Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2023, 10(9):116-123**

Review Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Computational Intelligence in Medicine: An Introduction

Matthew N. O. Sadiku[1], *Olusola A. Okhiria[2], and Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX 77446
[2]Microbiology, Public Health Wales, Cardiff, UK
[3]Juliana King University, Houston, TX, USA
Email: sadiku@ieee.org; olusola.okhiria@wales.nhs.uk; janetsadiku1@gmail.com

Abstract Computational intelligence is a novel computing tool for solving complex problems that are challenging to address with conventional techniques. It is a form of computing model based on the methods through which humans learn. It is a new concept for advanced information processing. Computational intelligence covers a number of nature-inspired computational techniques such as artificial neural networks, genetic algorithms, swarm intelligence, expert systems, evolutionary computing, and fuzzy systems. The computational techniques are employed to analyze, forecast, and solve predicaments in the medical field. Computational intelligence has the potential to solve real-life complex problems and to make intelligent-probabilistic decisions. Computational intelligence has increasingly been deployed in biomedical field to study the behavior and complexity of biological systems. This paper provides an introduction on the various uses of computational intelligence in medicine.

Keywords Computational intelligence, Soft computing, Medicine, Biological systems

Introduction

Computing is experiencing its most exciting moments in history, permeating nearly all areas of human activities. Computing is any activity that involves using a computer or a computing device to process a task. It is any goal-oriented activity requiring the use of computers. It is essentially mapping the given set of inputs to output using a formal algorithm to solve a problem. It is suitable for problems that are easy to model mathematically.

Computational intelligence (CI) is the theory, design, application, and development of biologically and linguistically motivated computational paradigms. CI plays a major role in developing successful intelligent systems, including games and cognitive developmental systems.

Computational intelligence is often referred to as soft computing. While hard computing is the traditional computing algorithm, which processes functions and data with a verifiable output, soft computing deals with computational tasks that cannot be described precisely. It is impossible to solve real-life problems using traditional computing methods because of complexity, uncertainty, or problems that do not have a proper definition. Computational intelligence techniques have gained increasing popularity due to their ability to cope with large amounts of clinical data and uncertain information. They have been successfully used in many "real-world" applications in a variety of engineering and medical problems [1]. Medicine is an area that affects directly the life quality of all human beings. It is a complex domain which usually involves a large quantity of professionals with a wide range of expertise, knowledge, skills, and abilities (from family doctors to medical specialists, nurses, laboratory technicians or social workers) have to co-ordinate efficiently their activities to provide the best possible care to patients. CI provides a basis for human like reasoning in medical systems.

What is Computational Intelligence?

Computational intelligence (CI) is the study of the design of intelligence systems. A system is regarded as "intelligent" only if it satisfies learning and decision making requirements. It is familiar that the best-known manifestation of intelligence is human intelligence. The characteristic of "intelligence" is usually attributed to humans so that CI is a way of performing like human beings and using human-like reasoning, i.e. it uses inexact and fuzzy knowledge. Thus the goal of CI is to recreate human-like intelligence in a human-made machine [2,3].

The term "computational intelligence" was coined by John McCarthy in 1956. The ongoing worldwide computerization has created new opportunities for researchers. All branches of science and art have become computational: computational biology, computational physics, computational chemistry, computational ecology, computational linguistics, computation electromagnetic, computational finance, computational mechanics, computational social science, computational epistemology, computational intelligence, and so on.

Although artificial intelligence (AI) and computational intelligence (CI) seek a similar goal of developing intelligent machines; they are different. AI is based on hard computing techniques, while CI based on soft computing methods. AI operates in a top-down manner, while CI operates in a bottom-up manner. Some regard CI to be a subset or branch of AI.

Computational Intelligence Techniques

CI approaches aim at creating intelligent systems by using innovative and nature-inspired algorithms. Traditionally CI therefore uses a combination of five main complementary techniques: Neural Networks, Fuzzy Systems, Evolutionary Computation, Genetic Algorithm, and Probabilistic Reasoning. Some of these CI techniques have their origins in biological systems and are shown in Figure 1 [4]. They are briefly explained as follows [5-8].

