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Review Article

Rejuvenating Research and Training in Biomedical Sciences in Nigeria: *Drosophila Melanogaster* as A Versatile Alternative Model

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Abstract

The challenges facing biomedical research and training in Nigeria have remained a huge concern. Asking the right questions that deeply feed into solving the health problems of the people, and using appropriate tools and methodologies have been challenging due to resource constraints including ethical and cost considerations for use of experimental animals. *Drosophila Melanogaster* is a versatile model organism that has been used for over a century in biomedical research to study wide range of phenomena. Although the fly has about 400 million years of divergent evolution with human, 75% of genes known to be involved in human diseases have homologues in Drosophila. This vital evolutionary conservation, the ease of culturing and manipulating in laboratory conditions and the short life cycle makes Drosophila an important model for biological and medical investigations, and teaching of biomedical sciences. The remarkable advances in molecular and cell biology have added complementary tools for the adaptation of the fly to study various disease conditions, gene regulation and interaction in health and diseases, biological basis of diseases, drug development and evaluation, mechanism of drug actions, and anatomical architecture and pathophysiology in disease states. The strategic deployment of the fly model for research and training in biomedical sciences in Nigeria will provide an affordable, readily available and high impact alternative to the current models and may revolutionize conduct, integrity, quality and applicability of biomedical research in Nigeria and, consequently, the training of health professionals.

Keywords: *Drosophila Melanogaster*, biomedical science, fly model, research, teaching, Nigeria

INTRODUCTION

Biomedical science, and more broadly the life sciences, has been a fulcrum of development of health care in Nigeria for almost a century. The pre- and early post-independence research landscape in the discipline beamed with unimaginable hope of vibrant scientific activities in the nation. This was poised ready to also influence health development on the continent following the Pan African political struggle. However, the efforts to sustain the achievements of the biomedical scientists of the sixties have been seldom successful. The research environment has changed too drastically in the last four decades. Despite spiking records of publications coming from Nigerian Universities in the last 20 years (Arencibia-Jorge *et al*., 2012.), several factors of multiple origin have contributed to the change observed. The lack of political stability, focused and robust national research agenda, prudency in the use of research grants, coordination of the university research environment and adequate research infrastructures, were drawbacks to growth of research and training in biomedical science or life science disciplines in Nigeria.

This paper is a scientific exploration of how to improve conduct, quality and relevance of biomedical research through the deployment of alternative insect model organism. Other factors affecting biomedical research environment that are political will be excluded in this consideration. Attention will be focused on examining research infrastructures and environment disrupting growth of quality research and training in biomedical sciences and how *Drosophila Melanogaster* - the fruit fly - can be used to turn these challenges into opportunities for novel advances in biomedical research and development of science and the health sector.

The research infrastructure challenge in perspective

With over 150 universities and 70 research institutes in Nigeria where research, directly or indirectly related to biomedical or life sciences is carried out, it is expected that the progress in direction, quality and application of the discipline would yield relatively high impact on the health of the population and Nigeria as a country. The situation is contrary. The agony of a biomedical scientist or trainee in the discipline is heavy.

Two fora of interaction with DrosAfrica in Nigeria, one at University of Ibadan and another at University of Jos where attendants were majorly biomedical scientists, identified research infrastructure as a major cause of agony or constraints to progress. Until recently, attention was paid on equipment to conduct research. International research organizations and grants for the North-South cooperation supported skill acquisition and equipment boost for research development in

