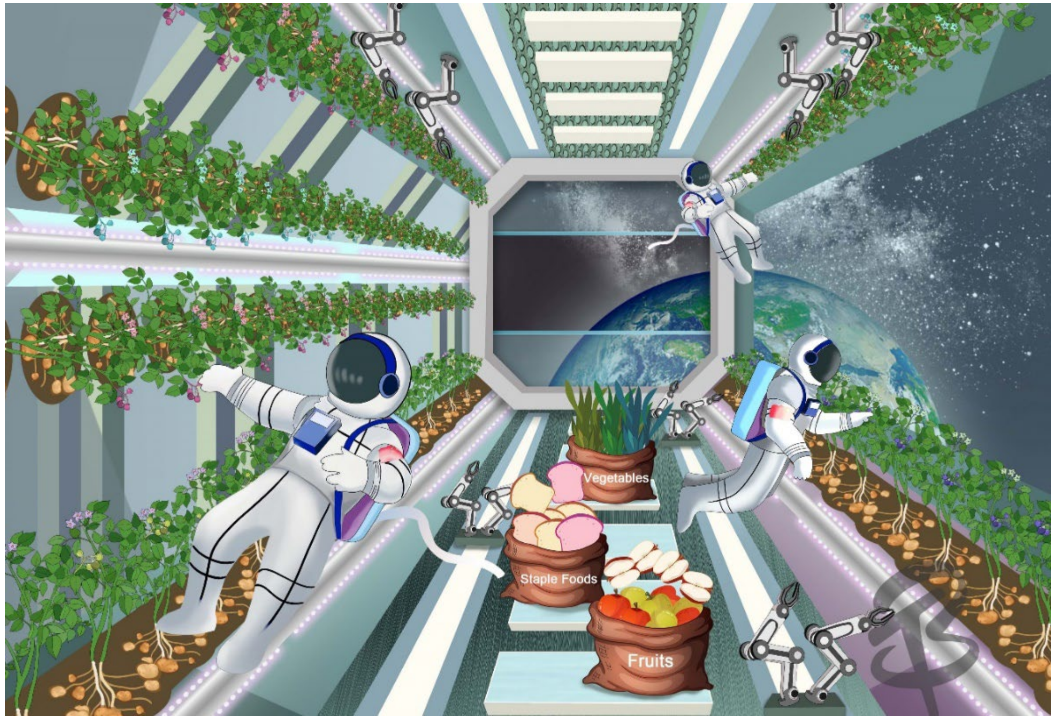


The first crop seedling to be successfully cultivated on the moon was grown in China’s Chang’e-4 lunar probe **by our team in 2019**. This breakthrough achievement has been widely reported by major media around the world, including *Nature* and *Science*.

2019年，我们团队在中国的“嫦娥四号”月球探测器上培育出了**第一颗在月球上成功培育的作物幼苗**。这一突破性成果被《自然》、《科学》等世界各大媒体广泛报道。

Multiplanetary Farming 星际农业

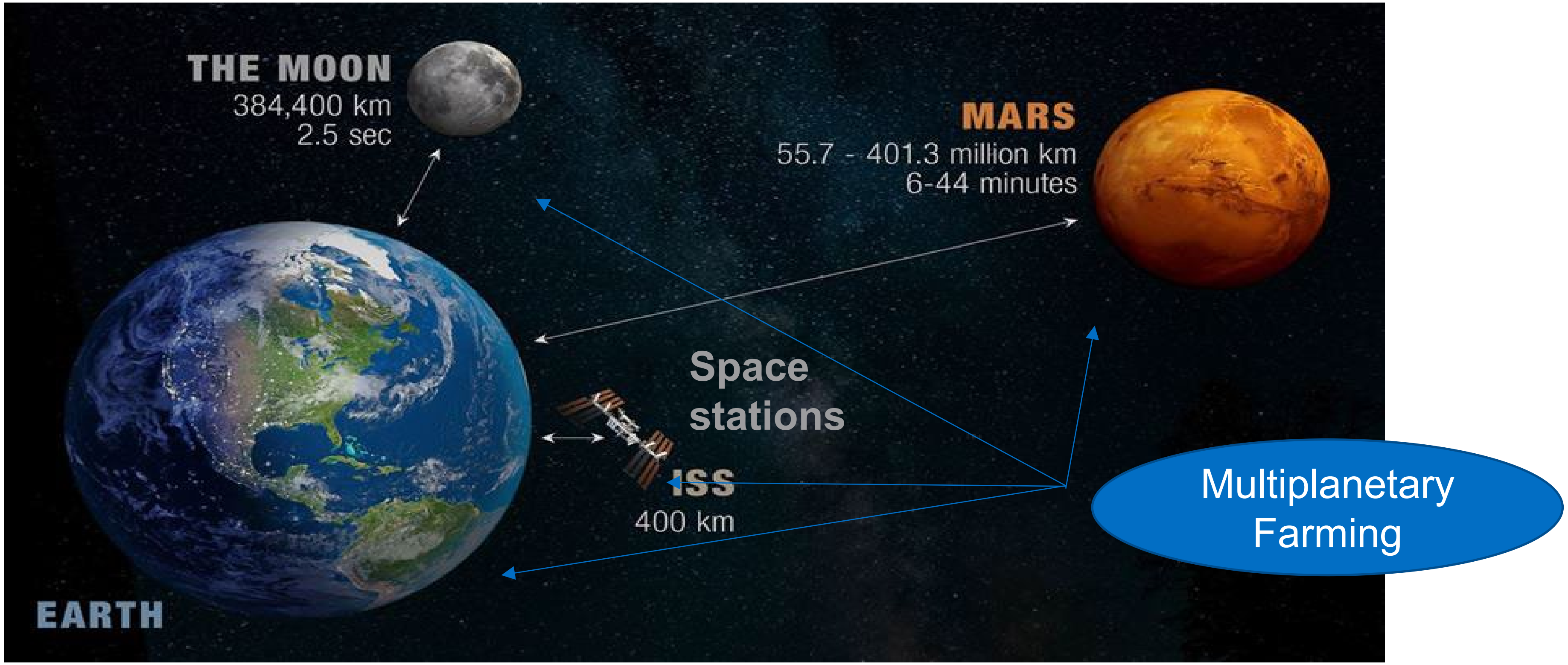




Interstellar farming: during space exploration and colonization, **establishing an efficient farming system** based on space crops and achieving food self-sufficiency is **crucial for long-term missions and human interstellar immigration**.

星际农业：在太空探索和殖民过程中，建立以太空作物为基础的**高效农业体系**，实现粮食自给自足，**对星际长期任务和人类星际移民至关重要。**

Overall goal 总体目标



- To establish theoretical, technological, and industrial systems for multiplanetary farming
- To build a universal farming system for Earth, Space station, Moon, and Mars
- 建立星际农业的理论、技术和产业体系
- 构建一套地球、空间站、月球和火星的通用农业系统

02

Potato+Microalgae are the Best Option for Multiplanetary Farming

马铃薯和微藻是星际农业的最佳选择

We proposed a whole-body edible and elite plant strategy for space crops improvement
我们提出了一种全体可食精英作物改良策略


nature COMMUNICATIONS

COMMENT

https://doi.org/10.1038/s41467-021-26238-3 OPEN

Check for updates

Biotechnological development of plants for space agriculture

Yongming Liu[1,2,3,5], Gengxin Xie[4,5], Qichang Yang[1,2]✉ & Maozhi Ren[1,2,3,4]✉

The ideal plant for cultivation in space would provide as many nutrients from as few inputs as possible. Here, we discuss how biotechnology could be used to produce a potato cultivar suitable for humans in space.

If humankind is ever to undertake long-term space missions and colonization, establishing an efficient space farming system would be essential for human survival in space. However, existing crops are not sufficiently cost effective and productive for use on space farms. Hence, we propose a Whole-Body Edible and Elite Plant (WBEEP) strategy for space crop improvement. Relying on plant biotechnology, the WBEEP strategy aims to develop crops with more edible parts, richer nutrient content, higher yields, and higher mineral nutrient use efficiencies for space farms.

Potato (*Solanum tuberosum* L.) is believed to be one of the top contenders for space agriculture due to the following advantages: (1) high harvest index and tuber yield and carbohydrate-rich tubers that can provide a large amount of energy for humans; (2) simple horticultural and food processing requirements; and (3) high tolerance against stresses with the ability to develop normally during spaceflight[1]. Importantly, potatoes can be asexually propagated through tubers and sexually propagated through seeds. Asexual reproduction can ensure the regeneration of food resources and stable nutritional value, while sexual reproduction can guarantee a higher propagation coefficient and lower storage and transportation costs[2]. However, potatoes cannot be efficiently cultivated in space until inherent defects related to their high solanine content, low yield and nutrient accumulation, and low fertilizer use efficiency are overcome. Below, we describe a WBEEP strategy for potato improvement that might create a WBEEP-potato for space farming (Fig. 1).

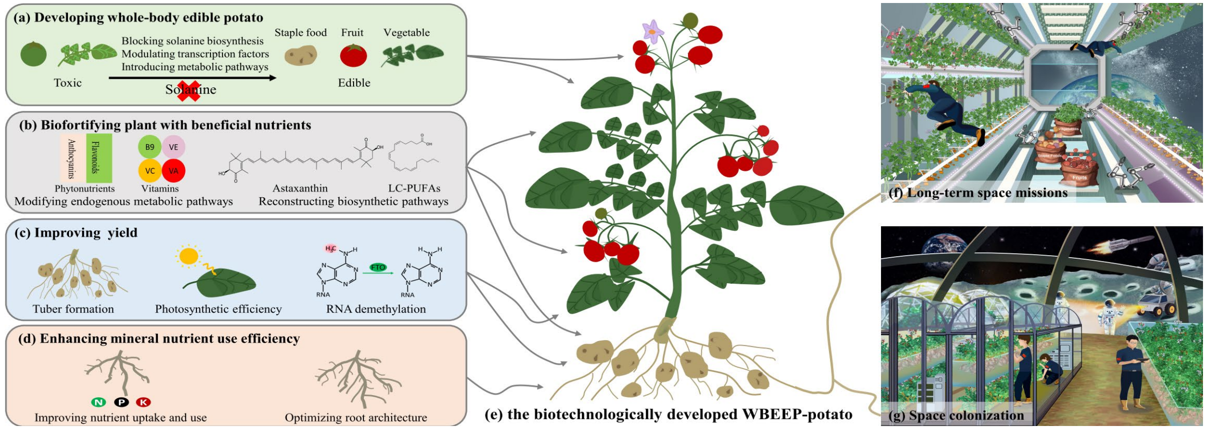
Developing whole-body edible plant for WBEEP-potato

Plants whose whole bodies are edible would be desirable for space farms because they can bring humans more food and reduce waste. However, potato stems, leaves, and berries are inedible. The aerial parts of potato plants contain accumulated solanine (primarily α-solanine and α-chaconine), which defends against pests and pathogens but is toxic to humans. In space farming systems, with highly controlled environments, solanine-mediated plant resistance would be unnecessary. If solanine were removed, the whole potato plant could potentially become edible. To block the accumulation of solanine in potato plants, biosynthesis can be targeted. For example, silencing or mutating genes encoding the cytochrome P450 enzyme GAME4, the dioxygenase DPS or the AP2/ERF transcription factor GAME9 greatly reduced solanine

[1] Laboratory of Space Biology, Institute of Urban Agriculture, Chinese Academy of Agricultural Sciences, 610213 Chengdu, China. [2] Zhengzhou Research Base, State Key Laboratory of Cotton Biology, School of Agricultural Sciences of Zhengzhou University, 450000 Zhengzhou, China. [3] Hainan Yazhou Bay Seed Laboratory, 572025 Sanya, China. [4] Center of Space Exploration, Ministry of Education (Chongqing University), 400044 Chongqing, China. [5] These authors contributed equally: Yongming Liu, Gengxin Xie. ✉email: yangqichang@caas.cn; renmaozhi01@caas.cn

https://doi.org/10.1038/s41467-021-26238-3

Liu *et al*. *Nat Commun*. 2021 Oct 14;12(1):5998.



Relying on plant biotechnology, the **whole-body edible and elite plant (WBEEP)** strategy aims to develop crops with **more edible parts, richer nutrient content, and higher yield and mineral nutrient use efficiency** to CEA. The study has been published in ***Nature Communications*** in 2021.

以植物生物技术为依托，**全体可食精英植物策略**旨在培育出可食用部分更多、营养成分更丰富、产量和矿质养分利用效率更高的作物。该研究已于2021年发表在**《自然通讯》**上。

We proposed biotechnological strategies for developing plants for multiplanetary farming
我们提出了开发星际农业植物的生物技术策略

Trends in Plant Science

CellPress

Forum

Biotechnological detoxification: an unchanging source–sink balance strategy for crop improvement

Yongming Liu,[1,2,3,6] Hussam Hassan Nour-Eldin,[4,6] Ling Zhang,[3,6] Zhanshuai Li,[2,3] Alisdair R. Fernie,[5,*] and Maozhi Ren[1,2,3,*]

The wide occurrence of natural phytotoxins renders many crops unfit for human consumption. To overcome this problem and produce detoxified crop varieties, we propose the use of biotechnological strategies that can enhance the harvest index without the need to increase crop biomass or alter whole plant architecture.

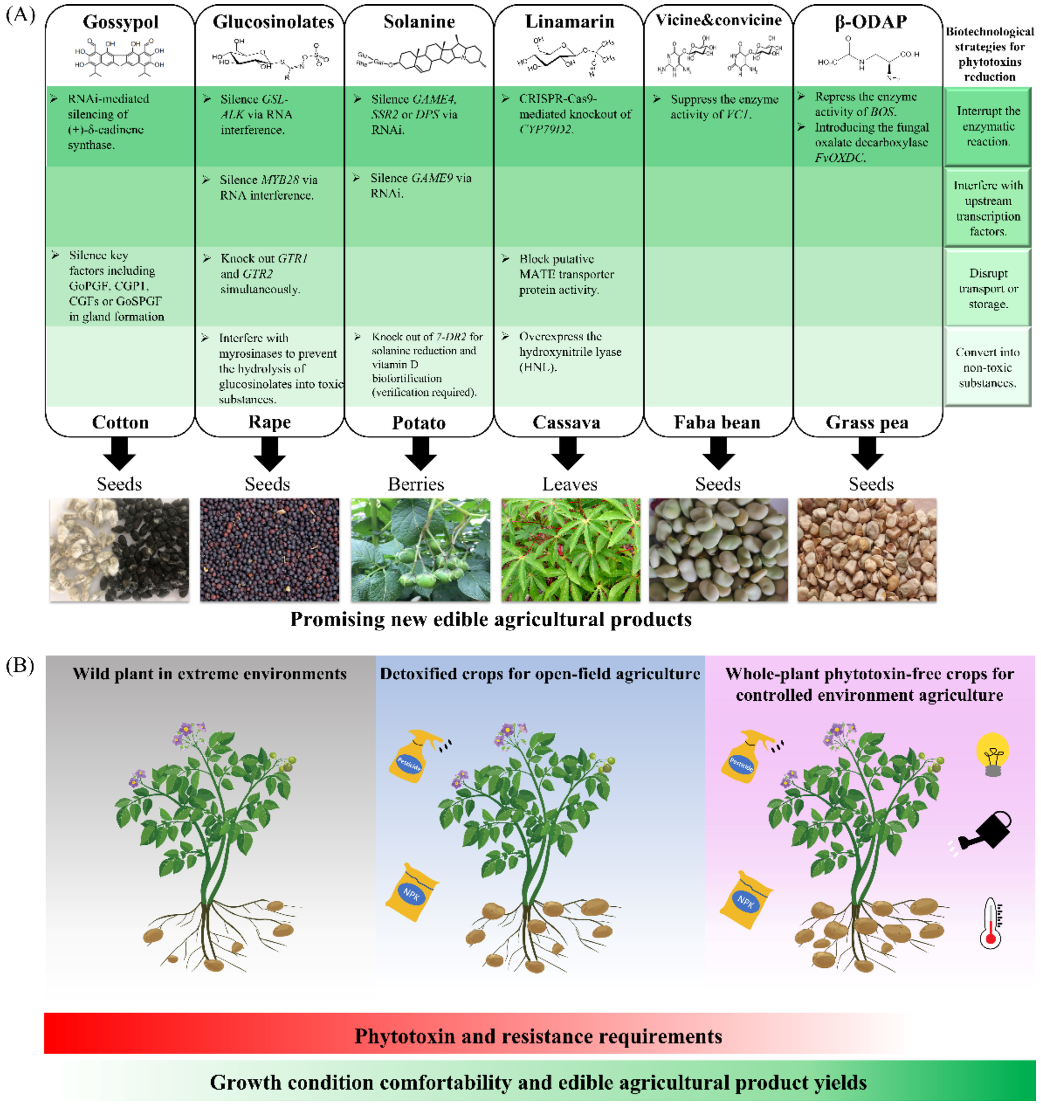
Phytotoxins are toxic secondary metabolites produced by plants as protective measures against herbivores and pathogens. These natural products are widely present in agricultural crops and can cause great damage to human health when consumed. Therefore, they limit the use of otherwise suitable parts of crops as a food source. We propose four biotechnological routes for the elimination of antinutrient metabolites: (i) inhibiting the biosynthesis of antinutrients, (ii) targeting upstream transcription factors, (iii) disruption of the transport or storage of antinutrients, and (iv) conversion of antinutrients into non-toxic substances. We provide case studies of the application of each of these approaches in various crop species (Figure 1A), and we argue that tissue-specific elimination of antinutritional metabolites will help to make more crops suitable for human consumption without compromising the plant defense systems. Current strategies for increasing yield by altering plant architecture are complicated by a lack of understanding of the link between metabolic, developmental, and signaling aspects underpinning source–sink transitions [1]. The strategy suggested here, the elimination of antinutritional metabolites from tissues, represents a much simpler approach for improving the harvesting index while circumventing the need to alter the source–sink balance (Table 1).

Removal of GSLs to harvest proteinaceous canola seeds

Canola/rapeseed (*Brassica napus*) is the world's third largest oilseed crop. Rape seeds contain 25–30% protein with a well-balanced amino acid composition. However, the antinutritional glucosinolates (GSLs) in seeds make rapeseed meal unfit for human consumption. The substances produced by the hydrolysis of GSLs can cause thyroid enlargement and poisoning symptoms such as respiratory paralysis, nausea, and vomiting. The biosynthetic pathway of the major rapeseed GSLs comprises elongation of the methionine side-chain, formation of the core structure, and modification of the side-chain. The GSL-ALK enzyme plays a role in the secondary modification. RNAi targeting *GSL-ALK* for silencing resulted in a reduction in the accumulation of antinutritional glucosinolates, and simultaneously increased the content of beneficial glucoraphanin in *Brassica* seeds [2]. The transcription factor MYB28 acts as a major regulator of short-chain aliphatic GSL biosynthesis, and silencing of MYB28 has been demonstrated to be an effective strategy to reduce overall GSL accumulation in *Brassica* crops [3]. GTR1 and GTR2 are responsible for the transport of GSLs into seeds, and the glucosinolate content in the quadruple mutant Bjgtr*2A1′2A2′2B1′2B2* was reduced by 62% [4]. The plant endogenous myrosinases (e.g., TGGs, PEN2, PEN3, and PYK10) facilitate GSL hydrolysis, and targeted blocking of their molecular functions could be a way to detoxify. The case of GSLs is interesting in that it highlights several of the dichotomies in antinutrient research. First, the examples described above highlight that it is possible to reduce the levels of antinutrients through a variety of approaches, but it is difficult to eliminate them entirely. Second, it should be noted that, although targeting the enzymes needed to produce toxic breakdown products is a potential strategy to avoid harmful effects, these enzymes could occur in other components of the diet or in the gut microbiome. Finally, it is important to note that some GSLs have been reported to have health-beneficial effects, and attempts to diminish GSL content could therefore be deleterious rather than beneficial. In summary, although a number of potentially promising strategies to increase the edibility of *Brassica* seeds have been developed, considerable research is still warranted.

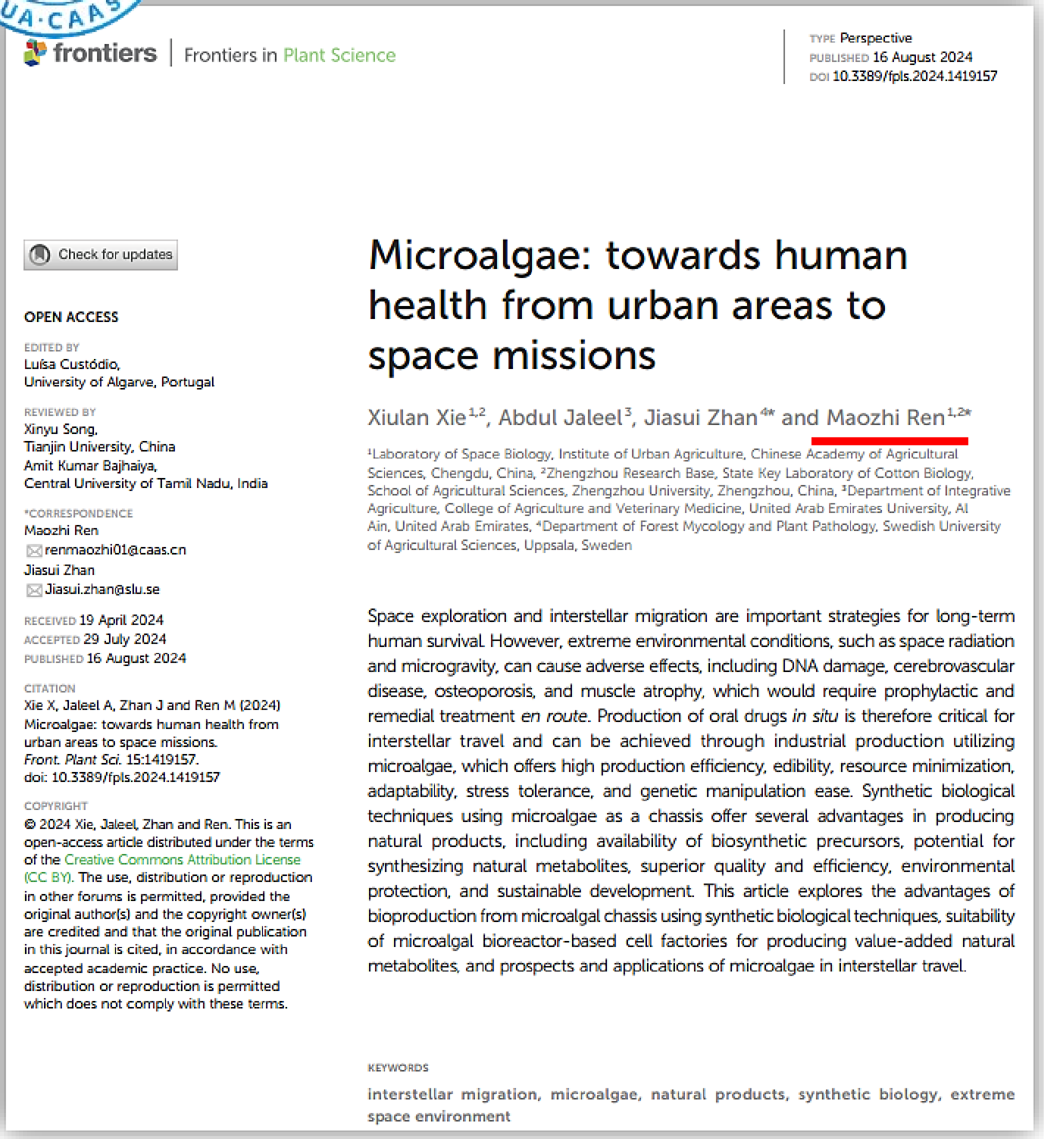
Exclusion of gossypol to generate high-protein cottonseeds

Cottonseed contains ~23% protein and is a potential source of high-protein food. It is estimated that, if cottonseeds were edible, the total amount of cottonseed protein produced globally each year could meet the annual needs of nearly 590 million people [5]. However, cottonseed contains phytotoxic gossypol, which severely damages the human respiratory system, reproductive system, and immune system. The enzymatic steps in gossypol biosynthesis have been well characterized, and silencing of several synthase genes can dramatically decrease gossypol levels [6]. Gossypol is stored in so-called cotton glands, and the level of gossypol can be diminished by inhibiting the formation of glands. Several key factors regulating gland formation have been identified, and silencing of *GoPGF*, *CGP1*, *CGFs*, or *GoSPGF* can lead to a sharp reduction in gossypol levels [7]. Although these findings fall short of complete removal of



Liu *et al*. *Trends Plant Sci*. 2022 Nov 25:S1360-1385(22)00301-6.

Microalga: the best chassis for producing natural products
微藻：生产天然产物的最佳底盘


frontiers | Frontiers in Plant Science
TYPE Perspective
PUBLISHED 16 August 2024
DOI 10.3389/fpls.2024.1419157

Check for updates

OPEN ACCESS

EDITED BY
Luísa Custódio,
University of Algarve, Portugal

REVIEWED BY
Xinyu Song,
Tianjin University, China
Amit Kumar Bajhaiya,
Central University of Tamil Nadu, India

*CORRESPONDENCE
Maozhi Ren
renmaozhi01@caas.cn
Jiasui Zhan
Jiasui.zhan@slu.se

RECEIVED 19 April 2024
ACCEPTED 29 July 2024
PUBLISHED 16 August 2024

CITATION
Xie X, Jaleel A, Zhan J and Ren M (2024) Microalgae: towards human health from urban areas to space missions. *Front. Plant Sci.* 15:1419157. doi: 10.3389/fpls.2024.1419157

Microalgae: towards human health from urban areas to space missions

Xiulan Xie[1,2], Abdul Jaleel[3], Jiasui Zhan[4*] and Maozhi Ren[1,2*]

[1]Laboratory of Space Biology, Institute of Urban Agriculture, Chinese Academy of Agricultural Sciences, Chengdu, China, [2]Zhengzhou Research Base, State Key Laboratory of Cotton Biology, School of Agricultural Sciences, Zhengzhou University, Zhengzhou, China, [3]Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, Al Ain, United Arab Emirates, [4]Department of Forest Mycology and Plant Pathology, Swedish University of Agricultural Sciences, Uppsala, Sweden

Space exploration and interstellar migration are important strategies for long-term human survival. However, extreme environmental conditions, such as space radiation and microgravity, can cause adverse effects, including DNA damage, cerebrovascular disease, osteoporosis, and muscle atrophy, which would require prophylactic and remedial treatment *en route*. Production of oral drugs *in situ* is therefore critical for interstellar travel and can be achieved through industrial production utilizing microalgae, which offers high production efficiency, edibility, resource minimization, adaptability, stress tolerance, and genetic manipulation ease. Synthetic biological techniques using microalgae as a chassis offer several advantages in producing natural products, including availability of biosynthetic precursors, potential for synthesizing natural metabolites, superior quality and efficiency, environmental protection, and sustainable development. This article explores the advantages of bioproduction from microalgal chassis using synthetic biological techniques, suitability of microalgal bioreactor-based cell factories for producing value-added natural metabolites, and prospects and applications of microalgae in interstellar travel.

KEYWORDS
interstellar migration, microalgae, natural products, synthetic biology, extreme space environment

Xie et al. *Front Plant Sci*. 2024 Aug 16:15:1419157.

Species / Parameters	Bacteria	Yeast	Insect cells	Mammalian cells	Plants	Microalgae
Yield	High 🔴	High 🔴	High 🔴	High 🔴	Medium 🟡	High 🔴
Timescale	Low 🔴	Low 🔴	Medium 🟡	High 🟢	High 🟢	Low 🔴
Cost	Low 🔴	Medium 🟡	High 🟢	Very high 🟢	Low 🔴	Low 🔴
Protein yield	High 🔴	Medium-high 🔴	Medium 🟡	Medium 🟡	Low-high 🟢	High 🔴
Storage condition	Aseptic cold 🟢	Aseptic cold 🟢	Aseptic cold 🟢	Aseptic cold 🟢	Room temperature 🔴	Room temperature 🔴
Need purification or not	Required 🟢	Required 🟢	Required 🟢	Required 🟢	Required 🟢	Not required 🔴
Glycosylation ability	Absent 🟢	Incorrect 🟡	Yes 🔴	Yes 🔴	Yes 🔴	Yes 🔴
Protein folding	Low 🟢	Medium 🟡	High 🔴	High 🔴	High 🔴	High 🔴
Can be prepared for oral vaccine	Impossible 🟢	Impossible 🟡	Impossible 🟢	Impossible 🟢	Possible 🔴	Possible 🔴
Safety risks	Endotoxins 🟢	None 🔴	Viruses, prions 🟢	Viruses, prions 🟢	None 🔴	None 🔴
Cytochrome P450 enzymes	None 🟢	Exist 🔴	Exist 🔴	Exist 🔴	Exist 🔴	Exist 🔴
Stress tolerance	Hardy 🔴	Moderate 🟡	Weak 🟢	Weak 🟢	Moderate 🟡	Hardy 🔴
Genetic transformation	Easy 🔴	Easy 🔴	very difficult 🟢	very difficult 🟢	Difficult 🟡	Easy 🔴
Availability of genetic tools	Very sophisticated 🔴	Very sophisticated 🔴	lacking 🟢	lacking 🟢	sophisticated 🟡	sophisticated 🟡
CRISPR genome editing	Available 🔴	Available 🔴	Available 🔴	Available 🔴	Available 🔴	Available 🔴
Alimentation mode	Heterotrophism 🟢	Heterotrophism 🟢	Heterotrophism 🟢	Heterotrophism 🟢	Autotrophy 🟡	Autotrophy/ heterotrophism /mixotroph 🔴

Favorability 🟢 Low 🟡 Medium 🔴 High

以微藻为底盘生产天然产物的优势

The function and applications of selenium-rich microalgae act on plants, animals, and the human body. 富硒微藻对植物、动物和人体的作用及其应用

Bioresource Technology 416 (2025) 131768

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Review

Microalgae: A good carrier for biological selenium enrichment

Shuang Liu[a,b,1], Muhammad Abu Bakar Saddique[a,b,1], Yiming Liang[a,b,1], Ge Guan[a,b,c], Haotian Su[a,b,c], Beibei Hu[a,b,c], Songqi Yang[d], Xiumei Luo[a,b,*], Maozhi Ren[a,b,c,*]

[a] Institute of Urban Agriculture, Chinese Academy of Agricultural Sciences, Chengdu 610000, China
[b] Chengdu Agricultural Science and Technology Center, Chengdu 610000, China
[c] Zhengzhou Research Base, State Key Laboratory of Cotton Biology, School of Agricultural Sciences, Zhengzhou University, Zhengzhou 450001 China
[d] Gansu Microalgae Technology Innovation Center, Hexi University, Zhangye 734000, China

H I G H L I G H T S

- Microalgae exceed plants in Se tolerance, growth, and conversion.
- Microalgae convert inorganic Se to crucial, usable forms, boosting one health.
- Environmental factors affect microalgae absorption, transport, and metabolism of Se.
- Se-rich microalgae are crucial in biofuel, bioresources, and biomass-based products.

A R T I C L E I N F O

Keywords:
Selenium-rich microalgae
Selenium metabolism
Selenoproteins
Nano-selenium

A B S T R A C T

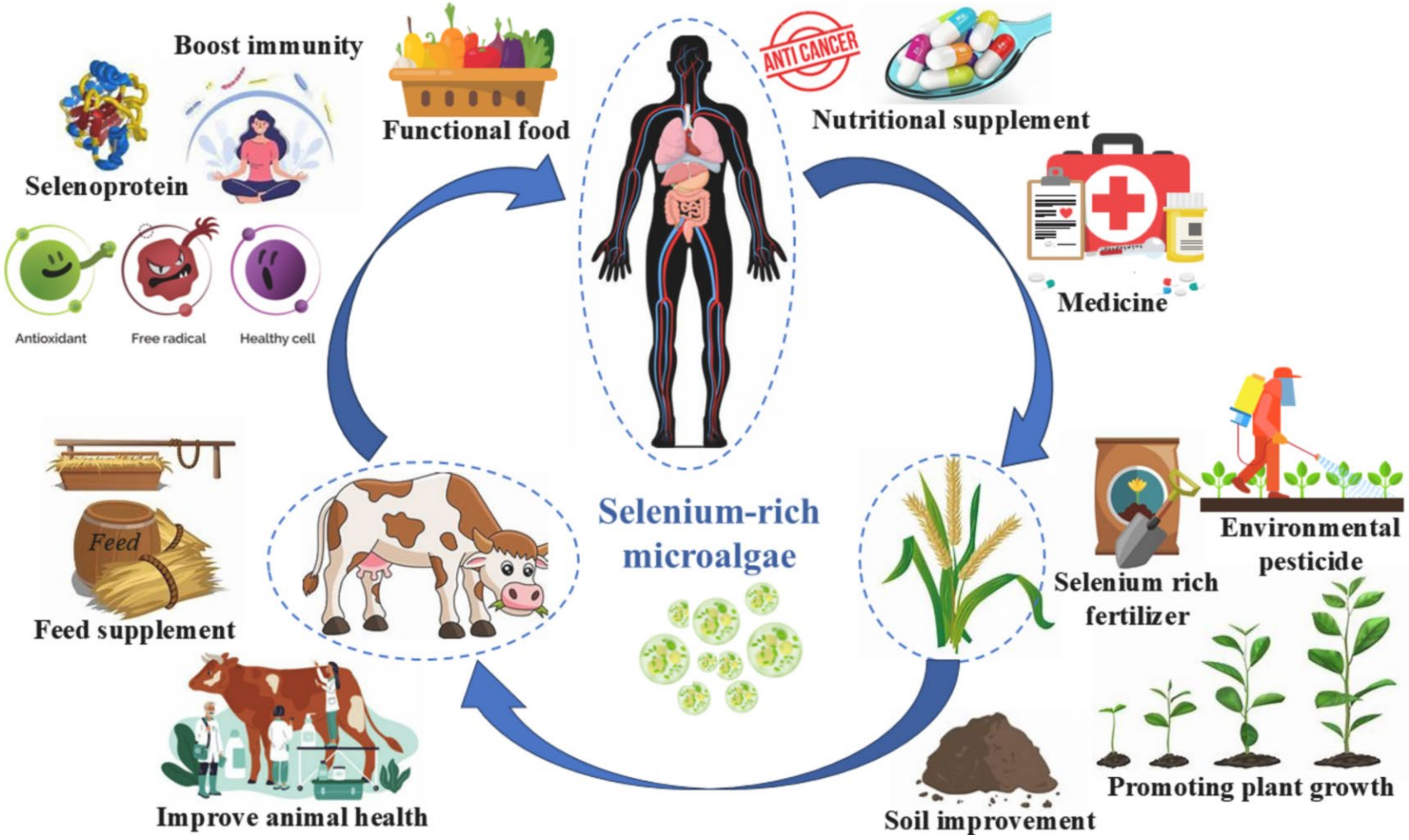
Selenium is a crucial micronutrient for human well-being, with significant contributions to antioxidant, anti-ageing, and antiviral activities. However, over one billion people globally struggle with selenium deficiency, leading to a pressing need for selenium supplementation. Conventional selenium-enrich food from plants and animals provides challenges in achieving precise selenium supplementation. Thus, it is crucial to discover selenium carriers that can be cultured in a controlled environment. Multiple studies have shown that microalgae are excellent carriers for selenium enrichment due to their rapid growth, suitability for plant consumption, ease of industrialization, high efficiency in converting organic selenium, and many others. This review focuses on single-celled microalgae, comprehensively reviewing their metabolic pathway, biological transformation, and valuable forms of selenium. Additionally, it forecasts the current application status and prospects of selenium-enriched microalgae in agriculture and global human health. This review provides a reference for the industrial supply of precise selenium-rich raw materials.

