UNIVERSITY OF GHANA
DEPARTMENT OF BIOCHEMISTRY, CELL AND MOLECULAR BIOLOGY

Proposal to introduce new graduate programs: Master of Philosophy (MPhil) and Doctor of Philosophy (PhD) in Molecular Cell Biology of Infectious Diseases (MCBI)

Introduction

In response to the World Bank's call for applications to establish African Centers of Excellence to promote higher education in Africa, the University of Ghana submitted a proposal to establish the West African Center for Cell Biology of Infectious Pathogens (WACCBIP). This proposal was led by faculty from the department of Biochemistry, Cell and Molecular Biology, in collaboration with the Noguchi Memorial Institute for Medical Research (NMIMR) and the University of Ghana Computing Systems (UGCS). The proposal was also supported by several local, regional and international institutions, including the American Society for Cell Biology (ASCB). The main aim of the proposed center is to provide Ghana and the West African sub-region in general with a site for world-class training and research on the cell and molecular biology of infectious diseases. Such training and research is necessary to provide innovation for diagnosis, prevention and control of infectious diseases in sub-Saharan Africa. Therefore, to help achieve the objectives of the center, we propose to introduce two graduate programs: Master of Philosophy (MPhil) and Doctor of Philosophy (PhD) in Molecular Cell Biology of Infectious Diseases. Below we describe the specifics of each program and show how it takes advantage of existing courses, and is strengthened by new specialized courses that will provide a unique education for talented biomedical scientists.

Program Objectives

The new programs will train the next generation of biomedical scientists in modern techniques of molecular cell biology and equip them with current knowledge on the major pathogens causing disease in sub-Saharan Africa. The course work will cover bacteria, viruses, fungi, helminths and protozoan pathogens, and will include training in epidemiology and biostatistics, pathogen biology, disease pathogenesis, immune responses, and targets for development of drugs and vaccines. All students will also receive training in the field and laboratory methods used to obtain current knowledge, empowering them both to understand the research literature and to contribute to new knowledge through research. The students who successfully complete their course work will work with a faculty mentor to define a research project on a pathogen that interests them. They will then be supported to complete original research for their dissertation and for publication in peer-reviewed journals. This training will prepare successful students for jobs in industry, government and the Universities and Health Research Institutions.

To ensure sustainability of the programs beyond the World Bank's support, WACCBIP will build Core facilities to provide fee-paying services in Flow cytometry, Mass spectrometry, Microscopy (fluorescent and confocal), protein expression and primer synthesis, and Biomedical High Performance Computing services (bioinformatics). In addition, the Center will leverage its improved technical resources and core facilities to compete for large research and training grants from major donors such as the Wellcome Trust, the Bill and Melinda Gates Foundation and the National Institutes of Health (NIH).

MASTER OF PHILOSOPHY IN MOLECULAR CELL BIOLOGY OF INFECTIOUS DISEASES (MPHIL MCBI)

Admission Requirements: A good first degree (at least 2nd class lower) in a relevant discipline.

Duration: Two years

Graduation Requirement:

- Coursework: 24 – 36 credits
- Seminar (2): 6 credits
- Thesis: 30 credits

Total: 60-72 credits

Program structure

Year 1

Semester 1

CORE		**CREDITS**
MCBI 601:	Bacterial and Viral Infections	3
MCBI 603:	Experimental Microbiology	3
*BCMB 603:	Advanced Molecular Biology	3
*BCMB 609:	Immune Response Mechanisms	3
*BCMB 630:	Research Methodology & Scientific Communication	3
	TOTAL	**15**

ELECTIVES (select maximum of 3 credits)

*BCMB 605:	Advanced Protein Chemistry	3
*BSTT 601:	Methods in Biostatistics I	3

Semester 2

CORE

MCBI 602: Eukaryotic Infections: Protozoan, Helminthic and Fungal	3
MCBI 604: Host and Pathogen Genomics	3
MCBI 606: Antimicrobial Therapeutics: Molecular Mechanisms and Concepts	3
MCBI 608: Molecular Epidemiology of Infectious Diseases	3
TOTAL	**12**

ELECTIVES (select 3-6 credits)

*BCMB 608: Signal Transduction	3
*BCMB 612: Applications of Biotechnology	3
*BCMB 614: Eukaryotic Cell Biology	2
*ENTO 606: Disease Vectors of Medical and Veterinary Importance	3
*BSTT 602: Methods in Biostatistics II	3

MCBI 610: Seminar I 3

Year 2

CORE

MCBI 600:	Thesis	30
MCBI 620:	Seminar II	3

***Existing Courses**

COURSE DESCRIPTIONS

***BCMB 603: Advanced Molecular Biology**

This course focuses on the study of life using techniques that reveal the molecular make-up of organisms. The major topics will include: key tools for cloning, gene identification and DNA libraries, sequencing, PCR; production of proteins from cloned genes and application of recombinant DNA technology in Agriculture, medicine and Industry will also be discussed. The course will however, begin with general review of structure and function of nucleic acids – DNA, RNA; cell biology of prokaryotes and eukaryotes; molecular nature of genes, plasmids, bacteriophages, cosmids, viruses and artificial chromosomes.

Reading List

Nelson, D. L., & Cox, M. M. (2008). *Lehninger*: *Principles of biochemistry* (5th ed.). New York, NY: W. H. Freeman and Company.

Sambrook, J., Fristch, E. F. & Maniatis (1989). *Molecular cloning, a laboratory manual* (revised ed.), Cold Spring Harbor, NY: Laboratory Press.

Weaves, R. F (1999). *Molecular biology* (1st ed.). Cold Spring Harbor, NY: WCB/McGraw Hill Companies Inc.

Berg, J. M. (2002). *Biochemistry* (5th ed). New York, NY: W. H. Freeman Publishers.

Voet, D., & Voet, J. G. (2008): *Biochemistry* (4th ed.). USA: Wiley and Sons Inc.

***BCMB 605: Advanced Protein Chemistry**

The goal of this course is to expose students to advanced topics in protein chemistry. Major topics such as physical properties of proteins, separation techniques, protein structure and stability, post-translational modifications, protein structure prediction and recent advances in protein chemistry research will be discussed. Additionally, Proteomics as a research tool to advance better understanding of cellular function will be introduced.

Reading List

Berg, J. M. (2002). *Biochemistry* (5th ed). New York, NY: W. H. Freeman Publishers.

Voet, D., & Voet, J. G. (2008): *Biochemistry* (4th ed.). USA: Wiley and Sons Inc.

Nelson, D. L., & Cox, M. M. (2008). *Lehninger*: P*rinciples of biochemistry* (5th ed.). New York, NY: W. H. Freeman and Company.

Sambrook, J., Fristch, E. F., & Maniatis (1989). *Molecular cloning, a laboratory manual* (revised ed.), Cold Spring Harbor, NY, USA: Laboratory Press.

Weaves, R. F (1999). *Molecular biology* (1st ed.). Cold Spring Harbor, NY: WCB/McGraw Hill Companies Inc.

***BCMB 608: Signal Transduction**

This is an advanced course on cell signaling designed to give students insights into the underlying molecular mechanisms and current trends in signal transduction research. The format includes lectures, presentations of original literature by students, and discussions of selected papers with emphasis on experimental approaches and results. Major topics covered include: Types of signaling molecules; Cell Surface and nuclear receptors; Monomeric and heterotrimeric guanine nucleotide binding proteins; Effectors and regulators of receptor tyrosine kinase signaling pathways, G-protein coupled receptor signaling; Cytokine receptor signaling; Signaling through ion channels; Receptor transactivation and Crosstalk.

Reading List

Bao, L., Shi, V. Y., & Chan, L. S. (2012). IL-4 regulates chemokine CCL26 in keratinocytes through the Jak 1, 2/Stat6 signaling transduction pathway: Implication for atopic dermatitis. *Molecular Immunology*, 50, 91-97.

Cui, X., Wang, B., Zong, Z., Liu, S., & Xing, W. (2012). The effects of chronic aluminum exposure on learning and memory of rats by observing the changes of Ras/Raf/ERK signal transduction pathway. *Food and Chemical Toxicology*, 50, 315-319.

Evdonin, L. A., Guzhova, I. V., Margulis, B. A., & Medvedeva, N. D. (2006). Extracellular heat shock protein 70 mediates heat stress-induced epidermal growth factor receptor transactivation in A431 carcinoma cells. *FEBS letters*, 580, 6674-6678.

Roy, K. S., Srivastava, R. K., & Shankar, S. (2010). Inhibition of P13/AKT and MAPK/ERK pathways causes activation of FOXO transcription factor, leading to cell arrest and apoptosis in pancreatic cancer. *Journal of Molecular Signaling*, 5(10), 1-13.

Straburger, K., Tiebe, M., Pinna, F., Breuhahn, K., & TeLeman, A. A. (2012). Insulin/IGF signaling drives cell proliferation in part via Yorkie/YAP. *Developmental Biology*, 367, 187-196.

