



Covenant University

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18TH INAUGURAL LECTURE

From Evolution to Revolution: *Biochemical Disruptions and Emerging Pathways for Securing Africa's Future*



SHALOM NWODO CHINEDU

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18th Inaugural Lecture



**From Evolution to Revolution:
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Emerging Pathways for Securing
Africa's Future***

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THE FOUNDATION

1. PROTOCOL

The Chancellor and Chairman, Board of Regents of Covenant University, Dr David O. Oyedepo; the Vice-President (Education), Living Faith Church World-Wide (LFCWW), Pastor (Mrs) Faith A. Oyedepo; esteemed members of the Board of Regents; the Vice-Chancellor, Professor AAA. Atayero; the Deputy Vice-Chancellor; the Ag. Registrar; Principal Officers and members of Covenant University Senate; faculty and staff; eminent scholars, special guests; Kings and Queens in Hebron; distinguished audience; ladies and gentlemen.

“Oh, give thanks to the Lord, for He is good! For His mercy endures forever... This is the day the Lord has made; we will rejoice and be glad in it.”

(Psalm 118: 1, 24; NKJV)

Chancellor, sir, permit me to commence this discourse by joyfully and profusely expressing my profound gratitude to the Almighty God, the source and giver of life, for the awesome privilege of life, and for the grace and honour He has granted me today to stand before you all to deliver the 18th Inaugural Lecture of Covenant University. I celebrate God, the builder of all things, for establishing this great citadel of learning. To His glory, we have today a global platform where we can mount to freely search out, create and expand the frontiers of knowledge; a solid pedestal upon which we can stand to boldly express our thoughts, hopes, and dreams of a sure, colourful future. God is gracious to us! I deeply appreciate His servant, our dear Chancellor and 'Visioner' of Covenant University, Dr David Oyedepo, for the obedience of faith, the unwavering commitment, and the tireless pursuit of the 'heavenly vision' that has birthed this world-class University!

2. THE KEY OF KNOWLEDGE

“The people which sat in darkness saw great light; and to them which sat in the region and shadow of death light is sprung up.” (Matthew 4 16, KJV)

It takes light to dispel darkness! Darkness connotes lack of vision, absence of motion, a state of helplessness and utter despondency. Knowledge is light; it is the key that opens the door of life! The University is a fountain of knowledge and a factory of solutions. In the words of our Chancellor, Dr David Oyedepo, “...a University is a place where solutions to societal problems are found and value-added to humanity. The real value of a University is only established by the problems it solves” (Oyedepo, 2012). Peter Okebukola, a former Executive Secretary of the National Universities Commission (NUC), in his remarks on the expectations of the 21st century African Universities, emphasized that “What Africa needs is a new generation of Universities that can serve as engines of economic development and social renewal. This requires a major paradigm shift on the part of government, academia, business and civil society to overhaul education, and put it squarely on the service of African people” (Okebukola, 2012). Covenant University clearly stands out as one of such Universities. It is a university driven by the compelling vision of 'Raising a New Generation of Leaders for the African Continent'. Her core mandate, among others, is “Raising a new generation of leaders who shall redeem the battered image of the black race and restore her lost glory...”

(a) The Africa I Know

Africa is a beautiful continent; the land of great people. Africa's population, land mass and location makes her the second largest continent in the world and the best 'habitable' part of the earth! Unfortunately, impacts of many disasters, man-made and natural, notably, the long years of slavery and servitude, colonization, political

upheavals, incessant wars, drought and poverty have left Africa in comatose, devastated, and at the bottom of all indices of global development. These have assaulted the psyche of Africans and eroded their self-esteem. But “in the beginning, it was not so!” By divine providence, Africa had always been at the forefront of every move for man's survival and advancement! The earliest known cradle of human civilization, the Fertile Crescent, comprised of ancient Egypt (North Africa) and Mesopotamia (Middle East). The ideals and ideas that ruled the old Roman Empire, and by extension, still rule the world today, were known to have been crafted in ancient Egypt. It is, therefore, not a coincidence that the world's oldest Universities: the University of Alkarouine, in Fez, Morocco (established 859 AD) and the Al-Azhar University in Cairo, Egypt (established 988 AD) were built in Africa by Africans!

(b) The Focus

An inaugural lecture is not just one of the academic rituals of a university. It is a veritable platform for the newly appointed Professors to disseminate (profess) to peers, students, and external audiences the knowledge they have generated over the years through research and rigorous studies. It is also an avenue for the supposed eggheads to dig into their past for worthy contributions they have made towards community, national or global renewal, and to project into the future to chart the pathways for sustainable development.

This Lecture presents a summary of my sojourn in the academia which has spanned 27 years. Looking back, I was amazed to realize that this chunk of my life has been spent at work within the four walls of the University. Today's Inaugural Lecture, titled: “From Evolution to Revolution: Biochemical Disruptions and Emerging Pathways to Securing Africa's Future” has Africa as its focal point. I will be examining some emerging trends, techniques and technologies in the Life Sciences, and exploring pathways for engaging them as practical

tools towards meeting Africa's critical needs, restoring her fortunes, and setting her on the path of economic growth and sustainable development.

Chancellor, sir, this lecture is, specially, dedicated to Africa and indeed, all Africans, both at home and in the Diaspora. Permit me, therefore, to celebrate Africa, our great continent, with these lines from my poem, titled: "God bless Africa".

God Bless Africa

God bless Africa,
Progenitor of my kind.

God bless Africa,
Africa, deep, drenched...
By floods and loud cascade showers
And storms of wild, Saharan wind,
The warm, scintillating sunbaths
Cleanse her white-washed mind!

God bless Africa,
Africa, fresh, regenerated...
With the dew of a new dawn
To the excellence of resplendent
Day star,
The bright, sublime bride
Smile to adorn her pride!

God bless Africa,
Africa, pure immaculate...
With ecstasy of flowery exuberance
To the full embrace of stupendous,
Celestial grace,
The fertile, volatile, virgin
Erupt in fervent renaissance!

God bless Africa,
Procreator and God-kind!

Culled from "Hope Africa: A Collection of Poems" by Shalom N. Chinedu

3. THE BACKGROUND

"He spoke about plant life, from the cedar of Lebanon to the hyssop that grows out of walls. He also spoke about animals and birds, reptiles and fish." (1 Kings 4: 33, NIV)

Life is awesome! Man, since ages, has always been fascinated by the phenomenon of life and the great diversities of living organisms on the earth. People of diverse backgrounds, cultures, and walks of life, ranging from kings to peasants, the clergy to laity, believers to atheists, philosophers to realists, scientists to laypersons, et cetera, have invested valuable time, energy (physical, mental and spiritual), and enormous resources in the attempt to unravel the mystery and meaning of life.

Perhaps more intriguing is man's unending quest to harness and exploit the huge reserve of bio-resources around him to meet his daily needs

(food, health, shelter, clothing, transportation, communication, etc.) and to advance the quality of his life. All through history, man has been engaged in a continuous search not only for new knowledge, but much more, for innovative techniques and technologies to practically translate the knowledge acquired into goods and services for his benefit. It is the economic outcome of these endeavours that culminate into community, national, and global development.

(a) What is Life?

“Life is like fire, not water; it is a process, not a pure substance. The simplest, but not the only, proof of life is to find something that is alive” – Chris McKay (2014).

Life has been defined in many varied ways but none seem to have captured the very essence of life. This is partly due to the fact that life is a process and not a substance (Mautner, 1997; McKay, 2014). Hence, the persistent search for the definition that is precise and acceptable to all. The scientific definition of life is descriptive. It considers life as a characteristic of 'something' that preserves, furthers or reinforces its existence in the given environment'. Mautner (2000) stated that: “life is the self-propagation of organic matter through gene/protein cycle. The effective purpose of life is to continue to live”.

Life is a characteristic that distinguishes physical entities that have biological processes, such as signalling and self-sustaining processes, from those that do not, either because such functions have ceased (they have died), or because they never had such functions and are classified as inanimate (Wikipedia). Seven characteristics of life have been identified as follows: homeostasis, growth, organisation, metabolism, adaptation, response to stimuli, and reproduction (Koshland 2002; McKay, 2014). A living organism is expected to exhibit all or most of these characteristics. However, there are a few borderline forms of life, such as viruses and

viroids, which do not possess these characteristics.

(b) Biology and the Life Sciences

Biology is the science of life. The word “biology” was derived from the Greek words "bios" (life) and "logos" (study). It is the natural science that studies life and living organisms, including their structure, function, growth, origin, evolution, and distribution (TSU, 2004). The science of biology undoubtedly stands out as the oldest and among the widest fields of study on the earth. The dramatic rise in its role since 1950s has led to the emergence of several branches/sub-branches as distinct disciplines. Today, biology has grown from a single discipline to a completely new sets of disciplines (fields), collectively referred to as “Life Sciences”. Recent advances in genomic technologies have birthed new fields of life sciences, such as, molecular biology, molecular genetics, biotechnology, molecular medicine, nanobiology and neuroscience (Ayla, 2015). The positive impacts of these advances are not only evident in science and technology but also in economic growth and development. Some disciplines in the life sciences are shown in Table 1.

Table 1: Some disciplines in the Life Sciences.

Aerobiology	Cytology	Mycology
Agriculture	Developmental biology	Nanobiology
Anatomy	Ecology	Ornithology
Bacteriology	Embryology	Paleontology
Biochemistry	Endocrinology	Pathology
Bioengineering	Entomology	Pharmacology
Biogeography	Environmental biology	Phylogeny
Bioinformatics	Epidemiology	Physiology
Biomechanics	Evolutionary biology	Phytogeography
Biological Earth Sciences	Genetics	Phytopathology
Biomathematics	Histology	Population biology
Biomedical research	Helminthology	Protozoology
Biomusicology	Hematology	Psychobiology,

Biophysics.	Herpetology	Quantum biology
Biological Psychology	Ichthyology	Sociobiology
Biosemiotics	Integrative biology	Structural biology
Botany	Lichenology	Taxonomy
Building biology	Limnology	Virology
Cell biology	Mammology	Zoology
Cognitive biology	Marine biology	Zoogeography
Conservation biology	Microbiology	
Cryobiology	Molecular biology	

(c) **Biochemistry**

Biochemistry, also called biological chemistry, is the study of the structure, composition, and chemical reactions of substances in living systems. It emerged as a separate discipline in the life sciences when scientists began to combine biology and chemistry principles and procedures to study the underlying mechanisms of biological processes, such as how cells obtain and use energy, the chemical basis of heredity, and the fundamental changes that occur in health and disease, etc. It focuses on processes that occur inside the cells at a molecular level. Advances in the field of Biochemistry have provided better understanding of many biological processes through the knowledge of relationships between structure and function at molecular and sub-cellular levels. This has led to major breakthroughs in the diagnosis, treatment and control of several human disorders, and the introduction of desirable characteristics into animals, plants and microbial cells. Today, biochemical analyses form essential parts of quality control regimes of many manufacturing and service industries, and constitute an integral aspect of key analytical and research protocols in the fields of medicine, agriculture, molecular biology and biotechnology.

Genetics and molecular biology disciplines are closely related to biochemistry. They are sometimes regarded as branches of biochemistry. Genetics is the study of the effect of genetic differences on organisms

whereas Molecular Biology studies the molecular basis of gene replication, transcription and translation processes. Molecular Biology and Biochemistry are almost used interchangeably. There has never been a hard-line among the disciplines in terms of content and technique. Biochemists increasingly combine the specific techniques native to biochemistry with the techniques and ideas developed in the fields of genetics, molecular biology and biophysics. Figure 1 is a schematic representation of the relationship between Biochemistry, Genetics and Molecular Biology.

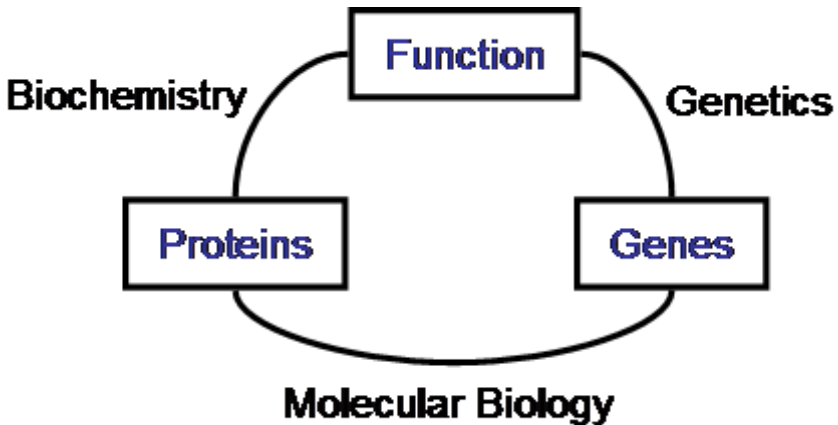


Fig. 1. Relationship between biochemistry, genetics and molecular biology.

4. EVOLUTION

The term “evolution” is used to refer to changes in the heritable characteristics (genes that are passed on from parent to offspring) of biological populations over successive generations (Hall and Hallgrímsson, 2008). The scientific theory of evolution by natural selection was proposed by Charles Darwin and Alfred Russell Wallace in the mid-19th century and set out in detail in Darwin's book on “the Origin

of Species” (Darwin, 1859). The theory states that “all species of organisms arise and develop through the natural selection of small, inherited variations that increase the individual's ability to compete, survive, and reproduce”. Evolutionary biology is the study of how evolution occurs; it holds that biological populations evolve through genetic changes that correspond to changes in the organisms' observable traits.

(a) The Summary

Below are the summary of Darwin's theory of evolution:

- (I) A species is a population of organisms that interbreed and has fertile offspring.
- (ii) Living organisms have descended with modifications from species that lived before them.
- (iii) Natural selection explains how this evolution has happened:
 - More organisms are produced than can survive because of limited resources.
 - Organisms struggle for the necessities of life; there is competition for resources.
 - Individuals within a population vary in their traits; some of these traits are heritable (passed on to offspring).
 - Some variants are better adapted to survive and reproduce under local conditions than others.
 - Better-adapted individuals (the "fit enough") are more likely to survive and reproduce, thereby passing on copies of their genes to the next generation.
 - Species whose individuals are best adapted survive; others

become extinct.

(b) The Controversies

Evolution theory sought to put a break to the concept of constant typological classes or types (kinds) in biology. However, 160 years after Darwin published his book 'On the Origin of Species by Means of Natural Selection, the world is still divided on the subject, and if anything, the controversy has grown both in size and intensity. Evolution battles have been fought, and still rages, in courtrooms, legislatures, educational institutions, worship places, school boards, and in the courts of public opinion. Many have questioned the scientific basis of evolution citing such issues as lack of credible data, irreproducibility of the events, and the unrealistic and unverifiable chronology. To make the matter worse, evolution is sometimes tied to atheism, an anathema to the religious world. The purported evolution of man from apes (hominid family) appears to be the most contentious of it all (Fahad, 2018). Pope John Paul II (1996) in his message to the Pontifical Academy of Sciences stated:

“The magisterium of the Church takes a direct interest in the question of evolution, because it touches on the conception of man, whom Revelation tells us is created in the image and likeness of God. The conciliar constitution, Gaudium et Spes, has given us a magnificent exposition of this doctrine, which is one of the essential elements of Christian thought. The Council recalled that “man is the only creature on earth that God wanted for its own sake.” In other words, the human person cannot be subordinated as a means to an end, or as an instrument of either the species or the society; he has a value of his own. He is a person. ... As a result, the theories of evolution which, because of the philosophies which inspire them, regard the spirit either as emerging from the forces of living matter, or as a simple epiphenomenon of that matter, are incompatible with the truth

about man. They are, therefore, unable to serve as the basis for the dignity of the human person.”