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the universities and other research institutions in the first 30 years post-independence of Nigeria. As the efforts expanded, there was rising challenge of inability to cope with use of both rodent animal models and human participants. With difficulties in getting human participants and samples for biomedical research, as may be required, the animal right group stepped up campaign against animal use for research globally (Ringach , 2011; Franco, 2013*).* Rearing animals for research is becoming less popular nowadays and the requirements to ensure their wellbeing have become unaffordable for most African institutions. Where experimental animals are available, the demand outweighs supply at estimated 100 fold rate. The increasing cost for size of population to use per experiment makes this research expensive and unaffordable to many scientists. Furthermore, the economic situation of the country and low allocation for research in many institutions impaired sustainable rearing of these animals; many existing animal houses collapsed, leaving few animals in cages, mostly for teaching purposes. This puts concerns on the quality of work and sometime compromised reporting of research findings, especially with the phenomenon of 'publish or perish' in the academic setting.
Today, asking the right scientific questions that deeply feed into solving health problems of the people appears not to be a priority for many academicians and researchers. Inconsistent research traditions in our universities and lack of openness to collectively build capacity in a systematic manner, and lack of love or instinct for sharing have led the way in dissuading younger generation form quality and responsible conduct of research. In order not to 'perish' in the academic environment, any research goes. The frustration associated with training under obvious lack of facilities and simple models, and bossing character of many supervisors and trainers in academic institution are already causing setback and lack of focus for younger generation. So the desire is to just publish something. The observed consequence has narrowed the scope of biomedical research with many concentrating on what resources and models available could do; more epidemiology, demographic, herbal extract effects and toxicity studies, but less mechanistic, applied biology, genetics, regenerative medicine and related studies. The rising health problems, despite considerable rise in publication rate nationwide, is an indication of lack of relevant new knowledge and innovation from biomedical science community to guide solutions to the health problems of the people.

Taking cue from other scientific communities, a solution to these obstacles rests in developing and making available more suitable models as alternatives. The history of science in Spain experience, taught important lessons. A scientific tradition did not first emerge, although scientists were produced. Until about the turn of 20th century and with concerted efforts of dedicated and responsible scientists, Spain throve in its science, particularly in biological or life sciences, through individual scientists who cooperated to work selflessly together and later established more institutions. The experimental model of interest in this article, *Drosophila Melanogaster*, played crucial role in the development of science and research tradition in Spain (Martinez-Arias, 2009). This therefore underscores the important of this article aimed to describe how *Drosophila* can be deployed to rejuvenate biomedical research in Nigeria.

The introduction of *Drosophila* as a model organism

The fruit fly, *Drosophila*, which originated in Africa (Pandey and Nichols, 2011), has been an extensively used as a model for investigating various aspects in life sciences. The fly has richly contributed to our understanding in genetics, aging pattern, neurodegenerative diseases, inflammation, immune responses, gastrointestinal and renal physiology, and many other aspects of our own biology and that of the organisms that surround us, and its value as a model organism in many areas of health sciences is incontestable.

Drosophila, as an invertebrate was not always considered a valuable resource in the study of biomedical science. In the field of genetics, it was introduced by T.H. Morgan at the beginning of the 20th century and soon afterwards became one of man's best model in biological research (Prasad and Hedge, 2010; Jennings, 2011). Thanks to their work in flies, Morgan and his students unraveled not only the principles of inheritance but also the mutagenic effect of X-rays. They were the first but not the last scientists who have been awarded a Nobel Prize for the discoveries they made in flies (Bellen and Yamamoto 2015; Rubin and Lewis, 2000). More importantly, scientists who trained working with flies, later moved on to other systems to make groundbreaking findings only possible; thanks to the critical thinking, flexibility and deep understanding of Biology developed in their training years.
The utility of the *Drosophila* resides in two resources: its small genome, which shows a degree of conservation with that of humans that makes it highly relevant to study our own nature, and its powerful genetic tools as a model system. Of particular interest for the biomedical field is the fact that over 70% of disease-causing genes in humans are conserved in the fly, providing opportunity to explore the genetic makeup and gain insights to genetics of disease, degeneration, and aging processes affecting human subjects. (Reiter *et al.,* 2001; Wilson – Sanders, 2011).

The main attributes that make the fly so powerful in research are its rapid generation time, short life cycle and life span, ease of handling and genetic manipulation, and low cost of culturing. The fly has a very rapid life cycle. A few fertile mating pairs can produce thousands of genetically similar offspring within 10 to 12 days at 25°C. This is in contrast to the traditional rodent models, in which only a handful of offspring are produced every 3 to 4 months.

