Enhancing Healthy Human Life

Through

Bioengineering and Rehabilitation Medicine

An Inaugural Lecture

By

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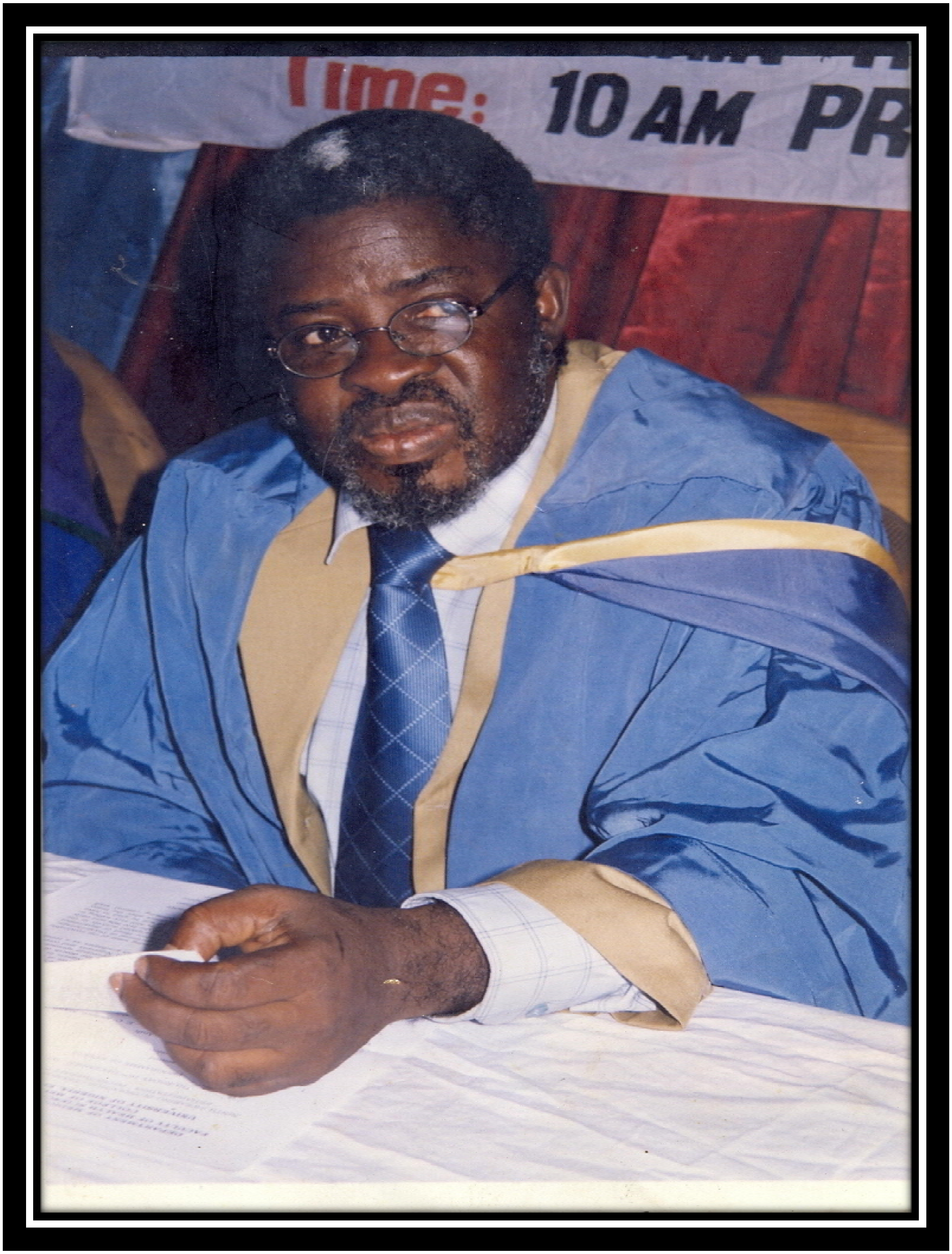
'A Scientist discovers that which exists. An Engineer creates that which never was'.
Theodore von Karman (May 11, 1881 – May 7, 1963)



Prologue

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 it very plausible that in the near future the problem of heart disease and its complications will be ameliorated through 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!

Since the subject of enhancing healthy human life through bioengineering and rehabilitation medicine is indeed a very wide one this presentation can only be the tip of the iceberg and cannot be exhaustive. I therefore crave the indulgence of this august audience to permit me to present this lecture from the perspective of somebody who has studied medicine and engineering.

Preamble

What is Life?

One may begin to look at life from the perspectives of the account from the Holy Writ as well as from contemporary theory of physics – study of Nature and its mechanistic approach. In this discourse I intend to discus life and therefore health from both the Christian religious standpoint as well as that of physics as there is an uncanny semblance of both accounts for according to Albert Einstein ***"All religions, arts and sciences are branches of the same tree".***

Genesis

And so "In the beginning God created the heavens and the earth (Genesis 1: 1). It is obvious that this account of creation when contrasted with that of contemporary physics when all of a sudden there was a "Big Bang" and all things in the Universe were created, to me shows some remarkable similarity. Then God the Omnipotent, Omniscient started creating the various things including living things of which Man was the last and probably the most complex.

Certainly, the Humankind was to be a very special creation in the scheme of things as God took the dust (chemicals) of the earth and moulded man after which He "breathed life" into this clay mould and he became a ***"living soul"*** or "human being" with a ***mind*** and ***personality*** in the "likeness of God" (Genesis). Further, God created Eve from Adam so that "male (XY chromosome) and female (XX chromosome)" He created them.

