Biomedical Technology And Healthy Human Life

by

GODDY CHUBA OKOYE

M.B., B.S. (Lagos) M.Sc. Ph.D. (Strathclyde)

Visiting Professor of Rehabilitation Medicine and Bioengineering
Department of Physiokinectics and Biomedical Technology
School of Health Technology
Federal University of Technology, Owerri. Nigeria.

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An Engineer creates that which never was".
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Dedication

This Lecture is dedicated to our dynamic and amiable Vice Chancellor

Professor COE Onwuliri

Epilogue

It may be pertinent to start this lecture with a recant of personal account of what transpired that led me to pursuing education and training in medicine and bioengineering. I was an impressionable young man still in secondary school when the war started. All of us males in the family, except my eldest brother who paid my school fees, joined the Biafran Army. After the war he came back from Denmark to die in 1972 at the age of 33 years, while all of us that joined the army came out alive.

By the end of the war I had made up my mind on my career choice which included medicine and aeronautic engineering as first and second respectively. I got admission for medicine and throughout my medical training I enrolled in correspondence course in digital logic and electronics with hands down practical in basic electronic circuits.

Throughout my medical training I have been thinking of designing, fabricating and implanting a total artificial heart as my brother died of Pulmonary Hypertension which is a complication of Valvular Heart Disease the origin of which was Rheumatic Fever itself a disease arising from infection with streptococcal bacterial organism. The advent of effective antibiotic for treating was not easily available by the time he was born. By the way infection by streptococcus causes simple sore throat or skin infection.

Since this sad experience of my brother's death I have not ceased to imagine that one day it will be possible to have an artificial heart that can extend the lives of people with irreversible heart failure.

By the time I went to the Bioengineering Unit of the University of Strathclyde, Glasgow for post-graduate studies, I already had had some design of completely implantable artificial heart which is still fresh in my mind till date. Very unfortunately there was no activity in artificial heart programme whereas I had to work on Deep Venous thrombosis and Stroke Rehabilitation.

I am happy to note that Jarvik 7 artificial heart has been successfully implanted in man in addition to other heart assist devices. The tremendous progress that has been made in science and technology makes very plausible that in the near future the problem of heart disease and its complications will be ameliorated bthrough advances in bioengineering in all its ramifications. The most plausible being through stem cell research and development of novel ways of stimulating the initiation, development and growth of autologous tissues and organs for transplantation towards a healthy human life!

Introduction

Biomedical Technology involves the application of ***engineering*** and ***technology*** principles to the domain of living or ***biological systems***. Usually *biomedical* denotes a greater stress on problems related to human health and diseases. ***Biomedical engineering*** combined with ***Biotechnology*** is often called *Biomedical Technology* or ***Bioengineering***. It has two wings: Biomedical Engineering (dealing more with the ***Biophysics***), and Biotechnology (dealing more with the ***Biochemistry***).

MAN can be said to be a "living machine" performing according to the grand design of Nature and therefore is amenable to various analytical considerations a good number of which require ***engineering principles and practice***. Thus, it became pragmatic for professionals in ***engineering*** and ***medicine*** to cooperate in the emerging and potentially lucrative and exciting field of ***Biomedical Engineering*** which is a natural consequence of the long association between the discipline of biology and medicine on the one hand with that of engineering on the other hand.

The process of engineering any product and in this case healthy human life is usually composed of three parts: analysis, synthesis, and design. Analysis is the study of systems in order to understand their function. Synthesis is the practical building of the systems under analysis. Both steps contribute to the end goal of engineering, which usually lies in the final design of the product. Many of the different engineering disciplines are founded on a particular pure science. Different branches of physics serve as bases for Civil Engineering, Mechanical Engineering, and Electrical Engineering. Similarly, different branches of chemistry serve as bases for Chemical Engineering, Nuclear Engineering, and Materials Science and Engineering. The engineering disciplines take off from a traditional science and use it to explore, innovate, and finally design.

Biomedical Engineering which is the melting pot of all engineering disciplines applicable to medicine can be defined as a synthesis of appropriately relevant aspects of all engineering disciplines in tackling diagnostic and therapeutic problems of biology and therefore medicine. The bioengineer employs the principles and practice of electrical, mechanical, chemical and nuclear engineering in the scientific study of practical problems of medicine. The fundamental aspect of this young discipline involves scientific measurements, development of devices and interaction with relevant aspects of clinical practice. The bioengineer naturally becomes an interface between the various medical equipments and the patient under the supervision of the clinician responsible for the management of the patient.

Biomedical Engineers apply the fundamentals of mathematics, physics, chemistry, and biology to solve medically-relevant problems. Examples of biomedical engineering activities include medical device design, fabrication, and testing, prosthesis fabrication, ergonomics and human factors, physiological function monitoring, home health care technology development, biomedical informatics, functional imaging and tomography, biomaterial development and biocompatibility, artificial tissue and organ fabrication, cell- and biomolecule-based sensors and therapeutics, gene therapy development, and biomedical microsystems.

While the above examples represent current areas of interest, biomedical engineering continues to change rapidly with advances in biology, medicine, and technology. Since the field of this young and growing discipline is quite wide, I crave your indulgence to permit me to limit myself in this lecture to health care equipment research and development for optimal health care delivery as well as attempting to peep into the fundamentals of physico-chemical interactions of life from the perspective of somebody that has studied medicine and engineering in medicine.

Human Life, Health and Disease

Life including human life is a condition that distinguishes ***organisms*** from non-living objects and is manifested by growth through ***metabolism*** and ***reproduction.*** Some living things can ***communicate*** and many can ***adapt*** to their environment through changes originating internally. A ***physical*** characteristic of life is that it feeds on ***negative entropy*** (Schrodinger, 1944; Margilius and Sagan, 1995).

Conventionally life including the human 'Life Machine' is a characteristic of organisms that exhibit the following phenomena:

Homeostasis: Regulation of the internal environment to maintain a constant state; for example, sweating to reduce temperature.

Organization: Living systems are composed of one or more cells, which are the basic building blocks of life.

Metabolism: Consumption of energy by converting nonliving material into cellular components (anabolism) and decomposing organic matter (catabolism). Living things require energy to maintain internal organization (homeostasis) and to produce the other phenomena associated with life.

Growth: Maintenance of a higher rate of synthesis than catalysis. A growing organism increases in size in all of its parts, rather than simply accumulating matter. The particular species begins to multiply and expand as the evolution continues to flourish.

Adaptation: The ability to change over a period of time in response to the environment. This ability is fundamental to the process of evolution and is determined by the organism's heredity as well as the composition of metabolised substances, and external factors present.

Response to stimuli: A response can take many forms, from the contraction of a unicellular organism when touched to complex reactions involving all the senses of higher animals. A response is often expressed by motion, for example, the leaves of a plant turning toward the sun or an animal chasing its prey.

Reproduction: The ability to produce new organisms. Reproduction can be the division of one cell to form two new cells. Usually the term is applied to the production of a new individual (either asexually, from a single parent organism, or sexually, from at least two differing parent organisms), although strictly speaking it also describes the production of new cells in the process of growth.

Healthy Human Life

In 1948, in its constitution, the World Health Organization (WHO) defined health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. In more recent years, this statement has been modified to include the ability to lead a "socially and economically productive life."

In the medical field, the technical term for health is ***homeostasis***, an organism's ability to efficiently respond to challenges (stressors) and effectively restore and sustain a "state of balance", harmony or wellness of the human organism.

The Hereditary Materials and Human Health

The hereditary materials or ***Human Genome*** determines life of every individual. On 26th of September, 2000, Bill Clinton the then US President with Tony Blair the then British Prime Minister declared that 'Today we are learning the language in which God created life' (**Microsoft Corporation, 2008**). **This was in response to the complete mapping of the Human Genome.** Recent research reports (Feinberg, 2008) has indicated that Individual human genomes change throughout a person's life being influenced by environmental or nutritional factors which may explain why illnesses such as cancer come with age. Furthermore, it has been found that the so-called epigenetic marks on the sequence of a person's DNA modify over the course of their life and the extent of such changes is similar among family members. Epigenetics refers to **altering gene function without altering DNA or** control of changes in gene function that do not involve changes in DNA sequences.

Current understanding from various studies show that we are beginning to see that epigenetics stands at the ***center of modern medicine*** because epigenetic changes, unlike DNA sequence which is the same in every cell, can occur as a result of dietary and other environmental exposure" (Feinberg, 2008). "Epigenetics might very well play a role in diseases like diabetes, autism and cancer. In their study, the team analysed the DNA sequences from 600 people who supplied DNA samples in 1991, and then again between 2002 and 2005. The variations in the levels of methylation, which is the main epigenetic modification, in 111 samples

was measured and in about a third of cases, the methylation levels had changed over the years (Feinberg, 2008).
"Inappropriate methylation levels can contribute to disease -- too much might turn necessary genes off, too little might turn genes on at the wrong time or in the wrong cell," (Gudnason, 2008). According to Fallin (2008) there is a detectable change over time, which is a proof of the principle that an individual's epigenetics does change with age and such changes could also be hereditary, which might explain why some families are more affected by certain diseases than others.

Health Care

Health care is the prevention, treatment, and management of illness and the preservation of mental and physical well being through the services offered by the medical, nursing, and allied health professions. According to the World Health Organisation, health care embraces all the goods and services designed to promote health, including "preventive, curative and palliative interventions, whether directed to individuals or to populations". The organized provision of such services may constitute a health care system. This can include a specific governmental organization such as the National Health Service in the UK, or a co-operation across the National Health Service and Social Services as in Shared Care.

The health of individuals can be assessed by medical practitioners and people are advised to have regular health check-up by qualified medical doctors at least once in two to five years. Usually after appropriate medical history which can be enhanced by recent developments in ***medical informatics*** whereby the genetic information of individuals can be obtained from database, the doctor orders for further tests. It is pertinent to state that the genetic make-up or sequence of DNA in all humans are the same - the variation being less than 1 percent of the DNA sequences!

Some tests that doctors routinely request include:

Blood pressure high blood pressure can lead to a heart attack or stroke; low blood pressure can signify a deficiency in iron. Blood pressure can be controlled through diet and exercise and in some cases, through medication.

Urinalysis urine is usually tested for sugar, for any blood and protein that might suggest a bladder or kidney problem, for hepatitis or other infections.

Blood tests blood tests may measure blood count, blood glucose, thyroid function, electrolytes (sodium and potassium), cholesterol and more, depending on family history.

Cholesterol level every adult should have his or her cholesterol level checked occasionally. A high blood cholesterol level is an important risk factor for coronary artery disease. If it is high, more specific tests like HDL and LDL cholesterol levels can be done. Some experts recommend that cholesterol screening be stopped when a patient reaches 65 years of age.

Chest x-ray x-rays can be done to detect lung abnormalities (e.g. tuberculosis, emphysema or lung cancer).

ECG (Electrocardiogram) men and women over 50 should have a baseline ECG done and repeat the test every two to three years. The ECG shows an electrical map of the heart rhythm and can indicate any changes or potential problems including heart attack, high potassium and irregular heartbeat.

Cancer testing for women a mammogram should be done annually after age 50, along with monthly breast self-examinations. For early detection of pelvic and cervical cancers, a PAP smear and pelvic exam should be conducted every one to three years, depending on the patient's risk level. Women with a high risk of osteoporosis should have their bone mass density tested.

Cancer testing for men in men from the age of 50, prostate and PSA (prostate specific antigen) levels may be checked for early detection of prostate cancer.

Colonoscopy and flexible sigmoidoscopy these tests are done to detect colon cancer. If you have a family history or other risk factors for colon cancer, a colonoscopy is recommended every 10 years. People over 50 should have a flexible sigmoidoscopy every five years.