- *Neural Networks*: These are the most popular artificial learning tools. Artificial neural network (ANN) is a CI method that mimics the neural system of human brain. NNs are parallel distributed networks that have the ability to learn and generalize from examples. NNs includes feedforward NNs, recurrent NNs, self-organizing NNs, deep learning, and convolutional neural networks. An NN architecture typically consists of an input layer, one or more hidden layers, and an output layer. With large numbers of input variables, it can be difficult for the user to understand the logic represented in this mapping of inputs to output. A typical structure of ANN is shown in Figure 2.
- *Fuzzy Systems*: Fuzziness refers to the inexact or imprecise nature of common terms. It constitutes a form of "approximate reasoning." This area of research includes fuzzy sets and systems, fuzzy clustering and classification, fuzzy controllers, linguistic summarization, and fuzzy neural networks. Fuzzy algorithms attempt to capture the uncertainty and imprecision in rule-based representations that are not easily quantified by other methods. They are very powerful for modeling systems where the descriptors or inputs do not cleanly separate into discrete values or are subjective.
- *Evolutionary Computation*: Evolutionary computation (EC) is a CI model used to mimic the biological evolution phenomenon. EC is a computational intelligence technique inspired from natural evolution. It solves optimization problems by generating, evaluating, and modifying a population of possible solutions. EC currently includes five algorithms: genetic algorithm (GA), evolutionary programming (EP), evolution strategies (ES), genetic programming (GP), and swarm intelligence (SI). EC is very useful for optimizing the connections and weightings between the input layer, the hidden layer(s), and the output layers for an NN model.
- *Genetic Algorithm*: This is a subset of evolutionary computation. It takes all its inspiration from nature. The concept of genetic algorithm is to mimic the natural selection in nature where the fittest elements are chosen.
- *Probabilistic Reasoning*: Probabilistic reasoning is often used in dealing with uncertain and incomplete data in artificial intelligence. The aim of probabilistic reasoning is to combine the capability of probability theory with the capability of deductive logic to exploit structure.

Today, these computing techniques are used in classification, regression, pattern recognition, medicine, system modeling, decision making, pattern, and food engineering. CI is an evolving field. In addition to the five main constituents, it encompasses computing paradigms like ambient intelligence, swarm intelligence, artificial immune systems, cultural learning, data mining, natural language processing, and artificial intelligence. The common characteristics of these techniques is their collective intelligence and adaptability to a changing environment. Due to their efficiency and simplicity, the algorithms have been employed successful for problem solving across social and natural sciences [9].

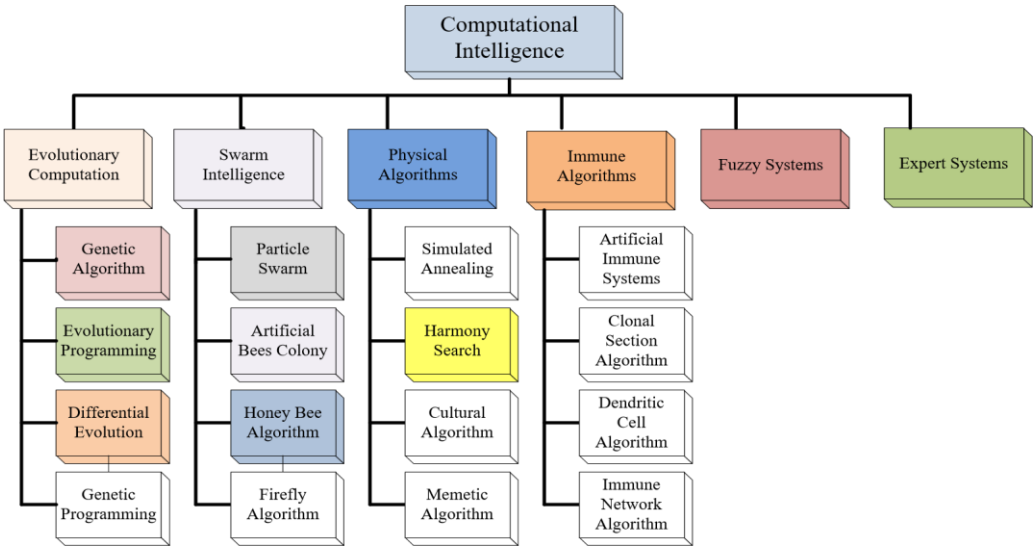

Figure 1: Computational intelligence techniques [4]

