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Some Aspects of the State-of-the-Arts in Biomedical Science Research: A Perspective for Organizational Change in African Academia

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Summary: In the biomedical sciences, there is need to generate solutions for Africa's health and economic problems through the impact of university research. To guide organizational transformation, the author here presents some aspects of the state-of-the-arts of biomedical science research in advanced countries using a perspective derived from the FASEB journal publications. The author examines the thirty three peer reviewed scientific research articles in a centennial (April 2012) issue of the FASEB Journal [Volume 26(4)] using the following parameters: number of authors contributing to the paper; number of academic departments contributing to the paper; number of academic institutions contributing to the paper; funding of the research reported in the article. The articles were written by 7.97±0.61 authors from 3.46±0.3 departments of 2.79±0.29 institutions. The contributors were classified into four categories: basic sciences, clinical sciences, institutions and centers, and programs and labs. Amongst the publications, 21.2% were single disciplinary. Two tier collaboration amongst any two of the four categories were observed in 16/33 (48.5%) of the articles. Three tier and four tier collaborations were observed amongst 7/33 (21.2%) and 3/33 (9%) of the articles respectively. Therefore 26/33 (78.7%) of the articles were multidisciplinary. Collaborative efforts between basic science and clinical science departments were observed in 9/33 (27.3%) articles. Public funding through government agencies provided 85 out of a total of 143 (59.5%) grants. The collaborative and multidisciplinary nature and government support are characteristic of biomedical science in the US where research tends to result in solutions to problems and economic benefits.

Keywords*:* Organizational Change, Biomedical Science, FASEB, Biomedical Research, Nigeria, Africa

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INTRODUCTION

Ezema (2010) records that Nigeria produces 148/351 or 42.2% of African Journals OnLine's listings, followed by South Africa's 67/351 or 19.1%, the rest of Africa contributing less. Of the 351 journals listed, 107 are in the field of medicine, while the rest are in other sciences and arts. Thus Nigerians are capable of setting a new pace for Africa in the field of biomedical science. Across the world, new patterns have set into biomedical science. These include multidisciplinary and collaborative research and state-of-the-arts utilization of cell biology and molecular biology (John, 2013) with supporting organizational changes (Roush, 1997; Service, 1999; Metzger and Zare, 1999).

To harness this trend for policy making in Nigerian universities and in other African countries, the author here presents a study of the peer-reviewed scientific publications in a centennial issue of the FASEB Journal.

MATERIALS AND METHODS

The FASEB Journal, Volume 26(4), April, 2012 is a publication (FASEB Journal (2012)) of the time-tested Federation of American Societies for Experimental Biology, established in 1912 and celebrating its centenary in 2012 (FASEB Centennial Home Page, 2012). Twenty six of the composite scientific societies are listed in a previous article examining the biomedical science techniques utilized in the articles (John, 2013). From BioxBio.com (2014) website information, the recent impact factors and cites of the FASEB Journal articles are in the Table 1 below.

Table 1. Four-year impact factors of the FASEB Journal

Year	Impact Factor (IF)	Total Articles	Total Cites
2013/2014	5.48	466	41104
2012	5.704	462	39540
2011	5.712	409	38304
2010	6.515	462	38538

In the FASEB centennial year, 2012, the topmost biomedical science journals had the following impact factors for 2011: Nature, 26.28; Cell, 32.4; Science, 31.20 and the FASEB Journal was #26 amongst the thousands of global English-language journals and had maintained a standard within this range for 5 years (Science TechBlog, 2012). The FASEB journal is described as "The Journal That Covers All The

Life Sciences And The Life of Science" (according to the slogan on the inside front cover of the issue studied) (FASEB Journal, 2012).

The thirty three peer reviewed scientific research articles in the April 2012 issue of the FASEB Journal (Volume 26(4): 1413-1763 were studied using the following parameters:

a) Number of authors contributing to the paper
b) Number of academic departments contributing to the paper
c) Number of academic institutions contributing to the paper
d) Funding of the research reported in the article

The frequencies were recorded for each parameter and were tabulated or presented as charts. The means, medians, and modes were generated from Microsoft Excel 2010 functions and the equality of these values for any parameter was used to indicate a uniform population of biomedical science studied and therefore to define the state-of-the-arts of biomedical science in the USA. These findings are used to recommend infrastructural and organizational development for Nigerian and other African institutions seeking excellence as centres of biomedical science research and innovation.

RESULTS

Collaborative Nature of Biomedical Science Research

Table 2 and Figure 1 show that the peer reviewed scientific research articles published in the issue of the FASEB Journal studied (Volume 26(4)) were written by an average of 7.97±0.61 authors from 3.46±0.3 departments of 2.79±0.29 institutions. Of the 33 articles, 2/33 was submitted from a single

Table 2. Some defining parameters of collaborative biomedical science research in the USA gathered from 33 peer reviewed research articles of the April 2012 issue of the FASEB Journal.

	No. of Authors	No. of Departments	No of Institutions
Mean±SEM	7.97±0.61	3.46±0.30	2.79±0.29
Median	7	3	3
Mode	7	2	1

Table 3. Types of departments contributing to the 33 peer reviewed research articles of the April 2012 issue of the FASEB Journal.