1. Introduction

Selenium (Se) is an indispensable microelement for human, which could drive one health through driving plant health, animal health, and human health. However, about one billion people worldwide are suffering from selenium deficiency (Schomburg, 2016), which has made them increasingly aware of the urgent need for selenium supplementation. In humans, Se is an integral part of twenty-five different enzymes, including thioredoxin reductase (TrxR), iodothyroxine, thyroxine 5′-deiodinase, glutathione peroxidase (GSH-Px), and other selenoproteins (Stolwijk et al., 2020). However, not all ingested selenium can be absorbed and utilized by the human body (Jafari and McClements, 2017), which can only be effectively utilized through the intestinal mucosal barrier. It enters the blood circulation, tissues, or organs and is converted into bioactive form as selenoproteins. Its deficiency will lead to Kaschin-beck disease, Keshan disease, cardiovascular and cerebrovascular diseases, cataracts, etc (Loscalzo, 2014). Excessive selenium intake (> 400 μg/d) is also toxic, with symptoms including alopecia, liver necrosis, brittle nail syndrome, brain edema, liver injury, and neurotoxicity (Yang et al., 2022). Thus, suitable selenium intake is

* Corresponding authors at: Institute of Urban Agriculture, Chinese Academy of Agricultural Sciences, Chengdu 610000, China (M. Ren, X. Luo).
E-mail addresses: luoxiumei@caas.cn (X. Luo), renmaozhi01@caas.cn (M. Ren).
[1] Contribute equally.

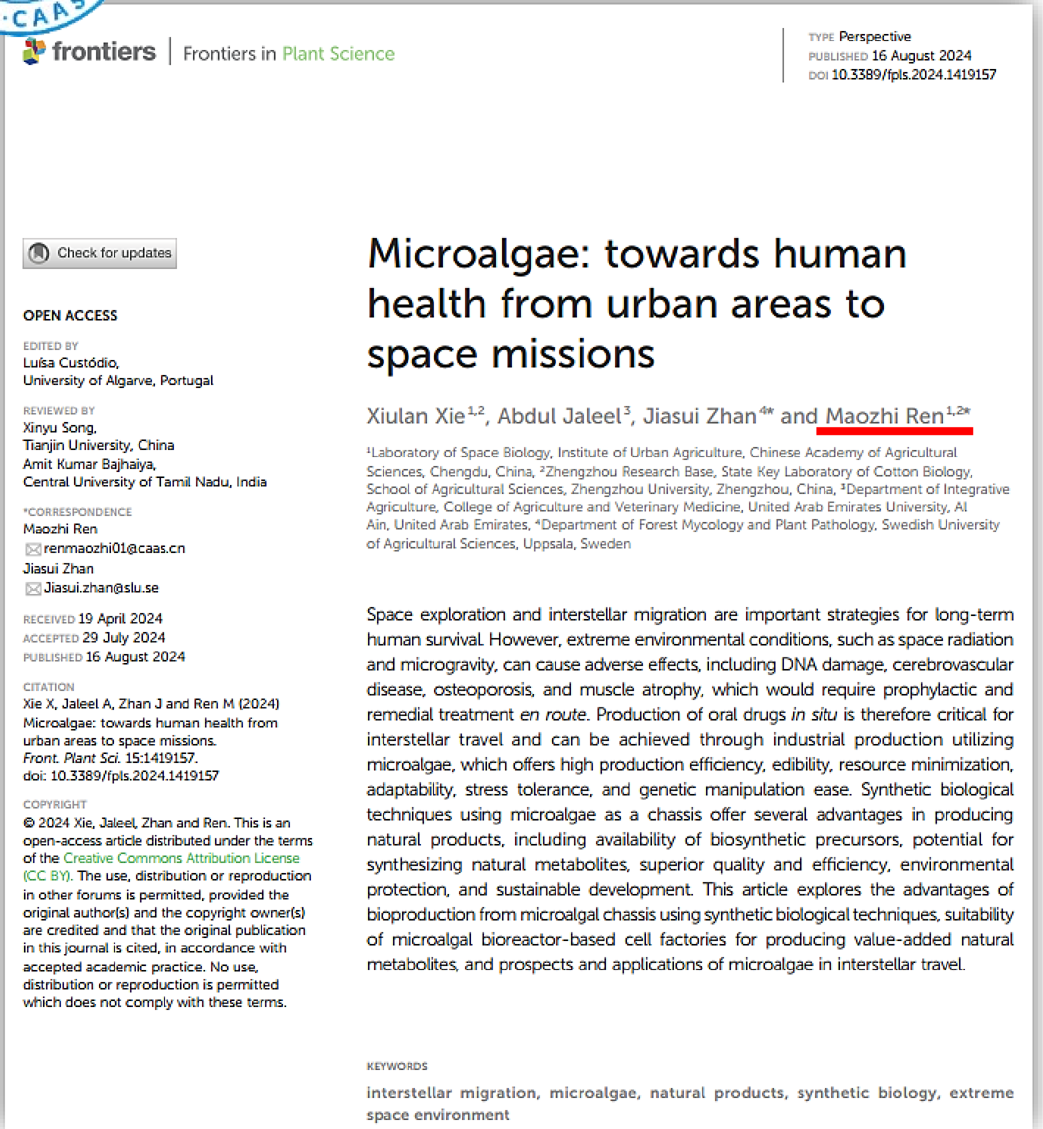
https://doi.org/10.1016/j.biortech.2024.131768
Received 4 June 2024; Received in revised form 4 November 2024; Accepted 5 November 2024
Available online 8 November 2024
0960-8524/



Liu et al. *Bioresour Technol*. 2024 Nov 8:416:131768

Production of high-value natural metabolites using a microalgal cell factory

利用微藻细胞工厂生产高价值天然代谢物



frontiers | Frontiers in Plant Science

TYPE Perspective
PUBLISHED 16 August 2024
DOI 10.3389/fpls.2024.1419157

Check for updates

OPEN ACCESS

EDITED BY
Luísa Custódio,
University of Algarve, Portugal

REVIEWED BY
Xinyu Song,
Tianjin University, China
Amit Kumar Bajhaiya,
Central University of Tamil Nadu, India

*CORRESPONDENCE
Maozhi Ren
renmaozhi01@caas.cn
Jiasui Zhan
Jiasui.zhan@slu.se

RECEIVED 19 April 2024
ACCEPTED 29 July 2024
PUBLISHED 16 August 2024

CITATION
Xie X, Jaleel A, Zhan J and Ren M (2024) Microalgae: towards human health from urban areas to space missions. *Front. Plant Sci.* 15:1419157. doi: 10.3389/fpls.2024.1419157

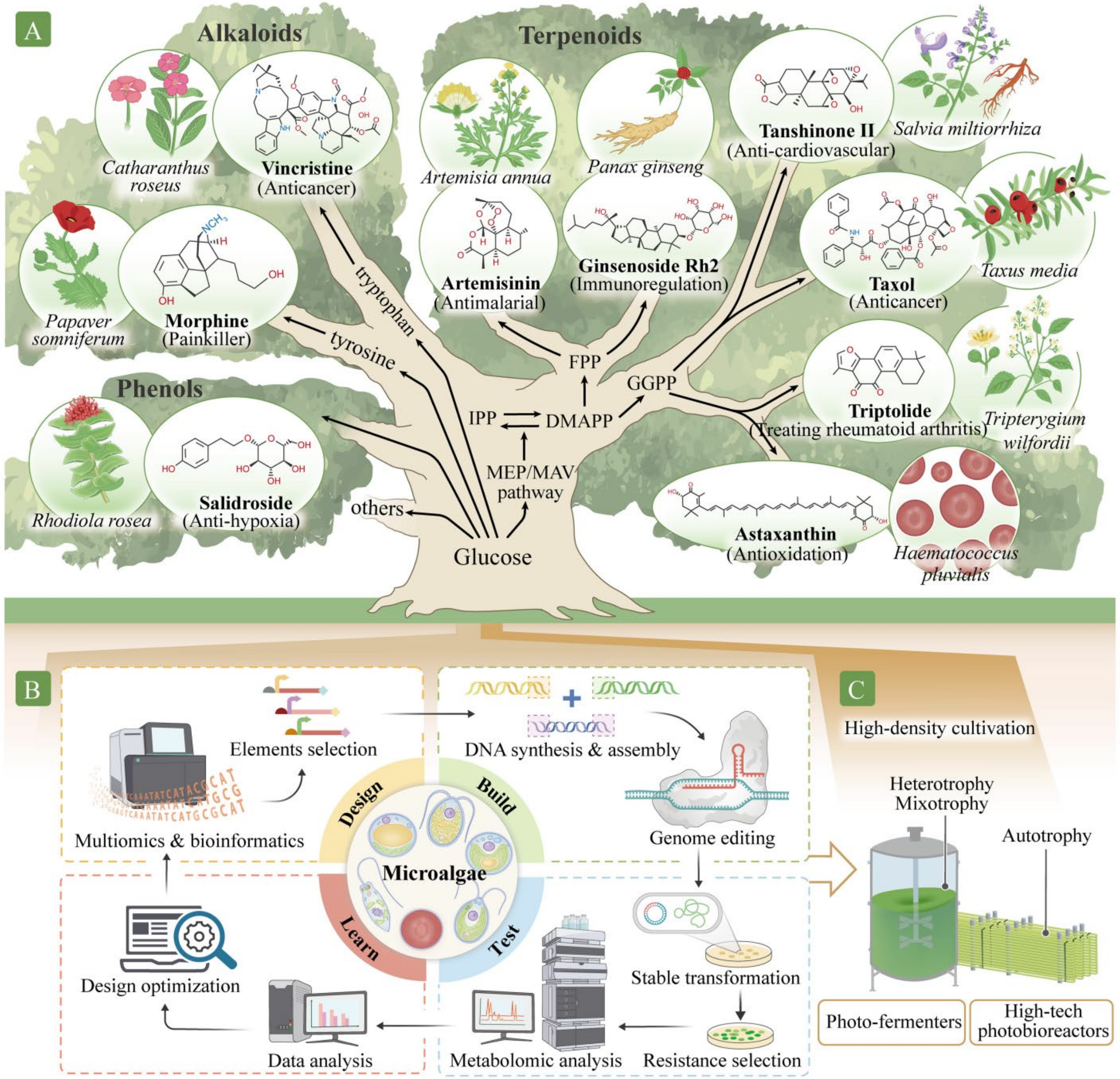
Microalgae: towards human health from urban areas to space missions

Xiulan Xie[1,2], Abdul Jaleel[3], Jiasui Zhan[4*] and Maozhi Ren[1,2*]

[1]Laboratory of Space Biology, Institute of Urban Agriculture, Chinese Academy of Agricultural Sciences, Chengdu, China, [2]Zhengzhou Research Base, State Key Laboratory of Cotton Biology, School of Agricultural Sciences, Zhengzhou University, Zhengzhou, China, [3]Department of Integrative Agriculture, College of Agriculture and Veterinary Medicine, United Arab Emirates University, Al Ain, United Arab Emirates, [4]Department of Forest Mycology and Plant Pathology, Swedish University of Agricultural Sciences, Uppsala, Sweden

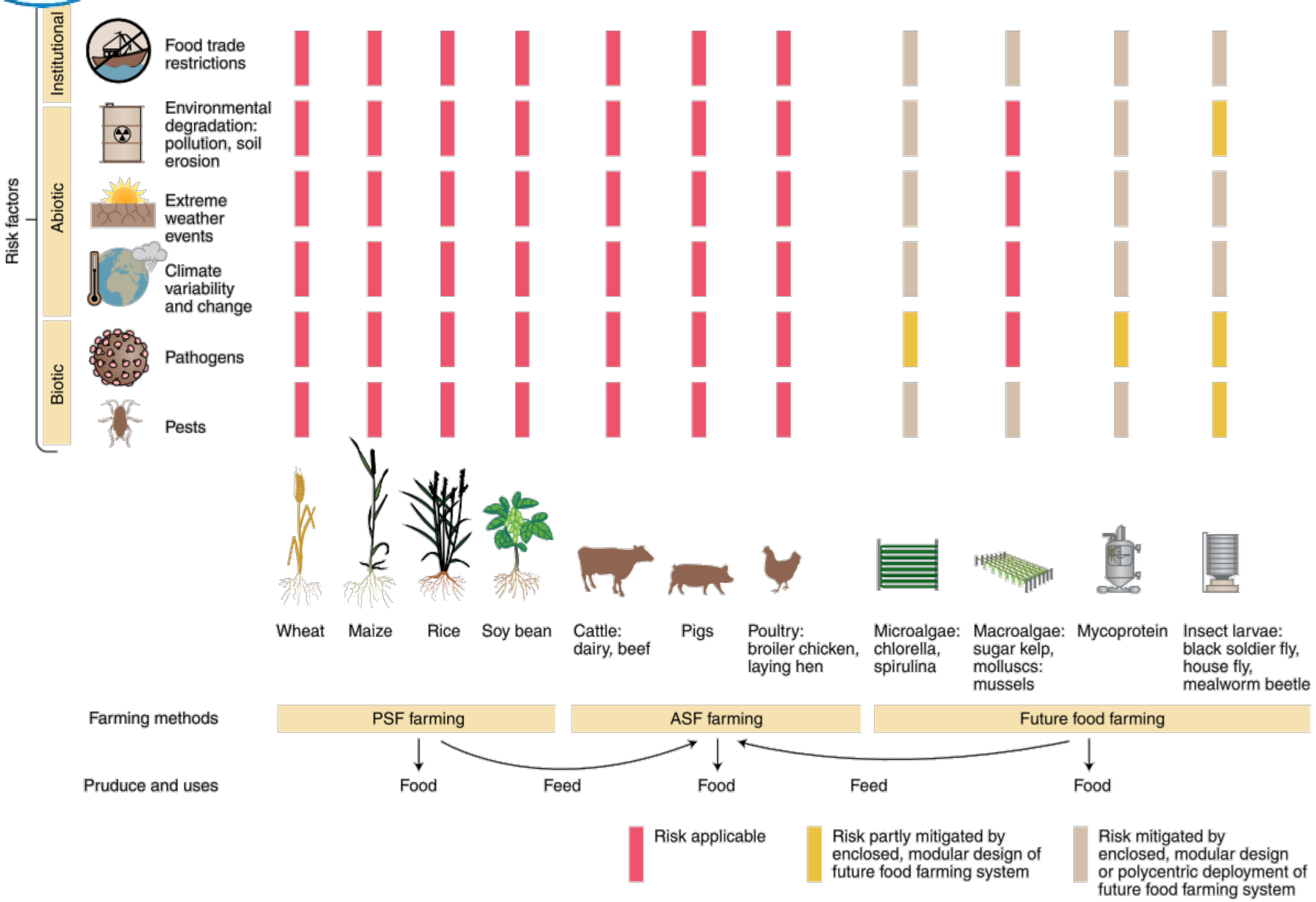
Space exploration and interstellar migration are important strategies for long-term human survival. However, extreme environmental conditions, such as space radiation and microgravity, can cause adverse effects, including DNA damage, cerebrovascular disease, osteoporosis, and muscle atrophy, which would require prophylactic and remedial treatment *en route*. Production of oral drugs *in situ* is therefore critical for interstellar travel and can be achieved through industrial production utilizing microalgae, which offers high production efficiency, edibility, resource minimization, adaptability, stress tolerance, and genetic manipulation ease. Synthetic biological techniques using microalgae as a chassis offer several advantages in producing natural products, including availability of biosynthetic precursors, potential for synthesizing natural metabolites, superior quality and efficiency, environmental protection, and sustainable development. This article explores the advantages of bioproduction from microalgal chassis using synthetic biological techniques, suitability of microalgal bioreactor-based cell factories for producing value-added natural metabolites, and prospects and applications of microalgae in interstellar travel.

KEYWORDS
interstellar migration, microalgae, natural products, synthetic biology, extreme space environment



Xie et al. *Front Plant Sci*. 2024 Aug 16:15:1419157.

Microalga: the best option for multiplanetary farming
微藻：星际农业的最佳选择



https://www.nature.com/articles/s43016-021-00269-x

- Fewer risk factors;
- Higher energy utilization efficiency;
- Less labor cost;
- Shorter growth cycle;
- Higher harvest index.

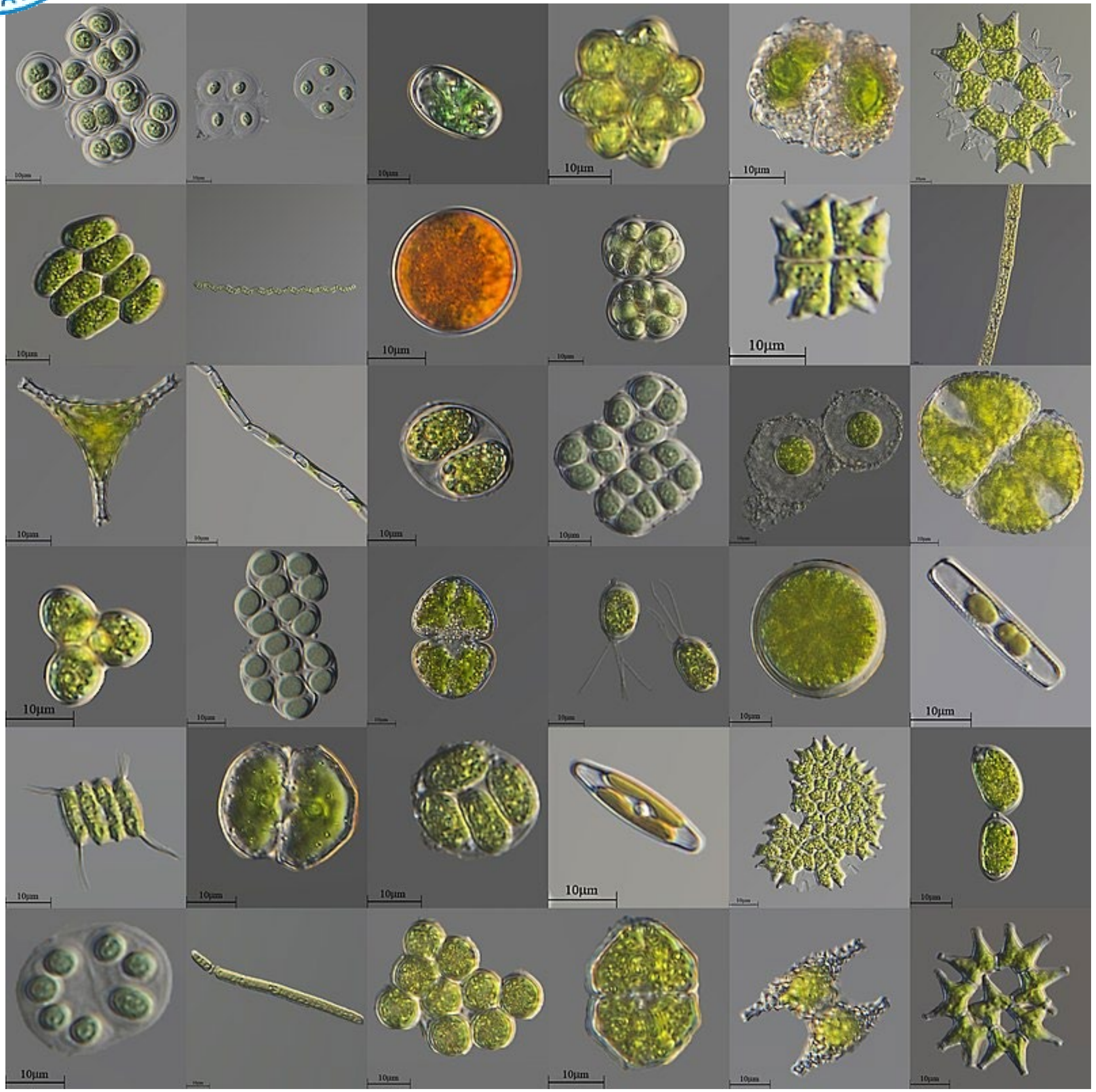
- 较低的危险因素;
- 更高的能源利用效率;
- 较低的的人工成本;
- 较短的生长周期;
- 较高的产量。

Microalga 微藻

- Microalgae are tiny groups of algae whose shape can only be discerned under a microscope
- Earth's lungs: produced 90% of the oxygen we breathe today.
- One of the earliest life on earth.
- In nature, microalgae are the food sources for many organisms.

- 微藻是一种微小的藻类，只有在显微镜下才能看清它们的形状
- 地球的肺：产生了我们今天呼吸的90%的氧气。
- 地球上最早的生命之一。
- 在自然界中，微藻是许多生物的食物来源。

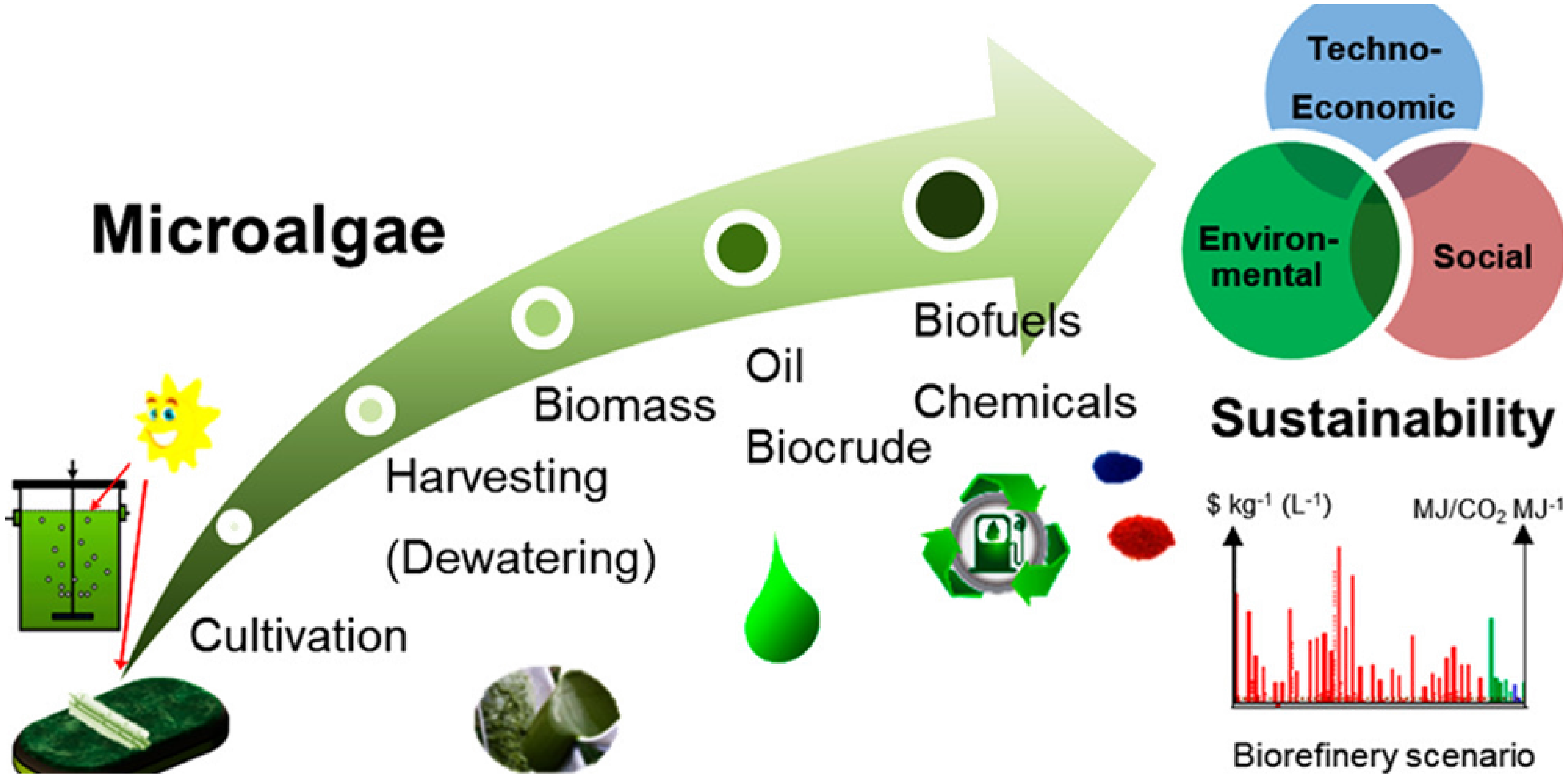
Diversity of Microalgae 微藻的多样性



- The biodiversity of microalgae is enormous. It has been estimated that about **200,000** species in many different genera exist of which about **50,000** species are described.

- 微藻的生物多样性是巨大的。据估计，在许多不同的属中约有**20万种**存在，其中约有**5万种**被研究发现。

Multiple Uses 微藻的多种用途

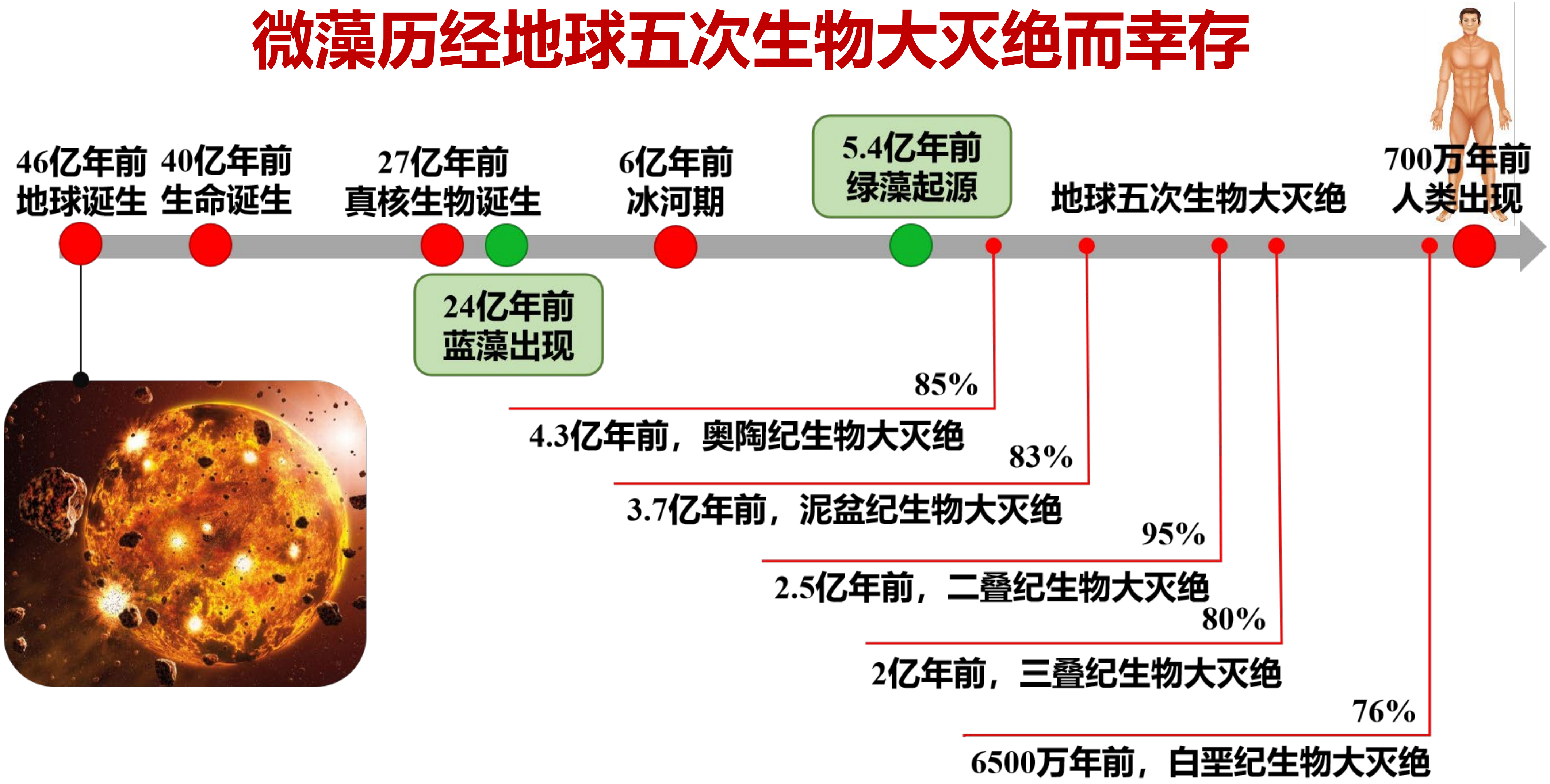


Microalgae can serve various purposes beyond food production. They can be used for biofuel production, wastewater treatment, and the extraction of valuable compounds such as pigments, oils, and pharmaceuticals.