Problems of Health Care Delivery in Under-developed Economies

It is obviously clear from the above requirements for ***healthy human life*** that basic health care equipment required for optimal health care delivery in most technologically under-developed countries are lacking, or when available, breaks down soon after being commissioned. The factors responsible for this state of affairs are multiple and include most importantly: lack of appropriately trained manpower for design, fabrication, maintenance, repair and service; lack of basic manufacturing engineering capability for simple medical equipment; and lack of spare parts. These factors are interrelated through the common denominator of research and production engineering. A pragmatic and practical solution to the intractable problem of health care equipment (HCE) lies in the establishment of a **BIOMEDICAL ENGINEERING RESEARCH AND PRODUCTION CENTRE** for the nation (Okoye, 1988 and 1995) . This will ensure the provision of adequately trained manpower for the design, development and production as well as utilization of simple medical equipment, the availability of adequate number and quality of health care equipment and their spare parts for effective maintenance and repair, for all levels of health care primary, secondary and tertiary.

The biomedical engineer, being able to apply engineering principles and practice to the solution of problems in the fields of medical diagnosis, prophylaxis and therapeutics, naturally becomes the centrepiece of the long-standing co-operation and association between engineering and medical practice. This co-operation has been as old as the civilisation of ***Homo sapiens***. Thus appliances like the walking stick and crutches are of simple mechanical design to ease off loading of a particular leg by the weight of the body acting through an axis while standing or walking. Man, to reduce bone fractures, has universally used such prosthetic and/or orthotic devices, including splinting. The value of such a simple physical device as an orthopaedic splint or crutches in the prevention of severe pain and in the treatment of certain deformities, ailment and amputation cannot be over-emphasised. Yet we take such a simple device for granted in this our environment without the slightest urge to scientifically study and improve on it as dictated by the dynamics of the requirements of individual patients.

The co-operation between medicine and engineering has been self-sustaining over the centuries. Many doctors have been great engineers and vice-versa. This is not surprising since the medical doctor can be aptly described as a "***human engineer***". This is because he has studied the human to such a detail that he is ever trying to find out what is wrong with the human "***life-machine***" so as to design appropriate optimal solution to almost all the problems of man.

A cursory look at the requirement for ensuring total health care delivery no doubt makes biomedical engineering in all its ramifications a sine qua non especially in our developing countries such as Nigeria which is undergoing a tremendous setback. Therefore there can be no gainsaying the fact that we need proper grounding in basic principles so as to use same in design, development and production as well as maintenance and servicing of medical equipment and health care instruments, in order to solve the intractable problem at hand the ***dearth of functionally available appropriate instrument and technologies***, and most importantly, the ***urgent for effective manpower development for design and production and therefore capability for effective use maintenance servicing of these equipment.***

Biomedical Engineering in Total Health Care Delivery

The health care delivery sector of modern socio-economic interaction has, consequent man's quest for high quality optimal health care services, become a highly technical enterprise, requiring advanced organisation and manpower development. Medical equipment acquisition and utilization in hospitals have grown considerably thereby raising expenses, which in turn raise health care delivery costs. Everyday, more and more complex equipment is added to already existing installations in order to meet increasing demands in number and quality of specific instruments to aid the clinician in the examination, diagnosis and treatment of patients.

As the use of engineering concepts and techniques in medicine is not yet widely understood by many clinicians and hospital administrators, the problems associated with the acquisition and utilization of medical equipment one does not understand the principles on which the equipment design and fabrication is based becomes real when the equipment breaks down or malfunctions. The resultant effect of these incessant breakdowns is that the objective necessitating its initial purchase is not achieved.

The administrative, managerial, financial and technical components of total health care delivery system with regards to medical equipment acquisition, maintenance and repair should be based on a sound education and training in all aspect of biomedical engineering applicable to all the levels of health care primary, secondary and tertiary. This can be effectively achieved through the establishment of **BIOMEDICAL ENGINEERING RESEARCH AND PRODUCTION CENTRE** for the nation. This will inevitably lead to the availability of trained manpower to man the **HEALTH CARE TECHNICAL SERVICES (HCTS)** for all levels of health care (Okoye, 1995).

Manpower Requirement
Why Biomedical Engineering Technology (BMET)?

As the healthcare field continues its rapid growth and the role of technology in diagnostic, therapeutic and research activities continues to expand, skilled biomedical engineers will be in demand. In fact, the biomedical engineering career field is increasing at about 26% per year through 2012 according to the U.S. Department of Labour. This is double the rate for all other jobs combined!

Combining traditional engineering expertise with an understanding of biological processes, biomedical engineering technology degree holders work with physicians, therapists and other technicians in the design, construction, implementation and maintenance of sophisticated healthcare equipment and lifesaving devices.

Medical equipment design, development, manufacture and use require special handling by appropriately trained and skilled personnel. The problem of total lack of appropriately trained personnel in the field of medical equipment design and fabrication has become acutely apparent with the economic recession afflicting most developing countries. The total dependence on foreign sources for supply of medical equipment should be sympathetically viewed from the angle of economic fluctuations that influence availability of equipment. Thus, the life of many a patient is intricately interwoven with the forces of economic law of demand and supplies especially those involving foreign exchange transactions. Effective HCE acquisition through research and production will obviate this intractable problem.

Standardisation and Specification

In technologically advanced countries, governments usually prescribe specific standards with which manufacturers of equipment must comply with if they are to remain in business. Such standardization often relates to designs and specification of materials for manufacture and the variety of models permissible. The lack of appropriate infrastructure for formulating and enforcing standardization and specification of imported medical equipment has led to a proliferation of various standards of equipment. Such equipment although performing similar functions quite often vary in size, shapes, components, durability and performance. The consequence of such multiplicity of sources of the various equipments is that one component part of one equipment will not fit into another of identical function because of different specification and design thereby adversely affecting effective repair, maintenance and servicing.

Spare Parts

The lack of spare parts is a major reason many medical equipment lie idle or redundant in many medical establishments. Very often people involved in the purchase of the equipment show little or no interest in the purchase of spares for routine maintenance and thus prolong the lifespan of the equipment. Usually, the process of importing spares is as difficult as importing a new equipment, being affected by the economic fluctuations and exchange controls. Consequently, the most pragmatic approach to solving this problem lies in the establishment of manufacturing engineering base where standard components can be produced.

Biomedical Engineering Technology for Effective Health Care Technical Services (HCTS)

The engineer has a role to play in medicine only because he has something arising from the basic nature of technology. Technology always has two important elements a general purpose to modify or manipulate the human environment by physical means so as to improve the circumstances of human life, and the specific aim to extend this human capability by devices, or mechanisms. Devices (mechanical, electromechanical and electronics) have been an integral part of medical practice for decades. These have enhanced health care delivery in many developed countries. Many useful medical devices are simple and a determined attack by a strongly oriented group of engineers and clinicians could make a rapid progress with regard to design, development, production, repair and maintenance of medical equipment.

Technological development evolves from appropriate application of the scientific method to the solution of the many and varied problems of socio-economic interaction. This scientific method, which is the basis of research both pure and applied, technological development and innovation, defines a problem whose solution is obtained through its application. Appropriate acquisition and development of technology should be based on actual practical planning and enthusiastic execution of research findings, through the application of the scientific method. Biomedical engineering utilizes engineering principles, methodology and practice in the solution of the many and varied problems of biology and therefore, medicine both in the diagnostic and the therapeutic fields.

The engineer, being a synthesizer assembles principles drawn from basic science to achieve, in practical form definable objectives. He depends very much on a detailed understanding of what happens when different mechanisms, or physical elements, are put together. This design process is very important in biomedical applications of engineering with regard to appropriate medical equipment acquisition in the fields of design, production, development, utilization, maintenance and repair.

Biomedical Engineering Perspective

The biomedical engineer being able to apply engineering principles and practice to the solution of problems in the fields of medical diagnosis, prophylaxis and therapeutics naturally becomes the centre-piece of the long standing co-operation between engineering and medical practice. This co-operation has been as old as the civilization of ***Homo sapiens***. Thus appliances like the walking-stick and crutches are of simple mechanical design to ease off loading of a particular leg by the weight of the body acting through an axis while standing or walking. Such prosthetic and orthotic devices including splinting have been universally used by man to reduce bone fractures. The value of such a simple physical device as an orthopaedic splint or crutches in the prevention of severe pain and in the treatment of certain deformities, ailment and amputation cannot be over-emphasised. Yet we take such a simple device for granted in this our environment without the slightest urge to scientifically study and improve on it as dictated by the dynamics of the requirements of individual patients.

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The human life machine is designed to be performing certain functions continuously, howbeit, rhythmically (e.g. cardiac and circadian rhythms) over a certain period (its lifetime) without irreversible breakdown of any of its component parts, while living. However, there are wear and tear problems of all the component parts at different times or simultaneously in their bid to maintain the dynamic equilibrium that is the hallmark of optimal health in the whole unit. Thus the human body becomes obviously analogous to man-made machine. Consequently, the functional tool of engineering including problem analysis, design and fabrication of appropriate instrumentation has been utilized by medicine in the study of the structure (anatomy) and function (physiology) of the human body while healthy and also while diseased (pathology). Thus engineering has played a central and dominant role in the progressive development of medicine and its technological innovations that has contributed in no small measure to the progress in diagnosis, prevention and treatment aspects of total health care delivery system.

The Bioengineer and Total Health Care Delivery

The Biomedical Engineer as a member of the total health care delivery team plays a major role in ensuring the success of the team in tackling its onerous task of ensuring the optimal health of the citizen and that of their environment. His role primarily lies in the research and production of appropriate instrumentation and equipment as well as other devices (e.g. artificial limbs) in addition to active research and development involved in genetic engineering including stem cell research. The interfacing of medical equipments to the patient for optimal effect falls into the specialised field of ***clinical engineering.***

A cursory look at the requirement for ensuring total health care delivery on doubt makes biomedical engineering in all his ramifications a sine qua non especially in our developing countries.

Man as a Living Machine and Its Organisation

The living machine has structure, both macroscopic and microscopic, designed to perform certain vital functions. Structurally and functionally, the human body can be regarded as comprising various organ systems programmed to work in harmony to ensure optimal functional performance in the maintenance of optimal health.

Molecular biology and therefore medicine has become an area of intense research and development arising from interest and knowledge of quantum mechanics and its applications to biological systems. This has ensured the continuous merging of biochemistry with biophysics. Genetic engineering and biotechnology techniques have become common areas of ambitious programmes that is going on now that has led to the complete mapping of human genome. Advances in genetic engineering have led to a complete cloning of a sheep recently in Scotland.

It may be safely said that without the contribution of engineering techniques and methodology, the great stride in our knowledge of the structure, especially at the microscopic level, of the human body, and its function (i.e. its physiology), would not have been possible. This is because most of the physiological interactions in the body are amenable to engineering analysis thus enabling the bioengineer to design appropriate instrument for physiological studies and diagnosis of the abnormal function. The optical and electron microscope has enabled us to have great insight into the microstructure of the living machine.

Perhaps one of the greatest feats of biomedical engineering is in the design and fabrication of total artificial organ to replace a diseased natural organ. Thus it is possible now for patients with kidney failure to live much longer than had been possible hitherto. There are now available liver support systems for people in liver (hepatic) failure. Only recently a total artificial heart (Jarvik 7) has been implanted in man in the U.S.A. and the patient has survived on it for 620 days. Prior to this medico-technological feat, there have been different types of cardiac assist devices including the implantable pacemaker. We can be at continuously hopeful that in the near future a patient in irreversible cardiac failure might survive longer than what is possible now when fitted with a totally implantable artificial heart.

Components of Biomedical Engineering

Biomedical Engineering, for convenience, can be broadly divided into biomechanics, medical electronics and instrumentation and artificial organs.

Biomechanics

Here the principles and practice of mechanical engineering are applied to the study of the human organism as a whole and its various components parts amenable to engineering analysis, thereby offering solution to the many and varied problems of its existence. Biomechanics covers a very wide field dealing with formal quantitative analysis of the structure/function relationships in living organisms, with strong emphasis on humans. It includes the cardiovascular system, pulmonary system, muscle mechanics, supporting systems, sports mechanics, biomechanical aspects of rehabilitation, ergonomics, crush injury mechanics, uterine mechanics, vestibular mechanics etc. Thus methods of measurement of biomechanical parameters and phenomena are developed to aid the clinician to treat his patient optimally.