Today, the controversy has pitched mankind into many opposing camps: the evolutionists, creationists, young earth creationists, intelligent design (ID) proponents, et cetera.

· Evolutionists are those that maintain and propagate the evolution theory as an absolute fact, supported by scientific findings. They try to downgrade the evolution controversy to a mere conflict between science and religion and canvass the argument that a combination of natural selection and environmental factors fully explain the origin and diversity of life as we have it on the earth (Masci, 2009). Evolutionists also are divided into camps, such as the “Punctualists” and “Gradualists”. The “Punctualists” believe that evolution usually occurs sporadically, in relatively short bursts, as the result of major environmental change whereas the “Gradualists” are more inclined to believe that evolution occurs more evenly, over longer periods of time. An evolutionist may or may not believe that evolution is the way in which a divine being has chosen to work in the world.

· Creationists, on the other hand, totally and unequivocally reject the evolution theory, maintaining strongly that each species in existence was put on earth by a divine being (God). A creationist might accept "micro-evolution" (changes in the form of a species over time based on natural selection), but rejects in absolute terms the notion that one species can over time become another species, e.g. an ape becoming a human.

· The young earth creationists believe that 'the earth is nowhere near the 4.6 billion years old that most evolutionists estimate, but is instead around 6,000 years old based on the recognition of a complete listing of the generations from Adam and Eve as contained in the book of Genesis to historical times.

· The intelligent design (ID) proponents may or may not reject the theory of evolution. At a minimum, ID proponents reject that evolution is randomly driven or, more generally, the notion that natural law and chance alone can explain the diversity of life on earth. Rather they argue, often from statistics, that the diversity of life is the result of a purposeful scheme of some higher power (who may or may not be the God of the Bible).

(c) Teaching of Evolution in Public Schools

The status of creation and evolution in public education has been a very contentious issue with a wide variety of views, globally. For more than a century, this has continued to provoke intense debates and conflicts in legal, political and educational circles (Harmon, 2011; Skehan and Nelson, 2000). Much of the 20th century witnessed attempts by opponents of evolution in the US to use legislative advantage to enact anti-evolution statutes in several States in a bid to abolish the teaching of evolution from public school science curricula or influence science instructors to teach a version of the creation story found in the biblical book of Genesis. A notable case was the so-called “Scopes Monkey Trial” of 1925, where a high school biology teacher, John Scopes, was fined \$100 by a local court for illegally teaching the evolution theory contrary to Tennessee statute. The verdict was later overturned by the Tennessee Supreme Court which also dismissed the case, stating that: “Nothing is to be gained by prolonging the life of this bizarre case.”

Since 1960s, the US Supreme Court has issued several verdicts that imposed severe restrictions on state governments that opposed the teaching of evolution, thus, effectively barring school boards, legislatures and government bodies from “prohibiting the teaching of evolution and or urging the teaching of creation science, either along with evolutionary theory or in place of it”. In 2006, the InterAcademy

Panel (IAP), a body representing national science organisations across the globe, in Trieste, Italy, issued a statement on the teaching of evolution, where it urged "decision-makers, teachers, and parents to educate all children about the methods and discoveries of science", asserting the "evidence-based facts about the origins and evolution of the Earth and of life on this planet." This was endorsed by 67 countries including some Muslim-dominated nations. Today, western countries, including US and Great Britain, have legislation that mandates only evolutionary biology to be taught in the appropriate scientific syllabuses (Harmon, 2011).

(d) The Way Forward

Nevertheless, there are groups and persons who consider the conflict between science and religion as very unnecessary. The US National Association of Science Teachers (NAST) in its Question and Answer (Q&A) document stated that "learning about the natural world does not and should not conflict with religious beliefs... Scientific knowledge cannot contradict religious beliefs because science has nothing to say for or against religious realities or religious values... By staying within these boundaries, science does not and will not enter the realm of religion and will never force students to make unnecessary choices about their beliefs" (Skoog, 2007). Pope Pius XII (1950) also stated that: "there is no conflict between evolution and the doctrine of the faith ... provided that we do not lose sight of certain fixed points". Ayala (1997) tried to draw a line between science and religion this way: "Scientific view of the world is hopelessly incomplete. Science seeks material explanations for material processes, but it has nothing definitive to say about realities beyond its scope. Once science has had its say, there remain questions of value, purpose, and meaning that are forever beyond science's domain, but belong in the realm of philosophical reflection and religious experience." In spite of such philosophical views, the conflict between science and religion may not go away very soon. For instance, legal battles may come up in the future over such theories as "The Big Bang," which also undermine the religious beliefs about creation.

My discourse today focuses on how to trigger quick and enduring progress in Africa! This underscores the call for us to move away from evolution (and, of course, the controversies) to revolution. The wisdom of the Tennessee Supreme Court of 1925 is still valid today: “Nothing is to be gained by prolonging the life of this bizarre case”. Absolutely nothing!

5. REVOLUTION

Revolution is “a sudden, complete or marked change in something” (Dictionary.com). The Merriam Webster defined revolution, among others, as (a) a sudden, radical, or complete change, (b) a fundamental change in political organization, (c) activity or movement designed to effect fundamental changes in the socioeconomic situation, (d) a fundamental change in the way of thinking about or visualizing something: a change of paradigm, (e) a changeover in use or preference, especially in technology.

The term “revolution” in our context, refers to any activity or movement which by deliberate design and execution or spontaneous action effect fundamental changes in the socioeconomic situation of a people or nation. The changes are usually sudden, dramatic, grand, positive and enduring. It is a transition from one level of development to the next, usually a higher realm. Nations and different regions of the world have at various periods experienced marked technological advancements leading to rapid economic growth and great improvement in the quality of lives, aptly described as revolution. Among them are the agricultural and industrial revolutions.

(a) Agricultural Revolution

The term “agricultural revolution” has been used to describe remarkable changes and developments in the agricultural sector which had played significant roles in advancing and improving the quality of human lives.

It is subdivided into three phases: the first, the second, and third agricultural revolutions.

i. The first agricultural revolution, also known as the Neolithic Revolution, was what led to the transformation of human societies from nomadic hunting and gathering societies to settled agrarian societies. The transition which occurred worldwide between 10,000 and 2000 BC brought with it great changes that radically altered the way people lived. It was characterized by people settling down in definite places, engaging in farming, particularly, the cultivation of food crops such as wheat, oats and soybeans, and the domestication of plants and animals. As humans availed themselves of a more reliable source of food, their population grew rapidly, and cities also began to evolve.

ii. The second agricultural revolution led to increase in the productivity of farming through mechanization and access to global market due to better transportation. The revolution, which occurred between 1700 and 1900 AD, began in Britain in the early 18th century and by the 19th century, spread throughout Europe and America. It coincided with the industrial and 2nd urban revolution, and benefitted immensely from the technology provided by industrial revolution to increase the production and distribution of agricultural products. It was a period of significant agricultural development marked by new farming techniques and inventions of equipment such as the plow, seed mill and reaper resulting in a massive increase in food production. The agricultural revolution brought about experimentation with new crops and new methods of crop rotation. These new farming techniques gave soil time to replenish nutrients leading to stronger crops and better agricultural output. Advancements in irrigation and drainage further increased productivity. Many developing countries did not experience the 2nd agricultural revolution when it occurred. Many are still in the process whereas others are yet to begin.

iii. The third agricultural revolution, also called the Green Revolution, involved a set of research and technology transfer initiatives which increased agricultural production worldwide, particularly in the developing world (Hazell, 2009). Green revolution occurred between 1950s and late 1960s, particularly in late 1960s; it was a wholesome package of new agricultural technologies that was intended to replace the traditional methods of farming (Farmer, 1986). The initiatives resulted in the adoption of the new technologies, including high yielding varieties of cereals, in conjunction with chemical fertilisers, controlled water-supply (usually involving irrigation) and new methods of cultivation, including mechanization. The green revolution, unfortunately, did not succeed in sub-Saharan Africa (SSA) due to several factors including lack of irrigation facilities, agro-dealer networks, credit and collateral. Others are harsh environmental conditions, high fertiliser prices and inability of farmers to adopt the fertilizers (Voortman, 2013).

(b) Industrial Revolution

The Industrial Revolution was a transition to new manufacturing processes that occurred in Europe, North America and Japan. It was a process of change that moved mankind from an agrarian and handicraft economy to a world of industry and machines. This process began in Britain in the 18th century (from 1760 to about 1830) from where it spread to other parts of the world and continued until the early 20th century. The main features of the industrial revolution were technological changes that enabled an enormous increase in the use of natural resources and mass production of manufactured goods. There were also many new developments of a broad order in non-industrial sectors, including agricultural, economic, political, social and cultural transformations. Just like the 2nd agricultural revolution, developing countries neither participated nor benefited from the industrial revolution, although slaves from sub-Saharan Africa (SSA) were said to have contributed to it through their slave labour which produced much of the raw materials for the growing industries.

6. BIOCHEMICAL DISRUPTIONS

Disruption, which literally means disturbance, has been defined as: “an interruption in the usual way that a system, process or events work” (Cambridge Dictionary). The Merriam Webster definition of disruption includes “a break or interruption in the normal course or continuation of some activity, process, etc.” The word “disruption” gained prominence few decades ago due to its use in the business circle to describe processes through which a smaller company with fewer resources can successfully challenge established, incumbent businesses (Christensen, 1977). Disruption is said to be destructive and creative at the same time, in the sense that it displaces an existing market, industry or technology to create something new, more efficient and worthwhile (Christensen et al., 2013).

Virtually all aspects of biochemical studies, including most of the techniques and tools involved are disruptive. For example, the cell constituents cannot be accessed without disrupting the cell membranes; enzymes (proteins) cannot be isolated and purified without disrupting the sub-cellular structures; DNA molecules cannot be cut and joined to produce recombinant DNA (rDNA) without engaging several disruptive processes. Biochemical disruption is a common feature of genetic engineering, animal cloning, and other biotechnological techniques used for molecular studies and in the production of goods and services. Hence, the concept “biochemical disruption” is used in this context to describe processes that disrupt and alter the natural genetic make-up of organisms.

BIOLOGICAL REVOLUTION

1. THE BIOLOGY AGE

The 19th century was described as the age of engineering because engineering disciplines provided the technology that propelled the industrial revolution in Europe and North America (Wengenroth, 2000). Similarly, 20th century was called the age of chemistry and physics

because the period witnessed novel discoveries and foundations in chemistry and physics such as radioactivity, atomic theories, quantum and relativity that revolutionized the science and technology (Agar, 2012). The 20th century also saw some key discoveries emerge in the biological sciences.

In 1919, exactly 100 years ago, Karoly Ereky (German: Karl Ereky), a Hungarian Agricultural Engineer, coined the word biotechnology, which he used to refer to “all the lines of work by which products are made from raw materials with the aid of living organisms” (Ereky, 1919). He had envisioned the advent of a new age, the age of Biology, which will be driven by biotechnology. Advances in the life sciences, at the turn of the century, led to remarkable discoveries, inventions, and technologies that boosted the development of new disciplines, especially young fields like molecular biology, modern biotechnology, molecular medicine, and neuroscience, which have indeed revolutionized agriculture, medicine, the industry and environment (Ayla, 2015).

The 21st century is indeed the age of Biology. Today, biotechnology is leading a sudden, new biological revolution! It has brought mankind to a world of "engineered" products, based in the natural world instead of the chemical/industrial processes, and taken humans far beyond ever known depths of understanding of chemical and physical basis of life and matter, to the molecular basis of creation. Evidence of biological revolution is demonstrated by the upsurge in the number of Nobel prizes awarded for discoveries in the life sciences. Table 2 is a compendium of discoveries and awardees of Nobel Prizes in Chemistry (2001 – 2018). Twelve out of eighteen (72.2%) Nobel Prizes in Chemistry between 2001 and 2018 were awarded for discoveries with roots and/or applications in the life sciences. This is beside the Nobel Prizes in Physiology or Medicine mostly awarded for discoveries, inventions and innovations in the life sciences.

Table 2: Discoveries and Recipients of Nobel Prizes in Chemistry (2001 – 2018).

Year	Recipient(s)	Discovery/Reason for the award	Discipline
2001	William Knowles and Ryoji Noyori	"for their work on chirally catalysed hydrogenation reactions"	Chemistry
	Barry Sharpless	"for his work on chirally catalysed oxidation reactions"	Chemistry
2002		"for the development of methods for identification and structure analyses of biological macromolecules"	Biology
	John Fenn and Koichi Tanaka	"for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules".	Biology
	Kurt Wiithrich	"for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution"	Biology
2003		"for discoveries concerning channels in cell membranes"	Biology
	Peter Agre	"for the discovery of water channels"	Biology
	Roderick MacKinnon	"for structural and mechanistic studies of ion channels"	Biology
2004	Aaron Ciechanover, Avram Haershko and Irwin Rose	"for the discovery of ubiquitin-mediated protein degradation"	Biology
2005	Yves Chauvin, Robert Grubbs and Richard Schrock	"for the development of the metathesis method in organic synthesis"	Chemistry
2006	Roger Kornberg	"for his studies of the molecular basis of eukaryotic transcription"	Biology
2007	Gerhard Ertl	"for his studies of chemical processes on solid surfaces"	Chemistry
2008	Osamu Shimomura, Martin Chalfie and Roger Tsien	"for the discovery and development of the green fluorescent protein, GFP"	Biology
2009	Venkatraman Ramakrishnan, Thomas Stitz and Ada Yonath	"for studies of the structure and function of the ribosome"	Biology
2010	Richard Heck, Ei-ichi Negishi and Akira Suzuki	"for palladium-catalysed cross couplings in organic synthesis"	Chemistry
2011	Dan Shechtman	"for the discovery of quasicrystals"	Chemistry

2012	Robert Lefkowitz and Brian Kobilka	"for studies of G-protein-coupled receptors"	Biology
2013	Martin Karplus, Michael Levitt and Arieh Warshel	"for the development of multiscale models for complex chemical systems"	Chemistry
2014	Eric Betzig, Stefan Hell and William Moerner	"for the development of super-resolved fluorescence microscopy"	Biology
2015	Tomas Lindahl, Paul Modrich and Aziz Sancar	"for mechanistic studies of DNA repair"	Biology
2016	Jean-Pierre Sauvage, Sir Fraser Stoddart and Bernard Feringa	"for the design and synthesis of molecular machines"	Biology
2017	Jacques Dubochet, Joachim Frank and Richard Henderson	"for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution"	Biology
2018	Frances Anold George Smith and Sir Gregory Winter	"for the directed evolution of enzymes", "for the phage display of peptides and antibodies"	Biology

2. BIOTECHNOLOGY

Biotechnology is the "practical application of biology to meet specific needs or solve problems". It involves the manipulation of biological objects to produce desirable goods and services. The United Nations Convention on Biological Diversity (UNCBD) defined biotechnology as "any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use". Biotechnology has a deep root in biological sciences where it draws from such fields as biochemistry, genetics, molecular biology and microbiology. The concept of biotechnology evolved through advances in biological sciences, chemistry, and engineering disciplines. Biotechnology combines physical potentials with biological and chemical possibilities to define the new products and services of the world. Modern biotechnology has become a tool for economic growth and for tackling the multifaceted challenges facing mankind particularly in the area of energy supply, food production, disease diagnosis and treatment, and environmental concerns like pollution, erosion, drought and desertification.