除了用作食品之外，微藻还可以用于多种用途。它们可用于生物燃料生产、废水处理以及颜料、油和药物等有价值化合物的提取。

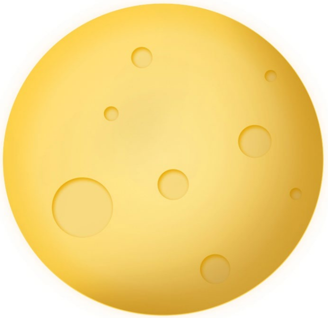
Microalgae have survived five mass extinctions on Earth

微藻历经地球五次生物大灭绝而幸存



核大战、行星撞击、火山爆发、气候极端变化等均可造成生物大灭绝

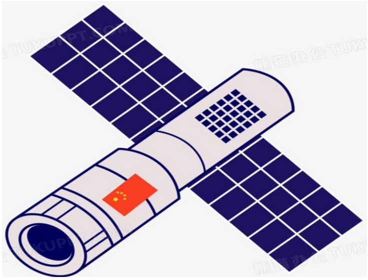
Outstanding advantages of microalgae : adapt to microgravity environment



月球

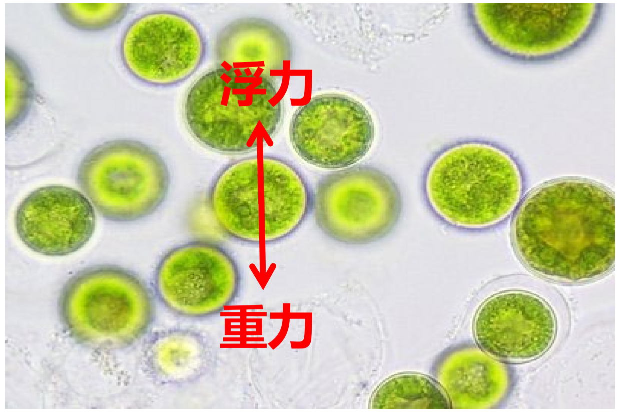
火星

地球

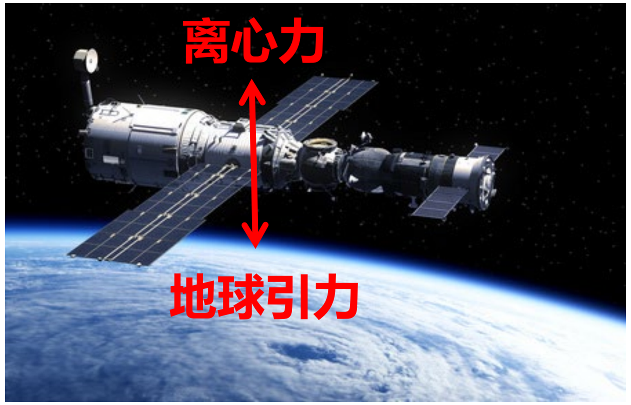


空间站

月球重力=1/6 地球重力；火星重力=1/3 地球重力；空间站重力≈0

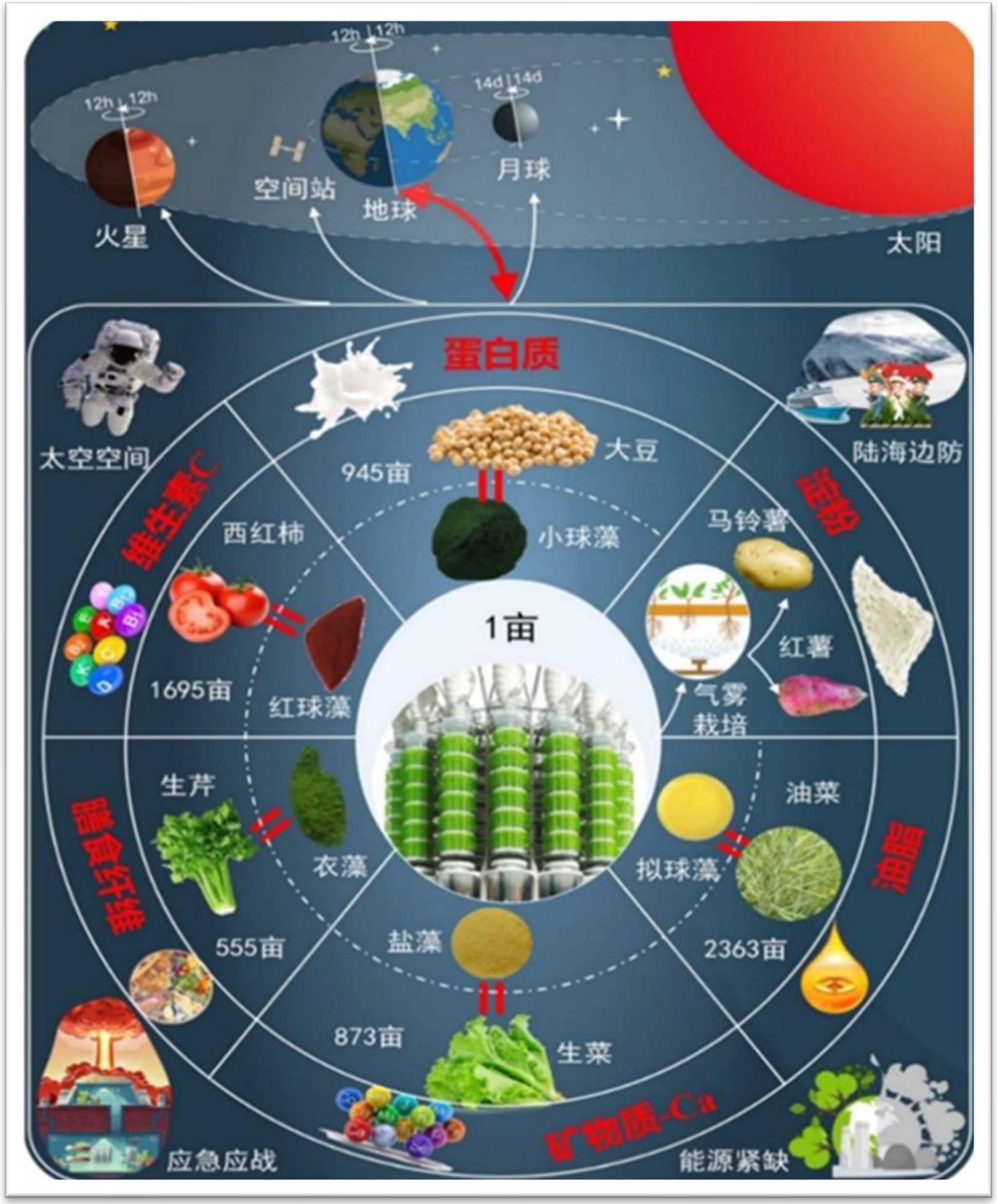


悬浮的微藻
(重力=浮力)



悬浮的空间站
(地球引力=离心力)

Microalgae: the Best Option for Multiplanetary Farming



微藻作为地球上最早出现的光合生命体，经历地球五次生物大灭绝而幸存

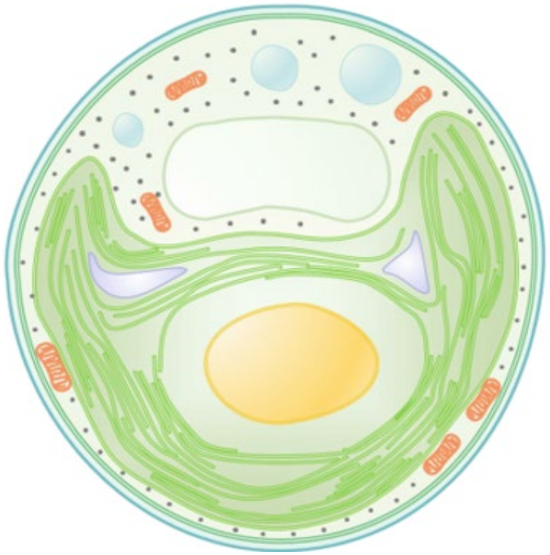
- 能源利用效率高
- 抗逆性、适应性强
- 成本低、产量高
- 营养价值高
- 全株可食
- 能够很好适应微重力环境

03

Edible Microalgae for Multiplanetary Farming

用于星际农业的可食微藻

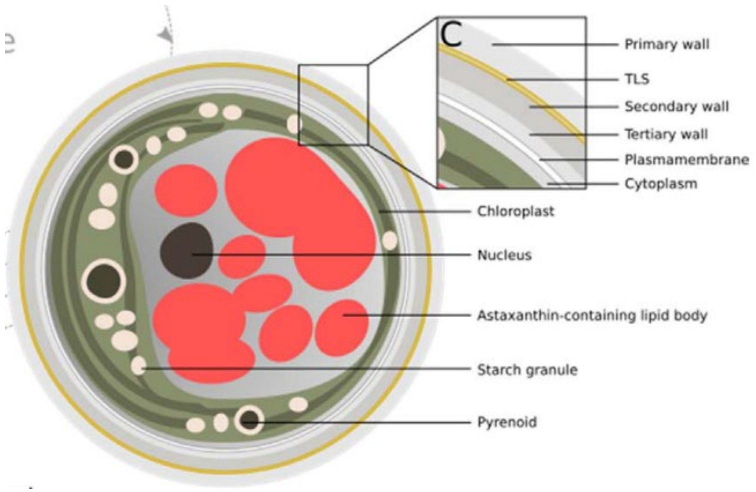
Edible microalgae No. 1: *Chlorella pyrenoidosa* No. 1 蛋白核小球藻



Chlorella pyrenoidosa
蛋白核小球藻

Name 名字	*Chlorella pyrenoidosa* 蛋白核小球藻
Classification 分类	Chlorophyta, Chlorella 绿藻门，小球藻属
Growth characteristics 生长特性	Photoautotrophic, chemotrophic, allotrophic 光能自养，化能，异养
Distribution 分布	All over the world except for the vicious environment of the North and South Poles 分布于世界各地除了恶劣的南北两极环境
Function 功能	Food, food additives, skin care products, feed, etc. 食品、食品添加剂、护肤品、饲料、有机肥等
Advantage 优势	With a protein content of about 60% 蛋白质含量约为60%
Industrial performance 工业性能	The growth rate is fast, suitable for high-density fermentation, and the cultivation cost is lower than that of yeast 生长速度快，适合高密度发酵，培养成本低于酵母

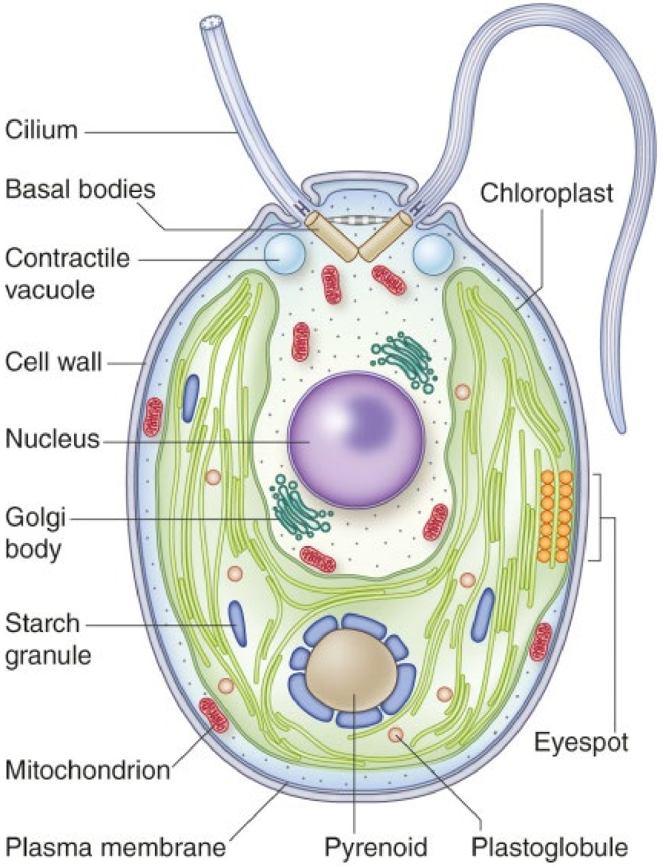
Edible microalgae No. 2: *Haematococcus pluvialis* No. 2 雨生红球藻



Haematococcus pluvialis
雨生红球藻

Name 名字	*Haematococcus pluvialis* 雨生红球藻
Classification 分类	Chlorophyta, Chlorella 绿藻门，小球藻属
Growth characteristics 生长特性	Photoautotrophic, chemotrophic, allotrophic 光能自养， 化能，异养
Distribution 分布	All over the world and is one of the earliest life on Earth 分布于全球，地球上最早的生命之一
Function 功能	Food, food additives, skin care products, feed, etc. 食品、食品添加剂、护肤品、饲料、有机肥等
Advantage 优势	Rich in "King of antioxidants" ——astaxanthin "抗氧化剂之王"——虾青素
Industrial performance 工业性能	The growth rate is fast, suitable for high-density fermentation, and the cultivation cost is lower than that of yeast 生长速度快，适合高密度发酵，培养成本低于酵母

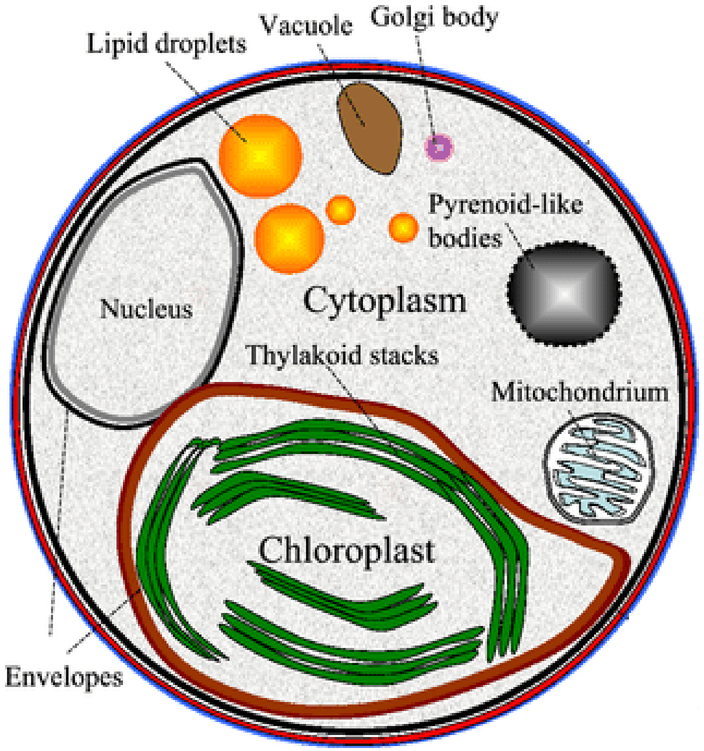
Edible microalgae No. 3: *Chlamydomonas reinhardtii* No. 3 莱茵衣藻



Chlamydomonas reinhardtii

Name 名字	*Chlamydomonas reinhardtii* 莱茵衣藻
Classification 分类	Phylum Chrysophyta, Chlorella 绿藻门，小球藻属
Growth characteristics 生长特性	Photoautotrophic, chemotrophic, allotrophic 光能自养， 化能，异养
Distribution 分布	Ditches, depressions and, lakes 分布于沟渠、洼地和湖泊中
Function 功能	Food, food additives, skin care products, feed, etc. 食品、食品添加剂、护肤品、饲料、有机肥等
Advantage 优势	Easy to cultivate, fast to grow, easy to genetically transform 易于栽培，生长快，易于基因转化
Industrial performance 工业性能	The growth rate is fast, suitable for high-density fermentation, and the cultivation cost is lower than that of yeast 生长速度快，适合高密度发酵，培养成本低于酵母

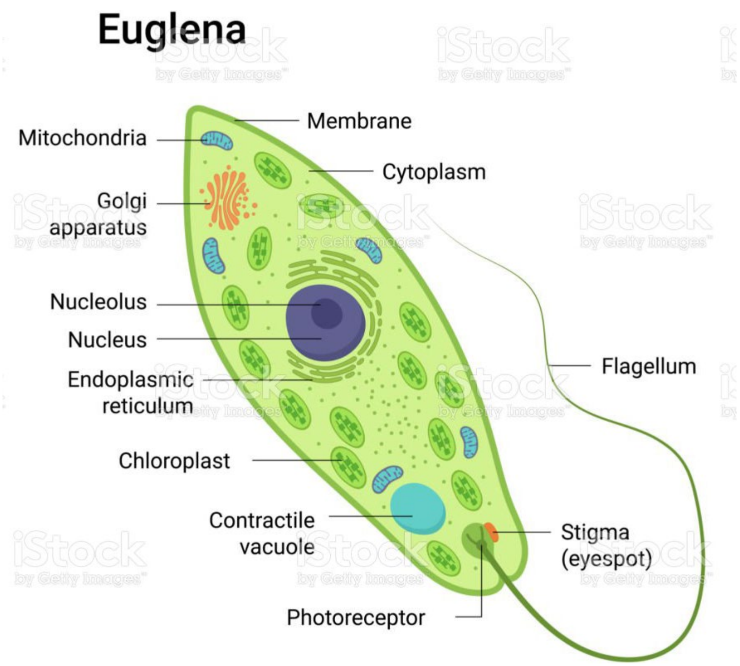
Edible microalgae No. 4: *Nannochloropsis gaditana* No. 4 拟微球藻



Nannochloropsis gaditana

Name 名字	*Nannochloropsis gaditana* 拟微球藻
Classification 分类	Chlorophyta, Chlorella 绿藻门，小球藻属
Growth characteristics 生长特性	Photoautotrophic, chemotrophic 光能自养，化能
Distribution 分布	It is widely distributed in seawater 分布于海水中
Function 功能	Food, medicine, aerospace, aquaculture, energy, etc 食品、医药、航天、水产、能源等
Advantage 优势	The lipid ratio is as high as 68%, and it is rich in EPA 脂质比高达68%，富含EPA
Industrial performance 工业性能	Suitable for large-scale breeding 适合大规模养殖

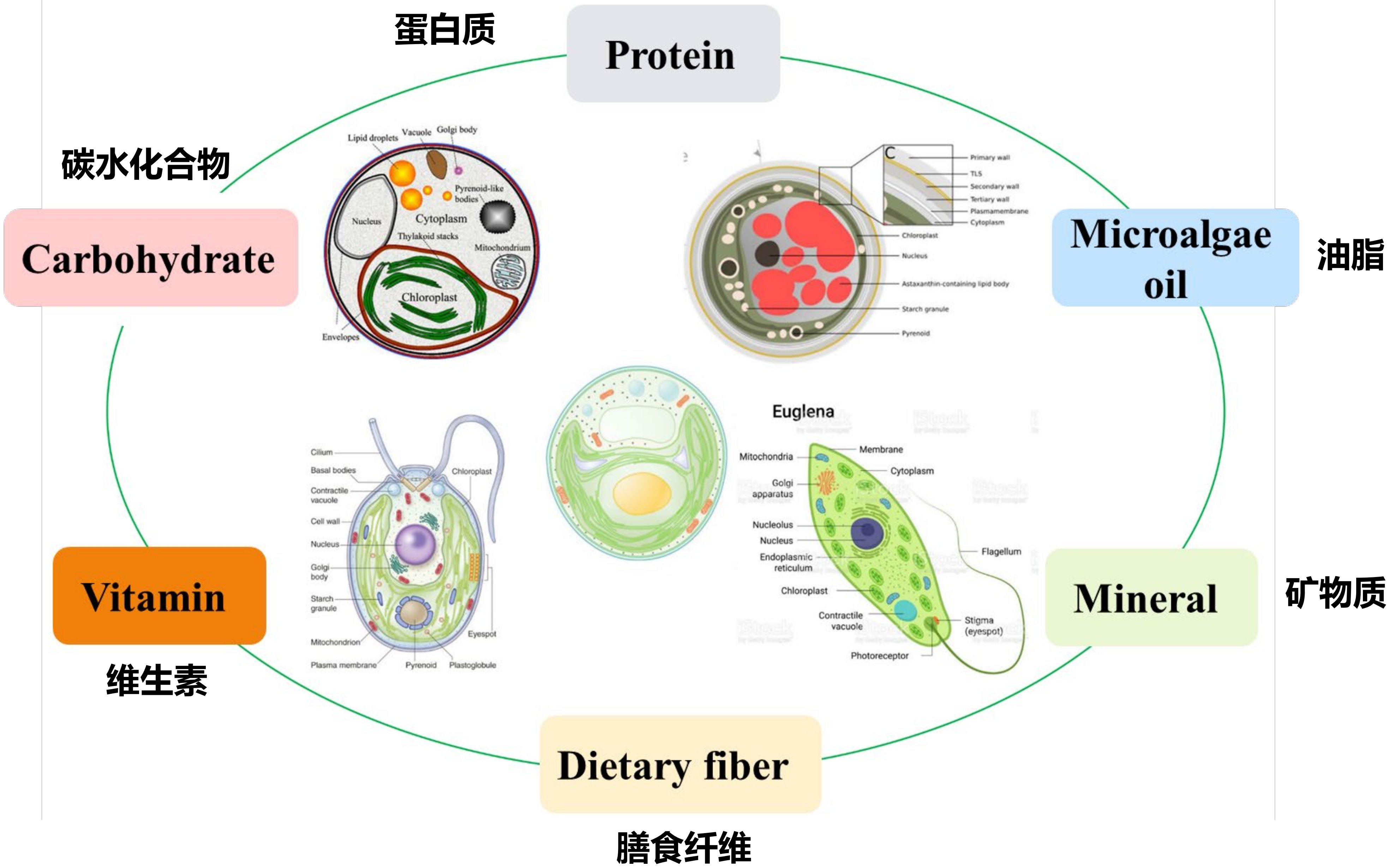
Edible microalgae No. 5: *Euglena gracilis* No. 5 裸藻



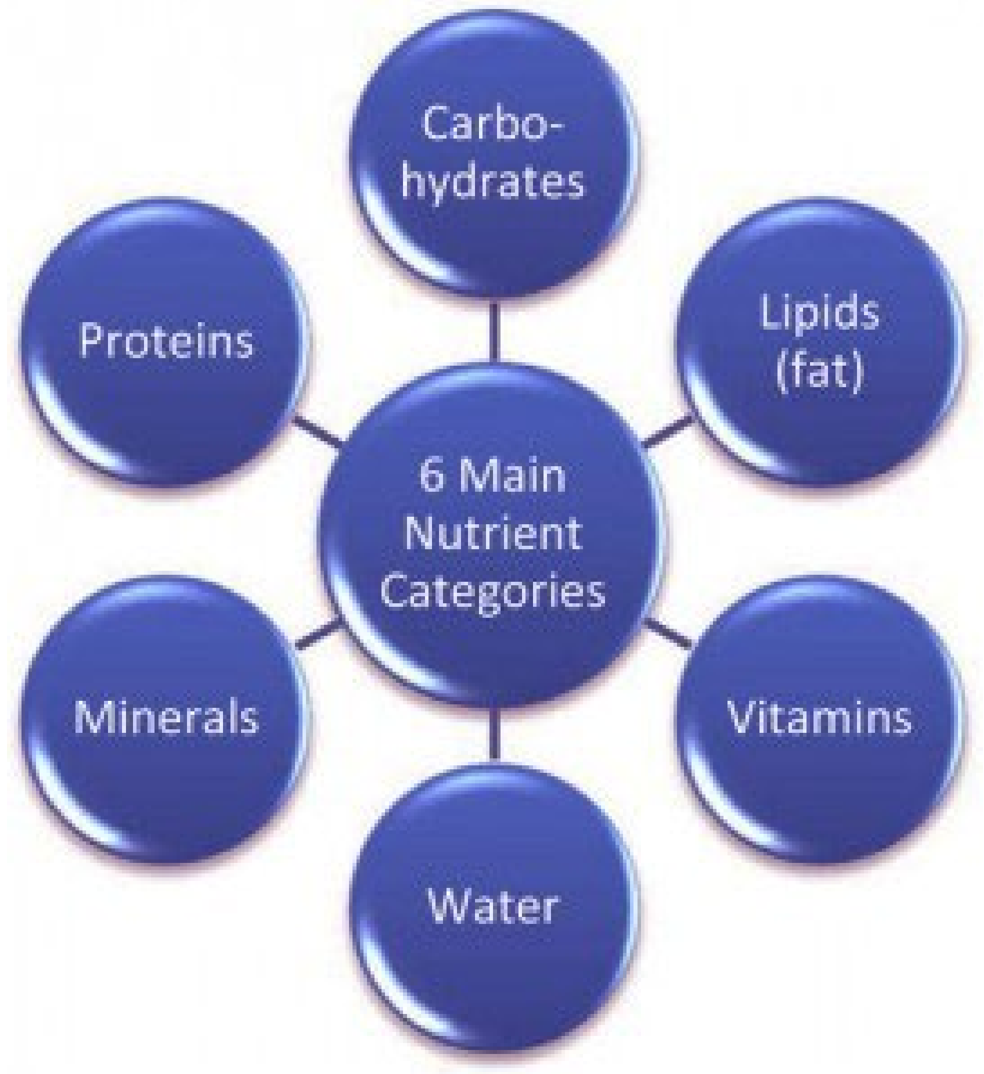
Euglena gracilis

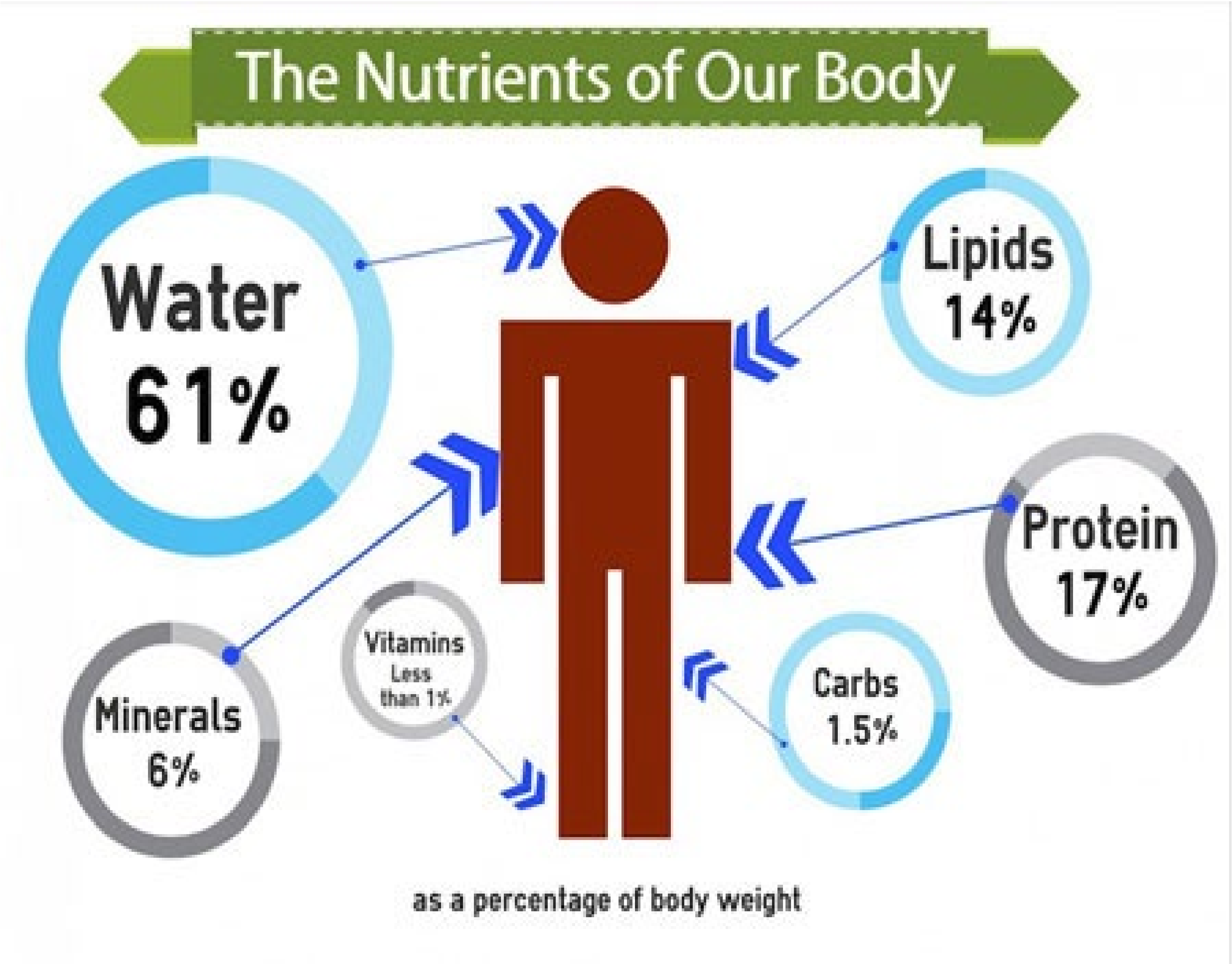
Name 名字	*Euglena gracilis* 裸藻
Classification 分类	Flagellates, Ophthalmopoda 裸藻科，裸藻属
Growth characteristics 生长特性	Photoautotrophic, chemotrophic 光能自养，化能
Distribution 分布	Lakes, ponds, and other freshwater with plenty of light 湖泊、池塘和其他有充足光线的淡水
Function 功能	Food, food additives, skin care products, feed, etc. 食品、食品添加剂、护肤品、饲料、有机肥等
Advantage 优势	It has the dual characteristics of animals and plants, with a large genome and a clear genetic background 具有动物和植物的双重特征，基因组大，遗传背景清晰
Industrial performance 工业性能	Suitable for large-scale breeding 适合大规模养殖

Five edible microalgae combinations 五种可食用微藻组合

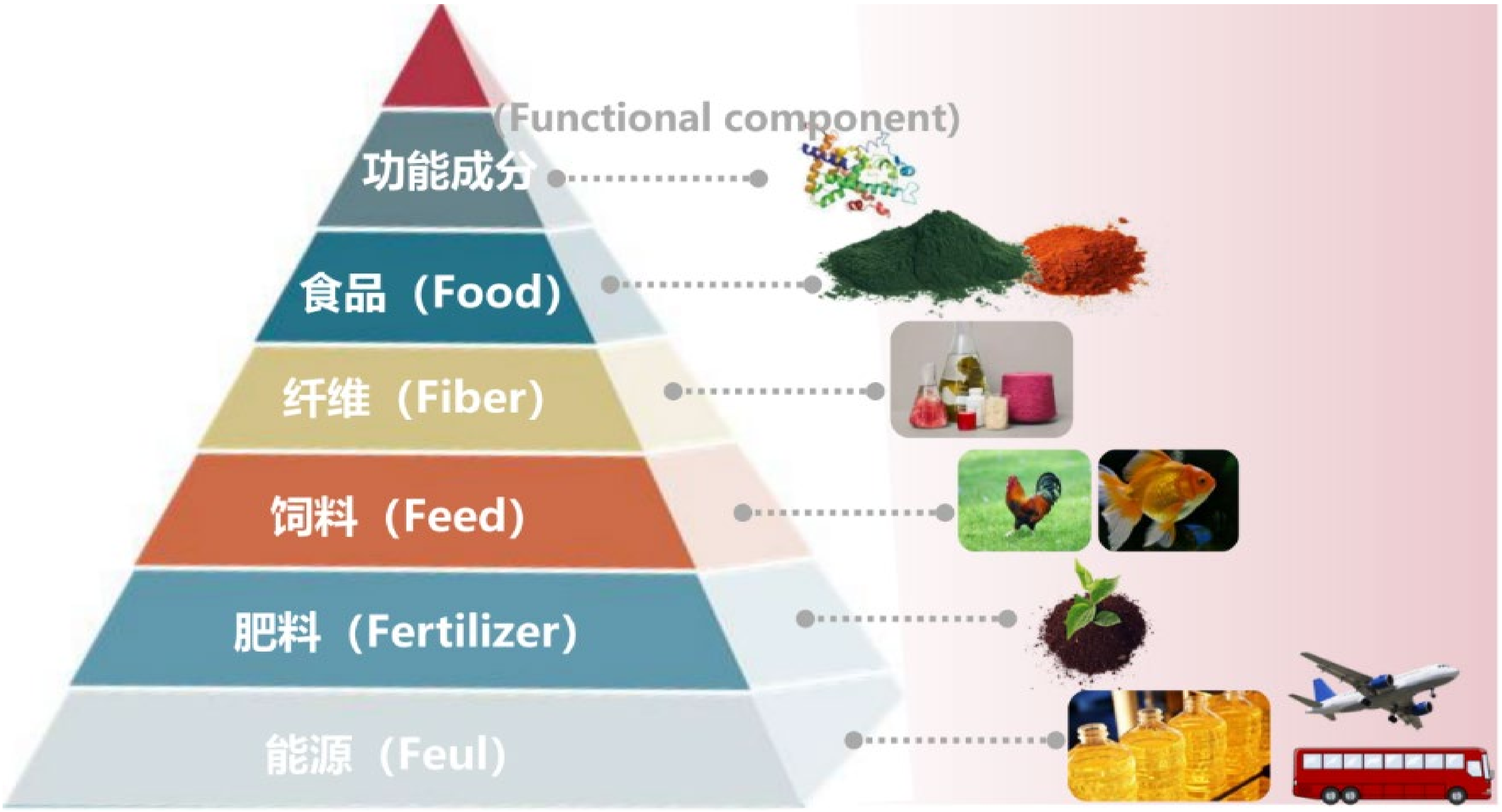


Five edible microalgae combinations meet human needs
五种食用微藻组合满足人类需求

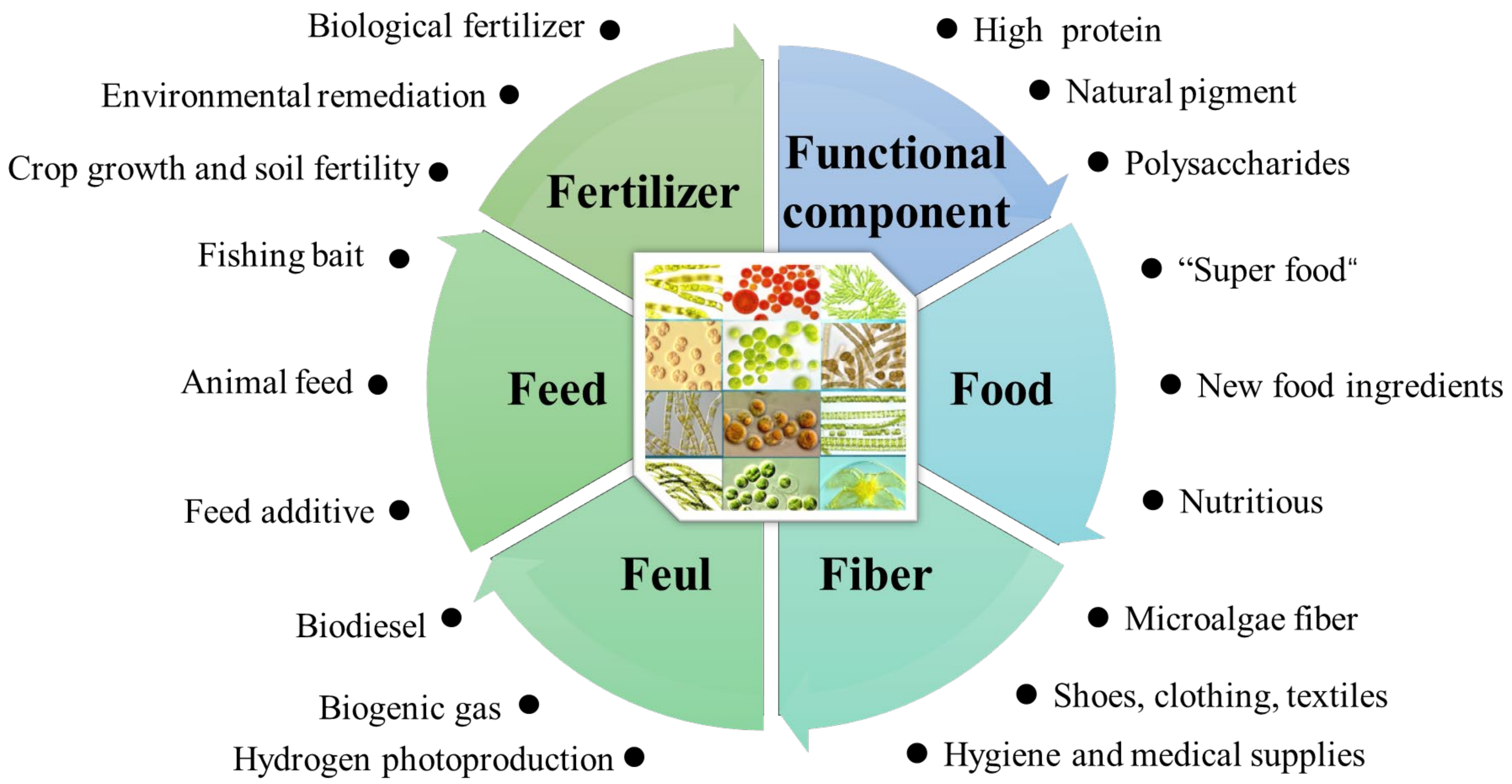




“6F” of functional microalgae 功能微藻的“6F”



