Photochemistry-Effect of Light in Everyday Life

'We can easily forgive a child who is afraid of the dark; the real tragedy of life is when men are afraid of the light.' -Plato

Prologue:

From time immemorial light has been one of men's greatest fascinations. The major source of light for not just earthlings but also to every planet in our galaxy is, the Sun. It is no wonder why sun is considered as god and worshipped in many places as the sun is considered the giver of life on earth. Our sun is an atomic furnace that turns mass into energy. Every second it converts over 657 million tons of hydrogen into 653 tons of helium. The missing 4 million tons of mass are discharged into space as energy. The earth receives only about one two-billionths of this. Scientists calculate that the sun should keep burning for another 10 to 30 billion years. It has been estimated that in 15 minutes our sun radiates as much energy as mankind consumes in all forms, during an entire year. The sun is approximately 93,000,000 miles from the earth, 864,000 miles in diameter, and is only an 'average' star in size, brilliance and age.

The next primary source of light created by man and considered one of the greatest invention of mankind is making of fire. The popular belief that, fire was most likely given to man as a 'gift from the heavens' when a bolt of lightning struck a tree or a bush, suddenly starting it on fire could be considered as a start after which man learnt to build fire. It would not have taken much time for men to realize that fire not just kept them warm but it also was a source of light and kept them safe from danger. The flaming torch and the campfire probably constituted early man's first use of 'artificial' lighting.

Light is all around us, from the breaking dawn to the glow of a street lamp. But the light we can see with our naked eyes constitutes only a fraction of all the wavelengths on the electromagnetic spectrum. And this is called as the visible light which is responsible for many of the major photochemical reactions on earth which sustains the very life in earth. Technologies that let us detect otherwise unseen light—radio waves, microwaves, infrared, ultraviolet, X-rays and gamma rays—have been crucial to advances in science and medicine.

Photochemistry, the science highlighting the chemical effects of light of any kind, is the latest brilliant invention of mankind which, in fact, has been existing from the very moment life began on earth. Light, especially, undergoes varied reactions when in contact with organic molecules with which very living organism in this world is made of. Organisms have evolved to detect and respond to light in numerous ways, ranging from photosynthesis to circadian rhythms and vision. Understanding how these and other systems convert photons into energy or biological signals is increasingly a focus of chemical biology research as scientists seek to define the mechanistic details of these processes and strive to more closely imitate them.

Light- A messenger, trigger and tool:

Photochemical reaction, a chemical reaction initiated by the absorption of energy in the form of light. The consequence of molecules' absorbing light is the creation of transient excited states whose chemical and physical properties differ greatly from the original molecules. These new chemical species can fall apart, change to new structures, combine with each other or other molecules, or transfer electrons, hydrogen atoms, protons, or their electronic excitation energy to other molecules. Excited states are stronger acids and stronger reductants than the original ground states. It is this last property that is crucial in the most important of all photochemical processes, photosynthesis, upon which almost all life on Earth depends.

Photosynthesis is the most fundamental connection between light and living organisms. Plants constitute more than nine-tenths of the total biomass on Earth. Plants dominate the Earth because the can capture sunlight and convert it into chemical energy through the process of photosynthesis. This conversion of light energy by photosynthesis yields approximately 100 terawatts of power annually: six times the power consumption of human civilization! Photosynthesis supports life on the planet, from microbes to humans. The photosynthetic machinery of plants, algae and cyanobacteria has been characterized in molecular and structural terms, which has furthered our understanding of how light is converted into energy-rich biomolecules. While we know the essential building blocks of the photosynthetic machinery, we understand less about the dynamics of this machinery, the diversity of photosynthetic functions among organisms, and how photosynthesis is regulated in an ever-changing environment. The important intellectual challenges remain in defining these complex systems with mechanistic clarity and applying this knowledge in practical areas. Research into light-harvesting complexes, which capture photons and shunt their energy to photosynthetic reaction centers, has revealed how natural systems harness light energy and, by extension, how chemical biologists might design artificial light-harvesting antennae for practical applications such as sustainable energy production.

Another natural application of photochemistry is, **Bioluminescence**, a form of chemiluminescence, is the production and emission of light by a living organism. Bioluminescence is a "cold light." Cold light means less than 20% of the light generates thermal radiation, or heat. Bioluminescence occurs widely in marine vertebrates and invertebrates, as well as in some fungi, microorganisms including some bioluminescent bacteria and terrestrial invertebrates such as fireflies. The chemical reaction that results in bioluminescence requires two unique chemicals: luciferin and either luciferase or photoprotein. Luciferin is the compound that actually produces light. In a chemical reaction, luciferin is called the substrate. The bioluminescent color (yellow in fireflies, greenish in lanternfish) is a result of the arrangement of luciferin molecules. Luciferase is an enzyme. An enzyme is a chemical (called a catalyst) that interacts with a substrate to affect the rate of a chemical reaction. The interaction of the luciferase with oxidized (oxygen-added) luciferin creates a byproduct, called oxyluciferin. More importantly, the chemical reaction creates light.

