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Learning Oceanography by cartoons

Marine popular Science Laboratory, RCEC

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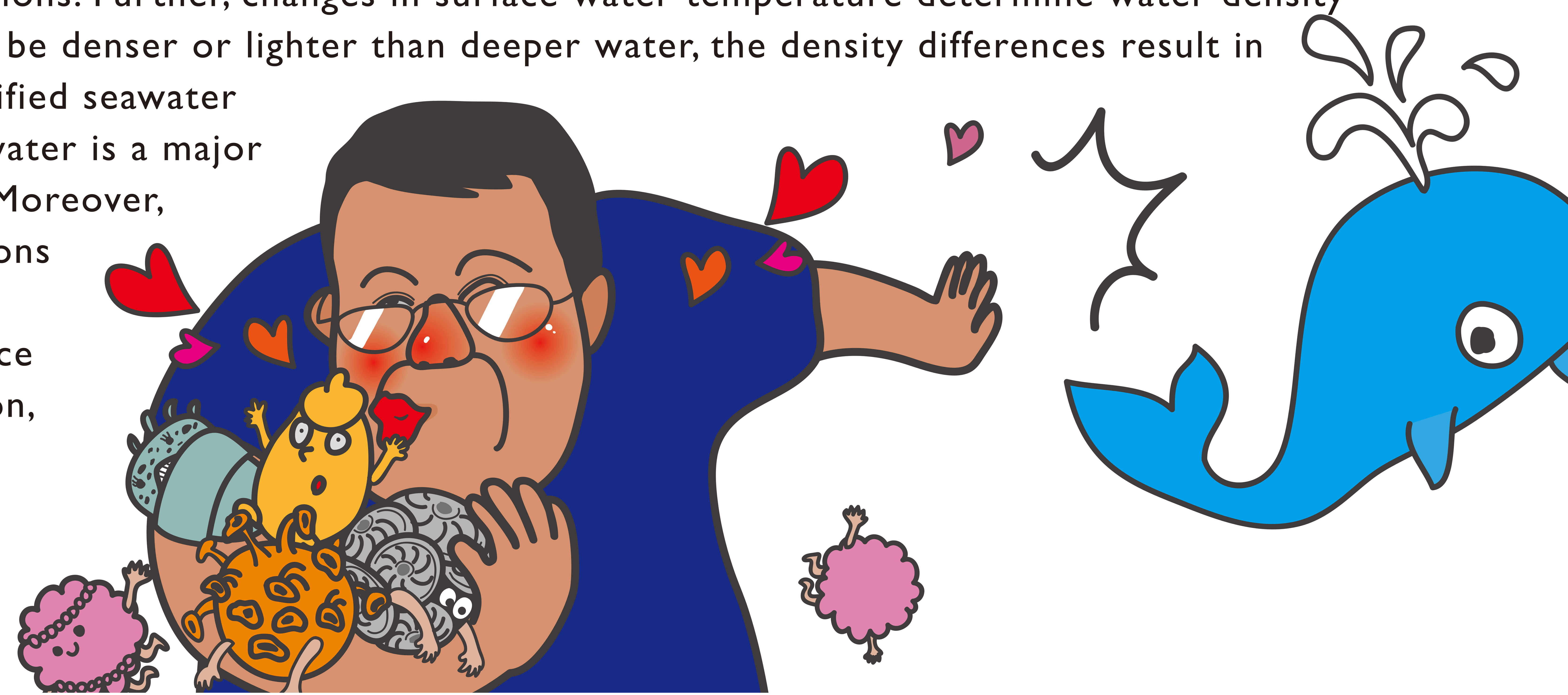
The Content of Oceanography

Dear students and teachers, although whales and dolphins are fascinating, oceanography doesn't focus on the study of fish. In fact, the core of oceanography is actually material and energy cycling processes! Thus, let us use the carbon cycle as an example to explain material cycling processes and the unique multi-disciplinary nature of oceanography.

Currently, one of the most severe environmental issues on the planet is the problem of global warming mainly caused by increasing carbon dioxide. Atmospheric carbon dioxide concentrations have risen over time due to excessive burning (Chemistry) of petroleum and coal by human beings. Because of the molecular absorption spectrum of carbon dioxide (Physics), it is the most important factor in controlling the surface temperature of the planet; further, one of the most important factors in regulating atmospheric carbon dioxide cycling is photosynthesis (Biology). Marine phytoplankton (Biology) accounts for half of the photosynthetic activity worldwide. More importantly, the supply rate (Earth Science) of limiting nutrients (Chemistry) is one of the most important factors in regulating the rapid and dynamic growth of marine phytoplankton (Biology). The factors affecting the supply rate of limiting nutrients are closely associated with climate (Earth Science) and dynamic changes in the movement of seawater and currents (Physics). The other major factor driving material cycling is physical in nature. The effect of physical forces on material cycling starts with the rotation of the earth and the revolution of the earth (Earth Science). Earth's rotation and revolution brings about diurnal and seasonal cycles of daylight and temperature (Physics). These cycles in turn regulate the variations in surface water temperature and sunlight intensity. With the additional influences of the spherical shape of the earth and angle of rotation, surface water temperature and sunlight intensity vary dramatically within the same day or same season in different oceanic regions. Further, changes in surface water temperature determine water density (Physics). Because surface water can either be denser or lighter than deeper water, the density differences result in either the sinking of surface water or stratified seawater layers, respectively. The sinking of surface water is a major driving force for thermohaline circulation. Moreover, wind-driven circulation, caused by fluctuations in sunlight and sea surface water temperature, is the other major driving force of atmospheric and surface water circulation, such as monsoons, winter storms, and typhoons (Physics). On the other hand, wind also affects the movement of surface water (e.g. Kuroshio current) and the



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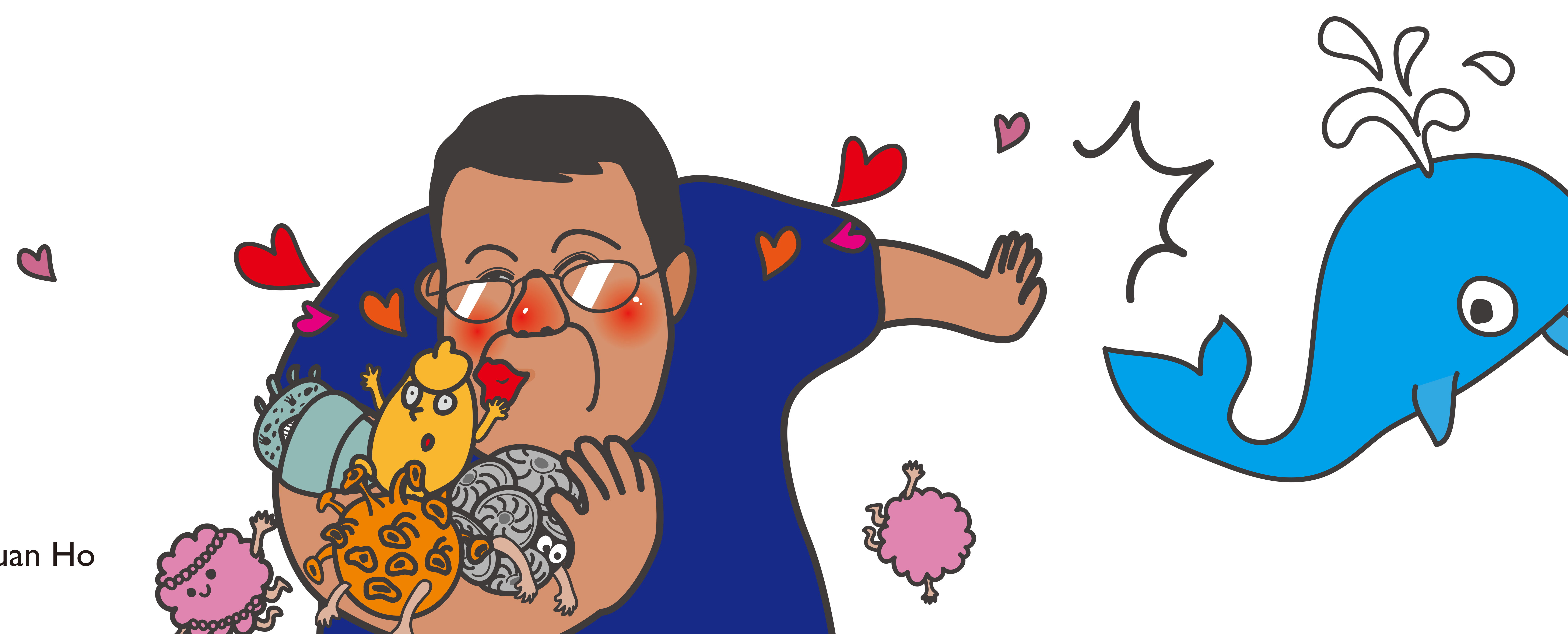
mixing of material in the water. For example, the nutrients in the subsurface water in Kuroshio current is transported to the surface water by physical mixing and the process of upwelling when it encounters a shallower region of the ocean floor (Physics). The mixing and upwelling processes are one of the major causes of biogeochemical reactions in the ocean (Biology). As mentioned above, material cycling in the ocean is closely related to biogeochemical and physical processes. Atmospheric carbon dioxide is also transported to the ocean floor through the photosynthesis and the sinking of organic matter. Microalgae transform carbon dioxide into organic carbon and inorganic carbon shells. Through the process of sinking, both organic and inorganic carbon are transferred to sediment and buried, where they will have to wait until the next mountain uplift event or volcanic eruption (Earth Science) to return to the atmosphere. Moreover, over many decades, carbon dioxide has continuously been dissolving into the surface ocean, resulting in gradual acidification of the seawater (Chemistry). Thereafter environmental conditions for coral reefs and other marine organisms (Biology) have been under great threat. As mentioned in the examples above, it can be seen that material cycling in the ocean is closely connected among the fields of Biology, Chemistry, Physics, Earth Science, and influences global environmental change and climate change.

Therefore, oceanography explores problems on the global scale! Although whales may seem big, their influence on global material cycling is much smaller than plankton! Even though plankton are small, they grow abundantly in rapidly changing communities and are the favorite of Marine Biogeochemists!



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Marine Biogeochemistry:

The cycling of material associated with biological components in the ocean is mainly the result of interconnected effects of biological growth and microbial decomposition, geochemical processes, geological activities, and other processes. These processes mainly take place in the ocean and its interfaces with the atmosphere and sediment. The investigation of the mechanisms and processes of material cycling has become the main subject of marine biogeochemistry.

The two main characters in marine biogeochemistry are plankton and all of its essential nutrients (please distinguish each character in the figure). Plankton can only grow by relying on essential nutrients; at the other end, essential nutrients originate from the decomposition of plankton biomass. Their mutual interdependence not only supports the circle of life but also drives the continuous cycling of material in the ocean and on Earth. Phytoplankton, through the process of photosynthesis, convert carbon dioxide into organic material, where almost all other organisms in the food chain take advantage of this hidden source of energy in organic carbon.

Compared to other major essential nutrients, carbon dioxide is plentiful in seawater and is rarely a limiting nutrient for phytoplankton growth in the ocean. Instead, nitrogen (mainly nitrate) and phosphorus (mainly phosphate) are not only the major elements found in plankton but are also the main limiting nutrients that regulate phytoplankton growth.

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Phytoplankton Growth

Phytoplankton (unicellular algae) in the ocean are able to acquire energy by respiring organic matter generated through photosynthesis, a process transforming carbon dioxide into organic matter.

Phytoplankton are unable to grow and multiply relying on photosynthesis alone; they still depend on various other nutrient sources to survive, multiply, and conduct numerous metabolic reactions. For example, protein synthesis requires nitrogen uptake, DNA or RNA replication requires phosphorus, and various enzymes depend on a variety of trace metal elements, such as iron. When the supply of all of the essential elements is sufficient, the reproduction rates of phytoplankton can double or triple on a daily basis.

In other words, when there is a limited supply of essential nutrients, phytoplankton growth and reproduction is then restricted. The major factors that limit phytoplankton growth and reproduction are chemical nutrients or key physical factors (temperature and light intensity). These factors are called limiting factors.

In terms of chemical limiting factors, as far as we know, the three biggest limiting essential nutrients in the ocean are nitrogen, phosphorus, and iron. If you pour these three elements in bioavailable form into the ocean, microalgae will multiply and overflow into the mountains and the valleys.