In the last century, advances in the biological sciences have put huge value on some non-mammals which are not only convenient materials but also share similarity in pharmacological and physiological properties with humans. As the other parts of the world with more discoveries in biomedical science research grew in the application of these non-mammal models- zebrafish, *C.elegans*, *D.melanogaster* and others- Nigerian institutions and biomedical scientists were busy propagating the rodents at considerable cost up until the turn of the millennium. At this time in history of biomedical research in the country, the demands of rodents for research outweigh the supply. Rearing the animals will take months and scientist have to wait on long list for supply to come. On the other hand, the development of animal welfare best practices has made experimental animals even more expensive and difficult to rear in the African setting. *D melanogaster* presents a unique opportunity to scale up investigation by scientists in the universities and research institutes which otherwise rodents could have been used for.

Drosophila in study of development and cellular processes

In recent times, *Drosophila* has been one of the most intensively studied organisms in biology. It serves as model system for investigations of many developmental and cellular processes. Many disciplines today benefit from the continuous generation of new knowledge that are tools for probing meaningful queries in health sciences. Such disciplines as biochemistry, physiology, embryology, pharmacology, and other allied bio-medical sciences, which have common interest in higher eukaryotes, including man, have used the model organism to foster our understanding of mechanism behind cellular processes.

Being one of the first organisms for which the genome was fully sequenced, the fly provided the best platform for the study of the biochemical pathways behind the cellular function and the molecular processes regulating them all. With the completion of the human genome project the conservation between the two organisms was brought to light and the biomedical relevance of *Drosophila* grew ever stronger making it the model of choice to understand human biology and disease processes (Pandey and Nichols, 2011).

The fly presents multiple model organisms in one, defined by its developmental stages. The embryo is available for fundamental developmental studies. The cellular pattern formation, cell fate determination, organogenesis, and neuronal development may be examined with ease of annotation and development tracking (Pandey and Nichols, 2011; Nichols, 2006). Of particular interest is the wandering third instar larva, which is routinely used to study behaviors (Wegman *et al.,* 2010). The emerging adult structures that are contained within the larva are valuable tools to follow up the differentiation and morphogenesis processes (Walther & Pichaud, 2007). The study of the molecular and genetic mechanisms underlying imaginal disc developmental processes in the pupa has provided significant insight into fly and human biology (Cagan, 2009; Beira and Paro, 2016). The adult fly is a very sophisticated and complex organism with structures that perform the equivalent functions of the mammalian heart, lung, kidney, gut, and reproductive tract. Significantly, the response of flies to many drugs that act within the CNS is similar to the effects observed in mammalian systems (McClung and Hirsh, 1998; Moore *et al.*, 1998; Bainton *et al.*, 2000; Nichols *et al.*, 2002; Rothenfluh and Heberlein, 2002; Satta *et al.*, 2003; Wolf and Heberlein, 2003; Andretic *et al.*, 2008). The visual system of the adult continues to be extensively studied and has been crucial in understanding not only vision but also other key systems that include signal transduction pathways such as *ras*, and transient receptor potential channels, among many other processes (Ready *et al.*, 1976; Nagaraj and Banerjee, 2004; Montell, 2005; Kumar, 2010). It also exhibits many complex behaviours that make it suitable to study from learning and memory to neuropsychiatric disorders, for example, Attention Deficiency Hyperactivity Disorder (De Luca *et al.* 2002; van Swinderen and Brembs, 2010) More facilities are gradually becoming available to study the behavior of the flies at genomic level (Neville and Goodwin, 2012, Stanley *et al.*, 2016).