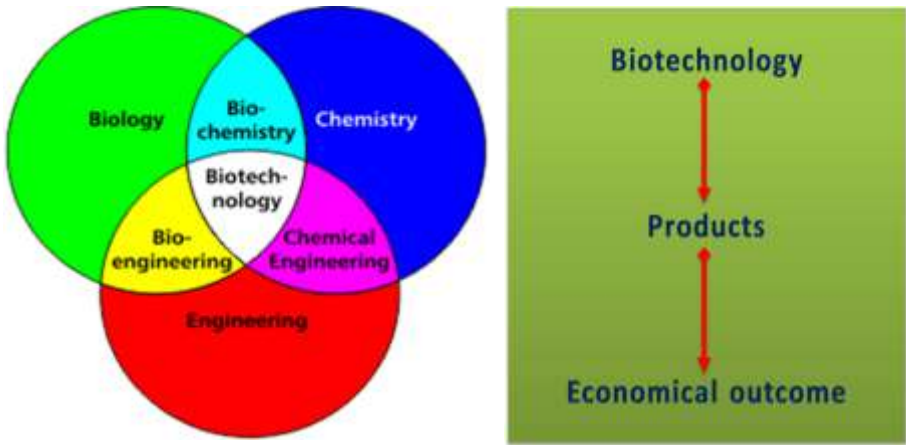


Fig. 2: (a) Concept, and (b) the Outcome of Biotechnology.

(a) Divisions of Biotechnology

The concept of biotechnology is not new. It is as old as mankind. What is new today is the development of the *in vitro* gene manipulation techniques that allow the removal, introduction and expression of small gene segments across the species barrier. This has divided biotechnology into two: traditional (old generation) and modern (new generation).

i. Traditional Biotechnology encompasses biotechnological techniques that do not involve “*in vitro*” gene manipulation. It includes processes, some of which have been in existence many centuries ago, such as plant and animal breeding, composting, and fermentation processes like brewing, baking, yoghurt and cheese production. The techniques are still applied in many areas, including agriculture, bioremediation, food processing, drug (antibiotics) and energy production. Plant or animal breeding is an *in vivo* genetic manipulation done to obtain the desired traits in the offspring.

ii. Modern biotechnology refers to biotechnological applications that involve “*in vitro*” manipulation of genes. It is specific and precise. It

began effectively in the 1970s and is driven by the introduction of new techniques and technologies such as cell/tissue culture, polymerase chain reaction (PCR), genetic engineering (Recombinant DNA technology), recombinant diagnostic, monoclonal antibodies, nanotechnology, biosensors, and microarrays. Some major discoveries which contributed to the development of modern biotechnology are listed in Table 3.

The main characteristics of modern biotechnology is in-vitro gene manipulation. This has been defined as “the formation of new combination of heritable material by the insertion of nucleic acid molecules produced by whatever means outside the cell, into virus, bacterial plasmid or other vector system so as to allow their incorporation into a host organism in which they do not naturally occur but in which they are capable of continued propagation”. Two important features of the in-vitro gene manipulation are (1) the ability to cross natural species barriers and place genes from any organism in an unrelated host organism, and (2) the ability to propagate a defined and relatively small piece of DNA in the host organism.

Table 3: Chronology of discoveries and Developments in Modern Biotechnology

<i>Year</i>	<i>Major Discovery/Development</i>
1865	Gregor Mendel investigated how traits are passed from generation to generation: called them factors.
1869	Johann Meischer isolated DNA from the nuclei of white blood cells.
1910	Thomas H. Morgan proved that genes are carried on chromosomes.
1919	The term 'Biotechnology' was coined by Karl Ereky.
1952	Alfred Hershey and Martha Chase confirmed that DNA is the genetic material (not protein).
1953	James Watson/ Francis Crick determined the double helix structure of DNA
1957	Francis Crick/ George Gamov explained how DNA functions to make protein
1958	Coenberg discovered DNA polymerase.
1966	Marshall Nirenberg/Severo Ochoa determined that a sequence of three nucleotide bases determine each of 20 amino acids.

1970	Isolation of reverse transcriptase by Howard Temin.
1971	Discovery of restriction enzymes by Werner Arber , Hamilton O. Smith , and Daniel Nathans.
1972	Paul Berg cut sections of viral DNA and bacterial DNA with same restriction enzyme, and spliced viral DNA to the bacterial DNA.
1973	Stanley Cohen/Herbert Boyer produced first recombinant DNA organism, marking the beginning of genetic engineering
1977	First practical application of genetic engineering human growth hormone produced by bacterial cells
1978	Genetic engineering techniques used to produce human insulin in E. coli by Genentech Inc., the first biotech company on NY stock exchange.
1979	Genentech Inc. produced human growth hormone and two interferons.
1980	US. Supreme Court decided that manmade microbes could be patented
1982	Humulin, human insulin drug produced for the treatment of diabetes, is the first biotech drug approved by FDA
1983	The Polymerase Chain Reaction (PCR) technique is conceived.
1985	Plants can be patented
1988	First living mammal patented
1990	First approved gene therapy treatment was performed successfully on a young girl who suffered from an immune disorder.
1992	FDA (US) approved the first GM food: "Flavr Savr" tomato.
1993	Flavr savr tomatoes sold to the public.
1996	Cloning of Dolly, the sheep, using DNA from two adult sheep cells.
2000	"Rough draft" of the human genome in the human genome project submitted.
2002	Rice became the first crop to have its genome decoded.
2003	The Human Genome Project was completed, providing information on the locations and sequence of human genes on all 46 chromosomes.

3. TECHNIQUES AND TECHNOLOGIES IN MODERN BIOTECHNOLOGY

(a) Genetic Engineering

Genetic engineering, also called Recombinant DNA technology (RDT), molecular cloning or gene cloning, is a procedure by which the DNA

sequence from one organism is cut and joined with a vector to form recombinant DNA (rDNA) and then introduced into another organism for propagation. The technique was first described by Peter Lobann of the Department of Biochemistry at Stanford University Medical School. Genetic engineering procedure is widely acclaimed as the basis of modern biotechnology. It produces genetically modified organisms (GMO) which carry and express the acquired foreign gene(s). Genes are located on the chromosomes; they are made up DNA molecules. The human genome contains 23 pairs (2n) of chromosomes (Fig. 3)

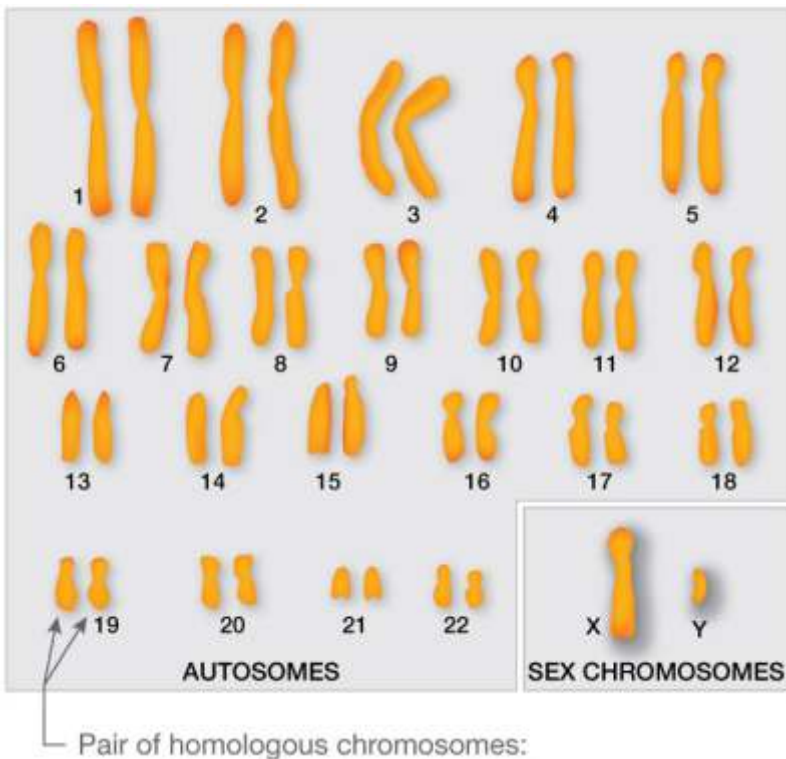


Fig. 3: Schematic representation of the human chromosomes. The somatic cell contains 23 pairs (2n) of chromosomes (22 pairs of autosomal and 1 pair of sex chromosomes).

Several microorganisms, crops, and animals have been genetically modified for various purposes or uses. Table 4 shows some species of genetically modified (GM) food crops cultivated commercially today. Pictures of some products of genetic modification of plants are shown in Fig. 4.

Table 4: Crop species with genetically modified version that is commercially grown.

<i>Crop</i>	<i>Traits</i>	<i>Type of Modification</i>	<i>% modified globally</i>
Alfalfa	Tolerance of glyphosate or glyphosinate.	Genes added	-
Apples	Delayed browning.	Genes added for reduced polyphenol oxidase (PPO) production from other apples	-
Canola/ Rapeseed	Tolerance of glyphosate or glyphosinate High laurate canola, Oleic acid canola	Genes added	21
Corn	Tolerance of herbicides glyphosate or glyphosinate, and 2,4-D. Insect resistance. Added: α - amylase converts starch into sugar to facilitate ethanol production. Viral resistance.	Genes, some from <i>Bacillus thuringiensis</i> (Bt) added.	26
Cotton (cottonseed oil)	Insect resistance	Genes, some from Bt added	49
Eggplant	Insect resistance.	Genes from Bt	Negligible
Papaya (Hawaiian)	Resistance to the papaya ringspot virus.	Gene added	
Potato (food)	Resistance to Colorado beetle, potato leaf roll virus and potato virus Y. Reduced when fried and reduced bruising.	Bt cry3A, coat protein from PVY "Innate" potatoes added genetic material coding for mRNA for RNA interference	0
Potato (starch)	Antibiotic resistance gene, used for selection Better starch production.	Antibiotic resistance gene from bacteria. Modifications to endogenous starch-producing enzymes	0
Rice	Enriched with beta carotene (a source of Vitamin A)	Genes from maize and a common soil microorganism.	-

Soybeans	Tolerance of glyphosate or glyfosinate. Reduced saturated fats (high oleic acid); Kills susceptible insect pests Viral resistance	Herbicide resistant gene taken from bacteria added; Knocked out native genes that catalyse saturation; Gene for one or more Bt crystal proteins added	77
Squash (Zucchini/ Courgette)	Resistance to watermelon, cucumber and zucchini/courgette yellow mosaic viruses.	Viral coat protein genes	
Sugar beet	Tolerance of glyphosate, glufosinate.	Genes added	9
Sugarcane	Pesticide tolerance High sucrose content.	Genes added	-
Sweet peppers	Resistance to cucumber mosaic virus.	Viral coat protein genes	Small quantity (China)
Tomatoes	Suppression of the enzyme, polygalacturonase (PG), retarding fruit softening after harvesting, and at the same time retaining both the natural colour and flavour of the fruit	Antisense gene of the gene responsible for PG enzyme production added.	Small quantity (China)

Genetic engineering procedure involves three key stages: (1) Gene of interest and host plasmid are cut out with same restriction enzymes; (2) The gene of interest is inserted into plasmid and joined with ligase, and (3) New (engineered) plasmid is inserted into bacterium thereby transforming it. The process is as shown in Fig. 4.

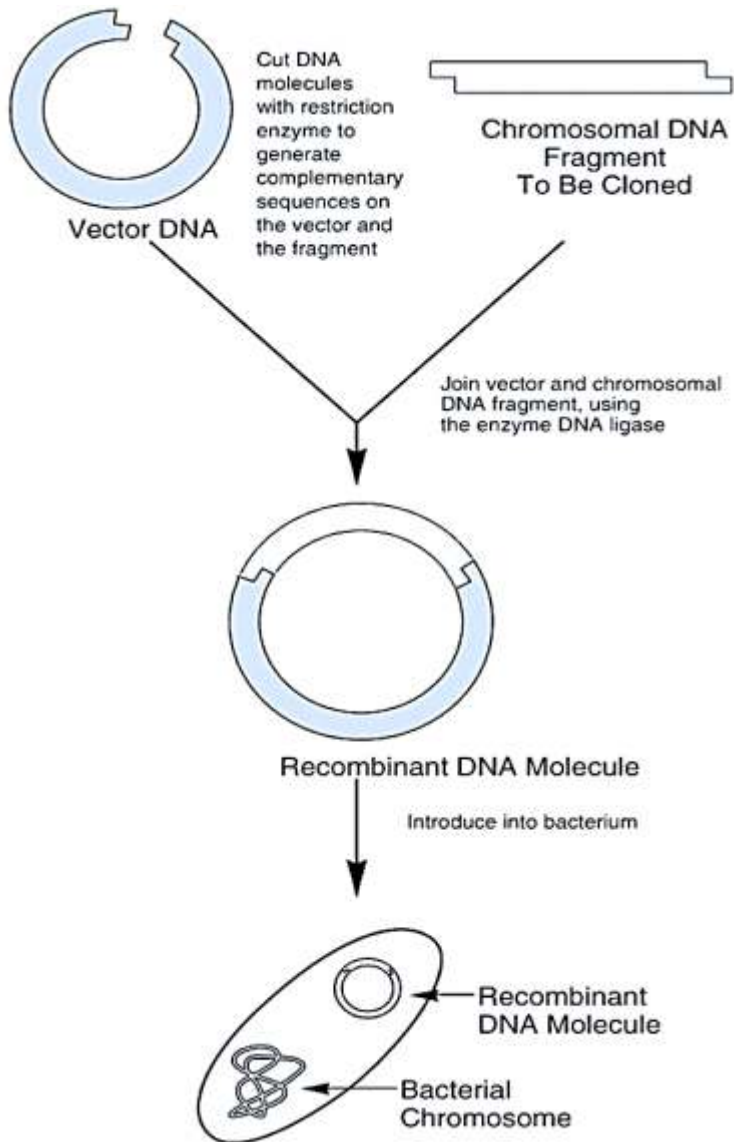


Fig. 4: Schematic representation of the genetic engineering procedure

Genetic engineering procedure for producing GMOs may involve any of these three types of gene manipulations: transgenic, sub-genic and cis-genic manipulations.

i. Transgenic manipulation is the process by which GMOs, referred to as transgenic organisms, are produced. Transgenic organisms have genes derived from another species (within or between kingdoms e.g., bacteria to plant) inserted into them. In many cases the inserted DNA has to be modified slightly in order to correctly and efficiently express in the host organism. Transgenic plants are used to express proteins like the cry toxins from *Bacillus thuringiensis*, herbicide resistant genes and antigens for vaccinations.

ii. Cisgenic organisms are made using procedures similar to that of transgenic organisms. However, unlike transgenic organisms, they are made using genes found within the same species or a closely related one. Cisgenic modification is useful for plants, such as potatoes, that are difficult to crossbreed by conventional breeding methods.

iii. Sub-genic manipulations suppress or delete some genes from an organism to produce a variant (GMO) that does not express the protein(s) encoded by the repressed or deleted genes. For example, the GM tomato has the antisense gene for galacturonase (enzyme involved in fruit softening) inserted to suppress the enzyme so as to improve the fruit's shelf-life. A Chinese researcher, Gao Caixia, deleted three copies of the genes encoding proteins that repress defences against mildew to produce the GM wheat that is resistant to powdery mildew. When a gene is deleted or inactivated in the genome of a species, it is called a knock-out (KO) organism (Tsien et al., 1996).