God placed Adam and his wife Eve in the "Garden of Eden" in total bliss of a ***healthy human life*** until … ***"sin"*** or ***"disease"*** came to disrupt the bliss which God intended man to enjoy to ***eternity***. The condition of Adam and Eve in the Garden of Eden to me represents a perfect "healthy human life" until ***dis-ease*** set in after which man can only aspire towards optimal health rather than the perfect situation God designed early in creation. Consequently we can only look for ways of enhancing healthy human life on earth which to me seem to be the challenge of ***Homo sapiens*** till date.

I am happy to note that God having created in his own image has indeed given us the wherewithal to apply revolutionary technologies of biology, engineering and nano-medicine resulting from bioengineering to provide therapies that one day may return mankind to the bliss of the Garden of Eden.

1. Introduction:

Nature, Matter, Energy and Fundamental Interactions

Nature can be defined as the sum total of all ***interactions*** between ***matter*** and ***energy*** which are different manifestation of the same thing according to Albert Einstein's formula $E = mc^2$ as energy and matter are equivalent. ***Life*** and therefore ***health*** is a property of ***Nature.*** The building blocks of matter are ***atoms.*** At each level of organisation, the various interactions between matter and energy provides exciting phenomenon for the inquisitive mind of the wise man or ***Homo sapiens***. These levels of organisation range from the sub-atomic interactions (nano-scale level 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 interactions 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 distance (nanometers – 10^{-9} meter) of strong and weak nuclear forces to the very long distances (> 10^{9} meter) of 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.

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 creation or evolution of ***life*** and therefore ***health*** 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.***

1.1. Order from Disorder

Schrodinger in his book “What is life” (1944) stated that life feeds on negative entropy as he looked at life from a mechanistic standpoint. That is to say ...living matter, while not eluding the "laws of physics" as established up to date, is likely to involve "other laws of physics" hitherto unknown, which however, once they have been revealed, will form just as integral a part of science as the former. The main principle involved with "order-from-disorder" is the second law of thermodynamics, according to which entropy (a thermodynamic property that can be used to determine the energy not available for useful work in a thermodynamic process) only increases. Schrödinger (1944) explains that living matter evades the decay to thermodynamical equilibrium by feeding on negative entropy. In thermodynamics, a thermodynamic system is said to be in thermodynamic equilibrium when it is in thermal equilibrium, mechanical equilibrium, radiative equilibrium, and chemical equilibrium. The word equilibrium means a state of balance. In an equilibrium state, there are no unbalanced potentials (or driving forces) within the system. A system that is in equilibrium experiences no changes when it is isolated from its surroundings.

The opposite of equilibrium systems are ***nonequilibrium*** systems that are instantaneously off balance and in the living system the balance between the ***metabolic*** processes of breakdown of matter to provide ***life energy*** (catabolism) is ***homeostatically*** balanced by the building up (anabolism) of matter to provide the necessary form of living organism. What Schrodinger (1944) speculated to be involved in the evolution and perpetuation of life could be interactions between matter and energy.

1.2.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 (Deoxyribo Nuleic Acid or DNA and Ribo Nucleic Acid or 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 independent 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! God created grasses before other life forms!

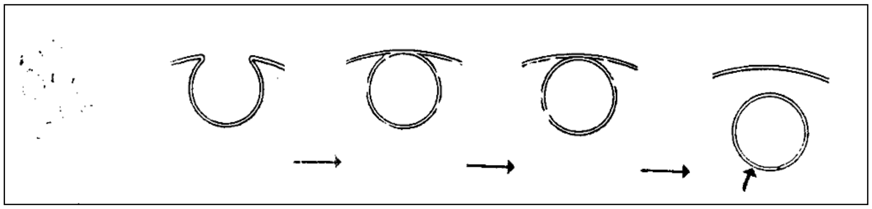
1.3. Evolution of Physico-Chemical Interactions of Life

It was Oparin (2011) 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 (2011) 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!

Figure 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 etc. 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 (2011) 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 different 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.

2. It is all in the GENES - DNA, RNA and Proteins

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*** which may be functionally structural (collagen) or enzymatic.

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 and non-living.

2.1. Genes and Heredity

A ***gene*** is a unit of ***heredity*** in a living ***organism*** and consists of some stretches of ***DNA*** and ***RNA*** that code for a type of ***protein*** or for an ***RNA*** chain that has a function in the organism. Living things depend on genes, as they specify all proteins and functional RNA chains. Genes hold the information to build and maintain an organism's ***cells*** – the building blocks of all living things and pass genetic ***traits*** to offspring, although some ***organelles*** or components of cells (e.g. ***mitochondria***) are self-replicating and are not coded for by the organism's DNA. All organisms have many genes corresponding to various different biological traits, some of which are immediately visible, such as ***eye color*** or number of limbs, and some of which are not, such as ***blood type*** or increased risk for specific diseases, or the thousands of basic ***biochemical*** processes that comprise ***life***.

2.2.Genome and Chromosomal organization

The total complement of genes in an organism or cell is known as its ***genome***. In single celled organism such as ***prokaryotes,*** (an example is the bacteria – ***Escherichia coli***) the vast majority of genes are located on a single pack of genes of ***circular DNA***, while ***eukaryotes*** (or multi-celled organism such as ***human being***) usually possess multiple individual linear DNA helices packed into dense DNA-protein complexes called ***chromosomes***. Genes that appear together on one chromosome of one species may appear on separate chromosomes in another species. Many species carry more than one copy of their genome within each of their ***somatic cells (XY or XX chromosomes for male and female respectively)***. In eukaryotes cells or organisms with only one copy of each chromosome are called ***haploid (X or Y or germ cells for female (egg) and male (sperm) respectively)***; those with two copies are called ***diploid (XX or XY)***; and those with more than two copies are called ***polyploid (e.g. XXY)***. The copies of genes on the chromosomes are not necessarily identical. In sexually reproducing organisms, one copy is normally inherited from each parent. The sequences of a person's DNA modify over the course of their life and the extent of such changes is similar among family members. Every individual has DNA peculiar to him or her which can be mapped out with the successful deciphering of the Human Genome and the genes through biotechnological methods of bioengineering.