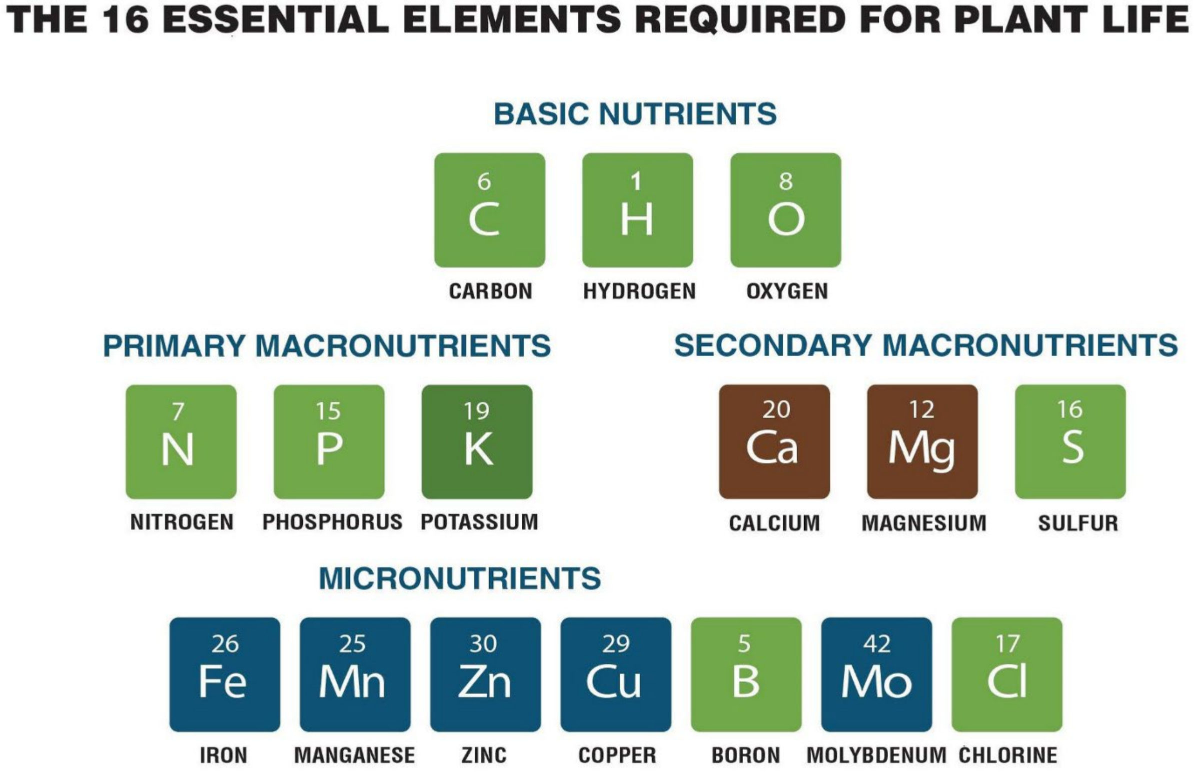
Application of Functional Microalgae in “6F” 功能性微藻在“6F”中的应用



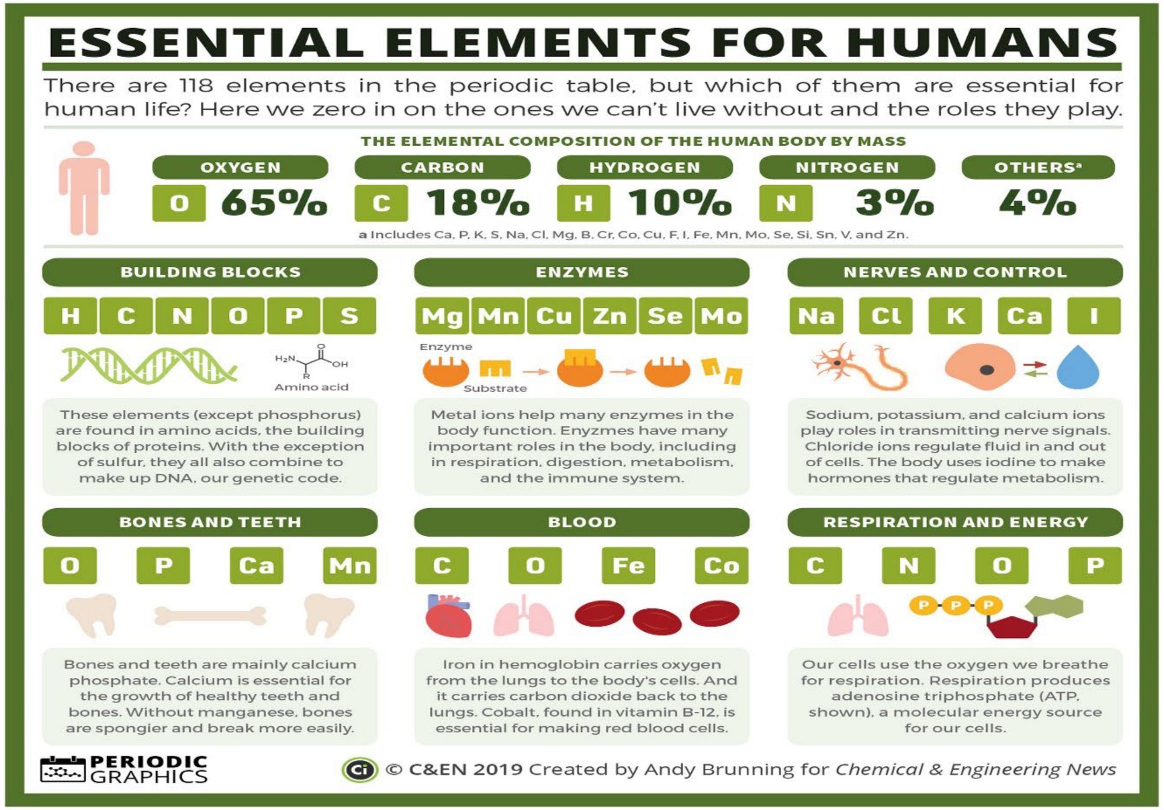
Different essential elements required for plants and humans: Na、Co、I、Se

植物和人类所需的不同基本元素: Na, Co, I, Se

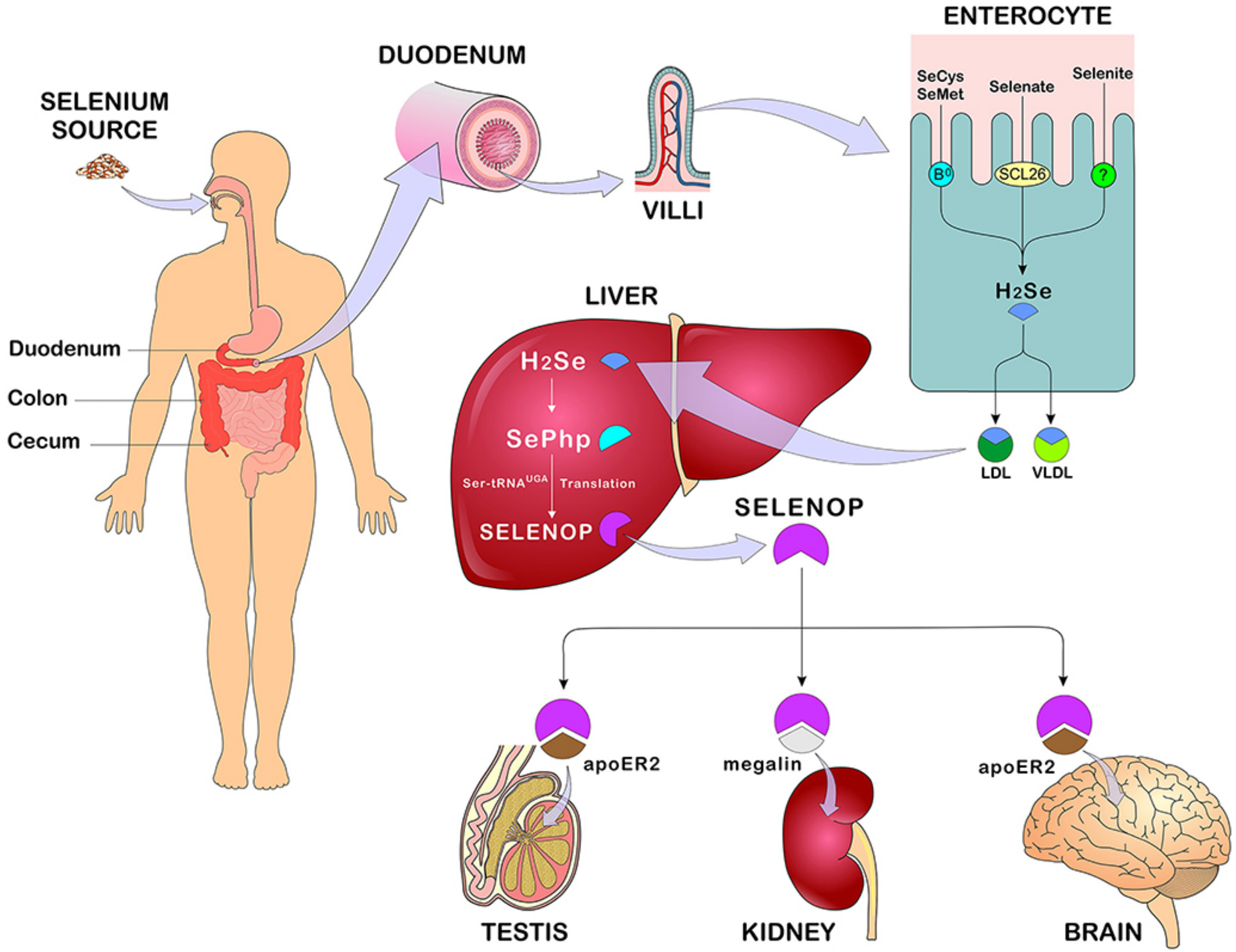
植物生命所需的16种基本元素



人体所需的20种基本元素

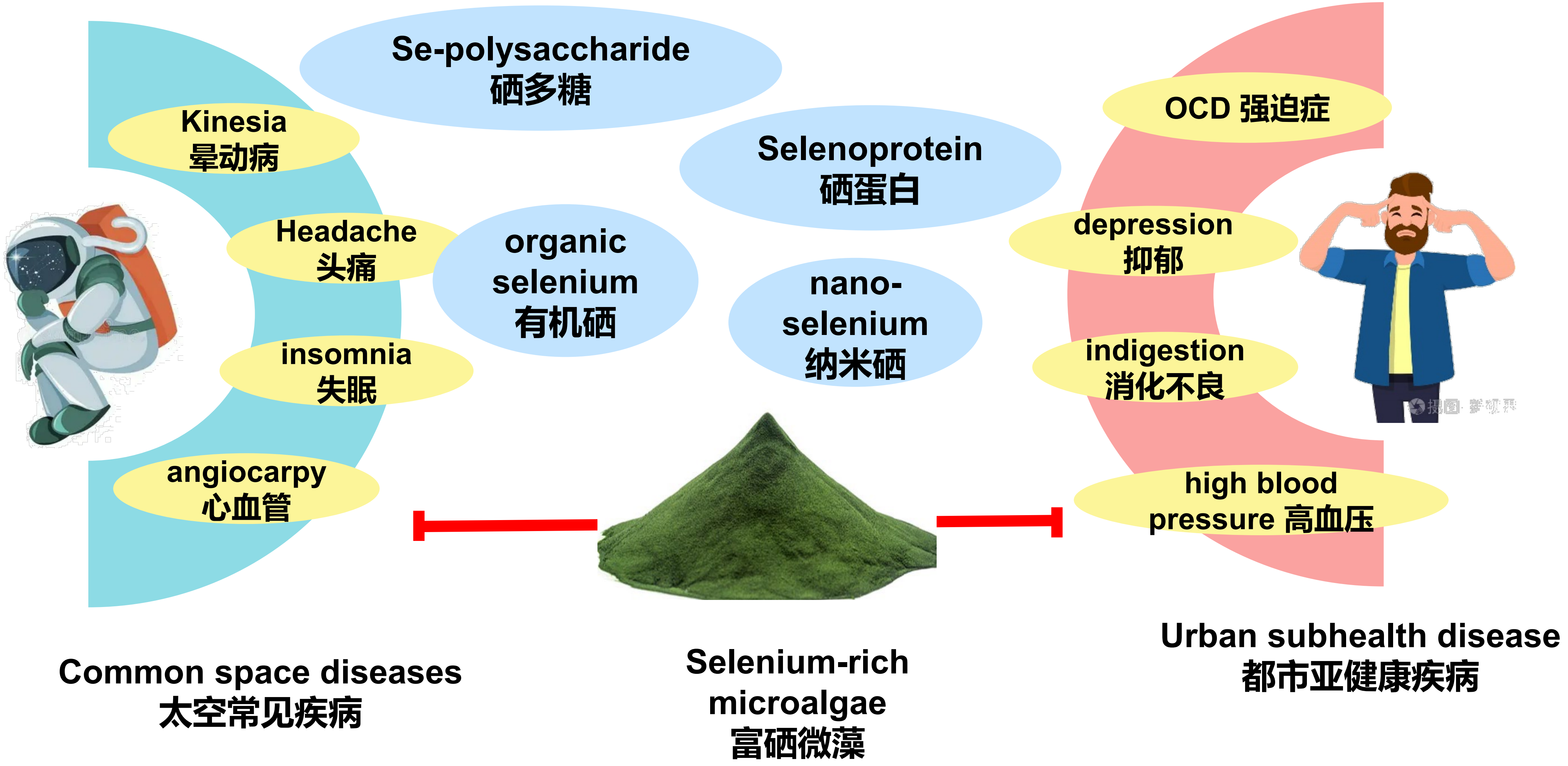


Selenium is the key to functional food 硒是功能性食品的关键

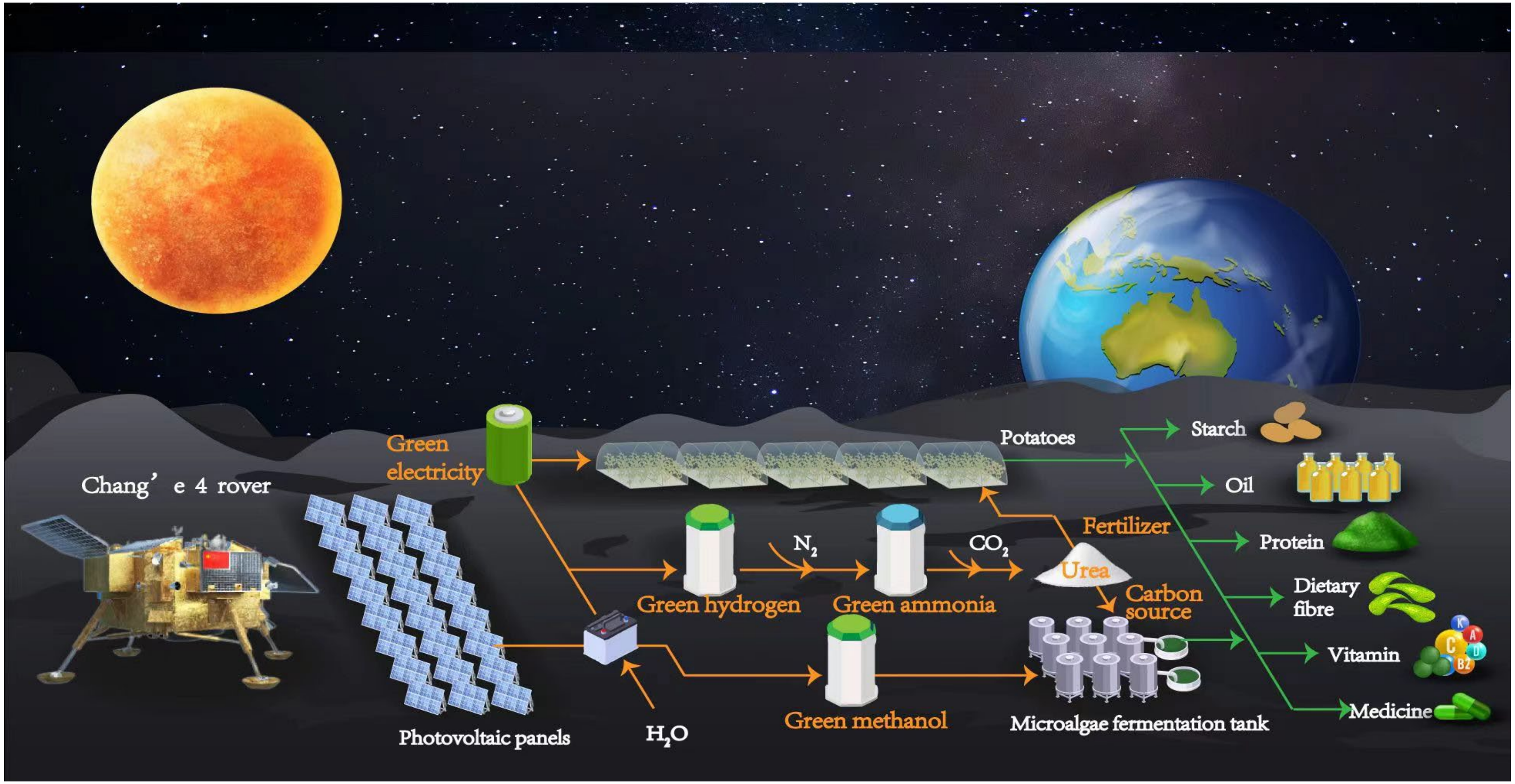


克山病
Keshan disease

Selenium-rich microalgae 富硒微藻



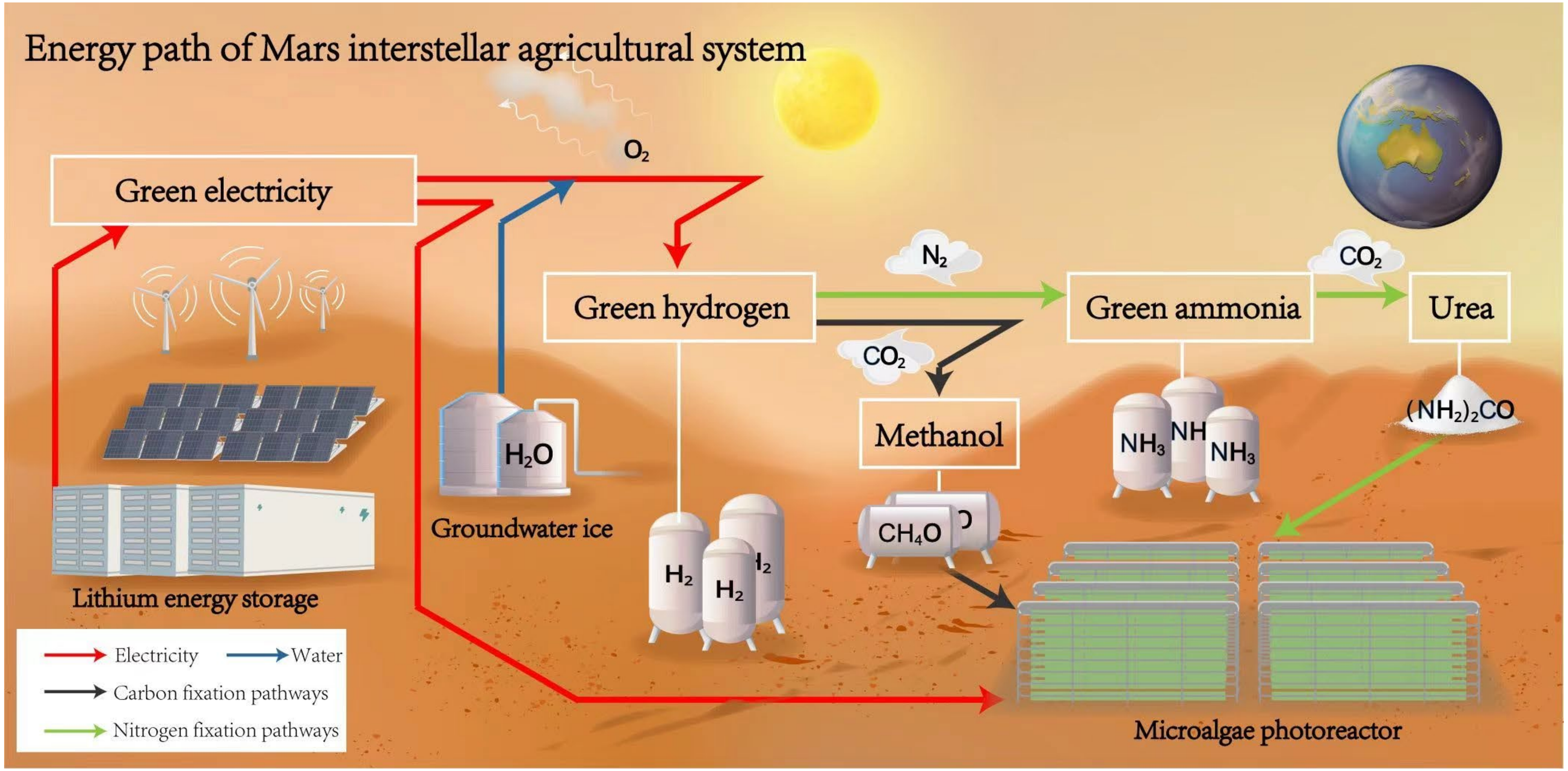
Lunar renewable energy sustainable agriculture system
本团队构建的月球新能源可持续农业系统



Photovoltaic Power+Lunar soil+Green hydrogen+ Green ammonia+Green alcohol+Microalgae energy storage+green product

光伏电能+月壤月岩+绿氢+绿氨+绿醇+微藻储能+绿色产品

Mars renewable energy sustainable agriculture system
本团队构建的火星新能源可持续农业系统



Photovoltaic/Wind energy+In situ resource+Green hydrogen+ Green ammonia+Green alcohol+Microalgae energy storage+green product

光风电能+原位资源+绿氢+绿氨+绿醇+微藻储能+绿色产品

Selenium-rich microalgae—aquaculture industry 富硒微藻—水产养殖业

Selenium-rich microalgae

富硒微藻

Purification of water: Microalgae can degrade pollutants in water, promote the recycling of nitrogen, phosphorus, etc., and is capable of biological nitrogen fixation.

净化水体：微藻能降解水中的污染物，能促进氮、磷等营养物质的循环利用，能生物固碳。

Feed:

- Selenium-rich fish and shrimp
- Microalgae can produce high-quality aquatic products
- Enhance the immunity of fish and shrimp and reduce the use of antibiotics

饲料：

- 富硒鱼虾
- 微藻含丰富生物活性物质，养殖高质量水产品
- 增强鱼虾免疫，减少抗生素使用

04

Progress of Our Research

研究进展

1.We have established a microalgae germplasm resource library

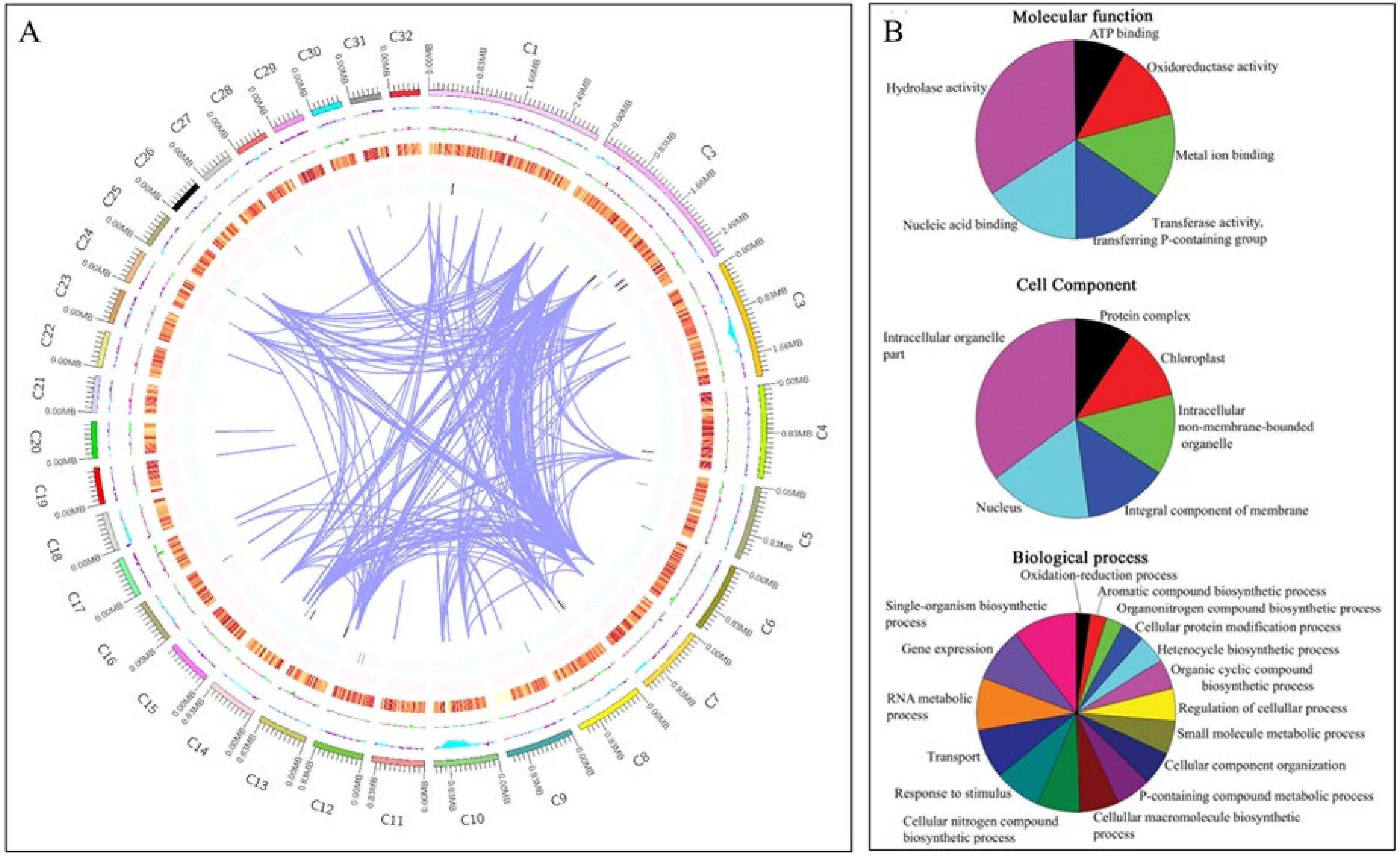
建立了小球藻种质资源库

200 strains of high-quality microalgae species were isolated from all over China.

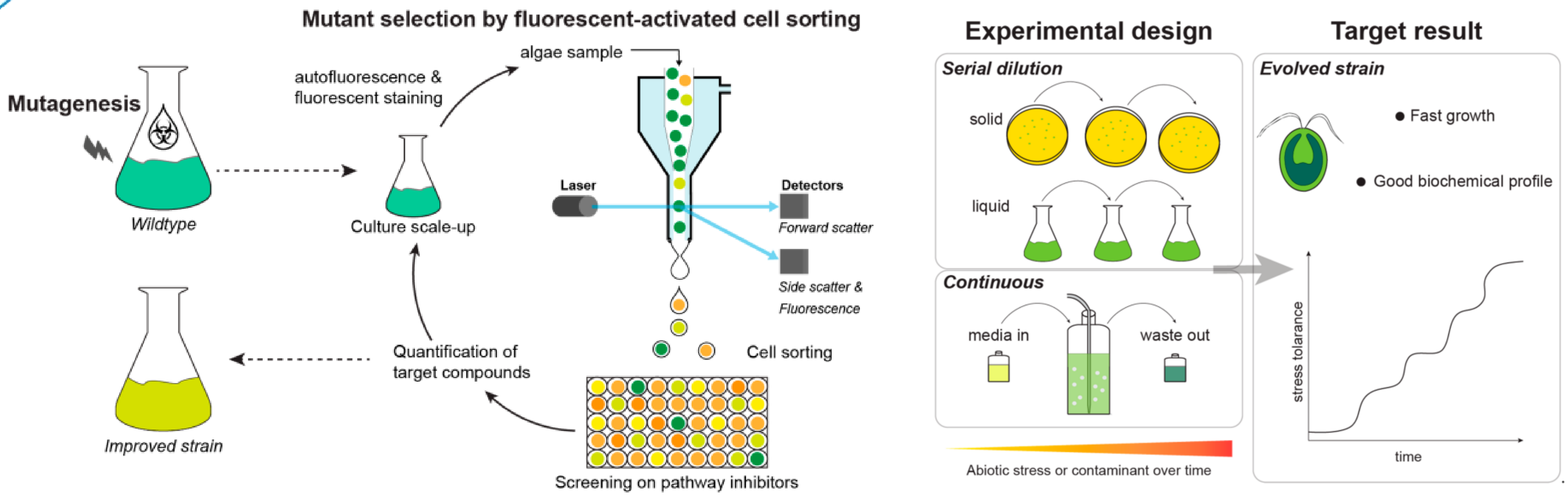
从全国各地分离到200余株优质微藻

2. We assembled the high-quality genome of *Chlorella pyrenoidosa*

我们组装了高质量的小球藻基因组



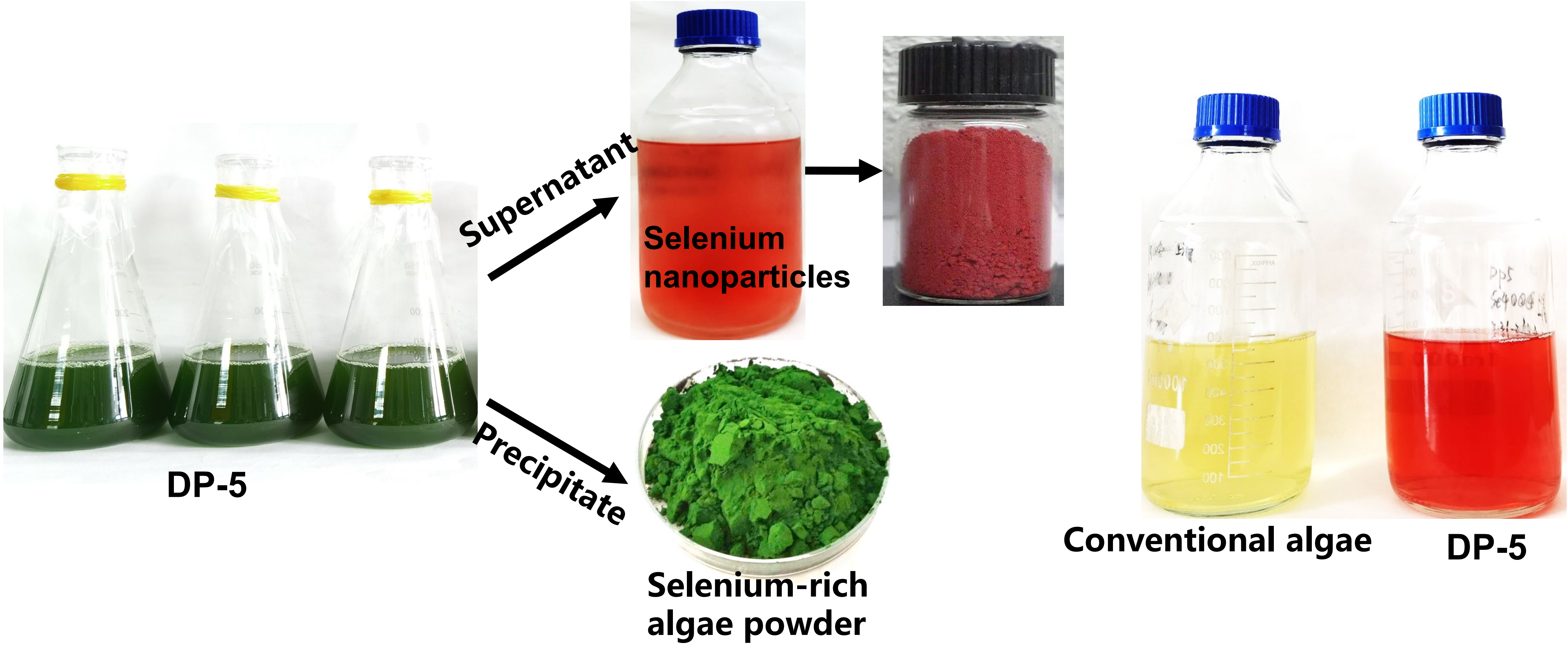
3. We have constructed a technical system for genetic improvement and directional cultivation of Chlorella 构建了小球藻遗传改良和定向培养的技术体系



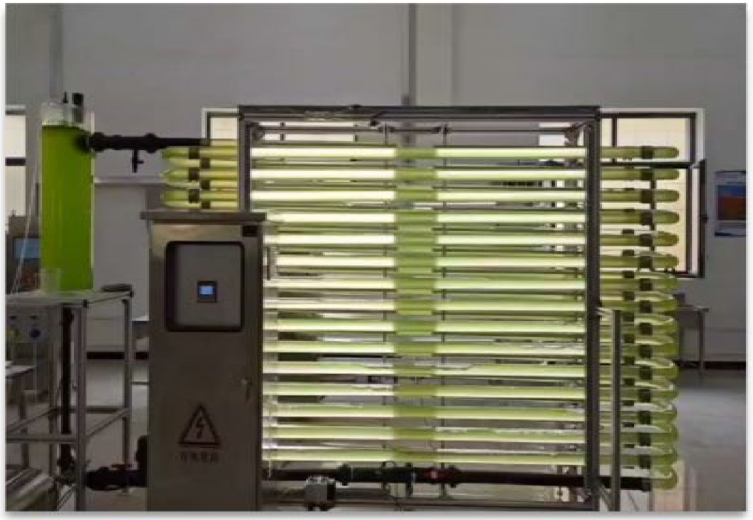
We constructed a strategy for genetic modification and directional cultivation of Chlorella with mutation, adaptive evolution, and high-throughput detection as core technologies.

