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THE BIOCHEMISTRY OF ENVIRONMENTAL POLLUTION

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Preface
Human activities including industrialization and urbanization have continued to impact on the environment, leading to rapid increase in environmental pollution. Exposure to various levels of pollution have affected and is still affecting man emotionally, psychologically and health wise, even leading to deleterious effects on the unborn babies. With the living tissues, there are certain chemical processes through which the environmental pollutants impact living systems. This informed the decision of the authors to compile a book "THE BIOCHEMISTRY OF ENVIRONMENTAL POLLUTION", which attempts to highlight the molecular basis of the many impacts of environmental pollution, in-vivo; starting with general principles in the relationship between Environmental impact, Biochemistry; The concept of pollution, Environmental Biochemistry and Toxicology; Pollution control; Acid, Bases and importance of Acid/Base balance; macromolecules such as; Carbohydrates, Lipids, Proteins and Nucleic Acids; Teratogenicity; Vitamins, then Detoxification and Metabolism of Foreign Compounds: the authors are committed to the following goal:

- To use fundamental Biochemical principles to approach environmental issues.
- To cover the principles needed to understand Toxicological/ Biochemical mechanisms as a result of environmental toxicants.
- Elementary understanding of Biomolecules and their simple biochemical structures and roles.
- To highlight the nexus between a breach in normal biochemical processes and attendant deleterious impact of common Environmental Pollutants to man and animals.

We are open to constructive criticisms of this edition and will graciously welcome any useful suggestion that will help in improving subsequent editions. It is hoped that this textbook will be invaluable to environmental practitioners, students of Biochemistry, Pharmacology and Toxicology, the academia and the general public.

1.01 Environmental Sciences

This is the most multidisciplinary of all sciences. Environmental sciences help us to understand the world we are in and how to live a better life. Therefore, all disciplines like History, Engineering, Geology, Physics, Medicine, Biology, Chemistry, Biochemistry and Sociology contribute to Environmental Science. Man creates problem for himself by population growth, ecosystem decline, global climatic change, loss of biodiversity and polluting his environment. Humans have also achieved great success in the society they live. We have brought under control, the major diseases that kill people; Learn to convert natural material into more useful manufactured goods for building cities, roads, vehicles, aircrafts, ships etc., for the wellbeing of man. All these human activities have very profound environmental consequences. Example, burning fossils, oil spillage, gas emission etc., creates pollution that makes people sick or even raises the temperature of the earth. Chemicals we use to control diseases and pests leaves residues that can poison us.

1.02 Problems of Global Climatic Change

The problem of global climate change today is associated with change due to accumulation of greenhouse gases especially carbon dioxide (CO_2) in the atmosphere. Carbon dioxide is a by-product of respiration by animals, burning fossil fuels crude oil, coal and natural gas. Due to increased burning of fossils, CO_2 levels in atmosphere has risen from about 280 parts per million (ppm) in 1900 to over 390 ppm in 2010. Naturally CO_2 is a component of the lower atmosphere including nitrogen and oxygen. It is required by plants for photosynthesis and is also very important to the earth-atmosphere energy system. CO_2 gas is transparent to incoming light from the sun, but it absorbs infra- red (heat) energy radiating from earth's surface and redirecting some back to earth, causing increase in the temperature of the earth. The absorption of infra-red energy by CO_2 warms the lower atmosphere and this process is known as the greenhouse effect.

Therefore, increase in atmospheric CO_2 will lead to increased temperature leading to global warming.

Therefore, it will be dangerous if something is not done to bring the rising emission of CO_2 and other greenhouse gas under control.

1.03 Loss of Biodiversity

The increasing growth in human population with increasing need for food, water, timber, fibre and fuel has accelerated the conversion of forest grasslands and wetlands to agriculture and urban development. The result is loss of wild plants (medicinal plants) and animals that occupy those natural habitats. Pollution also degrades habitat especially aquatic and marine habitat destroying, fish and other sea animals they support.

Mammals, reptiles, amphibians, fish, birds and butterflies as well as plants are exploited for their commercial values leading to earth losing many of its species.

The risk of losing Biodiversity is based on the fact that it is the main stay of agricultural crops and of many medicines. Biodiversity will therefore affect agriculture and drug production from medicinal plants. Biodiversity is a critical factor in maintaining the stability of natural systems and enabling them to recover after disturbances such as fires and other natural disasters.

Most essential goods and services provided by natural systems are derived directly from various living organisms and we threaten our own wellbeing when we diminish the biodiversity within these natural systems. These good and services are important in sustaining the poor in developing cities as Lagos, Aba, Ibadan in Nigeria where vultures assist in removing dead carcasses.

1.04 Government and Environmental Public Policy

There are laws and policies that protect plants and animal species within the environment. Government and concerned citizens created the Environmental Protection Agency (EPA) in 1970 and passed numerous laws promoting pollution control and wildlife protection including the National Environmental Policy Act of 1969, the clean Air Act of 1970, the Protection Act of 1872, the Endangered Species Act of 1973 and the Safe Drinking Water Act of 1974.