***BCMB 609: Immune Response Mechanisms**

This course is an advanced study of Immunology and takes a detailed look at the molecular mechanisms through which the immune system responds to pathogens. A major goal of the course is to prepare students for research in the fields of Immunology, disease pathogenesis and vaccine development. The content includes discussions of the mechanisms of antigen processing and presentation, T-cell and B-cell receptor gene rearrangements, recombination of VDJ gene segments, affinity maturation and somatic hypermutation. Current advances in immunological methods such as flow cytometry, and new developments in the search for vaccines for malaria and HIV will also be discussed.

Reading List

Charles, A. J. (2005). *Immunobiology: The immune system in health and disease* (6th ed.). New York, NY: Garland Science Publishing.

Tak, W. M. & Saunders, M. E. (2006). *The immune response: Basic and clinical principles*. Elsevier Academic Press, UK.

William, E. P. (2008). *Fundamental immunology* (6th ed.). Pennsylvania: Lippincott Williams and Wilkins.

Plattner, F., & Soldati-Favre, D. (2008). Hijacking of host cellular functions by the Apicomplexa. *Annual Review of Microbiology*, 62,471-487.

Sacks, D., & Sher, A. (2002). Evasion of innate immunity by parasitic protozoa. *Nature Immunology,* 3(11), 1041-1047. Review.

Sibley, L. D. (2011). Invasion and intracellular survival by protozoan parasites. *Immunological Reviews*, 240, 72-91.

***BCMB 612: Applications of Biotechnology**

Biotechnology deals with the application of living organisms, biological systems and processes or their derivatives to manufacture or modify a product and to render a service. The course combines knowledge from Biochemistry, Molecular Biology and Genetics, Microbiology, Cell Biology and links up with specialized areas in Chemical Engineering, which is Biochemical/Bioprocess Engineering. The advances in DNA recombinant techniques as well as the sequencing of the Human genome and that of several other organisms have lead to the expansion of opportunities in biotechnology. The course will expose students to the advantage of bioprocesses over the traditional methods of manufacturing such low energy demand and limited environmental impact.

Reading List

Glick & Pasternak (2003). *Molecular biotechnology: Principles and applications of recombinant* DNA (2nd ed). ASM.

Barnum, S. (2005). *Biotechnology: An introduction* (2nd ed.). Thomson Brooks/Cole.

Nelson, D. L., & Cox, M. M. (2008). *Lehninger*: *Principles of biochemistry* (5th ed.). New York, NY: W. H. Freeman and Company.

Sambrook, J., Fristch, E. F. & Maniatis (1989). *Molecular cloning, a laboratory manual* (revised ed.), Cold Spring Harbor, NY: Laboratory Press.
Weaves, R. F (1999). *Molecular biology* (1st ed.). Cold Spring Harbor, NY: WCB/McGraw Hill Companies Inc.

***BCMB 614: Eukaryotic Cell Biology**

This course focuses on membrane systems, organelles, the cell surface, cytoskeleton and extracellular matrix aspects of protozoan and some specialized higher eukaryotic cells. The ultra-cellular structures common to all the cell types of interest as well as the key features unique to all the cell types will be described in detail. Specialized organelles used by parasitic protozoan will also be discussed in the context of their role in pathogenesis and the interaction with host cell structures. The course will also cover various cellular processes and the dysfunction that cause disease.

Reading List

Bergman, N. H. (2007). *Comparative genomics* (vol. 1 & 2). New York City, NY: Humana Press.
Cooper, G. M. (2000). *The Cell: A molecular approach* (2nd ed.). Massachusetts, USA: Sinauer Asscociates.
Gilbert, S. F. (2000). *Developmental biology* (6th ed.). Massachusetts, USA: Sinauer Associates.
Lodish, H., Berk, A., Zipursky, S. L., Matsudaira, P., Baltimore, D. & Darnell, J. (2000). *Molecular cell Biology* (4th ed.). New York, NY: W. H. Freeman and Co.
Nelson, D. L., & Cox, M. M. (2008). *Lehninger*: *Principles of biochemistry* (5th ed.). New York, NY: W. H. Freeman and Company.

***BCMB 630: Research Methodology and Scientific Communication**

Students will be taken through various topics in research methodology and scientific communication. The major topics to be discussed are: elements of scientific project planning; research design and statistical analysis; laboratory quality assurance; standards for quality research; initial considerations; scientific and technical presentation; professional conduct.

Reading List

Buddenbaum, J., & Novak, K. (2001). *Applied communication research*. USA: Wiley Publishers.
Frey, L. R. (1992). *Interpreting communication research: A case study approach*. USA: Prentice Hall.
Manthey, R. (2010). *Techniques of scientific communication.* Universitatbonn.
Merrigan, G., & Huston, C. L. (2008). *Communication research methods* (2nd ed.). USA: Oxford University Press.
Stewart, D. T. (2002). *Principles of research in communication*. Boston, USA: Allyn and Bacon, Inc.
Watt, J. H., & Van den Berg, S. A. (2002). *Research methods for communication science.* Thousand Oaks, CA: Sage Publications.

***BSTT 601: Methods in Biostatistics I**

This module introduces the basic statistical concepts and methods as applied to diverse problems in public health. Students should be familiar with data handling commands in Stata. Topics to be covered are: an introduction to classical inference including the distinctions between population and sample, and between statistics and population values, and types of data. This component will also include analysis of continuous data (including linear regression), analysis of binary data, and analysis of count data within the concept of sampling distributions, estimation, confidence intervals, hypothesis tests, types I and II errors. Also included is the comparison of groups, association (contingency tables), stratification (Mantel-Haenzel methods) and interaction.

Reading List

Agresti, A. (2013). *Categorical data analysis* (3rd ed.). USA: Wiley and Sons.

Altman, D. (1991). *Practical statistics for medical research*. Florida: Chapman and Hall

Clayton, D., & Hills, M. (1993). *Statistical methods in epidemiology*. USA: Oxford University Press.

Kirkwood, B., & Sterne, J. (2003). *Essential medical statistics* (2nd ed.). Blackwell.

Sullivan, L. M. (2012). *Essentials of biostatistics in public health* (2nd ed.). Jones and Bartlett Learning, LLC.

Wang, D., & Bakhai, A. (2005) *Clinical trials: A practical guide to design, analysis, and reporting.* USA: John Wiley and Sons, Ltd.

***BSTT 602: Methods in Biostatistics II**

This module describes the logistic function, the popularity of the logistic model, and how the model may be applied in epidemiology. Several important special cases of the logistic model involving dichotomous exposure variable are considered with their corresponding odds ratio expressions. In particular focus, is a simple analysis of a fourfold table, and assessment of multiplicative interaction between two dichotomous variables. Models that account for the potential confounding effects and potential interaction effects of covariates are emphasized. It also describes the general maximum likelihood procedure in estimating the regression parameters. It discusses how to make statistical inferences using Maximum likelihood estimates.

Reading List

Agresti, A. (2013). *Categorical data analysis* (3rd ed.). USA: Wiley and Sons, Inc.

Altman, D. (1991). *Practical statistics for medical research*. Florida: Chapman and Hall

Clayton, D., & Hills, M. (1993). *Statistical methods in epidemiology*. USA: Oxford University Press.

Kirkwood, B., & Sterne, J. (2003). *Essential medical statistics* (2nd ed.) Blackwell.

Sullivan, L. M. (2012). *Essentials of biostatistics in public health* (2nd ed.). Jones and Bartlett Learning, LLC.

Wang, D., & Bakhai, A. (2005) *Clinical trials: A practical guide to design, analysis, and reporting.* USA: John Wiley and Sons, Ltd.

***ENTO 606: Disease Vectors of Medical and Veterinary Importance**

Arthropod vectors of disease; taxonomy, biology, and incrimination of vector capacity, ecology of vectors, epidemiology of vector-borne diseases, parasites transmitted by insect vectors, life cycle and symptomatology of diseases; animal reservoirs, vector control methods as applied to blackfly, tsetsefly, mosquitoes, ticks and mites. Emerging disease vectors of medical and veterinary importance.

Reading List

Eldridges, B. F., Edman, J. D., & Edman, J. (2003). *Medical entomology*. New York City, NY: Springer.

Harwood, R. F., James, M. T., & Herms, W. B. (1979). *Entomology in human and animal health*. Macmillan Publishers.

Marquardt, H. W. (Ed) (2004). *Biology of disease vectors* (2nd ed.). Elsevier Academic Press.

Mullen, G. R., & Durdey, A. L. (2002). *Medical and veterinary entomology*. Elsevier Academic Press.

Taken, W., & Knols, B. G. J. (Eds) (2010). *Olfaction in vector-host interactions*. Netherlands: Wageningen Academic Publishers.

MCBI 600: Thesis
Each student will undertake a major research project and present a written dissertation. In addition, students will present an oral defence of their thesis.

MCBI 601: Bacterial and Viral Infections
This course aims to provide insight on bacterial and viral infections that are major public health concerns in sub-Saharan Africa. Aspects to be discussed will include the biology of the pathogen, the pathogenesis of its infection, the pathophysiology of the human host, and current strategies for therapeutics and vaccinology. The molecular mechanism of each pathogen will be discussed, thereby elucidating the pathways for disease progression and pathogen success. Treatment of each pathogen will be organized in two complementary formats; the first based on the major classes of pathogens, and the second grouped according to the primary site of pathogenesis within the human host.