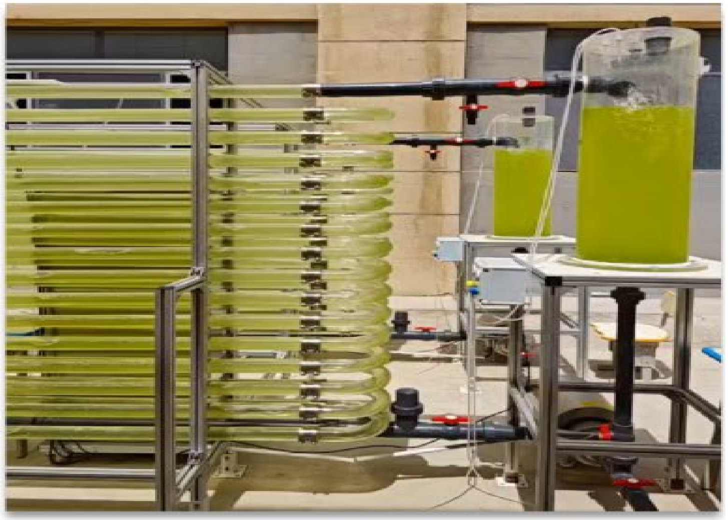
构建了以突变、自适应进化和高通量检测为核心技术的小球藻基因改造和定向培养策略。

4. We generated the selenium-rich Chlorella strains 培育了富硒小球藻菌株

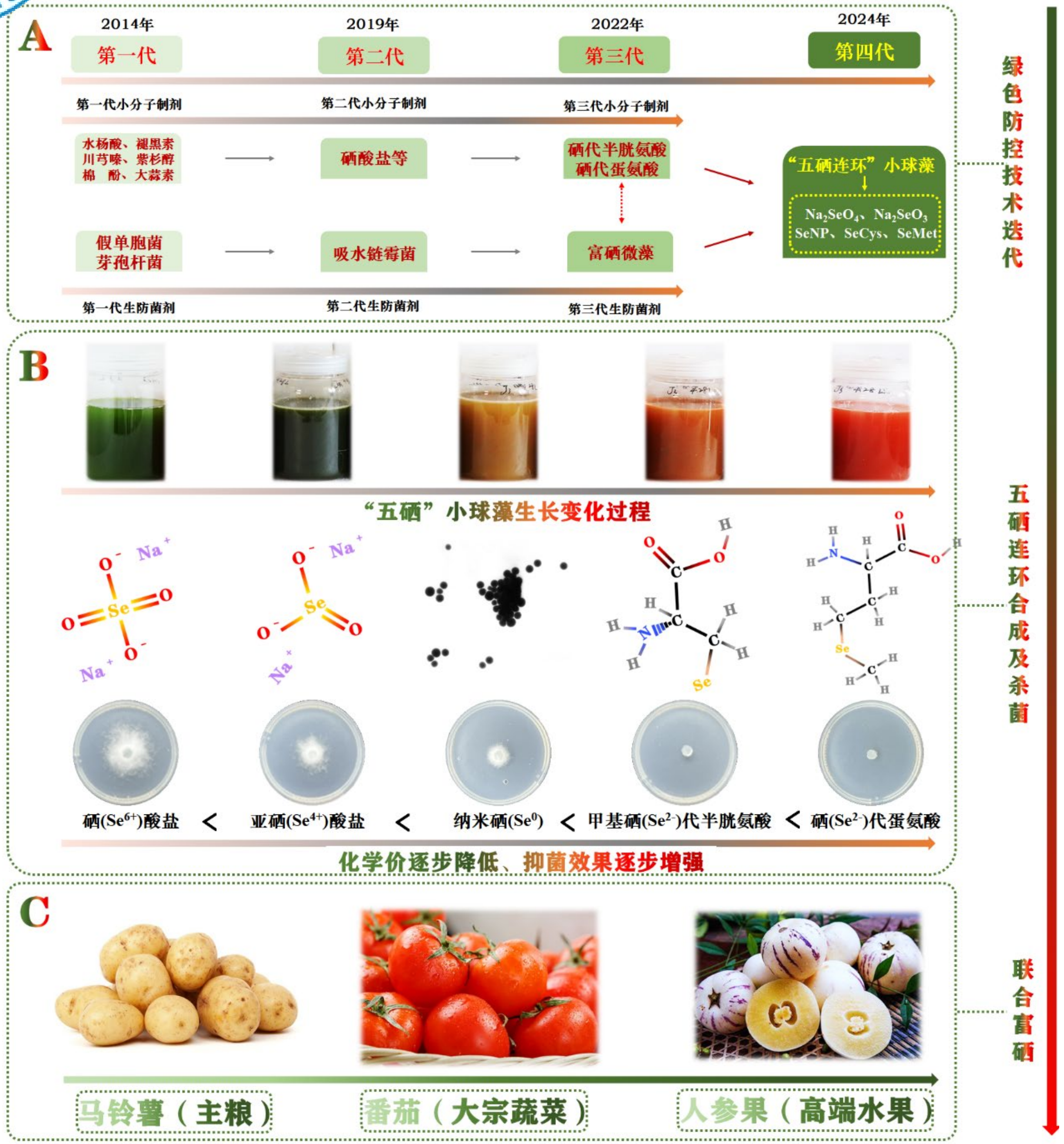


We have established an efficient production technology system for Chlorella 我们已经建立了高效的生产技术小球藻系统



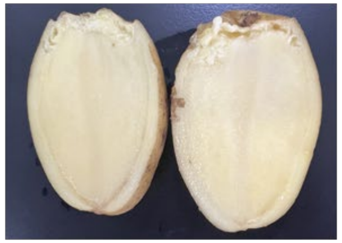


5. We established late blight control system of selenium-rich Chlorella
建立了富硒小球藻的晚疫病防控体系

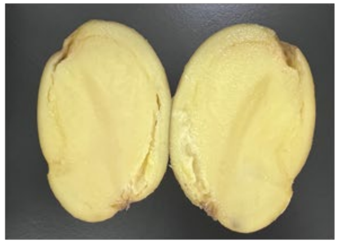


马铃薯长出菌丝、腐烂发臭


CK超纯水


棉酚30mg/L


棉酚50mg/L


棉酚80mg/L

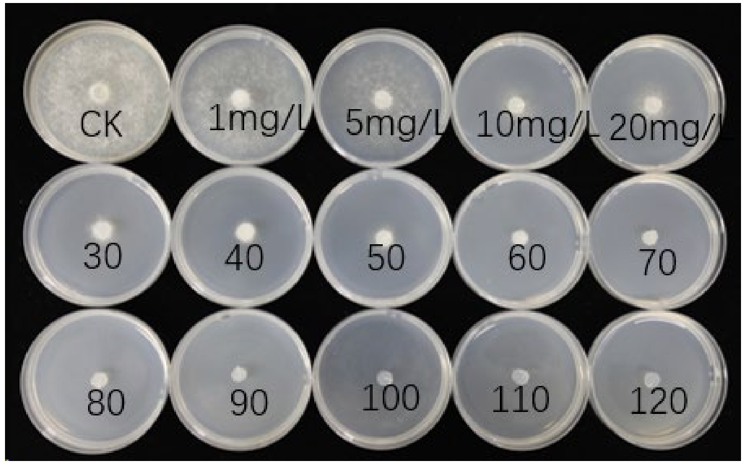
依然保持新鲜马铃薯原状


亚硒酸钠30mg/L

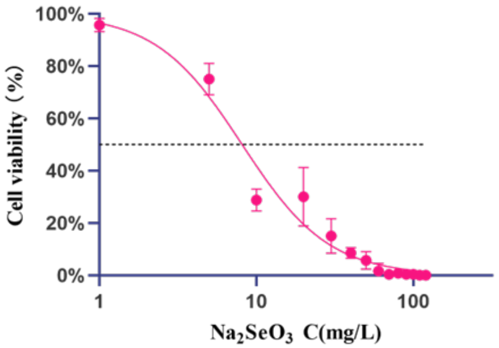

亚硒酸钠50mg/L


亚硒酸钠80mg/L

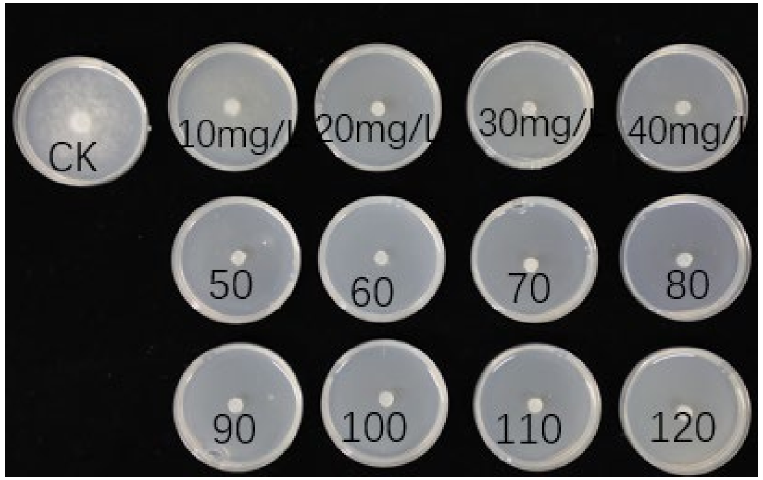
Effect of different selenium on mycelial growth of pathogenic Phytophthora infestans



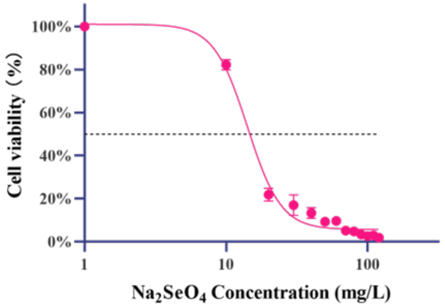
Na_2SeO_3



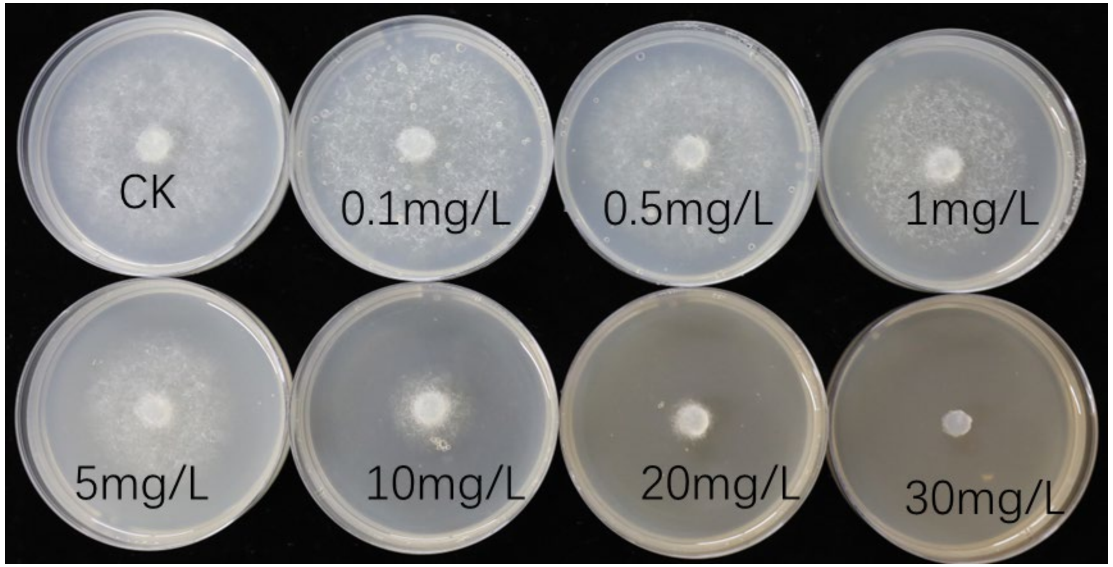
IC50=8.148mg/L



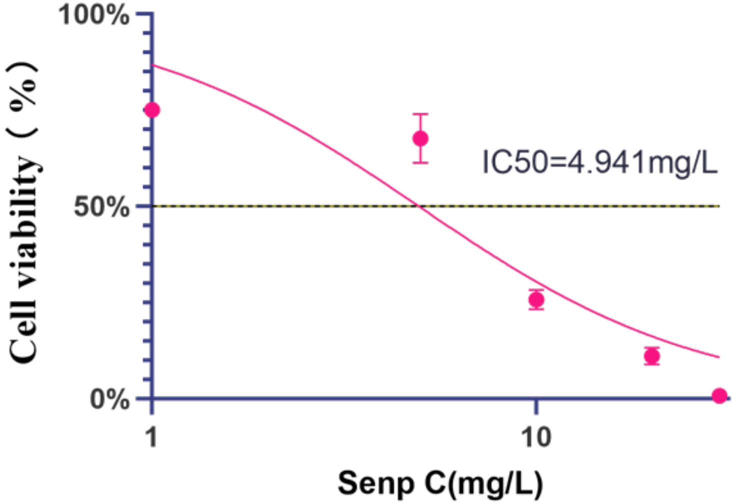
Na_2SeO_4



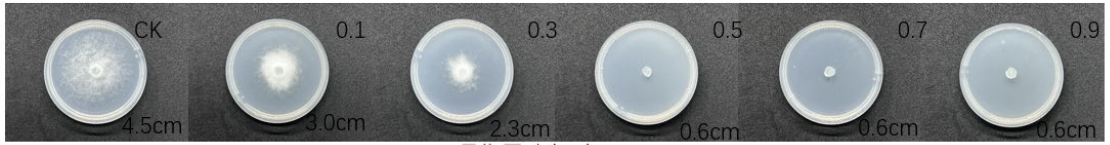
IC50=15.29mg/L



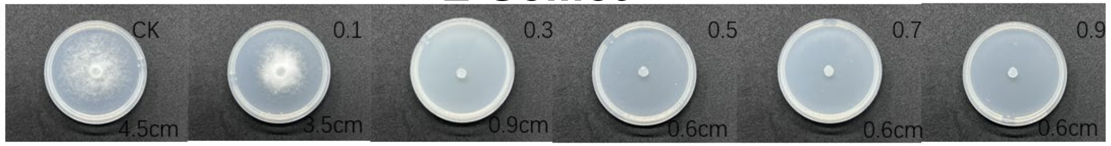
SeNp



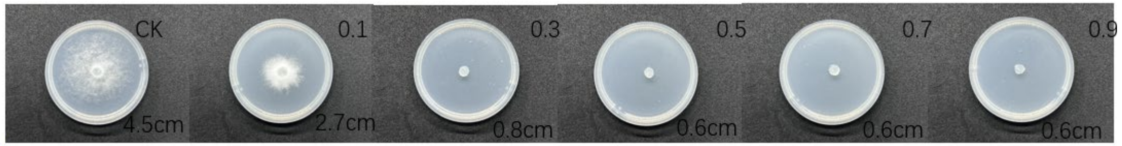
Effect of different selenium on mycelial growth of pathogenic Phytophthora infestans



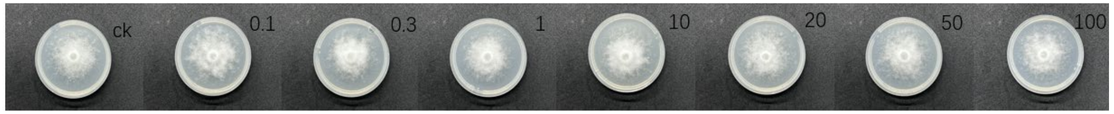
L-SeMet



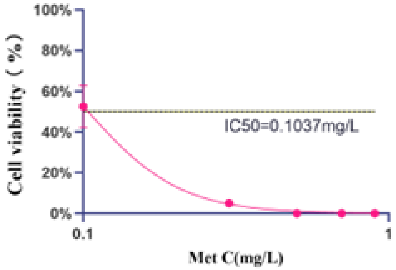
DL-SeMet



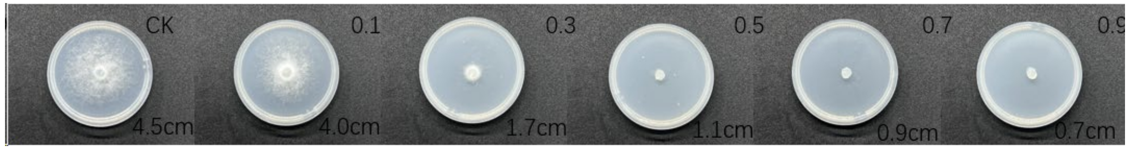
L-SeMet



Met



T30-4

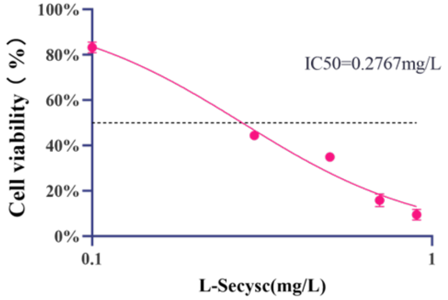


L-MeSeCys

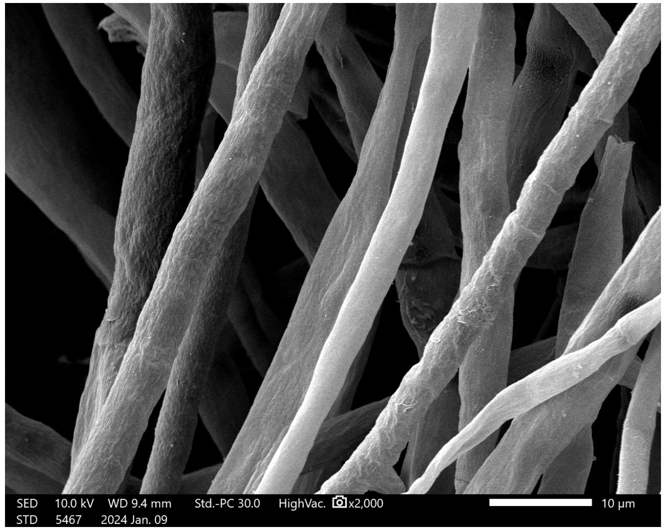
L-MeSeCys

SeCys

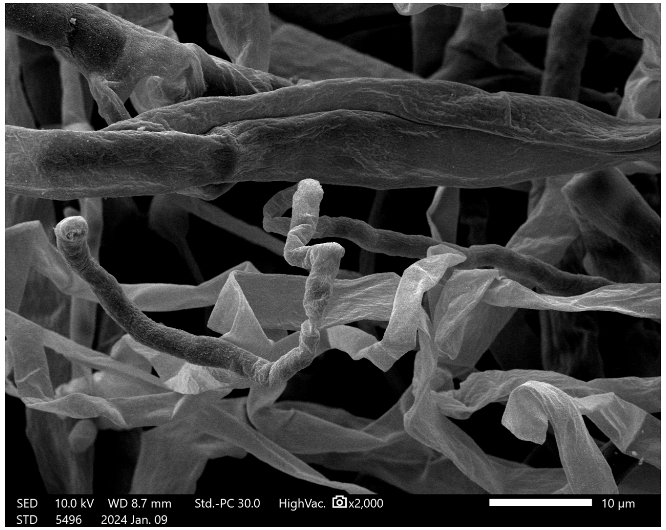
Cys



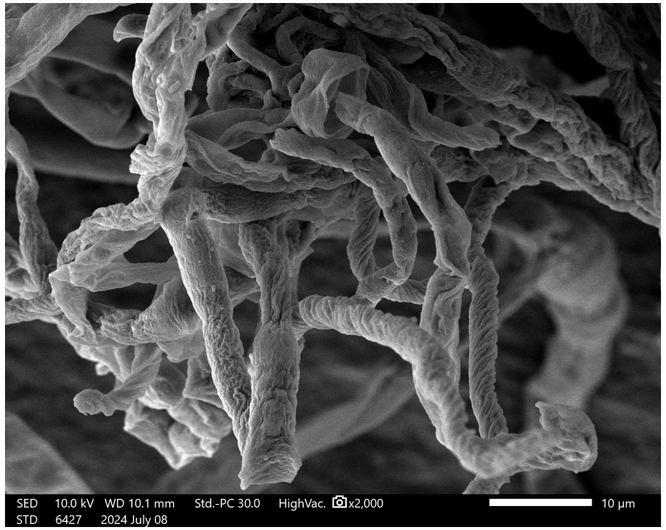
Characterization of Fungal Hyphae Morphology by SEM with Different Selenium Sources



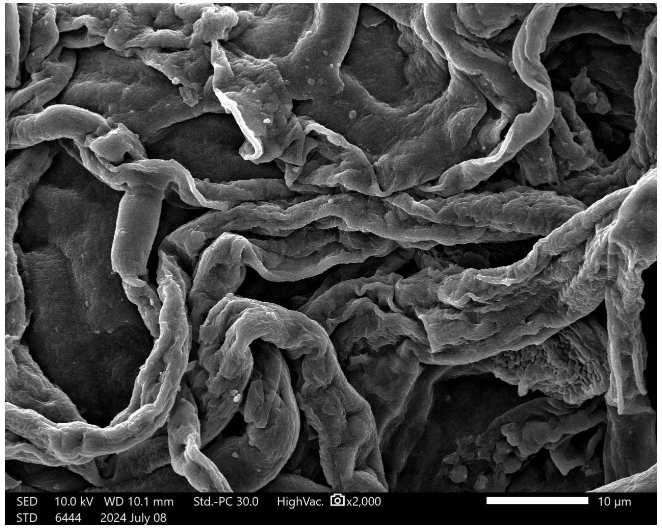
CK



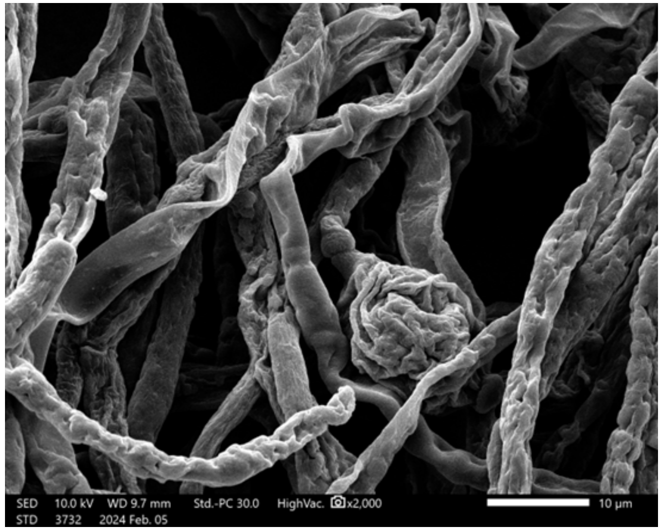
Na_2SeO_3 90mg/L



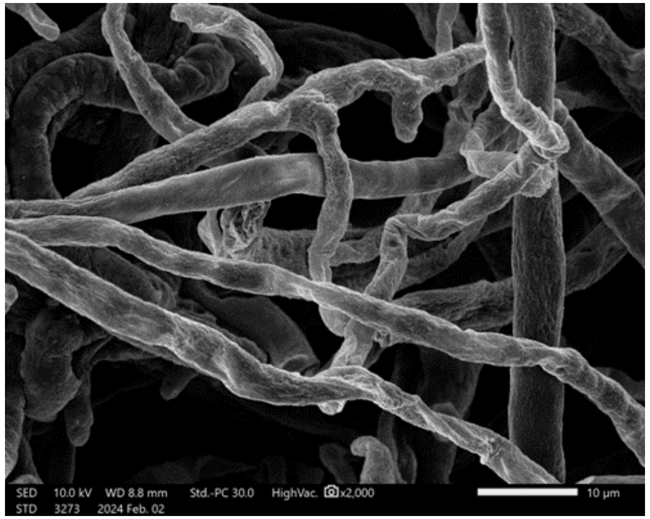
Na_2SeO_4 20mg/L



SeNp 20mg/L

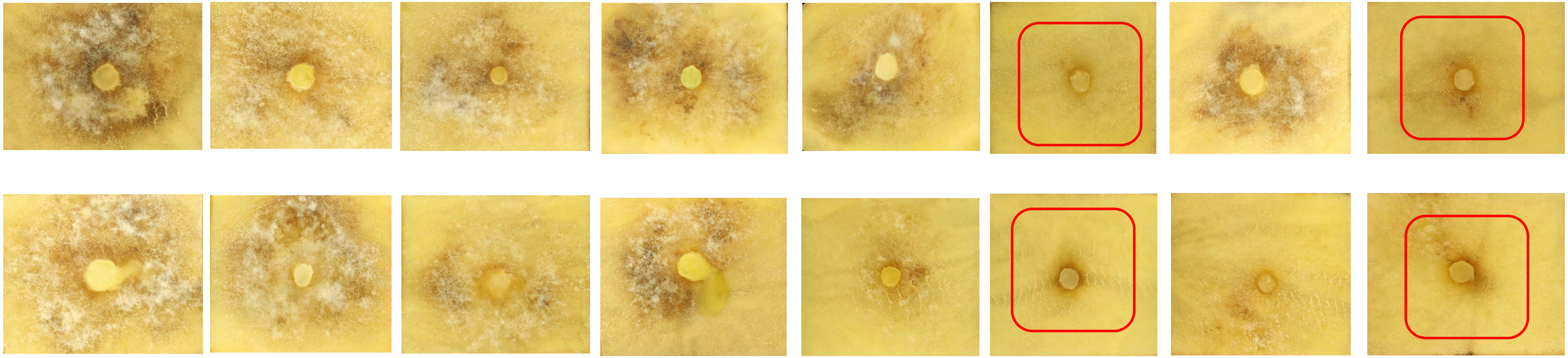


L-Se-Met 0.1mg/L



L-MeSeCys 0.7mg/L

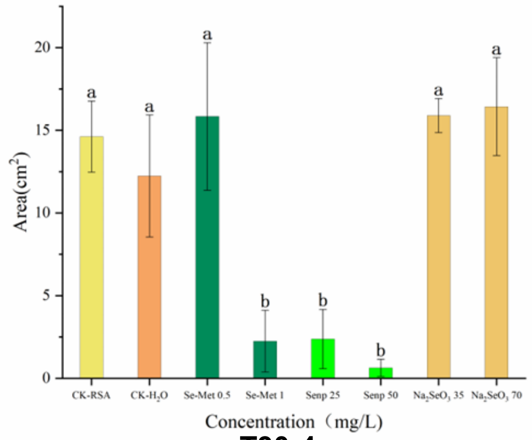
Tuber experiments revealed the effects of different selenium sources on the prevention and control of late blight



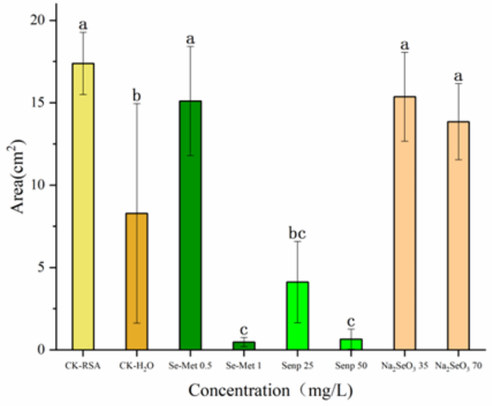
T30-4

88069

CK-RSA | CK-H_2O | Na_2SeO_3 35mg/L | Na_2SeO_3 70mg/L | Se-Met 0.5mg/L | Se-Met 1mg/L | Senp 25mg/L | Senp 50mg/L



T30-4

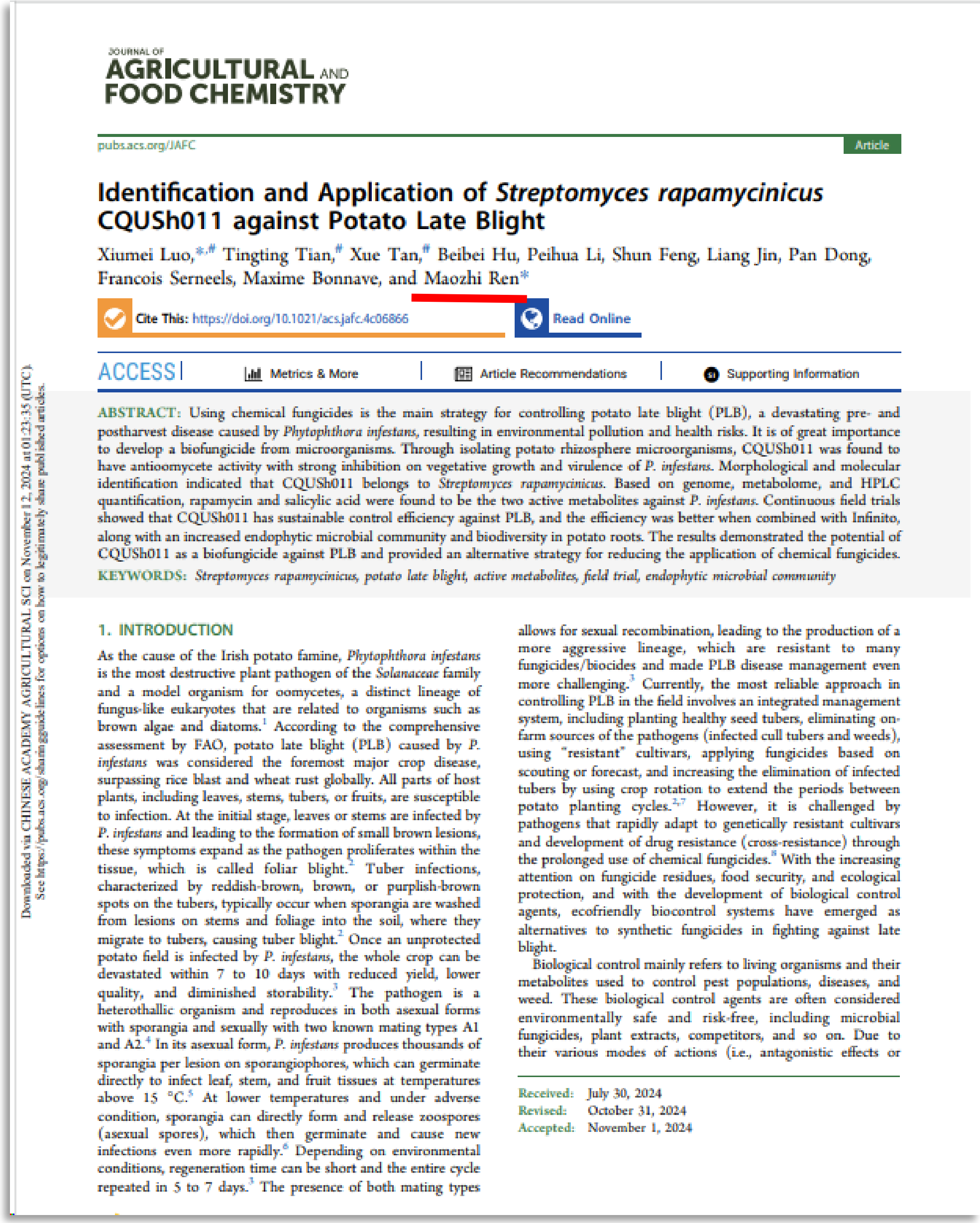


88069

1、三种硒源对致病疫霉均有抑制作用。
2、硒代甲硫氨酸和纳米硒抑菌效果较好。
3、硒代甲硫氨酸在浓度为1mg/L时完全抑制，纳米硒在50mg/L时候也完全抑制。

Pot experiments revealed the effects of different selenium sources on potato growth and the prevention and control of late blight

Identiffcation and Application of Streptomyces rapamycinicus CQUSh011 against PLB



JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

pubs.acs.org/JAFC Article

Identification and Application of *Streptomyces rapamycinicus* CQUSh011 against Potato Late Blight

Xiumei Luo,*,# Tingting Tian,# Xue Tan,# Beibei Hu, Peihua Li, Shun Feng, Liang Jin, Pan Dong, Francois Serneels, Maxime Bonnave, and Maozhi Ren*

Cite This: https://doi.org/10.1021/acs.jafc.4c06866 Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information

ABSTRACT: Using chemical fungicides is the main strategy for controlling potato late blight (PLB), a devastating pre- and postharvest disease caused by *Phytophthora infestans*, resulting in environmental pollution and health risks. It is of great importance to develop a biofungicide from microorganisms. Through isolating potato rhizosphere microorganisms, CQUSh011 was found to have antioomycete activity with strong inhibition on vegetative growth and virulence of *P. infestans*. Morphological and molecular identification indicated that CQUSh011 belongs to *Streptomyces rapamycinicus*. Based on genome, metabolome, and HPLC quantification, rapamycin and salicylic acid were found to be the two active metabolites against *P. infestans*. Continuous field trials showed that CQUSh011 has sustainable control efficiency against PLB, and the efficiency was better when combined with Infinito, along with an increased endophytic microbial community and biodiversity in potato roots. The results demonstrated the potential of CQUSh011 as a biofungicide against PLB and provided an alternative strategy for reducing the application of chemical fungicides.

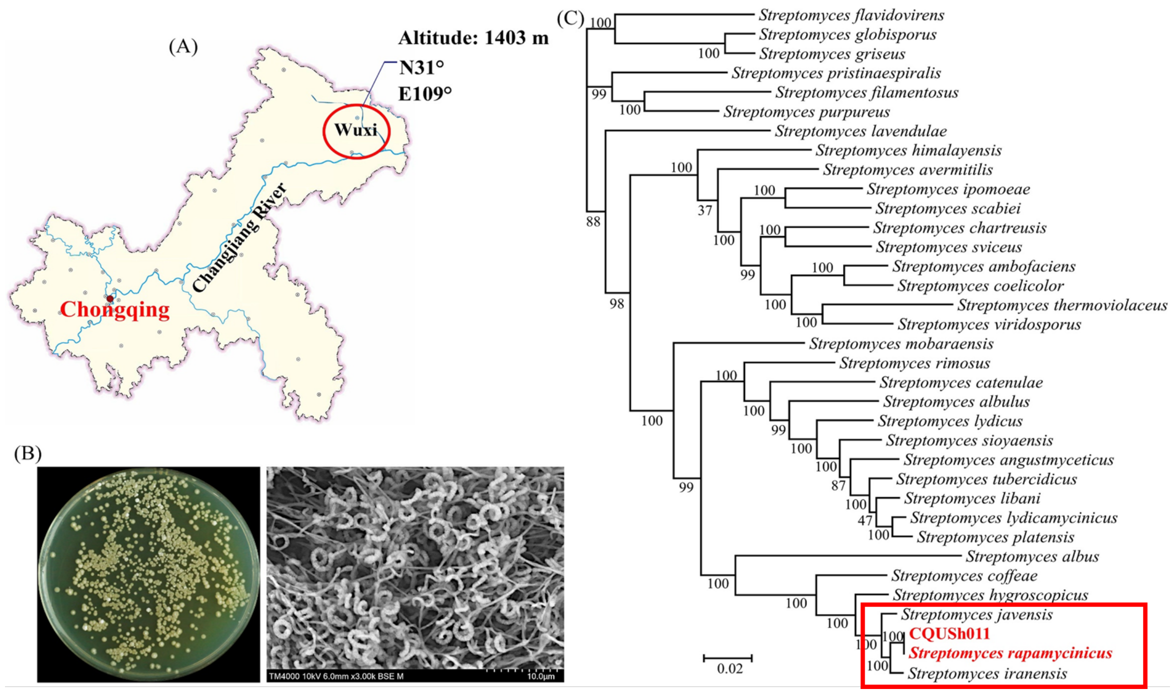
KEYWORDS: *Streptomyces rapamycinicus, potato late blight, active metabolites, field trial, endophytic microbial community*

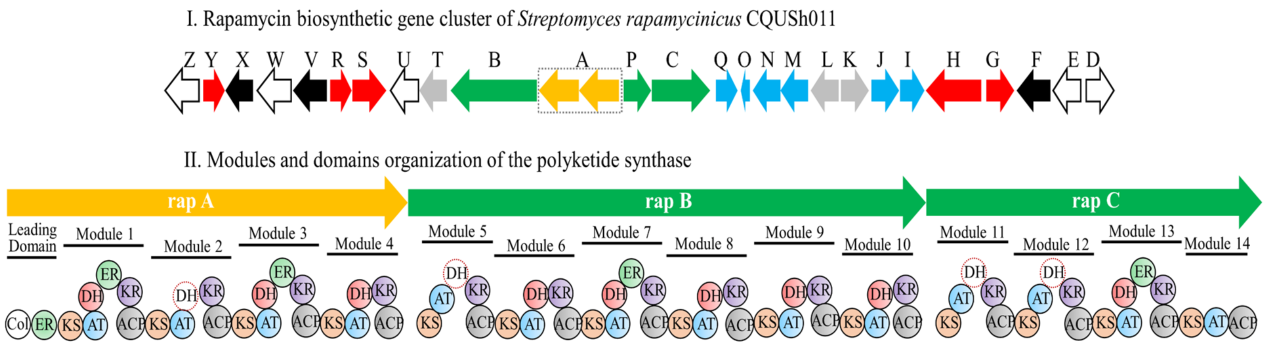
1. INTRODUCTION

As the cause of the Irish potato famine, *Phytophthora infestans* is the most destructive plant pathogen of the *Solanaceae* family and a model organism for oomycetes, a distinct lineage of fungus-like eukaryotes that are related to organisms such as brown algae and diatoms.[1] According to the comprehensive assessment by FAO, potato late blight (PLB) caused by *P. infestans* was considered the foremost major crop disease, surpassing rice blast and wheat rust globally. All parts of host plants, including leaves, stems, tubers, or fruits, are susceptible to infection. At the initial stage, leaves or stems are infected by *P. infestans* and leading to the formation of small brown lesions, these symptoms expand as the pathogen proliferates within the tissue, which is called foliar blight.[2] Tuber infections, characterized by reddish-brown, brown, or purplish-brown spots on the tubers, typically occur when sporangia are washed from lesions on stems and foliage into the soil, where they migrate to tubers, causing tuber blight.[2] Once an unprotected potato field is infected by *P. infestans*, the whole crop can be devastated within 7 to 10 days with reduced yield, lower quality, and diminished storability.[3] The pathogen is a heterothallic organism and reproduces in both asexual forms with sporangia and sexually with two known mating types A1 and A2.[4] In its asexual form, *P. infestans* produces thousands of sporangia per lesion on sporangiophores, which can germinate directly to infect leaf, stem, and fruit tissues at temperatures above 15 °C.[5] At lower temperatures and under adverse condition, sporangia can directly form and release zoospores (asexual spores), which then germinate and cause new infections even more rapidly.[6] Depending on environmental conditions, regeneration time can be short and the entire cycle repeated in 5 to 7 days.[3] The presence of both mating types allows for sexual recombination, leading to the production of a more aggressive lineage, which are resistant to many fungicides/biocides and made PLB disease management even more challenging.[3] Currently, the most reliable approach in controlling PLB in the field involves an integrated management system, including planting healthy seed tubers, eliminating on-farm sources of the pathogens (infected cull tubers and weeds), using "resistant" cultivars, applying fungicides based on scouting or forecast, and increasing the elimination of infected tubers by using crop rotation to extend the periods between potato planting cycles.[2,7] However, it is challenged by pathogens that rapidly adapt to genetically resistant cultivars and development of drug resistance (cross-resistance) through the prolonged use of chemical fungicides.[8] With the increasing attention on fungicide residues, food security, and ecological protection, and with the development of biological control agents, ecofriendly biocontrol systems have emerged as alternatives to synthetic fungicides in fighting against late blight.