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The Source and Fate of Nutrients :

Nutrients can enter the ocean through many routes. One of the major pathways is aeolian deposition, such as the input of ash from volcanic eruptions, lithogenic particles brought by sandstorms, and anthropogenic aerosols. Naturally occurring nutrients in terrestrial systems and those produced by human activity enter the ocean via the input of river water and groundwater. Phytoplankton utilize nutrients to grow and to produce organic matter. Most of the organic matter (90-99%) generated through photosynthesis is internally recycled in the surface layer of the ocean. Only a small amount of the material is transported to the deep ocean (export production). In contrast to regenerated production regulated by internally recycled limiting nutrients, new production represents the primary production generated by the input of external limiting nutrients. These inputs of limiting nutrients, mainly bioavailable nitrogen and phosphorus, determine new production in the ocean. If the amount of organic matter generated in the surface layer of the ocean is maintained at a steady state, the export production is equal to the amount of new production.

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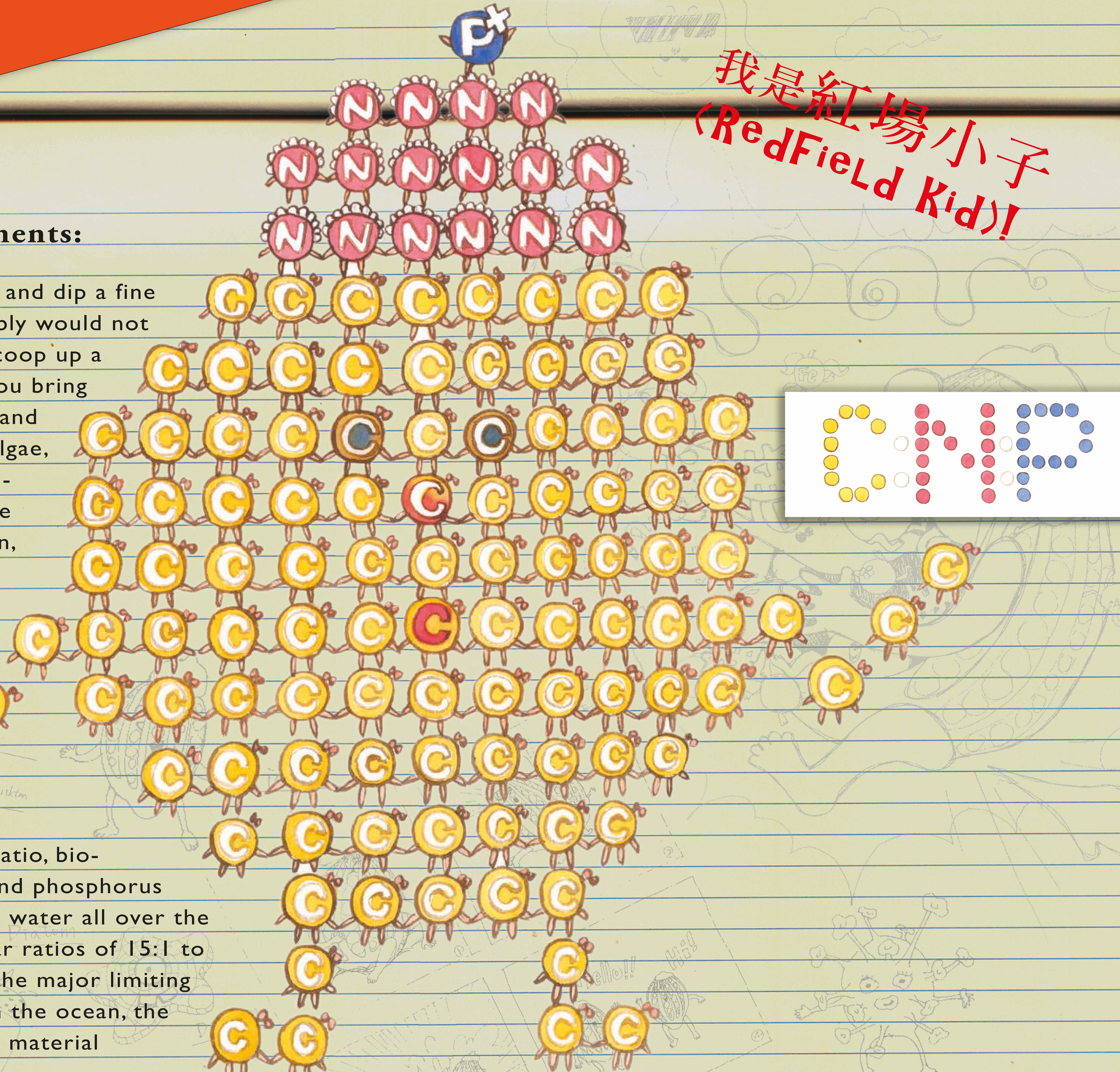
Biologically Essential Elements:

If you take a boat out on the ocean and dip a fine mesh net into the water, you probably would not be able to catch a fish. You would scoop up a bunch of phytoplankton (algae). If you bring this algae back to the lab at school and remove the water from inside the algae, and then analyze the elemental composition of the dehydrated algae, the top three elements would be carbon, nitrogen, and phosphorus (C, N, P). Interestingly enough, among the big three elements are an approximate constant molar or atomic ratio of 106:16:1. Oceanographers call this the Redfield Ratio. A professor at Harvard University named Redfield discovered that in addition to algae exhibiting this ratio, bio-available nitrogen (mainly nitrate) and phosphorus (mainly phosphate) in deeper ocean water all over the world surprisingly also shows similar ratios of 15:1 to 16:1. As nitrate and phosphate are the major limiting factors for phytoplankton growth in the ocean, the ratios are of great use in estimating material cycling in the ocean.



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What Are the Limiting Factors?

The biologically essential nutrient with the lowest relative amount in the environment becomes the limiting factor. If you put too much fish food in your aquarium at home or in the pond in the park, the water will turn green very soon. This means the algae is growing fast and multiplying quickly. It is the same with large reservoirs. If fruit trees are planted nearby and fertilizer is often added, after a heavy rain or typhoon, then the necessary but utterly lacking nutrients suddenly become available for the algae in the reservoir to grow. The vital but usually absent essential nutrient is the limiting factor for microalgal growth.

It is not good news for the ecosystem when nutrient supply is so high that biomass becomes so large that it is no longer sustainable for that ecosystem. Large amounts of biomass eventually become decomposing organic matter, which at the same time greatly enhance both heterotrophic bacteria growth and oxygen consumption. The high oxygen consumption rates cause the aquatic environment to become anoxic.

The open ocean is big and deep. The nutrient concentrations and supply rates in the surface layer of the open ocean are generally low. Thus, phytoplankton biomass is quite low. In contrast, nutrient supply rates are relatively high in the marginal seas. Nutrients can enter the ocean through the transport processes of river run off, atmospheric deposition, and submarine groundwater discharge. The relatively high supply rates of limiting nutrients in the marginal seas thus elevate primary production in the waters. The major nutrients in the ocean are nitrogen (N) and phosphorus (P). Aside from major nutrients, trace metals can also limit algal growth. For example, in the Southern Ocean and equatorial Pacific Ocean, nitrate and phosphate concentrations are high but the relative supply of iron is extremely low. Thus in the Southern Ocean iron becomes the main factor limiting algal growth.

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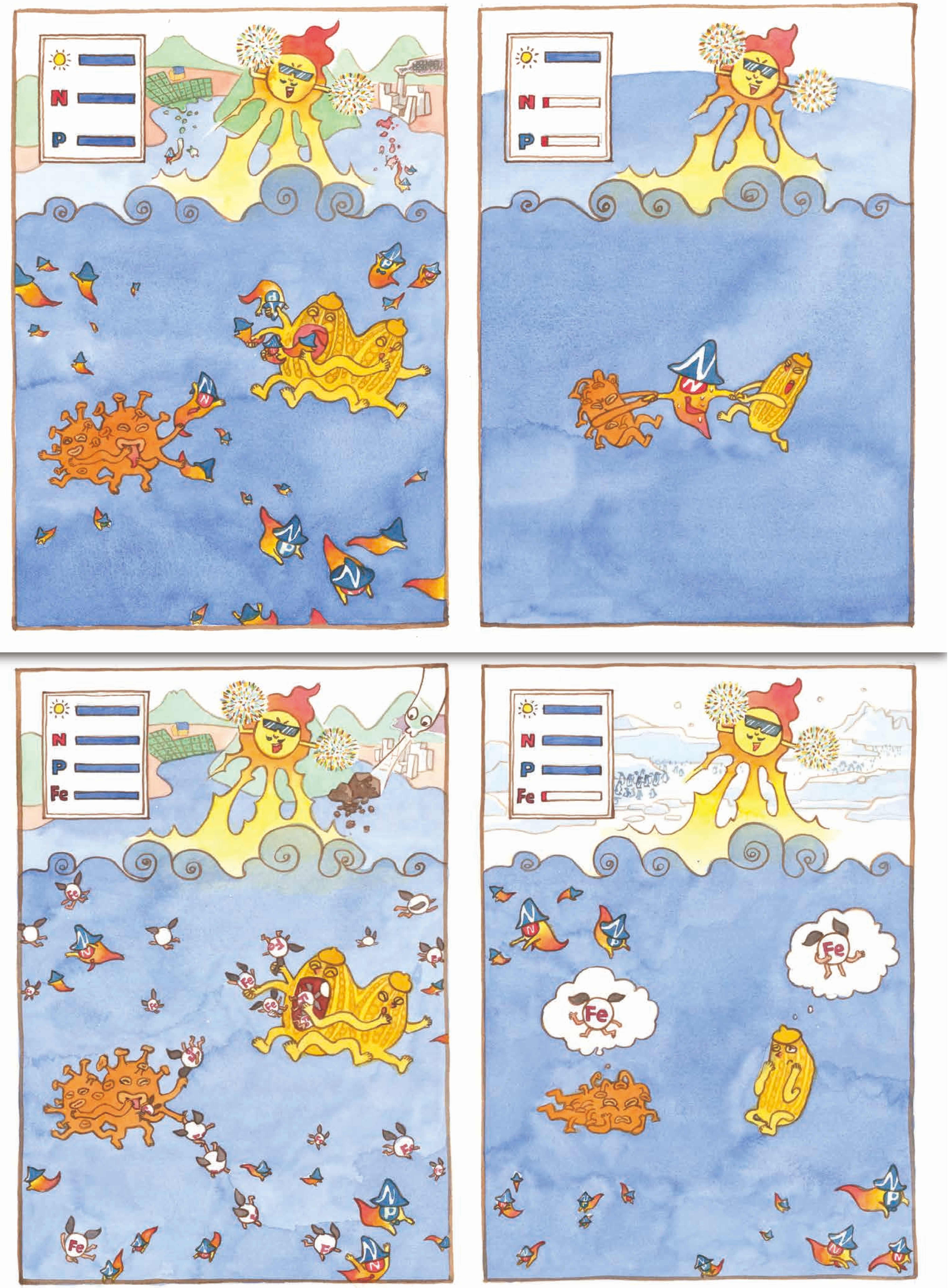

The Food Web in the Ocean— Microbial loop:

The three major players of the food web in the ocean are composed of phytoplankton, zooplankton, and heterotrophic bacteria. Because plankton and bacteria are all quite small and highly interconnected in the food web, we refer to their trophic relationship as the microbial loop. Zooplankton is the little monster that specifically eats phytoplankton. We say they are small because they are only the size of ants or even smaller, and we call them little monsters because they not only look strange but they also devour phytoplankton or other smaller zooplankton live and whole. In regards to their food web relationship with fish, zooplankton and fish are closely connected. Zooplankton are the main food source for many fish larvae as well as some very large marine fish (e.g. whale sharks) and whales. Heterotrophic bacteria depend on consuming organic matter to survive. At your house, food that falls on the floor leads to ants. In the ocean, organic matter that others have dropped is eaten by a myriad of super small decomposers. It can be the bodies of microalgae or excretions from zooplankton. The bacteria decompose these organic matter into inorganic nutrients, such as carbon dioxide, nitrate, phosphate, and trace metals. These inorganic nutrients are utilized and recycled by phytoplankton to carry out photosynthesis to grow. Phytoplankton use photosynthesis to generate organic food. Zooplankton eat phytoplankton to obtain energy and to transfer organic material up to a higher trophic level of the food web. Heterotrophic bacteria decompose the debris and bodies of organisms, releasing anew the nutrients phytoplankton need to grow. This whole process completes the circle of life.