Environmental Public Policy includes all of a society's laws and agency enforced laws including regulations that deal with that society's interactions with the environment. Public policies are developed at all levels of government: local, state, federal and international. In Abia State, Nigeria, there is Abia State Environmental Protection Agency (ASEPA) whose roles are to keep the environment healthy for the benefit of the people. Improvement of human welfare and protection of natural world.

1.05 Environment and Myth

One of the major constraints of good environmental control in underdeveloped world is poverty and illiteracy. Certain believe (Myth) can ruin a town, city or even a nation. For instance, Aba town in Abia State in Nigeria became one of the dirtiest cities in Southeast because of the myth that "Mammy water" has taken over 1/3 of the town turning the town into a slum for more than 30 years. However, between 2015 and 2021, Government decided to build drainages and concrete cement roads, as a strategy to channel storm water to the Aba River. Now all the so called 'Mammy water' in Aba has disappeared. Hence what seemed to be a purely environmental challenge was misconstrued as mermaid spirit. This is also common in Western Nigeria. In Lagos there are no vultures at present. Herbalist and "Juju men" said they have seized the entrance of vulture into Lagos. In more civilized cities like Pakistan and India, where there was a decline in population of vulture, research was conducted and discovered that diclofenac, a drug used by Vets for pains and inflammation in animals caused kidney and renal failure in vulture and over a long time the population of vultures declined to zero. Vultures clean up dead bodies and carcases in the environment.

Vultures are scavengers and they reduce the risk of disease and other unpleasant consequences of the presence of dead animals. Vulture population declined in 1990 in India and Pakistan even posing a serious risk of becoming extinct. The decline caused increased environmental problems and diseases because there were no vultures to take care of dead animals.

In 2000, Asian Vulture Crisis Project (AVCP) was established, and Dr Lindsay Oaks (Associate Prof of Microbiology and Pathology at Washington State University) was invited to investigate the possible reasons for the decline.

The AVCP team gathered in Pakistan and began with post- mortem examinations of hundreds of vultures. Over 85% of the dead vultures showed evidence of visceral gout which is commonly the result of kidney failure as a result of deposition of uric acid within the organs.

Since the primary food source of the vultures is dead domestic livestock, the team hypothesized that some veterinary substance being given to the farm animals might be responsible for the deaths. Investigations led to diclofenac, a non-steroidal anti-inflammatory drug often administered to animals to treat inflammation, pain and fever. It is known to be toxic to the kidney. The drug is cheap and sold over the counter. If the vultures feed on the carcass of animals treated with diclofenac, they will develop renal failure and die. To control this problem Government phased out the veterinary use of diclofenac and a safe drug was provided to replace the use of diclofenac for treating animals, thereby restoring the vulture population and completing the food chain with the scavengers in place.

Principal Health and Productivity Consequences of Poor Environmental Management

Environmental Problem	Effect on Health	Effect on Productivity
Water pollution and water scarcity	More than 3 million deaths and billions of illnesses a year are attributable to water pollution and poor household hygiene caused by water scarcity.	Fisheries are declining; rural household time (time spent fetching water) and municipal costs of providing safe water are increasing; water shortage constrains economic activity.
Air pollution	Many acute and chronic health impacts exist: Excessive levels of urban particulate matter and smoky indoor air are responsible for 2 million premature deaths annually.	Acid rain and ozone have harmful impacts on forests, agricultural crops, bodies of water and human artifacts.
Solid and hazardous waters	Diseases are spread by rotting garbage and blocked drains. Risks from hazardous wastes are typically local but often acute	Groundwater resources are polluted
Soil degradation	Effects include reduced nutrition for poor farmers on depleted soils and greater susceptibility to drought.	Some 23% of land used for crops, grazing and forestry has been degraded by erosion. Field productivity losses in the range of 0.5-1.5% of the gross national product are common on tropical soils.
Deforestation	Localized flooding leads to death and disease	Effects include reduced potential for sustainable logging and for prevention of erosion, increased watershed instability and diminished carbon storage capability for forests. Non timber forest products are also lost.
Loss of biodiversity	Effects include the potential Loss of new drugs	Ecosystem adaptability is Reduced, and genetic resources are lost.
Atmospheric changes	Such changes result in possible shifts in vector - borne diseases, risks from climatic natural disasters, and skin cancers attributable to depletion of ozone shield.	

Sources: World Bank, World Development Report, 1992 (New York: Oxford University Press, 1992); Millennium Ecosystem Assessment, 2005; UNEP Global Environment Outlook GEO 2007.

1.06 Matter in living and non-living systems

Living organisms need to be able to take in matter and energy from their environment in order to grow and function. For example, the bamboo that grows in the panda reserve can survive only because it is able to take the sun's energy and combine it with materials from the soil, air, and water around it to make the basic building blocks of its own tissues and to power its cellular activities. In turn, the giant panda will eat the bamboo and get energy and macro molecules matter necessary to build its own tissues and to do the work it needs to do in each of its cells. In order to understand this simple ecological relationship, we need to know some basic chemistry and physics. Later, we will explore what happens to energy and matter as they move through the biosphere.

1.07 Basic Units of Matter

Matter is defined as anything that occupies space and has mass. This definition covers all solids, liquids, and gases and all living as well as non-living things. Matter is composed of atoms small particles that are in turn combined to form molecules and these in turn can be combined into more complex structures.

