Cellular Biophysics
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Tutorial 7

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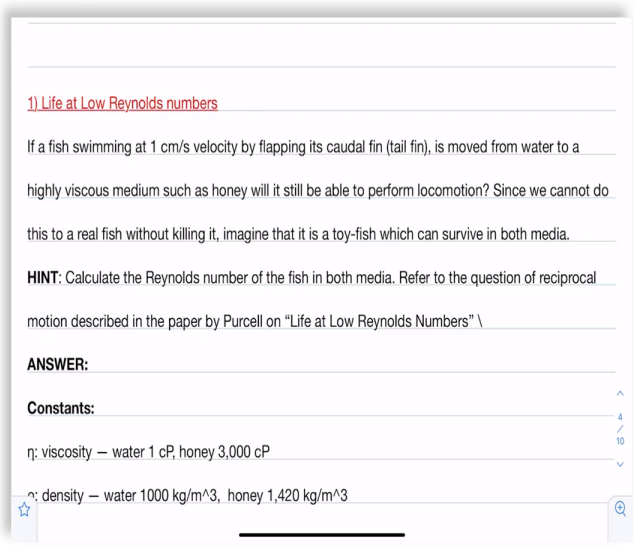

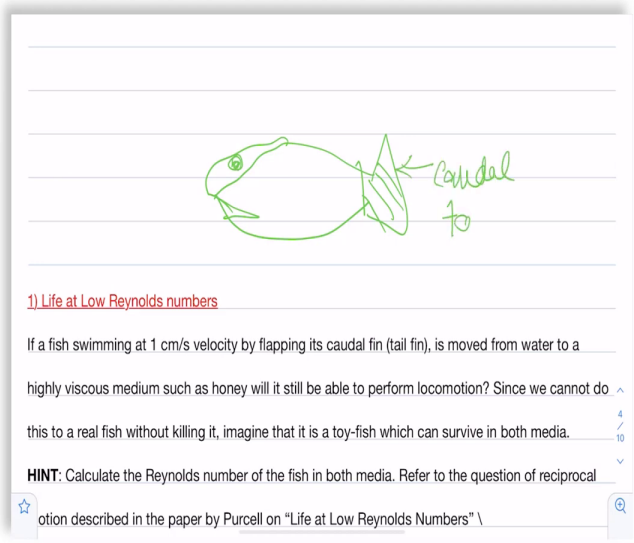

So in this segment, we are going to discuss a few problems. Many of you may have had the opportunity to look at fish swimming. And you are welcome to do a quick internet search, because that will tell you what the typical flapping wings, flapping nature of fish, caudal tail fin are, how they move. So we are going to ask the question that if a fish is swimming at one

centimeter per second, by flapping its caudal tail fin. So by caudal tail and caudal fin, I mean this part of my drawing this is the caudal tail. In such a case, if it is moved from water to a viscous solution, like honey, will it still be able to move? That is the first question.

And depending on your answer, you need to justify the answer. So, which means that you are not just expected to answer yes or no, because that is not interesting. You do not know how you think. The hint to this problem is to calculate Reynolds number of the fish both media and refer to the question of reciprocal motion that is described in the paper by purcell on life at low Reynolds numbers.

So, in a sense, I am asking you to do two three things, I am asking you to do your calculation, I am asking you to read, I am asking you to understand, and I am asking you to arrive at an answer for an experiment that you can actually do if you have such a toy fish. I am going to give you a few seconds to think about this.

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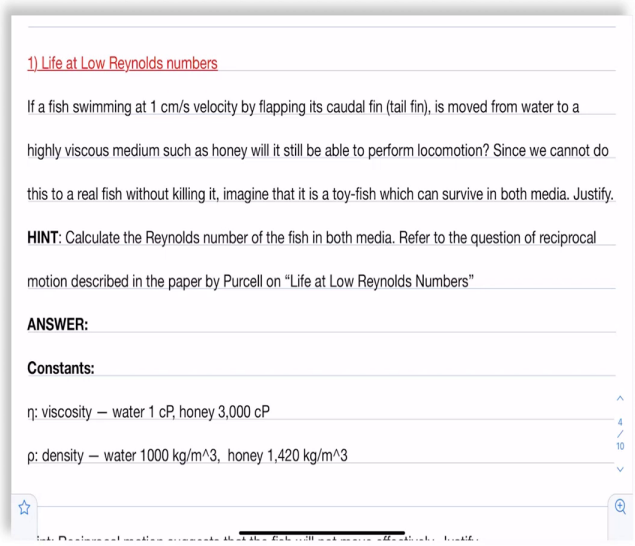