2.3.First Personal Genome Map Created

It is noteworthy that the first personal DNA map costing about $1,000,000 was done on the Nobel Prize-winning scientist who helped discover the molecular structure of DNA, Professor James Watson in June 2007 (Lozano, 2007). The map which is a breakdown of his DNA that shows illnesses he is predisposed to contracting is the first step in making the sequencing of individual human genomes quick, affordable and a routine part of future medical care. According to Lozano (2007) a review of the DNA map showed he has some variances that could induce cancer — which appeared to mirror his actual health as Watson has had skin cancer and his sister had breast cancer. The price of mapping someone's genome sequence could eventually drop to $1,000, making it easy for people to incorporate it into their medical care. According to Watson the prospect for a healthier and more compassionate world 50 years from now is a possible because of the technological advances we are celebrating today.

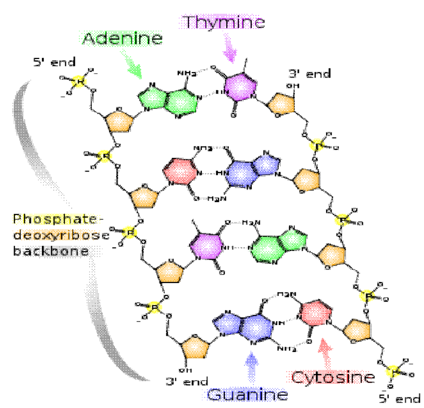


Figure 2: The chemical structure of a four-base fragment of a DNA double helix (Ball, 2011)

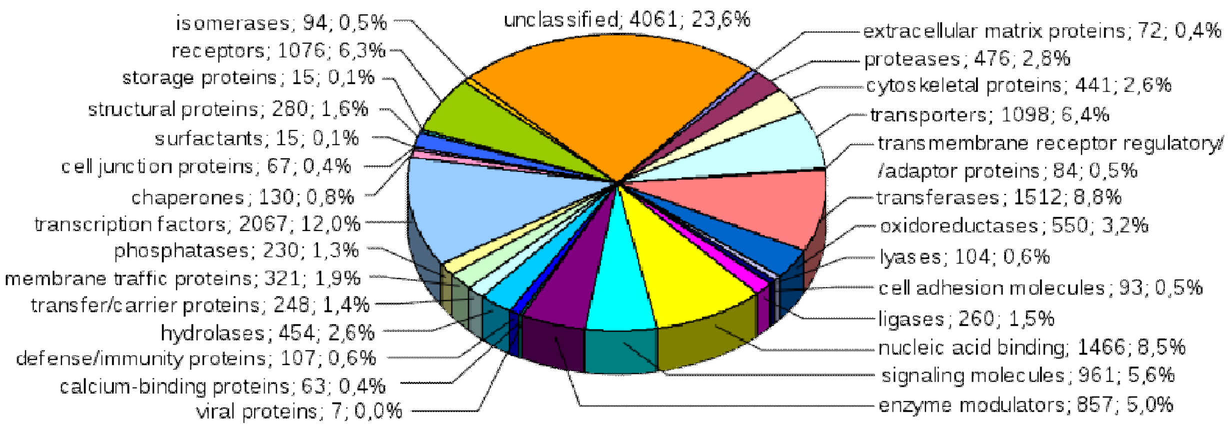


Figure 3: The Human Genome categorized by function of each gene product, given both as number of genes and as percentage of all genes (Panther Pie Chart, 2011).

I am happy to note that currently in the Faculty of Health Sciences and Technology of the College of Medicine, University of Nigeria today, where I am presently the Dean; a state-of-the art molecular biology laboratory capable of this feat of mapping personal human genome and analysing it for variances has been established by an alumnus of the Faculty (Dr Emmanuel Nna, PhD) who is indeed a great scientist and entrepreneur. It is hoped that in the future, health will become personalized as the genetic makeup of every individual will be known.

3. Human Life, Health and Disease

Life is a condition that distinguishes ***organisms*** from non-living objects, such as ***non-life***, and dead organisms, being 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). The human 'Life Machine' belongs to the above definition and the following itemise the characteristic that defines life including human life.

Conventionally life 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: Being composed of one or more ***cells***, which are the basic units 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 metabolized 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.

3.1. Technology and Healthy Human Life

Technology rules our contemporary world. And this is most true of modern medical practice which seeks to provide man with a healthy life. Clinical medical diagnosis and therapeutics form the major pedestal on which medical practice in its entirety is anchored since antiquity. Contemporary medical practice, including clinical proficiency, is heavily dependent on modern technology for much of diagnosis and therapy of most common ailments, in addition to the important ongoing research and development that is the hallmark of contemporary medicine. Technology has been playing a significant role in total health care delivery and will continue to do so in our ever-evolving health care delivery systems.

4. Bioengineering and Healthy Human Life

Biological Engineering, **biotechnological engineering** or ***Bioengineering*** (including biological systems engineering) is the application of ***engineering*** principles to address challenges in the fields of ***biology*** and therefore ***medicine.*** On the other hand, **Biomedical engineering** which is usually used interchangeably with bioengineering is the application of engineering principles and techniques to the medical field which tends to close the gap between engineering and medicine by combining the design and problem solving skills of ***engineering*** with medical and biological sciences to improve healthcare diagnosis and treatment. The ultimate goal of bioengineering is the enhancement of healthy human life.

4.1. Biomedical Engineering

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.

Biomedical Engineering can also 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 types of medical equipment and the patient under the supervision of the clinician responsible for the management of the patient.

4.1.1. 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.

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.