Drosophila and physiological activities

Drosophila is an excellent organism for human-related aging research which sheds more light on how best to maintain vitality of youth and preserving quality of life. Dietary restriction (DR) is a well-recognized phenomenon to extend *D. melanogaster* lifespan with identified greater effects in females. *Drosophila* longevity genes with human homologous have been identified. Selection of all such genes results in the "Methuselah" fly with a greatly extended life span (Lin *et al.*, 1998). Thus biomedical scientists that are interested in the aging research will find *Drosophila melanogatser* as a very lucrative model organism. Identification of specific genes that regulate life span in *D. melanogaster* which has been achieved by two processes: 1. Quantitative trait locus (QTL) analysis in which genetic elements affecting natural variation in longevity have been mapped to specific position along the chromosomes and 2. Mutational analysis which is another type where manipulation of gene or pathway function has demonstrated life span extension genes which are involved in stress response and the association between stress and life span has motivated the identification of many genes according to Paaby and Schmidt (2008, 2009).

The free radical theory of ageing proposed by Denham Harman (1956) postulated that, accumulation of free radical damage to cellular macromolecules, is the major underlying factor affecting aging and the major determinant of lifespan. This provided the rationale to explore tests for life span extension by increasing activity of genes that promote antioxidant defenses (Paaby and Schmidt, 2008). The over expression of both catalase (Cat) and superoxide dismutase have demonstrated increased organismal longevity (Harman, 1981; Parkes *et al.*, 1998). *Drosophila Melanogaster* has been extensively used in the aging research. The discovery of some anti-ageing compounds such as resveratrol was established with the use of *Drosophila Melanogaster* and some other related model organisms, relatively due to their short lifespan, ease of genetic manipulations and culturing. Another interesting fact about the biology of *Drosophila* is that, like many invertebrates, it is capable of expressing a form of diapause, a neuroendrocrine mediated physiological syndrome that results in reproductive quiescence and organismal persistence over long periods of suboptimal conditions (Orr and Sohal, 1994). In *Drosophila*, phenotypic variation shows significant variation in lifespan within and among natural population.

Drosophila for neurodegenerative disease

Although animal models have demonstrated importance in study of pathogenic mechanisms and therapeutic strategies,in the studies of human diseases, including neurodegenerative diseases, pathogenesis of diseases such as Parkinsons Diseases still remain not clearly understood to a large extent. Therefore, there was the need to develop other models for understanding the pathogensis and discovering new therapeutics to treat such diseases (Feany and Bender, 2000). Renewed efforts in this direction presented *Drosophila* an ideal model for understanding neuronal cell biology and diseases. The mitochondrial encephalomyopathies are a diverse set of disorders that includes neuropathy, ataxia, retinitis pigmentosa, famial bilateral striatal necrosis and maternally inherited Leigh syndrome. These diseases are characterized by tissue degeneration and neurological as well as muscular dysfunction. The characterization of a missence mutation in the fly, similar to those that produce human disease, demonstrated many phenotypes directly related to human disease symptoms suggesting the fly a wonderful model insect to examine these diseases. The works of Sherwood (2000), Trotta *et al.* (2004), Clark *et al.* (2006) and

Park *et al.* (2006) on the Spas proteins and mitochondrial contribution to disease pathology in several neurodegenerative disorders including Parkinson's disease are valuable contribution to showcase the usefulness of *Drosophila* in disease pathology studies.

Other investigations in which *Drosophila* has been put to remarkable use include studies on conceptual understanding of functional aspects of eukaryotic genetics, including chromosomal mechanics, and behavior genetic linkage and sex determination (Griffiths *et al.,* 2000). The advantage is that the fly has a wealth of mutants and special chromosomes that have been endowed with visible and molecular markers and other properties which can manipulate the gene. Using these molecular markers one can study the visible and lethal phenotype that can be study for number of generations (Zhai *et al.,* 2003). The other transposon-based methods for manipulating genes have also been developed. The P-transposon can be integrated into the chromosomes and allows experts to create the genetically modified and stable transgenic system in *Drosophila*.