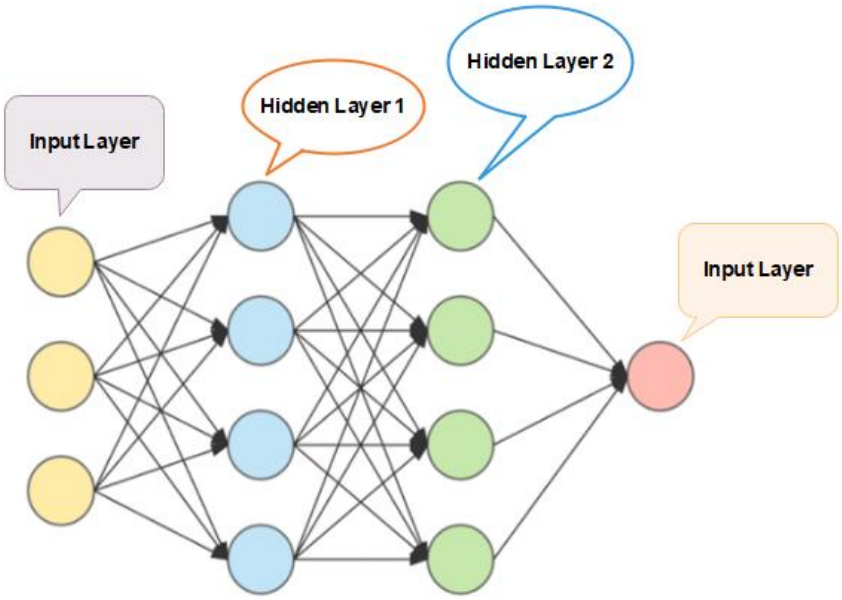

Figure 2: Typical structure of ANN

Applications in Medicine

Computational intelligence is a powerful methodology for a wide range of problems such as in financial forecasting, social media, industry, business, pattern recognition, data analytics, manufacturing, and medical studies. In medicine, researchers have used various CI techniques for early diagnosis of heart disease and to improve the heart disease diagnosis accuracy [10]. CI is currently being used by researchers to support medical professionals in clinical settings, from diagnosis and analysis to treatment and recovery. The application of CI can be either diagnostic or therapeutic. It can help diagnose diseases and in preventive purpose [11]. Applying

CI techniques in complex medical data can provide better management, faster performance, and higher level of accuracy. Common applications of CI in medicine include the following [12-14].

- *Bioinformatics:* Applications of CI in bioinformatics include the following areas of research: (a) microarray analysis, chromosome and proteome databases; (b) signal analysis (echocardiograph images and electroencephalograph time series); and (c) drug delivery and software for pattern recognition in biomedical data.
- *Information Systems:* The information in healthcare institutions is generally managed by computer applications deployed in medical centers. Traditional information systems used for data analysis are gradually being replaced by cognitive data analysis systems. Every information system must have a function for communicating. Intelligent information systems are designed not just to solve indicated problems, but also to foresee changes which may take place in the future in order to anticipate them and take preventive steps. They have become the foundation for building cognitive systems whose purpose is the simple analysis of data consisting in its recording, processing, and interpreting. Every piece of information coming from its structure is sent to the human brain, where it is analyzed, classified, and understood.
- *Medical Data Management.* These systems focus on the retrieval and processing of medical data, such that sources are accessed in a transparent way by a user, or by another decision support system. This approach permits to separate the knowledge source from its use. These systems crawl proactively the sources in order to maintain an up-to-date repository of knowledge.
- *Biomedical Image Processing:* This is similar in concept to biomedical signal processing in multiple dimensions. It includes the analysis, enhancement, and presentation of images captured via X-Ray, ultrasound, MRI, nuclear medicine, and visual imaging technologies. Figure 3 depicts the biomedical image of a brain [15].
- *Clinical Decision Support Systems:* Decision support is an important function for decision makers in many industries. Clinical Decision Support System (CDSS) has potential opportunities to improve overall safety, quality, and cost-effectiveness of healthcare. A typical CDSS is shown in Figure 4 [16]. CI offers tremendous opportunities to represent uncertain and imprecise knowledge in medical decision making. Approaches aimed to assist the professional in the execution of healthcare treatments. These systems use a knowledge base to support the inference process. Case-based reasoning and domain ontologies are two of the most used techniques to represent the medical knowledge. A decision support system for breast cancer detection using Bayesian networks has been reported. A diagnostic support system for bladder tumor grading has also been reported.

