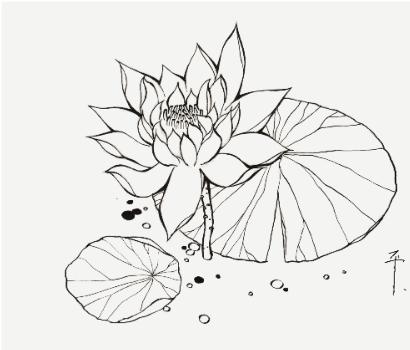

Photosynthesis

When I stayed in Bodhgaya, Bihar State, India, I loved to squat at the side of a small water tank, which contained pink lotuses in full bloom. The pink lotuses opened the petals fully showing the exquisite and delicate formation of carpels, stigmas, styles, anther, and filaments. I admired at the inexpressible beauty and precision of the arrangement; moreover, the miraculous life of nature. Sometime later, I was told that these were world famous Oga Lotuses that have been revived from the thousands' years dormancy.

The vitality of some plant seeds can be preserved almost indefinitely. The record for longevity is held by the Oriental lotus, which has been proved by carbon-14 dating to have successfully survived centuries of dormancy in Far Eastern peat bogs. Oldest of all were three lotus seeds, recovered in 1951, which had been buried in a neolithic canoe 18 feet under a peat bog near Tokyo. Carefully tended by experts, two of the three venerable seeds germinated and developed their characteristic flowers, and innumerable seeds as well as cuttings from these plants have since been sent to botanical institutions throughout the world.

Dr. Oga cut open the hard coat of the two thousand years old lotuses exposing the embryo within. Placed in water, the revivified seeds sprouted four days later. On the first day it resembled a *sake* bottle; on the second day, a *sake* cup; on the third day, a soup bowl; on the fourth day, a saucer. The full-blown pink lotus whose color Dr. Oga predicted 14 months earlier, developed exactly like a lotus today. After the fourth day, the petals turned brown and dropped off.

The plants are truly miraculous to create, to form, to preserve, and to revive the energy and matter that they formulated. The process is photosynthesis -- the process by which green plants and certain other organisms transform light energy into chemical energy. During photosynthesis in green plants, light energy is captured and used to convert water, carbon dioxide, and minerals into oxygen and energy rich organic compounds.

"It would be impossible to overestimate the importance of photosynthesis in the maintenance of life on Earth. If photosynthesis ceased, there would soon be little food or other organic matter on Earth. Most organisms would disappear, and in time the Earth's atmosphere would become nearly devoid of gaseous oxygen. The only organisms to exist under such conditions would be the chemosynthetic bacteria, which can utilize the chemical energy of certain inorganic compounds and thus are not dependent on the conversion of light energy.

Energy rich organic compounds are synthesized from low-energy atmospheric CO_2 using the energy of absorbed sunlight. (Some bacteria are nonoxygenic photosynthesizers, using hydrogen sulfide, H_2S, rather than water.) The resultant organic compounds initiate the flow of energy and carbon through the food chains of agricultural and natural ecosystems, intrinsically linking plants with heterotrophic life forms of the remaining four kingdoms of organisms. The oxygen liberated by plants (and certain photosynthetic protists and monerans) over geologic time, has oxygenated the Earth's atmosphere and has produced fossil fuels such as coal, gas, and oil.

Electromagnetic radiation having wavelengths between approximately 430 and 700 nanometres can be seen as light by the eye and constitutes the range absorbed by plants for photosynthesis. Blue light has a wavelength around 450 nanometres, and red light, wavelength of 650 – 700 nanometres.

Double membraned cell organelles called **chloroplasts** contain the photosynthetic apparatus: light absorbing pigments, other electron-carrying chemicals (cytochromes and quinones), and enzymes. (Pigments absorb light of particular wavelength; those wavelengths that are not absorbed are reflected and may be perceived as colour; hence, for example, the green colour of many plants.) The inner membranes of the chloroplasts are folded into flat tubes, the edges of which are joined to hollow, saclike disks called **thylakoids**. Stacks of thylakoids embedded with pigment molecules are called **grana**. The inner matrix of the chloroplast is called the **stroma**.

Photosynthesis consists of two interdependent series of reactions, the photochemical light reactions and the metabolic dark actions; the former are dependent on light, the latter on temperature. Light reactions occur in the grana and dark reactions in the stroma. The overall formula for the photosynthesis is $6CO_2 + 12H_2O$ -> $C_6H_{12}O_6$(glucose) + $6O_2$ + $6H_2O$.

The light reactions, the first stage of photosynthesis, convert light energy into chemical energy (ATP and NADPH). Light reactions comprise two interdependent systems, called photosystems I and II.

The dark reactions, the second stage of photosynthesis, use the chemical energy products of the light reactions to convert carbon from carbon dioxide to simple sugars. Light reactions consist of several hundred light-absorbing pigment molecules so arranged as to maximize the gathering of light energy. These "antennae" are coupled to a mini-circuit of electron-carrying chemicals. The pigments are chlorophyll *a* ($C_{55}H_{72}MgN_4O_5$) and chlorophyll *b* ($C_{55}H_{70}MgN_4O_6$) and various carotenoids. Absorbed light energy is transferred to specialized chlorophyll molecules called P_{700} and P_{680} in photosystem I and II, respectively. Once these specialized chlorophyll molecules acquire sufficient energy, electron are given up to the electron carriers within their photosystems, initiating an electron flow. (The carrier molecules include quinones and cytochromes.) The effect of this, when photosystems I and II function synchronously, is the formation of a chemiosmotic gradient of protons that phosphorylates (adds a phosphate group to) ADP, resulting in ATP. These reactions also effect the formation of NADPH from NADP. The P_{680} chlorophyll, upon loss of its electron, becomes a strong oxidizing agent that subsequently causes the water molecule to dissociate into proton and oxygen gas.