1.	Basic science departments	e.g. Department of Molecular and Cell Biology (Kemaladewi *et al.*); Department of Pharmacology and Toxicology (Zuo *et al.*); Department of Immunology (Dancyger *et al.*)
2.	Clinical science departments	e.g. Department of Anesthesiology and Intensive Care Medicine (Mirakaj *et al.*)
3.	Multidisciplinary departments	e.g. Department of Physiology, Anatomy, and Genetics (Levett *et al.)*
4.	Specialized research laboratories	e.g. Integrative Physiology of Exercise Laboratory (Huttermann *et al*); Cell Imaging Laboratory (Zhang *et al.*)
5.	Specialized centres	e.g. Center for Molecular Medicine and Genetics (Huttermann *et al.*); Center for Altitude, Space, and Extreme Environment Medicine (Levett *et al.*)
6.	Research institutes	e.g. Institute of Child Health (Levett *et al.*)
7.	Specialized research group	e.g. Computational Biology and Bioinformatics Group (Tal *et al.*)
8.	Specialized programs	e.g. Vision Science Program (Wang *et al.*); Program in Immunology and Infectious Diseases (Dancyger *et al.*)
9.	Clinics	e.g. Clinic of Anesthesiology, Intensive Care Medicine, and Pain Therapy (Mirakaj *et al.*)

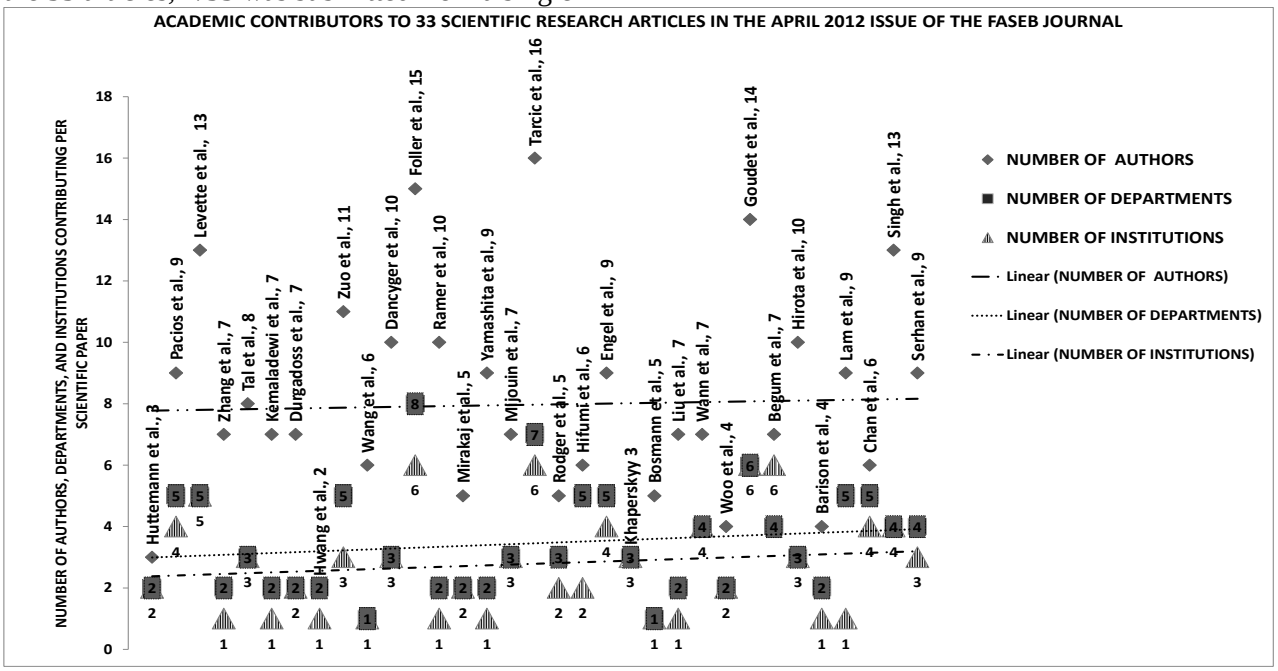

Figure 1. The 33 peer-reviewed research articles published in the April 2012 issue of the FASEB Journal showing some parameters that define collaborative efforts in the USA.

Table 4. Representations of basic science departments as contributors to the 33 peer-reviewed research articles in the April 2012 issue of the FASEB Journal.