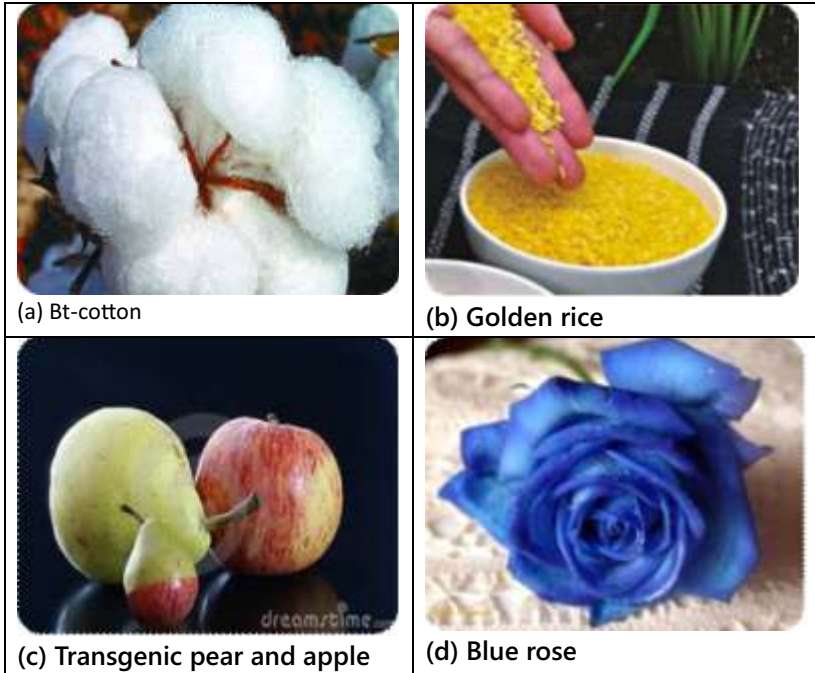


Fig. 5: GMOs: (a) Bt-Cotton (resist pests); (b) Golden rice (contain beta-carotene), (c) transgenic pear and apple, and (d) Blue rose.

(b) Animal Cloning

Animal cloning is a significant milestone in modern biotechnology. It was envisioned by Hans Spemann in 1938, in what he called a “Fantastic Experiment”, by which he referred to, “a transfer of nucleus from late stage embryo or adult cell into an egg!” The first trial experiment was in 1952 when Briggs and King sucked a frog's nucleus from the embryo into egg, but it yielded no development. The second attempt by John Gurdon in 1970 ended in a tadpole that died before they could start feeding it. Many other unsuccessful experiments led to a wrong conclusion that cloning is not possible with differentiated cells. A

breakthrough came in 1984 when a sheep was finally cloned from early embryo cells. The next ten years after the feat, saw several animals, including pigs, goats, rabbit and monkey cloned with early embryo cells. In 1995, Ian Wilmut cloned sheep using cultured cells derived from blastocyst embryo and again in 1996 he and his colleagues at Roslyn Institute, Scotland cloned a sheep, named Dolly, from specialised (adult udder) cells. Dolly was born in July 5, 1996 and died on February 14, 2003. Since then, several animals have been cloned. Cloning took a dramatic turn years later with the cloning of transgenic, 'knock-out', and 'cross species' animals. The cloning procedure and some cloned animals are shown in Fig. 6 and Fig. 7 respectively.

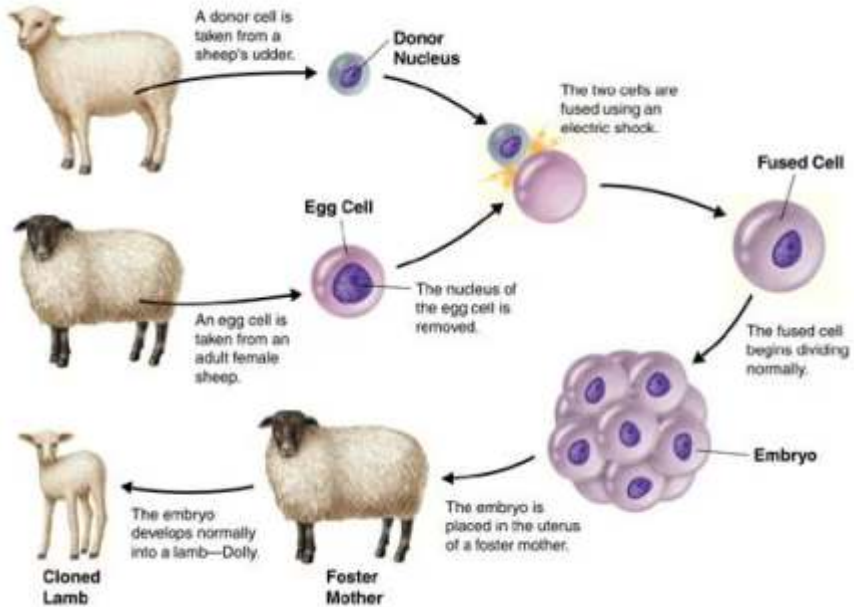
i. Transgenic animals are produced through a combination of genetic engineering and cloning techniques. The first cloned transgenic sheep, named Polly, carried the gene for human blood-clotting protein IX which it secreted in its milk. Since then, many cows and sheep had been cloned which over-express human proteins in their milk including α -1-antitrypsin used for cystic fibrosis treatment, insulin for diabetics, and human antibodies for treating antibiotic resistant infections, autoimmune diseases and haemophilia. ATryn®, a human antithrombin protein from transgenic goats, in 2006 became the first therapeutic protein in a transgenic animal approved for use in Europe and the USA. Transgenic pigs inserted with nematode gene for enzyme that converts omega 6 into omega 3 lipids (the healthy lipid found in high concentration in fish and flax seeds) have been cloned. Omega 6 is common in meat, and is believed to contribute to heart diseases, diabetes, etc. In 2006, Taiwan researchers cloned pigs that "glow in the dark". The pigs have a jellyfish gene, and allow the study of human disease without the need of a biopsy or invasive test.

ii. Knock-out animals are produced through sub-genic and cloning manipulations. Knock-out pigs, in which α 1,3 galactosyl gene was inactivated, were cloned in 2002 for human transplant

(Xenotransplantation). Inactivation of α 1,3 galactosyl proteins makes the pigs' organs evade the detection and attack of human immune system. Xenotransplantation may offer a potential solution to organ/tissue shortages for human recipients. Pigs have similar physiology and organ size, making porcine (pig) organs ideal substitutes for human organs. Researchers are also exploring the use of cell transplantation therapy for patients with spinal cord injury or Parkinson's disease. Transplantation of cells or organs from animals to humans is known to be associated with several risks. For example, there is the risk of transmitting fatal zoonotic diseases such as bovine spongiform encephalopathy, (mad cow disease), porcine endogenous retroviruses (PERVs) and Nipah encephalitis (Burroughs et al., 2002) into human population which could have devastating consequences.

iii. Cross species cloning is a special type of cloning in which a cell from one species is inserted into the enucleated egg of another species. This has the potential to save endangered species and “resurrect” extinct species with genetic remains. Cow eggs have been used to clone embryos of pigs, sheep, and monkeys. An Asian gaur (*Bos gaurus*), named Noah, was cloned in 2001 using cow egg by a surrogate cow. An endangered species of wild sheep (mouflon) from Sardinia, Corsica and Cyprus was cloned using post-mortem tissue and an egg from a domestic sheep. In 2003, two Javan banteng (*Bos javanicus*) were cloned from a tissue that was frozen and stored for 22 years which was inserted into Angus domestic cows (*Bos Taurus*) surrogates. Cross species cloning has raised serious ethical questions.

Fig. 6: The mechanism of cloning. (Source: www.chalieherrbiology.us)



© Designer Babies

A designer baby is a human embryo which has been genetically modified to produce desirable traits, usually prescribed by the parent, the doctor or scientist. It is produced using an in vitro fertilization (IVF) procedure known as pre-implantation genetic diagnosis (PGD) or germline engineering (Handyside et al., 1990; Stankovic, 2005). PGD has triggered the concept of genetically modified “superhuman” which can interbreed with and eventually replace modern humans. The first gene edited babies (twins) were born in November 2018. The babies were 'created' by a Chinese scientist, Jiankui He, using CRISPR-Cas 9. The tool, CRISPR-cas9, makes it possible to operate on DNA to supply a needed gene or disable one that's causing problems. Jiankui He claimed to have used the tool to alter the embryonic genes to prevent the baby from having HIV. He's claim moved human germline genome editing

from the lab to the delivery room Though genome editing looks promising for the treatment and prevention of some diseases, several bioethical concerns limit its application in human germ line cells and tissues. For instance, Jiankui He's research generated so much controversy and ethical questions that caused him his job.



(a) Ian Wilmut with Dolly



(b) A cloned wild sheep



(c) Knock-out pigs



(d) A cloned Javan banteng

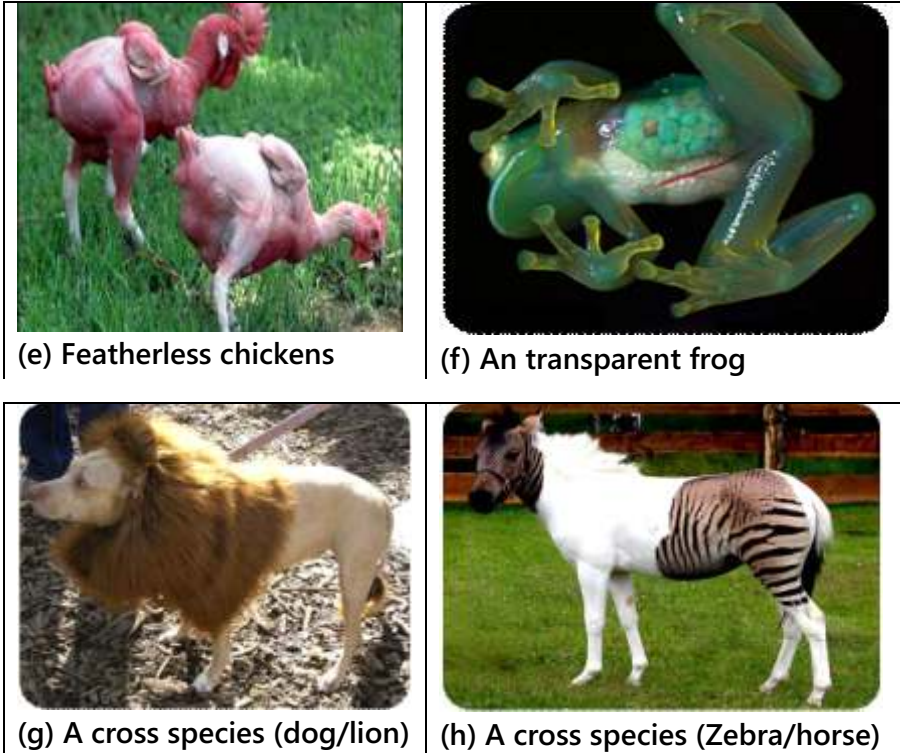


Fig. 7: Cloned animals: (a) Scottish researcher, Ian Wilmut, with cloned sheep, Dolly, (b) a wild sheep (mouflon) cloned from post-mortem tissue and the surrogate mother, (c) Knock-out pigs cloned for human organ transplant (Xenotransplantation), (d) a Javan banteng (*Bos javanicus*) cloned from tissue frozen stored for 22 years, (e) featherless chickens, (f) a frog engineered to see through for research purposes, (g) Cross species from a dog and a lion, and (h) cross species from a zebra and a domestic horse.

(d) The 'OMICS' Technologies

'Omics' technologies refer to tools, including genomics, epigenomics, transcriptomics, proteomics and metabolomics, which are used for the

wholesome study of molecules that make up the cell, tissue and organs of an organism. They help to explore the roles relationships and function of various molecules that make up an organism's cells (Horgan and Kenny, 2011).

i. Genomics, the oldest form of the 'omics' fields, focuses on identifying genetic variants associated with diseases, response to treatment or future patient prognosis. Over the years, genome wide association studies (GWAS) had been used to identify thousands of genetic variants associated with complex diseases in multiple human populations. Such studies involve screening of thousands of individuals for more than a million genetic markers and statistically significant differences in minor allele frequencies between cases and controls are considered evidence of association. GWAS studies provide an invaluable contribution to our understanding of complex phenotypes. Other commonly used technologies include next generation sequences (NGS) for whole-genome sequencing, genotype arrays, and exome sequencing (Hassin et al., 2017).

ii. Epigenomics focuses on genome-wide characterisation of reversible modifications of DNA or DNA-associated proteins, such as DNA methylation or histone acetylation. DNA and histone modifications are major regulators of transcriptional processes. These modifications are usually influenced by both genetic and environmental factors and can last for long period of time and are sometimes heritable. Differentially methylated regions of DNA can be used as indicators of disease status for metabolic syndrome, cardiovascular disease, cancer, and many other pathophysiologic states. Epigenetic signatures are often tissue-specific, and several large groups are working on establishing comprehensive epigenomic maps in multiple human tissues. In addition to insight gained from identifying epigenetic modifications correlating with diseases, data generated by these studies has great potential for enhancing our functional interpretation of genetic variants residing in those regions (Hassin et al., 2017). Associated technology includes assessment of DNA modifications using NGS.

iii. Transcriptomics examines RNA levels qualitatively and quantitatively. The central dogma of biology viewed RNA as a molecular intermediate between DNA and proteins, which are considered the primary functional expression of DNA. Other RNA functions such as structural or regulatory activities have often been regarded as odd exceptions to the general rule. The advent of large transcriptomic studies in the past decade has shown that while only 3% of the genome encodes proteins, up to 80% of the genome is actually transcribed. RNA-Seq studies have also shown that thousands of long non-coding RNAs transcribed in mammalian cells play critical roles in many physiological processes, for example, brown adipose differentiation, endocrine regulation, and neuron development. Dysregulation of long non-coding RNAs had also been implicated in diseases such as myocardial infarction, diabetes, cancer, etc. In addition to long non-coding RNA, NGS allows interrogation of short RNAs (microRNAs, piwi-interacting RNAs, and snRNAs) and identification of circular RNAs, a novel player in the family of RNAs (Hassin et al., 2017). Associated technologies include probe-based arrays and RNA-Seq.

iv. Proteomics is used to quantify peptide abundance, modification, and interaction. The analysis and quantification of proteins have been revolutionized by Mass Spectrometry (MS)-based methods and, recently, these have been adapted for high-throughput analyses of thousands of proteins in cells or body fluids. Interactions between proteins can be detected by classic unbiased methods such as phage display and yeast two-hybrid assays. The functions of a large fraction of proteins are mediated by post-translational modifications such as proteolysis, glycosylation, phosphorylation, nitrosylation, and ubiquitination. Such modifications play key roles in intracellular signaling, control of enzyme activity, protein turnover and transport, and maintaining overall cell structure. MS can be used to directly measure such covalent modifications by defining the corresponding shift in the mass of the protein (in comparison to the unmodified peptide). There are efforts to develop genome-level analyses of such modifications (Hassin

et al., 2017). Associated technologies include MS-based approaches to investigate global proteome interactions and quantification of post-translational modifications.

v. Metabolomics simultaneously quantifies multiple small molecule types, such as amino acids, fatty acids, carbohydrates, or other products of cellular metabolic functions. Metabolite levels and relative ratios reflect metabolic function, and out of normal range perturbations are often indicative of disease. Quantitative measures of metabolite levels have made possible the discovery of novel genetic loci regulating small molecules, or their relative ratios, in plasma and other tissues. Additionally, metabolomics in combination with modelling has been used extensively to study metabolite flux. Associated technologies include MS-based approaches to quantify both relative and targeted small molecule abundances. Microbiomics is a fast-growing field in which all the microorganisms of a given community are investigated together. Human skin, mucosal surfaces, and the gut are colonized by microorganisms, including bacteria, viruses, and fungi, collectively known as the microbiota (and their genes constituting the microbiome). The human microbiome is enormously complex; for example, the gut contains about 100 trillion bacteria from 1000 different species. Many studies have implicated perturbations in gut bacteria in a variety of disorders, including diabetes, obesity, cancer, colitis, heart disease, and autism. The microbiome can be profiled by amplifying and then sequencing certain hyper variable regions of the bacterial 16S rRNA genes followed by clustering the sequences into operational taxonomic units. Several analytic tools have been developed for analysing NGS data from targeted 16S or metagenomics analysis, such as QIIME (quantitative insights into microbial ecology). These allow accurate quantitative determination of taxa that can be correlated with disease or other phenotypes of interest (Hasin et al., 2017). Associated technologies include NGS application for 16S ribosomal abundance and metagenomics quantification.