Perhaps the most dramatic application of mechanical engineering is in the field prosthetic and orthotic design, fabrication and fitting (e.g. artificial limbs). Thus functional prostheses for total hip disarticulation are currently available. Various knee joint mechanisms, ankle joint and hip joint design have been made possible as a result of knowledge and experience gathered from detailed analytical study of structure and function of the mechanics of the human skeleton and locomotion. With the availability of adequate instrumentation (like the force plate with television monitoring etc) it has been possible to study the mechanics of walking which is not so easy to analyse since it is a complicated mechanical process. This has enabled the bioengineer to improve on the design and production feature of the various mechanical appliances used in orthopaedic surgery and rehabilitation engineering. Another aspect of biomechanics is in the area of cardiovascular dynamics and haemorheology. The availability of efficient heart-lung machine has made open-heart surgery in many centres of the world quite a fair routine.

TISSUE MECHANICS is a specialised application of mechanical viscoelasticity analysis to various tissues of the body (e.g. the skin, collagen fibres etc.) and with the knowledge gained from such analysis the plastic surgeon for instance may improve his technique for the benefit of the patient. The stress-strain relationship of bone tissue both in health and disease is amenable to analysis and the knowledge gained is applied when designing implantable prosthetic devices like the artificial hip joint or in the healing of fractures. Spinal disorders may benefit from analysis of both bones and collagen.

The pure and applied research in the application of mechanical engineering in solution of medical problems is an on-going activity in many centres of the world.

Medical Electronics and Instrumentation

Since life itself can be said to arise from the interaction of elementary particles protons, neutrons, electron and their various sub-particles, it is no wonder that the body is full of "electricity" arising from the flow and movement of electrons. Thus the body is influenced by the electric and electromagnetic fields. The presences of neutrons within the chemical elements that constitute the body ensure the availability of isotopic elements for both study and treatment by irradiation. Furthermore, the presence of an abundance of hydrogen atom or proton has made possible the currently available nuclear magnetic resonance imaging systems used for flow studies and whole-body imaging for diagnosis. The advances in Nuclear Magnetic Resonance imaging techniques have made it possible for us to map out in-vivo areas of the brain that is active during intellectual work as a result of the response of protons in water the most abundant life molecule to intense magnetic field as well as electromagnetic radiation at the radio wavelength.

The currently wide application of ultrasound technique for blood flow studies and imaging as well as therapeutic modalities and cleaning process has been possible because of the energy transduction effect in certain ceramic materials where mechanical stress leads to the production of an electric field and vice versa (piezo-electric effect) in these ceramics. Ultrasound energy is also used in physical medicine and rehabilitation to break up adhesions found in most rheumatic processes in vivo thereby reducing pain and improving mobility.

Instruments to aid the human senses have been a major feature of medicine and biology for many years. Anatomy and physiology have developed to a large extent by the application of physical measurement techniques. Consequently, the emergence of electronic instrument that has, and is continuing to enhance our capability for sensitive physical measurements was of great interest in medicine and the life sciences. The use of electronic instrument has made it possible for the clinician to record from the body, and examines in detail, electrical and other signals of which we are normally unaware.

The various areas of clinical medicine utilizing electronic instrument are quite wide but can be conveniently grouped into about four divisions including:

- Laboratory measurement
- Clinical physiological measurement
- Therapeutic techniques e.g. radiotherapy, physiotherapy and
- Electronic aids.

Since the procurement of these equipment, their repair and maintenance are generally capital intensive, draining a good chunk of foreign exchange earnings of most developing countries, being imported without regard to their suitability to environmental factors of ***climate***, it becomes imperative that effort should be geared towards appropriate research and development of these devices using components from any where that meets the standard specifications for the various socio-economic environments of developing countries. That is one sure way for appropriate technological development especially in our health care delivery system.

Biomaterials and Artificial Organs

Many synthetic materials and devices are available to supplant or supplement various functions or organs of the body. The support of malfunctioning organ is becoming commonplace with the use of complex apparatus such as artificial kidneys, heart-lung machine (pump and oxygenators), ventilators, heart valves, pacemaker and a host of other prosthetic and orthotic devices.

Although one is aware in certain cases of the possibility to transplant an organ from a donor to a recipient limited availability of transplants and the major problems of biological rejection associated with their use, presently militates against the procedure on a routine basis. This problem necessitates the need to look elsewhere for solution. The biomaterial science and artificial organ research and production aspect of biomedical engineering has been providing solutions to this problem of clinical practice.

Many reasonably biocompatible synthetic polymers have been of assistance in such fields as haemodialysis and haemoperfusion for blood purification. Consequently, people who may have died of kidney, pulmonary (lungs) or hepatic (liver) failure have a reasonable chance of prolonged survival on artificial kidney or dialysis machine, artificial lungs or blood oxygenators, and artificial liver or sorbent-based liver support devices.

All these accomplishments would not have been possible without research activities on biocompatible biomaterials. Furthermore, research effort is being expended on biocompatible material for implantable artificial heart, just as ***biodegradable glass*** currently being researched upon may one day replace fixation devices for orthopaedic implants thereby obviating another surgical procedure for removal of plates, pin and screws after bone union. Also, biodegradable materials may become a medium for drug administration for instance in obstetric and gynaecological practice and family planning.

Cardiac Bioengineering

One subject dear to my heart involves artificial heart research and development programme. This informed my original idea in pursuing education and training in Biomedical Engineering since I had an idea of an implantable artificial heart. Research and development of artificial heart pump is part of a revolution in cardiovascular research involving design of a vast array of new devices that provide life-saving help to patients with diseased hearts. The novel gadgets range from the seemingly simple, such as metal called stents that keep coronary arteries open after balloon angioplasty, to complex, implantable microelectronic machines that watch for and correct abnormal heart rhythms.

Mechanical Hearts

The design of "heart pumps" is one of the areas where rapid progress is occurring. Left Ventricular Assist Device (LVAD) is used to treat heart failure that may be caused by heart attack, infection or other diseases that leaves the heart too weak to function optimally. LVAD's are used as bridges to heart transplants. However, newer models are in clinical testing, give patients freedom that has not been possible with other models, as they allow patients to go home and do everything they normally do. The future may be bright enough that some permanency of such devices will become possible with further miniaturization and safety characteristic of such devices. The Jarvik 7 artificial heart was implanted a patient who survived on it for 620 days nearly 2years after implantation as I have mentioned above. Probably when the power problem of about 10watts can be solved for a totally implantable heart which is also optimally biocompatible with the individual, the age of true artificial heart will have arrived.

Personal Shock Therapy and Electroconvulsive Therapy

Damage to the heart muscle can kill far more suddenly if there is interference with normal electrical impulses controlling the heart beat than the gradual process of heart failure. Drug therapy for arrhythmias has not progressed beyond what has been available since the 1920's. Recent advances in devices called IMPLANTABLE DEFIBRILLATORS which can sense erratic heartbeats can shock it back to its normal rhythm thereby providing new hope for patients at risk.

In all these devices, the microprocessors that perform the diagnostic and sensory functions can be programmed to respond to each patient's heart and therefore can distinguish an exercising heart from one going into arrhythmia. Furthermore, areas of ectopic electric impulse generation responsible for many of the arrhythmias can now be coagulated using radiofrequency heating through an intra-cardiac catheter. The new Left Ventricular Assist Devices (LVAD) and implantable defibrillators depend on advances in microelectronics and other sophisticated technologies.

Furthermore in clinical Psychiatry, Electro-convulsive Therapy (ECT) is used to shock back the brain to normal rhythm in the management of certain forms of psychiatric illnesses.

Biomedical Engineering and Rehabilitation Medicine

One of the many successes of medical application of engineering techniques and methodology is in the rehabilitation of many a patient with various forms of disabilities. Rehabilitation engineering has produced a great number of contrivances to aid the amputee for instance towards better function, by using his remaining limbs aided by the artificial (prosthetic) limb (leg or hand) that has been designed, fabricated and fitted to enhance physiological function and anatomical balance for optimal performance with respect to his primary disability.

A good aspect of orthopaedic practice involves rehabilitative medicine of which artificial limb fitting (prosthetics and orthotics) involving replacement of a missing limb (prosthetics) and aiding a deformed or diseased limb (orthotics) remains one of the main facets. With the many accident victims who may lose one or more limbs, it becomes imperative to integrate artificial limb fitting into general rehabilitative medical practice, especially in view of the many patients that travel overseas for prosthetic and orthotic devices that could be profitably improvised and fitted locally. Consequently, there is no doubt that these unfortunate citizen, especially those that cannot afford foreign travel and treatment expenses, will benefit from the increasing advances in and utilization of technology and automation in health care delivery.

Role of Biomedical Engineering in Total Health Care Delivery

There are two fields that play important role in the development and adaptation of medical instrumentation for examination, diagnosis and treatment. These fields include medical and biological research, and technological innovation. Trial testing in real hospital environment represents an important source of information for researchers and industrialists, thus helping them to better discern the needs and problems of adaptation that can only be observed during actual use of equipment.

The primary role of the biomedical engineer is obviously to know the technical criteria, which should allow him either to appreciate an apparatus and compare it with existing competitors or to evaluate different solutions for certain technical or medical problems. He must be able to give a solid opinion on each technical solution's adaptability to the medical problem submitted by the user. Furthermore, he also has a place in medical research, because of the new ideas he has to offer, resulting from direct experience and contact with the medical team. Thus, the biomedical engineer is involved at many levels in the safe, appropriate and economical use of technology in the health care system.The role of the biomedical engineer can therefore be divided as follows:

- Advisory Service on Available Technology
- Evaluation and Purchase
- Maintenance
- Hazard Prevention
- Clinical Measurement
- General Technical Support
- Education and Training
- Research and Development

In developing countries, the need for biomedical engineering facility cannot be over-emphasised. The active role in research and development of devices and equipment to suit the socio-economic environment of most developing countries, especially now that there is a dire need of a sound foundation for technological take-off, must be pursued with utmost vigour.

Since the hospital sector of total health care delivery has, consequent upon man's quest for high quality optimal health, changed from the social medical stage to that of a highly technical enterprise, requiring advanced organisation and appropriate manpower development, it becomes incumbent on all developing countries to lay a sound foundation for appropriate technological development based solely on research, production and innovation. It becomes pertinent at this point in time of our development to emphasis the need for the cultivation of the habit of self-confidence in or ability to solve our technological problems. We must not lose sight of the fact that the contemporary world of ours is an interdependent one. We must give as much to technological development to humanity as we receive from the effort of others. That is the only way our socio-political greatness as ***Homo sapiens*** can be measured.

The Engineer and Medicine

The engineer has a role to play in medicine only because he has something arising from the basic nature of technology. Technology has two important elements - a general purpose to modify or manipulate the human environment by physical means so as to improve the circumstances of human life, and the specific aim to extend this human capability by devices or mechanism.
Devices (mechanical, electromechanical and electronic) have been an integral part of medical practice for decades. These have enhanced health care delivery in many developed countries. Many useful medical devices are simple and a determined attack by a strongly oriented group of engineers and clinicians could make a rapid progress with regard to design, development and production, repair and maintenance of medical equipment.

Many developing countries as at present are heavily dependent on imported equipment from all over the world. As there is no manufacturing engineering base for medical equipment, optimal utilization, maintenance and repair of such equipment of necessity imposes real problem to the health care delivery system of most of these developing countries. However, the provision of adequately trained manpower for design, development and production of simple medical equipment will lead to the availability of adequate number and quality of equipment and their spare parts. This will inevitably lead to the attainment of the goal of optimal health for all in the next millennium.

Technological development evolves from appropriate application of the scientific method to the solution of the many and varied problems of socio-economic interactions. This scientific method, which is the basis of research - both pure and applied, technological development and innovation, defines a problem whose solution is obtained through its application. Appropriate acquisition and development of technology should therefore be based on actual practical planning and enthusiastic execution of research findings, through the application of the scientific method.