BASIC SCIENCE DEPARTMENTS CONTRIBUTING TO 33 PEER REVIEWED SCIENTIFIC RESEARCH ARTICLES OF THE APRIL 2012 ISSUE OF THE FASEB JOURNAL	Huttemann *et al.*	Pacios *et al.*	Levett *et al.*	Zhang *et al.*	Tal *et al.*	Kemaladewi *et al.*	Durgadoss *et al.*	Hwang *et al.*	Zuo *et al.*	Wang *et al.*	Dancyger *et al.*	Foller *et al.*	Ramer *et al.*	Mirakaj *et al.*	Yamashita *et al.*	Mijouin *et al.*	Tarcic *et al.*	Rodger *et al.*	Hifumi *et al.*	Engel *et al.*	Khaperskyy *et al.*	Bosmann *et al.*	Liu *et al.*	Wann *et al.*	Woo *et al.*	Goudet *et al.*	Begum *et al.*	Hirota *et al.*	Barison *et al.*	Lam *et al.*	Chan *et al.*	Singh *et al.*	Serhan *et al.*
department of anatomy			*																														
department of applied chemistry																			*														
department of biochemistry												*																		*			*
department of biochemistry and molecular biology IV																				*													
department of biological regulation																	*																
department of biological sciences											*																						
department of cellular microbiology																													*				
department of cellular stress biology									*																								
department of chemistry																																	
department of craniofacial biology																								*									
department of environmental and molecular toxicology					*																												
department of human and molecular genetics									*																								*
department of immunology									*		*																						
department of microbiology																			*														
department of microbiology and immunology									*												*												
department of molecular and cell biology						*																											
department of neurosciences																									*								
department of pathology		*																				*									*		
department of pathology and laboratory medicine																					*												
department of pharmacology and toxicology									*																					*			
department of physics of complex systems																	*																
department of physiology												*															*						
department of physiology and pharmacology																												*					
department of physiology and medical physics																				*													
department of physiology, anatomy, and genetics			*																														
department of physiology, development, and neuroscience			*																														
department of systems biology																	*																
school of anatomy and human biology																								*									
school of engineering and material science															*																		
second department of anatomy															*																		
TOTAL BASIC SCIENCE DEPARTMENTS PER ARTICLE	0	1	3	0	1	1	0	0	5	0	2	2	0	0	2	0	3	0	2	2	2	1	0	2	1	0	1	1	1	2	1	0	2

department (Bosmann *et al*., Department of Pathology University of Michigan Medical School and Wang *et al.*, Vision Science Program, School of Optometry, University of California, Berkeley). Of the 33 articles, 10/33 were submitted from 2 departments within a discipline or between two disciplines. The remaining 21/33 articles were submitted by contributors from 3 or more departments within a discipline or across disciplines.

Contributing Departments

The types of departments contributing to the biomedical science research articles are listed in Table 3. Work published could be strictly disciplinary

Table 5. Representations of clinical science departments as contributors to the 33 peer-reviewed research articles in the April 2012 issue of the FASEB Journal.

CLINICAL SCIENCE DEPARTMENTS AND DIVISIONS CONTRIBUTING TO 33 PEER REVIEWED SCIENTIFIC RESEARCH ARTICLES OF THE APRIL 2012 ISSUE OF THE FASEB JOURNAL	Huttemann *et al.*	Pacios *et al.*	Levett *et al.*	Zhang *et al.*	Tal *et al.*	Kemaladewi *et al.*	Durgadoss *et al.*	Hwang *et al.*	Zuo *et al.*	Wang *et al.*	Dancyger *et al.*	Foller *et al.*	Ramer *et al.*	Mirakaj *et al.*	Yamashita *et al.*	Mijouin *et al.*	Tarcic *et al.*	Rodger *et al.*	Hifumi *et al.*	Engel *et al.*	Khaperskyy *et al.*	Bosmann *et al.*	Liu *et al.*	Wann *et al.*	Woo *et al.*	Goudet *et al.*	Begum *et al.*	Hirota *et al.*	Barison *et al.*	Lam *et al.*	Chan *et al.*	Singh *et al.*	Serhan *et al.*
department of anatomy with radiology																								*									
clinic of anesthesiology, intensive care medicine and pain therapy					*																												
department of anesthesiology and intensive care medicine														*																			
department of anesthesiology, perioperative and pain medicine																																	
department of endocrinology and diabetes																											*						
department of gastroenterology,hepatology, and endocrinology																																*	
department of internal medicine																																*	
department of medicine																								*									
department of neurology												*																					
department of neurosurgery																				*													
department of nursing																			*														
department of pediatrics																							*								*		
department of periondontics		3*																															
department of periondontology		*																															
division of cardiology				*																													
division of cardiothoracic surgery																														*			
division of colorectal surgery																														*			
division of gastroenterology																														*			
division of hematology and oncology																															*		
division of molecular and cellular neurosciences							*																										
division of neurodegenerative diseases												*																					
experimental and regenerative neuroscience																		*															
medical school university of Crete																											*						
Sackler school of medicine																		*															
second department of internal medicine													*																				
TOTAL CLINICAL SCIENCE DEPARTMENTS PER ARTICLE	0	4	0	1	1	0	1	0	0	0	0	2	1	1	0	0	0	2	1	1	0	0	1	2	0	0	2	0	0	3	2	2	0

but collaborative involving 2 or more departments from different institutions e.g., Pacios *et al*. was a paper contributed by a Department of Periondotics, University of Pennsylvannia, USA, a Department of Periondotics, Universitat Internacional de Catalunya, Spain; a Department of Periondontology, Peking University, China; and a Department of Periondontics, University of Medicine and Dentistry of New Jersey, USA plus a Department of Pathology, University of Pennsylvania, USA

Multidisciplinary Nature of Biomedical Science Research

There were 30 varieties of basic science titled departments (Table 4) amongst contributors to the 33 articles. Out of the 33 articles published, 12 articles did not list any of these basic science departments as contributors, 9 articles include one of these basic science departments as a contributor, and 12 articles list 2-5 of these basic science departments as contributors. In total, the mean number of basic science departments per research article was 1.15±0.2, the mode was 0, and the median was 1.