4. APPLICATIONS OF MODERN BIOTECHNOLOGY

Biotechnology has enormous applications in medicine (Medical/Red biotech), agriculture (agro/green biotech), industry (bioprocess/white biotech), marine (aquatic/blue biotech) and the environment. Medical Biotech aims to improve human health by developing new medicines and techniques for preventing diseases, curing ailments, producing products for transplants and improving the genetic makeup of individuals. It has considerable potential for improving the health of the developing countries in the future, especially in the area of vaccines, therapeutic agents and ability to genetically manipulate pathogenic vectors, and also the genetic improvement of foods and improved nutrition. Recent applications are in stem cell therapy, RNA therapeutics and genome editing.

Agro biotech consists of a range of tools, including traditional breeding techniques, used to improve plants, animals or microorganisms for specific agricultural uses. It has led to the emergence of seed companies producing plants with improved yields, resistance to pests and diseases, tolerance to environmental stress and increased nutritional quality. Industrial biotech aims to reduce cost and pollution to achieve cleaner industrial products and processes. For example, organisms are designed to produce a useful chemical while enzymes serve as industrial catalysts to produce valuable chemicals or destroy hazardous chemicals. Marine biotech uses marine organisms or their components to provide goods or services while environmental biotech targets areas such as bioremediation of polluted lands and water bodies and bioconversion of wastes into valuable products.

(a) Enzyme Technology

Enzyme technology is an important part of industrial biotechnology. It is best described as a technology associated with the application of enzymes as tools in agriculture, medicine, industry, and the

environment. Its overall goal is to design and create innovative products and processes that are competitive and sustainable. It is driven by the need to develop new and better products, and/or to improve the processes used in producing existing products, or from new raw materials, e.g. biomass. Commercial enzyme business is steadily growing as a result of improved production technologies, engineered enzyme properties and new application fields. Many industries today use enzymes as part of their analytical and production processes. Enzymes are part of a rapidly growing biocatalyst industry including genetically optimised living cells as chemical production factories. They have become a vital product of the biotechnological and pharmaceutical industries of many countries around the world with an annual output estimated at over 5 billion USD.

Enzymology, the science of enzymes, is the branch of biochemistry concerned with the properties and action of enzymes. Enzymes have wide applications and are thus, marketable products with increasing local and global demand. This has led to their production on a large scale. Commercial enzymes are obtained mainly from microbial sources; some are also derived from plants and animals. Enzymes in living cells, such as yeasts, as well as cell-free or immobilized enzymes can be used in industrial and non-industrial processes. Isolated enzymes were first used in detergents in the year 1914. Their large-scale production from microbial sources started in 1960s. Some uses of enzymes in the industrial production of various products are shown in Table 5.

Table 5: Some industries that use commercial enzymes in their production processes.

S/N	Industry	Enzyme	Effect/purpose
1.	Detergent	Proteinase	protein degradation
		Lipase	fat removal
		Cellulose	colour brightening
2.	Textile	Cellulose	microfibril removal
		Laccase	colour brightening

3.	Animal feed	Xylanase	fibre solubility
		Phytase	release of phosphate
4.	Starch	amylases	glucose formation
		glucose isomerase	fructose formation
5.	Pulp and paper	Xylanase	Biobleaching
6.	Fruit juice	pectinase	juice clarification
		cellulase, xylanase	juice extraction
7.	Baking	xylanase	dough conditioning
		α -amylase, glucose oxidase	loaf volume; shelf-life, dough quality
8.	Dairy	Rennin	protein coagulation
9.	Brewing	Lactase	lactose hydrolysis
		Glucanase	filter aid
		Papain	haze control

(a) Environmental Biotechnology

Environmental biotechnology is “the application of biotechnology to the environment or to the study of the natural environment”. It has been defined by the International Society for Environmental Biotechnology (ISEB) as “the development, use and regulation of biological systems for remediation of contaminated environments (land, air, water), and for environment-friendly processes (green manufacturing technologies and sustainable development)”. Areas of application of biotechnology to the environment include bioremediation of polluted lands and water bodies, biotransformation or bioconversion of wastes into valuable products, bioenergy such as production of biofuels from waste materials, and the use of biomarkers to measure environmental impacts of pollution.

The biotechnological processes applied to the environment involve the biodegradation of pollutants by living organisms or their products. Bioremediation uses living organisms such as microorganisms and plants to clean up contaminated soil or water whereas biological agents usually microorganisms are used in bioconversion to transform organic materials into energy, food and chemicals.

5. BIOTECHNOLOGY: RISKS AND CONCERNS

The deliberate transfer of genetic material across the natural species barrier has brought biotechnology out from the laboratory to the field. However, the intentional modification of genes and the resultant entities, GMOs, have triggered widespread concerns across the globe and raised considerable opposition to genetic manipulations who portray GMOs as a threat to environment and human health (Consumer Watch, 2003). Crossing species boundaries is a current topic of debate for bioethicists. These issues of concern, some of which are very glaring and significant, tend to discourage many developing countries that could benefit from the technology from taking advantage of it.

Incidentally, agricultural applications of transgenic technology are more fiercely opposed than the biomedical applications. However, it is pertinent to emphasize that most developed countries and regions where transgenic technology thrive have in place risk assessment procedures to counter the environmental risks associated with GM crops. It includes having accurate information about the role of the introduced gene and its effect on the recipient organism. It also includes specific questions/clarifications about the unintentional consequences such as the impact on non-target organisms, possibility of persisting in the environment or invading new habitats, and the likelihood and consequences of a gene being transferred unintentionally from the modified crop to other species. In addition, post approval monitoring by the product developer, independent researchers, and government scientists are necessary to help ensure that biotech crops continue to be safe for consumers and the environment (Poortinga and Pidgeon, 2004). African countries should adopt such measures and strengthen their systems to achieve compliance.

BIOTECHNOLOGY AND AFRICA'S ECONOMY

1. AFRICA: POPULATION AND ECONOMY

(a) Population

The world's population has risen to about 7.72 billion in 2019 (World population review, 2019). Africa has the highest growth rate (2.49%) in the world. Africa is the second biggest and also the second most populated continent of the world. With a population of 1.32 billion in 2019, Africa presently accounts for over 17% of the world's population. Her population density (43.57 persons/Km²) is a little below the world's average of 51.80/Km². Table 6 compares the 2019 population of the world's six continents. The 2019 population data for the different regions of Africa is also presented in Table 7. Sub-Saharan Africa has a population of about 1.08 billion people.

Table 6: 2019 population, growth rate and densities of the six continents of the world.

<i>Continent</i>	<i>2019 Population</i>	<i>Growth Rate (%)</i>	<i>Land Mass (Km²)</i>	<i>Pop. Density (Persons/Km²)</i>
Africa	1,320,038,716	2.49	29.65 million	43.57
Asia	4,584,807,072	0.87	31.03 million	102.85
Australia/Oceania	41,826,176	1.37	7.68 million	4.93
Europe	743,102,600	0.06	22.14 million	33.57
North America	366,496,802	0.73	18.65 million	14.83
South America	431,998,475	0.88	17.46 million	24.22
World	7,714,576,923	1.07	148.94 million	51.80

Table 7: 2019 population, growth rate and population density of different African regions.

<i>Sub-Region</i>	<i>2019 Population</i>	<i>Growth Rate (%)</i>	<i>Population Density (Persons/Km²)</i>
Eastern Africa	445,447,287	2.72	66.81
Middle (Central) Africa	173,692,967	3.06	26.74
Northern Africa	241,932,523	1.74	31.14
Southern Africa	66,789,825	1.24	25.20
Western Africa	392,176,114	2.67	64.67
Africa	1,320,038,716	2.49	43.57
<i>Sub-Saharan Africa</i>	<i>1,078,106,193</i>	<i>2.66</i>	<i>45.65</i>

(b) Economy

Africa was said to have experienced economic boom, akin to the Chinese economic boom, in the 2000s and was home to seven world's fastest growing economies in 2013. The African Union (AU) constitutes the world's 11th largest economy with a nominal GDP of 3.52 trillion USD and growth rate of 3.7% in 2017; The AU's economy measured as GDP per capita by purchasing power parity (PPP) totals 2,820 USD, ranking it after Russia. The AU has only 2% of the world's international trade, but that 2% makes up the bulk of real commodity traded worldwide and include 70% of the world's strategic minerals including gold and aluminium. Africa is also the largest market for European and Chinese industry. The AU's strategic future goals include the creation of a free trade area, a customs union, a single market thereby establishing an economic and monetary union, the African Economic Community, with a single currency by 2013. With expanding trade, English language skills, improving literacy and education, availability of splendid resources and cheaper labour force, Africa's economy is expected to continue to perform better into the future.

A comparative analysis of the global economy is shown in Table 8. Africa's economy is rated the least in the world (Figs. 8 and 9). Interestingly, Africa also has the least median age (19.4 years) which indicates a strong youthful population. It implies that Africa has a viable population and energetic labour force to drive the ongoing revolution and the emerging markets. This gives her a competitive edge over the other continents. Africa is, therefore, the continent to watch. All she needs is to put her acts together and take the appropriate steps towards the realization of African Union's strategic goals. The data also showed a moderate GDP growth rate of 3.7%. In 2013, Africa was recognized as the fastest-growing continent at the rate 5.6% a year, with the GDP expected to rise by an average of 6% a year for a ten year period, 2013 to 2023. Sub-Saharan Africa's growth is projected to reach 3.1 percent in 2018, and to average 3.6 percent in 2019–20 (World Bank, 2019).

Continent	GDP (2017), USD	GDP per Capita (USD)	GDP Growth rate (%)	Median Age (Years)
Africa	3.52 trillion (N); 6.36 trillion (PPP)	2,820 (6 th)	3.7 (3 rd)	19.4
Asia	28.23 trillion (N); 56.62 trillion (PPP)	6,690 (5 th)	5.7 (1 st)	30.7
Australia/Oceania	1.39 trillion (N); 1.27 trillion (PPP)	50,333 (1 st)	0.6 (6 th)	37.5
Europe	22.9 trillion (N); 26.7 trillion (PPP)	27,330 (3 rd)	2.4 (4 th)	41.8
North America	22.2 trillion (N); 23.7 trillion (PPP)	45,560 (2 nd)	2.3 (5 th)	38.1
South America	3.99 trillion (N), 6.57 trillion (PPP)	21,156 (4 th) (2016)	5.5 (2 nd) (2008)	30.5

N = Nominal; PPP = purchasing power parity. (World Bank/IMF data, 2017/2018)

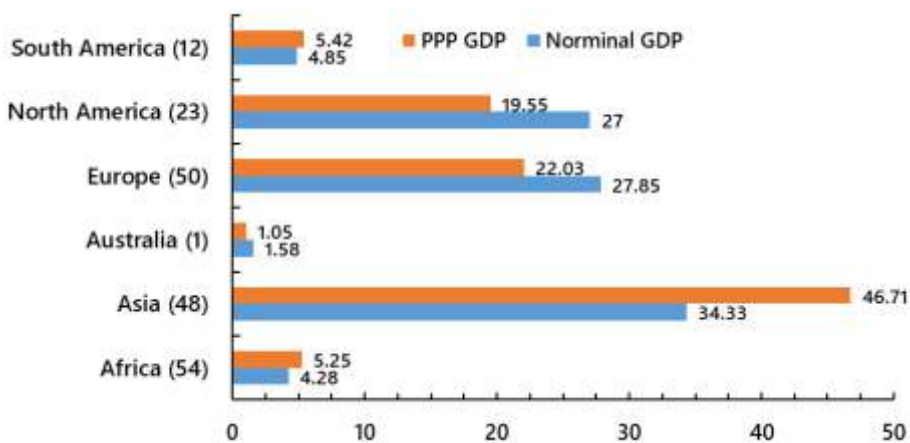


Fig. 8: GDP (\$ trillion) of the continents of the world: Africa, Asia, Australia, Europe, North America and South America. The number of countries in each continent is in bracket.

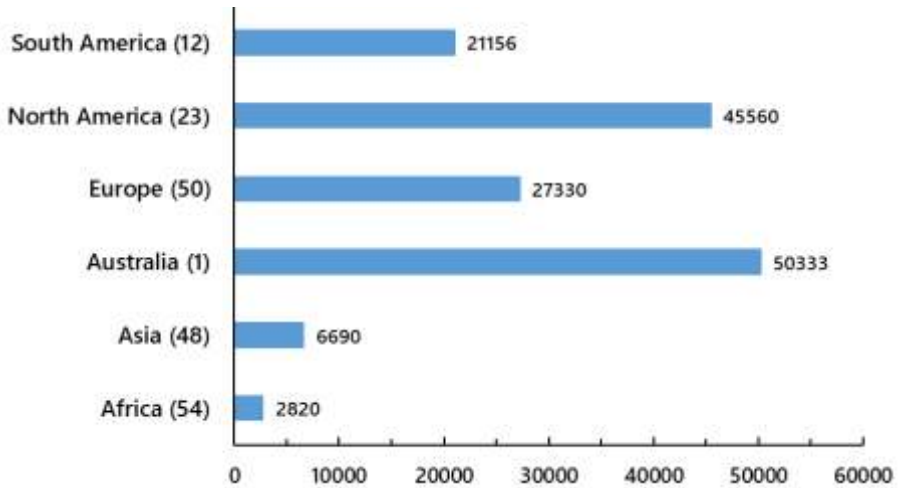


Fig. 9: GDP per capita (USD) of the continents of the world: Africa, Asia, Australia, Europe, North America and South America.

2. ECONOMIC IMPACT OF BIOTECHNOLOGY

Investment and economic output of all the applied biotechnologies constitute what is called 'bio-economy'. Biotechnology has great commercial potential because of its scope of activity which covers the entire spectrum of human life. During the period of genomic research, between 1988 and 2010, biotechnology made huge economic contributions estimated at \$796 billion with a return on investment as high as 141:1 in the US. It was also credited during the period to have generated at least 51,000 jobs and indirectly supported 310,000 jobs leading to an increase of about \$20 billion in personal income and \$67 billion contribution to the US economy. The economic impact of biotechnology has continued to grow beyond the genomic research era as indicated by the growth and strong showing of many biotech companies in the stock market. Genentech (now, acquired by Roche) was the first company to have been seeded in the 1970s following the cloning of human insulin in bacteria and the production of recombinant drug, humulin. Ten out of the 25 leading biotech companies in the world

are domiciled in US. Many of these companies were worth billions of US dollars as indicated by the exchanges on which the shares are traded or other publicly available sources (Table 9). BGI Genomics was ranked 26th globally, the US biotech company went public on July 2017 with an initial public offering of \$250 million.