Biological control mainly refers to living organisms and their metabolites used to control pest populations, diseases, and weed. These biological control agents are often considered environmentally safe and risk-free, including microbial fungicides, plant extracts, competitors, and so on. Due to their various modes of actions (i.e., antagonistic effects or

Received: July 30, 2024
Revised: October 31, 2024
Accepted: November 1, 2024





Luo et al. *Journal of Agricultural and Food Chemistry* 2024 72 (46), 25661-25674

Anti-Oomycete Effect and Mechanism of Salicylic Acid on Phytophthora infestans

Journal of Agricultural and Food Chemistry > Vol 71/Issue 51 > Article
Subscribed
AGRICULTURAL AND ENVIRONMENTAL CHEMISTRY | December 15, 2023

Cite Share Jump to Expand

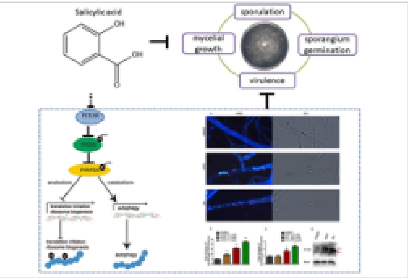
Anti-Oomycete Effect and Mechanism of Salicylic Acid on *Phytophthora infestans*

Shumin Zhang, Airong Huang, Xiulan Lv, Jiaomei Zhang, Meiquan Zhang, Yang Chen, Liting Yang, Hanyan Wang, Dongmei Guo, Xiumei Luo, Maozhi Ren*, and Pan Dong*

Open PDF | Supporting Information (1)

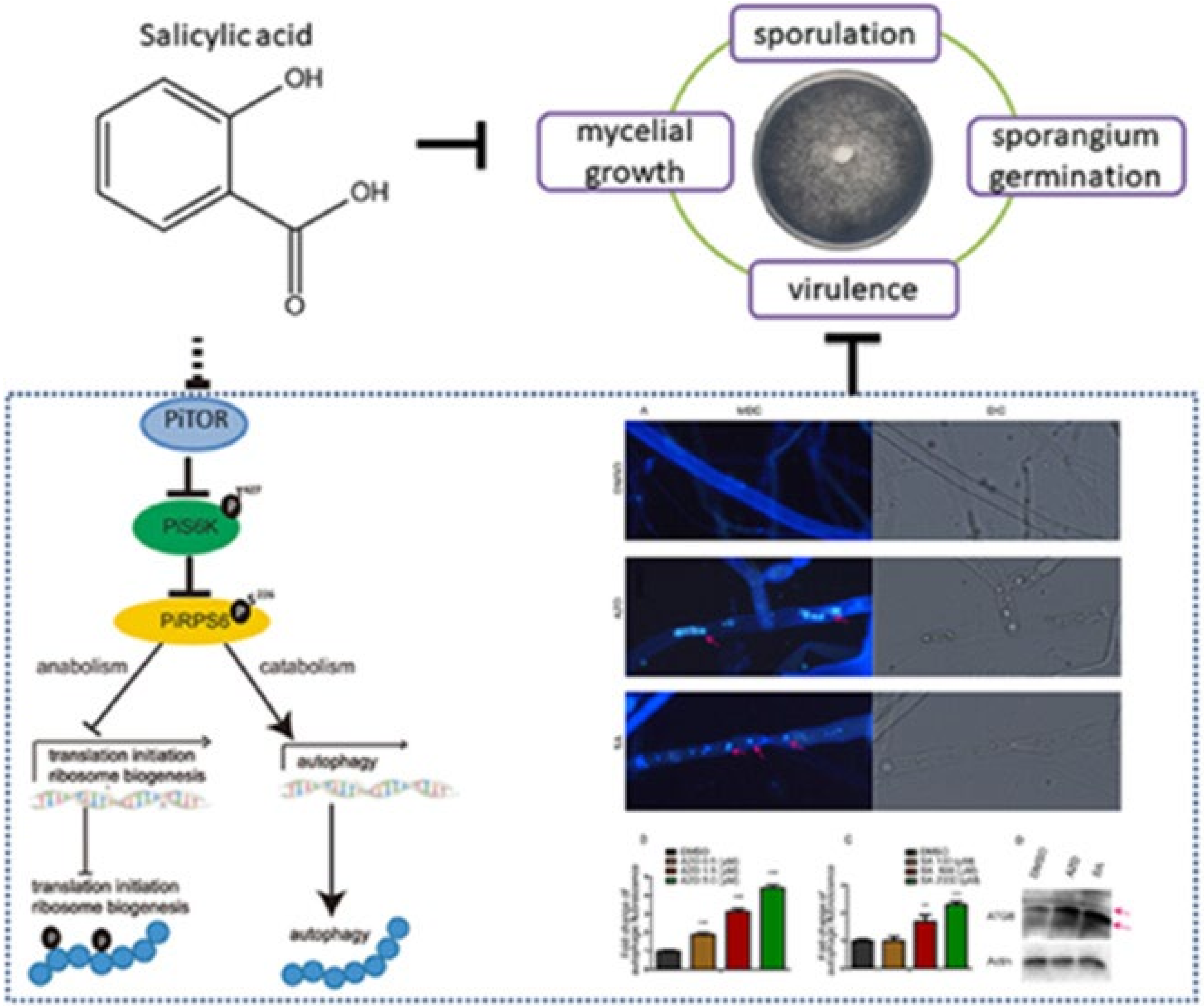
Abstract

Pathogenic oomycetes infect a wide variety of organisms, including plants, animals, and humans, and cause massive economic losses in global agriculture, aquaculture, and human health. Salicylic acid (SA), an endogenous phytohormone, is regarded as an inducer of plant immunity. Here, the potato late blight pathogen *Phytophthora infestans* was used as a model system to uncover the inhibitory mechanisms of SA on pathogenic oomycetes. In this research, SA significantly inhibited the mycelial growth, sporulation, sporangium germination, and virulence of *P. infestans*. Inhibition was closely related to enhanced autophagy, suppression of translation initiation, and ribosomal biogenesis in *P. infestans*, as shown by multiomics analysis (transcriptomics, proteomics, and phosphorylated proteomics). Monodansylcadaverine (MDC) staining and Western blotting analysis showed that SA promoted autophagy in *P. infestans* by probably targeting the TOR signaling pathway. These observations suggest that SA has the potential to control late blight caused by *P. infestans*.



Subjects
Autophagy | Genetics | Germination | Peptides And Proteins | Plant Derived Food

Keywords
Oomycete | Potato Late Blight | Plant Hormone | Bio-Oomyceticide | Multiomics



Zhang et al. *Journal of Agricultural and Food Chemistry* 2023 71 (51), 20613-20624

The TOR signalling pathway in fungal phytopathogens: A target for plant disease control

Molecular Plant Pathology
Open Access
BSPP British Society for Plant Pathology

REVIEW | Open Access

The TOR signalling pathway in fungal phytopathogens: A target for plant disease control

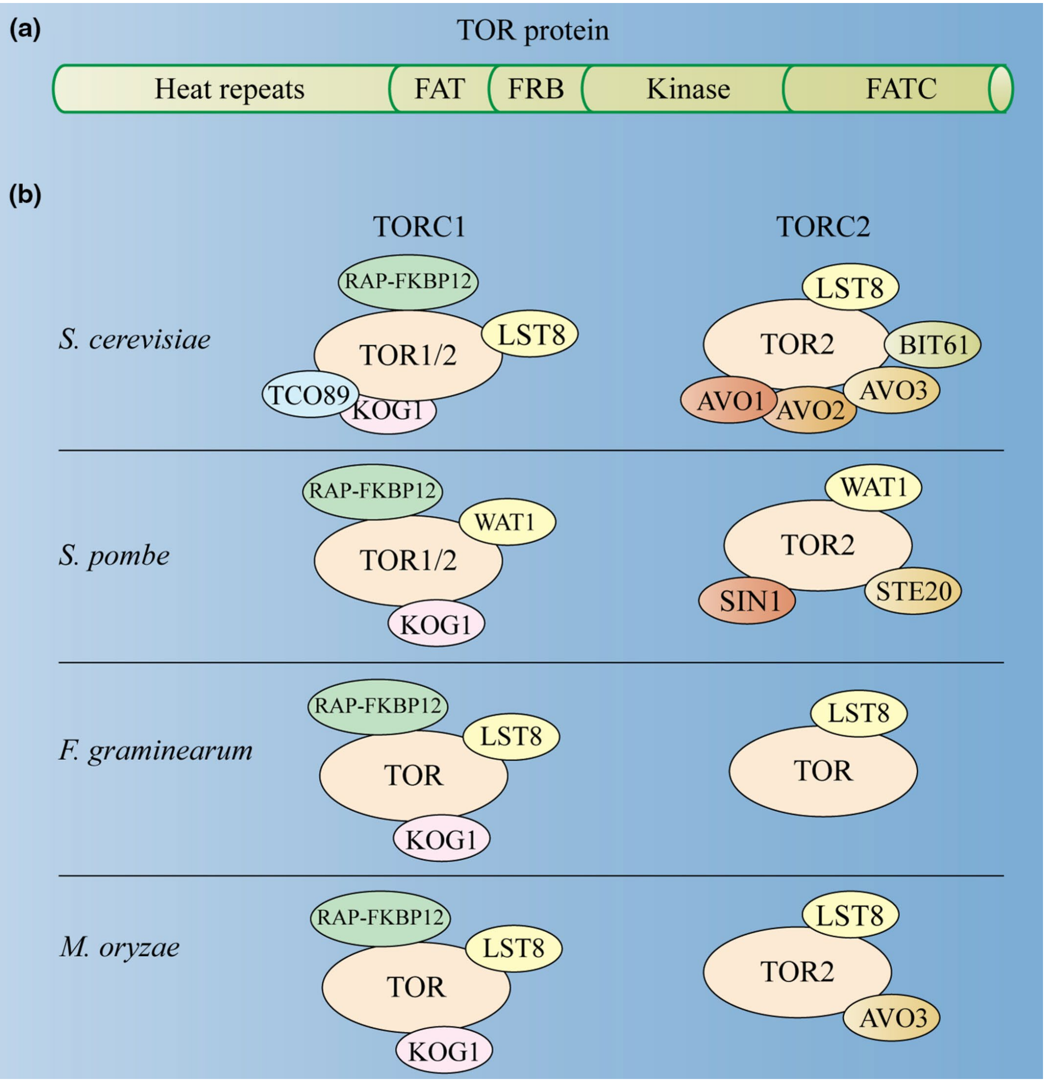
Yun Song, Yaru Wang, Huafang Zhang, Muhammad Abu Bakar Saddique, Xiumei Luo, Maozhi Ren

First published: 07 November 2024 | https://doi.org/10.1111/mpp.70024

SECTIONS PDF TOOLS SHARE

Abstract

Plant diseases caused by fungal phytopathogens have led to significant economic losses in agriculture worldwide. The management of fungal diseases is mainly dependent on the application of fungicides, which are not suitable for sustainable agriculture, human health, and environmental safety. Thus, it is necessary to develop novel targets and green strategies to mitigate the losses caused by these pathogens. The target of rapamycin (TOR) complexes and key components of the TOR signalling pathway are evolutionally conserved in pathogens and closely related to the vegetative growth and pathogenicity. As indicated in recent systems, chemical, genetic, and genomic studies on the TOR signalling pathway, phytopathogens with TOR dysfunctions show severe growth defects and nonpathogenicity, which makes the TOR signalling pathway to be developed into an ideal candidate target for controlling plant disease. In this review, we comprehensively discuss the current knowledge on components of the TOR signalling pathway in microorganisms and the diverse roles of various plant TOR in response to plant pathogens. Furthermore, we analyse a range of disease management strategies that rely on the TOR signalling pathway, including genetic modification technologies and chemical controls. In the future, disease control strategies based on the TOR signalling network are expected to become a highly effective weapon for crop protection.



Yun et al. *Mol Plant Pathol*. 2024 Nov;25(11):e70024.

Pathogenesis-related protein 1 suppresses oomycete pathogen by targeting against AMPK kinase complex

Journal of Advanced Research
Volume 43, January 2023, Pages 13-26

Original Article

Pathogenesis-related protein 1 suppresses oomycete pathogen by targeting against AMPK kinase complex

Xiumei Luo [a b c d], Tingting Tian [d], Li Feng [a b c], Xingyong Yang [e], Linxuan Li [a b c], Xue Tan [d], Wenxian Wu [a b c], Zhengguo Li [d], Haim Treves [f], Francois Serneels [g], I-Son Ng [h], Kan Tanaka [i], Maozhi Ren [a b c]

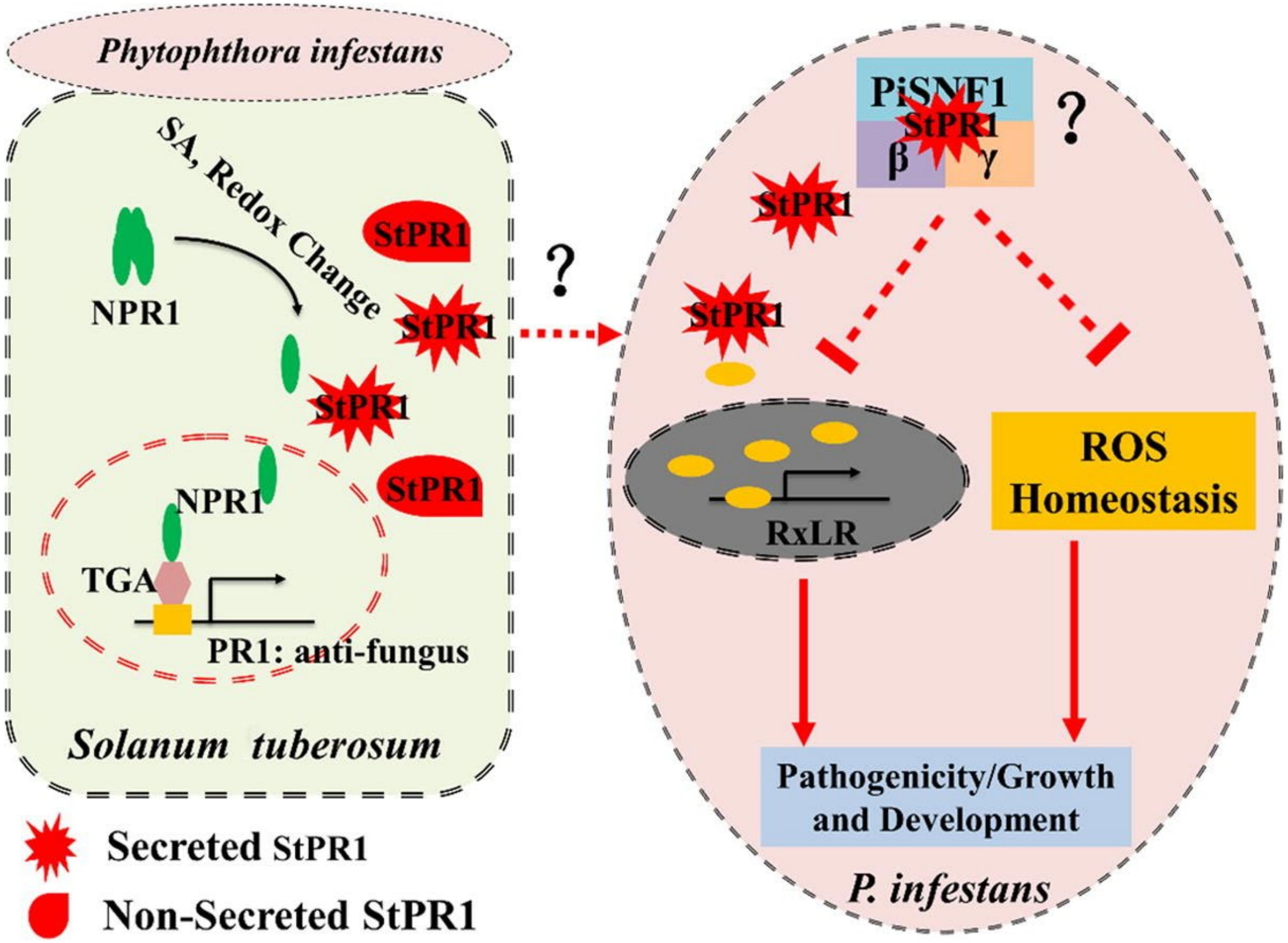
Show more

Add to Mendeley Share Cite

https://doi.org/10.1016/j.jare.2022.02.002 Get rights and content

Highlights

- Upon infecting by *P. infestans*, *StPR1* expression was induced in host and secretory StPR1 proteins translocated into pathogen.
- The translocated PR1 proteins target AMPK complex in *P. infestans*, and impaired the AMPK activation to downstream targets.
- StPR1 prevented ROS homeostasis and inhibited the expression of RxLR effector-encoding genes in *P. infestans*.



Luo et al. *J Adv Res*. 2023 Jan;43:13-26.

Ribosomal S6 kinases 2 mediates potato resistance to late blight, through WRKY59 transcription factor

Ribosomal S6 kinases 2 mediates potato resistance to late blight, through WRKY59 transcription factor

Yunmin Wei [1], Xue Tan [2], Tingting Tian [2], Xiumei Luo [3], Maozhi Ren [4]

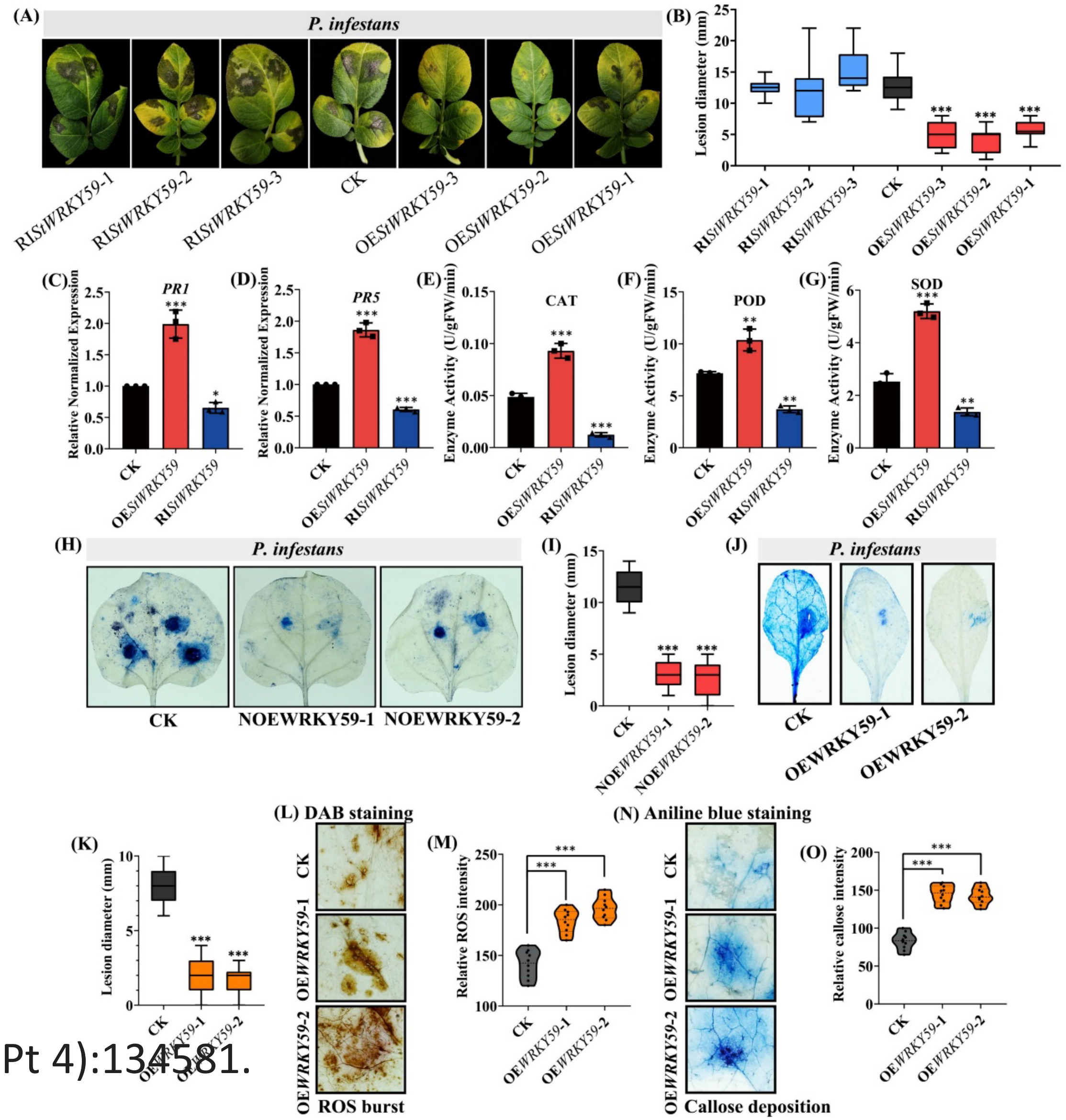
Affiliations + expand

PMID: 39122078 DOI: 10.1016/j.ijbiomac.2024.134581

Abstract

Potato late blight is the most devastating pre- and post-harvest crop disease in the world, which is widespread and difficult to control, causing serious economic losses. Cultivating resistant varieties is a major way to prevent and control late blight in a green way. However, due to the rapid evolution of pathogens, the plant resistance is losing. Therefore, mining effective and durable genes involved in disease resistance is crucial for breeding resistant varieties against late blight. In this study, we took "potato-Phytophthora infestans" as the "host-pathogen" model system to discover the potential disease resistance-related genes and elucidate their molecular functional mechanism. Through yeast two-hybridization, bimolecular fluorescence complementation, Co-immunoprecipitation assays, and gene function validation etc., we found that ribosomal protein S6 kinase 2 (StS6K2) is a key resistant protein, which is interacted with StWRKY59 transcription factor. Overexpression of StS6K2 and StWRKY59 both enhanced the plants resistance to P. infestans, and promoted the host immune response, such as ROS burst and callose deposition. In OEStWRKY59 lines, DEGs involved in secondary metabolites synthesis, plant hormone signaling transduction and plant-pathogen interaction were significantly enriched. These findings provide novel genetic resources for the breeding of resistant varieties.

Keywords: Potato late blight; Ribosomal protein S6 kinase 2; Transcription factor WRKY59.



Wei *et al. Int J Biol Macromol*. 2024 Oct;277(Pt 4):134581.

Modeling plant diseases under climate change: evolutionary perspectives

Trends in Plant Science
Special issue: Food security
Opinion

CellPress OPEN ACCESS

Modeling plant diseases under climate change: evolutionary perspectives

Li-Na Yang,[1] Maozhi Ren,[2,*] and Jiasui Zhan[3,*]

Infectious plant diseases are a major threat to global agricultural productivity, economic development, and ecological integrity. There is widespread concern that these social and natural disasters caused by infectious plant diseases may escalate with climate change and computer modeling offers a unique opportunity to address this concern. Here, we analyze the intrinsic problems associated with current modeling strategies and highlight the need to integrate evolutionary principles into polytrophic, eco-evolutionary frameworks to improve predictions. We particularly discuss how evolutionary shifts in functional trade-offs, relative adaptability between plants and pathogens, ecosystems, and climate preferences induced by climate change may feedback to future plant disease epidemics and how technological advances can facilitate the generation and integration of this relevant knowledge for better modeling predictions.

Highlights

Modeling is a unique and cost-effective approach to predict the long-term impacts of climate change on infectious plant diseases and sustainability.

Model predictions are hindered by a lack of evolutionary understanding of the individual and interactive impacts of climate change on plants, pathogens, and ecosystems.

Climate change creates a series of intra- and inter-specific trade-offs that modulate the entire epidemiological process of infectious plant diseases.

Climatic preferences of plants, pathogens, and their interactions evolve in response to change in local climatic conditions.

Technological advances offer unprecedented opportunities to generate and integrate biological, ecological, and evolutionary knowledge in polytrophic models.

Concerns on plant disease epidemic under climate change

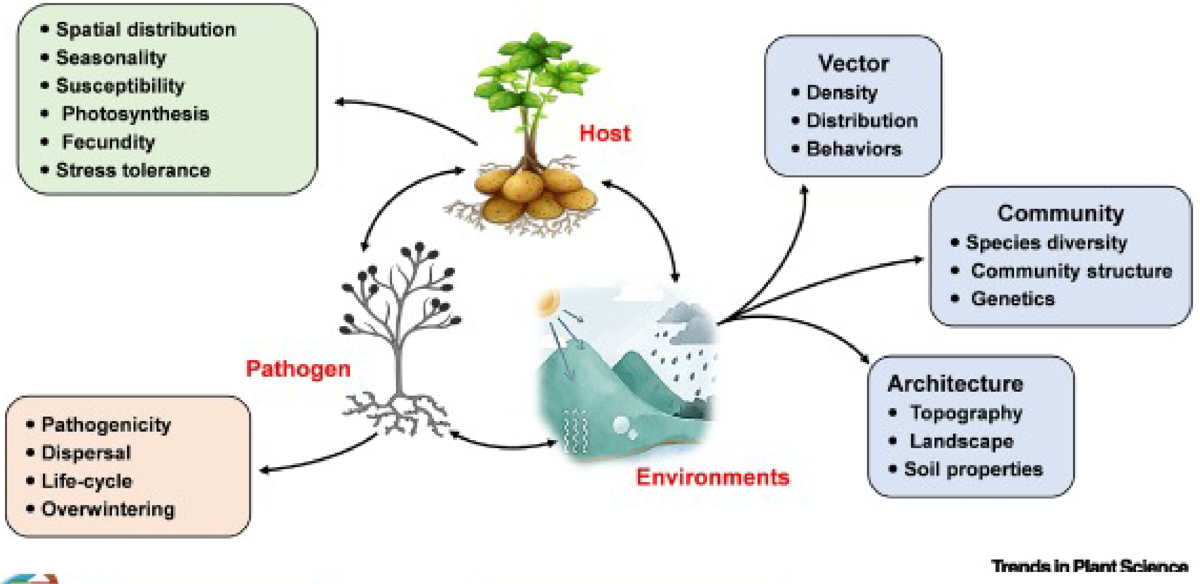
Plant pathogens have a significant impact on agricultural production, causing 13–22% of direct losses annually [1], in addition to indirect costs incurred through control attempts. Economic losses, together with environmental toxicity associated with some control approaches, and biodiversity degradation, greatly threaten socioeconomic and ecological sustainability [2]. The intensity of current global climate change is creating substantial alterations in both magnitude and range of air temperature, rainfall, radiation (UVR) and other climatic events. How these changes and associated secondary and even tertiary environmental and eco-evolutionary events affect epidemics of infectious plant diseases and, through this, primary food production is attracting increasing academic and public attention. As a cost-effective approach to address such complex social and natural scenarios that are not amenable to direct experimentation, computer simulation has become an irreplaceable option to assess these academic and public concerns for better predictions and mitigations [3–5].

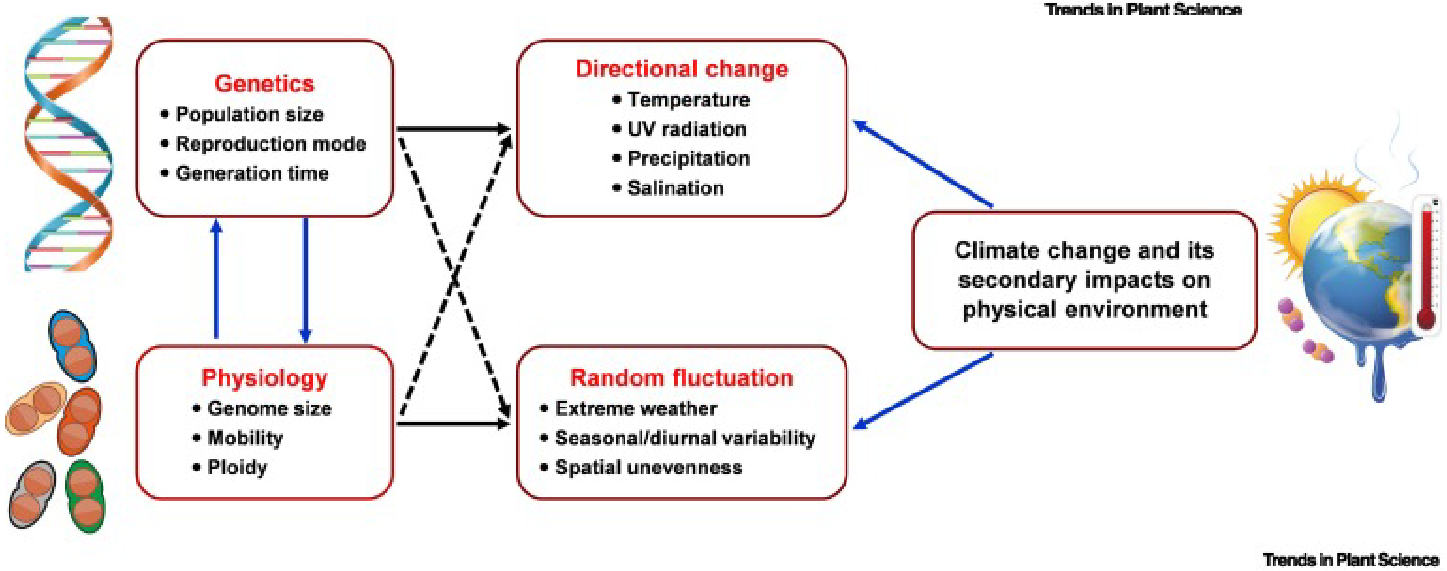
Current prediction dilemma and challenges

In recent years, considerable effort has been made to model how infectious plant diseases in agricultural and natural ecosystems may respond to global climate change, with the aim of developing better prevention and mitigation strategies. However, predictions from these theoretical models are generally inconsistent. Some models predict climate change may increase the occurrence and severity of future infectious plant disease, with more impact on northern than lower latitude areas and on developing rather than developed countries [6–9]. Other models suggest that climate change has no major impact on the epidemic risk of infectious plant diseases or may even result in lower epidemic frequency or intensity [10,11]. In addition to the difference in the intrinsic property of particular host–pathogen interactions responding to specific forms of climate change, these inconsistent results may be generated by insufficient knowledge of relevant pathogen and host biology and their interaction with the environment, thereby preventing the development of robust models for confident inference.

[1]Fujian Key Laboratory on Conservation and Sustainable Utilization of Marine Biodiversity, Fuzhou Institute of Oceanography, Minjiang University, Fuzhou, 350108, China
[2]Institute of Urban Agriculture, Chinese Academy of Agricultural Sciences, Chengdu National Agricultural Science and Technology Center, Chengdu, China
[3]Department of Forest Mycology and Plant Pathology, Swedish University of Agricultural Sciences, Uppsala, Sweden

*Correspondence:
renmaozhi01@caas.cn (M. Ren) and
Jiasui.zhan@slu.se (J. Zhan).





Yang et al. *Trends Plant Sci.* 2023 May;28(5):519-526.