Atoms The basic building blocks all of matters are atoms. Only 94 different kinds of atoms occur in nature, and these are known as the naturally occurring.

Elements Atoms are made up of protons, neutrons, and electrons, which in turn are made up of still smaller particles. For example, lead (Pb) is an element. An atom of lead is the smallest piece you could have, that has the characteristics of lead. A lead atom has a characteristic number of protons (positive particles), neutrons (neutral particles), and electrons (negative particles).

How these relatively few building blocks make up the countless materials of our world, including the tissues of living things. All chemical reactions, whether they occur in a test tube, in the environment, or inside living things (and whether they occur very slowly or very fast), involve rearrangements of atoms to form different kinds of matter.

Atoms do not change during the disassembly and reassembly of different materials. A carbon atom, for instance, will always remain a carbon atom. In chemical reactions, atoms are neither created nor destroyed. The same number and kind of different atoms exist before and after any reaction. This constancy of atoms is regarded as a fundamental natural law, the **Law of Conservation of Matter.** Nuclear reactions differ from chemical reactions and could result in the splitting of an atom of one element, for example, into multiple atoms of another element. However, this is a very specific, rare instance and is not a chemical reaction. Now, we turn our attention to the ways atoms are put together, which atoms make up the bulk of the bodies of living organisms, and how are they incorporated into organisms?

1.08 Molecules and Compounds

A molecule consists of two or more atoms (either the same kind or different kinds) bonded in a specific way. The properties of a material depend on the specific way in which atoms are bonded to form molecules as well as on the atoms themselves. **A compound** consists of two or more different kinds of atoms that are bonded. For example, the fundamental units of oxygen gas, which consists of two bonded oxygen atoms, are molecules (O_2), but not compounds. When an oxygen atom binds with hydrogen atoms to create water, it is both a molecule and a compound (H_2O).

On the chemical level, the cycle of growth, reproduction, death, and decay of organisms is a continuous process of using various molecules and compounds from the environment (food), assembling them into living organisms (growth), disassembling them (decay), and repeating the process. Driving the cycle is the genetically programmed urge living things have, to grow and reproduce.

1.09 Three (3) - Spheres

During growth and decay, atoms move from the environment into living things and then return to the environment. To picture this process, think of the environment as three open, non-living systems, or “spheres”, interacting with the biosphere. The **atmosphere** is the thin layer of gases (including water vapour) separating Earth from outer space. The **hydrosphere** is water in all of its liquid and solid compartments: oceans, rivers, ice, and groundwater. The **lithosphere** is Earth’s crust, made up of rocks and minerals. Matter is constantly being exchanged within and between these three spheres.

a) **Atmosphere:** The lower atmosphere is a mixture of molecules of three important gases, oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2), along with water vapour and trace amounts of several other gases. The gases in the atmosphere are normally stable, but under some circumstance, they react chemically to form new compounds (for example, ozone is produced from oxygen in the upper atmosphere). Plants take carbon dioxide from the atmosphere, usually through their leaves. Animals usually take oxygen through some type of specialized organ such as a lung, but some, like earthworms, can simply absorb oxygen through their skin.

b) **Hydrosphere:** While the atmosphere is a major source of carbon and oxygen for all organisms (and a source of nitrogen for a few of them), the hydrosphere is the source of hydrogen. Each molecule of water consists of two hydrogen atoms bonded to an oxygen atom, so the chemical formula for water is H_2O. A weak attraction known as hydrogen bonding exists between water molecules.

Water is an important molecule for living things and usually needs to be available in liquid form. Water occurs in three different states. At temperatures below freezing, hydrogen bonding holds the molecules in position with respect to one another, and the result is a solid crystal structure (ice or snow). At temperatures above freezing, but below vaporization, hydrogen bonding still holds the molecules close, but clean, dry air is a mixture of molecules of three important gases.

The hydrogen bond allows them to move past one another, producing the liquid state. Vaporization (evaporation) occurs as hydrogen bonds break and water molecules move into the air independently. As temperatures are lowered again, all of these changes of state go in the reverse direction. Generally, water undergoes melting and evaporation, but sometimes water molecules leave snow or ice and go directly into the air. This is sublimation. Despite the changes of state, the water molecules themselves retain their basic chemical structure of two hydrogen atoms bonded to an oxygen atom, only the relationship between the molecules changes.

One reason that the states of water matter so much to organisms is that moving from one state to another either releases or requires a great deal of energy. We take advantage of this when we sweat, we can easily get rid of a lot of heat by causing water on the surface of your skin to evaporate. The heat from our body acts as energy that moves the water from a liquid to a gas state, and because the heat is gone from your body, we feel cooler.

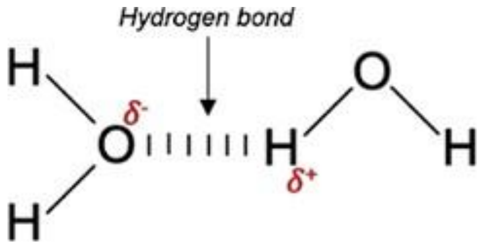

Figure 1.1 - Hydrogen bonding in water.

c) Lithosphere. All the other elements that are required by living organisms, as well as the 72 or so elements that are not required by them, are found in the lithosphere, in the form of rock and soil minerals. A mineral is a naturally occurring solid, made by geologic processes. It is a hard, crystalline structure of a given chemical composition. Most rocks are made up of relatively small crystals of two or more minerals, and soil generally consists of particles of many different minerals. Each mineral is made up of dense clusters of two or more kinds of atoms bonded by an attraction between positive and negative charges on the atoms.