Table 9: List of 25 leading biotech companies, ranked by market capitalization, as at 2017.

S/N	Biotech Company	Worth (USD)	Country
1	Amgen	\$129.09 billion	United States
2	Gilead Sciences	\$102.96 billion	United States
3	Novo Nordisk	\$96.18 billion (DKK 613.30 billion)	Denmark
4	Celgene	\$77.35 billion	United States
5	Biogen	\$66.14 billion	United States
6	Allergan	\$59.19 billion	Ireland, UK
7	Teva	\$48.75 billion	Israel
8	CSL	\$48.30 billion (A\$63.303 billion)	Australia
9	Regeneron Pharmaceutical	\$44.83 billion	United States
10	Shire	\$42.15 billion (£32.006 billion)	Ireland, UK
11	Vertex	\$37.03 billion	United States
12	Alexion Pharmaceuticals	\$28.65 billion	United States
13	Jiangsu Hengrui Medicine	\$27.90 billion (CNY 185.58 billion)	China
14	Incyte	\$24.28 billion	United States
15	Samsung Biologics	\$21.78 billion	South Korea
16	Mylan	\$20.86 billion	United States
17	Sun Pharmaceutical Industries	\$19.59 billion (INR 1.27 trillion)	India
18	Yunnan Baiyao Group	\$16.11 billion (CNY 107.160 billion)	China
19	Kangmei Pharmaceutical	\$15.63 billion (CNY 103.98 billion)	China
20	Shanghai Fosun Pharmaceutical Group	\$14.95 billion (HKD 116.641 billion)	Hong Kong/ China
21	BioMarin Pharmaceutical	\$14.51 billion	United States
22	UCB	-----	Belgium
23	Genmab	\$12.52 billion (DKK 79.33 billion)	Denmark
24	Sinopharm Group	\$12.36 billion (HKD 96.43 billion)	Hong Kong
25	Perrigo	\$11.90 billion	Ireland, UK

3. AFRICA AND BIOTECHNOLOGY

The contribution of biotechnology to Africa's economy is very low. Africa's approach to biotechnology could best be described as indifference or a cautious tactic of “let's watch and see”. Only few African countries like South Africa and Mali cultivate appreciable quantities of GM crops. There are also some indigenous Biotech companies established in Egypt and South Africa. In Egypt, we have such companies as Amoun, ClinArt MENA and Servier, and in South Africa, companies like Aspen Holdings, BioTechAfrica, BBI Solutions, Kapa Biosystems and Sanofi Genzyme. Africa must shake off this pervading apathy and ignorance to tap into the benefits of the ongoing biological evolution. Biotechnology has the potential to improve agriculture, boost food supply and counter famine, environmental degradation, disease and poverty. It can also trigger industrialisation and a rapid economic growth in Africa and give the continent a respectable place in the world. In 2007, twelve developing and eleven industrialised countries planted biotech seeds. The global market value for the biotech crops, estimated by Cropnosis, was 6.9 million USD, representing 20% of the 34 billion USD global commercial seed market. South Africa was among the top ten biotechnology countries in the world (Fig. 10).



Fig 10: Ten top biotech countries in 2007. (Source: International Service for the acquisition of Agri-biotech Applications).

4. THAUMATIN: A CASE OF DISINHERITANCE VIA BIOTECHNOLOGY

Europe, America, Asia and Australia have developed and prospered through industrial and agricultural revolutions, and yet exploding through biotechnology. Africa was not prepared and never benefitted from the previous revolutions, hence her backwardness! Now, if we do nothing in the present era of biotechnological revolution, Africa will not only be left behind but will be totally disinherited by biotechnology (Umeaghadì and Chinedu, 2011). Seasons do not wait for anyone!!

A typical example of disinheritance via biotechnology is the case of thaumatin, a naturally occurring protein sweetener (about 3000 times sweeter than sucrose). It has the ability to enhance elements of the flavour of other sweeteners and simultaneously mask other elements. Thaumatin is a globally traded commodity with a market value of over \$36 million in 2018, estimated to appreciate at a compound annual growth rate of 2.9% to hit almost \$42 million by 2023. The market is driven mainly by the food and beverage industry in the bid to meet the high demand in bakery, confectionary and low calorie specialty products in response to rising number of people with dispensable incomes and the growing emphasis on healthier life styles. Other end-use industry that contribute to the market are the pharmaceutical, nutraceutical, and cosmetics industry.

Thaumatin is the only commercially available 'natural protein' sweetener. It is extracted from fruits of the sweet prayers plant, *Thaumatococcus daniellii* (Benn.) Benth. Difficulties in obtaining thaumatin from its natural source or through cultivation in habitats different from the natural one, led to efforts to produce it in recombinant hosts (Witty and Higginbotham, 1994). It has been produced in several microorganisms (Table 10) and transgenic plants such as Tomato. Where does this place Africa? Though most industry researchers accept that the sweet berries from African native plants have been used for centuries by

local African communities to sweeten food and beverages, patent claims by the biotech industry neither recognize nor reward these communities as a source of knowledge or innovation. The implication is that Africa may not benefit from the emerging world market of the sweet proteins. Instead, she is being systematically disinherited of her biodiversity and impoverished through biotechnology!

Table 10: List of microorganisms reported to have been used to produce recombinant thaumatin (Faus and Sisniega, 2001).

aTrp/lac: *E. coli* tryptophan and lactose promoters; PgK: *S. cerevisiae* 3-phosphoglycerate promoter; Gapdh: *K. lactis* glyceraldehyde-3-

<i>Host</i>	<i>Promoter</i> ^a	<i>Secretion</i>	<i>Yield</i>	<i>Sweet phenotype</i>
<i>E. coli</i>	Trp/lac	No	Very low	No
<i>S. cerevisiae</i>	PgK	No	Low	No
<i>K. lactis</i>	Gapdh	Yes	Low	No
<i>B. subtilis</i>	-	Yes	1 mg/L	Yes
<i>S. lividans</i>	α-gal	Yes	0.2 mg/L	?
<i>P. roquefortii</i>	Gla	Yes	1±2 mg/L	Yes
<i>A. awamori</i>	Gla	Yes	5±7 mg/L	Yes
<i>S. tuberosum</i>	CaMV	No	Low	Yes

phosphate-dehydrogenase promoter; -amy: *B. subtilis*-amylase promoter; gal: *S. lividans*-galactosidase promoter; Gla: *A. niger* glucoamylase promoter; CaMV: cauliflower mosaic virus promoter for the 35S RNA.

The Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB) in its press release of January, 2003 described this phenomenon this way:

“One present-day form of colonialism works like this: A company sends researchers into the rainforest to discover promising new natural

substances. Once found, the company registers a patent or trademark and begins to cash-in. Even more effective is the latest variant: Instead of using the plant itself, the relevant gene is isolated and transplanted in a single-cell organism such as yeast or bacteria, allowing the substance to be reproduced in a fermenter located in the motherland. The disadvantage to this approach is well known: The exploited overseas country is left empty-handed". (IGB Press Release, January 12, 2003)

MY CONTRIBUTIONS

Chancellor, sir, permit me at this juncture to highlight some of my contributions to the body of knowledge in my field of study, particularly in my chosen area of specialization. These have come out of many years of rigorous studies, research, scientific reasoning and service in the university and to the society. They fall within the following categories:

1. BIOCONVERSION OF CELLULOSIC WASTES

Environmental pollution due to accumulation of wastes is a global challenge. The impact is prominent in developing countries due to inefficient waste disposal system (Ali et al., 1991; Funuoka et al., 1995). The residual plant biomass considered as 'wastes' can potentially be converted into various value-added products such as biofuels, chemicals, cheap carbon and energy sources for fermentation, improved animal feeds and human nutrients (Solomon et al., 1999; Belewu and Afolabi, 2000). Conversion of cellulosic wastes into such economic products could alleviate food and energy shortages, reduce pollution-load and transform these renewable organic matter into a valuable resource (Kumakura, 1997). One major way to turn cellulosic wastes into asset is by exploiting the natural biodegradation processes of microorganisms, via bioconversion.

We developed a scheme for the bioconversion of cellulosic wastes into value-added products (Fig. 11) and followed it to produce several

cellulolytic organisms (Fig. 12). The scheme was designed to transform the vast quantities of cellulosic wastes using microorganisms in our environment that naturally produce cell-wall degrading enzymes. It involved the isolation of suitable microorganisms from the wastes and processing the waste materials to serve as carbon source in microbial growth media and substrate for enzymatic hydrolysis (Nwodo-Chinedu et al., 2005 a; Chinedu, 2011).

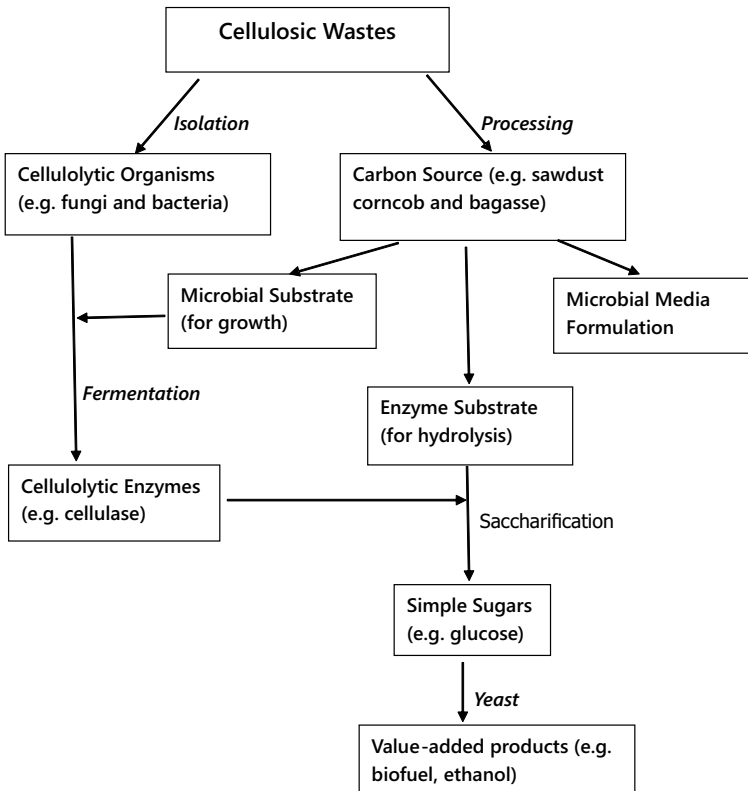



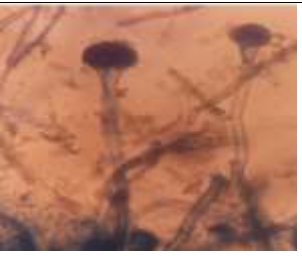
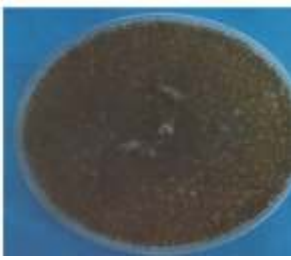



Fig 11: Scheme for the bioconversion of cellulosic wastes to valuable products (Chinedu et al. 2005, Chinedu, 2011).

2. ISOLATION OF CELLULOSIC MICROORGANISMS

We have isolated valuable cellulolytic fungi from wood-wastes that secrete large quantities of cellulolytic enzymes for the biodegradation of cellulosic wastes. Five of the isolates, were identified as: *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Penicillium chrysogenum*, and *Trichoderma harzianum*. (Nwodo-Chinedu et al., 2005 b) (Fig. 12). We have used the *Aspergillus niger* extensively for enzyme production and the *P. chrysogenum* to produce active antibiotics, penicillin.

S/N	Fungus	Culture Plate	Microscopic picture
1.	<i>Aspergillus flavus</i>		
2	<i>Aspergillus fumigatus</i>		
3.	<i>Aspergillus niger</i>		

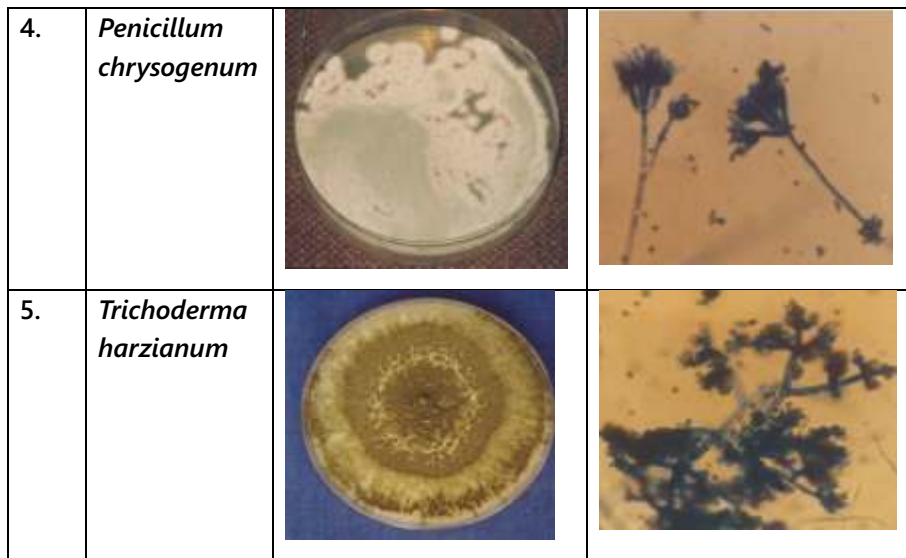


Fig. 12: Culture plates and microscopic pictures of fungal isolates from wood-wastes.

Other important products derived from the cellulosic wastes include cell-wall hydrolytic enzymes, microbiological media, antibiotics (penicillin), simple sugars, etc.

3. ENZYME PRODUCTION AND PURIFICATION

Cellulase is the principal enzyme for the conversion of cellulosic biomass into simple sugars which can subsequently serve as feed-stock for the production of chemicals and fuels via anaerobic fermentation (Ryu and Mandels, 1980; Zeikus, 1980). Xylanases and pectinases are also important enzymes for the complete hydrolysis of cellulosic biomass (Khan, 1980). These enzymes have potential uses in the food, brewing, pharmaceutical, textile, and pulp and paper industries as well as in the development of modified plant cells used for genetic research. They may eventually provide the ultimate answer to the problems associated with cellulosic waste disposal (Roy et al., 1990; Espana et al.,

1998).

We have produced and purified cellulolytic enzymes (cellulases, xylanases and pectinases) from microorganisms and fruits. They include cellulases of *A. niger* and *P. chrysogenum* isolated from wood-wastes (Nwodo-Chinedu et al., 2007; Chinedu et al., 2008 a,b; Chinedu et al., 2010; Chinedu et al., 2011 a,b) and from *Citrus sinensis* fruit (Chinedu and Daramola, 2011 c). Xylanases (Okafor et al., 2007; Chinedu et al. 2008 a) and pectinases have also been produced from microorganisms (Okafor et al., 2010) and from *Solanum macrocarpum* fruit (Chinedu et al. 2017). The activities of cellulolytic enzymes produced from these sources compare favourably with commercial enzymes used in the industries.

We have also used the cocktail of cellulolytic enzymes produced to hydrolyse cellulosic wastes into simple sugars and achieved considerable success; higher yields were obtained via ammonia pre-treatment of the wastes (Chinedu et al, 2008 b). The wild strain of *A. niger* (ANL 301) was also genetically modified by exposure to UV radiation for optimised production of pectinases (Okafor et al., 2010).

