ACTIVITIES REPORT

2015–2017

ACE AFRICAN CENTERS OF EXCELLENCE IN BIOINFORMATICS

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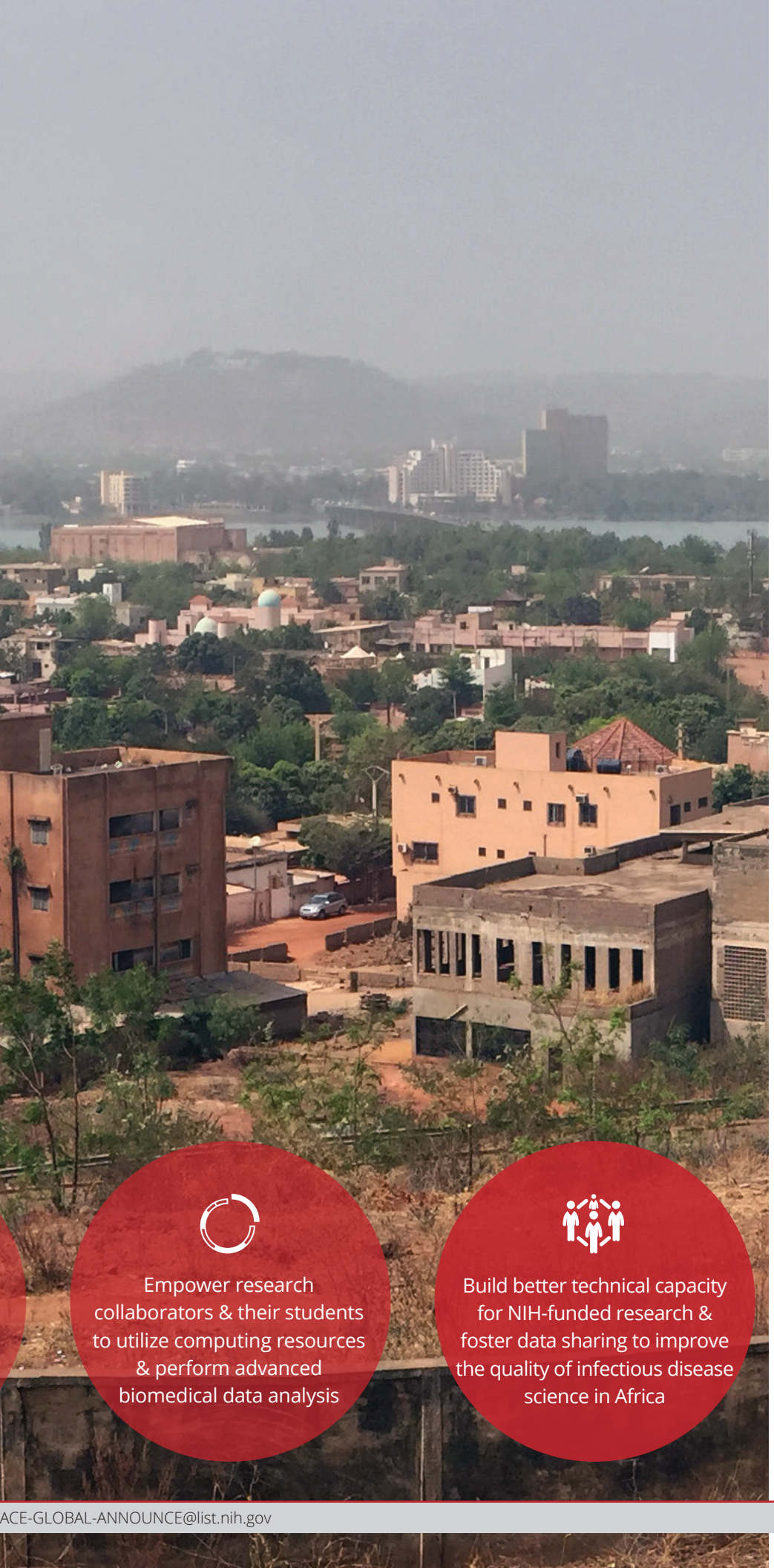
"Engagement in global health protects the nation's citizens, enhances the economy, and advances U.S. interests abroad."