Reading list

Bowie, A. G., & Unterholzner, L. (2008). Viral evasion and subversion of pattern-recognition receptor signaling. *Nature review immunology,* 8, 911-922.

Eduardo, G. (2000). *Principles of bacterial pathogenesis*. Academic Press.

Engelhardt, O. G., & Fodor, E. (2006). Functional association between viral and cellular transcription during influenza virus infection. *Reviews in Medical Virology,* 16, 329-345.

Flint, S. J., Enquist, L.W., Racaniello, V. R., & Skalka, A. M. (2009). *Principles of virology* (3rd ed.).Washington, DC: ASM Press.

Murray, P. K., Rosenthal, K. S., & Pfaller, M. A. (2012). *Medical microbiology* (7th ed.). USA: Saunders. .

Saito, T., & Gale, M. (2007). Principles of intracellular viral recognition. *Current Opinions in Immunology,* 19, 17-23.

Salyers, A. A., & Whitt, D. D. (2002). *Bacterial pathogenesis: A molecular approach* (2nd ed.). Washington, DC: ASM Press.

MCBI 602: Eukaryotic Infections: Protozoan, Helminthic and Fungal
This course will aim to teach the biology of eukaryotic pathogens with an emphasis on the molecular mechanisms underlying pathogen success. Treatments will elucidate diseases caused by both protozoan parasites (e.g., *Plasmodia*, Trypanosomes, *Leishmania*, and *Toxoplasma*) and selected pathogenic fungi and helminths. The uniqueness of each host-pathogen interaction will be developed, including pathways for infection and host cell invasion, host pathophysiology, and the survival strategies by each pathogen (e.g., immune evasion by antigenic variation). Modern efforts at vaccine development and the identification of new drug targets will be discussed, as well as the resistance mechanisms by these pathogens.

Reading list

Deitsch, K. W., Lukehart, S. A., & Stringer, J. R. (2009). Common strategies for antigenic variation by bacterial, fungal and protozoan pathogens. *Nature Review Microbiology,* 7, 493-503.

Kaye, P., & Scott, P. (2011). *Leishmaniasis:* Complexity at the host-pathogen interface. *Nature Review Microbiology,* 9, 604-615. Review.

McGuinness, D. H., Dehal, P. K., & Pleass, R. J. (2003) Pattern recognition molecules and innate immunity to parasites. *Trends in Parasitology,* 19(7), 312-319.

Plattner, F., & Soldati-Favre, D. (2008). Hijacking of host cellular functions by the Apicomplexa. *Annual Review of Microbiology*, 62, 471-487.

Sacks, D., & Sher, A. (2002). Evasion of innate immunity by parasitic protozoa. *Nature Immunology,* 3(11), 1041-1047. Review.

Sibley, L. D. (2011). Invasion and intracellular survival by protozoan parasites. *Immunological Reviews*, 240, 72-91.

Wheeler, R. J. (2010). The trypanolytic factor–mechanism, impacts and applications. *Trends in Parasitology,* 26, 457–464.

MCBI 603: Experimental Microbiology

This laboratory course aims at providing practical training and experience in the methods and practices necessary for a successful career in microbiology. Work will include: growth and characterization of various microbial organisms that are representative of important pathogens; methods to visualize cell specialization, such as light microscopy and the analysis of cell fluorescence; extraction and characterization of proteins and nucleic acids from cells; the infection of cells by viruses; and the methods used to characterize virus life-styles. Methods learned in this course will include sterile technique for handling pathogens, advanced light microscopy, operation of numerous instruments as well as separation methods.

Reading list

DeLeo, F. R., & Otto, M. W. (2008). *Bacterial pathogenesis: Methods and protocols*. Humana Press.

Flint, S. J., Enquist, L. W., Racaniello, V. R., & Skalka, A. M. (2009). Principles of Virology (3rd ed.). Washington, DC: ASM Press.

Horn, D., & McCulloch, R. (2010). Molecular mechanisms underlying the control of antigenic variation in African trypanosomes. *Current Opinions in Microbiology*, 13,700-705.

Slonczewski, J. L., & Foster, J. W. (2012). *Microbiology: an evolving science* (3rd ed.). New York, NY: W.W. Norton and Company.

Swift, H. F., Wilson, A. T., & Lancefield, R. C. (1943). Typing group A hemolytic streptococci by M precipitin reaction in capillary pipettes. *J Exp Med*, 78,127.

Yoneyama, H., & Katsumata, R. (2006). Antibiotic Resistance in bacteria and its future for Novel Antibiotic development. *Biosci Biotechnol Biochem*, 70 (5), 1060-1075.

MCBI 604: Host and Pathogen Genomics

This course aims to introduce students to the principles and tools for genomic and proteomic study of host-pathogen interactions. To that end it will discuss the content of multiple genomes elucidating their functions and organization. The course will also develop the modern, computer-based subjects of transcriptomics/metabolomics and the functional genomics of bacterial, viral and eukaryotic pathogens. Classical and complex disease genetics and quantitative trait locus (QTL) analysis, natural selection of pathogens, comparative genomics, genome wide association studies, genetic manipulations, computational learning (genome databases, modern methods for DNA sequencing, assembling pathogen genome sequences, genome-wide sequence read mapping and variant calling) will be discussed.

Reading list

Adomako-Ankomah, Y., Wier, G. M., & Boyle, J. P. (2012). Beyond the genome: recent advances in *Toxoplasma gondii* functional genomics. *Parasite Immunology,* 34, 80-89.

Anderson, T., Nkhoma, S., Ecker, A., & Fidock, D. (2011). How can we identify parasite genes that underlie antimalarial drug resistance? *Pharmacogenomics*, 12, 59–85.

Balu, B., & Adams, J. H. (2007). Advancements in transfection technologies for Plasmodium. *International Journal of Parasitology*, 37, 1-10.

Lakshmanan, V., Rhee, K. Y., & Daily, J. P. (2011). Metabolomics and malaria biology. *Molecular Biochemical Parasitology*, 175, 104-111.

Le Roch, K. G., Chung, D. W., & Ponts, N. (2012). Genomics and integrated systems biology in *Plasmodium falciparum*: A path to malaria control and eradication. *Parasite Immunology,* 34, 50-60.

Sibley, L. D. (2009). Development of forward genetics in *Toxoplasma gondii*. *International Journal of Parasitology,* 39, 915-924.

Subramaniam, C., Veazey, P., Redmond, S., Hayes-Sinclair, J., & Chambers, E. (2006). Chromosome-wide analysis of gene function by RNA interference in the african trypanosome. *Eukaryotic Cell*, 5, 1539-1549.

MCBI 606: Antimicrobial Therapeutics: Molecular Mechanisms and Concepts

This course is aimed at teaching concepts in drug discovery and development. Various types of drugs will be characterized: agonist/antagonists, biologics, protein/non-protein drugs, small molecule drugs. Where possible, their mechanisms will be described: inhibitors of bacterial cell wall biosynthesis, inhibitors of nucleic acids, inhibitors of metabolism, anti-mycobacterials agents, antiviral agents, antiparasitic agents, anti-helminthes, microbiocides. Recent work on novel therapeutic approaches and delivery methods, on drug recycling, host process targeting, and the use of modified peptides will be described. The course will also cover the complexities of antimicrobial therapy. Finally, we will examine mechanisms of resistance to antimicrobials, the biosynthesis of antimicrobials, ending with an overview of commercial drug development and the phases of clinical trials.

Reading list

Allahverdiyev, A. M., Kon, K. V., Abamor, E. S., Bagirova, M., & Rafailovich, M. (2011). Coping with antibiotic resistance: combining nanoparticles with antibiotics and other antimicrobial agents. *Expert Rev Anti Infect Ther*, 9(11), 1035-1052.

Augustyniak, D., Nowak, J., & Lundy, F. T. (2012). Direct and indirect antimicrobial activities of neuropeptides and their therapeutic potential. *Curr Protein Pept Sci* 13(8), 723-738.

Huang, J. X., Bishop-Hurley, S. L., & Cooper, M. A. (2012). Development of anti-infectives using phage display: biological agents against bacteria, viruses, and parasites. *Antimicrobial Agents Chemotherapy*, 56(9), 4569-4582.

Margolis, D. M., & Hazuda, D. J. (2013). Combined approaches for HIV cure. *Current Opinions in HIV AID, s*8(3), 230-235.

Powers, J. H. (2004). Antimicrobial drug development--the past, the present, and the future. *Clinical Microbiol Infect*, 10 Suppl 4, 23-31.

Rodríguez de Castro, F., Naranjo, O. R., Marco, J. A., & Violán, J. S. (2009). New antimicrobial molecules and new antibiotic strategies. *Semin Respir Crit Care Med,* 30(2), 161-171.

Shan, L., & Siliciano, R. F. (2013). From reactivation of latent HIV-1 to elimination of the latent reservoir: the presence of multiple barriers to viral eradication. *Bioessays*, 35(6), 544-552.

