





CURRICULUM DEVELOPMENT AND ASSESSMENT

PhysioCAFUN: a competency-based curriculum development guideline to strengthen physiology education in Africa

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Abstract

Physiology education in Africa faces challenges due to gaps in curricula across many of its universities, such as divergent content, a lack of standardized competencies, and suitable benchmarking. Here, we describe the development of the Physiology Curriculum for African Universities (PhysioCAFUN), a competency-based curriculum development guideline, as a first step to address such shortcomings. A committee of 15 physiologists from different African regions, Europe, and the United States was constituted to draft the PhysioCAFUN, which was introduced and revised during the joint East African Society of Physiological Sciences (EASPS) and African Association of Physiological Sciences (AAPS) conference held in Tanzania late 2023. The PhysioCAFUN consists of 23 modules. *Modules 1–15* cover the organ systems, including principles and concepts of physiology, molecular biology, and cell physiology. *Modules 16–23* contain optional content, including environmental physiology, pharmacology, and topics related to skill development. PhysioCAFUN serves as a freely available resource document for African stakeholders regarding the desired undergraduate physiology training and competencies. It will help universities in Africa, and elsewhere to draft a curriculum suitable for their local needs where there is a dearth of physiologists or to benchmark and revise their curricula where physiology programs are already in place.

NEW & NOTEWORTHY We described the development of Physiology Curriculum for African Universities (PhysioCAFUN), a competency-based curriculum development guideline to promote physiology education in Africa. This freely accessible resource document should help African universities where there is a dearth of physiologists and thus aid in drafting a curriculum suitable for their local needs. Likewise, it should assist universities globally where physiology programs are already in place to benchmark and/or revise their curriculum as may be needed.

African universities; competencies; competency-based curriculum; physiology education



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INTRODUCTION

Physiology has been recognized as the basis for clinical medicine for centuries, but it was not until the mid-19th century that physiology courses became a formal part of medical education (1). About the same time, physiology became a scientific profession, marked by the rise of research laboratories and academic departments offering graduate degrees in Europe and the Americas. Africa has not kept up with the growth of professional physiology training, however, and only a few countries and a relatively small number of universities currently offer physiology as a degree program (Table 1). An alarmingly high number of African higher institutions do not yet have a physiology program, either at the undergraduate or postgraduate levels, and as a result, the number of trained graduates is insufficient for the emerging need for physiologists as researchers and educators.

One barrier to increasing the number of African physiology programs may be the lack of well-developed and defined physiology curriculum outcomes to guide training. Education in Africa exhibits relatively large intra- and intercountry variations, making it difficult to have uniform learning outcomes in physiology teaching and learning, or to professionalize the discipline. As a first step to address this problem, a collaboration of physiologists working through the East African Society of Physiological Sciences (EASPS) and the African Association of Physiological Sciences (AAPS) established a committee to develop a comprehensive set of competency-based learning outcomes for physiology education. The Physiology Curriculum for African Universities (PhysioCAFUN) is intended to serve as a guideline for the development or evaluation of physiology curricula across a wide spectrum of institutions in Africa, with potential applicability to programs in other regions of the world.

Universities offering health sciences differ in their curricular structure. Some use an integrated system-based curriculum, consisting of teaching blocks by organ system. This design facilitates integration of anatomy, physiology, biochemistry, pharmacology, and other basic science disciplines to solve problems associated with each organ system. Other institutions use a more traditional, discipline-based curriculum that delivers each of these disciplines as separate subjects or modules (2). One disadvantage of teaching the disciplines separately is that students become less aware of the relevance of physiology to other basic sciences and to clinical practice (3).

Studies have reported that students taught in an integrated system-based curriculum performed better than those following a discipline-based one (4, 5), because the integration of disciplines reduces the sense of fragmentation and information overload (5) and promotes critical thinking, self-learning ability, deep learning, and clinical problem-solving skills (6–8). At the same time, however, adequate allocation of time for physiology content in the system-based integrative approach is a major challenge, leading to superficial learning of the discipline (9). Furthermore, the importance of general physiological principles is often underrepresented in integrated curricula, which results in students forming negative attitudes toward physiology. Student attitude correlates with academic performance, as those students with positive attitudes (toward their studies) perform better (10–

12). Thus careful design of the content and learning outcomes of physiology teaching modules is important, no matter what the curricular structure.

A second factor the PhysioCAFUN committee needed to consider was the relatively recent shift from traditional knowledge-based curricula to competency-based or outcome-based curricula that support not only knowledge acquisition but also the development of the skills and attitudes needed to function in modern-day economies. Competency-based curricula address the demands of real-world practice, where each situation is unique and needs a high level of decision-making based on appropriate, up-to-date knowledge (13).