4. SPECIAL PRODUCTS FROM CELLULOSIC WASTES

Two other outstanding products obtained from the cellulosic wastes were microbiological media and antibiotics, penicillin.

(i) The plant cell-wall residues can serve as carbon and energy sources in microbial media, and substrates for fermentation and enzymatic hydrolysis. Different types of plant wastes were found to serve as efficient substrates for media formulation (Chinedu et al., 2006) and fermentation (Onyegeme-Okerenta et al., 2009a). We also formulated special agar media containing different plant wastes as sole carbon and energy source for the selection of cellulolytic microorganisms (Nwodo-Chinedu et al., 2007).

(ii) One of the fungi isolated from the plant wastes, *Penicillium chrysogenum* (PCL501), was used to produce active penicillin that compared favourably in efficacy with standard commercial penicillin antibiotics (Onyegeme-Okerenta et al., 2009 b.). The penicillin secretion was greatly enhanced by UV mutation of the organism (Onyegeme-Okerenta et al., 2013). The crude extract from the *P. chrysogenum* was also found to exhibit antithrombotic and anticoagulant properties (Onyegeme-Okerenta et al., 2014).

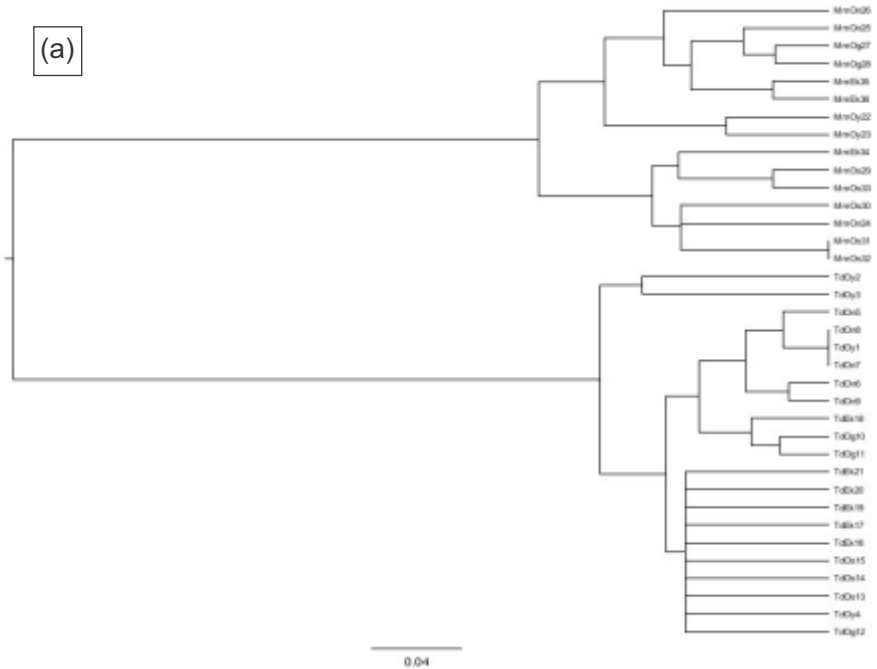
5. PROTEIN SWEETENERS FROM NATIVE AFRICAN PLANTS

Tropical Africa is endowed with a rich and fascinating biodiversity. These are huge bio-resources with great economic value or potential to generate wealth and improve lives! Unfortunately, African countries are unable to profitably utilize these bio-resources for economic gain due to gaps in knowledge capital, technical expertise and process technology. Several natural sweet and taste-modifying proteins were isolated from plants that grow in West African tropical rainforests. Among them are monellin from *Dioscoreophyllum cumminsii* Diels, thaumatin from *Thaumatococcus daniellii* (Benn.) Benth, pentadin and brazzein from *Pentadiplandra brazzeana* Billion, and miraculin from *Richadella dulcifica*. These sweet proteins are safe and unlike sugars, do not trigger insulin response. They have the potential to replace sugars and artificial sweeteners by acting as natural, low calorie sweeteners. Commercial development of natural sweeteners from these African plants could bite into the low-calorie sweetener market valued at over 2 billion USD (Chinedu, 2018).

My research team has carried out several studies on *T. daniellii* with the aim of improving the process of thaumatin extraction and purification, differentiating the ecotypes of the plant from other related plant species, and exploring other benefits and potential uses for the plant parts. Our findings are as follows:

I. Extraction and processing of thaumatin from *T. daniellii* requires a lot of expertise to obtain the desired quality. We have developed an effective procedure for thaumatin extraction and purification involving homogenization of the arils, enzymatic (pectinase) hydrolysis, centrifugation, and precipitation methods to obtain high quality thaumatin (unpublished data). A patent is being processed.

ii. We have established the phylogenetic relatedness and variation of ecotypes of the two plants in Nigeria using RAPD and ISSR molecular markers. Genetic differences were observed to be more among, than within the populations of *T. daniellii* and *M. macrostachyum*. (Chinedu et al, 2018). Fig. 13 shows the dendrograms generated by UPGMA cluster analyses with molecular markers. *Thamatococcus daniellii* and *Megaphrynium macrostachyum* are perennial understorey herbs with similar morphology and vegetative characteristics (Fig. 14).



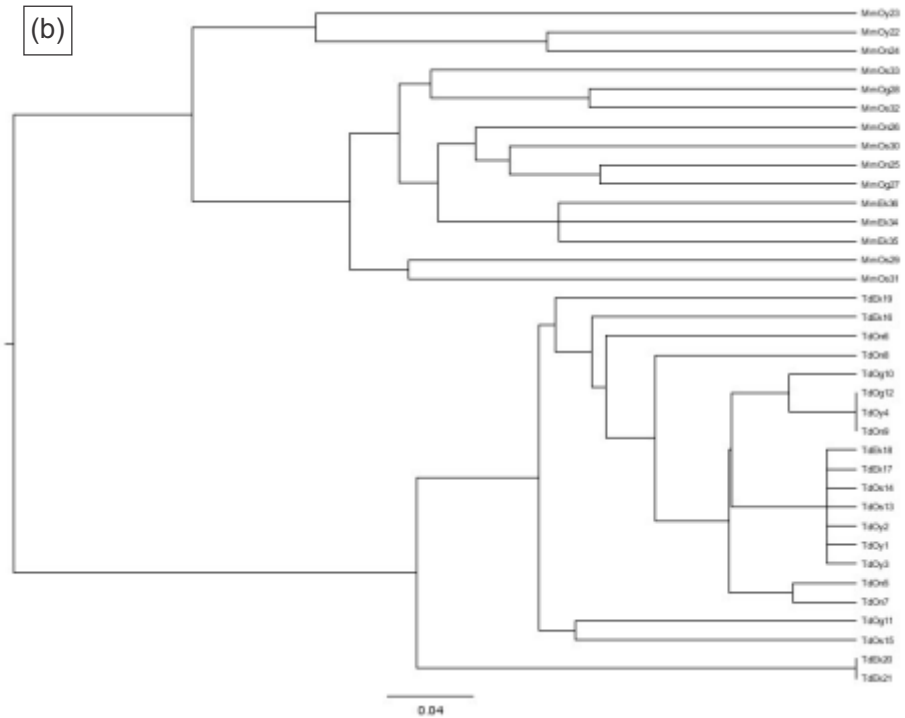


Fig. 13: Dendrograms generated by UPGMA cluster analyses, based on (a) 45 RAPD bands and (b) 46 ISSR bands depicting the genetic similarity between the individual plants.

I. We have also established some nutritional and medicinal values of the different parts of *T. daniellii* plant such as the leaves, fruits and seeds. Our findings showed high mineral content and potential antioxidant, hypolipidemic and hepatoprotective properties of *T. daniellii* leaves and seeds. Besides other local uses of the *T. daniellii* plant and its use as a sweetener, the plant can be exploited for formulating animal feedstuff and for ameliorating oxidative stress, hyperlipidemia and liver damages (Chinedu et al., 2014; Iheagwam et al., 2017; Chinedu et al., 2018).





Plant	Leaf	Fruits
<p><i>Thaumatococcus daniellii</i> (Benn.) Benth</p>		
<p><i>Megaphrynium macrostachyum</i> (K.Schum.) Milne-Redh:</p>		

Fig. 14: *Thaumatococcus daniellii* (Benn.) Benth and *Megaphrynium macrostachyum* (K.Schum.) Milne-Redh

6. PUBLIC HEALTH AND MEDICINAL PLANTS

Another area where we have made laudable contributions to existing body of knowledge is on weight-related public health issues such as obesity, diabetes, sickle cell anaemia and hypertension. Our studies have provided credible data on the relationships between body weight (expressed as body mass index, BMI) and Waist Circumference in

Nigerian Adults (Chinedu et al., 2013); BMI, age and gender in Nigeria (Chinedu and Emiloju, 2014; Chinedu et al., 2017a); trends in Weight Abnormalities of Children and Adolescents in Nigeria (Chinedu et al., 2012); BMI and hypertension (Chinedu et al., 2018 b), etc.

Our studies showed that BMI increased with age rising from childhood (under 5) through middle adulthood (Chinedu et al., 2017 b). Underweight was found to be the most prevalent abnormality in children whereas overweight took over at early adulthood (20-39 years) and escalated together with obesity at middle adulthood. Studies on adults aged between 20 and 70 years (Chinedu et al., 2018 b), showed that hypertension is most prevalent in the obese and middle aged (40-59 years) people. The prevalence of hypertension, prehypertension, normal BP and hypotension in the study was 36.8%, 32.9%, 21.3% and 8.9% respectively. Hypertension occurred more in males (38.7%) than in females (32.0%) whereas hypotension was more in females (11.9%) compared to the males (7.1%). Hypertension was found to correlate strongly with age, gender, BMI and job type (Chinedu et al., 2017c, Emiloju et al., 2017 b; Dokumu et al., 2018).

We also carried out studies on ways to mitigate weight gain and/or reduce body weight. Excessive body weight, mostly obesity, is a risk factor for hypertension and heart diseases. We examined the proximate and phytochemical composition, and health benefits of some local fruits and herbs. Fruits of two African eggplants, *Solanum aethiopicum* and *Solanum macrocarpon*, were found to be helpful in weight reduction. Both fruits reduced weight gain by the test animals (albino rats), in a dose-dependent manner, but had no significant effect on the blood glucose level (Emiloju and Chinedu, 2016). The fruits also had significant hypolipidemic effect and improved the lipid profile of the rats (Chinedu et al., 2013 c). Fig. 15 shows the fruits of *S. aethiopicum* and *S. macrocarpon*. Figs. 16 and 17 are plots of Age versus Mean BMI, and Age versus of Body Weight Abnormalities respectively

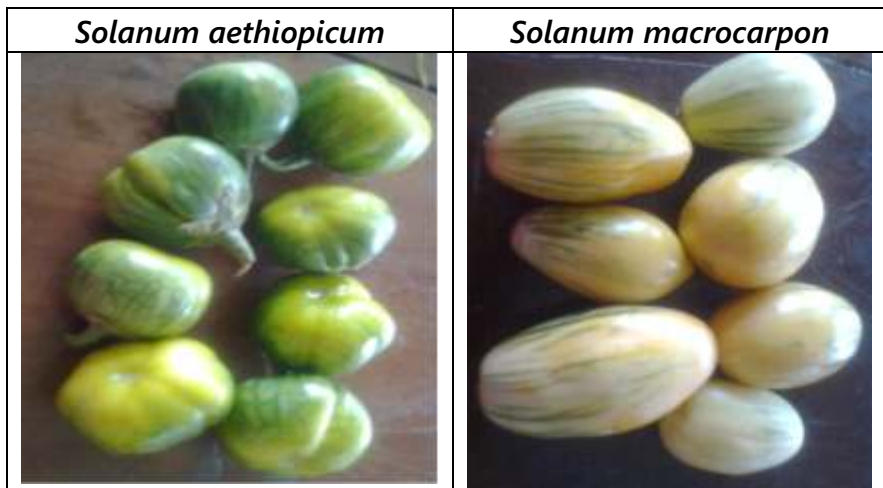


Fig. 15: The fruits of African eggplants, *Solanum aethiopicum* and *Solanum macrocarpon*.

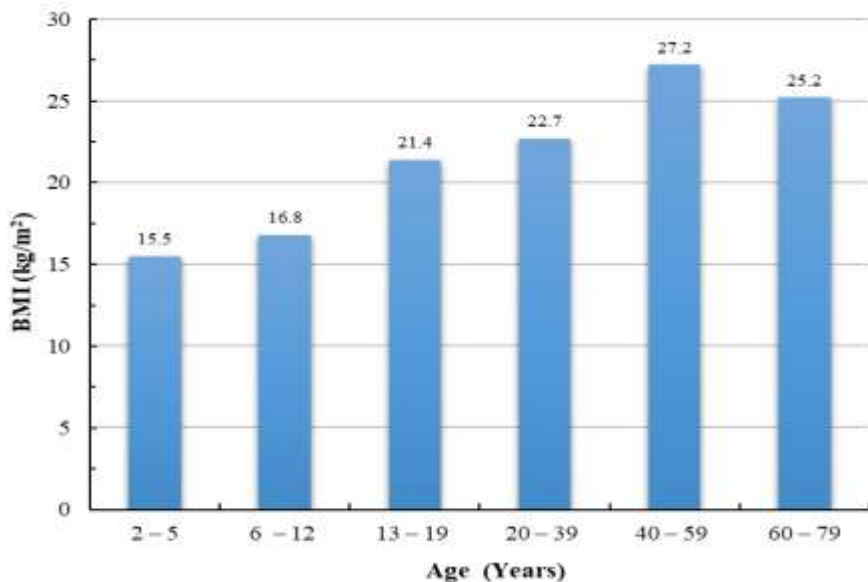


Fig.16: Mean BMI of different age groups in Ota community, Southwest Nigeria.

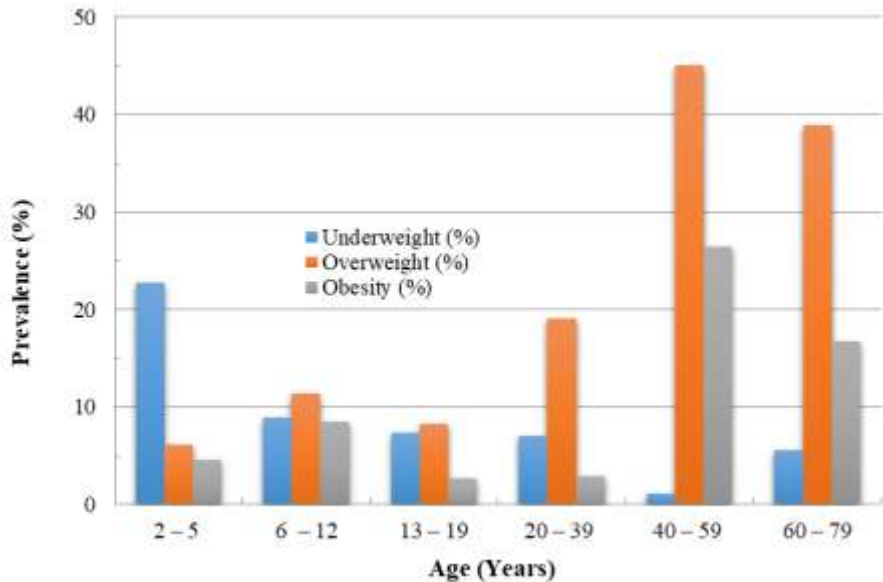


Fig. 17: Prevalence of underweight, overweight and obesity amongst different age groups in Ota community, Southwest Nigeria.