Biomedical engineering utilizes engineering principles, methodology and practice in the solution of the many and varied problems of biology and therefore medicine - both in the diagnostic and therapeutic fields. The engineer, being a synthesizer assembles principle drawn from basic science to achieve, in practical form, definable objectives. He depends very much on a detailed understanding of what happens when different mechanisms, or physical elements, are put together. This design process is very important in biomedical applications of engineering with regard to appropriate medical equipment acquisition in the fields of design, production, development, utilization, maintenance and repair.

Medical Equipment Acquisition, Maintenance and Repair

The problems associated with the acquisition and utilisation of medical equipment that one does not understand the principles on which the equipment designs and fabrication is based becomes real when the equipment breaks down or malfunctions. Most of the times in Nigeria equipment break down soon after being commissioned with the result that the objective necessitating its initial purchase is not achieved.

The factors responsible for this state of affairs are multiple. However, the most important of these factors include non-availability of appropriately trained manpower at all levels, indiscriminate importation of unsuitable equipment in addition to a fundamental lack of an objective national policy on medical equipment acquisition, maintenance and repair.

Appropriate acquisition of medical equipment should, as a matter of policy, be based on thorough training and education in all aspects of biomedical engineering. Research, design and development of medical equipment in Nigeria should be the cornerstone of any policy on equipment acquisition. This will ultimately lay a sound foundation for effective equipment maintenance and repair as many personnel effectively engaged in the equipment design and fabrication will be in a most knowledgeable position to train further personnel on the job for effective maintenance and repair job.

Nigeria and most other developing countries as at present are heavily dependent on imported medical equipment from all over the world. Consequently, a short-term solution would be a pragmatic approach to the training of qualified and interested personnel on the principles of maintenance and repair as applied to medical equipment. This is after appreciating and acquiring a working knowledge through appropriate education and training on the physical principles of equipment design and fabrication.

The long-term solution lies in the laying of a solid foundation for research, development and production of appropriate medical equipment. This should be based on the establishment and development of Biomedical Engineering as an innovative, research and development oriented approach to the solution of the many and varied technical problems of total health care delivery system of any nation especially those of the developing countries.

Scientific and technological research and development falls into two broad categories pure and applied research. Perhaps in view of the technological underdevelopment of most developing countries, appropriate applied technological research seems to be the best line of action in acquiring technological know-how. We seem to be lucky that the technological progress of mankind has been extensively documented and their various products available. Nothing stops us from undertaking a scientific study of the principles on which most of these products are made with a view to designing and producing them for our needs as well as the markets of the future. The various ways these can be done include the purchase of patent rights to enable the local production of appropriate medical equipment to suit our socio-economic environment. After laying a good foundation for applied research, then the fruit of the productivity accruing from such applied research should then be ploughed back into any aspect of pure scientific research so as to contribute our own quota to on-going technological development of mankind.

National Policies

As at now there are no clear-cut national policy objectives on appropriate medical equipment acquisition, maintenance and repair. What exist presently according to the Federal Ministry of Health are unwritten guidelines on equipment purchase, repair and maintenance. The Federal government of Nigeria purchases equipment through tender and a contract agreement is entered into with the vendor for maintenance and repair. Commonly, most vendors are mere agents without adequate infrastructure and manpower resources for effective repair and maintenance of the purchased equipment. The result of such lopsided agreement is that most equipment becomes redundant as appropriate resources for their maintenance and repair are lacking.

APPROPRIATE MEDICAL EQUIPMENT ACQUISITION, MAINTENANCE AND REPAIR

Before any medical equipment can be properly maintained, it must have been properly acquired and commissioned. Proper acquisition must of necessity involve equipment selection based on appropriate evaluation by competent personnel. A major source of problem regarding equipment maintenance and repair involve non-standardisation of equipment imported into the country in addition to the myriad of available medical equipment most of which are obsolete.

Selection

The many variety of equipment available to the medical profession arises from the fact that most equipment are designed to meet specific needs identified by a doctor and often developed and manufactured in close collaboration with a particular doctor. Consequently another doctor may find that this equipment does not suit his purpose. The end result of this phenomenon is the proliferation of medical equipment in the market with exaggerated claims of being the most appropriate for carrying out certain functions.

In Nigeria and many other technologically developing countries where development work in biomedical instrumentation is not done, doctors in line with the prevalent situation, with regard to appropriate technological acquisition, tend to select equipment they are familiar with during their apprenticeship and practice. This is without the slightest urge to consider its suitability to the socio-economic environment of its proposed use. Thus the technical aspects of its specifications do not come into consideration with respect to evaluation before purchase and commissioning.

The average apparent ignorance and lack of understanding of anything technical has been inimical to appropriate acquisition of medical equipment and therefore the ineffective maintenance and repair of inappropriately acquired equipment is a foregone consequence. Thus, the varieties of medical equipment that abound in this country are ineffective, of inferior quality or even dangerous. This problem is compounded by the fact that manufacturers and suppliers of medical equipment have a field day in Nigeria as they put anything - both irrelevant and obsolete equipment in the market - with little or no published specifications by which the equipment can be assessed.

Furthermore, the government or many hospital authorities do not have any technical basis for awarding contract on the supply of most medical equipment they purchase. Thus, they pay the least attention to the ability of the contractor to install, operate and maintain the equipment before it is purchased. The net result is that most government hospitals in Nigeria have warehouses full of equipment that have never been installed and commissioned or when improperly installed soon become redundant for one reason or another. Consequently, there is a need now to pay much attention than has been the case hitherto on the specification so that appropriate medical equipments, which are safe, cost-effective and easily maintained and repaired, can be purchased. This will enhance the technological requirements of the achievement of the goal of optimally Healthy Human Life in our socioeconomic environment.

Biomedical Engineering Perspective

The field of biomedical engineering encompasses all aspects of clinical practice and basic medical sciences. Thus bioengineering becomes indispensable to the physiologist or biochemist as well as the clinician, for instance the orthopaedic or cardio-thoracic surgeon amongst others. Generally, the activities in this field can be glimpsed from the following examples of complex installations used in certain highly technical specialities:

- **Radiology:** General and specialised diagnostic X-ray equipment, CAT (Computerised Axial Tomography) scanners, Thermography (thermal imaging), Ultrasonic imaging techniques, NMR (Nuclear Magnetic Resonance) imaging technique etc. PET (positron emission tomography). Ionising Radiation Therapy; Cobalt therapy, linear accelerators.
- **Laboratory:** Automated multi-channel analysers, measuring counters for radioisotopes, Gamma cameras. Genetic engineering, DNA sequencing, monoclonal antibody technique.
- **Cardiology:** Monitoring equipment, pacemakers, coagulators, defibrillators, haemodynamics specialised equipment, blood gas analysers.
- **Exploratory devices:** Electrocardiographs, electroencephalographs, ultrasonic echographs.
- **Specialised Surgery:** Open heart surgery equipment, anaesthesia machines, monitoring equipment, intensive care equipment, lasers.
- **Nephrology:** Artificial kidneys, chemical or radioisotopic exploratory devices for renal function. Shock wave lithotripsy.
- **Gastroenterology:** Endoscopes, liver support devices etc., shockwave lithotrypsy.
- **Computer System:** for management of health care

delivery, collection and management of laboratory results and analysis of biomedical signals and images, computerised tomography system.

The specialised field of medical electronics that covers the instrumentation required for the above applications are important in laboratory instruments, nuclear medical equipment, computers in medicine, clinical physiological measurements, and therapeutic techniques as well as other electronic aids like hearing aid etc. Most recently a functional visual prosthesis incorporating a miniature video camera with surface electrodes attached to the occipital area of the skull promises to be an effective aid for the blind. An artificial retina has been deviced and implanted and the promise of such prosthetic device in the management of blindness cannot be overemphasised. Moreover, a pacemaker for the phrenic nerve graft for the paraplegic is now in use.

Other areas of active research and development in biomedical engineering include biomechanics, tissue mechanics, rehabilitation engineering and artificial organs (including total artificial heart, lungs, kidney and liver) as mentioned above.

The fundamental research perspective for biomedical engineering in our peculiar environment must take cognisance of the whole field of activities. There is no doubt that there is a dearth of medical equipment in our socio-economic environment. The few equipment that are available no sooner than they are commissioned break down, sometimes irretrievably because of lack of adequate manpower resources to design, develop and fabricate equipment to suit our environment. Moreover, the present economic reality of our country makes it imperative that we should take the bull by the horn and create a conducive environment for proper and appropriate establishment and development of biomedical engineering facilities and technologies.

In view of appropriate long-term solution to the peculiar health care delivery problems, of most developing countries, a biomedical engineering unit should be organised to provide research, development and training facilities in the following specialised areas of activities:

- Biomechanics, Tissue mechanics and Rehabilitation engineering;
- Biomaterials and Artificial Organs - kidneys, liver, lungs and total artificial heart as well as assist devices;
- Medical Electronics and Instrumentation;
- Medical and Health Physics.

Biotechnology

Life is uniquely characterised by reproduction and metabolism inherent in all organisms ranging from such primitive forms as cyanobacteria (formerly known as blue-green algae) to plants and animals as we have seen above. The mechanism of reproduction is now known to be controlled by the properties of certain large molecules called nucleic acids. Deoxyribonucleic acid (DNA) constitutes the hereditary material that can be passed from one cell or organism to another, because DNA molecules can make copies of themselves by means of a process known as template replication. The DNA molecule consists of a long series of coded messages capable of directing the synthesis of specific proteins at any time in the cell or life cycle. In turn, these proteins are responsible for the synthesis of many other substances within the living organism. Reproduction therefore involves making copies of the molecules constituting an organism and ultimately results in copies of the organism itself

One of the central questions about life is how it originated. The generally accepted theory is that early in the history of the earth (about some 2 billion years ago) some system of replication powered by external sources of energy must have been formed. A further assumption is that the Darwinian principle of natural selection soon began to play an important role in this process, favouring those replicating molecules that could find energy most readily. Such an assumption is reasonable because evolutionary success through natural selection is measured in terms of the ability of a living system to perpetuate its replicating molecules, or genes. Thus, primitive systems capable of carrying out the metabolic processes necessary to perpetuate their genes had a competitive advantage and eventually evolved into cells. The changes that have taken place since the origin of the cellthe rise of prokaryotes, nucleated cells, multi-cellular organisms, and, ultimately, higher plants and animalsare also thought to have occurred as a result of natural selection (see Evolution). Given such an evolutionary progression, it is possible that parallel evolution could have occurred on other planets in the universe.

Quantum Physics and Molecular Biology

The study of life at the atomic and molecular level (molecular biology) is the hallmark of the transition from the twentieth to the twenty first century. A lot of studies have been made at this ending of the 20th century just like the quantum phenomena in the physical sciences. Biochemistry and biophysics, which are gradually merging, has given us a glimpse of what expect in the 21^{st} century.

The present trend towards the joining of chemistry and physics and the gradual merging of biochemistry with biophysics has necessitated the need for understanding of atomic and nuclear phenomena which involve sub-microscopic, or atomic space time level of consideration. Many biological phenomena not easily observable can now be observed as result of advancement in science and technology Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET), Computed Tomography Scan (CAT Scan), Patch Clamp Technology, electrophysiology, signal transduction in biological systems etc. Since our discourse is about life and how to keep it healthy, it may seem plausible to ask the question 'How did life originate'?

Physico-Chemical Evolution of Life and Living Organisms

It seems that, with the "BIG BANG" and its aftermath - which ensured the synthesis and availability of the basic life chemicals - water, proteins, nucleic acids (DNA, RNA), sugar and a host of other matter necessary for organic life, it was probably the chance synthesis of the organic pigment - chlorophyll, that led to the evolution of life processes, which essentially seems to be the conversion of sun's energy into life energy through the medium of interactions between the various components of matter and energy!