So, some of the constants that you will need for this are viscosity, which for water is one centipoise and for honey is 3000 centipoise. You remember we discussed this during one of the earlier tutorial examples of viscosity as measured using the ball drop viscometer and so we are using that number 3000 centipoise and for density we are using 1000 kg per meter and the density of honey is 1420 kg per meter cube.

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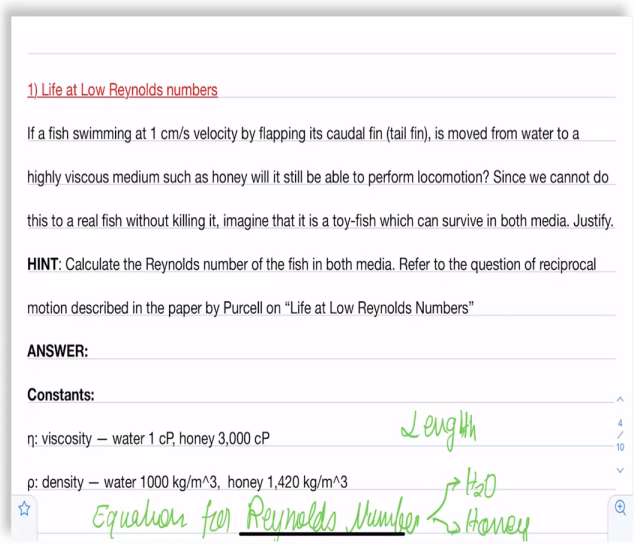

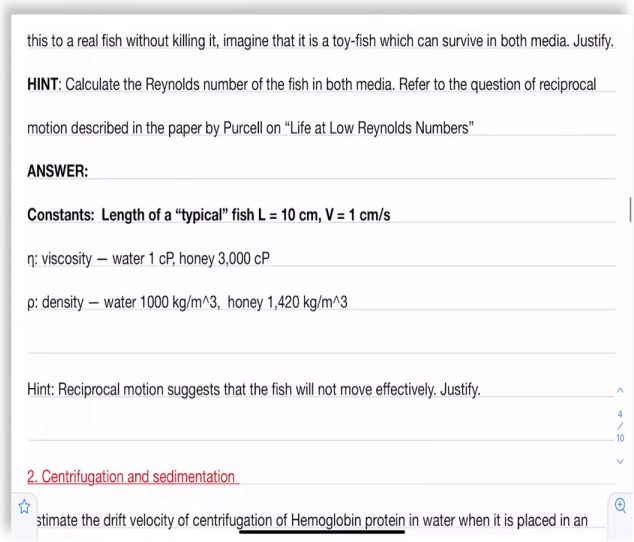

So, you need to substitute these values into the equation for Reynolds number in the case of water and in the case of honey, once you have done that, you will get an answer which tells you what the Reynolds number of the fish in the two media are, you will also need a typical length scale which I have not given you so I asked you to take a value for typical length of a typical fish to be L is equal to, now you can imagine fish come in all sizes from very large 10 to 50 meters to very small. So we will take an average size that is approximately 6 centimeters or the say 10 centimeters.

You can find 10 centimeter fish in the fish market. So that is. You will also need the velocity, but I have already provided it to you and it is v is equal to one centimeter per second, please recall that these values are not in SI units you will need to convert them this is also not in SI units, this is in SI units. So, with this in hand I think you should be able to solve the problem and the hint number two is that you need to use reciprocal motion and the answer in fact is no by the way, the fish cannot move in honey but you need to understand why so, justify this.