Water and its three states

a) Water consists of molecules, each of which is formed when two hydrogen atoms bond to an oxygen atom (H_2O).
b) In water vapour, the molecules are separate and independent.
c) In liquid water, the weak attraction between water molecules known as hydrogen bonding gives water its liquid property.
d) At freezing temperatures, hydrogen bonding holds the molecules firmly, giving the solid state, ice.

Interactions

Air, water, and minerals interact with each other in a simple, but significant, manner. Gases from the air and ions (charged atoms) from minerals may dissolve in water. Therefore, natural water is inevitably a solution containing variable amounts of dissolved gases and minerals. This solution is constantly subject to change because various processes may remove any dissolved substances in it, or additional materials may dissolve it. Molecules of water enter the air by evaporation and leave it again via condensation and precipitation. Thus, the amount of moisture in the air fluctuates constantly. Wind may carry dust or mineral particles, but the amount changes constantly because the particles gradually settle out from the air. The materials in these three spheres interact with the biosphere as living organisms take materials from these spheres and use them to build complex molecules in their bodies. We will discuss the process of building these molecules.

1.10 Organic Compounds

Our body is composed of relatively large chemical compounds in a number of broad categories, such as proteins, carbohydrates (sugars and starches), lipids (fatty substances) and nucleic acids (DNA and RNA). These compounds usually contain six key elements: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), and sulphur (S). Living things need other elements as well, sometimes in small but important doses.

Unlike the relatively simple molecules that occurs in the environment (such as CO_2, H_2O, and N_2), the key chemical elements in living organisms bond to form very large, complex molecules. The chemical compounds making up the tissues of living organisms are referred to as organic. Some of these molecules may contain millions of atoms. These molecules are constructed mainly from carbon atoms bonded into chains, with hydrogen and oxygen atoms attached. Nitrogen, phosphorus, or sulphur may be present also, but the key common denominator is carbon-carbon and carbon-hydrogen or carbon-oxygen bonds. Inorganic, then, refers to molecules or compounds with neither carbon-carbon nor carbon-hydrogen bonds. While this is the general rule, some exceptions occur; by convention, a few that contains carbon bonds, such as carbon dioxide, are still considered inorganic. This because carbon must contain hydrogen, among other elements to be organic but carbon dioxide, hydrogen is absent.

All plastics and countless other human-made compounds are also based on carbon bonding and are, chemically speaking, organic compounds. To resolve any confusion this may cause, the compounds making up living organisms are referred to as natural organic compounds and the human-made ones as synthetic organic compounds.

Therefore, the elements essential to life (C,H, O and so on) are present in the atmosphere, hydrosphere, or lithosphere in relatively simple molecules. In the living organisms of the biosphere, on the other hand, these elements are organized into highly complex organic compounds. In the case of the plant and animals, the simple molecules and atoms in the soil, air, and water are combined to form the tissues of the animal and eaten, digested, and recombined to make the tissues of the giant plant. When the animal or plant dies, the reverse process occurs through decomposition and decay.

1.11 Matter and Energy

This is the force that helps change chemical matter into substances that support life. The universe is made up of matter and energy. Matter is anything that occupies space and has mass. By contrast, light, heat, movement, and electricity do not have mass, nor do they occupy space. These are the common forms of energy with which we are familiar. What do the various forms of energy have in common? They affect matter, causing changes in its position or its state. For example, the release of energy in an explosion causes things to go flying-a change in position. Heating water causes it to boil and change of state are actually also movements of atoms or molecules. For instance, the degree of heat energy contained in a substance is a measure of the relative vibrational motion of the atoms and molecules of the substance. Therefore, we can define energy as the ability to move matter.

Energy Basics

Energy can be categorized as either kinetic or potential. Kinetic energy is energy in action or motion. Light, heat, physical motion, and electrical current are all forms of kinetic energy. Potential energy is energy in storage. A substance or system with potential energy has the capacity to do work i.e., to release stored energy due to its relative position to other parts of a system. Example, a spring has more potential energy when is compressed or stretched.