Competency-based curriculum design begins with clear documentation of what the students must know and be able to do at the end of the learning period. It must then cascade to the development of teaching and learning content and assessments to ensure that the expected outcomes are acquired by the students (14). Moreover, teaching and learning practices must show direct relevance (authentic learning) to clinical and wider practices because patient and public safety need a sound foundational knowledge-based practice (15). Such an approach is needed to enhance students' attitudes toward physiology, one of the goals of our effort to develop physiology curriculum guidelines.

We wish to emphasize that the PhysioCAFUN modular contents are suggestions and not mandates that must be covered. Curriculum design is a task under the control of each autonomous university and its supervising accreditation bodies. In addition, the content of PhysioCAFUN is far more comprehensive than any one program (except perhaps a Bachelor in Physiology) will be able to include in its typical course offerings. It is therefore a pliable document, and it is up to adopters, institutions, programs, and/or instructors to first define the knowledge, skills, and behaviors that they wish their graduates to achieve. They can then select specific outcomes to match content that will be included in their respective curricula.

MATERIALS AND METHODS

On September 12, 2023, a technical committee of 15 physiologists (who are the authors of this study) was constituted to produce a draft of the PhysioCAFUN. The draft was benchmarked against the Federation of European Physiological Societies (FEPS) document “Minimum standard and learning outcomes in physiology required by the Bologna process: end-terms of physiology in a medical curriculum” produced in 2010 (16) and the 2023 Human Anatomy and Physiology Society (HAPS) Physiology Learning Outcomes (17). The committee worked remotely and arranged several virtual meetings to achieve their mandates. The draft document was thereafter submitted to Professors Dee Silverthorn and Faadiel Essop for review and further refinements, with a greater emphasis now placed on outcomes-based curricular guidelines. After such critical inputs, the final version was jointly presented by Professors Abdullateef Alagbonsi (EASPS President) and Faadiel Essop (AAPS President) during the joint conference co-organized by the East African Society of Physiological Sciences (EASPS) and the African

Table 1. Availability of physiology degree programs in some African countries as of December 2023^a

S/No.	Country	Number of Universities with Physiology Program(s)	Name of Universities with Physiology Program at Undergraduate and/or Postgraduate Levels	Level of Program Available in the Country ^b
1	Rwanda	0 ^c		
2	The Gambia	0		
3	Somalia	0		
4	Tunisia	0 ^d		
5	Tanzania	1	Muhimbili University of Health and Allied Sciences	i. M.Sc. ii. Ph.D.
6	Zimbabwe	1	University of Zimbabwe	i. M.Sc. ii. Intercolated B.Sc.
7	Benin	1	University of Abomey Calavi	i. M.Sc. ii. Ph.D.
8	Namibia	1	University of Namibia	i. M.Sc. ii. M.Phil. iii. Ph.D.
9	Zambia	1	i. University of Zambia	i. M.Sc.
10	Senegal	2	i. Université Cheikh Anta Diop de Dakar ii. Université Iba Der Thiam de Thiès	i. M.Sc. ii. Ph.D.
11	Ivory Coast	2	i. Université Félix Houphouët Boigny Abidjan ii. Université Alassane Ouattara de Bouaké	i. B.Sc. (intercalated) ii. M.Sc. iii. Ph.D.
12	Burkina Faso	2	i. Université Nazi Boni de Bobo Dioulasso ii. Université Joseph Ki Zerbo	i. B.Sc. ii. M.Sc.
13	Uganda	3	i. Makerere University ii. Mbarara University of Science and Technology iii. Kampala International University	i. B.Sc. ii. M.Sc. iii. Ph.D.
14	Kenya	3	i. University of Nairobi ii. Jomo Kenyatta University of Agriculture and Technology iii. Maseno University	i. B.Sc. (intercalated) ii. M.Sc. iii. Ph.D.
15	Ethiopia	4	i. Addis Ababa University ii. Arbaminch University iii. Jimma University iv. Gondar University	i. M.Sc. ii. Ph.D.
16	Sudan	4	i. Alneelain University ii. University of Khartoum iii. International University of Africa iv. National Ribat University	i. M.Sc. ii. Ph.D.
17	South Africa	11	i. University of Cape Town ii. Stellenbosch University iii. University of Pretoria iv. North West University v. University of Johannesburg vi. Nelson Mandela University vii. Walter Sisulu University viii. University of Limpopo ix. University of KwaZulu-Natal x. University of the Witwatersrand xi. Sefako Makgatho University	i. B.Sc. ii. M.Sc. iii. Ph.D.
18	Egypt ^e	27 public universities	i. Cairo University ii. Alexandria University iii. Ain Shams University iv. Assiut University v. Tanta University vi. Mansoura University vii. Zagazig University viii. Helwan University ix. Menia University x. Menoufia University xi. Suez Canal University xii. South Valley University xiii. Benha University xiv. Fayoum University xv. Beni Suef University xvi. Kafr Elsheikh University xvii. Sohag University xviii. Port Said University xix. Damanhour University xx. Aswan University	i. B.Sc. (double major, which includes physiology and another related major) ii. M.Sc. iii. Ph.D.