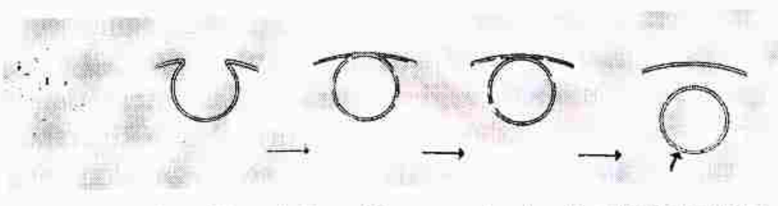
Evolution of Physico-Chemical Interactions of Life

It was Oparin in the former Soviet Union who in the 1930's made a systematic attempt to postulate the evolution of life on earth. The earth having existed for about 2 billion years after the "Big Bang", consisted of huge warm oceans in which were dissolved a variety of salts derived from rocks, and over which hung an atmosphere of gases including hydrogen, methane, ammonia and carbon dioxide, all originating from this thermo-nuclear explosive reactions that led to the creation of the various elements.

Under these conditions of the primitive earth, a number of organic compounds would have begun to be formed and scattered in solution throughout the sea. The interactions between and amongst these chemicals prevalent both in the atmosphere and oceans would have been dependent on precise reducing property of the primitive atmosphere and the steady influx of energy in terms of light energy - both visible and ultraviolet radiation from the sun. In these circumstances, carbon dioxide (CO_2), water (H_2O), methane (CH_4) and ammonia (NH_3) can react to give a mixture of products including amino acids, urea and many other organic substances.

Stanley Miller in America tried to verify the above postulate by passing electric charge through a gaseous mixture of hydrogen, methane and ammonia in a closed water bath for periods ranging from twenty or more hours. Analysis of the products at the end of the period showed the "creation" of more than eight different amino acids and seven mono-carboxylic acids, all of which are amongst the basic building blocks of present day living organisms.

The primitive oceans must have steadily increased in organic contents and these substances interacted with one another to form whole range of new substances. The surface of the earth's rocks and clays of the beds of these oceans and seas which contained iron, magnesium, zinc, copper et cetra provided catalytic surfaces on which the organic compounds would have begun to polymerise. Consequently, short chain peptides and nucleic acids and possibly carbohydrates as well would have also begun to accumulate - both bound to mineral surfaces and free in solution in the seas and oceans.



Polymerisation, Flocculation of larger molecules, Droplet formation. Coacervation leading to organelle formation E.g. RIBOSOMES that has evolved for the Production of PROTEINS!

Fig 1: **Solubilisation, coacervatiom, colloidal and droplet formation that may have led to unit membrane structure of living organisms** (Adapted from Okoye, 2004)

The availability of large polymers of organic molecules including amino acids, carbohydrates et cetra invariably led to their tendency to flocculate into larger molecules which broke down into droplets containing concentrated polymer molecules. Salts and lower molecular species surrounding the droplets tended to be sucked into the inside of the droplets together with other polymers arising from the energy provided by osmosis. This phenomenon is called coacervation and can be explained physico-chemically by the science of colloids. Coacervation droplets may be formed from mixtures containing for example gelatin and gum arabic.

Oparin hypothesised that in these primitive oceans containing polymeric organic compounds, such colloidal droplets would have begun to be formed, coalescing together into highly concentrated droplets. Within the droplets, the differrent compounds inside would have started to interact with one another because of their new proximity in space and time. An interesting property of some colloids or coacervate droplets is that of optimum size beyond which they break down into two or more smaller fragments of similar composition to the parent droplet. With the breakdown of unstable coacervate droplets, their products may have been incorporated into stable ones which, as it grows, divides further into similar droplets. Within these, more complex polymers would have been formed with metals ions acting as catalyst for favoured reactions. Enzymes and co-enzymes such as nucleotides would have become more active binding to peptide polymers to form proto-enzymes, and so on.
At some point during the several of thousands of millions of

years of these physico-chemical evolutionary interactions, the nucleic acids and proteins must have arisen as mutually interacting molecules capable of interdependent synthesis of each other through the DNA-RNA-PROTEIN complex which is today responsible for genetic transfer during the physico-chemical reaction referred to as the gene action. A triplet of a chain of nucleic acid molecules - usually referred to as codon is responsible for the initiation of a complex of biochemical reactions whereby a particular amino acid coded is linked to another leading to the synthesis of proteins.

Thereafter, with the evolutionary development of photosynthesis, the condition for existence of independent life processes and living organisms occurred.
Nucleic acids are self replicating and they constitute the partly living organisms called viruses which possess the replicating nucleic acids but lack the ability to convert energy. In order to obtain enough energy to reproduce, viruses act as parasites; they invade a host cell and cause it to follow the instructions of the viral genetic material. In this way the virus takes over the genetic apparatus of the host to create more virus particles, a process that prevents the host cell from reproducing normally. Virus particles consist only of nucleic acid wrapped in a protein coat. In some groups of viruses, the nucleic acid is ribonucleic acid (RNA) instead of DNA.

All viruses of which the most celebrated in recent times - Human Immunodeficiency Virus (HIV) or AIDS virus consists of packages of DNA and proteins. Once these inactive packages of organic molecules find the right environment - usually a living cell, they start to replicate themselves using the facilities provided by these cells according to the blueprint encoded in their DNA. Outside the living cell, they remain inactive.

Unicellular Organisms

The first forms of life to appear in the warm pre-Cambrian seas were simple unicellular organisms. The development of a membrane by the physico-chemical interactions between matter and energy led to the evolution of the unit cell membrane where there is the cell interior and the outside "sea" that made it possible for these early cells to evolve a chemical composition which differed from the surrounding sea water. It is possible that one of the characteristics of these early life-forms was the interaction between matter and energy that led to its evolution and within which units an integral active transport system for the chemical ions - Sodium (Na) and Potassium (K) across the membrane developed enabling the cell to maintain an internal sodium concentration lower than in the surrounding sea.

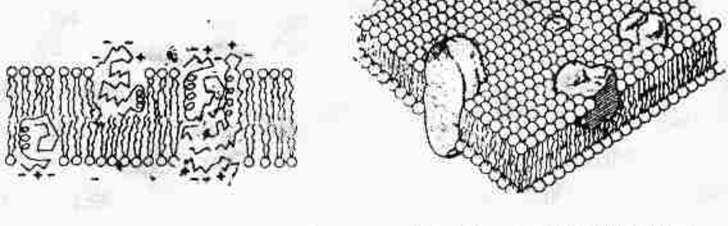


Fig 2: The unit cell membrane arising from solubilisation, coacervation, colloidal and droplet formation

These unicellular organisms depended on the constant composition of the sea surrounding them. Nutrients were taken up from the sea and waste products excreted into the vast oceans where they were so diluted that their toxicity was eliminated. However, with the development of multi-cellular organisms, a way had to be found for retaining this sea, so that each cell could be bathed in a fluid with the physico-chemical properties required for stable membrane and cell function.

Claude Bernard was the person who recognised that it was this fixity of the internal environment that is responsible for the condition of free and independent life! He hypothesised that there is a mechanism whereby any change in the internal environment would automatically initiate a reaction to minimise the change. This fundamental mechanism is called homeostasis and any disturbance of this homeostatic mechanism leads to the death of the organism. A fundamental property of life is the ability to maintain the constancy of internal environment.

Photosynthesis in the Evolution and Propagation of Life

A green plant can be regarded as a life machine which runs on solar or light energy. Light is an electromagnetic radiation of energy, powers photosynthesis - the process by which green plants convert carbon dioxide (CO_2) and water into sugars, starch and oxygen. Essentially, the plant captures sun's energy - through electromagnetic radiation in the visible as well as invisible range, and converts it into the substances that directly or indirectly sustain most other forms of life on earth as well as itself.

The photosynthetic pathway is probably the most dramatic example of the interaction between matter and energy whereby a system of molecules has evolved to ensure the perpetuation of life processes in an organised manner. These have led to the evolutionary realities of our contemporary world of living organisms as perceived by Homo sapiens!

ENERGY

CO_2 + H_2O CHLOROPHYLL CHO + O_2

* * * * * * * * *

Photosynthesis is one of the most fundamental of all life processes. It is essentially the fixation of carbon dioxide from the atmosphere into the larger biochemical molecules as we have seen above. This fixation or photochemical reaction involving sun's energy in the form of visible radiation is carried out through the enzymatic action of the photosynthetic enzyme - ribulose 1,5 - diphosphate carboxylase. It is through this reaction that energy of the sun is converted to chemical energy in the form of sugar and other molecules. It is through this reaction that photosynthesis provideds for both plant and animal life on earth. The enzyme ribulose 1,5 - diphosphate is very abundant on earth and is coded by its gene in all green plants.

The Elements and Molecules of Life

The analysis of how the chemical elements are present in the living system can be done in several analytical procedures. For instance the proportions of the various chemical elements can be determined by simple known techniques of analytical chemistry. The flame photometer can recognise the many metals present in biological material by simply burning the specimen in air, whereby the characteristic colour of the chemical element is determined quantitatively. Inorganic analytical procedures have given rise to the following quantitative proportions of the various chemical elements that interact to form the living human organism:

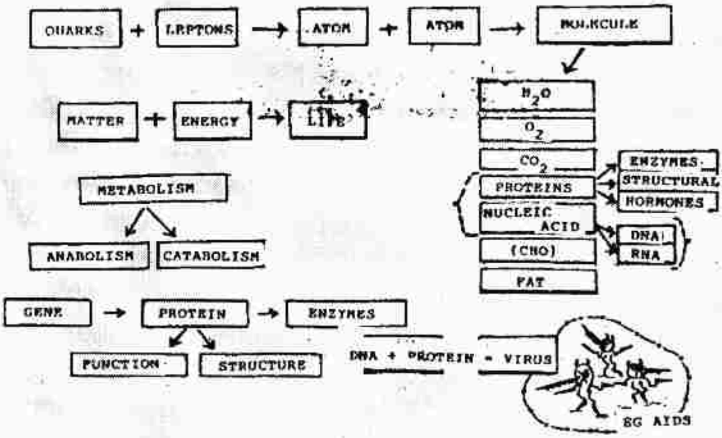


Fig 3: **Evolution of elements, molecules and species of living organisms e.g. the AIDS virus consisting of just DNA and a coat of PROTEIN!** (adapted from Okoye, 2004)

Table 1: **The elements of life**

CLASS	SUBSTANCE	% BODY WEIGHT
As Elements	Oxygen (O)	65
	Carbon (C)	18
	Hydrogen (H)	10
	Nitrogen (N)	3
	Calcium (Ca)	2
	Phosphorous (P)	1.1
	Potasium (Kalium, K)	0.35
	Sulphur (S)	0.25
	Sodium (Natrium, Na)	0.15
	Chloride (Cl)	0.15
	Magnesium (Mg), Iron (Fe), Manganese(Mn), Copper (Cuprum, Cu), Iodine (I) + Cobalt (Co), Zinc (Zn)	Trace
	Water	60-80
	Total Solids	20-40

The Chemical Interactions of Life Processes

The positively charged ions of potassium (K^+), sodium (Na^+), Calcium (Ca^{2+}) and magnesium (Mg^{2+}) on the one hand and the negatively charged chloride (Cl^-) and phosphates ($P_4O_3^{-}$ are very essential for the proper functioning of the cell. They maintain the constancy of the internal environment in the absence of which the macromolecules will be unable to function, or may even disintegrate. They are also essential as cofactors, co-enzymes or catalysts for many of the chemical reactions of the cells, as well as being directly involved in such cell function as nerve transmission and muscular contraction. The cells require energy for the maintenance of the constancy of the internal environment vis-à-vis external environment.

***Table 2:* Molecules of life**

CLASS	SUBSTANCE	% BODY WEIGHT
As	Proteins (Polyamino-acids)	
Types	NH_2	
Of	|	
Molecules	R - C - COOH	15 - 20
	|	
	H	
	Lipids (Fatty acids, oils	3 - 20
	Carbohydrate (Sugars or	
	Polysaccharide	1 - 15
	Small Organic Molecules	0 - 1
	Inorganic Molecules	1

A balanced diet for man and indeed other forms of life must have adequate complements of these Molecules of life!

Gene Action and Genetic Engineering

The gene is the hereditary material and it is probably the chance synthesis of the nucleotides, in addition to other biologically active molecular species, after the "BIG BANG", that led to the evolution of the sustained organised interaction of matter (both organic and inorganic) and energy - light, heat, ultraviolet and other energetic radiation, in the form known as "life" by Homo sapiens.