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The Various Groups and the Evolution of Phytoplankton:

Phytoplankton can be separated into two simple categories, prokaryotic and eukaryotic phytoplankton. Their names derive from Greek, where "pro" means "before," "eu" means "well," and "karyote" means "nut." The nucleus (核) refers to the nucleus inside a cell. Prokaryotic phytoplankton originated very early, and their sizes are relatively small. Eukaryotic phytoplankton originated relatively later, and their sizes are relatively big. One can say, one is old, and one is young; one is big, and one is small. The small ones are older; the bigger ones are younger. Prokaryotes do not have cell nuclei, while eukaryotes do have nuclei. Most prokaryotes are bacteria and do not have cell nuclei. Some bacteria are phytoplankton, and some phytoplankton are bacteria. Prokaryotic phytoplankton originated on earth very early on. As a matter of fact, they are the earliest life form on the planet. For example, blue green algae (cyanobacteria) appeared about three billion years ago. At that time, the atmosphere did not contain oxygen. Photosynthesis of blue green algae progressively transformed the ocean and the atmosphere into an aerobic environment. Only after this transformation were various eukaryotic phytoplankton, terrestrial plants, animals, or even people able to come into being. Scientists argue that prokaryotes were transformed into eukaryotic phytoplankton through the process of endosymbiosis. Organelles of eukaryotic phytoplankton, such as mitochondria and chloroplasts, originated in prokaryotic phytoplankton. Mitochondria originated in aerobic bacteria, and chloroplasts originated through endosymbiosis of photosynthetic prokaryotic blue green algae. In other words, eukaryotic phytoplankton originated from prokaryotic phytoplankton.

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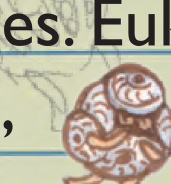
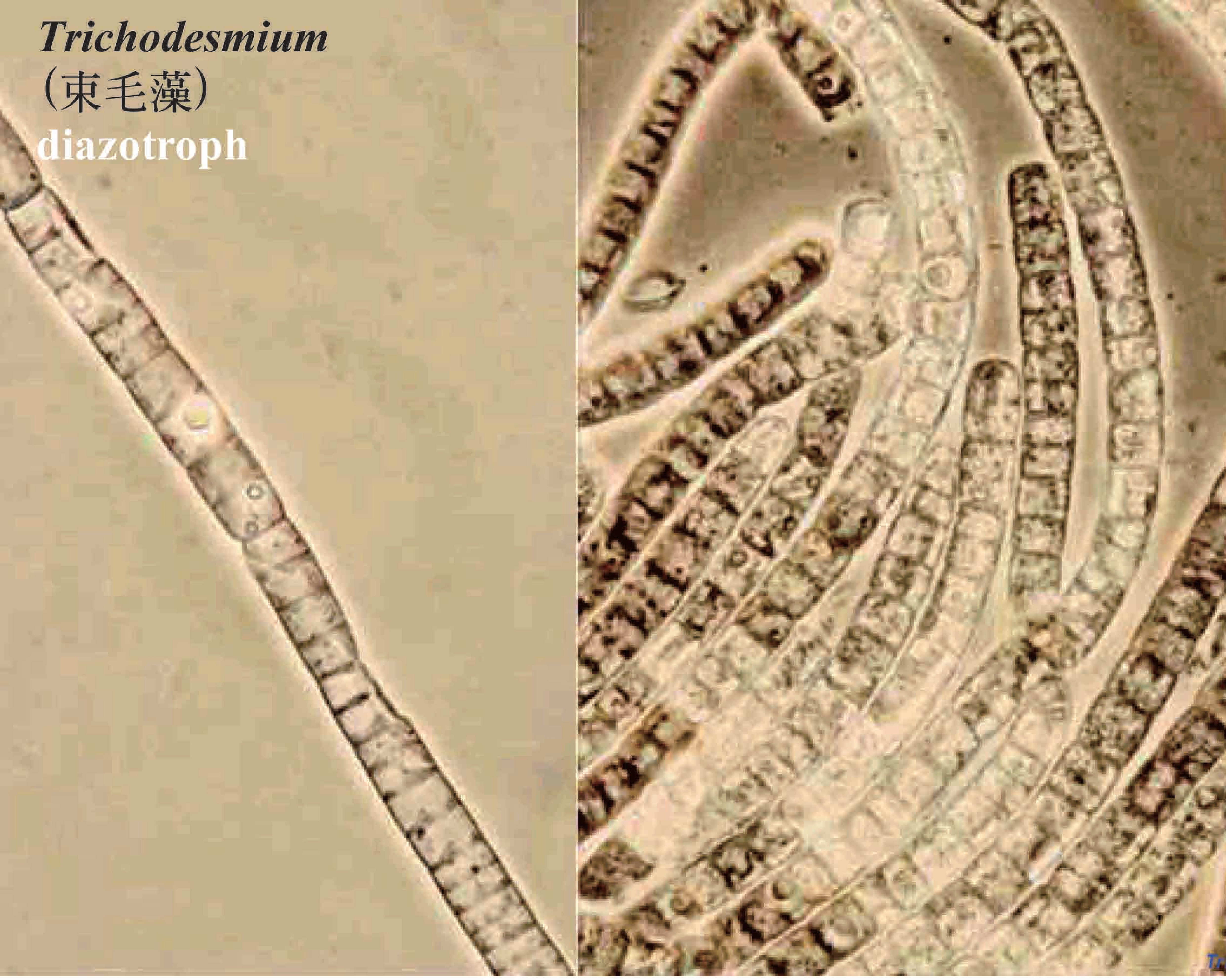
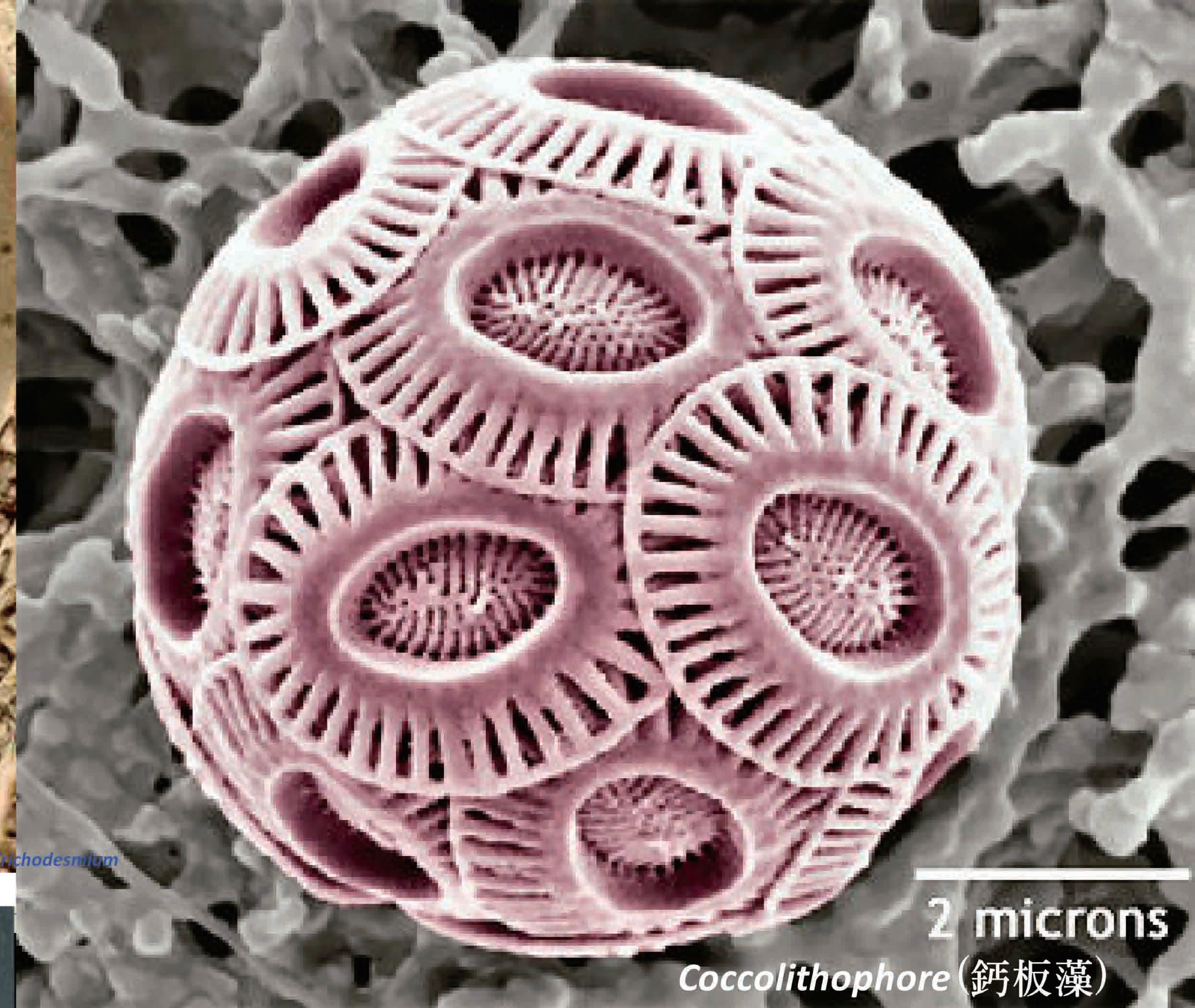
This is the reason why I said earlier that prokaryotic phytoplankton are very old. Not because they can live a long time but because they have been present since the very beginning of life on Earth. They are numerous in quantity, but they are very small in size, only about 0.5-2 μm in diameter (μm: 10^{-6} m). The diameter of a human hair generally ranges from about 17-180 μm. It appears that prokaryotic phytoplankton really are both old and small. Don't be tempted to underestimate them. Two thirds of the carbon dioxide fixed by phytoplankton is produced by prokaryotic phytoplankton. To have lived on the earth so long takes a great deal of special abilities. Eukaryotic phytoplankton are generally larger in size. The main ones are  diatoms,  coccolithophores, and  dinoflagellates.