"NIH research: Think globally," *Science*
Anthony S. Fauci and Francis S. Collins

Introduction

The African Centers of Excellence in Bioinformatics (ACE) are a consortium of research and training centers facilitated by the National Institute of Allergy and Infectious Diseases (NIAID) in collaboration with research institutions in Africa, private sector companies, and the Foundation for the NIH (FNIH). ACE delivers high performance computing infrastructure and training to collaborating research and academic institutions in Africa through a public-private partnership based on in-kind contributions. The Centers provide researchers working with NIH scientists with mentoring, compute resources, and the bioinformatics tools necessary for advanced data analysis. Additionally, ACE provides a platform for sharing skills, knowledge, and best practices between members of the global biomedical research community.



Empower research collaborators & their students to utilize computing resources & perform advanced biomedical data analysis

Build better technical capacity for NIH-funded research & foster data sharing to improve the quality of infectious disease science in Africa

Partner with other sponsors to build a network of self-sustaining centers that can tap into other sources of funding

The NIAID Operations Team

The African Centers of Excellence (ACE) program has a multidisciplinary team where each member provides expert knowledge in the areas of bioinformatics, computational biology, and data science, ensuring that we can offer a full range of training, consulting, and collaboration services.

From Monday, March 30 through Wednesday, April 1, 2015, computational biology specialists from the NIAID taught courses on bioinformatics topics and biocomputing tools at the University of Science, Technology, and Techniques of Bamako. At the end of the workshop, attendees received Certificates of Completion.

Mali ACE Founding Partners

CIO & Director, Office of Cyber Infrastructure & Computational Biology

Michael Tartakovsky

Chief, Bioinformatics & Computational Biosciences Branch

Darrell Hurt

Program Manager, International Biomedical Research Support Program

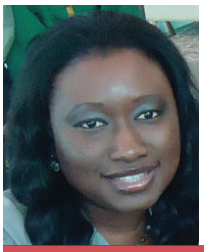
Christopher Whalen*

ACE Program Coordinator, Bioinformatics & Computational Biosciences Branch

Latrice Ware*

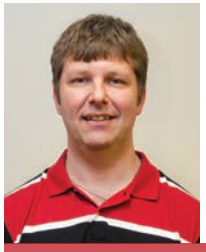
Communications & Outreach Lead, Bioinformatics & Computational Biosciences Branch

Karlynn Noble*



Bioinformatics Scientist, Bioinformatics & Computational Biosciences Branch

Aoua Coulibaly*



Computational Genomics Specialist, Bioinformatics & Computational Biosciences Branch

R. Burke Squires*

Lead Linux Systems Administrator, International Biomedical Research Support Program

Jimmy Griffin*

Senior Project Manager, International Biomedical Research Support Program

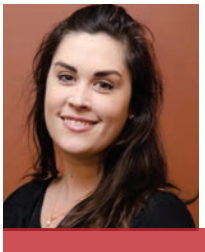
Brian Moyer*

Scientific Support Section Head, Bioinformatics & Computational Biosciences Branch

Mariam Quiñones

Phylogenetics Specialist, Bioinformatics & Computational Biosciences Branch

Kurt Wollenberg*



3D Printing & Biovisualization Program Lead, Bioinformatics & Computational Biosciences Branch

Meghan McCarthy*

** See Page 31 for information regarding supporting contracts.*

Timeline

2016

Instructors from the NIAID developed and delivered over 60 bioinformatics courses and seminars to the University in Mali

Senegalese student, Reine Bebey, presented a poster at the American Society of Tropical Medicine (ASTM) in collaboration with the University of Dakar at the annual meeting in Atlanta, Georgia, USA

Initiated collaboration between the University of Pennsylvania–ICEMR on clinical database

NIH Director Dr. Francis Collins Awards the partners for the development of the ACE program

Included ten Tulane University bioinformatics and data science courses into USTTB curriculum

Established collaboration between ACE and the Wellcome Trust-funded DELGEME program and Dr. Abdoulaye Djimde

Received requests for collaboration from other regions of Africa including Malawi, the Democratic Republic of Congo, and Uganda

2018

2015

Completed strategic public-private partnership between the NIAID, BioTeam, Intel Corporation's Health and Life Sciences Group, EMC Corporation, the Foundation for the NIH, and the University of Science, Technology, and Techniques in Bamako, Mali

Installed a high-performance computing server donated by Intel (with support from Hewlett-Packard) and configured by BioTeam

Built the telelearning center at the University to optimize communication and remote learning in Mali

Launched of the first ACE at the University

Enrolled first cohort of students in the M.Sc. Bioinformatics Degree Program at the University

2017

Graduated first cohort of students from Master's Program in Bioinformatics at USTTB

Aoua Coulibaly accepted into DELGEME Ph.D. fellowship program under Dr. Nicola Mulder of H3 Africa