Other areas where we have made outstanding contributions are in the fight against tuberculosis, a mycobacterial infection, and antimicrobial resistance by some strains of pathogenic bacteria. We have developed some natural products, consisting primarily of bioactive compounds derived from parts of Soursop plant, *Annona muricata* Linn., with considerable activity against mycobacteria responsible for tuberculosis (Iyanda-Joel et al., 2015, 2016 a,b) and fluoroquinolone (antibacterial) resistance (Iyanda-Joel et al., 2017). The nature and structure of specific bioactive compounds involved and the mechanisms of their action are being studied. Patents for the products are also being processed.

The Covenant University Public Health and Wellbeing Research Cluster (CUPHWERC), a research group which I am privileged to lead, is part of an international research initiative on prostate cancer, the Transatlantic Consortium on Prostate Cancer (CaPTC), comprised of researchers

from Universities in US, UK, Nigeria and the Caribbean. Our group in Nigeria has, among others, carried out research on: “Analysis of the functional consequences of single nucleotide polymorphisms in CYP3A4 gene to prostate cancer in men of African ancestry” (Rotimi et al., 2018a) and “*Androgen metabolism and incidence of prostate cancer in Nigeria” (Rotimi et al., 2018 b).

THE EMERGING PATHWAYS/RECOMMENDATIONS

Africa is endowed with abundant human and natural resources. They include a vast reserve of bioresources, comprising “the sum total of natural biological diversity (plants, animals, microorganisms and other forms of life) that have current potentials or economic value”. African bioresources have always been exploited to service the needs of the local people, such as food, medicine and shelter, and also to earn foreign exchange through the raw materials shipped to the developed nations for their growing manufacturing industries.

Incidentally, what Africa gets in return for these raw materials is not in any way commensurate with the resources being pillaged from the continent on daily basis. For instance, “of the hundreds of pharmaceutical products currently in use around the world, 74% have been derived from plants and 75% of the plants were from tropical forests in Africa and South America (Iwu, 1992). The question is, how much income comes from these pharmaceutical products to Africa and South America? Nothing significant! It is a well-known fact that proceeds from products derived from tropical African plants go to North America, Europe and Asia (China & South Korea) through their big pharmaceutical and biotech companies which make the products and also control the market. This is just one of the disparities occasioned by the unfair international trade that tend to perpetuate poverty and the deplorable state of the Africa's economy. Today, Africa faces a new form of colonization through biotechnology, whereby she is robbed of her bioresources because genes for the desired products have been craftily taken away from Africa's rich biodiversity and cloned into other organisms and used to make the desired products!

Africa must step up her engagement in the area of science, technology and innovation to counter this ugly trend. Africans, particularly, the scientists and professionals, must rise up to put an end to the continuous impoverishment of our continent and her people. One important tool to engage for this purpose is modern biotechnology. Biotechnology has become a veritable instrument for economic growth and tackling multifaceted challenges of mankind. It has the potential of providing enduring solutions national, regional and global problems.

1. THE CHALLENGES

What are the developmental issues facing Africa? The issues are multifaceted, but some are life threatening! Hunger and famine appear to be the worst issues confronting Africa. World Food Summit (1996) recognized hunger as a global challenge. According to the Rome declaration on world food security: “the problems of hunger and food insecurity have global dimensions and are likely to persist, and even increase dramatically in some regions, unless urgent, determined and concerted action is taken, given the anticipated increase in the world's population and the stress on natural resources”. Hunger is both persistent and escalating in sub-Saharan Africa (SSA); about 1 in 3 Africans are malnourished. The African continent imports at least 25% of its grain, a trend that places enormous strain on Africa's balance of payments. Many African nations rely on food aid from industrialized nations to combat starvation. Africa's priority must be to feed her people. Biotechnology provides an ideal solution to hunger because of its potential to improve agriculture and boost food supply!

Poverty has been identified as the most prominent cause of hunger. “The world has come to recognise that chronic hunger is not due to lack of food. It is due to poverty. In many countries there are abundant examples of hungry people in food surplus areas - people who lack adequate income or assets to purchase or produce enough food for themselves and their families” (FAO, 1996). The factors that contribute to Africa's poverty include external issues such as unfavourable balance of trade

and large external debts, and internal problems including armed conflicts, political instability, and inadequate public investment in agricultural research, training and infrastructure culminating to low agricultural productivity and declining food production.

2. RECOMMENDATIONS

I have in the course of this presentation highlighted a number of new developments in the fields of life sciences, notably, modern biotechnology, most of which are breath-taking and revolutionary. These innovative technologies and techniques constitute the emerging pathways which Africans should engage to secure Africa's future. Two key imperatives for empowering Africa economically are: suitable technologies and manpower development.

“Food production and rural development, particularly in those countries with significant food security inadequacies, require appropriate and up-to-date technologies which, according to sustainable development criteria and local food traditions, promote modernization of local production methods and facilitate transfer of technology. Full benefit from these technologies will require training, education and skill development programmes for local human resources.” (Rome Declaration on World Food Security, 1996)

In view of this, I will recommend the following as instruments for Africa's technological, and socioeconomic transformation and sustainable development:

(i) Invest maximally in Science, Technology and Innovation (ST&I).

Africa must invest heavily and continuously in ST&I to meet her developmental targets and improve the lot of her people. Science, ST&I is recognised globally as a catalyst of national development. Advancement in ST&I is the dividing line between the developed and under-developed nation. Hence, leaders of nations have always leveraged on ST&I to achieve a rapid growth (economic, social or

military) of their countries. Barrack Obama (2008) stated as follows: “The state of the economy calls for action, bold and swift, and we will act... We will restore science to its rightful place, and wield technology's wonders to raise health care's quality and lower its cost. We will harness the sun and the winds and the soil to fuel our cars and run our factories. And we will transform our schools and colleges and universities to meet the demands of a new age.” A former Nigerian President, Goodluck Jonathan, also said: “I am convinced that Science, Technology and Innovation (ST&I) remain the key tool that will help us to achieve the desired transformation. My conviction stems from the resourcefulness of our people, the gains of the application of the outputs of Science, Technology and Innovation in other countries, and the implications for the quick turnaround of the economy” (Jonathan, 2012). There must be a clear understanding of the role of ST&I in national development, and a visible commitment to this by African Leaders, particularly through the funding of researches and the establishment of state-of-the-art laboratories, workshops and Centres of excellence in schools and research institutes.

(ii) Emphasise more on process and product development

African researchers must strive to move their discoveries from the laboratory to the market. Most of the technologies and products people enjoy today came out from formal or informal 'laboratories'. Researchers should develop competences in problem-solving (applied) research and also the skills to attract grants for their research endeavours. This calls for collaborations between the academia, the industry and governmental agencies and non-governmental organisations (NGOs).

(iii) Promote biotechnological research and product development

The tools of modern biotechnology should be embraced and engaged by African researchers. Enlightenment is necessary to address a number of safety and ethical concerns in the application of new technologies such as genetic engineering, cloning of transgenic animals, and the use of GM crops in some quarters. There must be an immediate response to the challenge of continuous disinheritance of our biodiversity and source of

income by the developed economies through biotechnology. The good thing is that we can start from the old generation biotechnology and progress into the high-tech molecular products. South Africa and Egypt are already setting the pace with the establishment and growth of a number of biotech companies.

(iv) Negotiate the exploitation of African rich bioresources
Collaboration between big biotech companies and African researchers on one hand and negotiations between Governments of African nations and that of the industrialized nations could lead to a win-win partnership in the exploitation of Africa's rich bio-resources. The pharmaceutical and biotech companies should partner with researchers in Africa by funding relevant researches. A collaborative model should be developed that will address the interest of African communities who are the “knowledge reservoirs” for the bio-resources. Patent rights over products from various zones of Africa should be negotiated to benefit all the parties involved. Trust building is key to unimpeded access to the rich bioresources available in Africa, especially in the tropical rainforest zones. There should be renegotiation of International treaties such as the treaty on genetic resources, including the World Trade Organization's agreement on Trade-Related Intellectual Property Rights (TRIPS) to protect the rights of Africans to their natural bioresources.

(v) Focus on human resource development
We need persons with requisite skills and competence in the area of biotechnology to drive biological revolution in Africa. The place for human resource development in achieving food security and poverty eradication in Africa cannot be overemphasised. Training and retraining of academics, technologists and technicians in biotechnology and allied fields are needed to ensure rapid advancement through biotechnology.

(vi) Strictly regulate biotechnological research/ product development
It is very crucial to put in place strict regulations on biotechnological practice that will protect the health, beliefs and sensibilities of the

people. Every country should have a statutory body empowered by law to regulate and approve genetic research, production, importation or use of GM products in the country. Genetically modified (GM) products must be made under rigorous regulatory controls, and extensively tested to ensure quality and safety of the products prior to commercialization. There may be need to label GM crops, foods and other products to allow people the freedom to choose what they want.

(vii) Modernise agriculture to make it attractive to young people
Modernisation of local agricultural methods and transfer of technology are critical to improve food production and better yield. Most African countries still rely on outdated traditional methods of farming that involve intensive manual labour with very low returns on investment. Today, mainly the elderly, around 60 years on the average, are engage in serious farming in many African nations. Farming no longer appeals to young people. This puts Africa in a disadvantaged position considering her teeming population of young and energetic youths. Our agricultural processes must be improved for productivity and economic gain to make it attractive to the youths. Africa needs to revisit the second and third (Green revolution) agricultural revolutions.

(viii) Tackle the challenge of nomadic African tribes
The first agricultural revolution brought about the settling of people in definite locations, thereby, halting the erstwhile nomadic lifestyle. However, there are some tribes in Africa that are still engaged in nomadic way of life as a means of livelihood. A typical example is the Fulfulde (Fulani speaking) tribe of West and Central Africa. While some of them have fully settled in defined locations, a large part, involved in herding business, still roam about as nomads This hardworking tribal herdsmen have, through indigenouse breeding techniques, produced very virile cattle noted for high quality meat and milk production. Unfortunately, their grazing activities continues to provoke violent clashes with local farming communities in Nigeria resulting in incessant loss of lives and properties, and displacement of the rural dwellers. This has imposed a serious constraint on farming activities and adversely affected food

production. The government should boldly confront this situation and ensure that the cattle owners build ranches for the animals. The ranches could bring additional income to the herders as they can also engage in crop production and use the animal wastes as bio-fertilisers to improve the yields. Irrigation will be necessary to water and keep the ranches green all year round. This will require the intervention of state, and national governments as well as regional and international donor agencies. Settling these cattle rearing nomads in ranches will bring enduring peace and security, and a healthy relationship between the herders and the farming rural communities in Nigeria.

(ix) Handle the challenge of environmental degradation

Biotechnology has the prospect of impacting positively on the environment, particularly in the area of bioremediation of polluted environment and bioconversion of solid wastes such as cellulosic materials into value-added products. In addition, plants that are resistant to environmental stress such as drought, heat and acidic soils could be produced. Edible and economic plants that are fast disappearing in the desert prone areas in Africa could be engineered genetically to produce varieties that can thrive in hot arid zones of Africa. This can also tackle the challenge of desertification. Plants with long, soil-grasping roots could be engineered to deal with the issue of erosion.

CONCLUSION

Innovative technologies and techniques in the fields of life sciences have brought the world into a new era of genetically engineered products and processes with mind-blowing possibilities and tremendous benefits in the area of agriculture, medicine, industry and the environment. This era of biochemical disruptions, aptly described as biological revolution, has the potential to trigger an unprecedented turnaround for Africa and place her on the path of economic recovery and sustainable development. Africa must rise up from her state of cold indifference and ignorance to tap into the huge opportunities offered by the biotechnological advances that have radically altered the long, held norms and assumptions in

science and technology, and impacting global economy in a manner the world has never known. Biotechnology has the prospects to improve agriculture, boost food supply and counter famine, and provide enduring solutions to the challenges of environmental degradation, disease and poverty facing Africa today. It can also trigger industrialisation and a rapid economic growth in Africa and give the continent a respectable place in the world. If we can think it, we can do it! The time to act is now!

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“Having therefore obtained help of God, I continue unto this day...”
(Acts 26: 22, KJV).

God is the reason for my living. Therefore, I give Him thanks and praise for the gift and sustenance of life and especially, for giving my life a meaning! Truly, God is good to me! He has done all things well in my life! I return all the glory to Him for all His great and mighty acts in my life! I want to particularly thank God for making the event of today, not just a reality, but a huge success.

I can't stop celebrating God for His servant, the Chancellor of Covenant University, Dr David Oyedepo. He has demonstrated a strong, excellent and exemplary leadership, and also greatly impacted the lives and destinies of millions of people across the globe through his life and ministry. He is not only my Chancellor and leader, but much more, a prophet sent my way by the Almighty God. I came face to face with destiny and my life took a dramatic turn upward from the first day I sat under his prophetic ministry at the old Church in Raji Oba, Lagos in 1997. Since then until now, I have followed him unrepentantly and uninterruptedly and it is beginning to show a little bit. Sir, I am very grateful!

I deeply appreciate the Board of Regents and Management of Covenant University for the opportunities granted me to learn and grow in University administration and Leadership. I have been privileged to

serve in so many offices and platforms since I joined the university in 2006, I have served as the Head of Department of Biological Sciences, Sub-Dean of the School of Postgraduate Studies, Director of Quality Assurance and Academic Standards, Director in the Vice-Chancellor's office, Dean of the College of Science and Technology, Dean of the School of Postgraduate Studies and the Deputy Vice-Chancellor of Covenant University. I have also served in numerous University Committees either as a member or the Chair. To the glory of God, I am still serving today as the Director of African Leadership Development Centre (ALDC), the Chair of the University Publication Committee and the Chair of the University ethical review board, Covenant Health research Ethics Committee (CHREC). I sincerely thank the Board and Management for this honour and privilege.

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CLOSING THOUGHTS

It's wonderful to wish and dream of a great Africa. But until we wake up and work it out, we may never see the dream come true. Now is the time to effect the change we desire!

In closing, I want to boldly declare that there is hope for Africa. I can see the emergence of giants in all spheres of human endeavour across the continent of Africa!

Chancellor, sir, please, permit me to bring this discourse to a close with these verses from my poem titled: "Hope Africa":

Hope Africa

Hope Africa,
In dust, interred, out of sight!
Hope Africa,
Precious seeds sown are shooting out
Tender buds!
Sing Africa; sing at sun-set!
Sing through the dusk and darkening shadows...
Stars, bright, are rising
To guide the deepest night!

Hope Africa,
In storm, battered by bouts of tempests!
Hope Africa,
Heaven's windows are open, pouring out
Bounteous graces!
Dance Africa; dance in the rain!
Dance through the blitz and blares and hail...
This isn't the Noah's flood;
There's a rainbow in the clouds!

Hope Africa,
In pains, altered by sorrows of birth-pangs!
Hope Africa,
Womb, full-grown, is pushing out
Its due glory!
Shout Africa: travail and prevail!
Shout through the blood and sweat and tears...
Joys, joys, are bursting forth,
With the dawning of a new day!

Culled from "Hope Africa: A Collection of Poems" by Shalom N. Chinedu

Covenant 18th Inaugural Lecture – Shalom Nwodo Chinedu

Ladies and gentlemen, it has been a great privilege and wonderful experience for me to deliver the 18th Inaugural Lecture of Covenant University. To God alone, be all the glory!

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