There were 25 varieties of clinical science titled departments (or divisions) (Table 5). Out of the 33 articles published, 17 articles did not list any of these clinical science departments as contributors, 8 articles include one of these clinical science departments as a contributor, and 8 articles listed 2-4 of these clinical

Table 6. Representations of institutes and centers as contributors to the 33 peer-reviewed research articles in the April 2012 issue of the FASEB Journal.

INSTITUTES AND CENTERS CONTRIBUTING TO 33 PEER REVIEWED SCIENTIFIC RESEARCH ARTICLES OF THE APRIL 2012 ISSUE OF THE FASEB JOURNAL	Huttemann *et al.*	Pacios *et al.*	Levett *et al.*	Zhang *et al.*	Tal *et al.*	Kemaladewi *et al.*	Durgadoss *et al.*	Hwang *et al.*	Zuo *et al.*	Wang *et al.*	Dancyger *et al.*	Foller *et al.*	Ramer *et al.*	Mirakaj *et al.*	Yamashita *et al.*	Mijouin *et al.*	Tarcic *et al.*	Rodger *et al.*	Hifumi *et al.*	Engel *et al.*	Khaperskyy *et al.*	Bosmann *et al.*	Liu *et al.*	Wann *et al.*	Woo *et al.*	Goudet *et al.*	Begum *et al.*	Hirota *et al.*	Barison *et al.*	Lam *et al.*	Chan *et al.*	Singh *et al.*	Serhan *et al.*
A. A. Martinos center for biomedical imaging																										*							
Beatrice Hunter cancer research institute																															*		
center for altitude, space, and extreme environment medicine						*																											
center for experimental therapeutics and reperfusion injury																											*						
center for human and clinical genetics	*																																
center for molecular medicine and genetics							*																										
center for neuroscience																																	*
Dana-Faber cancer institute																																	
Forschergruppe 923 institute fur pharmakologie und toxiologie												*																					
German center for neurodegenerative diseases												*																					
Hertie-institute for clinical brain research																																*	
Instituo de investigacion sanitaria del hospital clinico san carlos																				*													
instituo de neuroquimica de la UCM																										*							
institut de genomique fonctionelle			*																														
institute for sport, exercise, and health																										*							
institute national de lasante et de la recherche medical			*																														
institute of child health																	*																
institute of molecular biology and biotechnology													*																				
institute of toxicology and pharmacology			*																														
instutute for human health and performance	*																																
Liggins Institute																																	*
Loker hydrocarbon research institute																												*					
national research center for growth and development											*																						
research center for applied medical engineering																	*																
Sheba cancer research center					*																												
TOTAL INSTITUTES AND CENTERS PER ARTICLE	2	0	3	0	1	1	1	0	0	0	1	2	1	0	0	0	2	0	0	1	0	0	0	0	0	3	1	1	0	0	1	1	2

science departments as contributors. In total, the mean number of clinical science departments per research article was 0.82±0.18, the mode was 0, and the median was 0.

There were 25 varieties of institutes and centres (Table 6). Out of the 33 articles published, 17 articles did not list any of these institutes and centres as contributors, 10 articles include one of these institutes and centres as a contributor, and 6 articles listed 2-3 of these institutes and centres as contributors. In total, the mean number of institutes

Table 7. Representations of specialized programs and laboratories as contributors to the 33 peer-reviewed research articles in the April 2012 issue of the FASEB Journal.

PROGRAMS AND LABORATORIES CONTRIBUTING TO 33 PEER REVIEWED SCIENTIFIC RESEARCH ARTICLES OF THE APRIL 2012 ISSUE OF THE FASEB JOURNAL	Huttemann *et al.*	Pacios *et al.*	Levett *et al.*	Zhang *et al.*	Tal *et al.*	Kemaladewi *et al.*	Durgadoss *et al.*	Hwang *et al.*	Zuo *et al.*	Wang *et al.*	Dancyger *et al.*	Foller *et al.*	Ramer *et al.*	Mirakaj *et al.*	Yamashita *et al.*	Mijouin *et al.*	Tarcic *et al.*	Rodger *et al.*	Hifumi *et al.*	Engel *et al.*	Khaperskyy *et al.*	Bosmann *et al.*	Liu *et al.*	Wann *et al.*	Woo *et al.*	Goudet *et al.*	Begum *et al.*	Hirota *et al.*	Barison *et al.*	Lam *et al.*	Chan *et al.*	Singh *et al.*	Serhan *et al.*
cell and imaging laboratory			*																														
human biology																*																	
IFR 136 agents transmissibles et infectiologie																				*													
integrative physiology of exercise laboratory																			*														
Japan science and technology agency-core research for evolutional science and technology																										*							
laboratoire de chimie et biochemie pharmacologiques et toxocologiques																										*							
laboratoire de neurobiologie de la cognition								*																									
laboratory of signal transduction																										*							
labotatoire de pharmacologie et biochimie de la synapse																											*						
MatTek corporation																												*					
Meakins-Christie laboratories																	*																
Program in immunology and infectious diseases																													*				
protein purification core facility																			*														
section of molecular oncology and immunotherapy																																	*
sensory plasticity laboratory																	*																
skeletal biology laboratory																*																	
unite des interactions bacteries-cellules																		*															
unite mixte de recherche 7102																*																	
UR1282 infectiologie animale et sante public										*																							
vision science program																									*								
world class university neurocytomics program																							*										
accelrys SARI																					*												
cell and gene therapy research group				*																													
child and youth health														*																			
computational biology and bioinformatics																															*		
TOTAL PORGRAMS AND LABORATORIES PER ARTICLE	0	0	1	1	0	0	0	1	0	1	0	0	0	1	0	3	2	1	2	1	1	0	1	0	1	3	1	1	1	0	1	0	1

and centres per research article was 0.73±0.16, the mode was 0, and the median was 0.