Assetou Diarra accepted into fellowship program in Tunisia

Began working with MaliREN to support connectivity and identity for bioinformatics research at Malian academic and research institutions

Enrolled second cohort of students in the M.Sc. Bioinformatics Degree Program at the USTTB

Newly developed BioCompACE image pushed to local workstations and laptops using SALT

Provisioned and provided logistical support for DELGEME servers with the help of silent partner CDW-G, the Mali Service Center, and the Mitchell Group for use in Kenya and Mali

Developed and delivered continual courses for ACE collaborating institutions in the use of cloud technologies such as Git and SALT for bioinformatics infrastructure

Taking Off: From Concept to Launch

High performance computing and high throughput data analysis are increasingly used in all areas of medical research to gain a more comprehensive understanding of disease, including the multiple biological factors that influence it. However, these technologies are under-utilized in some research settings due to a lack of access, properly trained staff, and infrastructure required to fully harness its capability.

Programs in Africa are particularly affected by the research informatics disparity. They often lack reliable access to local bioinformatics tools, infrastructure, and training to use these advanced methods.

Despite many training programs, workshops, and classes taking place across the African continent, there has not been the necessary investment to establish local infrastructure once the training is complete. The result is a continued lack of capacity for local computational research to combat the spread of emerging or re-emerging diseases in Africa and the rest of the world.

Why NIAID?

The National Institute of Allergy and Infectious Diseases (NIAID) has been supporting global research institutions in infrastructure challenged regions for many years. In 2001, Dr. Anthony Fauci, Director of the NIAID, recognized the need to build collaborative centers to improve the research quality focused on diseases in endemic regions—such as Africa—that could leverage both the intramural and extramural strengths of the NIH.

- The NIAID established the International Centers for Excellence in Research (ICER) program in Bamako, Mali and Entebbe, Uganda.
- In Mali, the center built on the experience gained from NIAID's long-standing malaria research collaboration with local scientists, the Malian government, and other academic partners.
- The proven success of the ICER program is the foundation for the public-private partnership that led to the establishment of the ACE.