MCBI 608: Molecular Epidemiology of Infectious Diseases

The course aims to teach the principles and practical approaches for the use of molecular laboratory techniques to address problems in the epidemiology of infectious diseases. These will include the use of molecular techniques in investigations of disease outbreaks, the characterization of disease transmission dynamics, and identifying risk factors for transmission. Epidemiological study designs such as case-control, cohort and cross sectional studies will be introduced and analysis of molecular or genetic data obtained from these studies. The course will also discuss molecular methods for identifying antimicrobial resistance and for determining the population structure of pathogens using genetics. Students will also be introduced to on-line tools and databases such as Sit-vit, and MIRU-VNTR plus for determining circulating strains.

Reading list

Foxman, B., & Riley, L. (2001). Molecular epidemiology: focus on infection. *American Journal of Epidemiology,* 153, 1135–1141.

Thompson, R. C. A. (2001). *Molecular epidemiology of infectious diseases*. London, UK: Arnold Publishers.

Foxman, B. (2011). *Molecular tools and infectious disease epidemiology*. Academic Press.

Morand, S., Beaudeau, F., & Cabaret, J. (2011). *New frontiers of molecular epidemiology of*

infectious diseases. Springer.
Peter, M. S., Hopewell, P. C., Samir, P., Singh, A., & Paz, J. P. (1994). The Epidemiology of Tuberculosis in San Francisco -- A Population-Based Study Using Conventional and Molecular Methods. *New England Journal of Medicine*, 330, 1703-1709.

MCBI 610: Seminar I – Proposal Seminar
Students will be required to present their research proposal and attend all departmental seminars. Each student will also review and present a selected recently-published research article each semester. These presentations will be attended by all graduate students and graded by all faculty members. In addition, students will be assigned into small groups (five or less) for more interactive journal clubs led by a faculty member, where they will review and critique recent seminal articles in a relevant field.

MCBI 620: Seminar II – Progress Report Seminar
Each student will deliver a presentation on the progress of his/her research work each semester. In addition each student will be required to attend all departmental seminars.

TEACHING FACULTY

NAME	HIGHEST DEGREE	RANK	AREA OF SPECIALTY
Dr. Gordon Awandare (Program Director)	PhD	Senior Lecturer	Malaria parasite biology, immunology and pathogenesis
Dr. Patrick K. Arthur	PhD	Lecturer	Chemical Biology and Proteomics
Prof. Sammy T. Sackey	PhD	Ass. Professor	Virology, molecular biology
Dr. Lydia Mosi	PhD	Lecturer	Buruli Ulcer, Molecular Biology, Bioinformatics
Dr. Osbourne Quaye	PhD	Lecturer	Zoonotic transmission of gastro-viral agents, Virology, Enzymology
Dr. Theresa Manful	PhD	Lecturer	Trypanosomes and *Leishmania*, Molecular Biology, Bioinformatics
Dr. Marian A. Nyako	PhD	Lecturer	Malaria parasite biology, Molecular cell biology
Prof. Naa A. Adamafio	PhD	Ass. Professor	Signal transduction, bioremediation
Dr. Jonathan P. Adjimani	PhD	Senior Lecturer	Bioenergetics, enzymology
Prof. Laud K.N-A Okine	PhD	Ass. Professor	Naturals products, toxicology
Rev. Dr. Winfred S. K. Gbewonyo	PhD	Senior Lecturer	Insect biochemistry, natural products
Dr. Augustine Ocloo	PhD	Senior Lecturer	Bioenergetics, protein chemistry

Dr. Nana A. Yeboah	PhD	Lecturer	Protein chemistry, molecular biology
Dr. Kodzo Gbewonyo	PhD	Visiting Scholar	Biotechnology, molecular biology
Dr. Abidat Lawal	PhD	Lecturer, Full Time	Bacterial pathogenesis, biotechnology
Prof. Kwadwo A. Koram	MD, PhD	Professor	Epidemiology of infectious diseases, malaria
Prof. Dorothy Yeboah-Manu	PhD	Ass. Professor	Bacteriology, molecular epidemiology, Antimicrobial therapeutics
Dr. Michael F. Ofori	PhD	Senior Research Fellow	Malaria parasite biology, placental malaria
Dr. Kwadwo A. Kusi	PhD	Research Fellow	Malaria immunology
Dr. Nancy Duah Quashie	PhD	Senior Research Fellow	Molecular epidemiology
Dr. Anita Ghansah	PhD	Senior Research Fellow	Genetic epidemiology
Prof. Isabella Quakyi	PhD	Professor	Malaria immunity and vaccine development
Prof. Julius Fobil	PhD	Ass. Professor	Malaria epidemiology and biostatistics
Dr. Samuel Bosomprah	PhD	Senior Lecturer	Biostatistics
Dr. Samuel K. Kwofie	PhD	Lecturer	Bioinformatics, structural biology, hepatitis
Dr. Elvis K. Tiburu	PhD	Ass. Professor	Targeted drug discovery and delivery, structural biology, cancer
Dr. George Obeng-Adjei	MD, PhD	Senior Lecturer	Malaria chemotherapy
Dr. Neils Quashie	PhD	Senior Lecturer	Molecular epidemiology, antimicrobial therapeutics
Dr. Robert A. Kwame-Aryee	MD	Senior Lecturer	Obstetrics and Gynaecology, Workshops
Dr. Richard Asmah	PhD	Senior Lecturer	Immunology and Molecular Biology

DOCTOR OF PHILOSOPHY IN MOLECULAR CELL BIOLOGY OF INFECTIOUS DISEASES (PHD MCBI)

Admission requirements: Candidates with a Master's degree in the biological sciences, physical sciences, or other fields relevant to Infectious Diseases may apply for direct admission into the PhD MCBI program. Candidates with a good first degree (at least 2nd class lower) in a relevant discipline, including Biological or Physical Sciences may also apply into the PhD MCBI program.

Duration: Four years full time, six years part time.

Graduation requirements:

- Course work: 18 – 24 credits
- Seminar (4): 12 credits
- Thesis: 45 credits

Total: 75-81 credits

Program structure

Year 1

Semester 1

CORE		**CREDITS**
MCBI 701:	Advanced Qualitative Research Methods and Information Literacy	3
*FASC 700:	Special Topics in Science	3
*FASC 701:	Science and Society	3
	TOTAL	**9**

ELECTIVES (select one elective)

MCBI 710:	Laboratory Rotation	3
*BCMB 701:	Advanced Topics in Bioinformatics	3
MCBI 601:	Bacterial and Viral Infections	3
*BCMB 609:	Immune Response Mechanisms	3

Semester 2

CORE		**CREDITS**
*FASC 702:	Advanced Quantitative Research Methods	3
MCBI 702:	Current Vaccine Approaches	3
*BCMB 708	Advances in Biomedical and Infectious Diseases Research	3

ELECTIVES (select one elective)

MCBI 704:	Advances in Drug Discovery and Development	3
*FASC 710:	Teaching Science at Tertiary Level	3
MCBI 602:	Eukaryotic Infections: Protozoan, Helminthic and Fungal	3
MCBI 604:	Host and Pathogen Genomics	3

Year 2

MCBI 700:	Thesis	
MCBI 720:	Seminar I	3
MCBI 730:	Seminar II	3

Years 3 & 4

MCBI 700:	Thesis	45

MCBI 740:	Seminar III	3
MCBI 750:	Seminar IV	3

***Existing courses**

COURSE DESCRIPTIONS

***FASC 700: Special Topics in Science**
The course examines historical and contemporary issues in science, relating to the student's area of specialization and relevance. Such topics are expected to challenge the students into exploring current and relevant research trends/discoveries in scientific approaches. The course will enable students explore scientific knowledge in modern science, and add on to their depth of information in their chosen areas of specialty. It is expected that, the course will complement other courses on the PhD flagship of the various departments in the Sciences and elsewhere. Additionally, it will expose students to current trends of presentations, and foster stronger confidence-building attitude that will enable enhanced international academic competitive spirit.

***FASC 701: Science and Society**
This course will enable students gain insights on the practice of science as a discipline including major scientific concepts like inductivism are examined as well as the history of science and science itself, an overview of current approaches to research and an understanding of research partnerships, networks and appropriate methods of communicating science depending on the audience. The aim of the course is to help students to fit their research to relevant trends and directions for national development. Course content will cover topics such as the basis for the scientific method; conceptual frameworks; the philosophy of science; ethics in research; pure versus applied science debates; approaches to research; science for development and the merit of broader impact criteria; north south/south south collaboration and partnerships; research networks; communicating science to the policy make, lay audience and to the media.

Reading list
Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). London, UK: Sage Publication.
Curd, M., & Cover, J. A. (1998). *Philosophy of science: The central issues.* New York, NY: Norton.
Gyekye, K., Osae, E., & Effah, E. (Eds.) (2005). *Harnessing research, science and technology for sustainable development in Ghana*. Accra, Ghana: National Council on Tertiary Education.
Kendler, H. H. (2003). Should scientists remain objective? *Science,* 301, 310-311.
Kuhn, T. S. (2012). *The structure of scientific revolutions*. Chicago, IL: University of Chicago Press.