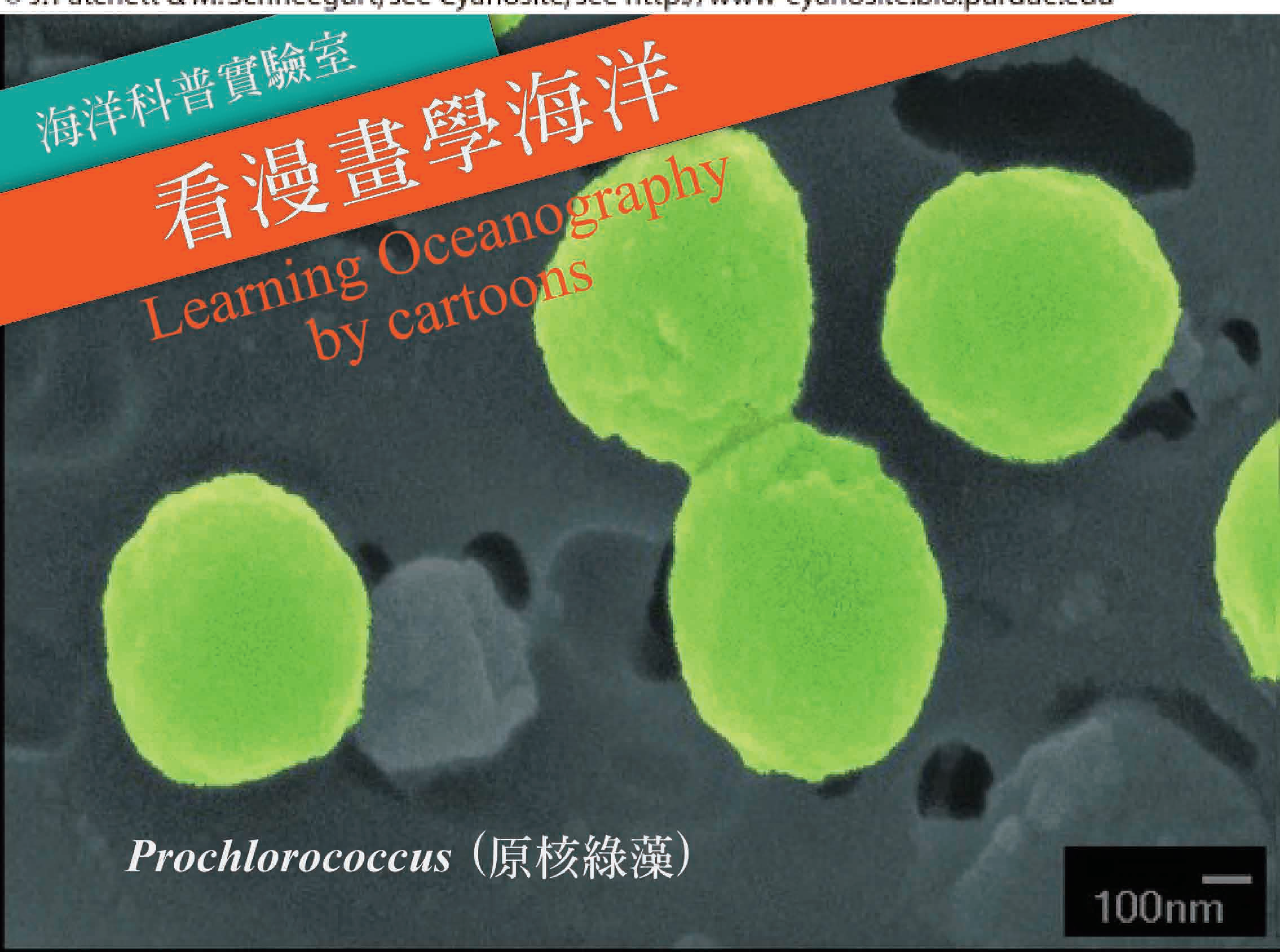


Trichodesmium
（束毛藻）
diazotroph

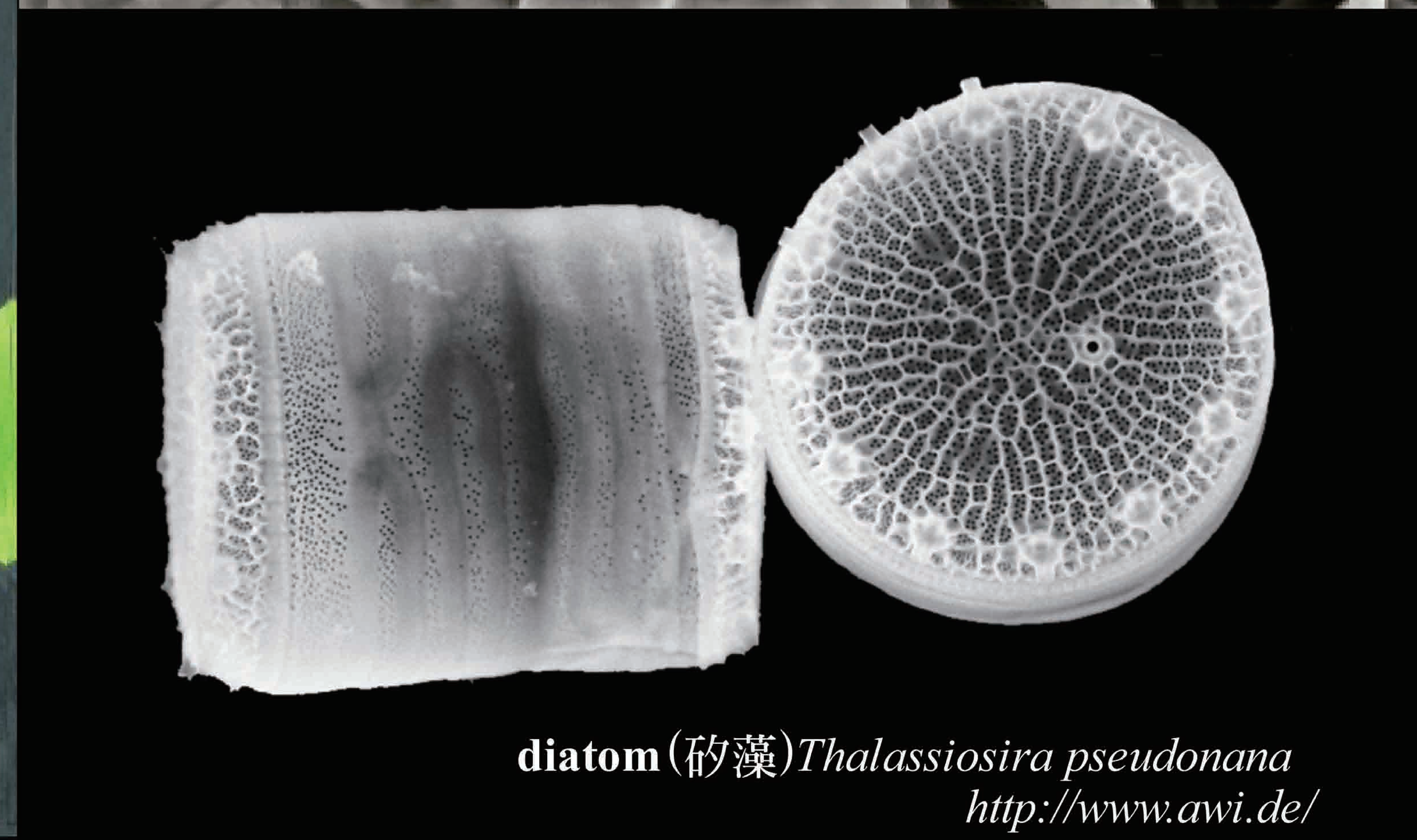
© J. Patchett & M. Schneegurt, see Cyanosite, see http://www-cyanosite.bio.purdue.edu



Coccolithophore（鈣板藻）



Prochlorococcus（原核綠藻）



diatom（矽藻）*Thalassiosira pseudonana*
http://www.awi.de/

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The Ecological Niches of Phytoplankton:

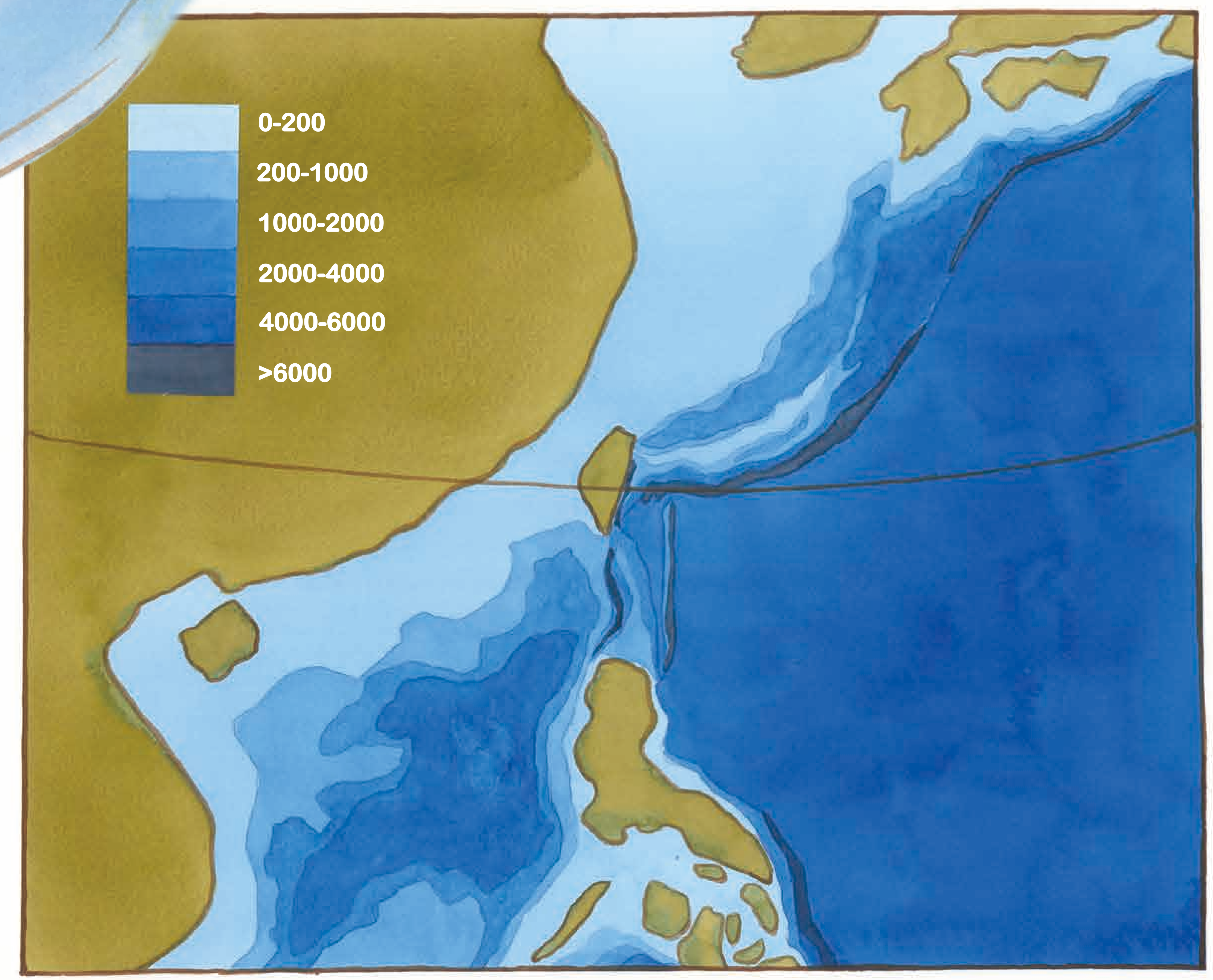
In order to understand material cycling in the ocean and on the planet, it is essential to know the distribution of phytoplankton and its controlling factors. Relatively large sinking particles generated in surface waters sink faster than relatively smaller particles, so they have higher probability to reach deeper ocean water. There, they are decomposed by bacteria into inorganic nutrients. The composition of sinking particles is associated with phytoplankton groups. For example, diatoms are relatively both big and heavy. After death or being grazed by zoo-plankton and formed into fecal pellets, they have a higher likelihood of generating larger sinking particles. It can be the opposite circumstance for prokaryotic phytoplankton. Unless aggregated, these relatively small particles tend to stay suspended in the surface water and are internally cycled.

Physical and chemical environmental conditions are major factors regulating organism growth and abundance. There are two key physical factors regulating the growth and distribution of phytoplankton in the ocean: first is temperature, second is light intensity. Generally, the higher the temperature and/or light intensity, the faster phyto-plankton reproduce and grow. Therefore, at high latitudes, such as the northern and southern polar regions, the physical factors of temperature and light intensity may become seasonal limiting factors for phytoplankton reproduction. Compared to chemical factors, physical limiting factors have relatively predictable temporal regularity. In tropical and subtropical open ocean regions, water temperatures are high and light illuminates the surface. However, primary production rates are relatively low in the euphotic zone of the open ocean, mainly due to relatively low nutrient inputs. Marine phytoplankton are usually present in relatively deep water. For example, in the Western Philippine Sea adjacent to Taiwan, phytoplankton are mainly present at 100-120 meters below the surface. Can you imagine what light intensity is like at that depth? Even though light is scarce, nutrients are in even shorter supply. This is because at this depth, nutrients are just barely diffusing or being transported up from even deeper water. The most important chemical factor is the available amount or supply rate of nutrients (or food). Additionally, the requirements and capacities to obtain different essential nutrients differs among various phytoplankton groups.

For example, the prokaryotic phytoplankton *Prochlorococcus* is able to grow under extremely low light conditions. *Synechococcus* requires a large amount of iron and possesses specific abilities to acquire iron in extremely low dissolved Fe oceanic surface water. Various kinds of phytoplankton grow in their own unique environmental conditions, referred to as Ecological Niches. The original meaning of niches comes from shrines, where statues of Gods are placed. The statues of idols range from big to small, and each are given their own space according to size.