1.12Elements Found in Living Organisms and the Locations of Those Elements in the Environment

Table 1.2: Biologically important Molecule or Ion in Which the Element Occurs.[1]

Element (Kind of Atom)	Symbol	Name	Formula	Atmo- sphere	Hydro- sphere	Litho- sphere
Carbon	C	Carbon dioxide	CO_2	X[2]	X	X(CO_3)
Hydrogen	H	Water	H2O	X	(Water itself)	
Atomic oxygen (required in respira- tion)	O	Oxygen gas	O_2	X	X	
Molecular oxygen (released in photosyn- thesis)	O_2	Water	H_2O		(Water itself)	
Nitrogen	N_2	Nitrogen gas	X	X	X	Via fix- ation
		Ammoni- um ion Nitrate ion	NH_4 NH_3		X X	X X
Sulphur	S	Sulphate ion	SO_4^{2}		X	X

1 A molecule is a chemical unit of two or more atoms that are bonded. An ion is a single atom or group of bonded atoms that acquired a positive or negative charge as indicated

2 X means that elements exist in the indicated sphere

Phospho- rus	P	Phosphate ion	PO_4^{2}	X	X
Potassium	K	Potassium ion	K+	X	X
Calcium	Ca	Calcium ion	Ca^2	X	X
Magne- sium	Mg	Magnesium ion	Mg^2	X	X
Trace Ele- ments[3]					
Iron	Fe	Iron ion	Fe^2, Fe^3	X	X
Manganese	Mg	Manganese ion	Mn^2	X	X
Boron	B	Boron ion	B^3	X	X
Zinc	Zn	Zinc ion	Zn^2	X	X
Copper	Cu	Copper ion	Cu^2	X	X
Molybde- num	Mo	Molybde- num	Mo^2	X	X
Chlorine	CI	Chloride	CI^-	X	X

Note: These elements are found in all living organisms, plants, and microbes. Some organisms require certain elements in addition to the ones listed. For example, humans require sodium and iodine.

1.13The Cycling of Matter in Ecosystems

Earlier we saw that the molecules that make up tissues contain certain key elements. In the bamboo and, panda, for example, all the organic molecules contain carbon, the photosynthesis in the bamboo requires water (hydrogen and oxygen) and carbon dioxide (carbon and oxygen), potassium is part of the energy-holding mechanism in each cell, nitrogen is contained in every protein, and sulphur bonds help proteins stay in the right shape. There are many others necessary in only very small amounts. For example, to make the protein haemoglobin, which carries oxygen in your blood, you need to have small amounts of iron.

According to the Law of Conservation of Matter, atoms cannot be created or destroyed, so recycling is the only way to maintain a Only small or trace amounts of these elements are required. dynamic system. To see how recycling takes place in the biosphere, we now focus on the pathways of three key elements heavily affected by human activities: carbon, phosphorus, and nitrogen. Because these pathways are circular and involve biological, geological, and chemical processes, they are known as biogeochemical cycles. The water or hydrologic cycle is very important in the environment.

1.14The Carbon Cycle

The global carbon cycle represents major pools of carbon, and arrows represent the movement or flux of carbon from one compartment to another. The movement of carbon is measured in gigatons (1 gigaton (Gt) = 1 billion metric tons (1.1 billion US tons), sometimes referred to as a 1 petagram). For descriptive purposes, it is convenient to start the carbon cycle with the “reservoir” of carbon dioxide (CO_2 molecules present in the air). Through photosynthesis and further metabolism, carbon atoms from CO_2 become the carbon atoms becomes the carbon atoms of the organic molecules making up the plant’s body. The carbon atoms can be consumed in plants as food, where they become part of the tissues of all the other organisms in the ecosystem. About half is respired by plants and animals, and half is deposited to the soil (a large reservoir) in the form of detritus (dead plant and animal matter). Respiration by organisms in the soil that eat dead matter returns more carbon to the atmosphere as CO_2. The cycle is different in the oceans: photosynthesis by phytoplankton and macro-algae removes CO_2 from the huge pool of inorganic carbonates in seawater and feeding moves the organic carbon through marine food webs. Respiration by the biota returns the CO_2 to the inorganic carbon compounds in solution.

Some processes other than the transfer of carbon among producers, consumers and organisms eating dead material are significant. The figure indicates two in particular: (1) diffusion exchange between the atmosphere and the oceans and (2) the combustion of fossils fuels, which releases CO_2 to the atmosphere. Some geological processes of the carbon cycle are not shown. For example, the fossilization of dead plants and animals produced coal deposits on many areas of Earth. This process removes vast amounts of carbon dioxide from the atmosphere and traps it underground. Burning coal and oil releases the CO_2 to the atmosphere. For another example, limestone (such as that formed by ancient corals) also keeps carbon out of circulation; however, the weathering of exposed limestone releases carbon into the aquatic system.

Because the total amount of carbon dioxide in the atmosphere is about 765 Gt and photosynthesis in terrestrial ecosystems removes about 120 Gt/year, a carbon atom cycles from the atmosphere through one or more living things and back to the atmosphere about every six years.

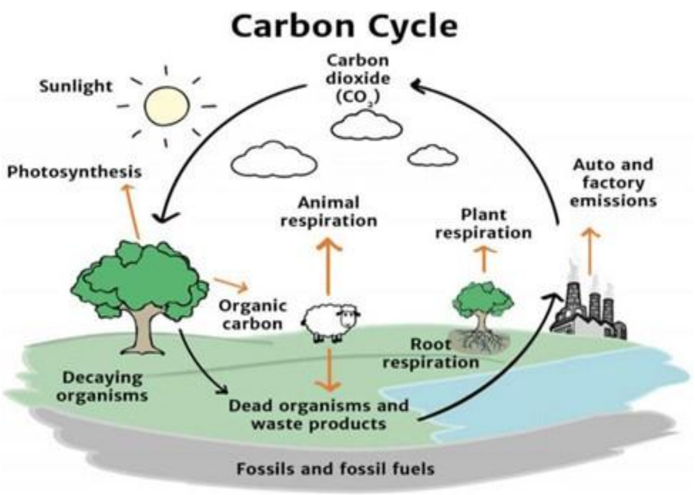

Figure 1.2 - The carbon cycle. Source: Jeffrey Amelse (2020)