***FASC 702: Advanced Quantitative Research Methods**
The course will serve as a step up for students who need to add up to their knowledge in quantitative methods of research techniques and analyses. Topics to be covered include: Sampling distributions and hypothesis testing. Sample size determination. Categorical data and chi-square, Non parametric tests. Principles of Design of Experiments. Analysis of variance and its assumptions. Experiments with single and multiple factors. Orthogonal and multiple Comparisons. Completely Randomized, Randomized Complete Block, repeated measures, cross over and Latin square designs. Nested designs. Fixed, random and mixed effects models. Factorial designs. Confounding. Fractional factorial designs. Split plot designs. Incomplete block designs. Analysis of covariance. Regression models: basic concepts; Regression Model Diagnostics. Categorical data analysis. Logistic regression, univariate and multivariate. Confounding and collinearity in logistic regression. Model selection in logistic regression.

Reading List

Clarke, G. M., & Kempton, R. E. (1997). *Introduction to the design and analysis of experiments*. London, UK: Edward Arnold.

Cochran, W. G., & Cox, G. M. (1957). *Experimental design*. New York, NY: John Wiley,

Lyman R. O., & Longnecker, M. (2001). *An introduction to statistical methods and data analysis* (5th ed.). California, CA: Duxbury.

Mead, R. (1988). *The design of experiments*. Cambridge, UK: Cambridge University Press.

Montgomery, D. C. (2000). *Design and analysis of experiments*. New York, NY: John Wiley.

Sokal, R. R., & Rohlf, F. J. (2012). *Biometry*: The *principles and practice of statistics in biological research* (4th ed.). New York, NY: W. H. Freeman and Co.

Stokes, M. E., Davis, C. S., & Koch, G. G. (2000). *Categorical data analysis using the SAS system*. New York, NY: SAS Publishing.

***FASC 710: Teaching Science at the Tertiary Level**

It is anticipated that many of the students who go through the PhD programme in the Sciences may nurse special interest in teaching and academia. Focusing on group discussions, this course is expected to equip students with the requisite knowledge in overall management of students at the tertiary level. The course will focus on teaching the methodologies and techniques in handling Science-teaching at the undergraduate level. Topics such as laboratory supervision and safety, grading issues, special needs students, lecturing and tutoring techniques, examination preparation, teacher/student relationship, tertiary education management, will be discussed through reading, class/group discussions as well as presentations.

Reading list

Alley, M. (2007). *The craft of scientific presentations: Critical steps to succeed and critical errors to avoid*. New York, NY: Springer-Verlag.

Arons, A. B. (1996). *Teaching introductory physics*. New York, NY: John Wiley and Sons.

Halfman, R. L., MacVicar, M. L. A., Martin, W. T., Taylor, E. F., & Zacharias, J. R. (1972). *Tactics for change*. Occasional Paper No. 11 of the Education Research Center, Massachusetts, MA: Massachusetts Institute of Technology.

Morrison, R. T. (1986). *The lecture system in teaching science*: *Undergraduate education in chemistry and physics*. Retrieved from http://entropysite.oxy.edu

Polya, G. (1981). *Mathematical discovery: On understanding, learning, and teaching problem solving*. New York, NY: John Wiley and Sons.

***BCMB 701 Advanced Topics in Bioinformatics**

This course will expose students to all the bioinformatic tools necessary for acquisition and comparative analysis of host and pathogen genomic data. Software programmes used for genomics, transcriptomics and proteomics/protein networks are considerably different, and hence it is important for students to learn the main softwares used in these fields of molecular biology as well as the new and updated versions that will be introduced from time-to-time. In addition to reviews of bioinformatic tools covering these main areas of molecular biology, softwares used in high-content image analysis, lipidomics as well as chemoinformatics will also be included to give students a holistic view of the bioinformatics. The course will be mainly conducted through the use of review articles selected by the lecturer during the period of the course for students to study in groups and present at lectures for discussions. At the beginning of the course, there will be a few lectures to be given by the course instructor to provide general overview of the bioinformatic lanscape.

Reading list

Baxevanis, D., & Ouellette, B. F. (2001). *Bioinformatics: A practical guide to the analysis of genes and proteins*. New York, NY: John Wiley and Sons Inc.

Lesk, A. M (2005). *Introduction to bioinformatics.* University of Cambridge. New York, NY: Oxford University Press Inc.

Maulik, U., Bandyopadhyay, S. and Mukhopadhyay, A. (2011). *Multiobjective genetic algorithms for clustering: Applications in data mining and bioinformatics*. Elsevier.

Mount, D. W (2001). *Bioinformatics; sequence and genome analysis*. (2nd ed.). Delhi, India: CBS Publishers and distributors (PVT.) Ltd.

Pevsner, J. (2009). *Bioinformatics and functional genomics*. New Jersey, USA: Wiley-Blackwell.

***BCMB 708 Advances in Biomedical and Infectious Diseases Research 3**

The course is aimed equipping students with knowledge on current methods for studying the transmission, diagnosis, and pathogenesis of diseases that are of public health concern in sub-Saharan Africa. Diseases to be covered include infectious diseases such as Malaria, HIV, and TB, neglected tropical diseases (NTDs) such as Leishmania, Buruli ulcer, and Schistosomiasis. Current knowledge of the biology of the causative agents, as well as progress towards improved therapeutic mechanisms and vaccine development will be discussed. The relevance of genomics and proteomics for research into the various diseases will also be emphasized.

Reading List

Griscelli, C., & Vossen, J. (1984). *Progress in immunodeficiency research and therapy: Proceedings of the first meeting of the European group for immunodeficiencies (Vol 1)*. International Congress Series 645. Excerpta Medica.

Krause, M. R., Gallin, J. I., & Fauci, A. S. (2000). *Emerging infections.* Biomedical Research Reports. Academic Press.

Slater, L. B. (2009). *War and disease: Biomedical research on malaria in the twentieth century.* Critical Issues in Health and Medicine.

Schmidt, A., Weber, O., Kaufmann, S. H. E. and Mercer, A. A. (2011). *Birkhäuser advances in infectious diseases.* New York City, NY: Springer.

Thompson, R. C. A. (2001). *Molecular Epidemiology of Infectious Diseases*. London, UK: Arnold Publishers.

***BCMB 609: Immune Response Mechanisms**

This course is an advanced study of Immunology and takes a detailed look at the molecular mechanisms through which the immune system responds to pathogens. A major goal of the course is to prepare students for research in the fields of Immunology, disease pathogenesis and vaccine development. The content includes discussions of the mechanisms of antigen processing and presentation, T-cell and B-cell receptor gene rearrangements, recombination of VDJ gene segments, affinity maturation and somatic hypermutation. Current advances in immunological methods such as flow cytometry, and new developments in the search for vaccines for malaria and HIV will also be discussed.

Reading list

Charles, A. J. (2005). *Immunobiology: The immune system in health and disease* (6th ed.). New York, NY: Garland Science Publishing.

Tak, W. M. & Saunders, M. E. (2006). *The immune response: Basic and clinical principles*. Elsevier Academic Press, UK.

William, E. P. (2008). *Fundamental immunology* (6th ed.). Pennsylvania: Lippincott Williams and Wilkins.

Plattner, F., & Soldati-Favre, D. (2008). Hijacking of host cellular functions by the Apicomplexa. *Annual Review of Microbiology*, 62,471-487.

Sacks, D., & Sher, A. (2002). Evasion of innate immunity by parasitic protozoa. *Nature Immunology,* 3(11), 1041-1047. Review.

Sibley, L. D. (2011). Invasion and intracellular survival by protozoan parasites. *Immunological*

Reviews, 240, 72-91.

MCBI 700: Thesis
Each student will undertake a major research project and present a written dissertation. In addition, students will present an oral defence of their thesis.

MCBI 701: Advanced Qualitative Research Methods and Information Literacy
This course will provide students with an advanced knowledge of qualitative research strategies including discussion of study design and methods for data collection and discuss their strengths and limitations. Approaches for collection, analysis and reporting of qualitative data will also be covered. Topics will include case studies, comparative analysis, predictive deduction, triangulation, and validity/reliability/generalizability. In addition, the course will cover information literacy to help students develop the ability to identify their information needs, effectively locate, critically evaluate and creatively use such information for their research. The course will also cover proposal writing, ethics of research and intellectual property issues.

Reading list
Bitektine, A. (2008). Prospective case study design - Qualitative method for deductive theory testing. *Organizational Research Methods,* 11(1), 160-180.
Dawn, M. S., & Scott, W. (2003). *Information literacy for educators: Professional knowledge for an information age*. Binghamton, N.Y.
James, E. H. (2011). *Improving students' web use and information literacy: A guide for teachers and teacher librarians*.
Marshall, C., & Rossman, G. (2011). *Designing qualitative research* (5th ed.). London, UK: Sage Publications.
Miles, M. B., & Huberman, A. M. (1984). *Qualitative analysis: A sourcebook of new methods.* Thousand Oaks. CA: Sage Publications.
Yin, R. K. (2011). *Qualitative research from start to finish*. New York, NY: The Guilford Press.

MCBI 702: Current Vaccine Approaches
This course aims to review recent developments in the design, development and delivery of vaccines against infectious diseases. An overview of the principles of vaccination and discussion of the successes and failures of historical vaccines including the small pox and yellow fever vaccines will be discussed. The strengths and limitations of current approaches to vaccine design will also be reviewed, including live attenuated, peptide and subunit vaccines and the applications of recombinant DNA vectors and idiotypic antibodies will be discussed. In addition, the factors hampering the development of vaccines to major infectious diseases such as malaria and HIV, as well as the promising new strategies for overcoming these challenges will be reviewed.