Ocean Currents, Terrain, and Nutrient Supply:

Try to guess the depths of the three seas surrounding Taiwan. Water depth and the material cycling system are closely connected. Using the Kuroshio Current as an example, the Kuroshio Current is a major wind-driven current in the North Pacific Ocean with a thickness of about 700-800m deep. The current originates from the North Equatorial Current (NEC) and flows north from the Eastern Philippines, continuing east of Taiwan. Nutrient levels are relatively high below the euphotic zone of the open ocean (upper layer at 150-200m). When the Kuroshio Current flows to Taiwan's northeast coast, the seabed becomes shallow so that the subsurface water is upwelled and provides high nutrient water to the euphotic zone of the region. This provides phytoplankton with a wealth of nutrients, thus, through the food web, causing the formation of an important fishing ground. Similarly, the subsurface Kuroshio water can also upwell to the East China Sea (ECS). This high nutrient water can be an extra nutrient source in the ECS where the water depth is shallow. Moreover, due to the input of high nutrient riverine water, estuaries are also high nutrient supply regions of the ocean. River discharge also influences nutrient material input and related biogeochemical cycling. Interestingly, the discharge levels of Chang Jiang River can influence the upwelling of the subsurface water of Kuroshio in the ECS. How these two high nutrient waters influence the biogeochemistry of the ECS deserve further study.



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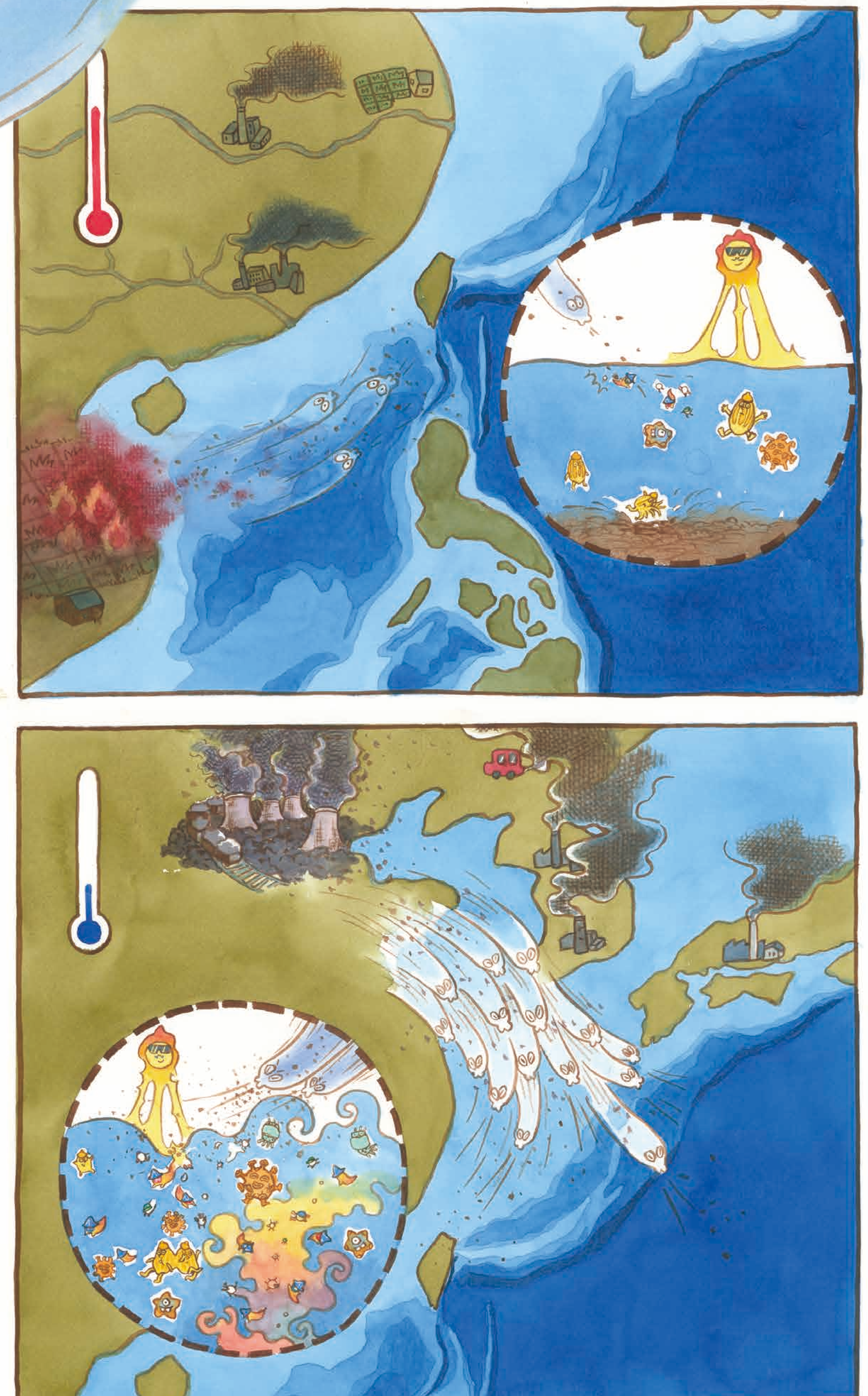
Monsoon and Nutrient Supply

It breezes gently from the southwest in summer; it blows fiercely from the northeast in winter. The monsoons not only bring terrestrial nutrient materials or pollutants, at the same time it is also the main stirring force that mixes oceanic surface water. The mixed layer refers to the depths at which water is fully mixed by the force of the wind. The mixed layer of the South China Sea is at a depth of about 20-30m in summer; in winter, the mixed layer deepens to 70-80 m. In other words, in winter more nutrients are stirred into the euphotic zone. Microalgae can grow even more in winter than summer because in winter the temperature of the surface water in the South China Sea is still quite high. In high altitude regions, because winter storms are extremely intense, in addition to low temperatures, the mixed layer can reach 200-300m. However, also because of low temperatures, it is difficult for phytoplankton to grow. They must wait for the warmth of early spring to utilize the high levels of nutrients provided by the mixing process during winter to multiply immensely. We call this phenomenon spring bloom.



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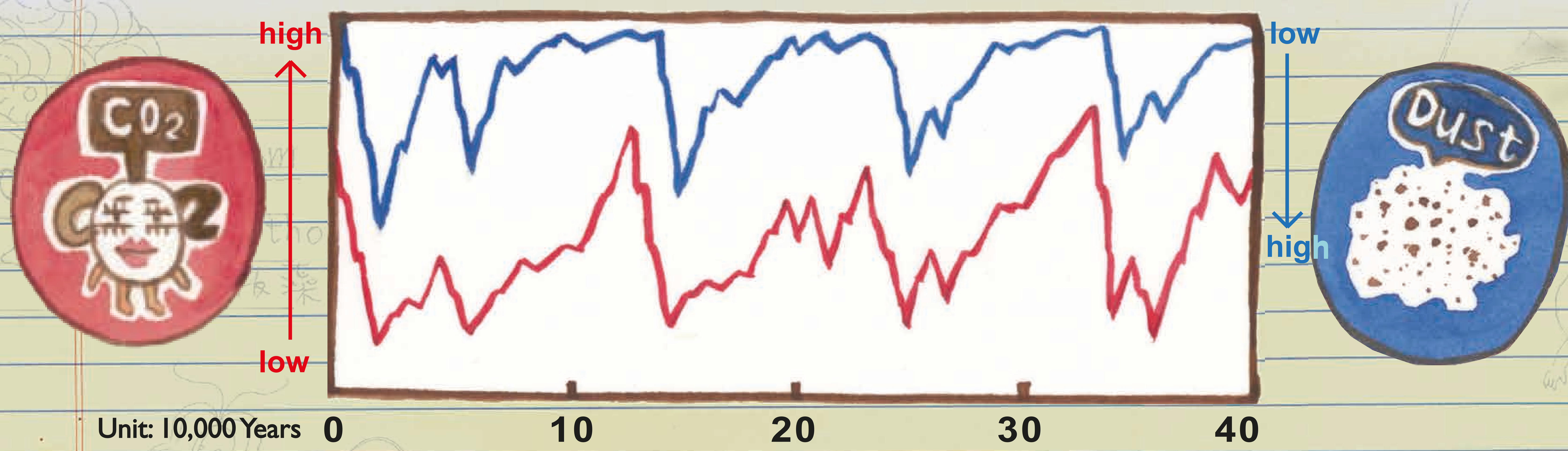
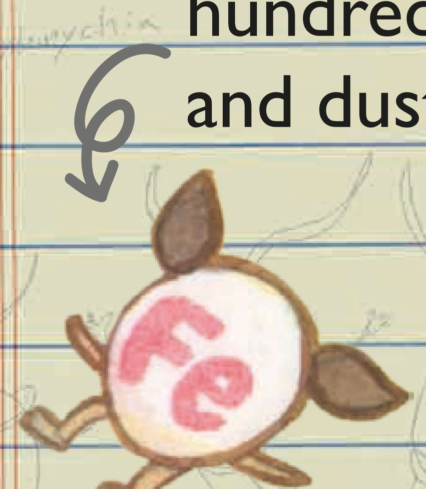
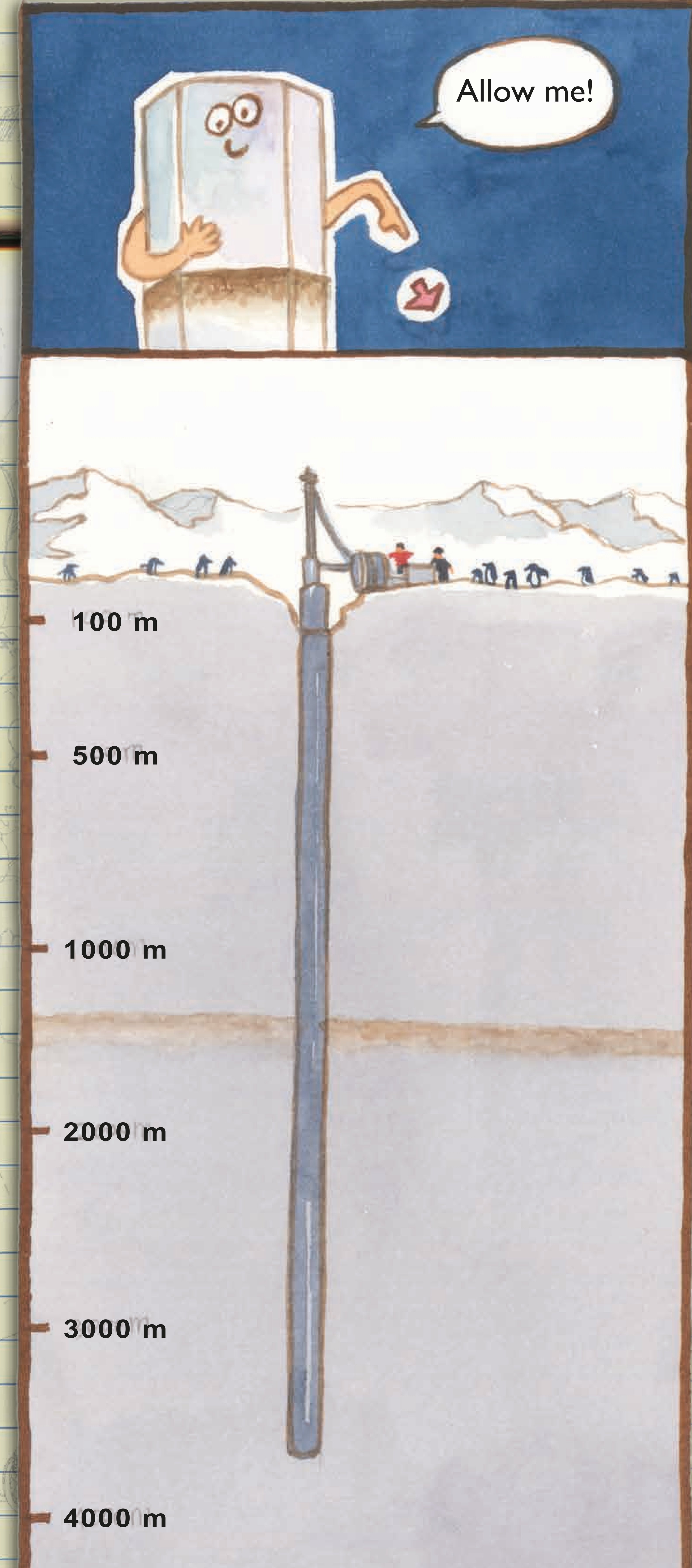


Paleoceanography:
If you do not know your past, how can you know how you've changed over time? To understand who you are now, you must first understand your growth process leading up to this time. Environmental change is the same. The studies related to characteristics and their controlling mechanisms in the ancient ocean is called Paleoceanography.