Human Impacts

Human intrusion into the carbon cycle is significant. As we will see shortly, we are diverting or removing 40% of the photosynthetic effort of land plants in order to support human enterprises. By burning fossil fuels, we have increased atmospheric carbon dioxide by 35% over preindustrial levels. In addition, the Millennium Ecosystem Assessment reports that until the mid-20th century, deforestation and soil degradation released significant amounts of CO_2 to the atmosphere. However, more recent reforestation and improved agricultural practices have improved this Profile.

1.15The Phosphorus Cycle

The phosphorus cycle is representative of the cycles of all the biologically important mineral nutrients-those elements that have their origin in the rock and soil minerals of the lithosphere, such as iron, calcium, and potassium. We focus on phosphorus because its storage tends to be a limiting factor in a number of ecosystems and its excess can seriously stimulate unwanted algal growth in freshwater systems.

The phosphorus cycle is illustrated in below. Like the carbon cycle, it is depicted as a set of pools of phosphorus and fluxes to indicate key processes. Phosphorus exists in various rock and soil minerals as the inorganic ion phosphate (PO_4^{3-}). As rock gradually breaks own, phosphate and other ions are released. This slow process is the normal means of replenishing phosphorus that is lost because of runoff and leaching. Plants absorb PO_4^{3-} from the soil or from a water solution, and once the phosphate is incorporated into organic compounds by the plant, it is referred to as organic phosphate.

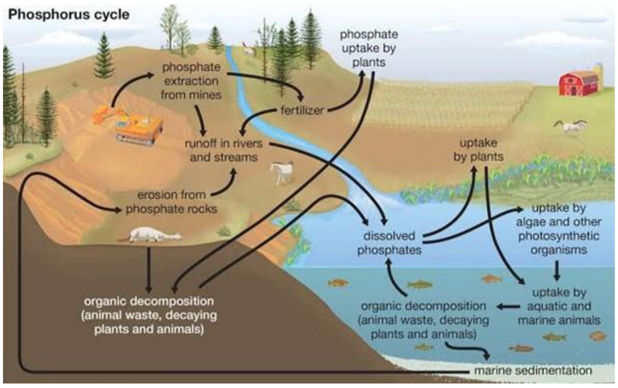

Figure 1.3 - The Phosphorus Cycle. Source: Encyclopaedia Britannica.

Organic phosphate

Moving through food chains, organic phosphate is transferred from producers to the rest of the ecosystem. As with carbon, at each step it is highly likely that the organic compounds containing phosphate will be broken down in cell respiration or by decomposers, releasing PO_4^{3-} in urine or other waste material. The phosphate may then be reabsorbed by plants to start the cycle again.

Phosphorus enters into complex chemical reactions with other substances that are not shown in this simplified version of the cycle.

For example, PO_4^{3-} forms solid, insoluble compounds with a number of cations (positively charged ions), such as iron (Fe^{3+}), aluminium ($A1^{3+}$), and calcium (Ca^{3+}). If these cations are in sufficiently high concentration in soil or aquatic systems, the phosphorus can be bound up in chemical precipitates (soil, insoluble compounds) and rendered largely unavailable to plants. The precipitated phosphorus can slowly release PO_4^{3-} as plants withdraw naturally occurring PO_4^{3-} from soil, water, or sediments.

Human Impacts

The most serious human intrusion into the phosphorus cycle comes from the use of phosphorus containing fertilizers. Phosphorus is mined in several locations around the world (e.g., Florida in the United States) and is then made into fertilizers, animal feeds, detergents, and other products. Phosphorus is a common limiting factor in soils and when added to croplands, can greatly stimulate production. Unfortunately, human applications have tripled the amount of phosphorus reaching the oceans, from the natural level of around 8 teragrams (8 million metric tons) of phosphorus per year (Tg/year) to the present flux of 22 Tg/year. This increase of 14 Tg/year is roughly equal to the global use of phosphorus fertilizers in agriculture. We are accelerating the natural phosphorus cycle as we mine it from the earth and as it subsequently moves from the soil into aquatic ecosystems, creating problems as it makes its way to the oceans. There is essentially no way to return this waterborne phosphorus to the soil, so the bodies of water end up overfertilized. This leads in turn to a severe water pollution problem known as eutrophication. Eutrophication can cause the overgrowth of algae, too many bacteria, and the death of fish.

1.16The Nitrogen Cycle

The nitrogen cycle (see below) has similarities to both the carbon cycle and the phosphorus cycle. Like carbon, nitrogen possesses a gas phase; like phosphorus, it acts as a limiting factor. The nitrogen cycle is otherwise unique. Most notably, unlike in the other cycles, bacteria in soils, water and leguminous plants.