Reading list
Bachmann, M.F., & Jennings, G. T. (2010). Vaccine delivery: A matter of size, geometry, kinetics and molecular patterns. *Nat Rev Immunol*, 10(11), 787-796.
Grimm, S. K., & Ackerman, M. E. (2013). Vaccine design: Emerging concepts and renewed optimism. *Curr Opin Biotechnol*, 24(6), 1078-1088.
Kurstak, E. (Ed) (2013). *Modern vaccinology*. New York City, NY: Springer.
Letvin, N. L. (2006). Progress and obstacles in the development of an AIDS vaccine. *Nat Rev Immunol,* 6(12), 930-939.
Plotkin, S. A., Brown, F., & Horaud, F. (1997). *Preclinical and clinical development of new vaccines.* USA: University of Michigan.
Schiller, J.T., & Lowy, D. R. (2012). Understanding and learning from the success of prophylactic human papillomavirus vaccines. *Nat Rev Microbiol,* 10(10), 681-692.

Vaughan, A. M., & Kappe, S. H. (2012). Malaria vaccine development: persistent challenges. *Curr Opin Immunol,* 24(3), 324-331.

MCBI 704: Advances in Drug Discovery and Development

This course aims to provide students with a deep understanding of the most modern approaches to discovery and development of drugs. Topics to be discussed will include mechanistic disease target discovery and validation, basic disease models, genes to medicines. In addition, advances in the development process will also be covered, including stage-gates from exploratory research targets (ERTs) to drug candidates, late discovery to early development, pre-clinical and candidate validation, clinical phases, post launch and drug surveillances.

Reading list

Allahverdiyev, A. M., Kon, K. V., Abamor, E. S., Bagirova, M., & Rafailovich, M. (2011). Coping with antibiotic resistance: Combining nanoparticles with antibiotics and other antimicrobial agents. *Expert Rev Anti Infect Ther*, 9(11), 1035-1052.

Bullard, K. M., DeLisle, R. K., & Keenan, S. M. (2013). Malarial kinases: Novel targets for in silico approaches to drug discovery. *Methods Molecular Biology*, 993, 205-229.

Huang, J. X., Bishop-Hurley, S. L., & Cooper, M. A. (2012). Development of anti-infectives using phage display: Biological agents against bacteria, viruses, and parasites. *Antimicrobial Agents Chemotherapy*, 56(9), 4569-4582.

Margolis, D. M., & Hazuda, D. J. (2013). Combined approaches for HIV cure. *Current Opinions in HIV AIDS*, 8(3), 230-235.

Powers, J. H.(2004). Antimicrobial drug development--the past, the present, and the future. *Clin Microbiol Infect*, 4, 23-31.

Rodríguez de Castro, F., Naranjo, O. R., Marco, J. A., & Violán, J. S. (2009). New antimicrobial molecules and new antibiotic strategies. *Semin Respir Crit Care Med*, 30(2), 161-171.

Trivedi, A., Lee, R. E., & Meibohm, B. (2013). Applications of pharmacometrics in the clinical development and pharmacotherapy of anti-infectives. *Expert Rev Clin Pharmacol*, 6(2), 159-170.

MCBI 710: Laboratory Rotation

This course is designed for students who are interested in exploring the research projects available in the various laboratories of the faculty members. Students will be placed on attachment to each laboratory for at least two months to experience research and then submit a written report for assessment.

MCBI 720: Seminar I

Each student will make a presentation on his/her thesis research proposal. In addition each student will be required to attend all departmental seminars. Students will also be assigned into small groups of five for journal clubs led by a faculty member, where they will review and critique recent seminal articles in a relevant field.

MCBI 730: Seminar II

For their experiential learning, students will be attached to local, regional, or international research partners, and they may use the period to collect and analyze pilot data, optimise methods or develop protocols. Students will be required to present (oral and written) reports of their attachments, which will be graded. In addition students will be required to attend all departmental seminars when they are not traveling.

MCBI 740: Seminar III

Students will be required to provide updates on their research projects at least once each semester through a progress report seminar presentation. In addition students will be required to attend all departmental seminars.

MCBI 750: Seminar IV
Students will be required to provide updates on their research projects at least once each semester through a progress report seminar presentation. In addition students will be required to attend all departmental seminars.

MCBI 601: Bacterial and Viral Infections
This course aims to provide insight on bacterial and viral infections that are major public health concerns in sub-Saharan Africa. Aspects to be discussed will include the biology of the pathogen, the pathogenesis of its infection, the pathophysiology of the human host, and current strategies for therapeutics and vaccinology. The molecular mechanism of each pathogen will be discussed, thereby elucidating the pathways for disease progression and pathogen success. Treatment of each pathogen will be organized in two complementary formats; the first based on the major classes of pathogens, and the second grouped according to the primary site of pathogenesis within the human host.

Reading list
Bowie, A. G., & Unterholzner, L. (2008). Viral evasion and subversion of pattern-recognition receptor signaling. *Nature Review Immunology,* 8, 911-922.
Eduardo, G. (2000). *Principles of bacterial pathogenesis*. Academic Press.
Engelhardt, O. G., & Fodor, E. (2006). Functional association between viral and cellular transcription during influenza virus infection. *Reviews in Medical Virology,* 16, 329-345.
Flint, S. J., Enquist, L.W., Racaniello, V. R., & Skalka, A. M. (2009). *Principles of Virology* (3rd ed.). Washington, DC: ASM Press.
Murray, P. K., Rosenthal, K. S., & Pfaller, M. A. (2012). *Medical microbiology* (7th ed.). USA: Saunders.
Saito, T., & Gale, M. (2007). Principles of intracellular viral recognition. *Current Opinions in Immunology,* 19, 17-23.
Salyers, A. A., & Whitt, D. D. (2002). *Bacterial pathogenesis: A molecular approach* (2nd ed.). Washington, DC: ASM Press.

MCBI 602: Eukaryotic Infections: Protozoan, Helminthic and Fungal
This course will aim to teach the biology of eukaryotic pathogens with an emphasis on the molecular mechanisms underlying pathogen success. Treatments will elucidate diseases caused by both protozoan parasites (e.g., *Plasmodia*, Trypanosomes, *Leishmania*, and *Toxoplasma*) and selected pathogenic fungi and helminths. The uniqueness of each host-pathogen interaction will be developed, including pathways for infection and host cell invasion, host pathophysiology, and the survival strategies by each pathogen (e.g., immune evasion by antigenic variation). Modern efforts at vaccine development and the identification of new drug targets will be discussed, as well as the resistance mechanisms by these pathogens.

Reading list
Deitsch, K. W., Lukehart, S. A., & Stringer, J. R. (2009). Common strategies for antigenic variation by bacterial, fungal and protozoan pathogens. *Nature Review Microbiology,* 7, 493-503.
Kaye, P., & Scott, P. (2011). *Leishmaniasis:* Complexity at the host-pathogen interface. *Nature Review Microbiology,* 9, 604-615. Review.
McGuinness, D. H., Dehal, P. K., & Pleass, R. J. (2003) Pattern recognition molecules and innate immunity to parasites. *Trends in Parasitology,* 19(7), 312-319.
Plattner, F., & Soldati-Favre, D. (2008). Hijacking of host cellular functions by the Apicomplexa. *Annual Review of Microbiology*, 62, 471-487.
Sacks, D., & Sher, A. (2002). Evasion of innate immunity by parasitic protozoa. *Nature Immunology,* 3(11), 1041-1047. Review.
Sibley, L. D. (2011). Invasion and intracellular survival by protozoan parasites. *Immunological*

Reviews, 240, 72-91.
Wheeler, R. J. (2010). The trypanolytic factor–mechanism, impacts and applications. *Trends in Parasitology,* 26, 457–464.

MCBI 604: Host and Pathogen Genomics

This course aims to introduce students to the principles and tools for genomic and proteomic study of host-pathogen interactions. To that end it will discuss the content of multiple genomes elucidating their functions and organization. The course will also develop the modern, computer-based subjects of transcriptomics/metabolomics and the functional genomics of bacterial, viral and eukaryotic pathogens. Classical and complex disease genetics and quantitative trait locus (QTL) analysis, natural selection of pathogens, comparative genomics, genome wide association studies, genetic manipulations, computational learning (genome databases, modern methods for DNA sequencing, assembling pathogen genome sequences, genome-wide sequence read mapping and variant calling) will be discussed.