To understand the changes of the past in the land and the seas, you must first search for specimens that hold a record of environmental changes. Think for a minute, where can you find good materials to study? How about the permanently frozen ice caps of Antarctica? The sediments on the seafloor of the deep ocean, the Loess Plateau of China, ferromanganese nodules at the bottom of the ocean, and so on are all useful materials. Among these, their chemical compositions may hold records of the ancient environmental conditions of the land and sea. We understand there is a close relationship between the concentrations of carbon dioxide and temperature in the atmosphere, and iron flux in the ocean over the past several hundred thousand years. These parameters are obtained from gas bubbles, water molecules, and dust trapped in the ice cores.





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The Iron Hypothesis and the Glacial-Interglacial Period

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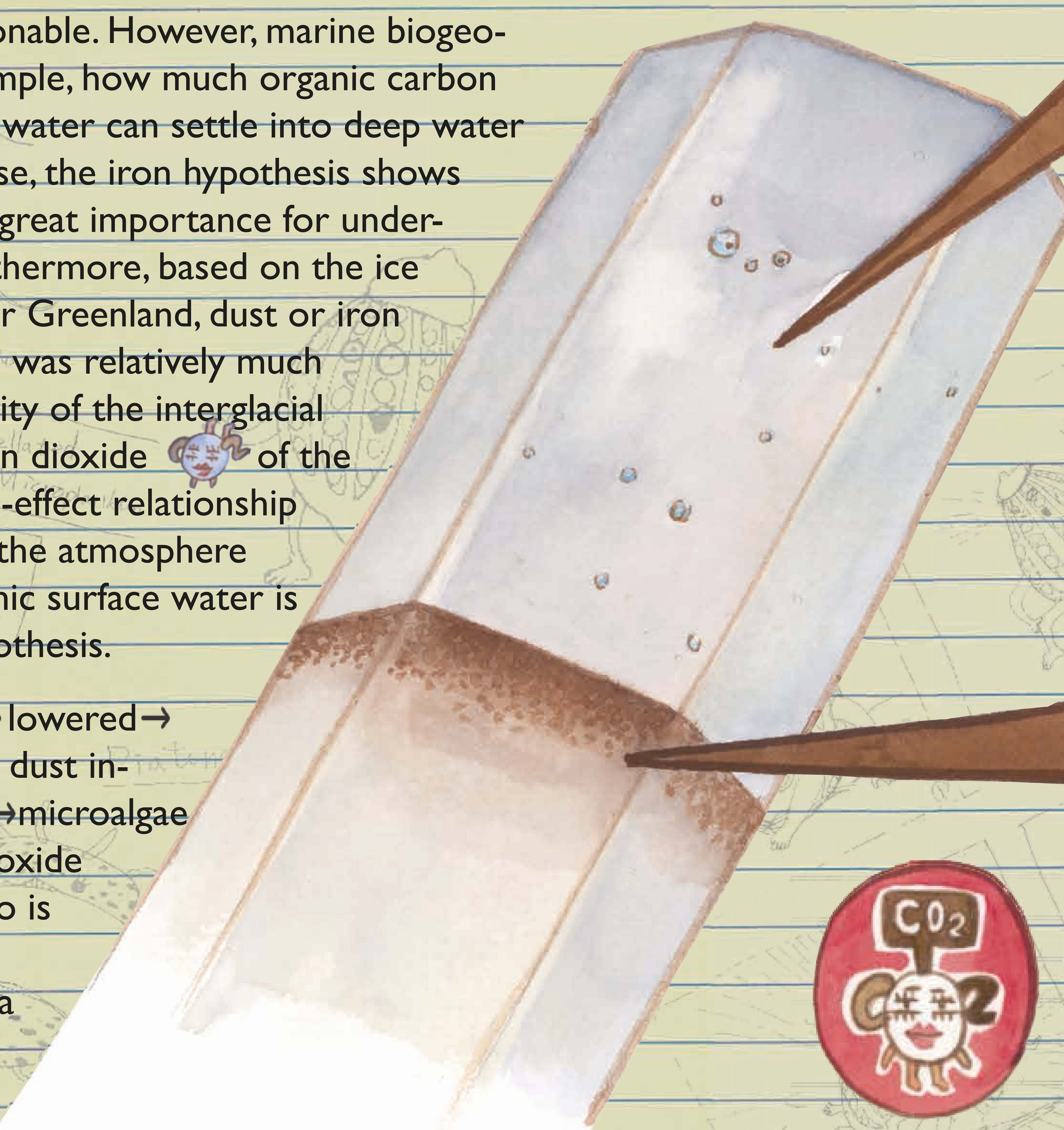
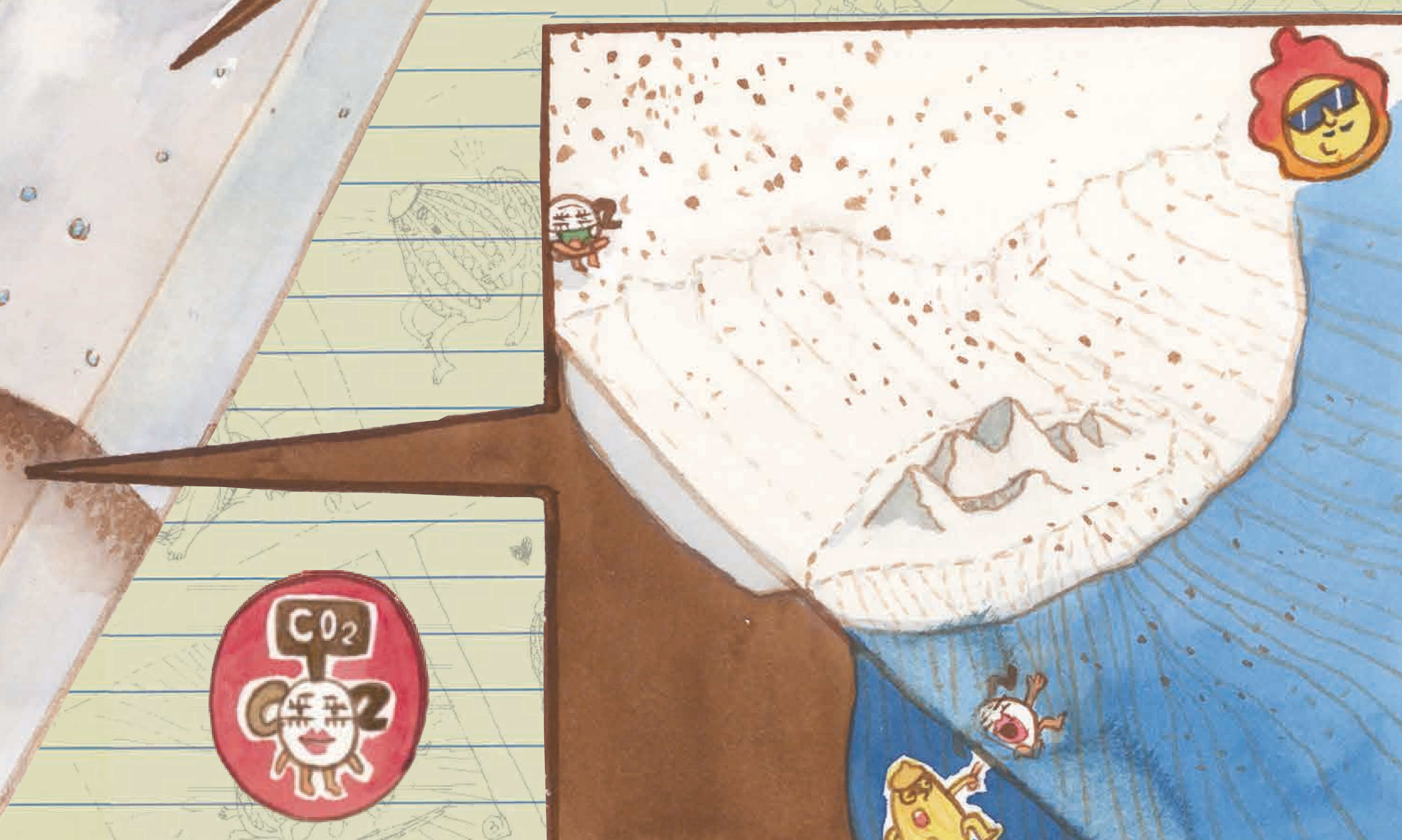
The growth of phytoplankton in one third of the oceans on the planet is mainly limited by iron. In these seas, major nutrient levels are relatively high, yet microalgae numbers are not as high as expected. The American oceanographer John Martin discovered that by adding iron into these high nutrient low chlorophyll (HNLC) domains, microalgae will multiply abundantly. 

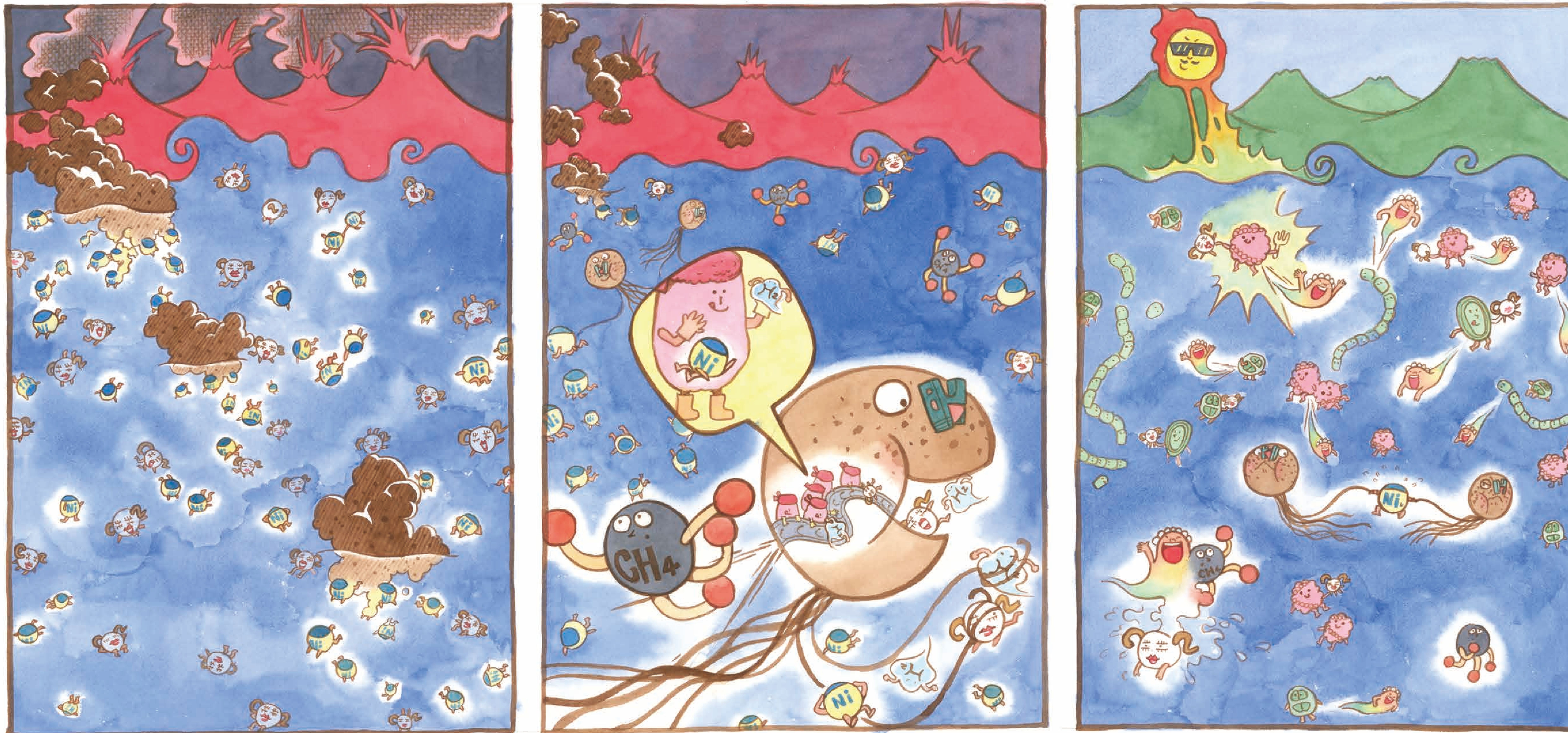
According to the elemental composition of microalgae, supplying one atom of iron into HNLC regions supposedly will allow phytoplankton to fix 100 atoms of phosphorus or 10,000 atoms of carbon. The HNLC region occupies a great majority of the waters around the South Pole and the concentrations of major nutrients are as high as 10uM. John Martin estimated that with the addition of Fe into the large HNLC regions, microalgae photosynthesis is then promoted under conditions replete with nitrogen, phosphorus, and iron. Atmospheric carbon dioxide will be converted to organic carbon and should be deposited into the ocean. The carbon dioxide content in the atmosphere will then fall to glacial period concentrations, about 200ppm and resolve the problem of global warming! This is the famous Iron Hypothesis.

