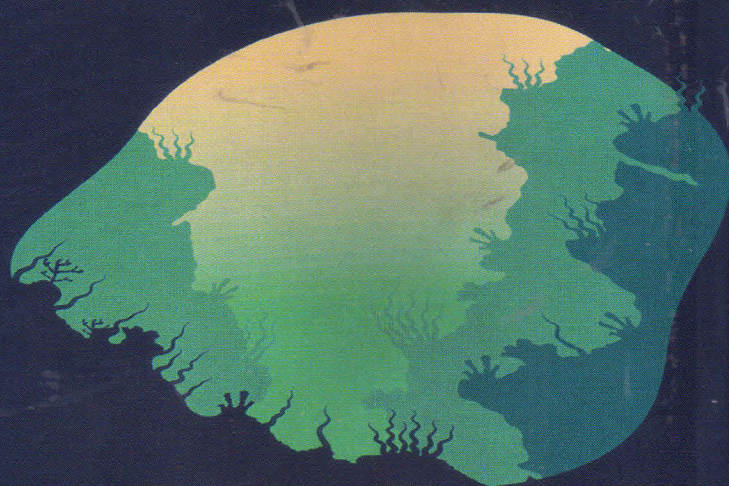


Invisible Forest

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terrestrial biosphere (the life-supporting part of the surface). While in the terrestrial biosphere, plants play a major role in pulling CO_2 out of the atmosphere through oxygenic photosynthesis by chlorophyll, the oceanic cycle contains both inorganic and organic carbons.

There are three main processes (or pumps) that make up the marine carbon cycle: the solubility pump, the inorganic carbonate pump, and the organic biological pump. The penetration and intensity of sunlight within the seawater are not uniform. Sunlight penetrating up to 200 metres below the sea surface is called sunlight or Epipelagic Zone. The faint light of the sun percolates in the zone, from 200 metres to 1000 metres. Hence, the zone is known as twilight or Mesopelagic Zone. Below the midwater zone comes the bottom zone of the sea, i.e., the depth from 1000 to 4000 metres. This zone is called the midnight or Bathypelagic zone.

WE live in a unique geological era of the Earth's history termed the Anthropocene, which is characterised by its inexorable and exceptionally strong influence on our environment. Ever since the very day of the inception of industrialisation in the 18th century, environmental pollution levels have been rising on Earth. The technological capability has created arrogance in man. In the words of EF Schumacher: "He (modern man) even talks of a battle with nature, forgetting that, if he won the battle, he would find himself on the losing." Indeed, human society has reached a critical threshold in its relation to its environment. We have irreversibly committed future generations to a hotter world.

Anthropogenic Carbon Dioxide (CO_2) and other Greenhouse Gases (GHGs) are warming the Earth's atmosphere to levels not experienced for a million years. The average global temperature in 2020 was about 14.9°C , 1.2°C above the pre-industrial (1850–1900) level. During the last century, global temperature increased at a rate of 0.05°C per decade, and the trend has accelerated to a rate of around 0.16°C per decade over the past three decades. Our situation is a bit like the proverbial frog put in water, which is very slowly heated. However, for all intents and purposes, global warming vis-à-vis climate change is the biggest challenge the world is facing today.

There are a number of feedback processes important in Earth's climate system and, in particular, its response to external "radiative forcings" — that is, human or natural factors that drive the energy balance up or down. In the global carbon cycle, having the most important set of carbon feedbacks, two main carbon reservoirs are the ocean and the

The Solubility Pump

CO_2 does not easily dissolve in seawater. Uptaking of it by the surface of the seawater depends primarily on the difference in CO_2 partial pressure between the seawater and the atmosphere. The sea surface water with a lower partial pressure of CO_2 than the overlying atmosphere will take up CO_2 from the atmosphere until pressure equilibrium is attained. Of course, the pressure-equilibrium process also works in the opposite direction from water to the atmosphere. Apart from partial pressure, the status of the atmosphere, seawater salinity, temperature, wind velocity and water wave also affect CO_2 absorption.

A certain proportion of absorbed CO_2 reacts with seawater molecules to form carbonic acid [stage-1]. With very few exceptions, these molecules, in turn, immediately split into hydrogen carbonate plus one hydrogen cation (which is a proton) [stage-11]. A carbonate anion is formed if hydrogen carbonate loses another proton [stage-111]. Thus, a chemical equilibrium occurs on the surface of seawater where carbon remains in three different dissolved forms, as shown in Table 1.

This type of carbon pump for transporting anthropogenic CO_2 into the deep sea occurs mainly in the Polar Regions.

The Inorganic Carbonate Pump

The inorganic carbonate pump, an extension of the biological pump, is the formation and sinking of calcareous skeleton material by some marine phytoplankton and animals. Calcification is the process by which marine organisms combine calcium with carbonate ($\text{Ca}^{++} + \text{CO}_3^{--} = \text{CaCO}_3$). Calcium carbonate is dense and sinks out of the surface water. Simply, the burial of CaCO_3 in deep-ocean sediments is one