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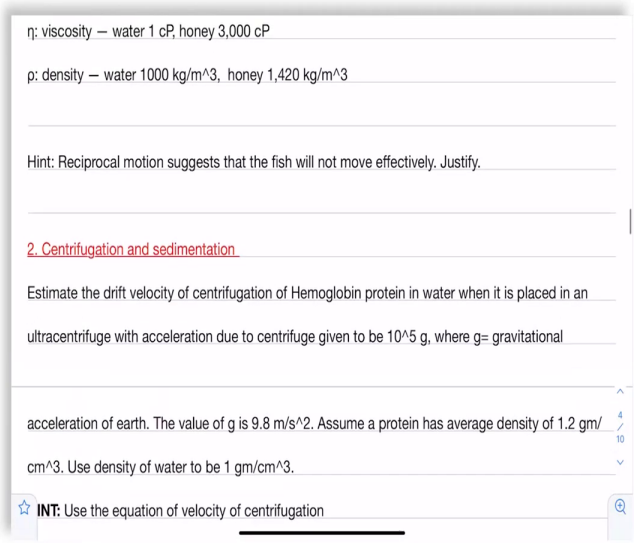

The next question relates to centrifugation and sedimentation. So, the question is as follows we have been talking a lot about blood and centrifugation. So, imagine that hemoglobin protein has been isolated and you are centrifuging it. Now hemoglobin can be assumed to be a globular protein if not a wrong assumptions, that is in its name globin. The solvent in which it is suspended is water and we are centrifuging it with acceleration due to centrifugation given by some factor of g. Here, we are stating it is 10^5 which is one lakh g that is 10000 which is 0.1 million or one lakh.

Now, g over here stands for gravitational acceleration of earth as you all know the value of G is 9.8 meters per second square. So, in other words the centrifugation acceleration is 9.8 x 10^5 approximately 10^6 g now it is six meters squared per second meters per second square. But this is something you can precisely write down so you know the answer by just taking the product of 10^5 and 9.8 meters per second square.

So, I misspoke earlier I must emphasize units of acceleration or meters per second square. Protein has to have some density because you probably recall you will need the density difference between the fluid and the solid that has been centrifuge and the density of protein is 1.2 grams per cm cube. What is the density of water? 1 gram per cc as we say usually so it is 1 gram per centimeter cube. Think about this question the hint is, of course that you need to use the equation of the velocity of centrifugation.

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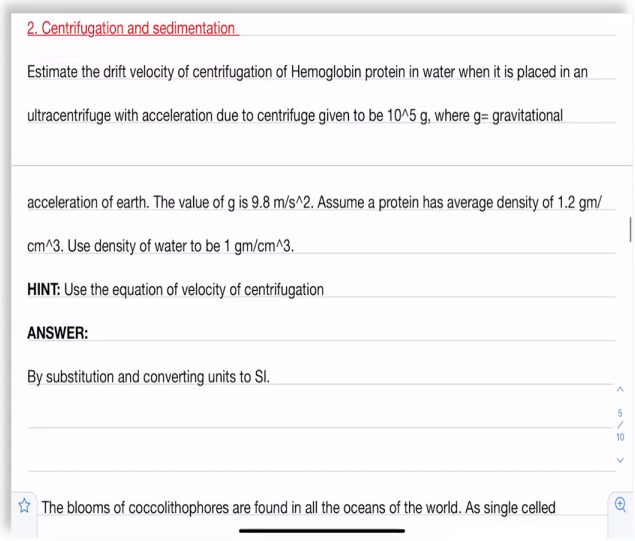

So presumably you have managed to do the substitution and converting units to SI you have managed to get an answer.

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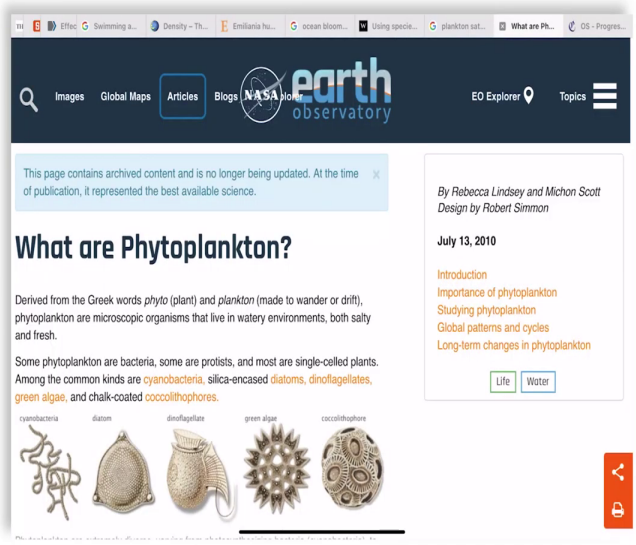