The concept behind this hypothesis is reasonable. However, marine biogeochemical cycling is not that simple. For example, how much organic carbon generated by photosynthesis in the surface water can settle into deep water or can be buried in the sediment? In any case, the iron hypothesis shows that studying marine biogeochemistry is of great importance for understanding material cycling on the planet. Furthermore, based on the ice core record discovered in the South Pole or Greenland, dust or iron availability in the ocean of the glacial period was relatively much higher than the concentrations and availability of the interglacial period. The known concentrations of carbon dioxide of the glacial period were relatively low. The cause-effect relationship between carbon dioxide concentrations in the atmosphere and iron availability in the ancient oceanic surface water is another important concept of the iron hypothesis.



Is it lowered atmospheric carbon dioxide → lowered → temperatures → drier climate → wind-blown dust increase or dust input to the ocean increase → microalgae grow and multiply → atmospheric carbon dioxide decrease? Exactly who is the cause, and who is the effect remains unclear. The figure shows that the Taiwan Strait became land when sea level decreased up to 120-130m during the glacial period.





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Nickel Hypothesis

From A to Z is the advertisement of Centrum, the vitamin supplement company. Z stands for Zinc. Organisms need essential trace metals, but if they consume too much they will get metal poisoning and if they consume too little their health will be greatly impaired. For example, the enzyme, superoxide dismutase (SOD), is essential to remove free radicals from the body. This enzyme requires Fe, Mn, or Cu and Zn to become functional. Many key biochemical reactions in the body are catalyzed by enzymes. Enzymes are mainly composed of amino acids. The most important part of an enzyme is the active site, where catalytic reactions take place. For most enzymes, trace metals are essential components in their active sites. Therefore, if an organism is lacking in a specific necessary metal or is unable to acquire an adequate amount, these metal requiring enzymes are unable to work. The organism's growth and reproduction will be limited. The transition from an anoxic to an oxic environment in the ocean was a critical turning point for biological evolution on Earth. The Nickel Hypothesis argues that the transition was caused by decreased supply of Ni in the ocean. For methanogens to form methane, they need to use three critical nickel containing enzymes. If the supply in the ocean drops, the metabolism of the methanogen that uses nickel will also drop. Following, the production of methane will drop, and photosynthesizing phytoplankton had the chance to become dominant in the ocean. Oxygen was then able to begin accumulating in the ocean and in the atmosphere, resulting in the evolution of marine and terrestrial organisms (Konhauser et al. 2009). Nickel is an element in the iron group with a relatively high melting and boiling point. In the early oceans, nickel mainly originated from high temperature eruptions from volcanoes. As the Earth gradually cooled and volcanic activity decreased, this supply also quickly decreased. In 2009, a Canadian scientist Konhauser and his colleagues observed the decreasing trend of nickel content in rocks and proposed the Nickel Hypothesis mentioned above.

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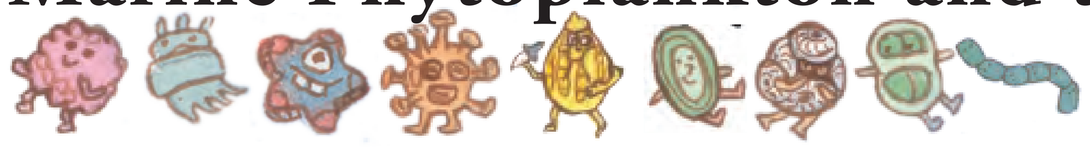
Marine Phytoplankton and the Great Oxygenation Event:

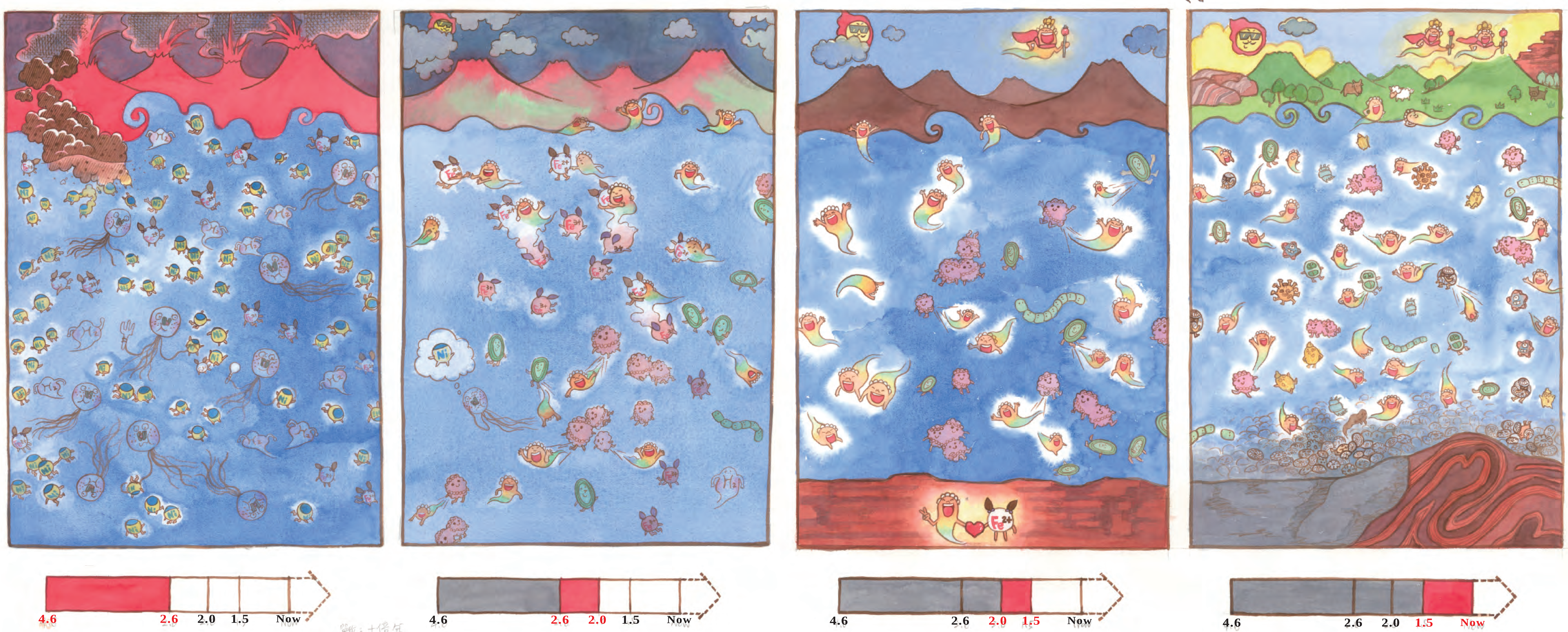


Based on the dating information from ancient sediment samples containing phytoplankton specific organic matter, scientists estimate that prokaryotic phytoplankton began to appear about 3.5 billion years ago. However, atmospheric oxygen  did not appear until about 2.4 billion years ago, almost one billion years later.

Why? The most plausible explanation is that the oxygen released from phytoplankton photosynthesis was removed by redox reactions with the large amount of the reducing substances in the early ocean. This way, oxygen in the ocean did not have the opportunity to appear in the atmosphere.

These reducing substances include ferrous iron , methane , and so on. Methane produced by methanogens also was stored in the ocean earlier than 3.5 billion years ago. Under high UV conditions, methane reacts with oxygen. Moreover, iron abundance in rocks reaches as high as 5% by mass. That is why the ancient ocean could contain up to mM concentrations of iron (II). Oxygen released from phytoplankton photosynthesis was oxidized by ferrous iron, forming the iron(III) oxide and iron hydroxide particles, which were deposited onto the ocean floor.

The formation of the Banded Iron Formation (BIF) is a powerful piece of evidence. The oxygen used to form the BIF is more than twenty times greater than the amount of oxygen currently in the atmosphere. One billion years later, ferrous iron and methane in the ocean have been exhausted, causing the start of oxygen accumulation in the ocean and the atmosphere. Thus also launching the evolution of organisms! Why has all the methane in the ocean been used up? It is probably because the numbers of methanogens kept dropping. How come methanogens did not keep dominating in the ancient ocean? Please take a look at the poster on the Nickel Hypothesis.



Unit: one billion years

Author: Tung-Yuan Ho / Illustrator: Ya-Ling Huang / Translator: Claudia Chern and Tung-Yuan Ho

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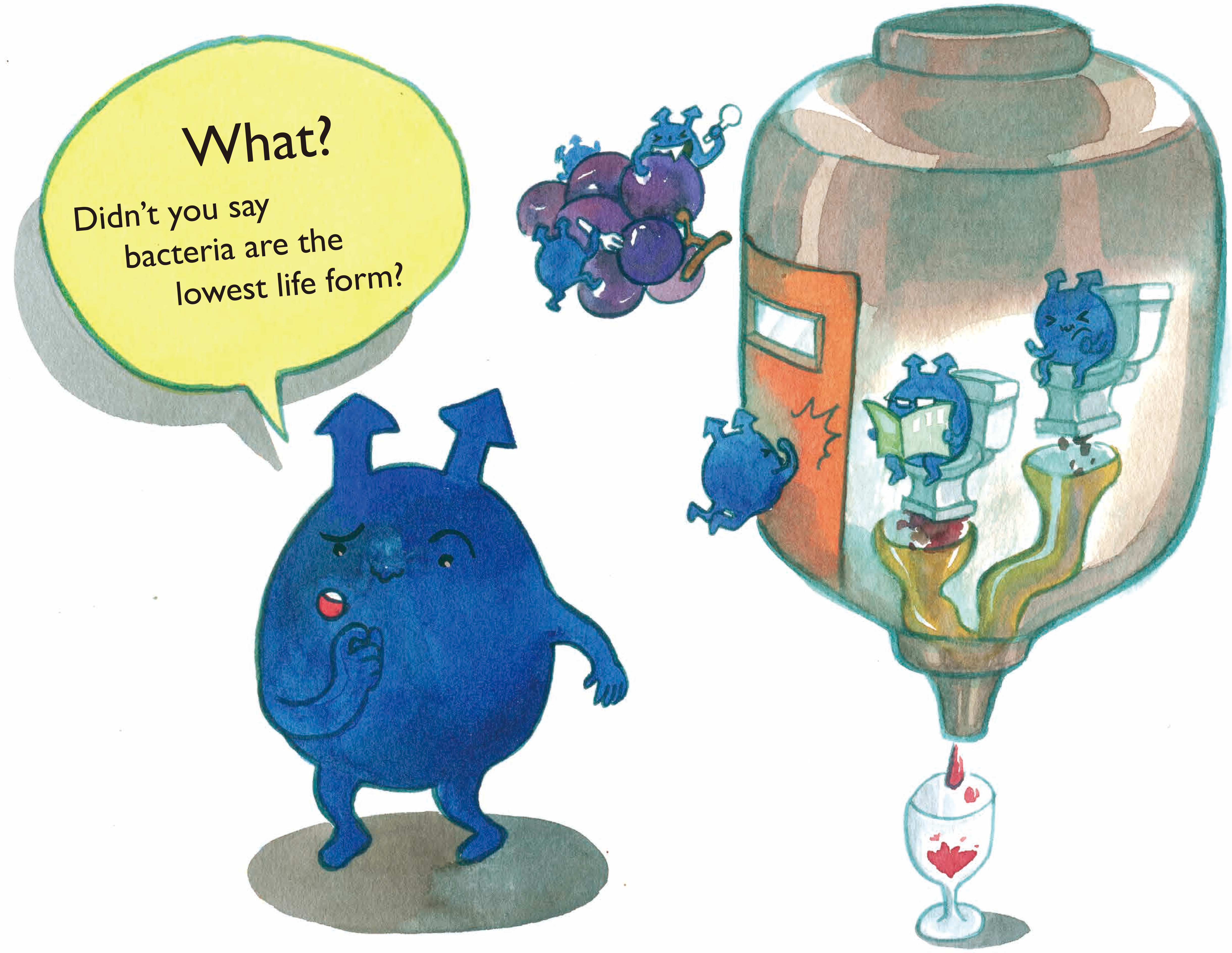
The Role of Humanity:

The human race seems very intelligent. We have discovered a great variety of scientific principles and developed many advanced technologies. We have found fossil fuels and utilized it to establish modern civilization. However, we seem to be quite slow to understand the huge problems we have caused. By burning fossil fuels and eradicating forests over the past two hundred years, we have raised atmospheric carbon dioxide concentrations to 400 ppm. Yet, over the past hundred thousand years atmospheric carbon dioxide concentrations had been oscillating between 180 to 280 ppm. The sharp increase has led to global warming, ocean acidification, and abrupt climate and environmental changes.