Continued

Table 1.— Continued

S/No.	Country	Number of Universities with Physiology Program(s)	Name of Universities with Physiology Program at Undergraduate and/or Postgraduate Levels	Level of Program Available in the Country ^b
19	Nigeria ^f	45	xxi. Damietta University	
			xxii. Sadat City University	
			xxiii. Suez University	
			xxiv. Arish University	
			xxv. New Valley University	
			xxvi. Matrouh University	
			xxvii. Luxor University	
			i. University of Ibadan, Ibadan	i. B.Sc.
			ii. University of Nigeria, Nsukka	ii. M.Sc.
			iii. Ahmadu Bello University	iii. M.Phil.
			iv. University of Lagos	iv. Ph.D.
			v. University of Benin	v. M.D.
			vi. Bayero University, Kano	
			vii. University of Calabar	
			viii. University of Ilorin	
			ix. University of Port-Harcourt	
			x. Federal University of Technology, Akure	
			xi. University of Uyo	
			xii. Nnamdi Azikiwe University, Awka	
			xiii. Federal University, Dutse	
			xiv. Alex Ekwueme Federal University, Ndufu-Alike	
			xv. Rivers State University, Port-Harcourt	
			xvi. Ambrose Alli University, Ekpoma	
			xvii. Abia State University, Uturu	
			xviii. Olabisi Onabanjo University, Ago-Iwoye	
			xix. Ekiti State University, Ado-Ekiti	
			xx. Lagos State University, Ojo	
			xxi. Ladoke Akintola University of Science and Technology, Ogbomoso	
			xxii. Benue State University, Makurdi	
			xxiii. Delta State University, Abraka	
			xxiv. Chukwuemeka Odumegwu Ojukwu University, Uli	
			xxv. Ebonyi State University, Abakaliki	
			xxvi. Gombe State University	
			xxvii. Cross River University of Science and Technology, Calabar	
			xxviii. Osun State University, Osogbo	
			xxix. Bauchi State University, Gadau	
			xxx. Yusuf Maitama Sule University, Kano	
			xxxi. Babcock University, Ilisha-Remo	
			xxxii. Madonna University, Okija	
			xxxiii. Igbinedion University, Okada	
			xxxiv. Bowen University, Iwo	
			xxxv. Redeemers University, Ede	
			xxxvi. Bingham University, Karu	
			xxxvii. Lead City University, Ibadan	
			xxxviii. Novena University, Ogume	
xxxix. Afe Babalola University, Ado-Ekiti				
xl. Baze University, Abuja				
xli. Adeleke University, Ede				
xlii. Gregory University, Uturu				
xliii. Ondo State University of Medical Sciences				
xliv. Arthur Jarvis University, Akpabuyo				
xlv. Pamo University of Medical Sciences, Port-Harcourt				

B.Sc., Bachelor of Science; M.D., Doctor of Medicine (equivalent of Ph.D.); M.Phil., Master of Philosophy; M.Sc., Master of Science; Ph.D., Doctor of Philosophy. ^aThe presented data are not a complete reflection of the availability of physiology programs in all the African countries. We presented those that we are aware of at the moment. ^bThe programs are based on what is available in the country, not what each university has. Some universities have only Bachelor, Master of Science (M.Sc.) or Doctor of Philosophy (Ph.D.) or all as the case may be. ^cUniversity of Rwanda was recently accredited for M.Sc. in Physiology after the launch of Physiology Curriculum for African Universities (PhysioCAFUN), while University of Global Health Equity (UGHE) was also inspected for M.Sc./Ph.D. program in Biomedical Sciences with a Physiology Exit track. ^dA university offers Physiology and functional exploration course as a specialty in Medicine with 4 years of residency program. ^eData sourced from the website of the Ministry of Higher Education and Scientific Research, Egypt. To the best of our knowledge, all public universities, through their colleges of science, offer Physiology degrees at undergraduate and postgraduate levels. The departments of physiology in the colleges of medicine in the same universities are responsible for teaching physiology courses to students in other professional programs like Medicine, Nursing, Pharmacy, Dentistry, and Physiotherapy as a foundational science. In addition, the Colleges of Medicine offer postgraduate physiology programs (M.Sc. and Ph.D.) in medical physiology. We are also aware that private universities only teach physiology courses to medical and health-allied students without running it as a degree program. ^fData concern only Bachelor of Science program in Physiology as published by the National University Commission (NUC), Nigeria. Many Universities in Nigeria have M.Sc. and Ph.D. programs in Physiology, but their exact number is not reported on the NUC website.