The appearance of bioluminescent light varies greatly, depending on the habitat and organism in which it is found. Bioluminescence is used by living things to hunt prey, defend against predators, find mates, and execute other vital activities. This bioluminescence, observed in animals such as jellyfish and fireflies, have similarly served as archetypical examples linking light and biology where the emitted light requires both protein scaffolds and environmentally sensitive small molecules within these scaffolds. Applying previous knowledge of the photophysical properties of small-molecule dyes to the rational dissection of fluorescent protein behavior led to demonstrations that these proteins could be manipulated to serve more broadly as tools in biological research. Since then, scientists have studied a wide range of natural and engineered fluorescent proteins, seeking variants with improved stability, brightness and excitation and emission wavelengths across the visible spectrum and beyond.

‘When you possess light within, you see it externally.’ ~Anaïs Nin

Vision is the ability to interpret the surrounding environment by processing information that is contained in visible light. White, is the combination of all colors; black is the absence of color.In the same way, the experience of coldness is real, yet "cold" does not exist as a physical phenomenon: it is simply the absence of heat.

The mixture of pigmentation is an entirely different matter from the mixture of light. In artificial pigmentation, the primary colors—the three colors which, when mixed, yield the remainder of the shades on the rainbow—are red, blue, and yellow. Red mixed with blue creates purple, blue mixed with yellow makes green, and red mixed with yellow yields orange. Black and white are usually created by using natural substances of that color—chalk for white, for instance, or various oxides for black. For light, on the other hand, blue and red are primary colors, but the third primary color is green, not yellow. From these three primary colors, all other shades of the visible spectrum can be made.

The mechanism of the human eye responds to the three primary colors of the visible light spectrum: thus, the eye's retina is equipped with tiny cones that respond to red, blue, and green light. The cones respond to bright light; other structures called rods respond to dim light, and the pupil regulates the amount of light that enters the eye.

The eye responds with maximum sensitivity to light at the middle of the visible color spectrum—specifically, green light with a wavelength of about 555 nm. The optimal wavelength for maximum sensitivity in dim light is around 510 nm, on the blue end. It is difficult for the eye to recognize red light, at the far end of the spectrum, against a dark background. However, this can be an advantage in situations of relative darkness, which is why red light is often used to maintain vision for sailors, amateur astronomers, and the military on night maneuvers. Because there is not much difference between the darkness and the red light, the eye adjusts and is able to see beyond the red light into the darkness. A bright yellow or white light in such situations, on the other hand, would minimize visibility in areas beyond the light.

IMPORTANCE OF PHOTOCHEMISTRY:

Photochemistry is concerned with reactions which are initiated by electronically excited molecules. Such molecules are produced by the absorption of suitable radiation in the visible and near ultraviolet region of the spectrum. photochemistry is basic to the world we live in.with sun as central figure, the origin of life itself must have been a photochemical act in the primitive earth conditions radiation from the sun was the only source of energy. simple gaseous molecules like methane ammonia and carbondioxide must have reacted photochemically to synthesize complex organic molecules liike proteins and nucleic acid through the ages, nature has perfected her machinery for the utilization of solar radiant energy for all photobiological phenomenon and providing food for the propagation of light itself. Photobiology, the photochemistry of biological reactions, is a rapidly developing subject and helps the understanding of phenomena like photosynthesis, phototaxis, photoperiodosm, photodynamicaction, vision and mutuagenic agents effects of light. In doing so iittris to integrate knowledge of physics, chemistry and biology.

The relevance of photochemistry also lies in the varied applications in the science and technology. Synthetic organic photochemistry has provided methods for manufacture of many chemicals which could not be produced by the dark reactions. Moreover, greater efficiency and selectivity of these methods have an added advantage. Some examples of industrially viable photochemical syntheses may be mentioned here:

i) synthesis of vitamin D2 from ergosterol isolated from certain yeasts,

ii)synthesis of cubans which are antiviral agents,

iii)industrial synthesis of caprolactum, the monomer of nylon 6,

iv) manufacture of cleaning solvents, insecticides, and halogenated aromatics (used as synthetic intermediates) by photochlorination, and

v) synthesis of antioxidants by photosulponation.

Certain chemicals change their color ,that is ,their absorption characteristics,when exposed to suitable radiation and reverse when the irradiation source is removed.these are known as photochromic materials.awell known example is spiropyranss. Their use in photochromic sunglass is obvious.but they have application in information storage and self developing,selferasingfilms in digital computers also.it is said that a company experimenting on such photochromic memory used uv light for writing the information,green light for reading itand blue light for erasing it.unfortunately organic substances usually lack the stability for very large numbers of reversals.