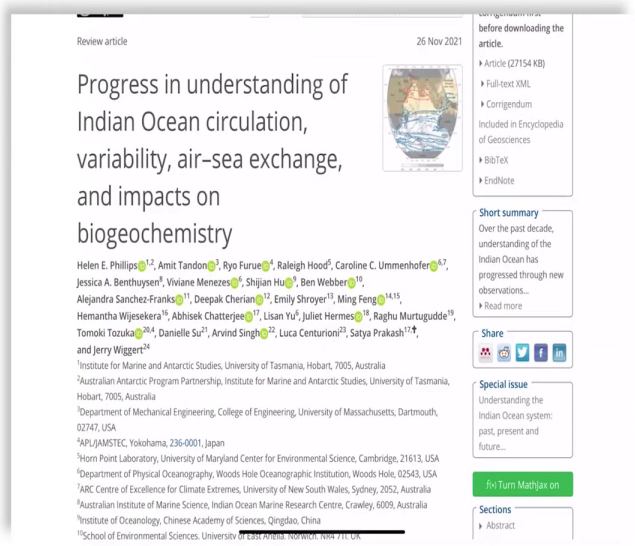

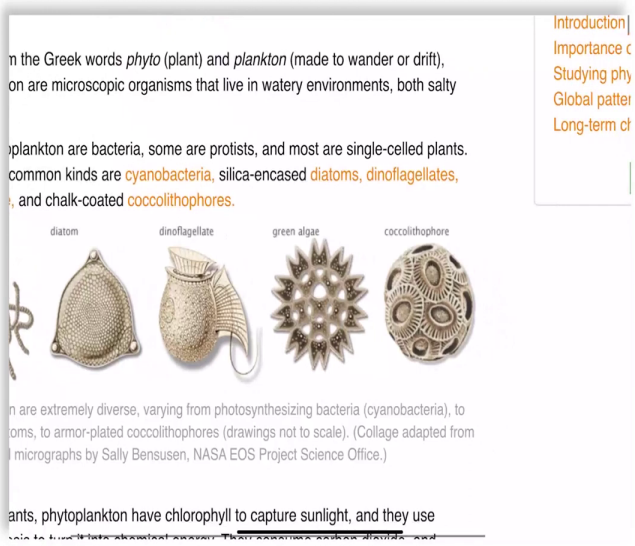

The last question relates to ocean science and something called phytoplankton. So you will find that the air-sea exchange of gases biogeochemistry the planetary food web depends strongly on something called phytoplankton. And in this particular paper, you see the Indian Ocean and the detailed geochemistry of air-sea interactions. But we are going to focus on something called phytoplankton which stands for phytos plant, plankton made to wander or drift. They are microscopic organisms.

They live in both salt and freshwater. And they come in very diverse forms. So from the left to right, you are looking at cyanobacteria, which sometimes are called blue green algae, diatoms, diatomaceous earth is something you may have heard of. If you look at the components of your toothpaste, you will find diatoms in it, yes toothpaste Colgate, dinoflagellates, green algae and coccolithophores. Now, the coccolithophores are calciferous deposited organisms calcium deposited organisms, whereas cyanobacteria are chlorophyll containing organisms all of them are single cells. Some of them do have some colonial forms.