Drosophila as a model for infectious diseases

Innate immunity

Between 1996-2011, significant research breakthrough showed similarities in both humoral and cellular immune response of insects and mammal. *Drosophila* respond to wound signals (Boman *et al.*,1972), phargocytosis and encapsulation of invading pathogens (Kemp and Inler, 2009; Costa *et al.*, 2009) Many genes involved in the regulation of *Drosophila* haemotopoesis and cellular immunity are conserved for homologues in mammal (Abedin and King, 2010; Pollard and Cooper, 2009). Futher details are available in the review of Fauvarque and Williams, 2011).

The cellular response by blood cells (haemocytes) includes recognition, phagocytosis and encapsulation of microbes. The humoral factors were reported to induce haemolymph coagulation, melanization and synthesis of antimicrobial peptide (Williams, 2007; Lavine and Strand, 2002; Cherry and Silverman, 2006; DeGregorio *et al.* 2002). It is clear from the few examples mentioned in this section that Drosophila holds valuable tools for understanding innate immunity and response to pathogens or tissue repair

Human infections (modelling humans)

Drosophila has been reported in very many studies as useful organism to understand the pathogenesis of infectious agents such as bacteria, viruses or fungi in human. The past few years have witnessed use of *Drosophila* to study innate immue response from organisms that are beneficial or pathogenic to human. The microbes interaction with *Drosophila* has helped in defining innate immunity pathways and description of mechanism of microbial pathogenesis. Panayidou and co workers (2014) created a catalogue of 68 bacterial, fungal, and viral species that were studied in flies from which 43 of them were relevant to human health. The article discussed studies of human pathogens in flies revealing the elicitation and avoidance of immune response, mechanisms of tolerance, host tissue homeostasis, regeneration, and predisposition to cancer. Biomedical scientists in Nigeria universities with research interest in microbes and host pathogen interaction studies may find *Drosophila Melanogaster* helpful in their quest for answers to varieties of questions in their investigations.

D. melanogaster has a short generation time with analogous organ structure compared with human, Its defense mechanisms against invading organisms are highly conserved in mammals. The signaling pathways that have notably been conserved include NFκB, JNK, and JAKSTAT which are critical regulators of the immune responses in both flies and mammals (Igboin *et al.*, 2012; Stec and Zeidler, 2011). The first line of the *Drosophila* defense against microbes is mediated by barrier epithelia and their responses. The homeostasis and regeneration of tissues are also part of know defense response in *Drosophila* (Ferrandon,2013; Apidianakis *et al.*,2007; Hamilos *et al.*, 2012**).** The primary process of fighting microbes in *Drosophila* uses the production of conserved antimicrobial peptides, fat body (an analog of the mammalian liver), deposition of melanin that traps microbes and phagocytosis by the plasmatocytes, the analogous of the mammalian macrophages. It is possible therefore to define in part the pathogenesis and immune response to diseases caused by a great number of bacteria, fungi, and viruses in *Drosophila melanogatser*.

Vector insects and host-pathogen interactions (modelling mosquito)

It is a fact that in order to understand the host-pathogen interactions, studies using the relevant infectious agent in its native host is of paramount importance. There are situation in which the particular vectors may not be the ideal experimental organism for some reasons. From a biologist's point of view, the mosquito, for example, is not an ideal experimental organism due to complex rearing and culturing. Female Anopheles will require blood for breeding. In such circumstance, alternative model will be preferred.

Drosophila melanogatser can be used as a model mosquito for two reasons; first, identifying interesting genes that may be conserved between the two insects such as immune system, and second is that *Drosophila*, in vector biology research, can be used to study host-pathogen interaction by directly infecting flies with the parasite of interest. The large collection of genetic mutants, the simplicity of phenotypic screens in the fly and the sequence of the *Drosophila* genome (Schneider and Shahabuddin, 2000) provide important resources. *Drosophila* can be used directly as a model insect to study aspects of malarial transmission (Schneider, 2000). Today, scientist have found that *Plasmodium gallinaceum*, an avian plasmodia, is not infectious when fed to *Drosophila* but it can infect the fly when it is injected to the haemocoel. It was noted that the parasite develops in haemocoel from an ookinete into an infective sporozoite but does not seem to enter the salivary glands. When the parasite is injected into the haemolymph, it is rapidly cleared. This clearance is due to the cellular-immune response of the fruit fly and with this *Drosophila* is a good model to study immune response system. The available genetic tools for genome analysis have provided opportunity to examine *Drosophila* and vector mosquitoes developmental genes (Behura *et al.*, 2011). These efforts would have implication for vector control strategies, for example, in malaria or virus transmission.