Association of Physiological Sciences (AAPS) held in Tanzania between November 29 and December 10, 2023. This was a highly successful conference (18) that marked the beginning of pragmatic efforts to promote physiology education, research, and practice in East Africa and beyond (19). After inputs made by congress members (from 24 countries), the draft PhysioCAFUN was ratified. The final version of PhysioCAFUN has since become an official resource document and can be accessed on the AAPS website (20).

RESULTS

The PhysioCAFUN document is a blend of modules that will train graduates to achieve the following goals:

- 1) A high level of understanding of the current models of normal function of the human body;
- 2) A high level of understanding of the pathophysiological basis of diseases affecting various body systems;
- 3) Appropriate skills for carrying out clinical measurements, interpreting them in various disorders of the body systems, and monitoring therapeutic efficacy;
- 4) Knowledge and skills to participate in the diagnostic process by supporting clinicians in noninvasive clinical measurements;
- 5) Highly developed communication skills and ethical conduct that will optimize the results of clinical measurements and patient counseling;
- 6) Management and practical skills needed to participate actively in research collaboration and execution;
- 7) Adequate knowledge and skills to pursue doctoral studies and carry out high-profile research in medical sciences; and
- 8) Competence in physiology education and biomedical sciences to teach undergraduate students the required knowledge of physiology.

The PhysioCAFUN document begins with 12 general learning outcomes that form the basis of the competencies expected from students at the completion of their physiology program. These program-level outcomes are broad and range from acquisition and application of knowledge to communication and technical skills as well as behaviors such as global citizenship, teamwork, and leadership (Table 2). Each of the 23 PhysioCAFUN modules is keyed to the general outcomes covered in that module, as shown in Table 3.

The content of all 23 modules reflects the goals and general learning outcomes agreed upon by the committee. In the first 15 organ system modules, broad content learning outcomes were constructed so that adopters could decide for themselves what level of detail is appropriate for their students and circumstances. Adopters may also choose to skip some outcomes completely or add additional content not contained in PhysioCAFUN.

The organ system modules begin with general principles and concepts of physiology, molecular biology and cell physiology, cell-cell communication, and control systems in *modules 1–3*. These topics are unbundled to enable learners to have an in-depth knowledge about the basic principles of life. *Modules 4–6* are about the control systems in the body,

which are also unbundled to enhance assimilation by the learners. *Module 7* discusses muscles, followed by *modules 8–12* on the cardiopulmonary-renal systems. *Module 13* covers the integrated control of fluid-electrolyte and acid-base homeostasis. *Module 14* combines gastrointestinal and metabolic physiology. *Module 15* focuses on reproductive physiology. Detailed content of all modules can be found in Table 4.

Modules 16–23 cover topics that are not always found in a traditional systems physiology curriculum. These modules contain optional content and skill development suggestions that may be applicable to some programs but not necessarily to others. The modules range from scientific topics such as environmental physiology and pharmacology to skills that are important for employability. For example, *module 18* covers principles of animal experimentation and biomedical instrumentation. It introduces learners to a range of laboratory animals (mammals, amphibians, and flies) and how to use them in research. The students also learn biometry and principles of operation of biomedical research equipment.

Modules 19 (epidemiology, biostatistics, and research methodology), *21* (seminars on current topics in physiology), and *23* (dissertation research) contain learning outcomes that are important to build the research competency of students (Table 4). *Module 19* covers the essential concepts, methods, and tools needed for descriptive and analytical research in biomedical sciences. The learning outcomes also help students define their inquiry model and then develop and design of a study protocol for their research project. The current topics seminars (*module 21*) train students to do an extensive literature review of a topic or produce a critical analysis and presentation of their findings. *Modules 19* and *21* should also prepare and cascade the students to their dissertation (*module 23*) by training them on how to acquire the methodology and scientific approach(es) to generate innovative solutions to research problems.

Module 20 on clinical placements in laboratories and *module 22* on entrepreneurship emphasize employability skills. *Module 20* strengthens student experience in performing, recording, and interpreting various non-invasive clinical measurement procedures used to assist diagnosis of organ function. The learners first assist in executing the procedures and then perform the procedures themselves, with the goal of being able to discuss results with clinicians or others. *Module 22* introduces students to the concepts of entrepreneurship, entrepreneurial knowledge, and skills and behaviors needed in 21st-century physiology. The goal of this module is to propel students to become job creators and self-reliant, thereby attenuating the current, relatively large unemployment figures in some African countries.