Another revolutionery application of electronically excited molecular systems in laser technology.lasers are intense sourses of monochromatic and coherent radiation.from their early development in 1960 they have found wide fields of application.they have provided powerful tools for the study of diverse phenomena ranging from moonquakes to pico second processes of nonradiative decay of excitational energy in molecules .the intense and powerful beam of coherent radiation capable of concentrationto a tiny point is used for eye surgery,cuttingmetals,boringdiamonds,asmilitiary range finders, and detectors,and many such applications.the advent of tunable dye lasers has increased the possiblity of their application in science and technology.

A further impetus to the study of photochemical reaction has been provided by the energy crisis.this has initiated researches into the conversion and storage of solar energy,processes which plants carry out so efficiently.solar energy provided a readily available sourses of energyespecially in those countries which lies between the tropics of cancer and capricon.in these areas,the daily incident energy per squAREkilometre is equalto 3000 t0nes of coal.if suitable photochemical reactios are discovered and devices for proper utilization of this abundant source of energy perfected half the world’s energy problem might be solved.solarbateries working on the principle of photovoltaic effectis one such effect.for basic researches in these fields,the understanding of various photophysical and photochemical processes is essential.the fundamental study of excited study of molecules is exciting by itself.short lived energy states with nano and pico second. Reaction kinetics have led to proper understanding of chemical reactions modes of energy transfer and the and the intricate structure of matter.flash photolysis and states.now it is possible to excite individual vibronic levels of isotopically substituted compounds by using appropriate beams from tunable dye lasers.

Manipulating light:

Electrical science has revealed to us the true nature of light, has provided us with innumerable appliances and instruments of precision, and has thereby vastly added to the exactness of our knowledge. –Nikola Tesla

Mankind has also learned to control light. The use of mirrors and lenses to divert light, or to magnify images, dates from pre-history. Microscopes and telescopes, using multiple mirrors and/or lenses are two closely related inventions from just a few hundred years ago. The modern era of organic photochemistry began in 1866, when Russian chemist Carl Julius von Fritzche discovered that a concentrated anthracene solution exposed to UV radiation would fall from the solution as a precipitate. Then the fundamental understanding of the basis for fluorescence and phosphorescence emerged. The internal energy introduced to the molecule by absorption must be equal to the total of the energies of each individual process of energy dissipation. Implicit in the previous sentence is the photochemical equivalence law, also called the Stark-Einstein law, which states that a single molecule may absorb exactly one photon of light. The amount of energy absorbed by a substance is the product of the number of photons absorbed and the energy of each photon, but it is the radiation intensity and the number of absorbed photons per second, and not their energy, that determine the extent of photochemical processes.

This led to emergence of a new field of science, Photonics, the science of light (photon) generation, detection, and manipulation through emission, transmission, modulation, signal processing, switching, amplification, and detection/sensing. Photonic technologies provide new tools for doctors and surgeons, new developments in optometry and vision science improve quality of life, and light-based technologies are used every day in medical diagnostics.

Breakthroughs in light technology continue to revolutionize the medical industry. Medical imaging, surgical procedures, and even diagnoses rely upon the use of light.

Medical imaging is the process of creating visual representations of the interior of a body for further medical analysis. Such imaging is generally used in medical fields such as neuroscience, cardiology, psychiatry, and psychology, amongst others. Common applications include CT (computed tomography) scans, MRIs (magnetic resonance imaging), ultrasounds, and X-rays (a form of radiography).

With the invention of the laser just over 50 years ago, the role of light in medical procedures has grown immensely. Lasers are especially crucial in dermatology (skin), ophthalmology (eyes), and dentistry due to their precision and high power density. In fact, lasers are now widely used for common procedures such as tumor, tattoo, hair, and birthmark removal. Eye surgery and

other surgical procedures now also use the power of lasers rather than invasive methods of the past.
More recently, light applications - specifically lasers - have been used in medical diagnosis due to their non-invasive properties. Routine diagnostics such as tissue oxygenation, early detection of tumors by fluorescence, and early detection of dental cavities are all performed by laser-based medical apparatus.

In order to elucidate biological processes on a molecular level, precise external control over these processes is required. Light represents an ideal external control element as it possesses several advantages over traditional modulators of gene function. Most importantly, light irradiation can be easily controlled in a spatial and a temporal fashion, conveying spatiotemporal control of biological activity to the system under study. Light irradiation is a non-invasive technique that results in minimal secondary perturbation of cellular processes, and the potential to regulate its amplitude enables the ability to tune the desired biological effect. Hence, the photochemical regulation of gene function is a rapidly advancing research field in the functional genomics area.

Epilogue:

Come forth into the light of things, let nature be your teacher. –William Wordsworth

Nature has been and will always be our teacher. Mankind's greatest inspiration is nature and light is the major factor which enlightens the mind, body and soul of every creature on earth. The history of the study of light has involved virtually all the major figures of science and their stories reveal the human side of science in many different ways. There is still more to come in the field of science with light, the structural and functional basis of every life on our planet.