Figure 3: Biomedical image of a brain [15]

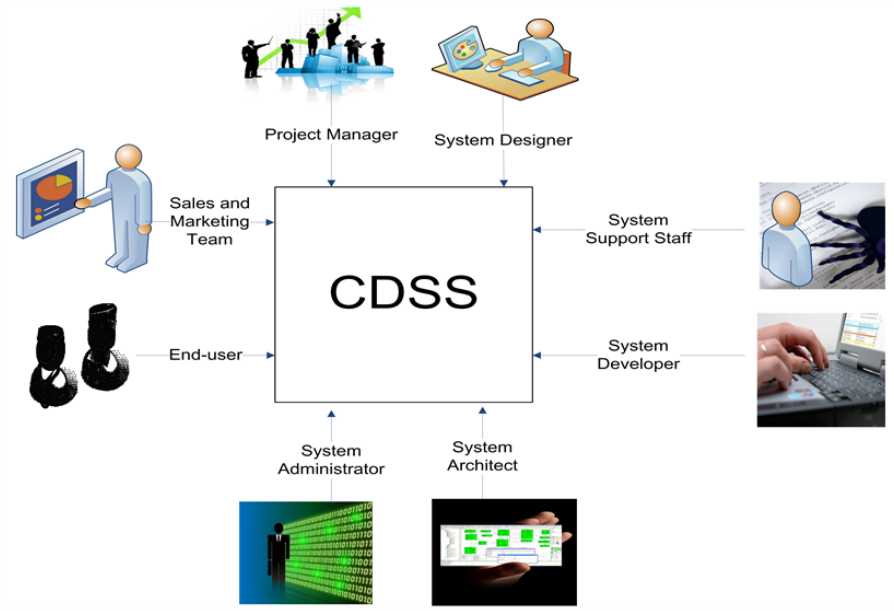

Figure 4: A typical clinical decision support system [16]

Benefits and Challenges

Computation intelligence is very useful in addressing real-life problems. It can consider real-life complexity and then make probabilistic decisions. This makes it useful in cases of scheduling industry procedures, disease diagnostics, video games visualization, translation systems, intelligent robots, autonomous vehicles, etc.

Emergency medicine represents a particularly challenging care setting for clinical information management. The development of intelligent medical decision support systems is a difficult and complex process that raises a lot of technological and research challenges that have to be addressed in an interdisciplinary way.

Conclusion

Computational intelligence is based on biologically inspired computational algorithms. It is a way to imitate the reasoning process of human intelligence. The key pillars of CI are neural networks, genetic algorithms, and fuzzy systems. CI has applications over a wide variety of real-life problems.

If you are looking to further your research or access research datasets in the area of computational intelligence, take advantage of the free individual subscription to IEEE DataPort and become a member of Computational Intelligence Society (CIS). You benefit from the many opportunities of expanding and updating your knowledge, developing new knowledge and professional practices, networking with your peers, and promoting your career. All CIS members automatically have a free individual subscription to IEEE DataPort [17]. For more information on computational intelligence in medicine, see the books in [12, 18-46]. A lot of information is also available in the following journals devoted to CI:

- *Computational Intelligence*
- *Computational Intelligence. An International Journal*
- *Computational Intelligence and Neuroscience*
- *Computational and Mathematical Methods in Medicine*
- *Applied Computational Intelligence and Soft Computing*
- *IEEE Transactions on Emerging Topics in Computational Intelligence*
- *IEEE Transactions on Computational Intelligence and AI in Games*
- *IEEE Computational Intelligence Magazine*
- *Journal of Computational Intelligence in Finance*
- *Journal of Computational Intelligence in Bioinformatics*
- *Journal of Advanced Computational Intelligence and Intelligent Informatics*

- *International Journal of Computational Intelligence Systems*
- *International Journal of Computational Intelligence and Applications*
- *International Journal of Computational Intelligence*
- *International Journal of Computational Intelligence and Organizations*
- *International Journal of Computational Intelligence Research*
- *International Journal of Computational Intelligence Theory and Practice*

References

[1]. E. López-Rubio et al., "Computational intelligence techniques in medicine," *Computational and Mathematical Methods in Medicine*, 2015.

[2]. M. N. O. Sadiku, S. M. Musa, and O. M. Musa, "Computational intelligence: A primer," *International Journal of Advanced Engineering and Technology,* vol. 3, no. 4, October 2019, pp. 34-36.