Bioengineering or biological engineering can be all encompassing as many fields of applications are becoming very useful in management of healthcare towards a healthy human life. These new fields include:

- Tissue engineering
- Regenerative medicine
- Genetic engineering and gene therapy, etc

4.1.2. Tissue Engineering and Regenerative Medicine

Current clinical technologies, especially donor transplants and artificial organs, have been excellent life-saving and life-extending therapies to treat patients who need to reconstitute diseased or devastated organs or tissues as a result of an accident, trauma, and cancer, or to correct congenital structural anomalies (Ikada, 2006). For long, most scientists and clinicians believed that damaged or lost tissues could only be replaced by organ transplantation or with totally artificial parts.

According to Ikada (2006), Tissue engineering emerged as a promising alternative in which organs or tissues can be repaired, replaced, or regenerated. The tissue engineering paradigm is to isolate specific cells through a small biopsy from a patient, to grow them on a three-dimensional scaffold under precisely controlled culture conditions, to deliver the construct to the desired site in the patient's body, and to direct new tissue formation into the scaffold that can be absorbed over time.

Stem cell treatments are a type of intervention strategy that introduces new cells into damaged tissue in order to treat disease or injury. Many ***medical researchers*** believe that stem cell treatments have the potential to change the face of human disease and alleviate suffering (Lindvall and Kokaia, 2006). The ability of ***stem cells*** to self-renew and give rise to subsequent generations with variable degrees of differentiation capacities (Weissman, 2000), offers significant potential for generation of tissues that can potentially replace diseased and damaged areas in the body, with minimal risk of rejection and side effects.

4.1.3. Cardiac Bioengineering

One subject dear to my heart involves artificial heart research and development programme. About 3,000 patients in the United States await a donor heart and worldwide, 22 million people live with heart failure – my eldest brother Chux died from it. 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.

4.1.3.1. 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.

During the 10-year pivotal clinical study, 79% of patients receiving the Total Artificial Heart (figure 4) survived to transplant (Copeland et al., 2004). This is the highest bridge-to-transplant rate for any heart device in the world. Recent developments indicate that artificial hearts can be temporarily implanted to allow the natural heart heal after which it is removed.

All artificial hearts presently available mimic the natural heart in its rhythmic pumping action. Recent design which has been successfully implanted in calves incorporate continuous flow (such as that found in ventricular assist devices) and still pumps oxygenated blood to the body and deoxygenated to the lungs. This design has rotary pump and is much smaller in size than pneumatic and other electrical types.

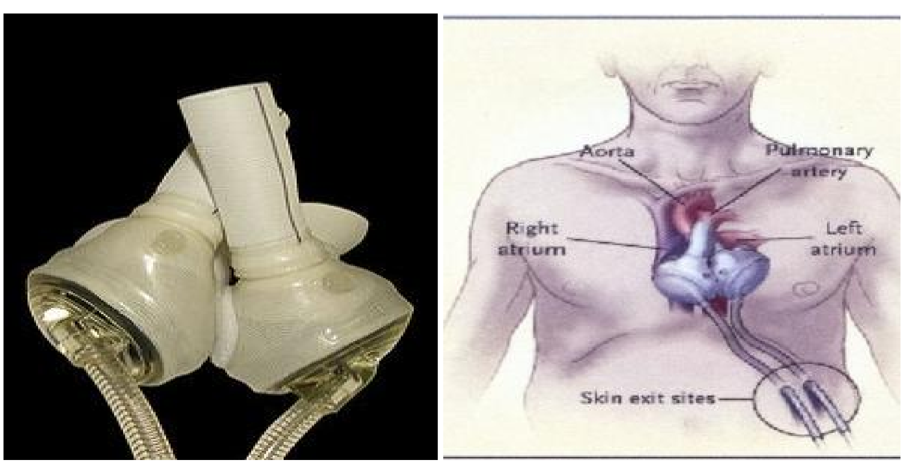


Figure 4: The SynCardia temporary CardioWest Total Artificial Heart (Copeland et al., 2004)

With increased understanding of the heart and continuing improvements in ***prosthetics*** engineering, ***computer science***, ***electronics, battery*** technology, and ***fuel cells***, a practical mechanical artificial heart may become a reality.

4.2. Tissue Engineering and Development of Biological Heart for Implantation

Recently researchers at the Biomedical Engineering Department of Technion- Israel University developed beating heart muscle with built-in blood supply was created from stem cells (Caspi et al., 2007). This represent the first time that three-dimensional human cardiac tissue complete with blood vessels have been constructed that may have unique applications for studies of cardiac development, function and tissue replacement therapy (Caspi et al., 2007).

Further a method to create an artificial heart using the extracellular matrix of an actual heart that has been stripped of all cells may hold promise for its use in transplant surgery (Ott et al., 2008). Generating an artificial heart requires engineering of the cardiac architecture, appropriate cellular constituents and pump function.

One of the goals of tissue engineering is to create artificial organs (via biological material) for patients that need organ transplants. Biomedical engineers are currently researching methods of creating such organs. Researchers have grown solid jawbones and tracheas from human stem cells towards this end. Several bladders (Atala, 2006) actually have been grown in laboratories and transplanted successfully into patients. Bioartificial organs, which use both synthetic and biological components, are also a focus area in research, such as with hepatic assist devices that use liver cells within an artificial bioreactor construct.

4.3. Genetic engineering

Genetic engineering, recombinant DNA technology, genetic modification/manipulation (GM) and gene splicing are terms that apply to the direct manipulation of an organism's genes. Genetic engineering is different from traditional breeding, where the organism's genes are manipulated indirectly. Genetic engineering uses the techniques of molecular cloning and transformation to alter the structure and characteristics of genes directly. Genetic engineering techniques have found success in numerous applications. Some examples are in improving crop technology (not a medical application per se), the manufacture of synthetic human insulin through the use of modified bacteria, the manufacture of erythropoietin in hamster ovary cells, and the production of new types of experimental mice such as the oncomouse (cancer mouse) for research.