There were 25 varieties of programs and laboratories (Table 7). Out of the 33 articles published, 14 articles did not list any of these programs and laboratories as contributors, 15 articles include one of these programs and laboratories as a contributor, and 4 articles listed 2-3 of programs and laboratories as contributors. In total, the mean number of programs and laboratories per research article was 0.76±0.14, the mode was 1, and the median was 1.

The collaborative activities were analysed in 4 tiers (Table 8): one tier collaboration amongst basic science departments, amongst clinical science departments, amongst institutes and centres, or amongst programs and special labs were observed in 7/33 (21.2%) publications. Therefore 21.2% of the studies were single disciplinary. Two tier collaboration amongst any two of the four categories were observed in 16/33 (48.5%) of the articles. Three tier collaboration amongst any three of the four categories were observed amongst 7/33 (21.2%) of the articles. Four tier collaboration amongst the four categories were observed in 3/33 (9%) of the articles. Therefore 26/33 (78.7%) of the articles were multidisciplinary involving two-tier, three-tier, or

Table 8. The 33 peer-reviewed research articles in the April 2012 issue of the FASEB Journal showing collaborations across four tiers of disciplines.

	Huttemann *et al.*	Pacios *et al.*	Levett *et al.*	Zhang *et al.*	Tal *et al.*	Kemaladewi *et al.*	Durgadoss *et al.*	Hwang *et al.*	Zuo *et al.*	Wang *et al.*	Dancyger *et al.*	Foller *et al.*	Ramer *et al.*	Mirakaj *et al.*	Yamashita *et al.*	Mijouin *et al.*	Tarcic *et al.*	Rodger *et al.*	Hifumi *et al.*	Engel *et al.*	Khaperskyy *et al.*	Bosmann *et al.*	Liu *et al.*	Wann *et al.*	Woo *et al.*	Goudet *et al.*	Begum *et al.*	Hirota *et al.*	Barison *et al.*	Lam *et al.*	Chan *et al.*	Singh *et al.*	Serhan *et al.*	
TOTAL BASIC SCIENCE DEPARTMENTS PER ARTICLE	0	1	3	0	1	1	0	0	5	0	2	2	0	0	2	0	3	0	2	2	2	1	0	2	1	0	1	1	1	2	1	0	2	
TOTAL CLINICAL SCIENCE DEPARTMENTS PER ARTICLE	0	4	0	1	1	0	1	0	0	0	0	2	1	1	0	0	0	2	1	1	0	0	1	2	0	0	2	0	0	3	2	2	0	
TOTAL INSTITUTES AND CENTERS PER ARTICLE	2	0	3	0	1	1	1	0	0	0	1	2	1	0	0	0	2	0	0	1	0	0	0	0	0	3	1	1	0	0	1	1	2	
TOTAL PORGRAMS AND LABORATORIES PER ARTICLE	0	0	1	1	0	0	0	1	0	1	0	0	0	1	0	3	2	1	2	1	1	0	1	0	1	3	1	1	1	0	1	0	1	
basic-clinical collaboration		*			*							*							*	*				*			*			*	*			9
1 tier collaboration	#							#	#	#					#	#						#												7
2 tier collaboration		&		&		&	&				&		&	&				&			&		&	&	&	&		&	&		&		16
3 tier collaboration			@		@							@					@		@									@					@		7
4 tier collaboration																				$							$				$				3
																																		TOTALS