[3]. M. N. O. Sadiku, J. Foreman, and S. M. Musa, "Computational intelligence," *European Scientific Journal*, vol. 14, no. 21, July 2018, pp. 56-60.

[4]. M. H. Hussain et al., "Computational intelligence based technique in optimal overcurrent relay coordination: A review," *The International Journal of Engineering and Science,* vol. 2. No. 1, 2013, pp. 1-9.

[5]. "What is computational intelligence? "https://cis.ieee.org/about/what-is-ci

[6]. D. Hecht, "Applications of machine learning and computational intelligence to drug discovery and development," *Drug Development Research*, vol. 72, 2011, pp. 53-65.

[7]. U. Kumari, "Soft computing applications: A perspective view," *Proceedings of the 2nd International Conference on Communication and Electronics Systems*, 2017, pp. 787-789.

[8]. M. N. O. Sadiku, Y. Wang, S. Cui, S. M. Musa, "Soft computing: An introduction," *International Journal of Advanced Research in Computer Science and Software Engineering*, vol. 8, no. 6, June 2018, pp. 63-65.

[9]. I. Fister et al., "Computational intelligence in sports: Challenges and opportunities within a new research domain," *Applied Mathematics and Computation*, vol. 262, 2015, pp. 178-186.

[10]. M.A.Jabbar, B.L Deekshatulu, and P. Chandra, "Computational intelligence technique for early diagnosis of heart disease*," Proceedings of IEEE International Conference on Engineering and Technology* (ICETECH), Coimbatore, India, March 2015.

[11]. S. Wiwanitkit and V. Wiwanitkit, "Computational intelligence in tropical medicine," *Asian Pacific Journal of Tropical Biomedicine*, vol. 6, no. 4, 2016, pp. 350-252.

[12]. I. Bichindaritz et al. (eds.), *Computational Intelligence in Healthcare 4: Advanced Methodologies.* Springer, 2010.

[13]. A. M. Salem, "Computational intelligence for digital healthcare," https://ceur-ws.org/Vol-2711/paper20.pdf

[14]. El. Rakus-Andersson and L. C. Jain, "Computational intelligence in medical decisions making," https://www.diva-portal.org/smash/get/diva2:835735/FULLTEXT01.pdf

[15]. "Artificial intelligence improves biomedical imaging," October 2019, https://latinamericanpost.com/30381-artificial-intelligence-improves-biomedical-imaging

[16]. A. Kumar, "Stakeholder's perspective of clinical decision support system," Open Journal of Business and Management," vol.4, no.1, January 2016, pp. 45-50;

[17]. "Computational intelligence society member benefit: Free IEEE DataPort subscription,"https://cis.ieee.org/news/493-computational-intelligence-society-member-benefit-free-ieee-dataport-subscription

[18]. G. Schaefer, A. Hassanien, and J. Jiang (eds.), Computational *Intelligence in Medical Imaging: Techniques and Applications*. Boca Raton, FL: CRC Press, 2009.

[19]. R. Tadeusiewicz, *Modern Computational Intelligence Methods for the Interpretation of Medical Images*. Springer Science & Business Media, 2008.