DISCUSSION

The publication of PhysioCAFUN provides a freely available resource that stakeholders in Africa can consult regarding the optimal training and competency of physiologists. The guidelines should help African universities where there is a dearth of physiologists who are able to draft a curriculum suitable for their local needs.

Table 2. Program-level learning outcomes

Code	Program (Curriculum) Learning Outcomes
A	Knowledge and understanding
A1	Physiological mechanisms of the functions of organ systems of the human body
A2	Pathophysiology, epidemiology, risk factors, and treatment options for common diseases of the different systems of the human body
A3	Variation in physiological needs depending on age group, physical exercise, or different pathologic conditions
A4	Noninvasive clinical measurements
A5	Quality control and calibration of clinical measurement equipment
A6	Research and statistical methods used in biomedical sciences
A7	Biomedical laboratory management skills
B	Cognitive/intellectual skills/application of knowledge
B1	Apply the clinical measurement procedures that are appropriate to the individual patient needs
B2	Interpret clinical measurement results and integrate them with clinical information, including identification of abnormal results
B3	Accurately record clinical measurements and appreciate records keeping of results
B4	Recognize the limitation of the procedures being used in clinical measurements and laboratory
B5	Supervise scheduled follow-up testing to evaluate therapeutic efficiency
B6	Standardize and manage procedures in a clinical measurement laboratory
B7	Develop standard operating procedures for clinical measurement laboratories
B8	Contribute to innovations of methods in physiology
B9	Critically appraise current scientific information and its applications
B10	Demonstrate skills of scientific communication: proposal/grant writing, scientific presentations and writing for publications
B11	Carryout animal experimentations and relate the findings to human situations
B12	Use molecular methods in research and diagnosis
C	Communication/ICT/numeracy/analytic techniques/practical skills
C1	Communicate details of clinical measurement procedures with patients for effective cooperation during the process
C2	Correctly perform calibration of equipment and use instruments to carry out clinical measurements;
C3	Apply safety standards in the use of equipment
C4	Correctly troubleshoot malfunctioning equipment used in clinical measurements
C5	Provide appropriate community education on human bodily functions
D	General transferable skills
D1	Demonstrate ability to guide students on procedures for clinical measurements
D2	Demonstrate effective teaching abilities to students
D3	Demonstrate critical and analytical thinking
D4	Demonstrate ability for decision making
D5	Demonstrate ethical conduct and professionalism
D6	Demonstrate teamwork and reflective practice
D7	Demonstrate confidentiality in the management of information and records
E	Personal, intellectual, and professional autonomy
E1	Demonstrate the ability to independently work under little or no supervision at highest level of performance
F	Employability and career development
F1	Teach Physiology at undergraduate level in medicine and all other health-related courses that need Physiology as part of their curriculum in higher learning institutions

Continued

Table 2.— Continued

Code	Program (Curriculum) Learning Outcomes
F2	Work in hospitals, various research laboratories, institutions as well as in pharmaceutical and sport industries where specific investigations on body functions and mechanisms of drug actions are done
F3	Set up independent private clinical measurement laboratories as well as in government and nongovernmental agencies with interest in public health and noncommunicable diseases
F4	Participate actively in epidemiological investigations and control
F5	Design and execute research and field works
F6	Handle and experiment with laboratory animals
G	Global citizenship
G1	Demonstrate the ability to work locally and internationally with acceptable qualifications required of a physiologist
H	Lifelong learning
H1	Demonstrate acquired skills and knowledge in the practice of physiology and to keep them up-to-date
H2	Accept and respond to constructive feedback from others
H3	Recognize gaps in their knowledge and understanding and be able to find or ask for help
H4	Demonstrate resilience and flexibility
I	Collaboration, teamwork, and leadership
I1	Effectively collaborate and work with team members to any desired result
I2	Critique others' work and ideas constructively and respectfully
J	Research, creativity and innovation, scholarship, and inquiry
J1	Demonstrate the ability to think critically and formulate research thoughts to solve societal problems
K	Ethical, social, and professional understanding
K1	Demonstrate the ability to relate with different strata of society, socially and morally, with a high professional display of integrity
L	Financial literacy
L1	Demonstrate the ability to formulate, execute, and manage budget effectively

ICT, information and communication technology.

PhysioCAFUN should also assist universities with existing physiology programs to benchmark their curriculum and revise it as needed.

Institutions can also use PhysioCAFUN to identify the core physiology knowledge and competencies required by medical and health sciences programs, including Bachelor of Medicine and Surgery, Bachelor of Dentistry, Bachelor of Pharmacy, Bachelor of Medical Laboratory Sciences, Bachelor of Radiotherapy, Bachelor of Veterinary Medicine, and Bachelor of Nursing degrees. For example, learning outcomes for students pursuing physiology and other biosciences have been highlighted by the Bioscience in Nursing (BiNE) group (21), and they overlap with many of the outcomes presented in PhysioCAFUN. Examples include the ability to understand anatomical and scientific terminology; physiological principles of health; physiological basis for clinical observations and tests; and pathophysiological processes. The PhysioCAFUN designed by our team and presented herein addresses most of these outcomes.