Reading list

Adomako-Ankomah, Y., Wier, G. M., & Boyle, J. P. (2012). Beyond the genome: Recent advances in *Toxoplasma gondii* functional genomics. *Parasite Immunology,* 34, 80-89.
Anderson, T., Nkhoma, S., Ecker, A., & Fidock, D. (2011). How can we identify parasite genes that underlie antimalarial drug resistance? *Pharmacogenomics*, 12, 59–85.
Balu, B., & Adams, J. H. (2007). Advancements in transfection technologies for Plasmodium. *International Journal of Parasitology* ,37, 1-10.
Lakshmanan, V., Rhee, K. Y., & Daily, J. P. (2011). Metabolomics and malaria biology. *Molecular Biochemical Parasitology*, 175, 104-111.
Le Roch, K. G., Chung, D. W., & Ponts, N. (2012). Genomics and integrated systems biology in *Plasmodium falciparum*: A path to malaria control and eradication. *Parasite Immunology,* 34, 50-60.
Sibley, L. D. (2009). Development of forward genetics in *Toxoplasma gondii*. *International Journal of Parasitology,* 39, 915-924.
Subramaniam, C., Veazey, P., Redmond, S., Hayes-Sinclair, J., & Chambers, E. (2006). Chromosome-wide analysis of gene function by RNA interference in the african trypanosome. *Eukaryotic Cell*, 5, 1539-1549.

Details of Experiential Learning

After their PhD research proposal is approved, each student would be attached to a research laboratory for their experiential learning. The experiential learning period will give students the opportunity to learn research techniques in a practical setting. This period could also be used to develop protocols, optimise methods, or collect preliminary data. Students will submit a written report of their laboratory attachment or field work, and also present a seminar.

Students will have the option to work on some of the ongoing research projects being led by faculty members and their international collaborators. The departmental graduate committee will ensure that each student is assigned to the projects that will provide the appropriate training. A summary of the research projects currently available is provided below. This list will be updated annually to reflect addition of new projects or termination of existing ones.

1. **Alternative molecular mechanisms for erythrocyte invasion by *Plasmodium falciparum* in Ghana (PIs, Gordon Awandare & David Conway):** This study is investigating the relationship between sequence variation in malaria parasites genomes which may result from immunological pressure, and the invasion mechanisms deployed by the parasites to infect red blood cells. Malaria parasite isolates are being collected from children in Navrongo and Kintampo. Students would benefit from experience in sample collection and processing at the

various sites, and the subsequent molecular and immunological analysis (red cell invasion assays, ELISA, real time PCR, genome sequencing), and bioinformatics in our laboratories and with our collaborators at the London School of Hygiene and Tropical Medicine and the Sanger Institute. This study is funded by a Royal Society-Leverhulme Africa Award.

2. **Role of complement receptor 1 in erythrocyte invasion by *Plasmodium falciparum* in semi-immune Ghanaians (PI, Gordon Awandare):** These studies focus on the role of complement receptor 1 (CR1) in malarial pathogenesis in children exposed to varying intensities of transmission. Samples are being collected in Navrongo, Kintampo, and Accra, and we are determining the relationship between expression of CR1 protein on the RBCs of children with malaria, peripheral parasitemia, and ligand-specific antibody titers. In addition, molecular and immunological techniques are being used to confirm the role of *P. falciparum* Rh4 as a ligand for CR1 and also to look for novel CR1 ligands. These studies will help identify new targets for vaccine development, and students will benefit from the field work as well as the molecular and immunological analysis in our laboratories at Legon and the laboratories of our collaborators at Penn State University, PA, USA. The study is funded by a grant from the National Institutes of Health (NIH), USA.
3. **Zoonotic risks of non-tuberculous mycobacteria between humans and small mammals (potential transmission of Buruli ulcer) in Cote d'Ivoire and Ghana (PIs, Lydia Mosi and Bassirou Bonfoh):** This collaborative project aims to discover the underlying zoonotic potential of non-tuberculous mycobacterial transmission between the environment, small mammals and humans. The aims and objectives of this study employs a ONE HEALTH approach to deciphering the mode of transmission of Buruli ulcer and other non-tuberculous mycobacterial diseases. These studies provide studies with opportunities to experience field work, the use of animal models of disease, and to learn techniques in microbiological handling and molecular diagnosis. This project is funded by the Wellcome trust/ Afrique One consortium.
4. **Microbiology of secondary infections in Buruli ulcer lesions: implications for therapeutic interventions (PI, Lydia Mosi):** This Project is designed to determine the occurrence of secondary infections in Buruli ulcer lesions and the rate of antibiotic resistance emergence associated with treatment. Students participating in this project will learn techniques for molecular diagnosis and handling of microorganisms. The project is funded by a grant from the University of Ghana Research Fund.
5. **Characterisation of trypanosome infections over the lifetime of cattle in Ghana (PIs, Theresa Manful and Mark Carrington):** The aim is to determine the molecular diversity of trypanosomes infection in cattle in two different geographical locations in Ghana and to identify whether there is a correlation between age and predominant infecting trypanosome species. Students will learn the use of molecular fingerprinting to identify individual trypanosome genotypes and characterise the epidemiology of the trypanosome populations present in individual cows over their lifetimes. This study is funded by a Royal Society-Leverhulme Africa Award and a CAPREX fellowship.
6. **Proteomic analysis of the molecular mechanisms of latency and drug-resistance in *Mycobacterium africanum I* and screen for novel antimycobacterials from fungal sources (PI, Patrick Arthur).** This project seeks to discover new and more effective drugs for tuberculosis from fungal sources using an integrated proteomics platform, which determines both the mechanism of drug action and resistance. This project makes use of our assembled library of wood decaying fungi and marine endophytic fungi, which have demonstrated the production of metabolites with anti-microbial activities. Students will gain experience in proteomics, drug susceptibility testing for microorganisms and purification and characterization of novel compounds. This study is funded by a grant from Grand Challenges Canada.
7. **Towards effective control of Buruli ulcer (PI, Dorothy Yeboah-Manu):** This project aims to improve understanding of the ecology and transmission of *Mycobacteria ulcerans,* analyse for

evolution of Buruli ulcer wounds to determine underlying mechanism(s) of wound healing delay and improve diagnosis by development, improvement and evaluation of point-of-care diagnostic laboratory test systems. Students involved with this project will learn techniques including conventional and real-time PCR, western blotting, ELISA, DNA sequence analysis, and conventional microbiological methods. The project is funded by the UBS Optimus foundation and VW Foundation.

8. **Understanding the genomic diversity between *Mycobacterium africanum (MAF)* and *Mycobacterium tuberculosis (MTB)* (PI, Dorothy Yeboah-Manu):** This is a prospective molecular epidemiological study of tuberculosis in one urban district and one rural district of Ghana. The study aims to define the genetic diversity (including drug resistance) of MTB and MAF circulating in these areas and compare the transmission of MTB and MAF and associated risk factors, such as HIV, drug resistance, and diabetes in these areas. Gene expression profiles of MTB and MAF will also be examined. This study will use several techniques which students would learn from, including, Spoligotyping, MIRU-VNTR, SNP analysis, genomics-bioinformatics, gene expression by RNAseq, conventional microbiological methods. The project is funded by the Wellcome Trust, UK.
9. **Measuring changes in reservoir of malaria infection in northern Ghana using molecular diagnostic methods (PI, Kwadwo Koram):** This project aims to characterize the reservoir of malaria infection by microscopy and PCR-based methods, to calculate multiplicity of infection by MSP2 genotyping, and assess the frequency of drug resistance alleles. Students involved with this project will be trained to measure linkage disequilibrium in *P. falciparum* using microsatellite repeat loci and genome-wide single nucleotide polymorphisms (SNPs) and to characterize the reservoir of infection in terms of the number of *var* gene types in the population. The project is funded by Howard Hughes Medical Institute/NIH.
10. **Impact of Distinct Eco-epidemiology on Malaria Drug Resistance in Ghana (PI, Anita Ghansah).** This project seeks to compare the clinical and parasitological efficacy of anti-malarial drugs in two ecological zones of Ghana over time. This is being done by determining the multiplicity of infections (MOI) in the two ecological zones and their association with drug resistance over time. The study will also characterize and compare the frequency of known drug resistance markers in the two zones and their correlations with ex vivo drug response over time. This project gives students exposure to cohort study design and statistical analysis, SNP genotyping, PCR, high resolution melting curve technique, genome-wide sequencing and analysis. The studies are funded by a grant from the National Institute of Allergy and Infectious Diseases (NIAID), NIH, USA.
11. **Exploring *Plasmodium falciparum* genome to understand the genetic diversity, emergence of drug resistance and vaccine efficacy (PI, Anita Ghansah).** This study is investigating *P. falciparum* population diversity in parasites circulating in forest and coastal Savanna zones of Ghana, by examining the genetic structure of *P. falciparum* over space and time in the study area, and mapping the Linkage Disequilibrium architecture of parasite isolates to detect signatures of natural selection in the Ghanaian parasite pool. The study will also determine the frequency distribution of polymorphisms in candidate vaccine antigens and known drug resistance genes. This project will teach students in field study design, DNA extraction techniques, whole genome sequencing and analysis of whole genome data. The project is funded by the MRC Centre for Genomics and Global Health.
12. **Association of strong T cell responses to HLA class I-restricted CSP and AMA1 epitopes with the risk of *P. falciparum* infection (PI, Kwadwo Asamoah Kusi):** The aim of this study is to determine the relationship between T cell responses to HLA class I–restricted epitopes within the Plasmodium antigens CSP and AMA1, and the risk of infection with Plasmodium and/or the incidence of clinical malaria in a longitudinal cohort from a malaria endemic area. Methods that students could learn through this project include IFN-γ ELISPOTS, Flow cytometry, HLA typing, and bioinformatics. The study is funded by a grant from the University of Ghana Research fund.