Drosophila for drug development and phytomedicine research

D. melanogaster has emerged as a very useful tool in drug discovery, from target discovery, to high throughput screening

(HTS) to effectively and rapidly identify small collections of higher quality hits from larger collections to then proceed to more traditional mammalian models. The addition of the fly to the discovery process provides a unique opportunity to test the drugs in a whole organism. This enable scientists to understand the cell-cell interactions at very early stages. Thus, in the environment of other cells, the target cell responses and effects may be carefully studied. The process will predictably enhance quick identification of substances that may likely not make it through due to toxicity effects. Obviously, the rate of discovery at reduced costs to potentially identify new targets and therapeutics would be enhanced.

Myriad of hypotheses in phytomedicine can be tested with the fly and screening the plants for possible activities on a wide range of biochemical and physiological processes can be carried out. There are numerous studies today in which the potential protective or curative effects of herbal products used in several local settings all over the world have been screened in *Drosophila* model for evaluation of reported anecdotal activities. In a study, the gut injury was induced in *Drosophila* and extracts of Asparagus cochinchinesis was used to demonstrate protection against metal ion induced gut injury (Zang and Jin, 2016). Another example is in Janse and coworkers (2014) who worked on five ayurvedic herbs on locomotion behavior in Pakinsons diseases model of Drosphila. Several other reports exist on different experiment on herbs using Drosophila model.

Beyond the scientific discoveries: a tool for science and research training

Following the introduction of *Drosophila Melanogaster* through the 2011 neuroscience workshop and 2012 dedicated Drosophila for biomedical science research workshop in Ishaka, Uganda, our team had been able to establish the use of the fruit fly for both undergraduate and postgraduate research studies and training of medical and pharmacy students in basic practical in pharmacology. Introducing *Drosophila* for teaching and practicals in biology and biomedical sciences in higher institutions and secondary schools is gaining more grounds in different parts of the world (Woodruff and Thompson, 1999; Harbottle *et al.*, 2016). Our experience at the Institute of Biomedical Research, Kampala International University, in Ishaka; organizing open day for secondary school students and research day in the University for undergraduate students, postgraduate students and university teachers showed encouraging interest from the participants. Consideration to include *Drosophila* as a model to teach relevant topics in biology, biochemistry, physiology, anatomy and pharmacology was ignited and discussed at different times for adoption. The fruit fly offers opportunities to conduct laboratory practical experiment with living organism. In the least, data analysis techniques can be taught to students from participating in measuring motor performance of old and young flies, response of treated and untreated flies, reproductive competence and aging . In other situations elsewhere, students were taught socially relevant topics of alcohol and made to dissect or stain larvae of the fly to learn genetics and enzymatic basis of alcohol metabolism, mechanism of genetic variance and principle of evaluation (Harbottle *et al.*, 2016).

It is possible that Nigerian Universities will benefit from reorganizing curriculum to accommodate teaching and practicals in biological and biomedical sciences using *Drosophila* model. This will help in students learning of genetics, metabolism, mechanism of actions of biological and pharmaceutical products, enzymatic actions, bioenergetics and many others.

In addition to many postgraduate students who did their research in our laboratory in the span of five years, a total of 6 undergraduate pharmacy students who also took their final year research projects using *Drosophila* in different applications and enquiries. Table 1 showed the different projects and recommendation relative to their counterparts following a panel examination.