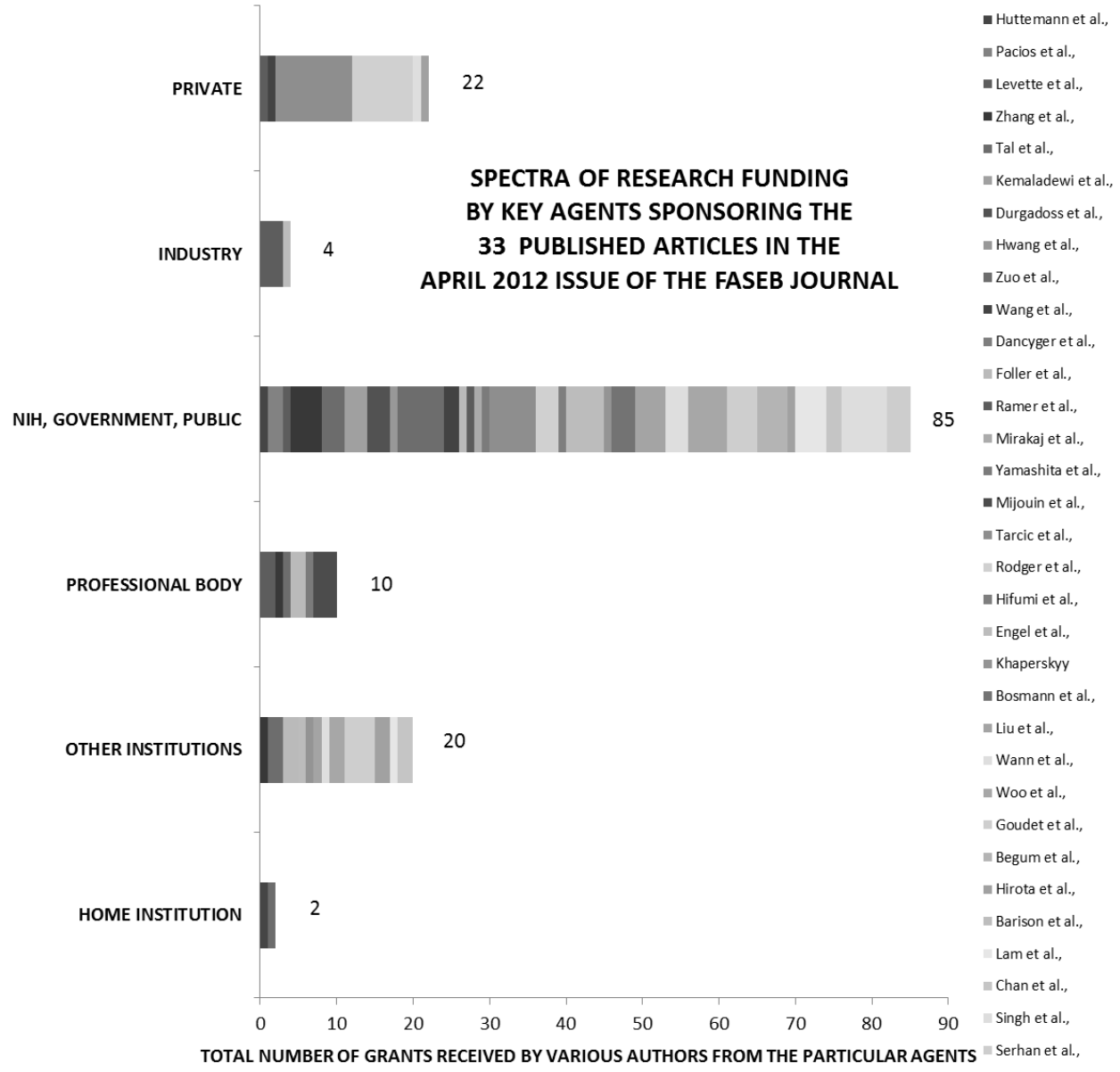

Figure 2. A Perspective of funding of biomedical science research in the USA from articles published in the April 2012 issue of the FASEB Journal.

Table 9. Number of grant support per research article in the April 2012 issue of the FASEB Journal

Authors	Total Funding
Huttemann *et al.,*	2
Pacious *et al.,*	2
Levette *et al.,*	7
Zhang *et al.,*	6
Tal *et al.,*	4
Kemaladewi *et al.,*	3
Durgadoss *et al.,*	3
Hwang *et al.,*	1
Zuo *et al.,*	9
Wang *et al.,*	3
Dancyger *et al.,*	0
Foller *et al.,*	5
Ramer *et al.,*	1
Mirakaj *et al.,*	1
Yamashita *et al.,*	2
Mijouin *et al.,*	3
Tarcic *et al.,*	16
Rodger *et al.,*	11
Hifumi *et al.,*	1
Engel *et al.,*	7
Khapersky *et al.,*	2
Bosmann *et al.,*	3
Liu *et al.,*	5
Wann *et al.,*	5
Woo *et al.,*	7
Goude *et al.,*	8
Begum *et al.,*	4
Hirota *et al.,*	4
Barison *et al.,*	0
Lam *et al.,*	5
Chan *et al.,*	4
Singh *et al.,*	6
Serhan *et al.,*	3

four-tier collaboration. Collaborative efforts between basic science and clinical science departments were observed in 9/33 (27.3%) articles.

Funding of Research

A total of 143 grants produced the 33 published research articles. The major categories of sponsors of the research articles are shown in Figure 2. Public funding directly through government agencies provided 85 grants out of the total of 143 grants (59.5%). Private funding provided 22/143 grants (15.39%), other institutions provided 20/143 grants (14%), and professional bodies provided 10/143 grants (7%). The Industry contributed 4/143 grants (2.8%) and home institutions contributed 2/143 grants (1.4%). Table 9 shows the number of funding support per research article. The list is according to stated sponsors. Two papers did not list sponsors but were from specialized institutes, the institutes being government owned. Number of grants per article ranged from 1-16, the mean being 4.3, the mode being 3, and the median being 4.

DISCUSSION

The study of the 33 peer-reviewed research articles of the April 2012 issue of the FASEB Journal shows that each paper was produced by collaborative efforts of authors from separate departments within the same discipline or between different disciplines. About seven authors and 3 departments usually contribute to such publications delivering various types of evidence that help to answer the questions being asked in the investigations.