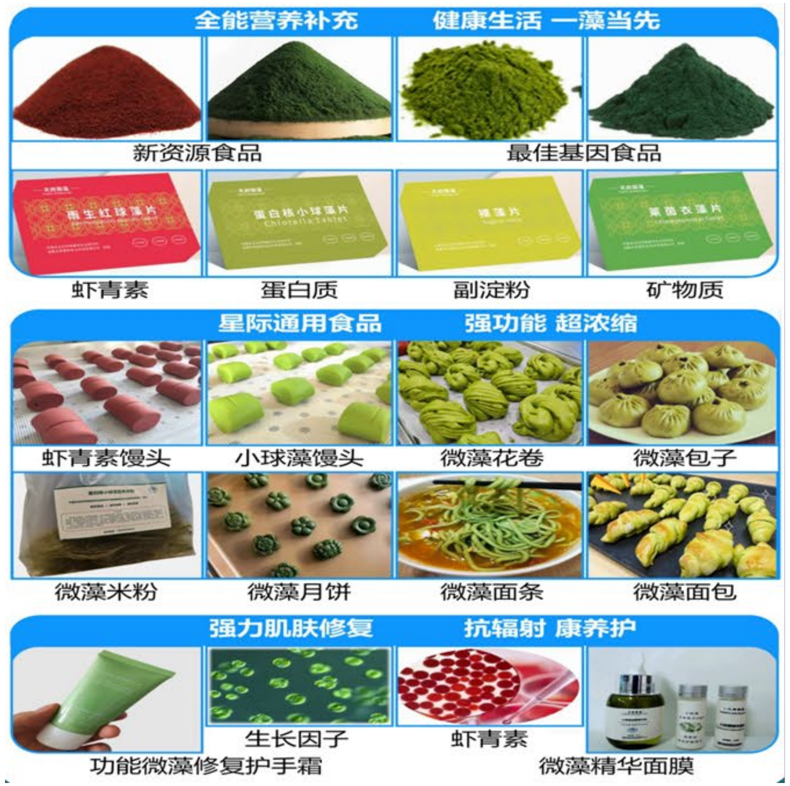
6. We have established an efficient production technology system for Chlorella 我们已经建立了高效的生产技术小球藻系统

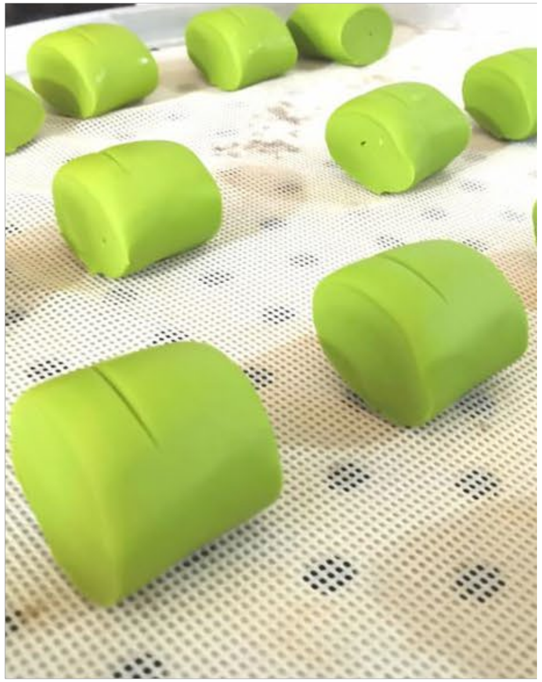
微藻产业线

富硒微藻工业化生产干重达100g/L以上

7. We have developed a large number of microalgae functional products

我们已经开发了大量的微藻功能产品

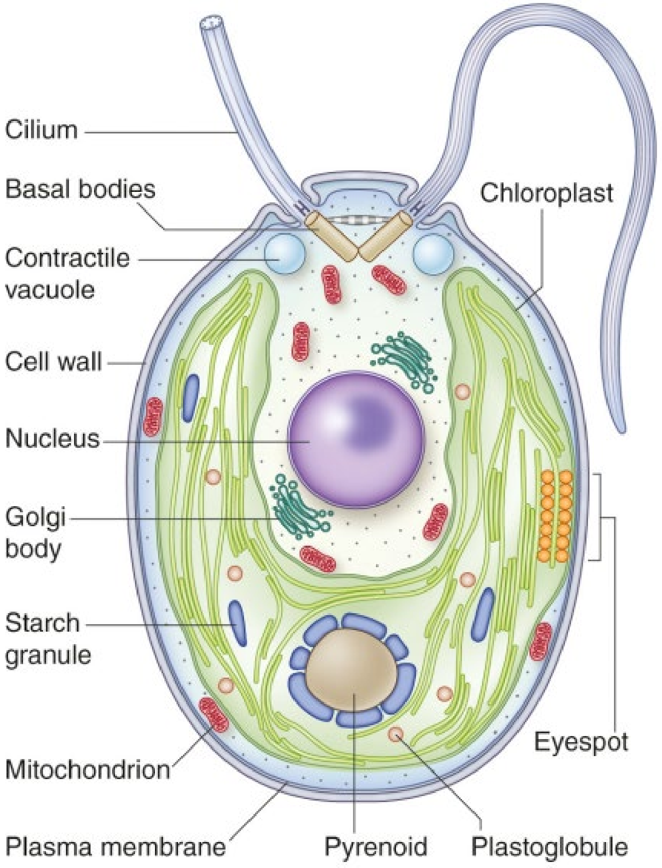




Based on chlorella, functional products such as algae powder, algae flakes, pasta, and skin care products have been developed.

以小球藻为基础，开发了藻粉、藻片、面食、护肤品等功能性产品。

Edible microalgae : *Chlamydomonas reinhardtii*

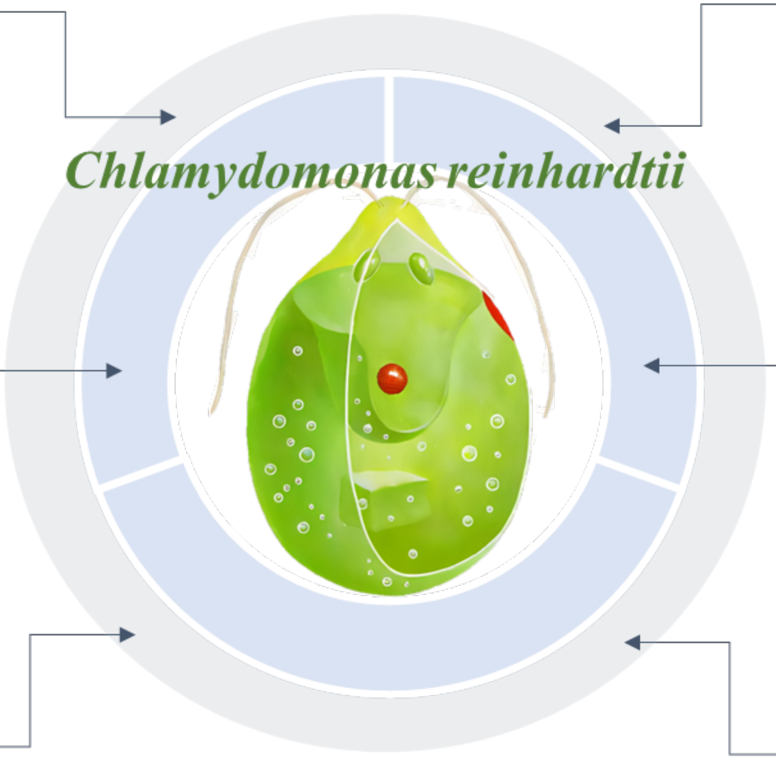


Name	*Chlamydomonas reinhardtii*
Classification	Phylum Chrysophyta, Chlorella
Growth characteristics	Photoautotrophic, chemotrophic, allotrophic
Distribution	Ditches, depressions and, lakes
Function	Food, food additives, skin care products, feed, etc.
Advantage	Easy to cultivate, fast to grow, easy to genetically transform
Industrial performance	The growth rate is fast, suitable for high-density fermentation, and the cultivation cost is lower than that of yeast

Chlamydomonas reinhardtii is considered the most promising "green cell factory"

01 New food ingredients

02 Contains 10 types of selenoproteins



03 Genetic transformation system is mature

04 Possesses post-translational modification mechanisms similar to those of mammals

05 Easy to cultivate, fast growing

06 Suitable for high-density fermentation culture

Chlamydomonas reinhardtii is a natural bioreactor for producing selenoproteins

Department of Food Safety Standards and Monitoring and Assessment

食品安全标准与监测评估司

主站首页 | 首页 | 最新信息 | 政策文件 | 关于我们

通告公告

您现在所在位置： 首页 > 最新信息 > 风险监测 > 通告公告

关于莱茵衣藻等36种“三新食品”的公告

发布时间： 2022-05-11 来源: 食品安全标准与监测评估司

2022年 第2号

根据《中华人民共和国食品安全法》规定，审评机构组织专家对莱茵衣藻等3种新食品原料、喹啉黄铝色淀等18种食品添加剂新品种、磷酸锆（2:1）等15种食品相关产品新品种的安全性评估材料进行审查并通过。

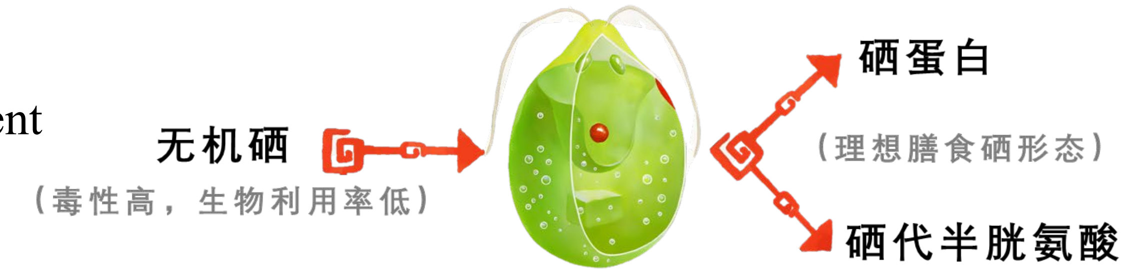
特此公告。

附件：莱茵衣藻等36种“三新食品”的公告文本

国家卫生健康委

2022年5月5日

Announcement on 36 "three new foods" including Chlamydomonas reinhardtii

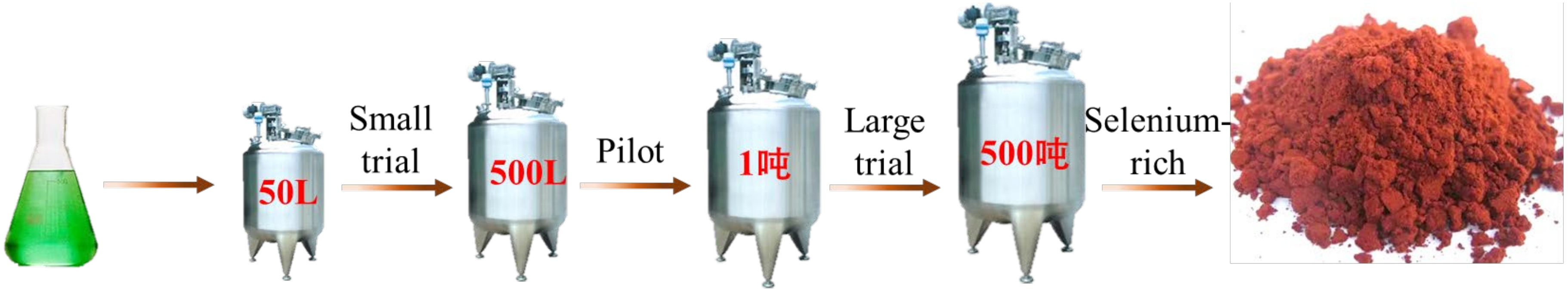


Symbol	Name	Sec location (protein size)
TR	Thioredoxin reductase	532 (533)
SelK	Selenoprotein K	91 (92)
SelW2	Selenoprotein W	16 (82)
SelW1	Selenoprotein W	14 (88)
SelT1	Selenoprotein T	61 (181)
SelM2	Selenoprotein M	33 (138)
SelM1	Selenoprotein M	46 (140)
MrsA1	Methionine-S-sulfoxide reductase	20 (159)
GPX2	Glutathione peroxidase	78 (161)
GPX1	Glutathione peroxidase	75 (201)

Ten selenoproteins from Chlamydomonas reinhardtii

Ghuge et al., *antioxidants*, 2022

Production and application scenarios of *Chlamydomonas reinhardtii* selenoprotein

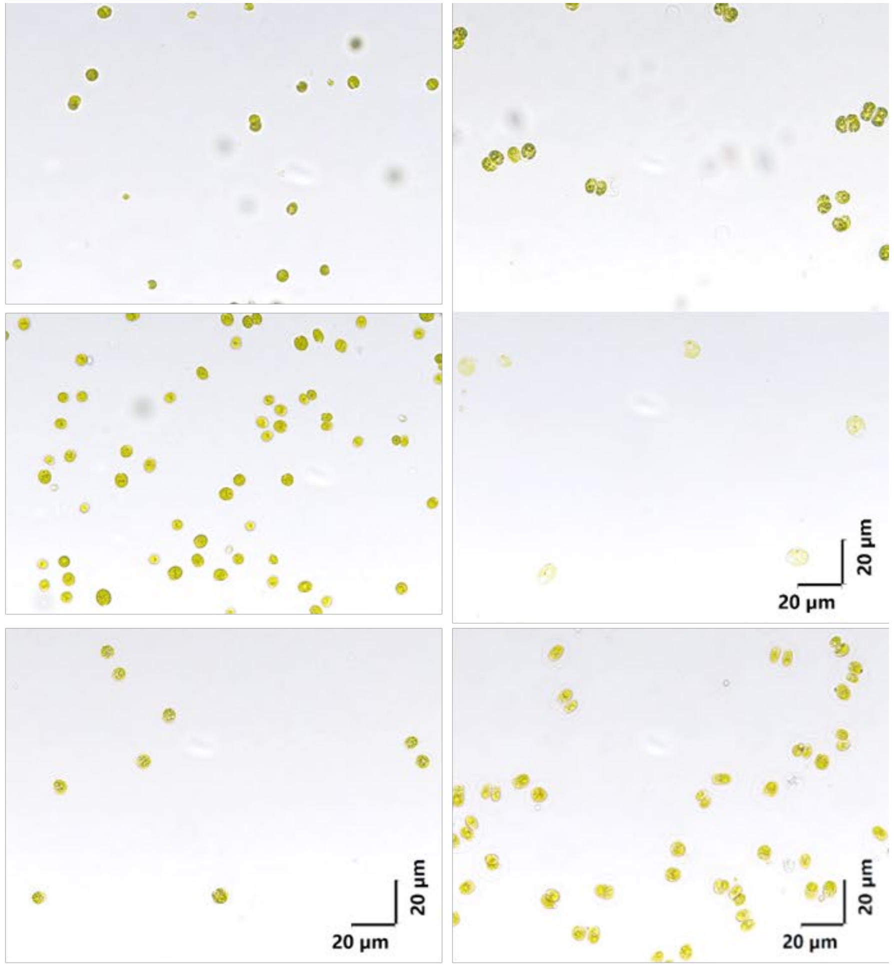


Selenoproteins from *Chlamydomonas reinhardtii*

More than 10 strains of *Chlamydomonas reinhardtii* have been obtained through separation, screening and identification

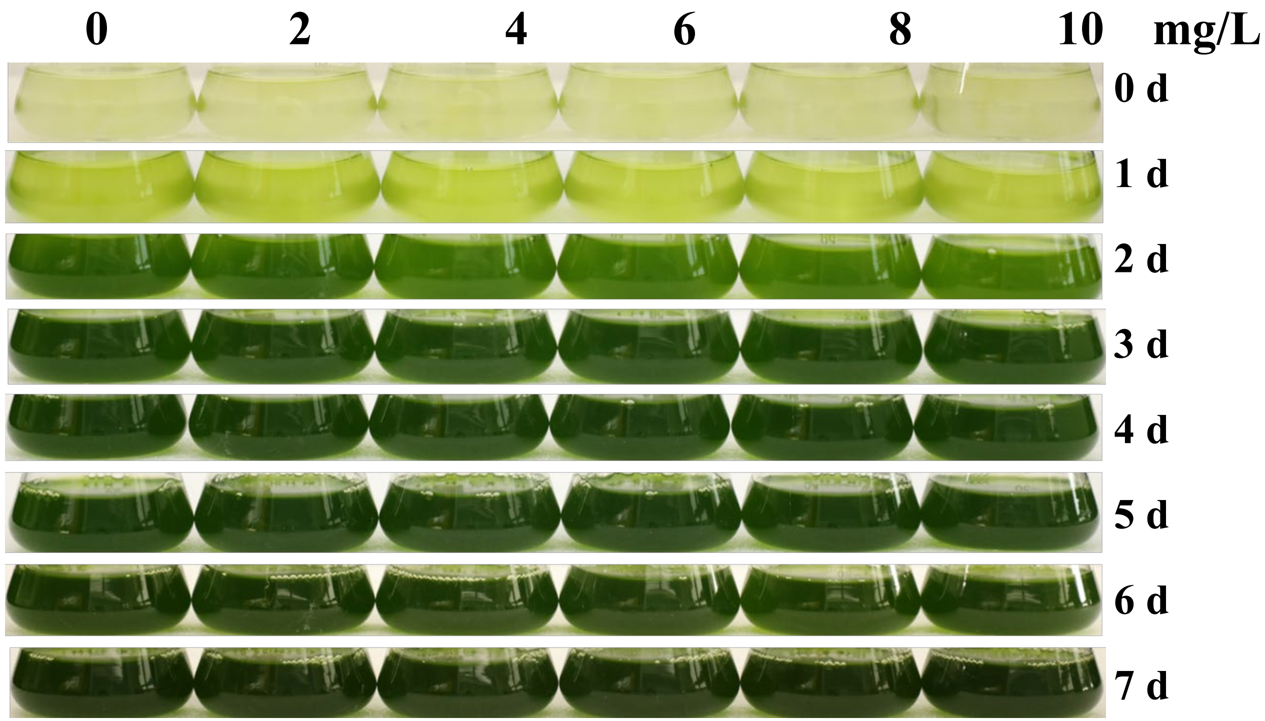
Collecting samples

Dilution plate streak method

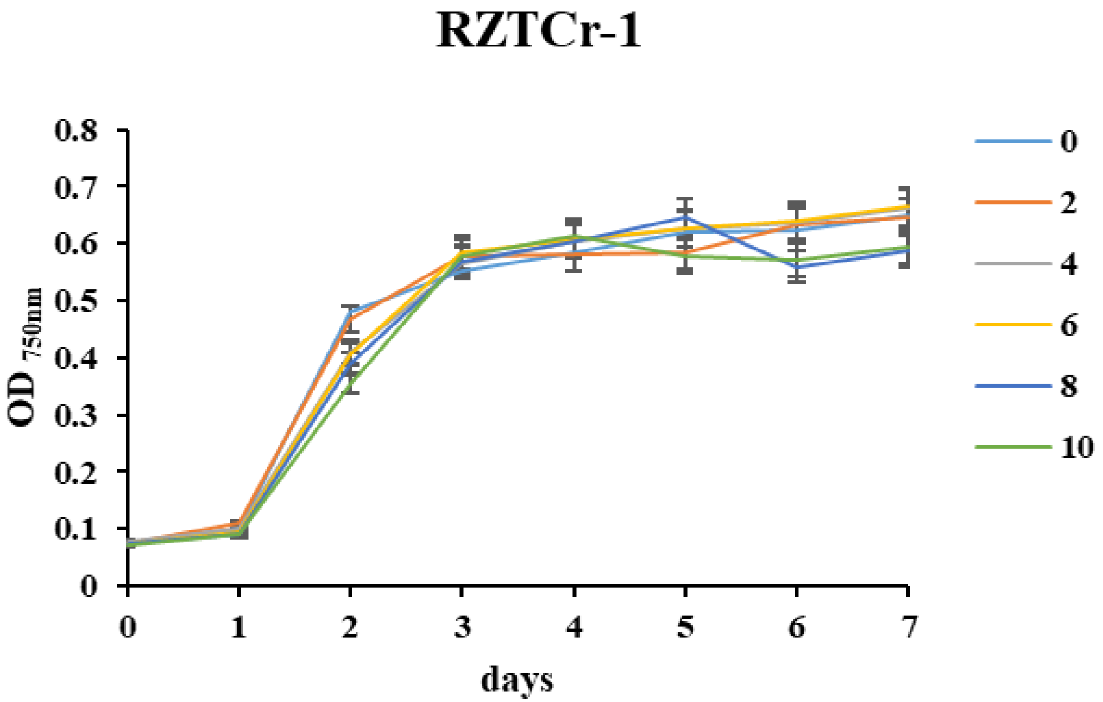


Microscopic examination

Chlamydomonas reinhardtii RZTCr-1, a product with independent intellectual property rights, has fast growth rate and strong tolerance to sodium selenite

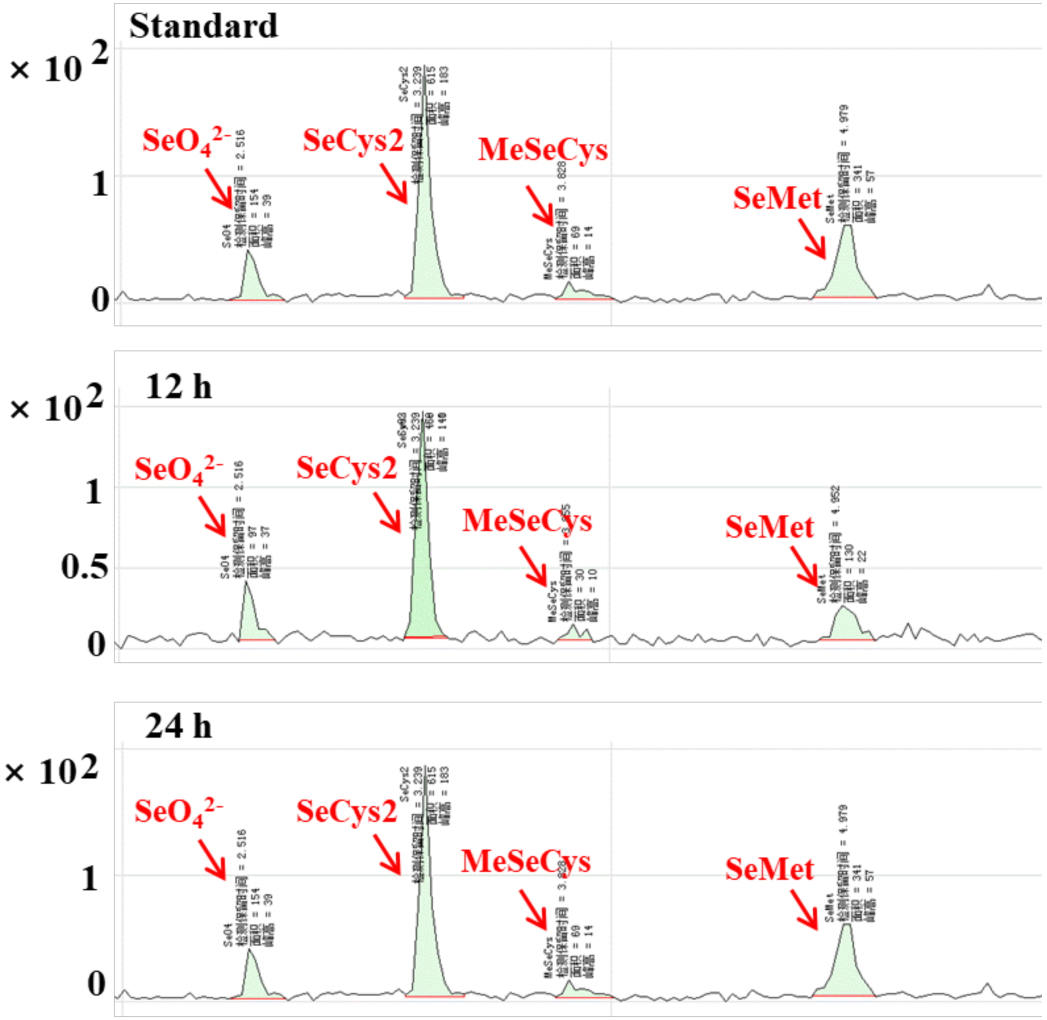


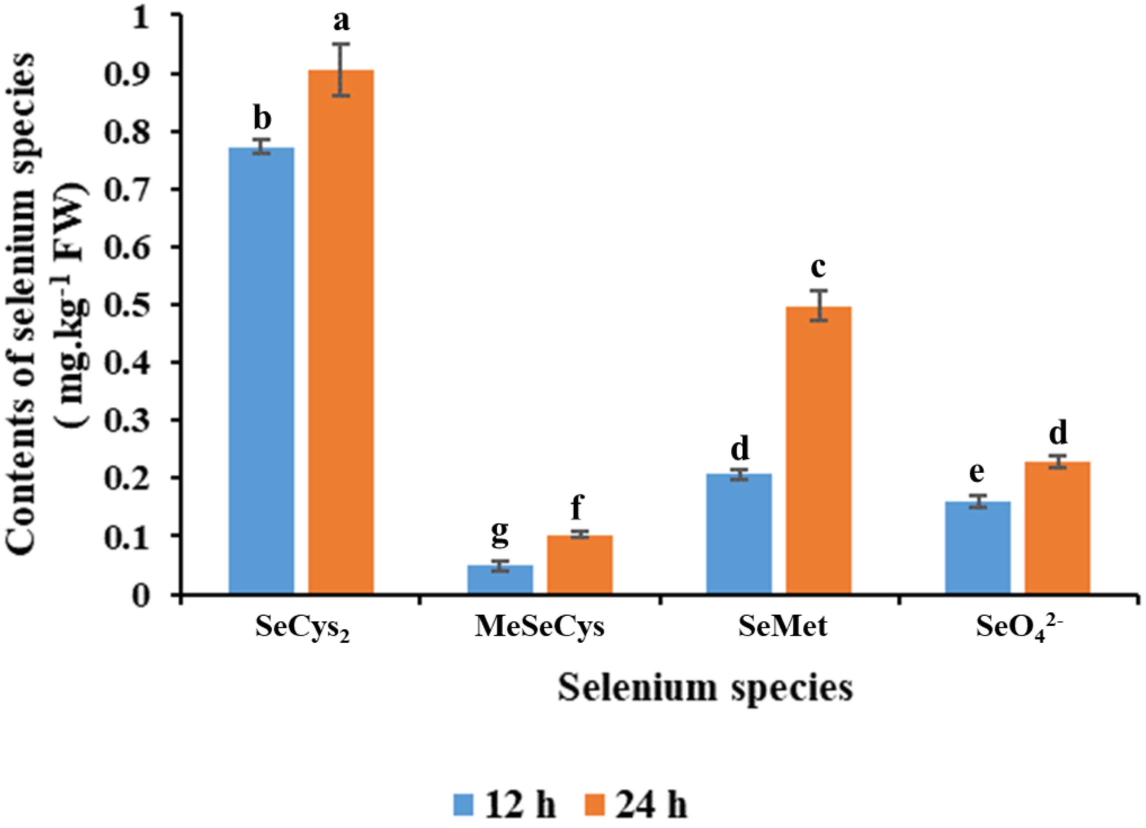
Growth of RZTCr-1 under Na_2SeO_3 treatment



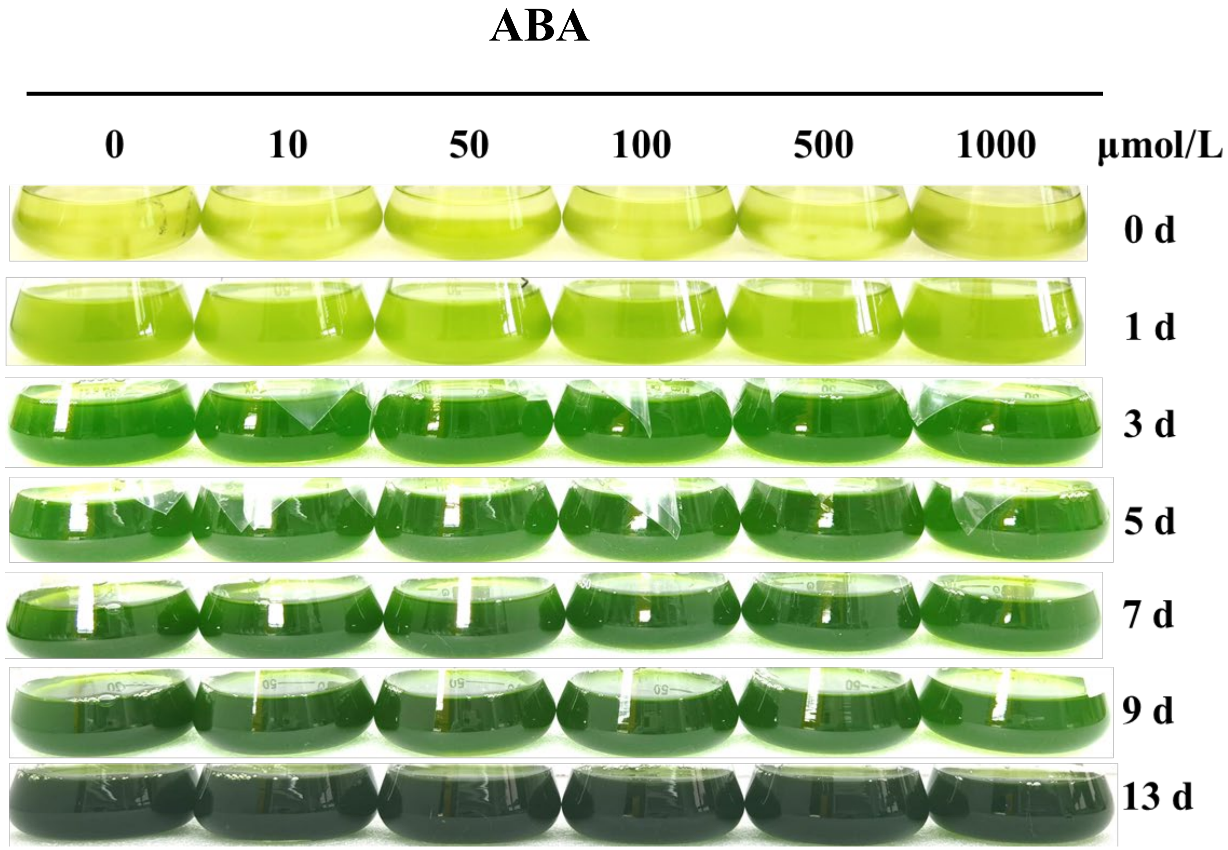
Cell density of RZTCr-1 under Na_2SeO_3 treatment

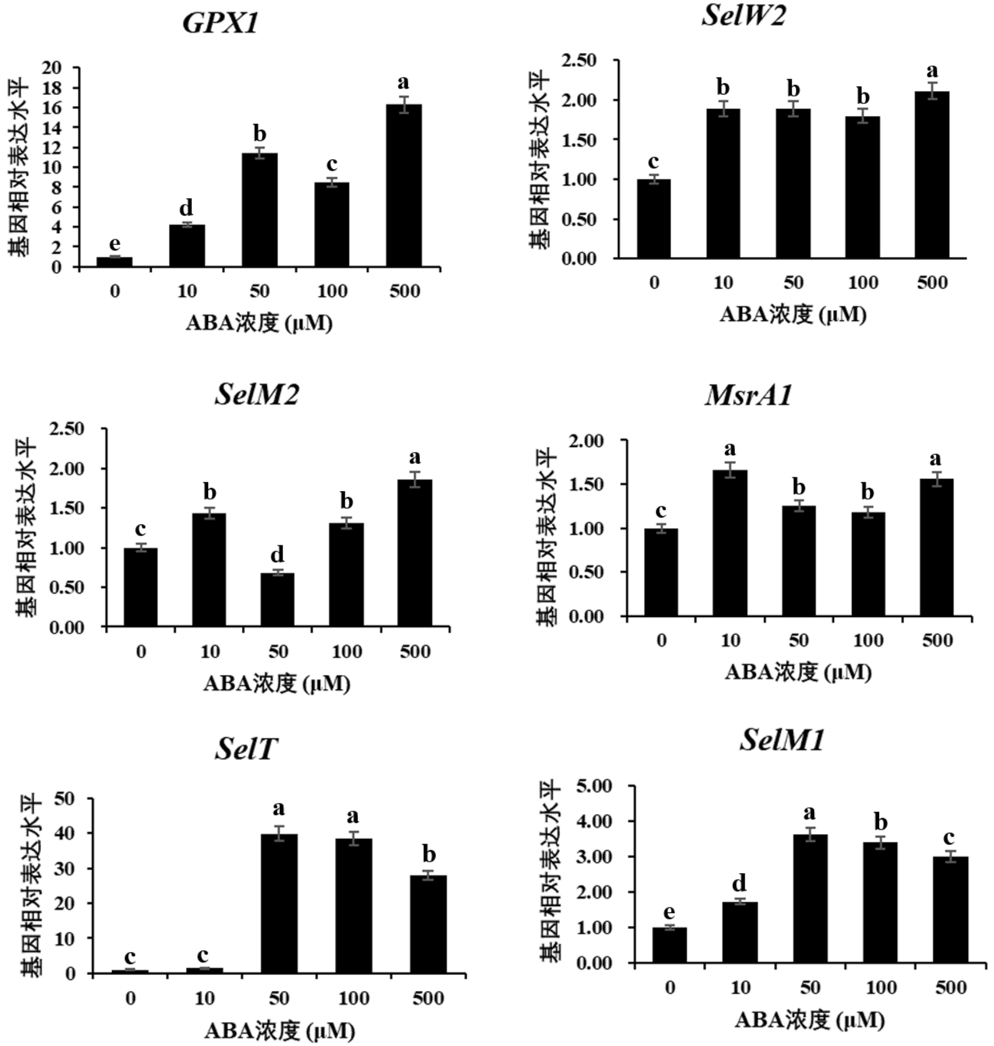
Selenium species and contents in selenium-enriched *Chlamydomonas reinhardtii* RZTCr-1