A very important application of genetic engineering is the Human Genome Project which is an initiative of the U.S. Department of Energy (“DOE”) that aims to generate a high-quality reference sequence for the entire human genome and identify all the human genes.

The DOE and its predecessor agencies were assigned by the U.S. Congress to develop new energy resources and technologies and to pursue a deeper understanding of potential health and environmental risks posed by their production and use. In 1986, the DOE announced its Human Genome Initiative. Shortly thereafter, the DOE and National Institutes of Health developed a plan for a joint Human Genome Project (“HGP”), which officially began in 1990.

4.3.1. Cloning

Cloning involves the removal of the nucleus from one cell and its placement in an unfertilized egg cell whose nucleus has either been deactivated or removed.

There are two types of cloning:

1. Reproductive cloning. After a few divisions, the egg cell is placed into a uterus where it is allowed to develop into a fetus that is genetically identical to the donor of the original nucleus.
2. Therapeutic cloning. The egg is placed into a Petri dish where it develops into embryonic stem cells, which have shown potentials for treating several ailments.

In February 1997, cloning became the focus of media attention when Ian Wilmut and his colleagues at the Roslin Institute announced the successful cloning of a sheep, named Dolly, from the mammary glands of an adult female. The cloning of Dolly made it apparent to many that the techniques used to produce her could someday be used to clone human beings. This stirred a lot of controversy because of its ethical implications.

4.3.2. Genetic testing

This involves the direct examination of the DNA molecule itself. A scientist scans a patient's DNA sample for mutated sequences.

There are two major types of gene tests. In the first type, a researcher may design short pieces of DNA ("probes") whose sequences are complementary to the mutated sequences. These probes will seek their complement among the base pairs of an individual's genome. If the mutated sequence is present in the patient's genome, the probe will bind to it and flag the mutation. In the second type, a researcher may conduct the gene test by comparing the sequence of DNA bases in a patient's gene to disease in healthy individuals or their progeny

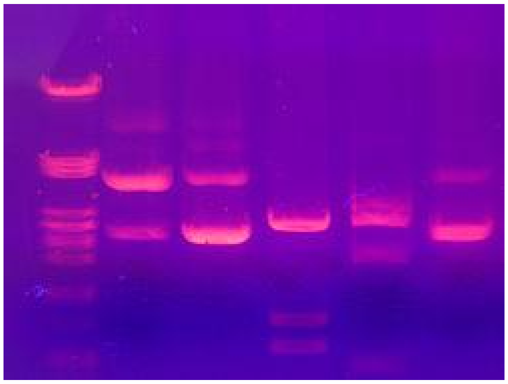


Figure 5: Gel electrophoresis depiction of genes or DNA fragments (http://en.wikipwedia.org, 2011)

Genetic testing is now used for:

- Carrier screening, or the identification of unaffected individuals who carry one copy of a gene for a disease that requires two copies for the disease to manifest;
- Confirmational diagnosis of symptomatic individuals;
- Determining sex;
- Forensic/identity testing;
- Newborn screening;
- Prenatal diagnostic screening;
- Presymptomatic testing for estimating the risk of developing adult-onset cancers;
- Presymptomatic testing for predicting adult-onset disorders.

The bacteria ***Escherichia coli*** are routinely genetically engineered. The recent crisis involving a possibly mutated strain of E. coli that has killed about 22 people in Germany and caused serious morbidity state on about 2,200 people as this bacterium is ubiquitous in genetic engineering technologies.

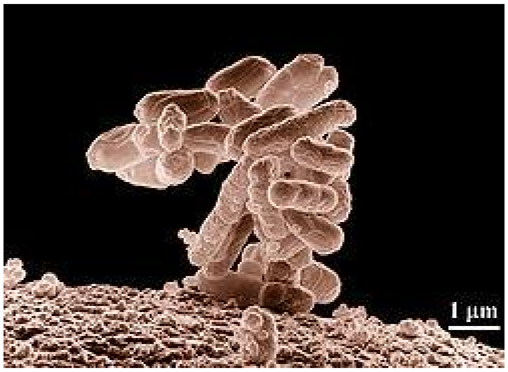


Figure 6: A colony of the bacteria Escherichia coli (http://en.wikipedia.org, 2011)

4.3.3. Gene therapy

Gene therapy may be used for treating, or even curing, genetic and acquired diseases like cancer and AIDS by using normal genes to supplement or replace defective genes or to bolster a normal function such as immunity. It can be used to target somatic (i.e., body) or gametes (i.e., egg and sperm) cells. In somatic gene therapy, the genome of the recipient is changed, but this change is not passed along to the next generation. In contrast, in germline gene therapy, the egg and sperm cells of the parents are changed for the purpose of passing on the changes to their offspring.

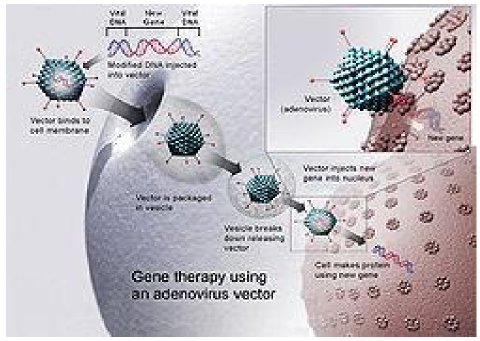


Figure 7: Gene therapy schematic using adenovirus vector (http://en.wikipedia.org, 2011)

In the above technique a new gene is inserted into an adenovirus vector, which is used to introduce the modified **DNA** into a human cell. If the treatment is successful, the new gene will make a functional ***protein*** such as insulin for treating diabetes**.**

There are basically two ways of implementing a gene therapy treatment:

1. *Ex vivo*, which means "outside the body" – Cells from the patient's blood or ***bone marrow*** are removed and grown in the laboratory. They are then exposed to a virus carrying the desired gene. The virus enters the cells, and the desired gene becomes part of the DNA of the cells. The cells are allowed to grow in the laboratory before being returned to the patient by injection into a vein.
2. *In vivo*, which means "inside the body" – No cells are removed from the patient's body. Instead, vectors are used to deliver the desired gene to cells in the patient's body.