Dark reactions are responsible for the conversion of carbon dioxide to glucose. The essential reaction involves the combining of CO_2 with the five-carbon **ribulose 1,5-bisphosphate** (RuBP) in a series of reaction called the **Calvin-Benson cycle**. This reaction yields an unstable intermediate, which breaks down into the molecules of phosphoglycerate (**PGA)**, a three-carbon acid. Each reaction is catalyzed by a specific enzyme. Six revolutions of the cycle means that six CO_2 molecules react with six RuBP molecules to produce 12 molecules of PGA; two three-carbon PGA molecules combine to form the six-carbon glucose, and 10 PGAs are recycled to regenerate six molecules of RuBP. The ATP and NADPH from light reactions provide the energy and reducing power to form glucose and refurbish the CO_2 acceptor, RuBP.

The transition from light energy via photosynthesis to chemical energy via sugar may be immediate or delayed, according to the need: the energy is there, available in the chemically very stable sugar, and it can be saved for millions of years, as in coal, gas, or oil finally to be used by any heterotrophic organisms.

Yet for all its chemical stability, sugar also is the main source for all plant and animal cells – that is to say, the moment it is needed, this chemically stable product can become so reactive that their energy available for all cellular processes. The trigger that fires it is phosphate, provided by that same ATP that works so energetically in the photosynthesizing process. A sugar combined with phosphate abruptly becomes one of the most reactive compounds in the cell. But if sugar molecules become very reactive when they combine with phosphate, they become equally non-reactive when the phosphates detach themselves again. Without phosphate, the long chains of sugar molecules that formed in their phosphate phase may become cellulose, one of the most stable organic substances in existence. Paper, can be treated with concentrated acid or alkali or other common solvents, and it still stays intact.

All these compounds come from a few relatively simple materials. The same basic chemical structure is used over and over to provide energy storage, energy supply, mechanical strength, tissue stiffness, mechanics for cell-wall growth and drought protection. This certainly is ingenuity of the highest order.

The simplest oxygen-producing plants -- which presumably resemble the first ones that developed on the earth, are known generally as algae. There are several kinds of algae, the most primitive being the blue-green algae, tiny organisms that grow for the most part in fresh water and cause the characteristic dark green scum on ponds that have been polluted or overfertilized with manure. Blue-green algae are sometimes single-celled but more often come in clusters, threads or chains. However, they never form more complex organizations, nor can they produce sexually. Their cells are less than one 200^{th} of an inch long and can be seen with naked eye only when present in enormous numbers. Algae are the most well adapted to their environments: they contain green pigments known as collectively as chlorophyll, the vital agent that absorbs the sunlight energy and can change it into the chemical energy that plants need for growth.

With the exception of some bacteria, plants that do not contain chlorophyll cannot produce their own food. Like animals, they must get their energy ultimately from green plants. They belong to two groups: the bacteria, microscopic in size and as simple in form as the simplest algae; and the far larger and far more complicated fungi: mushrooms, toadstools, and puffballs, but also the slime molds and other similar forms, as well as parasites like smuts, blights and mildews.

Fungi developed to a certain extent parallel to algae, but differ from them in not having chlorophyll. A figure consists basically of quantity of hairlike threads, such as the fuzzy "mold" sometimes found on a piece of stale bread. Sometimes these threads, or hyphae to form organized structure – for example, a mushroom. But the mushroom or toadstool that one sees poking its head up from the forest floor is only the visible part of spore-producing part of the fungus. The mushroom forms when the fungus is ready to reproduce itself, but its continuing and more fundamental part is the unseen web of hyphae hidden in the soil. These minute threads can grow through the smallest holes, which makes it possible for fungi to penetrate plants and animal bodies wherever the body surface is injured. Once inside, the threads range far and wide, infecting bodies and taking nourishment from the individual cells of their host.

The slime molds are the most puzzling group, so much so that taxonomists have been disagreed whether to classify them as plants or animals. They seem to have qualities of both. They are made up of streaming masses of protoplasm with many nuclei but no cell walls. And they fan out; they engulf their food by slowly flowing over it."

Heterotrophic organisms have no chlorophyll, so they depend upon their energy on autotrophic organism. It is obvious that the reason why heterotrophic organisms were created -- the role to promote and maintain the cycle of energy by breaking down the substances – cellulose into organic chemicals again. The balance and harmony between producer and consumer are the basic order of life.

Once the heterotrophic animals came into existence, they started ruthless competition among themselves for survival, which we call 'revolution' to upset the balance and harmony between the producer and consumer. The ruthless survival is the most tragic and threatening the true meaning of life. We have to doubt all the beauty and attraction of nature, the sacredness and loftiness of personality unless we, all of us realize to abide in the real role and meaning of heterotrophic life.

However, formation of matter is one phase of life, dissolution of it reversing the photosynthetic process is another phase. The anti-matter inhales the dismissed oxygen and exhales carbon dioxide by burning glucose; moreover, they should digest and disintegrate the glucose into energy. That is another phase of life, which we call respiration or metabolism, complete the cycle of energy flow. This lifestyle is the heterotrophic life. The autotrophic plants and heterotrophic animals should be kept in perfect balance; otherwise, both parties will die out. It is calculated that all trees and plants in the world produce 150 billion tons of sugar every year. We do not know how many percent is used by the trees and plants themselves for growth, reproduction and maintenance of themselves, and how much is the surplus that they can spare for the heterotrophic lives. If we, the heterotrophic lives are too greedy and not satisfied with their proper allotment and they demand more than they deserve, they would destroy the true resource of their own life.

Natsuo Shibuya (in part paraphrased from his reference texts)