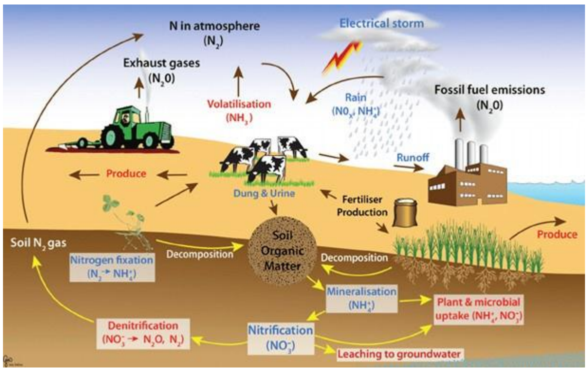

Figure 1.4 - Scheme showing the principal components of the terrestrial nitrogen cycle. Source: G. P. Sparling (2010)

Sediments perform many of the steps of the nitrogen cycle. Like phosphorus, nitrogen is in high demand by both aquatic and terrestrial plants.

The main reservoir of nitrogen is the air, which is about 78% nitrogen gas (N2). This form of nitrogen is called nonreactive nitrogen because most organisms are not able to use it in chemical reactions. The remaining forms of nitrogen are called reactive nitrogen (Nr) because they can be used by most organisms and make chemical reactions more easily.

Plants in terrestrial ecosystems (non-N-fixing producers) take up Nr as ammonium ions ($N^{4}{}_{a}^{+}$) or nitrate ions ($NO3^{-}$). The plants incorporate the nitrogen into essential organic compounds such as proteins and nucleic acids. The nitrogen then moves from producers through consumers and, finally, to decomposers (organisms that live on dead plant and animal matter, referred to as heterotrophs. At various points, nitrogenous wastes are released, primarily as ammonium compounds. A group of soil bacteria, the nitrifying bacteria, oxidizes the ammonium to nitrate in a chemosynthetic process that yields energy for the bacteria. At this point, the nitrate is once again available for uptake by green plants-a local ecosystem cycle within the global cycle. In most ecosystems the supply of nitrogen cycle in aquatic ecosystems is similar.

Nitrogen Fixation

A number of bacteria and cyanobacteria (chlorophyll-containing bacteria, formerly referred to as blue-green algae) can use nonreactive N through a process called biological nitrogen fixation. In terrestrial ecosystems, the most important among these nitrogen-fixing organisms are bacteria in the genus Rhizobium, which live in nodules on the roots of legumes, the plant family that includes peas and beans. The legume provides the bacteria with a place to live and with food (sugar) and gains a source of nitrogen in return. From the legumes, nitrogen enters the food web. The legume family includes a huge diversity of plants, ranging from clovers (common in grasslands) to desert shrubs and many trees. Without them, plant production would be sharply impaired due to a lack of available nitrogen. In aquatic ecosystem, cyanobacteria are the most significant nitrogen fixers.

Three other important processes also fix nitrogen. One is the conversion of nitrogen gas to the nitric oxide form by discharges of lightning in a process known as atmospheric nitrogen fixation: nitrogen oxides then come down with rainfall. The second is the industrial fixation of nitrogen in the manufacture of fertilizer; the Haber-Bosch process converts nitrogen gas and hydrogen to ammonia. The third is a consequence of the combination of fossil fuels, during which nitrogen from coal and oil is oxidized; some nitrogen gas is also oxidized during high-temperature combustion. These last two processes lead to nitrogen oxides (NOx) in the atmosphere, which are soon converted to nitric acid and then brought down to Earth as acid precipitation. Such acid rain is discussed in Chapter 8.

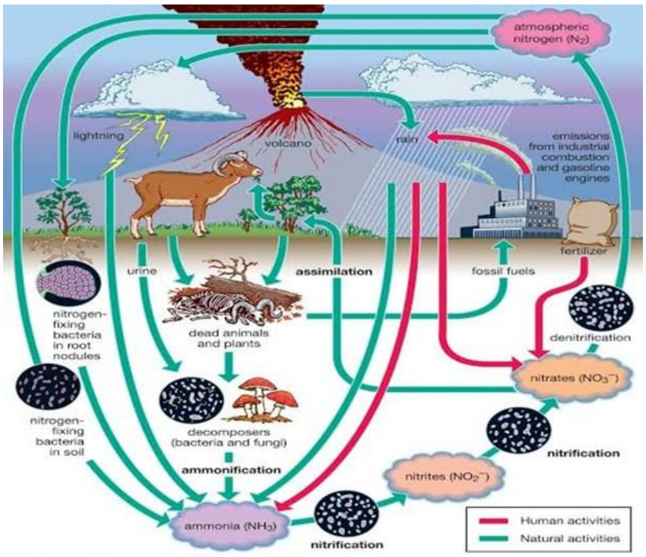

Figure 1.5 - Nitrogen Fixation.

Denitrification

Denitrification is a microbial process that occurs in soils and sediments depleted of oxygen. A number of microbes can take nitrate (which is highly oxidized) and use it as a substitute for oxygen. In so doing, the nitrogen is reduced (it gains electrons) to nitrogen gas and released back into the atmosphere. In sewage treatment systems, denitrification is a desirable process and is promoted to remove nitrogen from the wastewater before it is released in soluble form to the environment.