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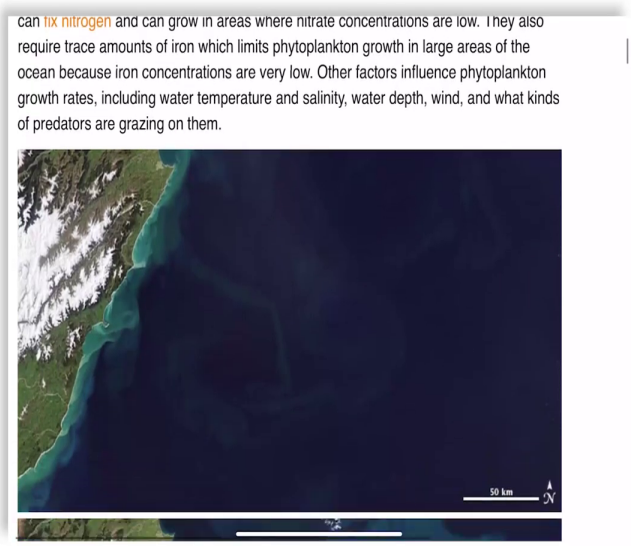
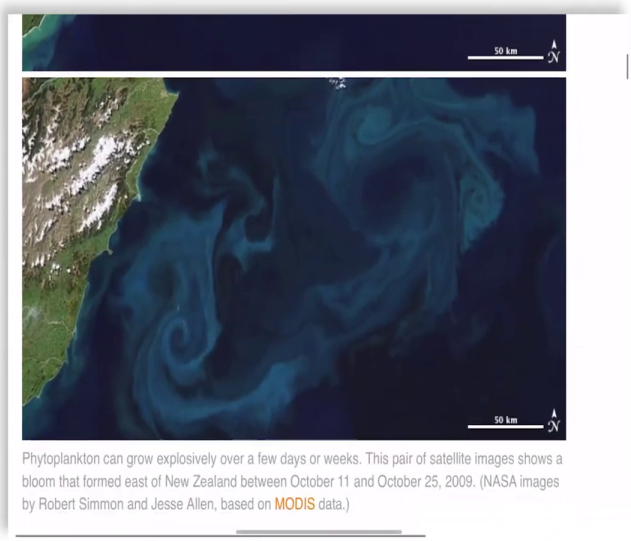
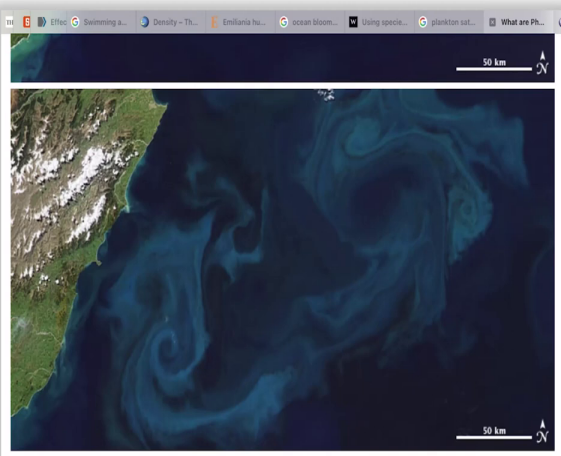






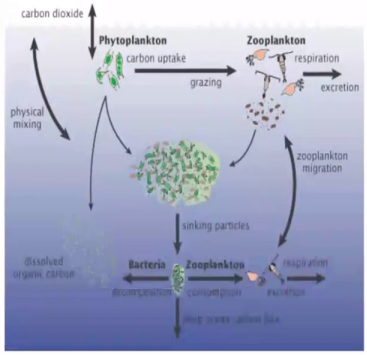
Phytoplankton can grow explosively over a few days or weeks. This pair of satellite images shows a bloom that formed east of New Zealand between October 11 and October 25, 2009. (NASA images by Robert Simmon and Jesse Allen, based on MODIS data.)

The food web

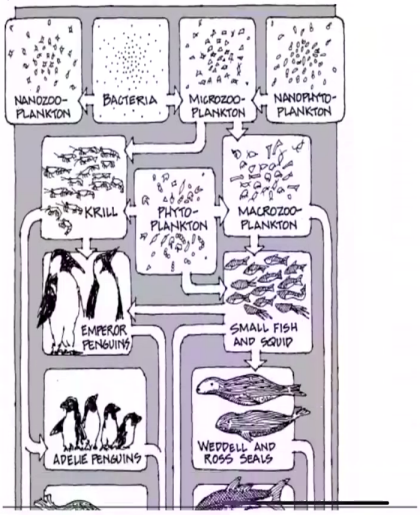
Phytoplankton are the foundation of the aquatic food web, the primary producers, feeding everything from microscopic, animal-like zooplankton to multi-ton whales. Small fish and invertebrates also graze on the plant-like organisms, and then those smaller animals are eaten by bigger ones.