4.4. Medical imaging

Medical/Biomedical Imaging is a major segment of *Medical Devices*. This area deals with enabling clinicians to directly or indirectly "view" things not visible in plain sight (such as due to their size, and/or location). This can involve utilizing ultrasound, magnetism, UV, other radiology, and other means.

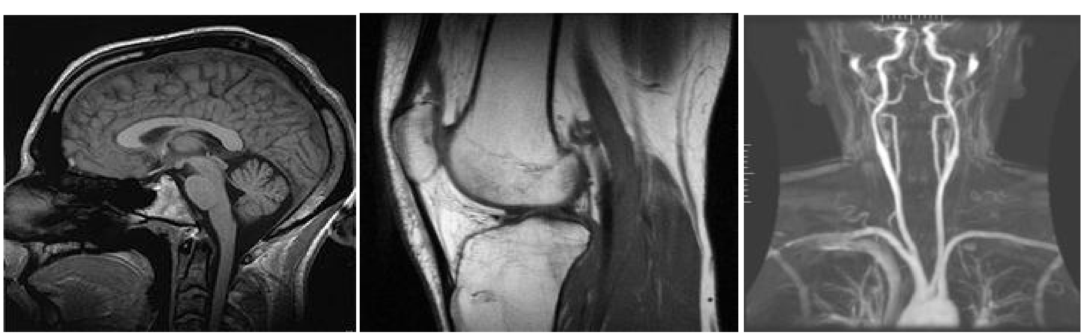


Figure 8: An MRI scan of a human head, knee and blood vessels of the aortic arch (carotid and subclavian) - examples of biomedical engineering application of electrical engineering to diagnostic imaging (http://en.wikipedia.org, 2011)

Imaging technologies are often essential to medical diagnosis, and are typically the most complex equipment found in a hospital including:

- Fluoroscopy
- Magnetic resonance imaging (MRI)
- Nuclear Medicine
- Positron Emission Tomography (PET) PET scansPET-CT scans
- Projection Radiography such as X-rays and CT scans
- Tomography
- Ultrasound
- Optical Microscopy
- Electron Microscopy

4.5. Implants

An implant is a kind of medical device made to replace and act as a missing biological structure (as compared with a transplant, which indicates transplanted biomedical tissue). The surface of implants that contact the body might be made of a biomedical material such as titanium, silicone or apatite depending on what is the most functional. In some cases implants contain electronics e.g. artificial pacemaker and cochlear implants. Some implants are bioactive, such as subcutaneous drug delivery devices in the form of implantable pills or drug-eluting stents.

Figure 9: Artificial Limbs: The right arm is an example of a prosthesis, and the left arm is an example of myoelectric control, on the right of the figure is a prosthetic toe from ancient Egypt made of wood and attached to the wearer by sewing with leather (http://enwikipedia.org, 2011).

Figure 10: Implants in situ seen through X-ray imaging technique, such as artificial hip joints, are generally extensively regulated due to the *invasive* nature of such devices (NIH Hip replacement Image 3684-PH.jpg, http://en.wikipedia.org, 2011).

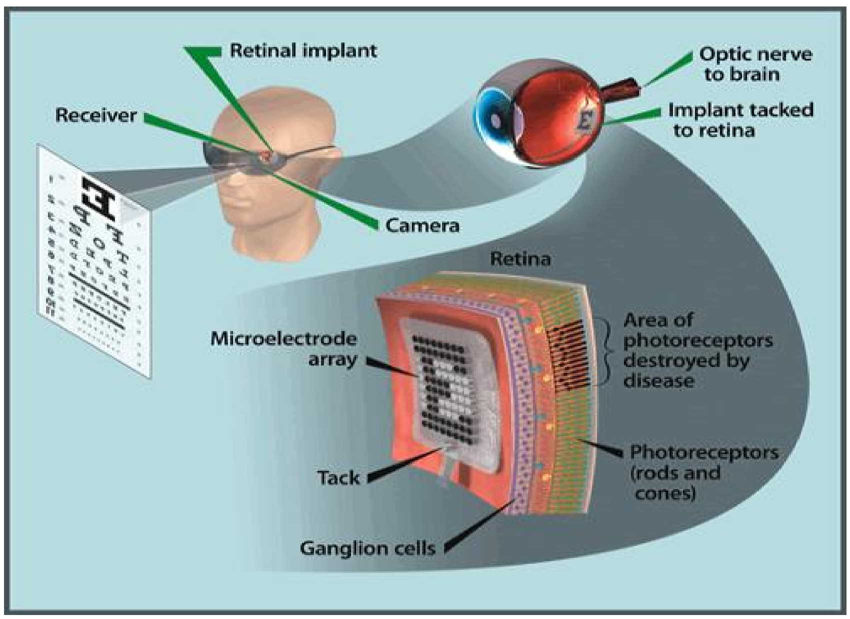


Figure 11: Artificial Retina for the Blind consisting of a camera with a transmitter with semi-conductor microelectrode receiver implanted into the eye and tacked to the retina.

4.6. Clinical engineering

This is the branch of biomedical engineering dealing with the actual implementation and interfacing of medical equipment and technologies in hospitals or other clinical settings. Major roles of clinical engineers include training and supervising biomedical equipment technicians (BMETs), selecting technological products/services and logistically managing their implementation, working with governmental regulators on inspections/audits, and serving as technological consultants for other hospital staff (e.g. physicians, administrators, I.T., etc.). Clinical engineers also advise and collaborate with medical device producers regarding prospective design improvements based on clinical experiences, as well as monitor the progression of the state-of-the-art so as to redirect procurement patterns accordingly.