***Drosophila* model for a part bailout from lack of genomic studies in African population**

Africa, where the world's poorest people live, presently lack adequate data on genomics to be able to address diseases that affect the population. Many of these diseases have remained understudied. Genetic risk factors are little known in the African populations relative to their counterparts in European populations where genomic research has proven to be a considerably valuable tool to understand and tackle diseases. An important step in genomic research will be identifying diseases and health problems that are more likely to be influenced by genetic factors and assessing the risk of a particular disease in an individual.

Table 1:
Examples of training and publications with undergraduate students at Kampala International University, Ishaka, Uganda

Projects title	Trainee	Year of training	Remark of panel
1. Development of depressive-like behavior in *Drosophila Melanogaster* and activities of fluoxetine	Akaso Emmaculate	2012	Top 5%
2. Activities of Fluoxetine and ascorbic acid on behavior of stressed *Drosophila Melanogaster*	Violet Namiwanda	2013	Top 2%
3. Activities of fluoxetine, ascorbic acid, pidolo, and ketamine on cognitive and motor system of stressed *Drosophila Melanogaster*	Yotham Sojick	2013	Top 5%
4. Effects of antimalarial drugs on motor aand behavioral programs in *Drosphila melanogaster*	Emmaculate Kwikiriza	2015	Top 1%
5. Preliminary evaluation off effects of Coartem, Quinine and fansider on developmental stages of *Drosophila Melanogaster*	Adamo Samuel	2015	Top 2%

6.	Screening antimalarial drugs for modulation of aggressive behavior in *Drosophila Melanogaster*	Regina Mary Namirimu Top 1%

Table 2.
Some important resources and available tools for use in *Drosophila* research

	Resource/Tool	Description	Available source	Reference
1	**Information Resource** i. Drosphila Information Service -	i. Collection of Drosophila stock list (for 572 stocks of Bridge and Demerec, in 1934 ii. Bridges and Brehme Catalogue of mutant alleles in 1944	From Fly group at the Califonia Institute of Technology	
	ii. Fly base	Whole genome shot gun sequence earler annotated as Celera Genomics and Berkeley Drosophila Genome Project (BDGP). On line Resources available: i. DNA resources ii. Multiple Insertional Mutagenesis Collections iii. Comprehensive RNA interference for targeted gene knockdown iin cells and flies. iv. Protein Trap Collections v. Human Disease Model Report	On line	Stapleton *et al.*, 2002 Bellen *et al.*, 2011 Boutros et al, 2004, Flockharte *et al.*, 2012; Diatzi *et al.*, 2007; Ni *et al.*, 2011 Mirin *et al.*2001; Buzczak *et al.*, 2007; Nagarka-Jaiwal *et al.*, 2015, Millburn *et al.*, 2016
2	**Genetic Tools**			
	Mutagenic agent Ui. Protocol for mutagenesis	Ethyl methane	Thomas Aldersons work in 1905 Lewis and Bacher in 1968	Alderson, 1965
	iii. Mutant alleles, Transposible element insertion alleles, GFP tagged protein, GAL4 drivers, Dupllication kits, deficiency generators, Wild type lines	Different other genetic tools	Obtainable from Bloomington Drosphila stock Centre.	Lindsley *et al.* 1972.
3.	**Other References**			
	i. Manuals	Fly husbandry; Fly genetics, anatoomy and development; Laboratory protocols	Reference books	

These efforts will make scientists be in a position to develop new ways to treat, cure or even prevent the thousands of diseases that afflict people and assess the risk that exposure to toxic agents poses to individuals. Biomedical scientists in Africa have a lot waiting to be carried out about genomic studies therefore.

With seemingly complex engagement, challenges of appropriate laboratory, samples and expertise, coupled with low funding of research, introduction of *Drosophila Melanogaster* model of human diseases will come with some support to move the condition of health of African population studies forward by manipulating the fly for suitable experiments.