The building blocks of hereditary materials or GENES are made up of multiple molecules of nucleotides (i.e. polynucleotides). These materials are found in the chromosomes of the cell nucleus. Thus, with the availability of the requisite molecules at optimal concentration in the vicinity of appropriate environment, the right conditions for the sustained interactions that have come to be known as life occurred. It is the sequence of nucleic acid making up the genetic material that is responsible for the coding function of the genes. A triplet of nucleic acid in a particular sequence determines the amino acid to be linked in the process of protein synthesis that is the hallmark of the genetic action.

The nucleotides including DeoxyriboNucleicAcid (DNA) and RiboNucleicAcid (RNA) occupy a remarkable position in the molecules of life since they constitute the biochemical codes that determine the organisation of the form and character of all living things. In fact, the smallest molecular species that can be said to be living under certain conditions are made up of just nucleotides. These molecular species are known as viruses, of which one of the most celebrated in our contemporary world is the one that causes the dreaded human disease - acquired immune deficiency syndrome or AIDS.

Nucleotides including adenine, cytosine, thymine and guanosine form the building blocks of the genes - genetic material that encodes and directs the creation and maintenance of all inheritable traits towards the sole objective of the perpetuation of species. Thus it is because of the genes that a man is a man and not a goat! Furthermore, in procreating, the genes ensure that a human begets a human and no other organism.

However, the genes can be influenced by the many and varied interactions of our physico-chemical world to give rise to evolutionary trends in organic life. Gene action is the scheme of things which makes it possible for a human being to beget a human being according to the grand design of its genetic constituents. The creation of the nucleotides and other molecules was important in the evolution of life from physico-chemical interactions.

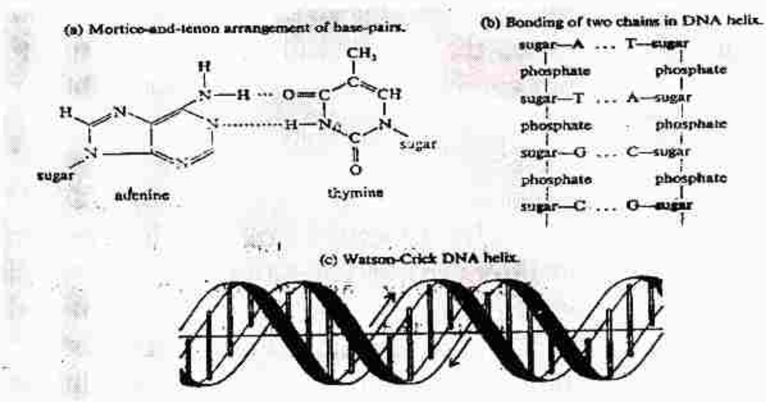
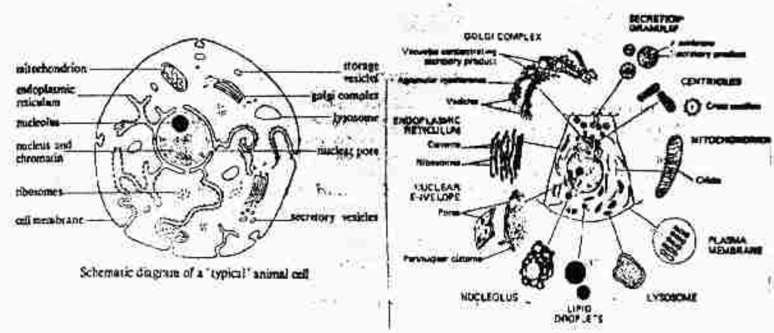


Figure 4: **The chemical molecular structure of DNA the Watson-Crick model showing the hydrogen bonds**

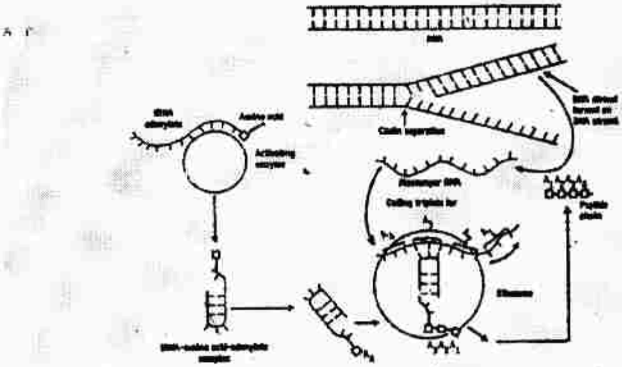


Ultra-structure of the common organelles and inclusions. The endoplasmic reticulum illustrated here is the granular type, with ribosomes attached to it. Some cells also contain tubes of membrane without ribosomes (agranular endoplasmic reticulum). The pores in the nuclear envelope are closed by thin, homogenous membrane. (Modified and reproduced, with permission, from Bloom and Fawcet, 1975).

***Figure 5:* The ultra-structure of animal cell showing the organelles responsible for the various metabolic processes of the living organism** (Okoye, 2004)

The Gene Action

The genetic code chemically consists of the arrangement of the nucleotides in the long chain DNA - the genetic material of the cell chromosomes. The genes exert their influence through the proteins they encode. The main action of proteins as biomaterials is to serve as structural materials as well as enzymes, hormones etc. We have learnt that the enzyme ribulose 1,5 - diphosphate carboxylase is one of the most abundant enzyme on earth. They are found in green plants and are coded by genes. All enzymes - biological catalysts, are proteins and are coded by the genes.



Diagrammatic outline of protein synthesis. The nucleic acids are represented as lines with multiple short projections representing the individual bases. (Reproduced, with permission, from Haggis GH & others: *Introduction to Molecular Biology*. Wiley, 1964.)

***Figure* 6: The gene action and protein synthesis**

When a gene is induced, its double strand DNA sequence which consists of nucleotides, designated by the letters A, T, G, and C, is transcribed into single strand messenger RNA (or mRNA). This mRNA code is in turn translated into a particular protein. This protein maybe part of a structure or may perform a function that helps to determine the form of the living organism. Many genes are themselves controlled by the DNA sequences immediately surrounding the gene. These regulatory regions govern the expression of a gene by modulating its transcription into mRNA. Also light - a form of energy apart from providing photosynthetic transduction of light energy into chemical energy for all life processes also regulates and controls the process (i.e. gene action in all photosynthetic plants), in a homeostatic manner.

Fig 7: **An iconic image of genetic engineering; this "autoluminograph" from 1986 of a glowing transgenic tobacco plant bearing the luciferase gene of the firefly, illustrating the possibilities of genetic engineering (after Wikipedia, 2008).**

Genetic engineering, genetic modification (GM) and gene splicing are terms for the process of manipulating genes, usually outside the organism's normal reproductive process.

It involves the isolation, manipulation and reintroduction of DNA into cells or model organisms, usually to express a protein. The aim is to introduce new characteristics or attributes physiologically or physically, such as making a crop resistant to a herbicide, introducing a novel trait, or producing a new protein or enzyme. Examples can include the production of human insulin through the use of modified bacteria, the production of erythropoietin in Chinese Hamster Ovary cells, and the production of new types of experimental mice such as the OncoMouse (cancer mouse) for research, through genetic redesign.

Since a protein is specified by a segment of DNA called a gene, future versions of that protein can be modified by changing the gene's underlying DNA. One way to do this is to isolate the piece of DNA containing the gene, precisely cut the gene out, and then reintroduce (splice) the gene into a different DNA segment. Daniel Nathans and Hamilton Smith received the 1978 Nobel Prize in physiology or medicine for their isolation of restriction endonucleases, which are able to cut DNA at specific sites. Together with ligase, which can join fragments of DNA together, restriction enzymes formed the initial basis of recombinant DNA technology (Wikipedia, 2008).

Applications of Genetic Engineering toward Healthy Human Life

The first Genetically Engineered drug was human insulin approved by the USA's FDA in 1982. Another early application of GE was to create human growth hormone as replacement for a drug that was previously extracted from human cadavers. In 1986 the FDA approved the first genetically engineered vaccine for humans, for hepatitis B. Since these early uses of the technology in medicine, the use of GE has expanded to supply many drugs and vaccines.

- One of the best known applications of genetic engineering is that of the creation of genetically modified organisms (GMOs).
- There are potentially momentous biotechnological applications of GM, for example oral vaccines produced naturally in fruit, at very low cost.
- A radical ambition of some groups is human

enhancement via genetics, eventually by molecular engineering.

DNA sequencing is a technique which is used to identify each base in DNA. Although the costs of DNA sequencing has dropped dramatically, the NIH estimates it costs at least $10 million to sequence 3 billion base pairs - the size of the whole human genome.

Molecular biologists can through genetic engineering replace the plasmid genes with the genes of their choice. This is then transferred to cells in tissue culture or outright implantation. In plant biology, the plasmid of the bacteria known as ***Agrobacterium tumefaciens*** is used whereas in animal cells the plasmid of ***Eschericha coli*** is used.

Fundamental Interactions, Nature, Matter and Energy

NATURE can be defined as the sum total of all interactions between matter and energy. At each level of organisation, the various interactions between matter and energy provides exciting phenomenon for the inquisitive mind of Homo sapiens. These levels of organisation range from the sub-atomic interactions (where our fundamental particles such as the quarks and leptons on the one hand, interact with energy on the other, being mediated by the gauge bosons of our fundamental forces of nature, such as the photons and gluons), to the astronomical order of magnitude limited by the radius of curvature of the Universe.

These interaction between matter and energy give rise to the fundamental forces of nature including gravitational, electromagnetic, strong nuclear and weak nuclear. Accordingly, the ranges of effect of the fundamental forces of nature extend from the very short strong and weak nuclear forces to the very long gravitational and electromagnetic forces.

A vast knowledge of the interactions between matter and energy has been glimpsed at owing to the scientific method, which has provided man with an avenue into the secrets of nature. However, the much that is known at present is certainly the tip of the iceberg as what is not known is locked up in the secrets of the fundamental unit of matter and energy and their interactions in space and time. The quarks and leptons being regarded as the fundamental unit of matter presently may only be relative to the chosen level of organisation. Thus, the quarks and leptons may be composed of other units when considered at other levels of organisation.

If one may imagine what nature is like, from the microphysical level of apparent nothingness to that of the macrophysical level of the order of the radius of curvature of the Universe, then one can appreciate the immense problems facing scientists within the constraint of their ability as humans. Since infinity and finity tend to each other, no wonder the great complexity and yet simplicity of Nature. All we can glimpse from nature is the interaction between matter and energy and not what matter or energy is since we ourselves are made up of matter and energy, being a consequence of these fundamental interactions that has led to the evolution of life and its perpetuation on earth.

This is to say that any consideration can only be relative to a chosen level of reference.
For instance, we are yet to learn if life, as we know it here on earth, exists on any of the other planets in the Universe. In such a consideration by Homo sapiens, life can only be considered with regard to their experience of life here on earth. It is definitely not out of place to speculate that life may in fact exist in other modes that may be incomprehensible by our limited brain! The facts of matter - antimatter duality of existence makes such speculation a very feasible proposition. However, the chances of life evolving on other planets are very plausible. It is left for man to discover that through his fundamental invention - the scientific method.

This invention has led to the knowledge of the various interactions between atom and energy whose application in the service of humanity has led to the various technological developments. Thus, the application of scientific principles has assisted man in adapting to his environment. Thus, the motor car, aircraft, ships, atomic energy, rockets, computers etc. have been invented by man using scientific knowledge and method. Science means knowledge and its study. The current extent of man's civilisation is dependent on the scientific method and its application that is the essence of technological acquisition and development par excellence.

Comparative Analogy

The unity and simplicity of nature can be glimpsed from the basic pattern of the various levels of organisation of the interactions between matter and energy. Thus the atom which relates to the basic elements of which all matter is constructed appears as a small solar systems and galaxies in the Universe. The nucleus of the atom can be extrapolated to the sun and other stars in terms of density and energy potential whereas the electrons can be extrapolated to the various planets in terms of their revolution around the sun and spin on their axis. However, whereas electromagnetic forces determine the interactions between the positive nucleus and the negative electrons, the forces through which the sun and the various planets interact are largely gravitational.