We believe that PhysioCAFUN guidelines also have a value that extends beyond the academic community. We are of the opinion that this document will help employers and

Table 3. *PhysioCAFUN modules and associated program outcomes*

No.	Module Title	Associated Program Level Outcomes
1	Principles and core concepts of physiology	A1–A3; C5; D2–D4
2	Molecular biology and cell physiology	A1–A3; C5; D2–D4
3	Cell-cell communication and control systems	A1–A3; C5; D2–D4
4	Endocrine physiology	A1–A3; C5; D2–D4
5	Cellular neurophysiology	A1–A3; C5; D2–D4
6	Systems neurophysiology	A1–A3; C5; D2–D4
7	Physiology of muscle	A1–A3; C5; D2–D4
8	Blood	A1–A3; C5; D2–D4
9	Immune physiology	A1–A3; C5; D2–D4
10	Cardiovascular physiology	A1–A3; C5; D2–D4
11	Respiratory physiology	A1–A3; C5; D2–D4
12	Renal physiology	A1–A3; C5; D2–D4
13	Integrated control of fluid-electrolyte and acid-base homeostasis	A1–A3; C5; D2–D4
14	Gastrointestinal and metabolic physiology	A1–A3; C5; D2–D4
15	Reproductive physiology	A1–A3; C5; D2–D4
16	Environmental physiology	A1–A3; C5; D2–D4
17	Systemic pharmacology	A1–A3; C5; D2–D4
18	Principles of animal experimentation and biomedical Instrumentation	A6–A7; B8; B11–B12; C1–C4; D1; D5–D7
19	Epidemiology, biostatistics, and research methodology	A6; B9–B10; D3–D5
20	Clinical placements in laboratories	A4–A5; B1–B7; C1–C4; D1; D5–D7
21	Seminars on current topics in physiology	A6; B9–B10; D5–D7
22	Physiology entrepreneurship	E; F; G; I; J; L
23	Research project	A6–A7; B8–B12; D5–D7

Program-level outcomes: each outcome has multiple parts, as shown in Table 2. A: Knowledge and understanding; B: Cognitive/intellectual skills/application of knowledge; C: Communication and practical skills; D: General transferrable skills; E: Personal, intellectual, and professional autonomy; F: Employability and career development; G: Global citizenship; H: Lifelong learning; I: Collaboration, teamwork, and leadership; J: Research, creativity and innovation, scholarship and inquiry; K: Ethical, social and professional understanding; L: Financial literacy. PhysioCAFUN, Physiology Curriculum for African Universities.

policymakers better understand the competencies expected of a physiologist. This should enhance the broader public’s understanding of and confidence in the expertise of qualified physiologists or of those graduates who studied physiology as part of their professional training. Although we developed PhysioCAFUN for use in Africa to address the existing problems associated with physiology education in the continent, we encourage educators from outside of Africa also to use it to develop new competency-based physiology curricula or to revise and strengthen existing curricula.

A typical curriculum contains learning outcomes, modular content, learning activities, teaching strategies, assessment methods, learning resources, among others. However, PhysioCAFUN is not a single curriculum: it is intended only as a guideline for curriculum development, and hence we presented modular contents that help to achieve the intended learning outcomes to enable students to acquire the stipulated competencies. The prescription of learning activities, teaching strategies, assessment methods, and learning resources in the heterogenous African context is therefore not currently possible and is unrealistic for the following reasons:

- Curricular design varies widely, with some universities implementing integrative system-based curricula while others employ discipline-based ones;
- Teaching and learning methods vary widely, with some universities using didactic methods, while others use flipped classroom or active learning strategies;
- There is variation in terms of the assessment methods employed by different African universities; and
- The availability of learning resources depends on institutional financial capacity, which widely varies within and between African countries.

Finally, curriculum and curricular elements are not universal across the continent. They are prescribed locally, in the academic policies of autonomous universities in different countries following approval by the institution’s academic senate and regulatory accreditation bodies. In that light, PhysioCAFUN should therefore be viewed as a unique and extensive set of suggested guidelines to assist universities in developing competency-based physiology curricula that are tailored to their institution, their programs, and their culture. Thus there is no prescription regarding how specific universities should teach or assess their chosen modules, just as there are no stipulations regarding teaching strategies and resources because these will vary based on the institutional context. To ensure broader adoption of PhysioCAFUN, we accordingly focused on modular contents and competencies for benchmarking purposes while leaving areas associated with methods of teaching and assessment to the institutions to decide on, based on their unique contexts.