For **number of authors**: the mean was 7.97±0.61, the median was 7 and the mode was 7 therefore authors who wish to write good state-of-the-arts biomedical science research reports can use this popular trend as a guide: to *involve about half a dozen collaborators/co-authors/experts*.

For **number of departments** and number of institutions the mean, mode, and median did not coincide reflecting a definite diversity using this parameter. The *multiplicity of departments and institutions* (Table 2, Figure 1) can be another guide for researchers embarking on a study. While only two studies were submitted by contributors from a single department, 31/33 articles were submitted by contributors from 2 or more departments within a discipline or across disciplines and within an institutions or across institutions.

The contributing departments include traditional basic and clinical science departments [Table 3,(1.) and (2.)] as well as a variety of diverse, specialised, and innovative research outfits [Table 3, (3.)–(9.)] showing a shift from traditional subject departments in various cases. In Nigerian and other African universities, while traditional basic and clinical science subject departments are needed as important subject teaching turfs, there may be need for *innovation of numerous and diverse specialized research outfits with specific developmental goals*, similar to or different from those we see in Table 3. This may be a significant part of any effort towards specific research that serves national health and economic needs more. The present analysis revealed co-existence of departments with traditional disciplines and departments that make a diversion from traditional turfs in developed countries. Amongst the contributing departments were basic science departments, clinical science departments, multidisciplinary departments, specialized research laboratories, specialized centers, research institutes, specialized groups, and clinics as stated in the Results (Tables 3, 4, 5, 6, and 7). This reflects **organizational innovations** to facilitate research interests. Specially organized research activity can

also attract specific sponsors that have a focus on particular interests.

Infrastructural and organizational deficiencies are well recognized in Nigeria and other parts of Africa (John, 2009, 2010, 2012a). As seen in the results, collaboration in developed countries goes across national borders and this aspect may also need to be better addressed in African sub-regions. **Pan-African research** collaborative efforts may help offset the hindering aspects of poverty and low funding across Africa and provide a platform for combining resources and a potential for more successful research.

Beyond Pan-African collaborations, Nigerian and other African researchers can find long-term support in the sophisticated research outfits of advanced countries in Europe and Asia as well as in the USA and Canada. Noteworthy amongst the 33 articles is collaboration that extends *beyond continental boundaries*. For example, Pacios *et al*., was a collaboration between periondontics researchers in the USA, Spain, and China and Tarcic *et al*., was a collaboration by multidisciplinary researchers in USA, Israel, and Greece. Therefore, for Africans also, **global support** through the extension of roles and sharing of topic expertise, technical knowhow, sophisticated research procedures, expensive and high-maintenance equipment and infrastructure, and materials and supplies can allow African researchers to embark on and complete ambitious and profitable investigations which they cannot afford to do on their own.

While research funding in the USA appears to be largely dependent on the government (Figure 2), this kind of support may not be possible in African nations that do not enjoy lasting political stability. Seventeen years ago, the author of this article was a beneficiary of a grant of $10,000.00 from the Organization of African Unity Scientific and Technical Research Committee, a well-organized, high achieving organization that gave out research grants regularly to individual African scientists from different fields. This committee no longer exists because the OAU was disbanded on July 9th, 2002 and replaced by the African Union. The African Union has a Human Resources, Science, and Technology Commission but had, by 2012, only been able to make two calls for award of research grants, one in 2012 and for 3 specific topics: post-harvest and agriculture, sustainable energy, and sanitation (African Union, 2012). Thus biomedical science was not yet one of its out reaches. Where once Africans have tried to set up appropriate research collaborations, political instability or changes may have been the bane of such efforts. Nigerian and other African scientists indeed need to find ***sustainable means*** of continuous scientific collaborations and funding which cannot be disturbed by any political climate and which is resistant to negating economic factors. The professional bodies such as The West African Society for Pharmacology (WASP/SOAP 2012) and The West African Health Organization (WAHO 2012) may need to generate private funds, independent of governments, to distribute to individuals or groups competitively for research.

Tables 4-7 show that *biomedical science research* is being done by diverse departments which can be grouped into: basic science departments, clinical science departments, institutes and centers, and specialized programs and laboratories. This can only be possible if there are basic scientists working in clinical departments, institutes, and specialized programs and laboratories as well as if there are physician scientists who not only work in clinics but actually do bench research like the basic scientists do. The author of this article was a PhD Pharmacologist, working for a few years as an assistant professor in a clinical department, a neonatology unit, in the USA. This is a common occurrence in the USA. Of the 33 articles studied in this report, twelve articles did not list a basic science department as contributor therefore the biomedical science research was done beyond basic science turf. In the USA, for the sake of collaborative, multidisciplinary research supported by grant awarding bodies, efforts have been made to reduce departmental territoriality and promote **employment of a diversity of researchers** as needed in respective research outfits (Roush, 1997; Service, 1999, Metzger and Zare, 1999).