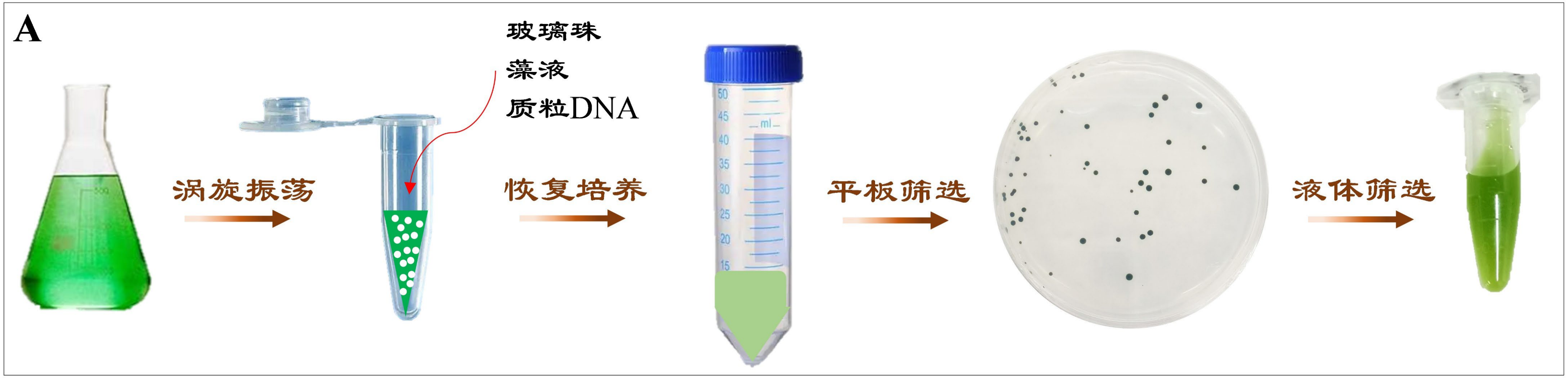


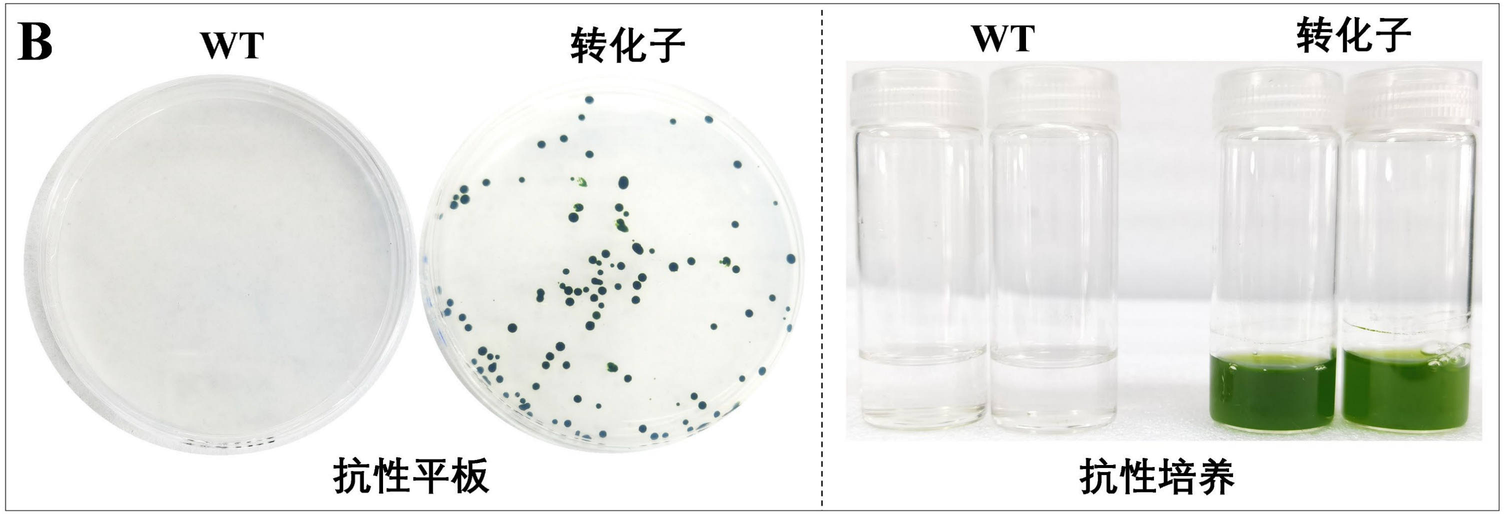
Plant hormone ABA promotes the expression of selenoprotein genes in *Chlamydomonas reinhardtii*

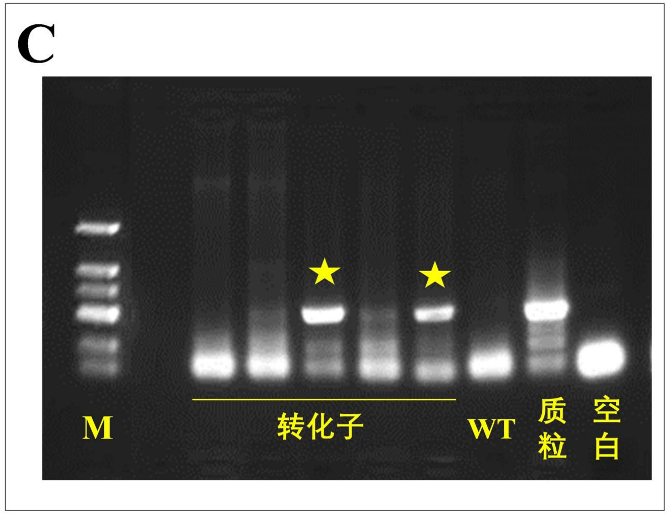




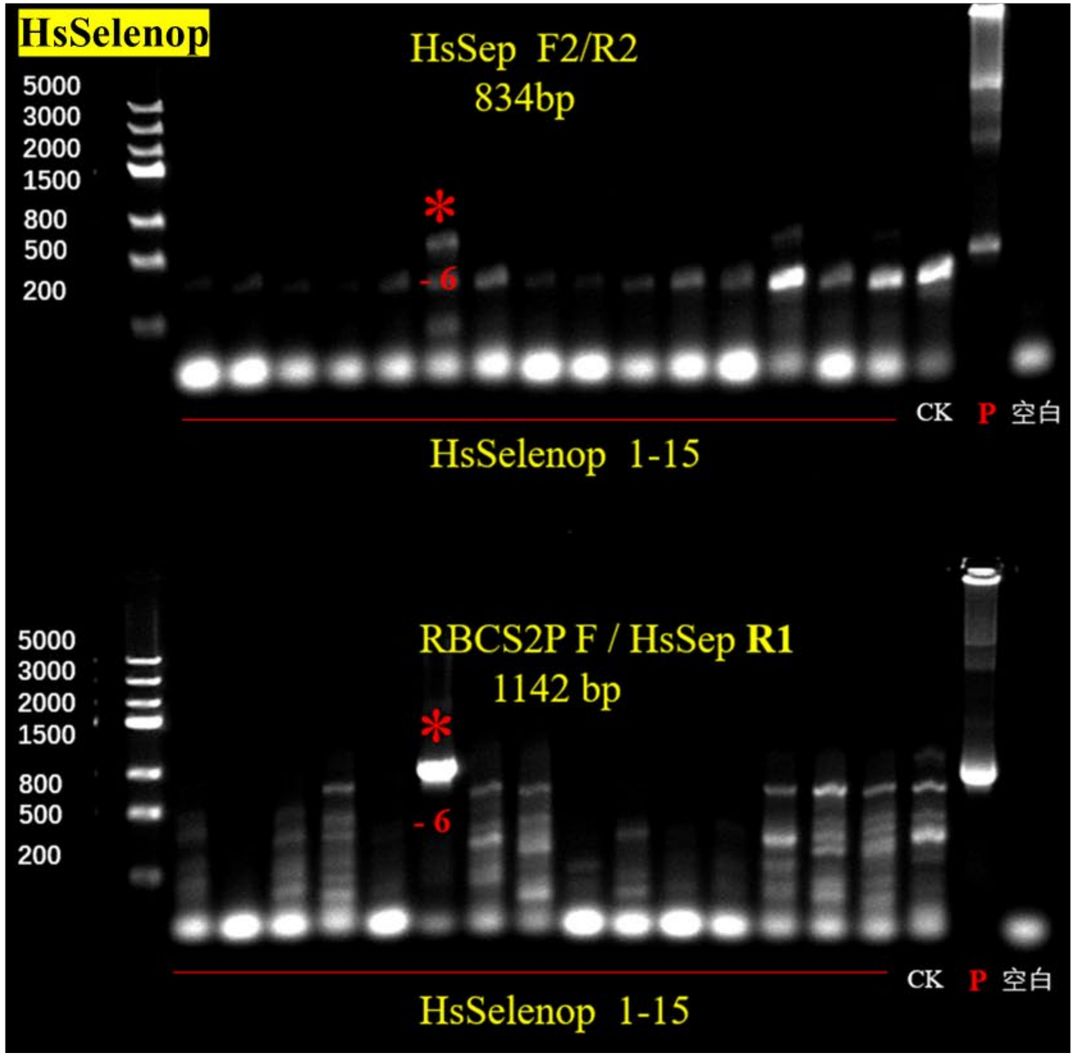
A mature and stable genetic transformation system for *Chlamydomonas reinhardtii* has been established

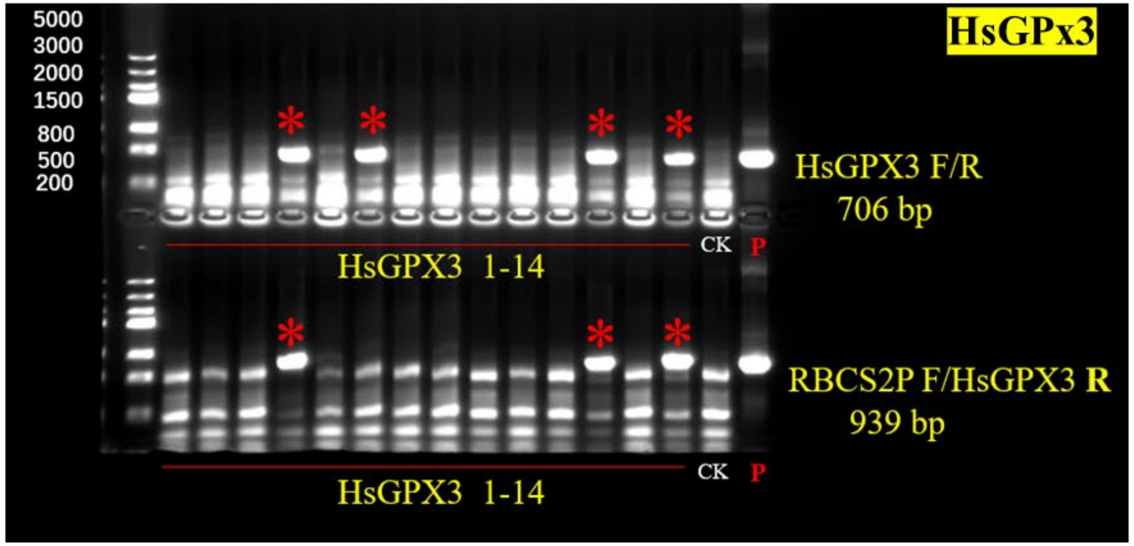


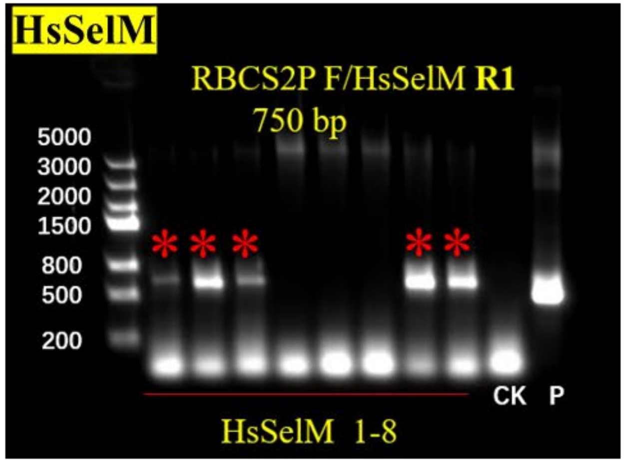


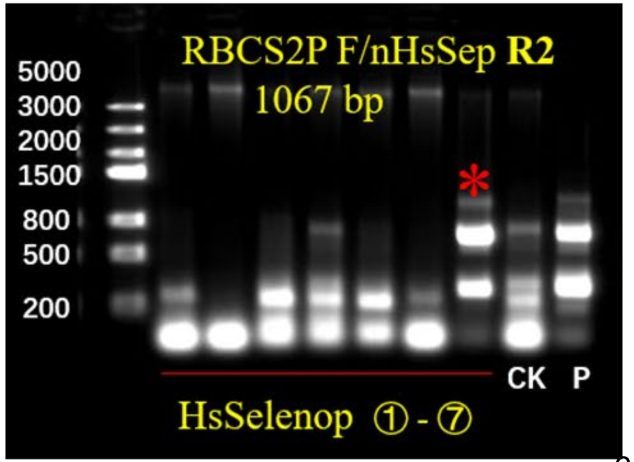


Fifteen algal strains stably expressing human selenoprotein P, GPx3, and SelM have been obtained









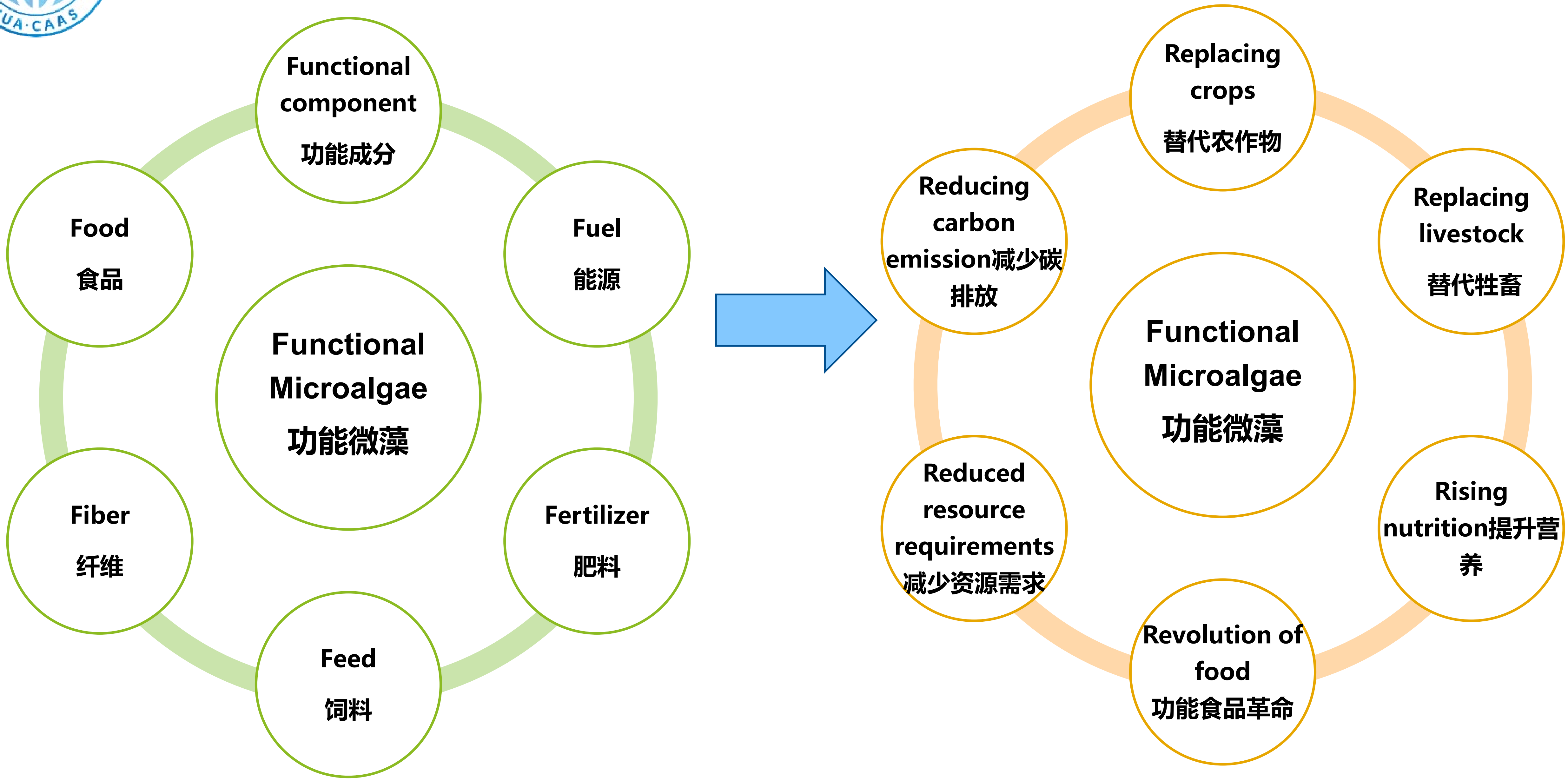
05

Conclusions:

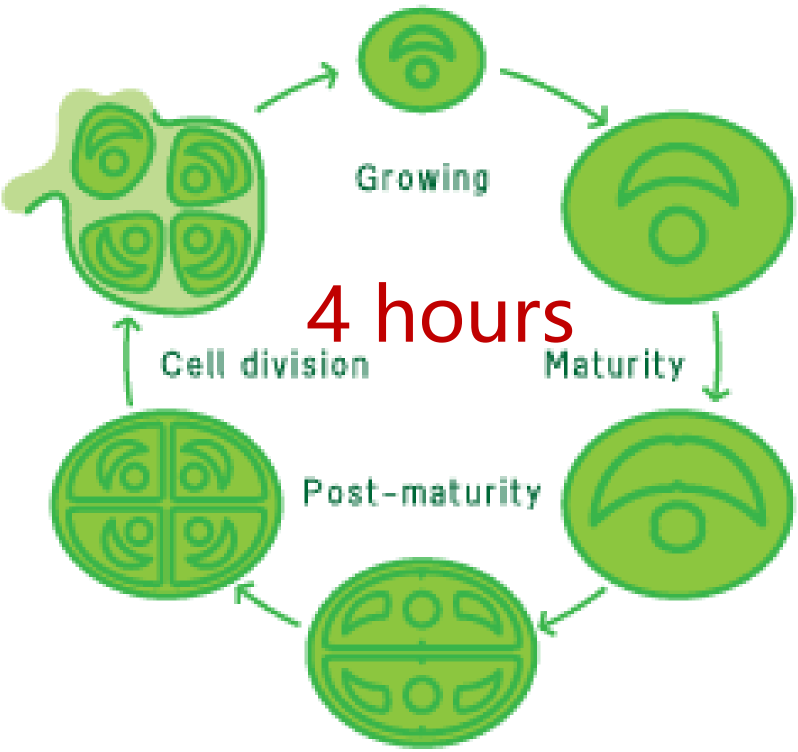
Functional Microalgae from “6F” to “6R”

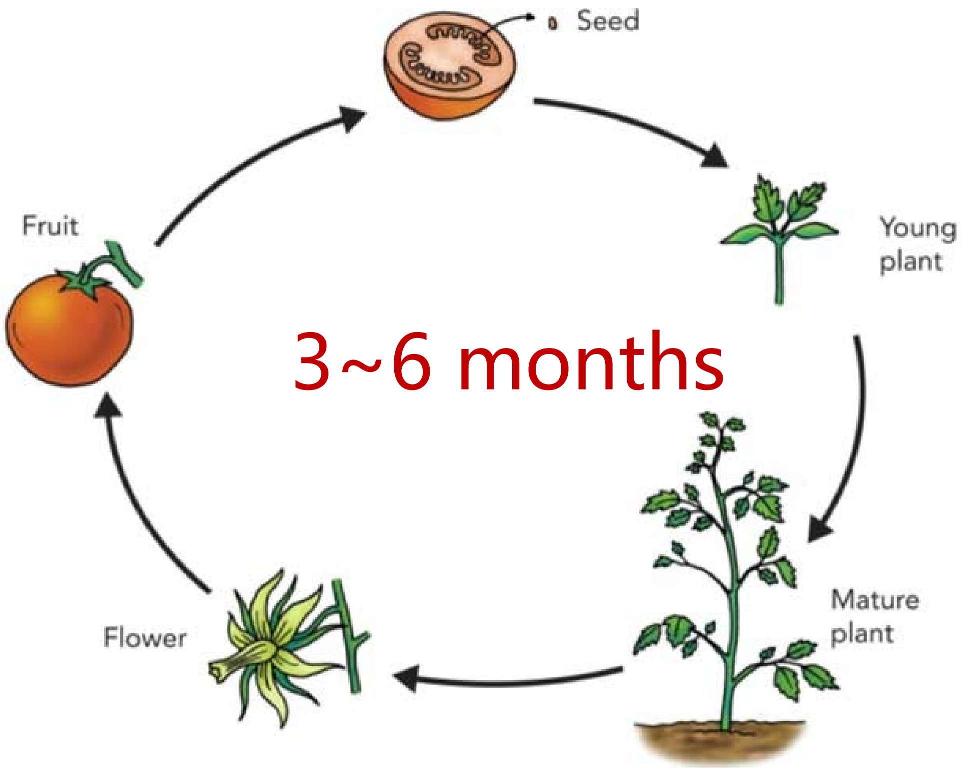
结论：功能微藻从“6F”到“6R”

“6F” of functional microalgae 功能微藻的“6F”



1. Microalgae replacing crops for producing oils and carbohydrates
微藻代替作物生产油脂和碳水化合物

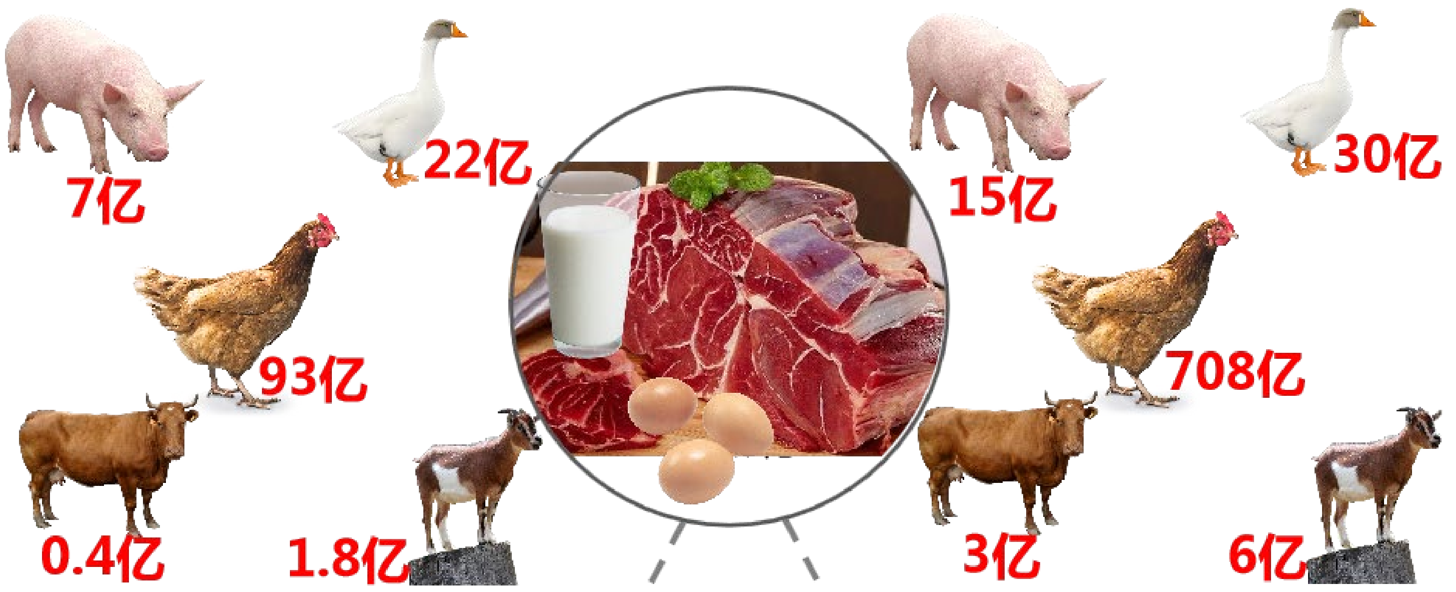




Microalgae have rapid growth rates compared to traditional crops. They can multiply quickly, allowing for efficient biomass production in a shorter time frame.

与传统作物相比，微藻的生长速度很快。它们可以快速繁殖，从而在更短的时间内实现高效的生物质生产。

2. Microalgae replacing livestock for producing proteins
微藻代替牲畜生产蛋白质



2020年**中国**家禽家畜需求量

2020年**全球**家禽家畜需求量

消耗大： 全球80%农地+33%淡水

排放多： 56%空气污染+57%水污染

High consumption: 80% of the world's agricultural land +33% freshwater

High discharge: 56% air pollution +57% water pollution

转化少： 18%热量+37%蛋白

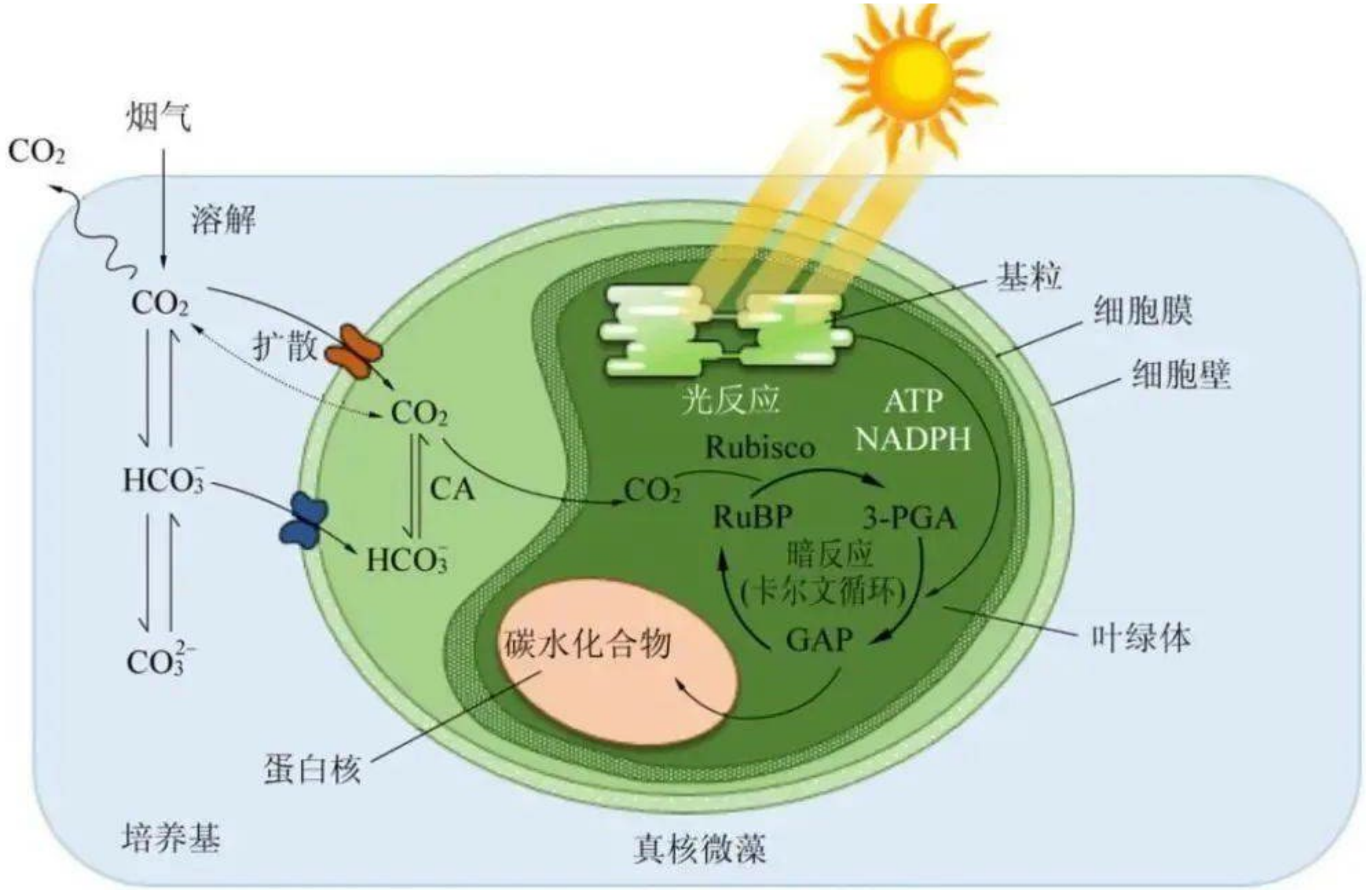
风险高： 新冠+禽流感+猪瘟+N

Low conversion: 18% calories +37% protein

High risk: COVID-19 + avian influenza + swine fever +N

数据来源于FAO

3. Microalgae reducing carbon emission for carbon neutrality
微藻减少碳排放，实现碳中和



In the process of evolution, microalgae formed the "**carbon dioxide concentration mechanism (CCM)**" which uses carbon sources efficiently. Microalgae biological carbon sequestration contributes to the national ecological economic war of "**carbon peak and carbon neutrality** "

微藻在进化过程中形成了高效利用碳源的“**二氧化碳浓缩机制（CCM）**”微藻生物固碳助力“**碳达峰、碳中和**”国家生态经济战

4. Reduced resource requirements 减少资源需求

Microalgae cultivation generally requires less land, water, and fertilizers compared to traditional crops.

与传统作物相比，微藻种植通常需要更少的土地、水和肥料。

5. Microalgae for revolution of food 微藻引发功能性食品革命

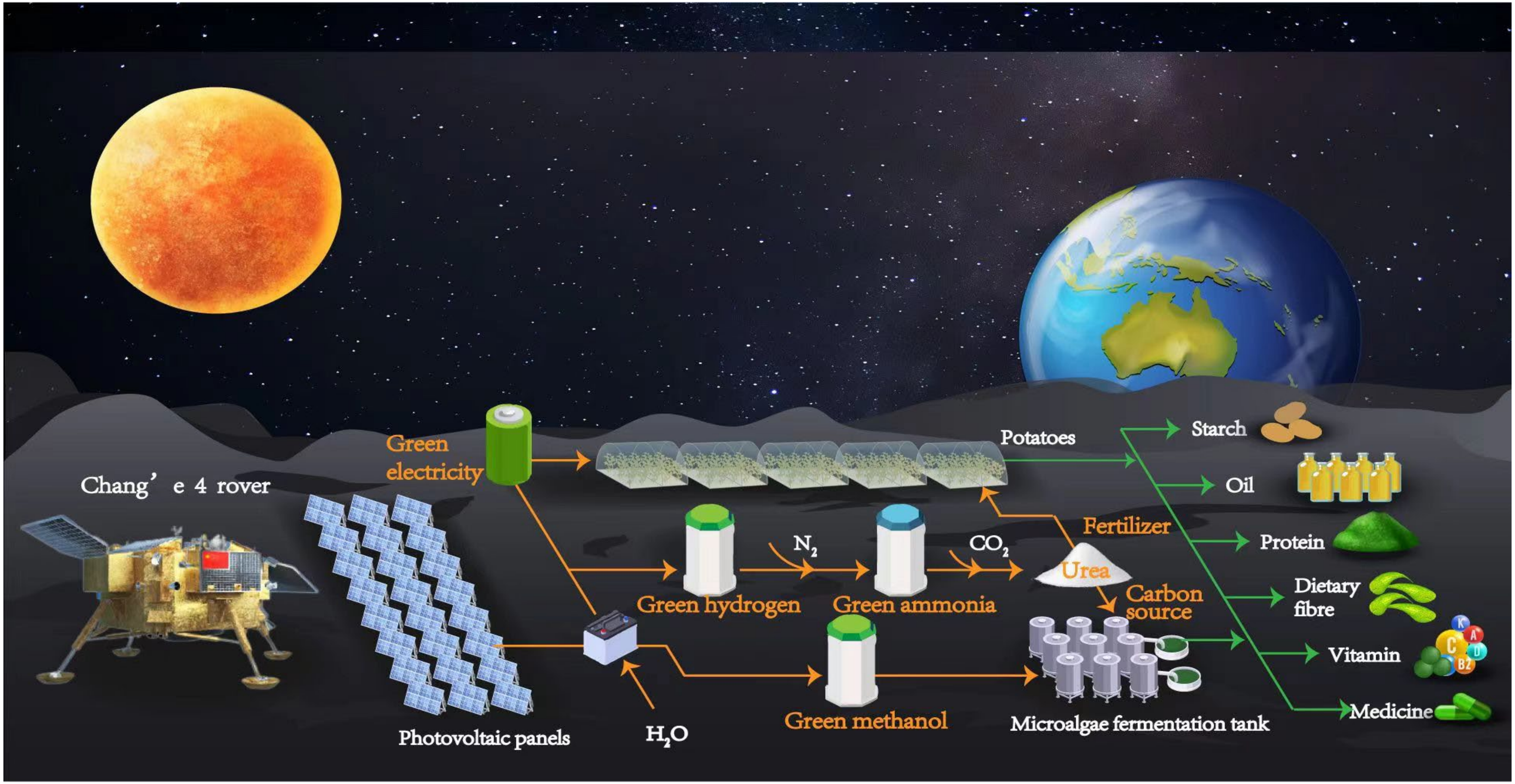
1 g
Chlorella
小球藻

1 kg
Vegetables
蔬菜

Microalgae have high nutrient density and are rich in essential nutrients, which can provide a concentrated nutrition supply per unit planting area and effectively promote the healthy development of the functional food industry.

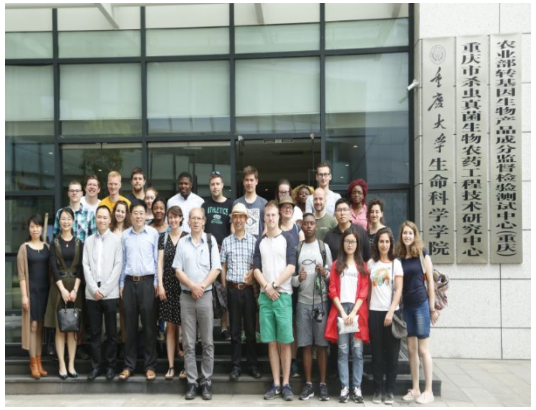
微藻营养密度高，富含必需的营养物质，能提供每单位种植面积的集中营养供应，能够有效推进功能食品产业的健康发展。

6. Refactoring farming system towards interstellar immigration
面向星际移民重塑农业系统



Thanks for your attention!






E-mail: renmaozhi01@caas.cn; Tel and Wechat: 13527313471