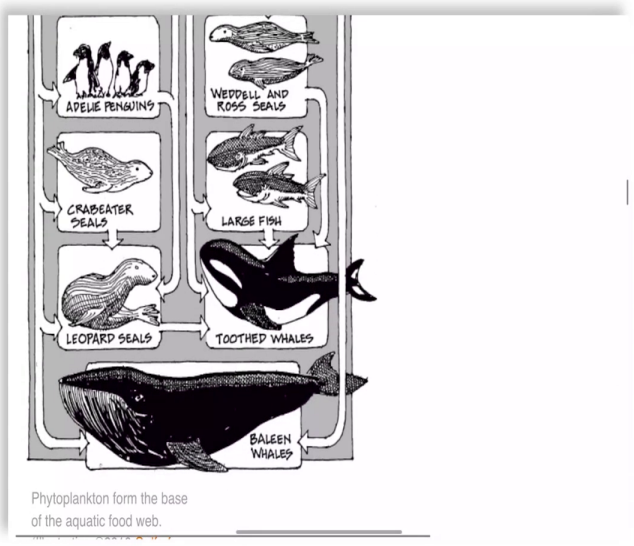
Phytoplankton can also be the harbingers of death or disease. Certain species of phytoplankton produce powerful biotoxins, making them responsible for so-called "red tides," or harmful algal blooms. These toxic blooms can kill marine life and people who eat contaminated seafood.

Through photosynthesis, phytoplankton consume carbon dioxide on a scale equivalent to forests and other land plants. Some of this carbon is carried to the deep ocean when phytoplankton die, and some is transferred to different layers of the ocean as phytoplankton are eaten by other creatures, which themselves reproduce, generate waste, and die.



Phytoplankton are responsible





Now when you look at satellite images, you will find that phytoplankton can form huge carpets like a bacterial colony plate except at a planetary scale 10s of kilometers. So this scale is 50 kilometers scale bar, please note, and the blue color over here is explosive growth that was observed in the space of only 14 days between 11th October and 25th October 2009. These images are from NASA, their website is Earth Observatory, NASA. The location of this photograph is from New Zealand. Now, the phytoplankton form an important part of the food web as I mentioned earlier, and whales, which are mammals of the sea, eat huge amounts of them.

So, but not just whales, even small fish graze on these, this is the lowest trophic pyramid, trophic level in the food pyramid in the oceans. So the health of phytoplankton is very important for ecology and for the carbon cycle, indeed this aquatic food web illustrates to you the interactions between nano zooplankton micro zooplankton, phytoplankton and overall phytoplankton combining to be fed by krill, which are small fish, small crustaceans, small fish and squid which are in turn it in by seals and penguins, which are in turn eaten by larger fish. And eventually also baleen whales eat directly the phytoplankton.

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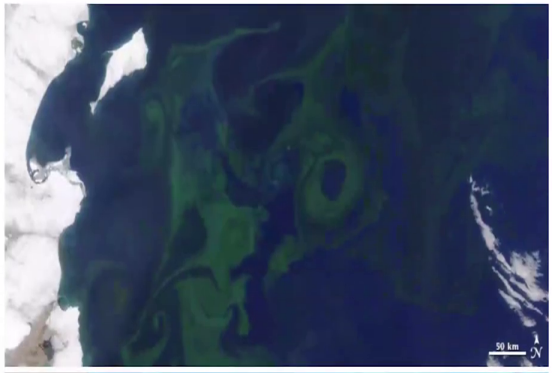
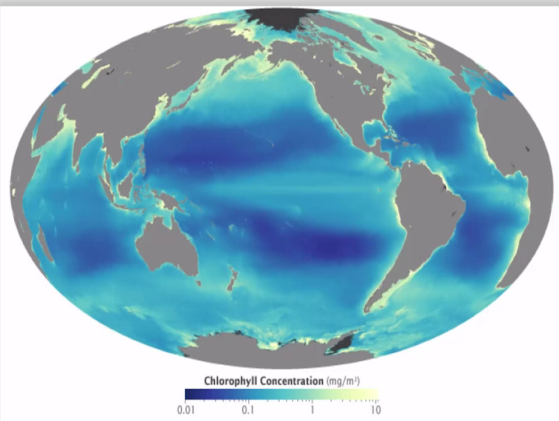
Marine biologists use plankton nets to sample phytoplankton directly from the ocean. (Photograph ©2007 Ben Pittenger.)