The main strength of PhysioCAFUN is that it was formulated by experts representing the major geographic areas in Africa, together with international experts with rich and experienced insights regarding physiology and curriculum design. These guidelines also emphasize the necessity to acquire the skills that enhance the employability of the graduates.

One limitation of the current PhysioCAFUN document is that it is based on expert opinion only, without any data gathered from actual programs. Moreover, as we learned when writing this paper, there is a lack of accurate information regarding the number and kind of physiology programs currently available in African countries.

Table 4. Detailed Module Content

Module	Key Topics in The Module
	<i>Cell physiology</i>
Module 1: Principles and the core concepts of physiology	Structure-function relationships, homeostasis, mass and energy balance, gradients and flow, energy, properties of physical systems that affect physiology, and the general concepts of pathophysiology
Module 2: Molecular biology and cell physiology	Biomolecules, genes and proteins, cell biology, body fluid compartments, transport of solutes across membrane, electrophysiology, and channelopathies and disorders of molecular transport across membranes
Module 3: Cell-cell communications and control systems	Local and contact-dependent signaling, long-distance signaling, signal actions on target cells, intracellular receptors, and disorders associated with second messengers
	<i>Control systems</i>
Module 4: Endocrine system	Organization of the endocrine system, peptide hormones, steroid hormones, amine hormones, hypothalamic-pituitary axis, endocrine regulation of growth, thyroid gland, adrenal gland, endocrine pancreas, parathyroid glands, pineal gland, and endocrine pathophysiology
Module 5: Cellular neurophysiology	Cells of the nervous system, development of neurons and glial cells, physiology of neuronal ion channels and transmitters, action potentials and signal transduction along neurons, elements of neuronal circuits, and disorders associated with synaptic transmissions and neurotransmitters
Module 6: Systemic neurophysiology	Organization and divisions of the nervous system, circuits, processes, regulatory function of the central nervous system (CNS), sensory physiology (somatic and special senses), autonomic nervous system, physiological diagnostic procedures for the nervous system, and disorders of the nervous system
	<i>Systems physiology</i>
Module 7: Muscles	Mechanisms of muscle action potentials, excitation and contraction of smooth and skeletal muscles, mechanisms of muscle relaxation, and pathophysiology of muscular contraction and relaxation processes
Module 8: Blood	Functions of blood cells and their mechanisms of actions, regulation of hematopoiesis, hemoglobin structure and hemoglobinopathies, regulation of hemostasis, pathophysiology of the blood, and techniques for measuring hematological parameters
Module 9: Immune system	Functional anatomy of the immune system, inflammatory mechanisms and the role of pro- and anti-inflammatory cytokines, antigen-antibody interactions, response of immune system to infectious diseases, physiological significance of transplantation, blood grouping system, genotypes, and blood transfusion, disorders of the immune system, and disorders associated with the ABO and rhesus systems
Module 10: Cardiovascular physiology	Functional overview of the cardiovascular system, excitation and contraction of a cardiac myocyte, initiation of heartbeat and neural control, electrocardiography, cardiac cycle, assessment of cardiac output, control of stroke volume and cardiac output, hemodynamics, vascular smooth muscle, and blood vessel anatomy, microcirculation, neural and chemical control of blood vessels, coordinated cardiovascular responses to control mean arterial pressure, and disorders of the cardiovascular system
Module 11: Respiratory physiology	Functional anatomy of the respiratory system, mechanics of ventilation, gas exchange in the lungs, ventilation and perfusion of the lungs, transport of oxygen and carbon dioxide in blood, control of ventilation, respiratory function and adaptation in special environments, lung function tests for diagnosis and monitoring, and pathophysiology of the respiratory system
Module 12: Renal physiology	Functional anatomy of the urinary system, glomerular filtration and its control, tubular reabsorption, tubular secretion, clearance, micturition and excretion, metabolism of the kidney, pathophysiology of the renal system, laboratory estimation of renal functions, and principles of renal dialysis, urography, and other techniques
Module 13: Fluid-electrolyte and acid-base homeostasis	Regulation of plasma volume, body fluid, and osmolarity, regulation of blood volume and blood pressure, acid-base physiology, and disorders associated with fluid, electrolyte, acid, and base balance
Module 14: Gastrointestinal and metabolic physiology	Functional anatomy of the digestive system and its accessory organs, secretion of saliva and mastication, swallowing process, gastrointestinal motility, regulation of gastrointestinal functions, phases of digestion, digestion, and absorption of macromolecules, intestinal water and electrolyte transport, absorption of water-soluble vitamins and minerals, structure-function of the liver and large intestine, the gut microbiome, nutrients and metabolism, hormonal modulation of metabolic pathways, energy balance and factors that control hunger and satiety, thermoregulation, and pathophysiology of gastrointestinal functions and metabolism
Module 15: Reproductive physiology	Sexual differentiation, male reproductive system, female reproductive system, fertilization, pregnancy, lactation, fetal and neonatal physiology, and male and female factor infertility
	<i>Optional topics</i>
Module 16: Environmental physiology	Deep-sea diving physiology, high-altitude physiology, flight and space physiology, body responses to hyperbaric and hypobaric environments, diseases associated with environmental pollution, temperature regulatory mechanisms, and management of environment-associated disorders
Module 17: Systemic pharmacology	Introduction to general pharmacology, mechanisms of actions of drugs relevant to the treatment of disorders in various body systems, such as disorders of the nervous system and other systems, autotoxins, and chemotherapy Basic principles and ethics of using experimental animals as alternatives to human subjects in physiological research. Arguments for/against animal use in research, choice of animals and/or