4.7. Biomedical Engineering and 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. 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.

Some tests that doctors routinely request:

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 High Density Lipoprotein or **HDL** and Low Density Lipoprotein or **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 EKG 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.

5.5. 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. 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 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.

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.

5. 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.

Rehabilitation medicine or Physical medicine and rehabilitation or **physiatry** is a branch of **medicine** which aims to enhance and restore ***functional ability*** and ***quality of life*** to those with physical impairments or disabilities. A ***physician*** who has completed training in this field is referred to as a **physiatrist**. In order to be a physiatrist in the United States, one must complete four years of ***medical school***, one year of ***internship*** and three years of ***residency***. Physiatrists specialize in restoring optimal function to people with injuries to the muscles, bones, tissues, and nervous system (such as stroke patients).[1] The first Department of Physical Medicine was established at Mayo Clinic in 1936.

5.1. Medicine adds *years* to life: Rehabilitation Medicine adds *life* to years!

A glimpse of what Rehabilitation Medicine can contribute to healthy human life is provided by the story of our ace footballer – Kanu Nwankwo who was diagnosed with a heart problem, had open heart surgery and was rehabilitated to complete functional capability. The relationship between the physicians involved with his management including cardiologists, surgeons and rehabilitation medical practitioners and other members of the multidisciplinary healthcare team can be seen to have been very effective in his complete recovery! Medicine has indeed added years to his years to his life and rehabilitation medicine has added life to his years as he is still very active physically and mentally. The Kanu Heart Foundation is a veritable testimony to this fact of a healthy human life.

5.1.1. Scope of the field of Physical Medicine and Rehabilitation

Physical medicine and rehabilitation or rehabilitation medicine involves the management of disorders that alter the function and performance of the patient. Emphasis is placed on the optimization of function through the combined use of:

- medications,
- physical modalities,

- physical training with therapeutic exercise,
- movement & activities modification,
- adaptive equipments and assistive device,
- orthotics (braces),
- prosthesis, and
- experiential training approaches.

Common conditions that are treated by physiatrists include

- amputation,
- spinal cord injury,
- sports injury,
- stroke,
- musculoskeletal pain syndromes such as
- low back pain,
- fibromyalgia and
- traumatic brain injury.

Cardiopulmonary rehabilitation involves optimizing function in those afflicted with heart or lung disease. Chronic pain management is achieved through multidisciplinary approach involving:

- psychologists,
- physical therapists,
- occupational therapists,
- chiropractors, and
- interventional procedures when indicated.

In addition stroke is often treated with the help of a:

- speech therapist and
- recreational therapist when possible.

5.1.2. Philosophy

Generally, the major concern of the field is the ability of the person to function optimally within the limitations placed upon them by a disease process for which there is no known cure. The emphasis is not on the full restoration to the premorbid level of function, but rather the optimization of the quality of life for those who may not be able to achieve full restoration. A team approach to chronic conditions is emphasized, using interdisciplinary team meetings to coordinate care of the patients.

5.1.3. Subspecialty

Six formal sub-specializations are recognized by the field in the United States:

- Pain medicine
- Pediatric rehabilitation
- Spinal cord injury medicine
- Neuromuscular medicine
- Sports medicine
- Hospice and palliative medicine

5.2. Rehabilitation Medicine and Multi-Disciplinary Team (MDT)

Rehabilitation medicine cannot work without a full MDT. There is now clear evidence of the effectiveness of such a team over and above individual therapists working in isolation. Such evidence is emerging in the context of stroke, traumatic brain injury, and multiple sclerosis (Semylen et al., 1998; Freeman et al., 1997). The key to MDT working is that professional roles are somewhat blurred, particularly as the rehabilitation goals are set to the wishes of the disabled person rather than the wishes of an individual department. The key members of a MDT include:

- ***Nurses:*** Rehabilitation nurses have a crucial role as they are with the person 24 hours a day, at least in the post-acute inpatient setting. They carry over the skills learned in therapy into daily tasks. There are an increasing number of specialist nurses who are either disease specific (e.g. multiple sclerosis) or symptom specific (eg incontinence), and who work in hospital and community settings.
- ***Occupational therapists:*** Occupational therapists work on strategies to promote independent daily living, and advise on appropriate aids and adaptation to facilitate such independence. Occupational therapists work closely with colleagues in the community to facilitate reintegration of the individual at home and to help them maintain a state of maximum independence.
- ***Physiotherapists***: Physiotherapists concentrate on restoring and maintaining joint range, muscle power and balance in order to facilitate walking. They often have a key role in the provision of wheelchairs and suitable seating and play an important part in pain relief or promoting strength and cardiovascular fitness.
- ***Speech and language therapists***: Speech and language therapists work on all aspects of communication including language, phonation, articulation and the use of communication aids. They have developed particular expertise in aspects of swallowing and often take the lead in the management of dysphagia.
- ***Dietitians****:* Dietitians work closely with speech and language therapists to ensure correct diet. Many disabled people have changing metabolic requirements, particularly when recovering from an acute injury and the role of the dietitian can be vital at both early and later stages.
- ***Clinical psychologists:*** Clinical psychologists are responsible mainly for assessing the psychological impact of disability and work to ameliorate psychological or behavioural problems through a variety of retraining programmes. Clinical neuropsychologists are a central part of any team dealing with traumatic brain injury and it is doubtful that a neuro-behavioural unit could function without neuropsychological input.

A number of other therapists and professionals assist the rehabilitation team, including social workers, counsellors, art and music therapists, prosthetists, orthotists and bioengineers. There is an increasing emphasis on technological advances to support people with disabilities, particularly in wheelchairs, environmental control, and communication aids. Appropriately trained bioengineers are vital in a modern rehabilitation team.