The theories of relativity and quantum mechanics are fundamental to the understanding of atomic and nuclear phenomena as well as the astro-physical phenomena of the cosmos. The special theory of relativity predicts that at speeds approaching that of light, the mechanics of particles is different from Newtonian mechanics. The concepts of space and time are interrelated and a particle speed greater than that of light is impossible since the mass of the particle becomes heavier as it approaches the speed of light!

Scope of Science and Technology in the 21st Century

Our discourse has taken us through the frontiers of science whose application has endowed man with a formidable weapon - ***technology***, to probe ***nature*** of which he is a part. What is the origin of matter and energy? Was our world created by an intelligent being or force, or did it evolve from the chance occurrence of matter with its correspondent antimatter whose mutual interaction with energy led to the "big bang"! How did life arise from the interaction between matter and energy?

The apparent dilemma concerning the origin of matter and energy can only be resolved by considering nature in its entirety. Thus, it is that, when the "WORD" was with GOD, all matter had their antimatter, and the mutual annihilation between them gave rise to energy which then interacted with matter to give rise to all things in our immediate world! In all interactions between matter and energy there is an underlying dynamic balance between order and disorder. This is manifested in the various interactions ranging from the quark antiquark, electron - positron, matter - antimatter duality to the ultimate life process involved in ***metabolism - anabolism or building up*** and ***catabolism or breaking down*** processes. The whole science of thermodynamics tends to study this order - disorder duality in the realms of the physical sciences.

That infinity and finity tend to each other in nature can be glimpsed from the effect of the mutual annihilation between electron-positron pair that is the generation of high-energy gamma radiation. The electron and positron are finite discrete quantities of negative and positive charged matter and antimatter respectively whose mutual annihilation leads to gamma radiation of infinite range of action. Thus, electron and positron have mass and can be weighed and if appropriately enlarged can be seen and touched as any physical object whereas gamma radiation has no mass and cannot be touched as a physical object. Yet both are in perpetual existence and cannot be destroyed!

That something can be created out of apparent nothingness is a fact of our world and is a consequence of the "WORD" and therefore language! All around us, our senses can only distinguish between being and not being, which when extrapolated into the electron - positron pair interaction leading to the production of gamma radiation, immediately exposes the apparent limitation of the human brain. Thus, although the gamma radiation emitted from the interaction exists, it is not immediately obvious to our senses and therefore maybe said to be non-existing, whereas it actually exists.
We are lucky that technology, which is one of the fruits of man's inquisitiveness and inventiveness, has made the detection of the gamma radiation possible and therefore has enhanced man's understanding of something existing in apparent nothingness!

The whole of science and technology of our contemporary civilisation is concerned with deciphering the secrets of nature with a view to adapting them for the benefit of mankind and the universe. Whether our world was created or evolved remains a philosophical question that should not becloud the apparent order and disorder which may have arisen owing to the way the interaction between matter and energy has made the brave ***Homo sapiens*** to understand, within the limitations of his brain, an environment or substance of which he is part and parcel of.

The apparent limitations of such an understanding are obvious. However, within the limit of such resources, the scientific method - man's most profound invention, has ensured the continued search and use of nature's secret that is wholly embodied in all scientific and technological endeavours of ***Homo sapiens***. With mathematics as an indispensable tool, science and technology has synergistically nurtured each other, sometimes to man's benefit and sometimes has led to the destruction of his life, a consequence of inherent order and disorder in nature.

Science and technology has aided us in learning that the ***essence of life*** seems to be the interchange between matter in the form of biological molecules and chemical elements, and energy in the form of electromagnetic and other radiation as in photosynthetic green plants. Ultimately, this basic life process of energy or food intake, of bio-molecules, sourced mainly from the nuclear reactions of our sun, has evolved to the huge array of living organisms known to man in our contemporary world. The possibility of man creating ***artificial life*** by mimicking nature is an intense area of research currently.

Technology Acquisition and Development for Nigeria

The acquisition of technology has remained an intractable problem in many under-developed countries including Nigeria because political and economic policies have in the main, centred on the ***illusion*** of the so-called ***"transfer of technology"*** supposedly from the technologically advanced countries. The simple truth is that technology as we know it in our contemporary world politics can **NEVER** be acquired on a platter of gold, but by a well planned and co-ordinated hard-work towards intelligent and pragmatic policies leading to its appropriate acquisition and development. There is an ***urgent*** need for a fundamental re-orientation of our national psyche about technology as perceived by the average Nigerian, especially those at the helm of affairs whose duty it is to formulate policies with regard to the acquisition and utilisation of technology. We should take the bull by the horn and begin to lay a sound foundation for a quantum leap through education and training of our youth for appropriate acquisition and development of technology especially that involving health care that is the ***melting pot*** of all engineering sciences.

Fundamental Problem of Technology Acquisition

Technology is the scientific study of practical and industrial arts problems, which can be the sole pedestal of socio-economic interaction. Thus it should not be acquired by buying the products (of technologically advanced countries) only, but by developing our own appropriate technology based on the same scientific principles, methodology and practice used by the designers and fabricators of the consumer products we are avid at buying. We cannot continue urbanising without industrialisation which seems to be the norm now. We seem to be avid at making wealth without utilising the various opportunities available for wealth creation. No wonder the treasury looting and certificate forgery etc. that has become the big shame of our contemporary socio-economic environment.

Does it mean that the African lacks the basic tool for the acquisition and development of modern technology? The honest answer is NO. The most important pre-requisite for technological development is the advanced brain of Homo sapiens. This has developed as a result of appropriate stimulus bordering on basic biological needs of our socio-economic interaction at any point in time as well as evolutionary adaptation to environment consequent upon the satisfaction of these biological needs.

Civilisation as we know it started in Africa - Egypt to be precise, just as ***Homo sapiens*** or "***the wise man***" according to contemporary science probably ***evolved*** in Africa before the inevitable migrations towards all the corners of the earth with its attendant adaptive evolutionary diversity of the human race. The great pyramids of Egypt bear testimony to erstwhile African ingenuity, which apparently has been ***temporarily*** lost. Our forefathers obviously did not need the Europeans to fabricate their hunting implements, nor smelt their iron ore to provide our hoes and machetes for agriculture. The Ife and Benin bronze casters did not need the "transfer of technology" from Europeans for their famous bronze art work which was a big ***industrial*** undertaking then. The Igbo-ukwu technologist of the "iron and pottery" ages of our history definitely did not know the Europeans before developing their contemporary technology.

The artistic products of our forefathers, which were developed with their own relevant and ***appropriate technology*** remains the envy of Europeans in the various museums all over the world. Recently, the Biafran experience has shown conclusively that with the right and appropriate stimulus, the latent ingenuity in the African as a member of the ***Homo sapiens*** can be utilised to design and develop appropriate technology in tackling its problem of socio-economic interaction. The Biafrans did not need

'transfer of technology' from the Americans, Japanese and/or the Soviets to build the steel complex that armoured the available vehicles, produced mines, rockets (including those with multiple independently targetable war-heads of varying degrees of charges) and other weapons. They did not need transfer of technology to build their improvisedly contrived refineries that provided the needed petroleum products during the war. Rather, appropriate development of technology was embarked upon by studying the practical and industrial arts problems of the period using scientific principles, methodology and practice by utilising its manpower resources and available materials to solve its problems.

There is no doubt that in Nigeria today both the manpower and material resources abound that if properly harnessed will be capable of catapulting our society into the aegis of technological advancement. This will certainly lead to the upliftment of our socio-economic environment to the extent of competition with the erstwhile-established technology of modern industrialised societies. In achieving the development of our own technology to suite our micro- and macro- environment, nothing stops us from taking whatever we can from the experiences of the technologically developed societies, for we have the advantage of the "wiseman who learns from the experiences of others". And in the same token, nothing stops us from contributing to the continuous advancement of the technological progress of mankind in tackling many of its existential problems of political, social and economic interaction.

Technology Transfer

According to Rushmer (Huntsman, 1991), the greatest breakthroughs may result when explorers step off the well-trodden path of conventional wisdom, of prior art, of well-respected theory, and dare to do the unconventional. By pursuing non-conventional goals, Rushmer and colleagues in the 1950s at the University of Washington, not only revolutionised our understanding of the function of the heart but also laid the foundation for an entirely new department of bioengineering in 1967 and of a new, interdisciplinary way of combining ***science, engineering, and medicine.*** The tools of physics, chemistry, and engineering were increasingly applied or adapted to studies of living organisms.

By the end of 2nd World War, many tools of physiology were primitive. A notable example was the almost universal dependence on smoked-drum kymographs (paper-covered revolving drums) and mechanical levers for the study of function and control of isolated or exposed hearts of dogs. But the development of more quantitative and sophisticated techniques accelerated after the war. In the early 1950s, Rushmer and colleagues (Huntsman,1991) had unconventional idea as they believed that studies in live animals will lead to better understanding of the function of the heart as opposed to carrying them out in the traditional, static way using excised hearts or exposed hearts in anaesthetised animals. They believed that the results obtained from live, active animals would be more representative of normal cardiac function. The results of the pioneering efforts of Rushmer (Huntsman, 1991) challenged the generally accepted concepts of cardiac function and control, which suggested the need for more quantitative analysis of the heart under conditions that were as normal as possible. So a team of mainly undergraduate engineering and physics students was recruited to develop sensing devices that could be implanted in and on the heart ventricles of healthy active dogs in order to monitor changing dimensions, pressures, and blood flows of the heart and blood vessels.

The signals from these devices provided as many as twenty six simultaneous measurements, including stroke volume and cardiac output, ejection velocities, and power. These measurements permitted cardiovascular function to be analysed during all kinds of activities, exercise, eating, sleeping as well as in cases of heart abnormalities. And the role of the central nervous system in cardiovascular control could be explored using electrodes implanted in the brain to stimulate reactions.

Activities in bioengineering expanded to include the development of diagnostic devices for clinical medicine. The first of those was a portable ultrasonic Doppler flow meter to measure peripheral vascular blood flow and foetal heart action, developed by Strandness, Rushmer, and colleagues and commercialised by the Smith-Kline Instrument Company in 1964. This was an advance that set the stage for the development and commercialisation of many technologies in co-operation with local industry in the years to come.

Rushmer (1970) in his pioneering effort recognised that such an interdisciplinary program could not be adequately accommodated in any one department and the Centre for Bioengineering was established in 1967 in an arrangement unusual for its time. Both the College of Engineering and the School of Medicine managed the program. According to Rushmer (1970), the enthusiastic and unremitting administrative support by four generations of deans of both ***medicine*** and ***engineering*** coupled with widespread faculty involvement, led to the development of the largest and most diverse bioengineering program in the USA. The interactions between representatives of local industries and the University on the emerging techniques and technologies with commercial potential for clinical applications led to commercialisation of research and development effort of Rushmer and colleagues (Huntsman, 1991).

During the last several years, the design, development and manufacture of medical equipment and instruments constitute a major aspect of modern industrial and socio-economic interaction. Consequently, many industrialised nations' economic activity and capital revolve around medical equipment design, development evaluation and use. The growing field of biomedical engineering field has ensured the availability of required medical equipment as well as other technologies and innovations that are the hallmark of contemporary medical advance.

The diversity of medical equipment in hospitals has grown considerably thereby raising expenses, which in turn raise health care delivery costs. Everyday, more and more complex equipment is added to already existing installations, e.g. diagnostic and monitoring systems, new automated laboratory equipment, as well as the increasing multiple use of computers for medical care.

In order to be optimally efficient, modern medical practice demands an ever-increasing number of specific instruments to aid in the examination, diagnosis and treatment of patients, as well as the evaluation of therapeutic results. The complexity and variety of data is such that collection and analysis of information poses real problems to most doctors. Therefore, the complexity of modern health care delivery is such that organised teamwork is required to be most efficient, as each team of specialists forms a specific department or service.