Continued

Table 4.— Continued

Module	Key Topics in The Module
Module 18: Principles of animal experimentation and biomedical instrumentation	isolated tissue, and ethical issues in animal experimentation. Introduction to laboratory methods and design in physiological experimentation. Standard laboratory procedures, including handling and husbandry of common laboratory animals. Alternative animal models and comparative physiology of different animal species. Principles of operation of biomedical equipment, and operation and maintenance of biomedical equipment
Module 19: Epidemiology, biostatistics, and research methodology	Applied computing, descriptive and analytical epidemiology, descriptive and analytical biostatistics, demography, types of study, modeling, literature survey, research design, proposals, manuscripts, and other writing, data collection techniques and interpretation, operational and evaluative research, ethics in research on human subjects, qualitative research methods, and presentation of research findings
Module 20: Clinical placements in laboratories	Hands-on skills acquisition in electrocardiography, echocardiography, spirometry, electroencephalography, electromyography, sensory organ, chemical pathology, and molecular biology laboratories
Module 21: Seminars on current topics in Physiology	Literature search and different search engines, proper use of the library and referencing styles, how to write research proposals and manuscripts, reviews of articles, meta-analysis of available data, data collection, how to present scientific findings, principles of academic writing in biomedical sciences
Module 22: Principles of entrepreneurship	Definition and modes of businesses (micro, small, medium, and large-scale businesses), concepts of teamwork and partnership in business operation, strengths and weaknesses of different modes of businesses, trends expected of successful business models, specialization and diversification of businesses: lessons from various models, ethics and social responsibility of businesses, entrepreneurial opportunities in various areas of physiological sciences, case studies of existing businesses in physiological science, and proposal development on physiological businesses
Module 23: Research project	All components of a dissertation: problem statement and contextual framework, literature review, materials and methods, data analysis, interpretation and discussion of results, conclusions and recommendations, and references. Proposal writing and defense, presentation of findings in a seminar, presentation, and defense of the dissertation before examiners

Thus the present study represents initial steps toward developing PhysioCAFUN, with further studies planned to assess the efficacy of these guidelines in terms of advancing physiology education on the African continent. Finally, we will continue collaborations with notable physiological societies and educational bodies to enhance advocacy in terms of the adoption of PhysioCAFUN by African universities and beyond.

Another ongoing response to improve physiology education has recently been initiated. In 2023, the AAPS together with the International Union of Physiological Sciences (IUPS) established the first physiology mentoring program in Africa (22, 23). The program pairs early-career faculty members (who are the mentees) with two experienced mentors, one in Africa and one from outside of Africa. The aim of the mentorship is to assist the early-career mentees to grow their skills in curriculum development and teaching. Another effort to strengthen physiology education simultaneously with PhysioCAFUN is the organization of educational workshops and symposia as an integral part of scientific meetings of physiological societies in Africa. For instance, the 2023 joint EASPS-AAPS conference in Tanzania included training workshops (arranged by ADInstruments) for physiology tests, focusing on electrocardiogram, electroencephalogram, and spirometry. This was in addition to physiology education-focused plenary talks. In line with this outlook, for the 2025 AAPS conference to be held in Egypt (February 13–15, 2025, Ismailia), different symposia and plenary talks focusing on physiology teaching and learning will be included in the final program (www.esps-egypt.org). Together these collaborative strategies should help promote the implementation of the competency-based PhysioCAFUN across the African continent and perhaps beyond.

DATA AVAILABILITY

Data will be made available upon reasonable request.

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AUTHOR CONTRIBUTIONS

A.I.A. conceived and designed research; A.I.A. analyzed data; A.I.A. drafted manuscript; A.I.A., M.F.E., Y.E.-W., T.N., G.F., F.M., A.M.S., G.J.M.S., E.B., Y.R., F.B.S., A.S., A.E., U.P., and D.U.S. edited

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