This is not an exhaustive list but illustrates the wide range of skills required by the ***rehabilitation physician*** and his team in order to use the expertise of other specialists in a timely and appropriate fashion towards a healthy human life.

Rehabilitation medicine services also need links with primary care and other community services. This is particularly important in times of re-integration into the community after an acute event such as stroke or traumatic brain injury. The General Medical Practitioner or GP and the primary care team will need to be involved in discharge arrangements and ongoing care packages in a hospital after acute care under a rehabilitation physician. Other community-orientated services, such as consumer groups, voluntary sector, education, employment, housing and social services, are vital. Finally, there is a growing need for rehabilitation services to work with legal colleagues to assist those in the process of seeking compensation.

5.2.1. Academic Medicine

There is an increasing evidence base for the efficacy of rehabilitation medicine in adding life to years of patients under care. Excellent evidence from randomised, placebo-controlled studies shows the efficacy of multidisciplinary rehabilitation in the context of stroke (Langhorn et al., 1993). There is also emerging evidence of the efficacy of rehabilitation techniques in the context of traumatic brain injury, multiple sclerosis and community-orientated rehabilitation (Semylen et al., 1998; Freeman et al., 1997; Barnes and Radermacher, 2003).

In the UK and US it is good to see that many medical undergraduate curricula now contain compulsory teaching on rehabilitation medicine but more emphasis on education and training in this specialty is still needed at undergraduate and postgraduate level. There is a dire need for its establishment in this only University of Nigeria.

6. Scope of Science and Technology in the 21st Century

This 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 and its antimatter component - 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, as in the recent nuclear disaster – technological product of man, in Japan following the devastating earthquake and tsunami - all natural disasters, 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 – result of God creating man in His own image!

6.1. 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 i.e. Biomedical Engineering.

6.1.2. Fundamental Problem of Technology Acquisition in Nigeria

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 eloquent 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 “wise-man 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.

6.2. Technology Transfer and Biomedical Engineering

According to Rushmer (2002), 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.

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 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.

6.3. Acquisition and Development of Appropriate Technology for Health

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.

6.3.1. 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 good 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.

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.

7.1. 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. Nature has endowed with immense potential resources for wealth creation to ensure a healthy nation!

7.1.1. Technology Development: Need to look inwards

In a purpose designed mechanical engineering workshop, it has been possible for the author to design surgical operating table (Figure 11 A, B and C), 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/Innovators Exhibition in 1989.

(A)

(B)

(C)

Figure 12: The Author's Award-winning Hydraulic variable height multi-position surgical operating table wholly designed and developed with wholly locally sourced materials (A, B and C depicts different positions)

Figure 13: Author's Electronic Stethoscope

Figure 14: Author's Designed and Produced Automated Dental Chair commissioned by the Vice Chancellor UNN in 2006

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.

The former Vice Chancellor of the University of Nigeria, Professor CO Nebo commissioned me to design and develop an automated dental chair. This product (figure 13) was unveiled by the former Pro-Chancellor and Chairman of Council of the University of Nigeria, Professor Bolanle Awe.

During my sabbatical leave at the Federal University of Technology, I developed a programme in Biomedical Technology and graduated two sets of candidates. I am happy that one of them Mr Samuel Uzoechi, who has been one of my most enthusiastic students of Biomedical Technology is now doing an MSc at the University of Twente, Netherlands and his current research there is on tissue engineering of artificial kidney. Medical equipment including electronic stethoscope (Figure 12) were designed and fabricated by my students under my supervision.

8. 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*** as God Almighty has planned in the beginning. 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 since the "sin" at the Garden of Eden. 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 palliative—that is, they relieve symptoms but do not reverse the underlying disease. Sometimes no treatment is needed because the disease will get better by itself. In all these bioengineering and rehabilitation medicine has been a common denominator.

8.1. Healthy life expectancy (HALE) at birth (years)

This is the average number of years that a person can expect to live in "full health" by taking into account years lived in less than full health due to disease and/or injury. According to the World Health Organisation (WHO) substantial resources are devoted to reducing the incidence, duration and severity of major diseases that cause morbidity but not mortality and to reducing their impact on people's lives. It is important to capture both fatal and non-fatal health outcomes in a summary measure of average levels of population health. Healthy life expectancy (HALE) at birth adds up expectation of life for different health states, adjusted for severity distribution making it sensitive to changes over time or differences between countries in the severity distribution of health states.

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 which probably started with “sin” or dis-ease of the Garden of Eden)) and effectively restore and sustain a "state of balance". In the field of alternative medicine the term used to describe one's overall state of being is ***wellness.***

At the turn of the 20^{th} 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 20^{th} 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.

Bioengineering which is the common denominator to all progress of man towards a healthier life has been privy to improvement in health status of the developed economies and certainly will be of immense benefit to us in Nigeria. The Senate Development Committee in its wisdom has approved the establishment and nurturing of BIOMEDIAL ENGINGINEERING RESEARCH AND DEVELOPMENT CENTRE for the University of Nigeria. The time is auspicious for a focused and solid foundation in Bioengineering in all its ramifications for the nation which should be pursued with utmost vigour especially in our only University of Nigeria.

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. 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.

Epilogue

I have discussed the beginning of our world both living and non-living through creation by the ALMIGHTY GOD with the other perspectives of contemporary physics in the “BIG BANG”. In both scenarios no account was given about ***what was*** and ***how it all began***. Did our world have a beginning? And if God created the Universe, who created God? On the other hand what was the origin of what gave rise to the so-called explosive “BIG BANG”? The apparent dilemma can only be resolved by regarding our **ALMIGHTY GOD -** the author and finisher of our faith as the “**BEGINNING WITHOUT A BEGINNING**”! Period.

Thank you for listening.

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