Human Impacts

Human involvement in the nitrogen cycle is substantial. Many agricultural crops are legumes (peas, beans, soybeans, alfalfa), so they draw nitrogen from the air, thus increasing the rate of nitrogen fixation on land. Crops that are non-leguminous (corn, water, potatoes, cotton, and so on) are heavily fertilized with nitrogen derived from industrial fixation. Both processes benefit human welfare profoundly. Also, fossil fuel combustion fixes nitrogen from the air. All told, these processes add some 165 teragrams of N to terrestrial ecosystems annually. This is approximately 1.5 times the natural rate of nitrogen fixation. In effect, we are more than doubling the rate at which nitrogen is moved from the atmosphere to the land.

The consequences of this global nitrogen fertilization are serious. Nitric acid (and sulphuric acid, produced when sulphur is also released by burning fossil fuels) has destroyed thousands of lakes and ponds and caused extensive damage to forests. Nitrogen oxides in the atmosphere contribute to ozone pollution, global climate change, and stratospheric ozone depletion. The surplus nitrogen has led to "nitrogen saturation" of many natural areas, whereby the nitrogen can no longer be incorporated into living matter and is released into the soil. There it leaches cations (positively charged mineral ions) such as calcium and magnesium from the soil, which leads to mineral deficiencies in trees and other vegetation. Washed into surface waters, the nitrogen makes its way to estuaries and coastal areas of oceans, where, just like phosphorus, it triggers a series of events leading to eutrophication, resulting in dead seafood, harmful effects on human health, and areas of the ocean that are unfit for fish. This complex of ecological effects has been called the nitrogen cascade, in recognition of the sequential impacts of N as it moves through environmental systems, creating problems as it goes.

Comparing the Cycles

The three cycles we have looked at in depth differ in some important ways (Table 1.2) Carbon is found in large amounts in the atmosphere and in a form that can be directly taken in by plants, so carbon is rarely the limiting factor in the growth of vegetation. Both nitrogen and phosphorus are often limiting factors in ecosystems. Phosphorus has no gaseous atmospheric component (though it can be in air-bone dust particles) and thus, unless added to an ecosystem artificially, enters very slowly. Nitrogen is unique because of the importance of bacteria in driving the cycle forward.

All three cycles have been sped up considerably by human actions. Nitrogen compounds in the atmosphere contribute to acid rain, and carbon dioxide is being moved from underground storage in carbon molecules to the atmosphere, where it is acting as a greenhouse gas.

Table 1.3 Major Characteristics of the Carbon, Phosphorus and Nitrogen Cycles.

Nutrient	Major Source	Interesting Feature	Human Impact
Carbon	Air	Taken in directly by plant leaves	Burning fuel moves it to air from underground
Phospho- rus	Rock	No atmospheric com- ponent	Fertilizer use adds it to waterways
Nitrogen	Soil	Bacteria drive the cycle	Fertilizer moves it to soil, burning moves it to air

Both nitrogen and phosphorus are put on soil as fertilizer or get into water from sewage and runoff. Both act in water to promote overgrowth of algae.

Although we have focused on carbon, phosphorus, and nitrogen, cycles exist for oxygen, hydrogen, iron, sulphur, and all the other elements that play a role in living things. Also, while the routes taken by distinct elements may differ, all of the cycles are going on simultaneously, and all come together in the tissues of living things.

As the elements cycle through ecosystems, energy flows in from the sun and through the living members of the ecosystems.

The various fields of ecology show that the science of ecology encompasses living things and their relationships with each other and the environment. We will look at two ecological levels in greater detail and what happens with them individually (organismal ecology). To understand the flow of matter and energy, we will also highlight some simple, basic components of life forms: the atoms, molecules, and the laws of energy.

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FOREWARD

One of the problems facing developing countries is how to keep our environment healthy. This comes in form of pollution which could be water pollution, air pollution, noise or indoor pollution by insecticides.Water becomes unsafe for drinking leading to Cholera, Dysentery or outbreak of Typhoid fever. Air pollution can lead to cough, sneezing and lung diseases. Noise caused by loud sounds could lead to ear problems. Indoor pollution caused by insecticides can lead to kidney and lung diseases.

Interaction of the environmental pollutants to the chemistry of carbohydrate, lipid, protein and nucleic acid e.g. in nucleic acid biochemistry, pollutants can cause serious mutation of DNA (gene) due to wrong protein coding. Roles of vitamins in metabolism, elimination of foreign substance by the body. In all these, there's no available and affordable literature authored by indigenous academics at tertiary level. It is important that academics strive to write books which will help students and other stakeholders to have a better understanding of our environmental safety.

I'm honoured by the invitation of the authors to write a forward for this book entitled "The Biochemistry of Environmental Pollution" which covers the basic chemical reactions involved in the environment and how the biochemical reactions in the living tissue control and brings safety. The metabolism of indigenous and xenobiotics.

The authors and publishers of this book "The Biochemistry of Environmental Pollution" should be commended for providing much needed reading and materials for degree and postgraduate students of Life and Environmental Sciences and other related disciplines.

The book is therefore recommended for students, lecturers, teachers and other stakeholders
Professor James Ayatse **(Professor of Biochemistry)**