Some helpful tools available for studying different processes in *Drosophila*

Since after Morgan and others studies on genetics using *Drosophila Melanogaster*, advances in recent times have come long way to make some valuable resources available to the present and next generation scientists who chose to use Drosophila to answer their research questions. Drosophila has remained at the center of many biological mechanism queries for year as earlier mentioned. With the increasing relevance to development or biological sciencs several experimental tools and resources have been developed or are being developed. The types of resources available for D. melanogatser research can be categorized into three: databases and other source information, biological materials and experimental services (Matthew et al., 2005; Yamamoto et al., 2014). These resources had come from efforts of scientists to conduct research in mechanism of inheritance, construction of animal body plan, formation of nervous system, and forces acting on genetic variation in natural population selection. These resources will be valuable to promote the wide adoption of Drosophila as model for biological research by biomedical scientists in Nigeria. Table 2 summarizes the tools and value application.

What the community of Drosphilists taught the science community

There has not been yet a community of scientists that has been as open and cooperative as the Drosophilists community.

They share information as rapidly as they are gathered in the lab (Oliver, 1976; .Kohler, 1994). The flies are easy to request from colleagues. They offer collaborative assistance and help with any tough problem a colleague may be facing without expectation of reward for their efforts. They do not request to be on the needy publication or team or grant to help out in difficult situation. The message is important to the biomedical community and other knowledge generating communities in Nigeria and other developing nations. The science advancement that is so much desired for the development of this region cannot entertain hide and seek attitudes, selfishness, self-aggrandizement or arrogance. Complete attitudinal change is brought along with introduction of Drosophila in any university or research laboratory. The teams around Drosophila research are usually happy helping others. This has helped in the rate of development of biomedical research in developed nations around the world, and the Drosophila research community is the most accommodating community with huge investment sharing and advancements.

Engaging in sustainable development agenda 2030 with *Drosophila*

There is no doubt that Biomedical Scientists in Nigeria and elsewhere have got roles to play in achieving the Global Sustainable Development Goals- 2030. The priorities, as it will affect developing nations, iuncluding Nigeria, would require proper alignment for engaging scientist in matters relating to health and environment toxicity. More researches are required to fight antibiotic resistance, improve nutritional health, diagnose environment poisoning, fight cancer with new drugs, reduce stress and associated ill health burden, improve biosociobehavioral response to health solutions and many more. DrosAfrica, is willing to support the strategies to revitalize biomedical scientists and allied groups skills in use of *Drosophila* for research and training. The efforts have started with mobilizing individuals and universities within the country. The Nigerian Academy of Science and relevant government establishment would be required to support and pilot the efforts for national benefits.

Conclusion

Drosophila Melanogaster is simple yet powerful biological system that has been utilized over the years in addressing fundamental questions of genetic, biomedical and clinical origins. The similarities in genome between man and *Drosophila* have offered a great deal of facility for exploration. This organism offers great experimental advantages in cell and molecular biology. It is possible to understand etiologies and pathogenesis underlying a number of disorders that have been successfully replicated in *Drosophila* system such as neurological, reproductive, gastrointetinal, neuroendocrine and central nervous system disorders. The causative mutations of these disorders can be transgenically introduced, or loss of function mutations can be made for thorough studies in the fly. It is noteworthy that many aspects of *Drosophila* biology and physiology are waiting to be explored by genetics and the new genomic approaches. This fruit fly will be the fruitful model for testing many medicinal herbs, plants and natural products that would furnish the drug development world with novel molecules for management of many disease conditions. It is a promising model organism for the discovery of anti-ageing drugs in the nearest future. *Drosophila* genome sequence and Human genome sequence can offer biomedical scientists in Nigeria and other parts of Africa, greater opportunity to look beyond surface scratching of biological questions, to think outside the box, to explore more in depth analysis of processes, and to answer the "What", "Why" and "How" of research questions of their investigations. Recent studies also showed that this fruit fly is abundant in the northern part of Nigeria in the wild with genetic similarity in the savannah zone described, for domestication for teaching and higher manipulations (AbdulAzeez *et al.,* 2016). The future is bright for *Drosophila* in biological experiments and the various human diseases researches that can be conducted using this simple, beautiful and wealthy model organism. The sky is not the limit for biomedical researchers; they can now contribute to novelties in the quest for knowledge.

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