Samples may be sealed and put on ice and transported for laboratory analysis, where researchers may be able to identify the phytoplankton collected down to the genus or even species level through microscopic investigation or genetic analysis.

Although samples taken from the ocean are necessary for some studies, satellites are pivotal for global-scale studies of phytoplankton and their role in climate change. Individual phytoplankton are tiny, but when they bloom by the billions, the high

surface reflects light.





Phytoplankton are most abundant (yellow, high chlorophyll) in high latitudes and in upwelling zones along the equator and near coastlines. They are scarce in remote oceans (dark blue), where nutrient levels are low. This map shows the average chlorophyll concentration in the global oceans from July 2002–May 2010. **View animation:** small (5 MB) large (18 MB). (NASA image by Jesse Allen & Robert Simmon, based on MODIS data from the GSFC Ocean Color team.)

2. Centrifugation and sedimentation

Estimate the drift velocity of centrifugation of Hemoglobin protein in water when it is placed in an ultracentrifuge with acceleration due to centrifuge given to be 10^5 g, where g= gravitational acceleration of earth. The value of g is 9.8 m/s^2. Assume a protein has average density of 1.2 gm/cm^3. Use density of water to be 1 gm/cm^3.

HINT: Use the equation of velocity of centrifugation

ANSWER:

By substitution and converting units to SI.

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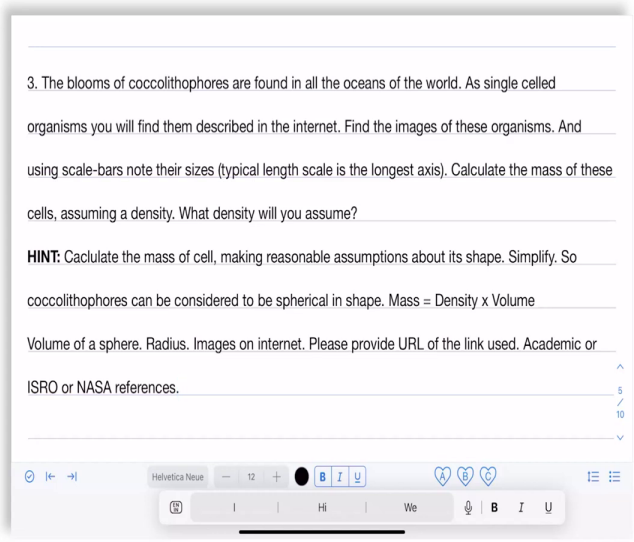

Their study requires sampling of the oceans and also satellite photography of chlorophyll content. And for the moment I will leave you with this idea that there is more to read and ask you a simple question what is the size of a coccolithophore in terms of length scale and mass you need to find the length and the mass of a coccolithophore. In order to do this, you will need to perform calculate the mass of a cell making reasonable assumptions about its shape.

Now, if you recall, I had mentioned in the earlier lectures also that a physics approach means that we simplify so coccolithophores can be considered to be spherical in shape. The mass therefore, is equal to the density multiplied by the volume. Since density is mass per unit volume, we basically get the mass of the coccolithophore for which you need to get the volume and for volume we say we calculate the volume of a sphere for that the characteristic number you need to know is the radius.

This you will capture from the images on the internet. Please provide URL of the link used. Remember, you will find all kinds of references try to find academic or ISRO or NASA references not any other. So think about this, how you will go about finding the size of each individual coccolithophore single celled in terms of its length, and in terms of its mass. With that I end this section.