13. **Immortalization of B cells from *P. falciparum*-exposed individuals for the production of parasite-specific monoclonal antibodies (PI, Kwadwo Asamoah Kusi):** The aim of this project is to develop a protocol for the continuous production of immortalized human B cells and subsequently purify/characterize secreted antibodies that have specificity for selected *P. falciparum* antigens. Students involved with this project will be trained on Cell culture, cell cloning by limiting dilution, ELISA, SDS PAGE, Western blotting, and fluorescence microscopy. This project is funded by a grant from the World Academy of Sciences (TWAS).

Funding and International Collaborations

The proposed new MCBI graduate programs will be funded by a grant (approximately $8M) from the World Bank's African Centers of Excellence Initiative. In addition, the programs will benefit from collaborations with regional partners and international institutions including the American Society for Cell Biology (ASCB). Through these collaborations, the MCBI programs will benefit from short teaching visits from some of the leading Infectious Disease research scientists in the world, as well as opportunities for laboratory attachments at partner institutions. Some of the ongoing collaborations include:

1. American Society for Cell Biology (ASCB): This collaboration is for the purpose of organizing annual training workshops on the Cell Biology of Infectious Diseases. The ASCB has a vast network of renowned scientists, including Prof Keith Gull of Oxford University, Prof. Kirk Deitsch of Cornell University, NY, and Prof Dick McIntosh of the University of Colorado, who have committed to supporting the MCBI program.
2. London School of Hygiene and Tropical Medicine (LSHTM), UK: This is based on two collaborative research grants between Dr. Gordon Awandare and Prof. David Conway of LSHTM. It includes training and joint supervision of students and is funded by grants from the Royal Society, UK, and the European Research Council. These collaborations also include regional partners including Dr Ambroise Ahouidi (International Center of Excellence in Malaria Research (ICEMR), Universite Cheikh Anta Diop in Senegal), Dr Mahmadou Diakite (University of Bamako in Mali), and Dr Alfred Amambua-Ngwa (MRC Laboratories in The Gambia).
3. Penn State University School of Medicine, Hershey, PA: This is based on a collaborative research grant between Dr. Gordon Awandare and Prof. Jose Stoute of Penn State. It includes training and joint supervision of students. It is funded by a National Institutes of Health, USA grant award.
4. Cambridge University, UK: This is based on a collaborative research grant between Dr. Theresa Manful and Prof. Mark Carrington of Cambridge. It includes training and joint supervision of students. It is funded by a Royal Society-Leverhulme Africa award.
5. Malaria Vaccine Research and Capacity Building in Ghana (MAVARECA): This is a DANIDA-funded collaboration with NMIMR and the University of Copenhagen, for the training of PhD students in malaria vaccine research. It is being led by Prof Kwadwo Koram and Dr. Michael Ofori.
6. Centre Suisse de Recherche Scientifique (CSRS), Cote d'Ivoire: This is based on a collaboration between Prof. Bassirou Bonfoh of CSRS and Dr. Lydia Mosi on a Wellcome Trust/Afrique-One funded research and training project in molecular epidemiology of Buruli Ulcer in Ghana and La Cote d'Ivoire. It includes training and joint supervision of students.
7. Centre National de Recherche et de Formation sur le Paludisme (CNRFP), Burkina Faso: This is based on previous collaborations between Dr. Sodiomon Sirima of CNRFP and NMIMR for malaria research and training. CNRP is a partner for the proposed center of excellence (WACCBIP) and will continue to collaborate on research and training on malaria.

TEACHING FACULTY

NAME	INSTITUTION	HIGHEST DEGREE	AREA OF SPECIALTY
Dr. Gordon Awandare (Program Director)	University of Ghana, Biochemistry, Cell and Molecular, Biology, (BCMB)	PhD	Malaria parasite biology, immunology and pathogenesis
Dr. Patrick K. Arthur	University of Ghana, BCMB	PhD	Chemical Biology and Proteomics in Infectious Diseases
Prof. Sammy T. Sackey	University of Ghana, BCMB	PhD	Virology, molecular biology
Dr. Lydia Mosi	University of Ghana, BCMB	PhD	Buruli Ulcer, Molecular Biology, Bioinformatics
Dr. Osbourne Quaye	University of Ghana, BCMB	PhD	Zoonotic transmission of gastro-viral agents, Virology, Enzymology
Dr. Theresa Manful	University of Ghana, BCMB	PhD	Trypanosomes and *Leishmania*, Molecular Biology, Bioinformatics
Dr. Marian A. Nyako	University of Ghana, BCMB	PhD	Malaria parasite biology, Molecular cell biology
Prof. Naa A. Adamafio	University of Ghana, BCMB	PhD	Signal transduction, bioremediation
Dr. Jonathan P. Adjimani	University of Ghana, BCMB	PhD	Bioenergetics, enzymology
Prof. Laud K.N-A Okine	University of Ghana, BCMB	PhD	Naturals products, toxicology
Rev. Dr. W. S. K. Gbewonyo	University of Ghana, BCMB	PhD	Insect biochemistry, natural products
Dr. Augustine Ocloo	University of Ghana, BCMB	PhD	Bioenergetics, protein chemistry
Dr. N. A. Yeboah	University of Ghana, BCMB	PhD	Protein chemistry, molecular biology
Dr. Kodzo Gbewonyo	University of Ghana, BCMB	PhD	Biotechnology, molecular biology
Dr. Abidat Lawal	University of Ghana, BCMB	PhD	Bacterial pathogenesis, biotechnology
Prof. Kwadwo A. Koram	University of Ghana, Noguchi Memorial Institute for Medical Research (NMIMR)	MD, PhD	Epidemiology of infectious diseases, malaria
Prof. Dorothy Yeboah-Manu	University of Ghana, NMIMR	PhD	Bacteriology, molecular epidemiology, Antimicrobial therapeutics

Dr. Michael F. Ofori	University of Ghana, NMIMR	PhD	Malaria parasite biology, placental malaria
Dr. Kwadwo Asamoah Kusi	University of Ghana, NMIMR	PhD	Malaria immunology
Dr. Nancy Duah Quashie	University of Ghana, NMIMR	PhD	Molecular epidemiology
Dr. Anita Ghansah	University of Ghana, NMIMR	PhD	Genetic epidemiology
Ama Dadson	University of Ghana Computing Systems	MSc	ICT
Barfi-Adomako Owusu	University of Ghana Computing Systems	MSc	ICT
Prof. Isabella Quakyi	University of Ghana, School of Public Health	PhD	Malaria immunity and vaccine development
Prof. Julius Fobil	University of Ghana School of Public Health	PhD	Malaria epidemiology and biostatistics
Dr. Samuel Bosomprah	University of Ghana School of Public Health	PhD	Biostatistics
Dr. Samuel K. Kwofie	University of Ghana, Biomedical Engineering	PhD	Bioinformatics, structural biology, hepatitis
Dr. Elvis K. Tiburu	University of Ghana, Biomedical Engineering	PhD	Targeted drug discovery and delivery, structural biology, cancer
Dr. George Obeng-Adjei	University of Ghana Medical School	MD, PhD	Malaria chemotherapy
Dr. Neils Quashie	University of Ghana Medical School	PhD	Molecular epidemiology, antimicrobial therapeutics
Prof. Robert A. Kwame-Aryee	University of Ghana, School of Allied Health Sciences	MD	Obstetrics and Gynecology, Workshops
Dr. Richard Asmah	University of Ghana, School of Allied Health Sciences	PhD	Immunology and Molecular Biology
Dr. Lucas Amenga-Etego	Navrongo Health Research Center	PhD	Host and Pathogen genomics, Bioinformatics
Dr Seth Owusu-Agyei	Kintampo Health Research Center	PhD	Molecular Epidemiology of Infectious Diseases, Malaria Epidemiology
Dr. Kwaku Poku Asante	Kintampo Health Research Center	MD, PhD	Research Methods, Malaria epidemiology
Prof. Bassirou Bonfoh	Swiss Centre for Scientific Research, Cote d'Ivoire	PhD	Zoonotic parasitic diseases, transmission risk analysis
Dr. Alfred Amambua-Ngwa	Medical Research Council, The Gambia	PhD	Host and Pathogen genomics, Bioinformatics
Dr. Sodiomon B. Sirima	Centre National de Recherche et de Formation sur le Paludisme (CNRFP), Burkina Faso	PhD	Malaria epidemiology
Prof. Keith Gull	University of Oxford, UK	PhD	African trypanosomes, *Leishmania*

Prof. Kirk Deitsch	Weill Medical College of Cornell University, USA	PhD	Molecular biology of Plasmodia
Prof. Dick McIntosh	University of Colorado, Boulder, CO	PhD	Mitosis, Kinetochore-Microtubule Interactions
Prof. David Conway	London School of Hygiene and Tropical Medicine, UK	PhD	Population genetics, molecular biology and immunology of malaria
Prof. Mark Carrington	University of Cambridge, UK	PhD	Molecular cell biology of Trypanosomes, Genomics