Apart from the departmental collaborations within disciplines, we see departmental collaborations across disciplines. Table 8 shows that only 21.2% of the publications were from contributors from a single discipline and 78.7% of the publications were by multidisciplinary collaborations. This reflects the fact that *much of biomedical science research is* ***topic-based research*** (cancer, HIV-AIDS, effects of hypoxia, lung function, etc.) rather than subject based (anatomy, physiology, biochemistry, pathology, microbiology, paediatrics, surgery, etc.). Research thus appears to be done to find solutions to prevailing societal health problems and to support existing clinical needs or to produce marketable services and products according to the aims of sponsors. The involvement of subject disciplines in any study appears to be as needed and without discrimination or rigidity of subject boundaries. Two-tier collaboration was most common (48.5%) and four tier collaborations were least common (9%) indicating that *collaboration is not an end but a means*. About a quarter (27.3%) of collaborations were between basic science and clinical science departments and the

majority of collaborations extend the diversity amongst institutes and centers and specialized programs and laboratories.

This analysis of research funding shows that the home institutions possibly contributed the least funds (1.4%) to the research work emanating from themselves. **Abundant local funding** (59.5%) is from organized government functionaries and their grant awarding bodies. The involvement of specially organized governmental research funds awarding organizations that award research money routinely and competitively shows that *much of the research is actually guided towards national interests.* In Africa, more government involvement in research direction and funding is necessary to obtain good long-term solutions that meet local health and economic needs. Since *academic freedom* is an important aspect of research, researchers also need to be able to obtain funding for their own *curiosity research* interests different from those directed by government interests. From these results, the availability of funding from private sectors (15.39%), other institutions (14%), and professional bodies (7%) makes it possible for scientists to seek funding from preferred sponsors according to scientists' research interests or research focus. Interestingly, industry appears to produce 2.8% of the total funding in these publications.

The apparent low contribution by industry to funding of published biomedical science as seen in this investigation may reflect corporate and private-interest policies of discretion and non-publication of profitable research, powerful research, secret research, or questionable research (Resnik, 1998, 2006a; Levine, 1988; Krimsky 2003). It is well recognized that: **"**Modern science is big business. Governments, universities, and corporations have invested billions of dollars in scientific and technological research in the hope of obtaining power and profit. For the most part, this investment has benefited science and society, leading to new discoveries, inventions, disciplines, specialties, jobs, and career opportunities. However, there is a dark side to the influx of money into science. Unbridled pursuit of financial gain in science can undermine scientific norms, such as objectivity, honesty, openness, respect for research participants, and social responsibility" (Resnik, 2006b). Apart from the issue of trade secrets, some of industry sponsored research is clinical research and may be held from publication because of protection of confidentiality (Shamoo and Resnik, 2003) required by the Privacy Rule of the Healthcare Information Portability and Accountability Act (HIPAA). Of course, amongst these articles studied, there may be no classified research even though it is known that: "The U.S. government spends more on military and national security research than all other types of research combined" (Kintish and Mervis 2006).

Collaborations with advanced countries can help to gain the exposure needed to attract significant **foreign funding.** As mentioned above, amongst the studies analysed, Pacios *et al.* (2012) was from collaborations between the USA, China, and Spain and Tarcic *et al.* (2012) was from collaborations between the USA, Israel, and Greece. The former paper was sponsored by two US grants from the US National Institute of Dental and Craniofacial Research. The latter paper was sponsored by 3 grants from the US National Cancer Institute, plus grants from The European Commission, The German-Israeli Project Cooperation, The Israel Cancer Research Fund, the Dr. Miriam and Sheldon G. Adelson Medical Research Foundation, the Kekst Family Institute for Medical Genetics, the Kirk Center for Childhood Cancer and Immunological Disorders, the Women's Health Research Center funded by the Bennett-PrItzker Endowment Fund, the Marvelle Koffler Program for Breast Cancer Research, the Leir Charitable Foundation, the M.D. Moross Institute for Cancer Research, and The Susan G. Komen Foundation while two of the contributors' professorial chairs were endowed by sponsors: Harold and Zelda Goldenberg and Henry J. Leir.

SPECULATION

In advanced countries such as the USA, biomedical science research, as published in the 33 peer reviewed research articles in a centennial (April 2012) issue of the FASEB Journal is characterized by ***collaborative efforts*** amongst about 7 investigators, typically from 2 or more departments of 2 or more institutions which may include different countries. Biomedical science research in the USA is typically ***multidisciplinary*** involving 2 or more basic medical sciences, clinical sciences, or both or innovative research organizations. Biomedical science research in the USA is heavily ***funded by government*** agencies. While biomedical science in the USA may not be a model in every respect (John, 2011, 2012b), these factors may benefit Nigerian and other African biomedical scientists and researchers as they try to forge ahead for better results in biomedical science. *Well-funded, collaborative, and multidisciplinary organization of research projects may be a means to national progress and development.*

CONCLUSION

From the present study, ideas arising for organizational change towards transformative academic biomedical science research in Nigeria and other African countries are: a) cross-territorial topic-based in addition to territorial subject-based biomedical science research; b) generation of novel

academic research outfits; c) involving several diversified experts from different departments in a study; d) involving collaborating departments, institutions, and countries in particular studies; e) sharing of organizational resources to support transformative research; f) sustainable means of continual funding and resource generation; g) structures for sufficient local funding, especially from governments; and h) global support. These are, perhaps, some of the important tasks for the present day Nigerian, indeed African, academic in the field of biomedical science to accomplish or improve and to consider in faculty development and organizational change exercises.

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