[20]. R. Begg, D. T. H. Lai, and M. Palaniswami, *Computational Intelligence in Biomedical Engineering*. Boca Raton, FL: CRC Press, 2007.
[21]. K. Suzuki (ed.), *Computational Intelligence in Biomedical Imaging*. New York: Springer, 2014.
[22]. K. Raza (ed.), *Computational Intelligence Methods in COVID-19: Surveillance, Prevention, Prediction and Diagnosis*. Springer Nature, 2020.
[23]. H. Yoshida et al. (eds.), *Advanced Computational Intelligence Paradigms in Healthcare-1*. Springer, 2007.
[24]. S. Vaidya and H. Yoshida (eds.), *Advanced Computational Intelligence Paradigms in Healthcare-2*. Springer, 2007.
[25]. S. Brahnam and L. C. Jain (eds.), *Advanced Computational Intelligence Paradigms in Healthcare 5: Intelligent Decision Support Systems*. Springer Science & Business Media, 2010.
[26]. I. Maglogiannis, S. Brahnam, and L. C. Jain, *Advanced Computational Intelligence in Healthcare-7*. Springer Berlin Heidelberg, 2020.
[27]. U. Maulik, S. Bandyopadhyay, and J. Wang, *Computational Intelligence and Pattern Analysis in Biological Informatics*. John Wiley and Sons, 2010.
[28]. U. Kose et al., *Computational Intelligence For COVID-19 and Future Pandemics*. Springer Singapore, 2022.
[29]. A. Khamparia et al. (eds.), *Computational Intelligence for Managing Pandemics*. Walter de Gruyter GmbH & Co KG, 2021.
[30]. A. Kelemen, A. Abraham, and Y. Liang (eds.), *Computational Intelligence in Medical Informatics*. Springer Science & Business Media, 2008.
[31]. S. Ali (ed.), *Multidisciplinary Computational Intelligence Techniques: Applications in Business, Engineering, and Medicine: Applications in Business, Engineering, and Medicine*. IGI Global, 2012.
[32]. L. Jain and P. De Wilde (eds.), *Practical Applications of Computational Intelligence Techniques*. Springer Science & Business Media, 2001.
[33]. M. Sordo, S. Vaidya, and L. C. Jain, *An Introduction to Computational Intelligence in Healthcare: New Directions*. Springer, 2008.
[34]. S. De et al. (eds.), *Applied Smart Health Care Informatics: A Computational Intelligence Perspective*. John Wiley & Sons, 2022.
[35]. A. Kelemen, A. Abraham, and Y. Chen (eds.), *Computational Intelligence in Bioinformatics*. Vol. 94. Springer, 2008.
[36]. M. Sudha *Applied Computational Intelligence*. Educreation Publishing, 2019.
[37]. K. Raza (ed.), *Computational Intelligence in Oncology: Applications in Diagnosis, Prognosis and Therapeutics of Cancers*. Springer Nature, 2022.
[38]. A. K. Manocha et al. (eds.), *Computational Intelligence in Healthcare.* Springer, 2021.
[39]. K. Pancerz and E. Zaitseva, *Computational Intelligence, Medicine and Biology*. Springer, 2015
[40]. G. Schaefer, A. Hassanien, and J. Jiang (eds.), *Computational Intelligence in Medical Imaging: Techniques and Applications*. Chapman and Hall/CRC, 2009.
[41]. S. Tamrakar, S. B. Choubey, and A. Choubey (eds.), *Computational Intelligence in Medical Decision Making and Diagnosis Techniques and Applications.* Boca Raton, FL: CRC Press, 2023.
[42]. S. S. Kshatri et al., *Computational Intelligence and Applications for Pandemics and Healthcare.* IGI Global, 2022.
[43]. S. Brahnam and L. C. Jain (eds.), *Advanced Computational Intelligence Paradigms in Healthcare 6: Virtual Reality in Psychotherapy, Rehabilitation, and Assessment*. Springer, 2011.
[44]. P. Tanwar et al. (eds.), *Computational Intelligence and Predictive Analysis for Medical Science: A Pragmatic Approach*. De Gruyer, 2021,
[45]. D. Saini, G. Chaudhary, and V. Gupta (eds.), *Computational Intelligence for Information Retrieval*. Boca Raton, FL: CRC Press, 2021.
[46]. D. Poole, A. Mackworth, and R. Goebel, *Computational Intelligence: A Logical Approach.* New York: Oxford University Press, 1998.

About the Authors

Matthew N.O. Sadiku is a professor in the Department of Electrical and Computer Engineering at Prairie View A&M University, Prairie View, Texas. He is the author of several books and papers. His areas of research interests include computational electromagnetics and computer networks. He is a life fellow of IEEE.

Olusola A. Okhiria has a PhD degree in Microbiology from Cardiff Metropolitan University, Cardiff; Postgraduate Certificate in Education (PGCE) from Cardiff University, Cardiff, UK. She is a Biomedical Scientist in Microbiology department, University Hospital of Wales, Cardiff and also involved in training, mentoring and consultancy in academic careers. Her areas of research include biofilm and wounds. She is a Fellow of IBMS, UK.

Janet O. Sadiku holds bachelor degree in Nursing Science in 1980 at the University of Ife, now known as Obafemi Awolowo University, Nigeria and Master's degree from Juliana King University, Houston, TX in December 2022. She has worked as a nurse, educator, and church minister in Nigeria, United Kingdom, Canada, and United States. She is a co-author of some papers and books.