Acquisition and Development of Appropriate Technology

Technology connotes the application of scientific knowledge and practice to the solution of practical and industrial arts' problems of socio-economic interactions. Thus the many and varied problems of our socio-economic interaction is amenable to scientific study, the result of which can be applied to its solution. The ***scientific method*** defines the problem or observation, which is then analysed for possible modes of solution, after which one or more options are tried, by designing appropriate experiment whose methodology determines the result that may solve the problem or reveal startling undiscovered phenomenon.

Therefore ***education*** naturally becomes a fundamental tool for the acquisition, development and advancement of technology. With appropriate investment in basic and advanced applicable education which is well planned and enthusiastically manned and operated, the theories and laws of physics, chemistry and biology using mathematics as an indispensable tool should be imparted to our learning children right from infancy to adulthood in an interestingly motivating manner.

The application of the theories and laws of these physical sciences has led to the disciplines of engineering (including electrical /electronic, mechanical, chemical and others), and also medicine and the related applied scientific professions. A good grasp of the fundamentals of the pure sciences and mathematics is a ***sine qua non*** for appropriate technological development in our total environment.

What Strategy?

A realistic approach to the solution of our technological problems should logically define the short and long term strategies.

- The short term approach should address itself to the mobilisation of already available human and material resources,
- Whereas the long term one should be to use available human and material resources to educate our children towards a technologically biased goal right from infancy to the university in a ***relatively*** free, stimulating and congenial system of educational instructions.

I regard this long-term approach as the most important fundamental basis for the acquisition and development of appropriate technology.

Therefore, to generate an unwavering confidence in us towards technological development, a declaration of a ***state of emergency*** for technological development and evolution should be instituted now. A free, compulsory and indoctrinative education at the primary and secondary level should be embarked upon with utmost vigour and urgency.

Education should be free at the secondary level, both at the technical/vocational and classical secondary schools respectively. At the tertiary level, free education should ensure the production of high level manpower in the management, scientific and technological fields. Thus, free education at all levels is a ***sine qua non*** for technological development. The funding for our educational pursuit is definitely available if we are honest to ourselves as if all leaky holes of treasury looting are plugged and effective taxation are employed, the funding will certainly be available!

I am not unaware of the dearth of science and mathematics teachers for our primary and secondary schools. This is one area where application of modern microcomputer technology can come to our rescue. There are many and varied affordable microcomputers with a good range of software, which can be adapted for use in teaching science and mathematics in our schools. Our educational policy and practice should be result oriented and biased towards technological development. Furthermore, government sponsored handicraft centres should be established in all local government headquarters and in selected schools within reach of all primary school children. Handicraft techniques in metallurgy (blacksmith), welding and fitting as well as workshop practice should be instituted. Also demonstration and practical classes in simple electronic devices, thereby demonstrating the principles and circuit designs, should be embarked upon in a most palatable manner. Here also, current microcomputer technology can come to our rescue in the teaching process. Just as arithmetic logic to base 10 (decimal) is taught in our primary schools, so also arithmetic logic to base 2 (binary arithmetic) should be. It is noteworthy to state that President Bush increased education budget inherited from former President Clinton just to improve the teaching of ***Mathematics*** as it was found that Chinese children do better in ***Mathematics*** than the American children! Can this be said of total education budget in Nigeria where it still remains abysmally below recommended minimum?

Nigeria and in fact the whole world is a repository of Chinese products and technology. Are we surprised? Certainly not. This is because the Chinese take the education of their children serious and they perform better in Mathematics right from childhood. This is a far cry from what is obtainable here where our political leaders are only interested in what they can acquire rather than what they can do for their country and citizen!

We should invest optimally in our youth in a well-organised manner, as they ever remain the repository of creative minds and a goldmine of ideas that could be harnessed properly for the benefit of all. Our graduate engineers and scientists should be mobilised and motivated to try many of their ideas towards the solution of some of our societal problems.

Cultural Re-orientation

Culture is a dynamic process that changes with time. A good part of this cultural dynamics involves man in his total environment. Scientific and technological pursuits are part and parcel of cultural dynamics of ***Homo sapiens***. Therefore, for us to be true members of the cultural process of the scientific and technological community, we should be able to mobilise all our manpower and material resources towards a true and appropriate development of our own technology to suit us in our peculiar socio-economic environment. Appropriate investment in the development of our human capital, which nature has endowed us with in abundance, will certainly ensure a rapid socio-economic development in all facets of human endeavour.

The apparent hindrance to the above recommendations may arise consequent upon the "poor" economic state of our country. Many critics may, in their true colour, argue that the "money" to fund the "relative" free education at all levels is not available. It is my contention that the "poor state of our economy" rather than being a stumbling block should be regarded as a big opportunity never to be missed, as the most important stimulus for innovation and improvisation. I believe that when a national Scientific and Technological Foundation is established after the declaration of the technological revolution, many patriotic nationals with the wherewithal will inevitably answer the national call for appropriate technological development. The industries especially the financial sectors whose profits have been increasing over the years show that our economy is not in a "poor" state. You can only make huge profits in a buoyant economy. The poor state of our economy seems to refer to distribution of money in circulation as well as essential commodities.

In a purpose designed mechanical engineering workshop, it has been possible for me to design surgical operating table, which is simply a system of levers capable of various positions necessary for a variety of surgical procedures. Since the design and production of this simple equipment is wholly dependent on local sources for materials, the intractable problem of spare parts for effective maintenance and repair becomes greatly minimized, as they can be readily fabricated. The personnel involved in the fabrication process will be in a most knowledgeable position to effect repair and maintain the equipment. The devices produced are simple in design and construction. They have been found to be robust, safe and functional. The only criticism may arise from finesse in finish, which can be readily achieved at more than double the cost of production of the finished unit. With the economic adversity afflicting most developing countries further pursuit of fine finish even though aesthetically desirable is certainly not an appropriate technological solution of the fundamental problem of lack of basic medical equipment for the achievement of optimal health care delivery in most technologically under-developed countries.

The devices produced are simple in design and construction and won a prize at the Federal Ministry of Science and Technology Inventor/Innovation Exhibition.
There are two fields that play important role in the development and adaptation of medical instrumentation for

examination, diagnosis and therapy. These fields include medical and biological research, and technological research and innovation. Trial testing in a real hospital environment represents an important source of information for researchers and industrialists, thus helping them to better discern the needs and problems of adaptation that can only be observed during actual use of equipment (Okoye, 1986a &b).

Furthermore, an offshoot of the author's research work in Glasgow was a whole-body balance bed, which can be easily adapted for non-invasive intensive care monitoring. This device requires minimal maintenance if well developed. The development of such a device, which will be suitable for use in most developing countries, will go a long way in enhancing our match to technological development. Furthermore, with the availability of semi-conductor devices with relevant specifications, many simple electronic medical devices can be easily fabricated and/or assembled.

Of Engineering and Medicine!

Medicine (Latin ***medicus***, "physician") is the science and art of diagnosing, treating, and preventing disease and injury. Its goals are to help people live longer, happier, more active lives with less suffering and disability. Medicine goes beyond the bedside of patients. Medical scientists engage in a constant search for new drugs, effective treatments, and more advanced technology. In addition, medicine is a business. It is part of the health care industry, one of the largest industries in the United States, and among the leading employers in most communities.

Disease has been one of humanity's greatest enemies. Only during the last 100 years has medicine developed weapons to fight disease effectively. Vaccines, better drugs and surgical procedures, new instruments, and understanding of sanitation and nutrition have had a huge impact on human well-being. Like detectives, physicians and other health care professionals use clues to identify, or diagnose, a specific disease or injury. They check the patient's medical history for past symptoms or diseases, perform a physical examination, and check the results of various tests. After making a diagnosis, physicians pick the best treatment. Some treatments cure a disease. Others are palliativethat is, they relieve symptoms but do not reverse the underlying disease. Sometimes no treatment is needed because the disease will get better by itself.

While diagnosing disease and choosing the best treatment certainly require scientific knowledge and technical skills, health care professionals must apply these abilities in imaginative ways. The same disease may present very different symptoms in two patients, and a treatment that cures one patient may not work on another.

The top 25 and the bottom 25 nations ranked according to Disability-Adjusted Life Expectancy (DALE)

Rank	Nation	DALE	Rank	Nation	DALE
1	Japan	74.4	166	Djibouti	37.9
2	Australia	73.2	167	Guinea	37.8
3	France	73.1	168	Afghanistan	37.7
4	Sweden	73.0	169	Eritrea	37.7
5	Spain	72.8	170	Guinea-Bissau	37.2
6	Italy	72.7	171	Lesotho	36.9
7	Greece	72.5	172	Madagascar	36.6
8	Switzerland	72.5	173	Somalia	36.4
9	Monaco	72.4	174	Congo	36.3
10	Andorra	72.3	175	Central African Republic	36.0
11	San Marino	72.3	176	Tanzania	36.0
12	Canada	72.0	177	Namibia	35.6
13	Netherlands	72.0	178	Burkina Fasso	35.5
14	Britain	71.7	179	Burundi	34.6
15	Norway	71.7	180	Mozambique	34.4
16	Belgium	71.6	181	Liberia	34.0
17	Austria	71.6	182	Ethiopia	33.5
18	Luxembourg	71.1	183	Mali	33.1
19	Iceland	70.8	184	Zimbabwe	32.9
20	Finland	70.5	185	Rwanda	32.8
21	Malta	70.5	186	Uganda	32.7
22	Germany	70.4	187	Botswana	32.3
23	Israel	70.4	188	Zambia	30.3
24	United States	70.0	189	Malawi	29.4
25	Cyprus	69.8	190	Niger	29.1
			191	Sierra Leone	25.9

SOURCE: World Health Organization, 2000.

At the turn of the 20th century, many men and women were feeble by age 40. The average American born in 1900 had a life expectancy of 47.3 years. Effective treatments for disease were so scarce that doctors could carry all their drugs and instruments in a small black bag. By the end of the 20th century, medical advances had caused life expectancy to increase to 76 years. Modern health care practitioners can prevent, control, or cure hundreds of diseases. People today remain independent and physically active into their 80s and 90s. The fastest-growing age group in the population of developed world now consists of people aged 85 and over.

This medical progress has been expensive. In 1998 Americans spent $1.1 trillion on health care, an average of $4,094 per person. In the same year, health care accounted for about 13.5 percent of the gross domestic product (GDP), about one-seventh of the country's total output. Spending has grown rapidly from earlier in the century. In 1940, for instance, the United States spent $4 billion on health care.

In Nigeria and other developing countries especially Africa life expectancy hovers around 40 years. Can this be improved upon? The honest answer is yes. However, there must be political will to develop the socio-economic system through education and therefore good health care system. The trend now is for our political leaders to travel overseas for medical check-up and treatment. Oftentimes they meet highly qualified and skilled Nigerians there. This is the tragedy of the under-development of Nigeria!

Engineering has been privy to improvement in health status of the developed economies and certainly will be of immense benefit to us in Nigeria through appropriate establishment and development of Biomedical Technology. That is where the pioneering effort of Federal University of Technology, Owerri should be encouraged. The time is auspicious for a focused and solid foundation in Biomedical Technology which should be pursued with utmost vigour.

The marriage between engineering and medicine has been as old as antiquity and yet still growing, as it seems that the honeymoon has just started! This is a marriage destined to last to eternity from all indications. However, the only conceptual area of friction involves the axiomatic exactness of engineering with respect to figures and measures in contrast to variability inherent in biology. Thus, engineering science tends to be dogmatically exact. Medical science aspiration to exactness is hampered by the subtle but wide variation in human anatomy and physiology. Therefore, the blend of engineering and medicine requires a working compromise, between axiomatic exactness and anatomico-physiological variability, to be, solely, governed by the ultimate aim of medical science to preserve the health of the individual and therefore humanity (Okoye, 1984). Therefore, any engineering contrivance or technique designed to assist the diagnosis, prevention and treatment of disease in order to maintain optimal health of humanity will be most welcome whether it has undergone the exactness of engineering test or not as long as it is seen to be beneficial in the maintenance of health within a wide margin of safety.

To cap it all..

'A Scientist discovers that which exists. An Engineer creates that which never was'.

- Theodore von Karman

Thank you for listening!

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