How well do we understand how the planet works? We aren't even able to accurately forecast the time and location of typhoons making landfall. How much confidence can we hold in the ability to forecast the future of environmental changes on the planet? Can the workings of the global environment be as simple as handling a car, tell it to reverse and it will reverse? Or is it like a boat, taking considerably long to reverse? Or is it like the Titanic, with an iceberg collision in its future, never again able to revert to its original state?

Who said the human race is the highest life form? These fermenting bacteria may not agree. When drinking alcohol, be sure to appreciate the contribution of the fermenters. Then your spirit might be quiet enough to hear what nature is trying to say.



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About the Author: How I Got Into Oceanography

I really like this credit card commercial. A grandma is holding a credit card and she says, "I want to study abroad!" She puts it well! A lot of opportunities are not always available. When the opportunity presents itself, one must jump to obtain it, be bold and willing to give it a go! Grandpas, grandmas, dads, and moms who want to study abroad should go themselves and should not tell others to go.

My grandfather gave me my name. If you Google my Chinese name 東垣, you will not only find 何東垣 but also 李東垣, who was a famous doctor in the past. You have guessed right. My grandfather originally hoped that I would become a famous doctor. Additionally, the original definition of 垣 means city wall. My hometown is located at 苑東 Village of Yuanli (苑裡) Township, and it also holds a sense of safeguarding the home. My name was chosen in quite a scholarly manner. However, I gradually came to find that this 垣 character is a bit too erudite. Very few people know the correct pronunciation and strokes. A large number of people read it as huan2 桓 or heng2 恒. Some people even think they are quite clever and think I wrote one extra stroke. When they return my letter, they actually change it to 何東坦 Tung-Tan Ho! For a while, I complained about Taiwan's Chinese teachers.

As a student, my preferred way to introduce myself was to use phrases like 垣 in 北斗星垣 or in 省垣, which both use my character. Yet, people who knew what I was talking about were still few; later, I finally had to use the phrase 恆 but say to change the left side of the character from "heart" to the character for "earth." And tell them to pronounce it like the word for 圓. This kind of introduction is pretty tedious. In middle school, my older sister wanted to help me. She said 垣 is just a combination of one 一 earth 土 day 旦. Sometimes I borrow this comical way to introduce myself. It isn't easy having this name! In high school, I chose the field of medicine and agriculture, but even though my name is Tung-Yuan, my college entrance exam score was not high enough to enter medical school. At the time, if you didn't get into medical school, the next option in my category was agriculture, fisheries, or animal husbandry. I still remember that summer 30 years ago. Right after the college entrance exam and with nothing left to do, I went to a choir practice with the Chinyun Chorus. I heard that there were many pretty girls there; you must know what 18 year old boys daydream about. I really did encounter a pretty older girl with a pleasant disposition. At the time, I had not filled in my preferences for my college major, and I asked for her opinion. I also told her about my problem. I didn't know which direction to go. Agriculture? Oceans? Or Animal Husbandry? You know what? Her advice really influenced my decision. She said, "The oceans are vast and wide, fitting for a boy like you…" So that was that. I selected the oceans related departments on my form and started down the path towards oceanography. I would say this was the beginning of my career.

However, the careers available to oceans related graduates are limited. In my senior year of college, I began to feel the vastness of what the future held. Almost all of my classmates made career changes after graduation. Those who stayed in the research field were mainly in the biological sciences departments. Looking back, why did I still stay in the oceanography field? I slowly realized there was an even deeper reason. It is because when I was young, I had many wonderful experiences with the ocean! I was born in Yuanli and lived there until I was seven. There is a small harbor in my hometown. The traditional market is only 50 meters away from my home. Every morning it was full of all kinds of freshly caught seafood. I used to go with my grandpa or grandma to buy groceries; up until now, I still enjoy chatting with the vendors who sell produce and fish in traditional markets. Moreover, my aunt lived in the adjacent township Tongxiao, which used to have a big beautiful beach. When I was little, I often went there to play in the sand, in the water, catch hermit crabs…I also spent my four years of college in the beautiful Sizihwan Bay and after graduation was assigned to Penghu for my two year military service. I greatly enjoyed the fantastic ocean views in Penghu. When I looked back upon these unique and wonderful experiences, I then realized that I have been near the sea since childhood and filled with curiosity for the ocean, yet did not know it before.

Regardless of whether or not she had the insight, I must thank the pretty older girl. After I took the college entrance exam, I really did not know which direction to go. Even though I did not succeed at becoming a doctor, I have become a happy oceanographer! As an adult I've also realized, riding a bicycle and driving a car have their own sceneries to enjoy. A car can drive fast to see far away landscapes, while riding a bike allows one to have a clear view of roadside scenes. Often eating gourmet foods of course cause envy from others, but then you do not experience the great enjoyment of eating gourmet foods gained from eating it only once in a while. The delights of social interactions at traditional markets also cannot be replaced by the comfort of air conditioning at supermarkets. Life is short and opportunities are limited. Try to understand yourself and your individual niche. Then pursue it with courage. Then you are able to take responsibility for yourself and confidently face the consequences. You ought to succeed, but if unsuccessful, it is still worthwhile, as you will have no regrets in life. And you can always start the journey anew. How can grandpa, grandma, dad, and mom not be touched by such a conscientious child? And how can they not give their full support?

-Tung-Yuan Ho

Translator: Claudia Chern and Tung-Yuan Ho

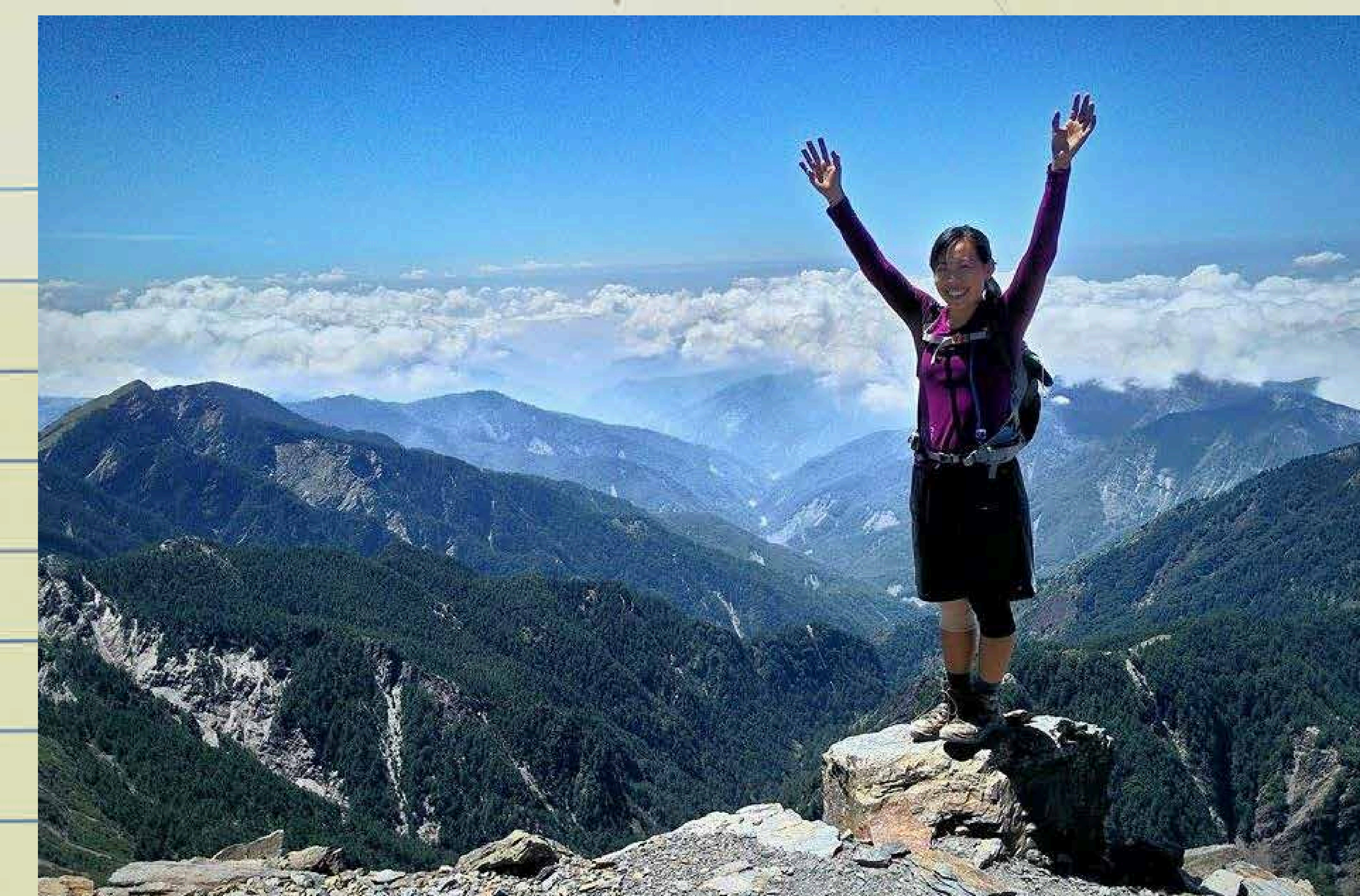
About the Illustrator and Translator:

Ya-Ling Huang

Illustrating the Marine Science posters was the first time that I have undertaken a long project that relied heavily on large amounts of discussion. Dr. Ho told me I was the illustrator in Taiwan who held the best understanding of the ocean and that these science illustrations would play a very important role in marine science education. It appears I had no idea this project would hold such great significance to me at that time. During our first meeting when I was introducing myself, I was like many others and thought fish were the subject of marine science. Thus, I gave this kind of self-introduction. I said I saw this National Geographic program called Treasures of the Deep on TV once. I saw many kinds of fish with very strange appearances and that's how I developed an interest for this project. Then Dr. Ho said fish are a part of the ocean but definitely are not the ocean. It was then my understanding of the oceans was expanded.

As I was creating the scientific illustrations, bringing the microalgae characters to life was one of the most interesting things; not just creating an interesting picture but most importantly accurately conveying the concepts of marine science. This is what I found to be most challenging. I found completing an illustration after many edits brought me a great deal of joy. If these illustrations leave the reader with an interest in oceanography, then I would be most excited and proud of my work.

I don't think these illustrations are to make people to think I am talented but to allow people to feel happy looking at the work. When Dr. Ho said, these illustrations that I have drawn play a significant role in marine pop science education, and on top of that the ocean is very important to the global environment, the impact far exceeded what I originally imagined. I began to understand the extraordinary meaning that the illustrations could bring both to readers and to me. I didn't know that little me could put forth such strength. Where we live is just like being in the middle of the vast ocean. Through the endless cycling of materials, we are one small link in a huge system, but an indispensable one. From this day forward, after getting to know the ocean, perhaps you will also be captivated.



Claudia Chern

I was born and raised in California and returned to Taiwan to explore the oceanography research field, learn Chinese and get to know my ancestral home. I am very thankful to Dr. Ho for this opportunity and to the members of the Marine Biogeochemistry Lab for their patience and willingness to teach. In my time here, I have enjoyed exploring Taiwan's breathtaking high mountains and discovered a love for rock climbing by the sea on the scenic Northeast Coast. This is my first formal translation project. I am excited for this opportunity to contribute my skills to a project of significant impact, while enhancing my language skills through an academic topic of interest. Although I already knew the oceans significantly influence the global environment, especially in face of climate change, my understanding of just how immense and intricately balanced that impact can be has bourgeoned through the course of this project and my time in the lab. From my previous experiences with popular science education, I have come to understand the importance and challenges of communicating scientific concepts to the public well. I am honored to contribute to such a valuable resource for marine popular science education.

Additional contributers: Mei-Chen Lu, Betty Liu, and Zhong-Ning Zeng