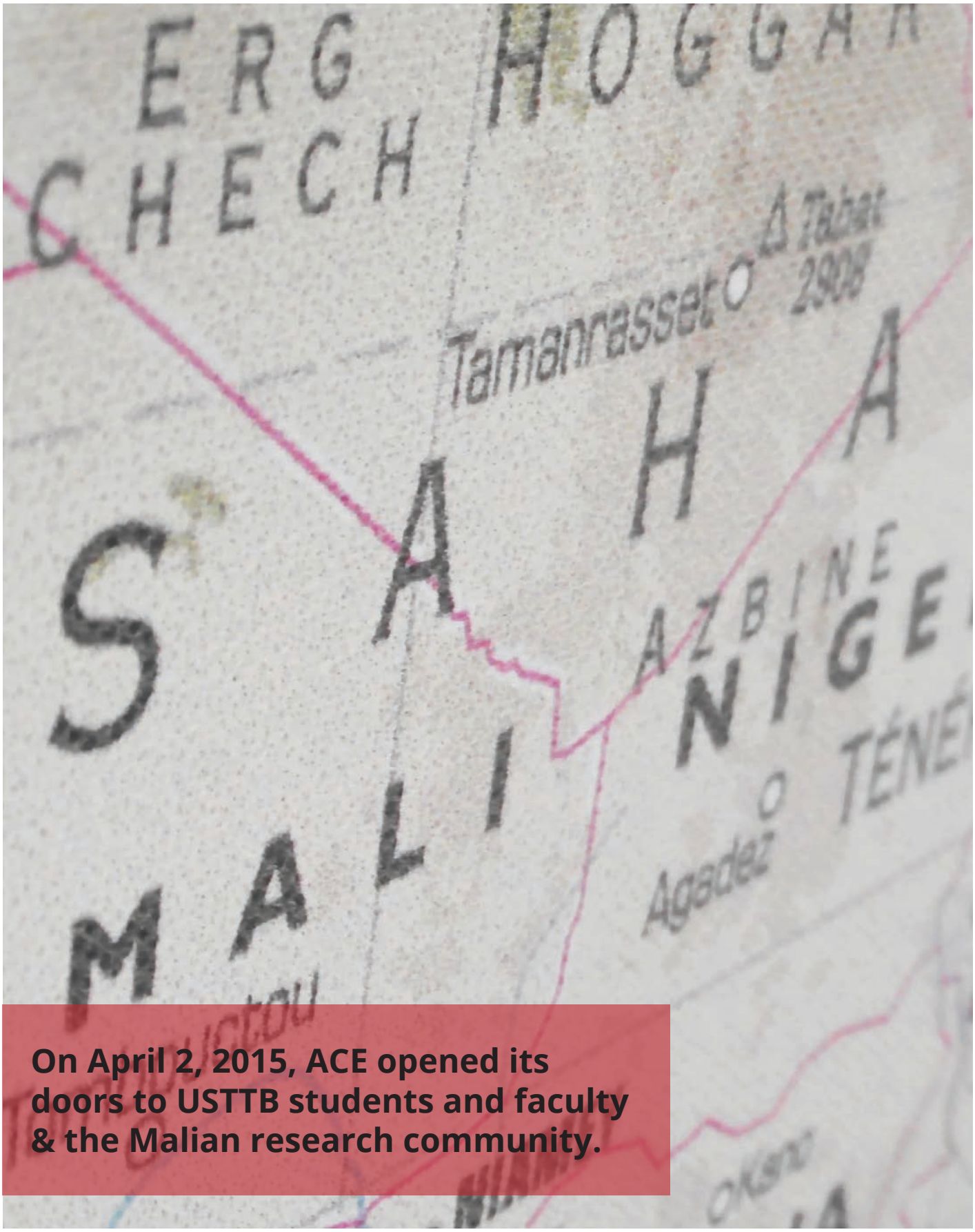
ACE Germination

In 2009, the NIAID Office of Cyberinfrastructure and Computational Biology (OCICB) was one of the founding partners for the African Society for Bioinformatics and Computational Biology (ASBCB). For several years after the inaugural meeting in Bamako, Mali, NIAID worked with various partners to deliver training workshops to students and researchers across Africa. Workshop attendees consistently felt they could not continue accessing the tools and platforms to maintain their skills at the conclusion of the training.

In response, in 2014 NIAID established a public-private partnership with the USTTB, Intel, BioTeam, EMC, and the Foundation for the NIH to build the first ACE, creating a bridge between training and NIH research.

Intel coordinated with HP to donate a server (the BioCompACE) with 120 processing cores, 1024 GiB of RAM, and 500 TB of attached storage. EMC donated a state-of-the-art disk-to-disk backup system with advanced deduplication technology. BioTeam provided consulting services to build the suite of bioinformatics applications on the server. NIAID shipped the server to the ICER data center and set up a telelearning center using the equipment.

At the same time that the ACE launched in Bamako, the USTTB started a Master's program in Bioinformatics to leverage the new infrastructure. The University also donated the classrooms and offices, and named a Director to oversee the degree program and the ACE.



On April 2, 2015, ACE opened its doors to USTTB students and faculty & the Malian research community.

"We need to build strong health systems to prevent and fight diseases, to augment capacity to understand pathogens using the latest technology, and to share information with a global network."

Suzan Zelle, U.S. Chargé d'Affaires

The Mali ACE Opening Ceremony

On April 2, 2015, the Chief of Mission for the United States in Mali, the Chief Information Officer of the NIAID, the Rector of the USTTB, and the Minister of Higher Education for Mali cut the ribbon at the Faculty of Science opening the first African Center of Excellence in Bioinformatics (ACE) in Bamako, Mali.

Ribbon cutting ceremony at the USTTB telelearning center. From left to right: Prof. Adama Keita, Rector, USTTB; Prof. Mamadou Wele, USTTB; Chargée Susan Zelle, U.S. Embassy; Minister for Higher Education and Research, Mr. Mountaga Tall; Dr. Sharif Mohammadi Abolmohsen, Iranian Ambassador to Mali; Mr. Michael Tartakovsky, CIO, NIAID

Following the opening ceremony, NIAID co-organized a Scientific Symposium at the USTTB Regional Center of Solar Energy (CRES). Opening remarks were given by Dr. Seydou Doumbia, Chair of the Department of Public Health, USTTB Faculty of Medicine (now Dean). Professor Doumbia emphasized the scientific opportunities available to the students and faculty of the new program.

Dr. Patrick Duffy, Chief of the NIAID Laboratory of Malaria Immunology and Vaccinology, gave the first talk, "Malaria: BIG Data for a BIG Problem." His presentation touched on placental malaria, the next generation sequencing pipeline for big data, and how findings are influencing research on severe cases of malaria.

Dr. Andrew Oler, High-Throughput Sequencing Bioinformatics Specialist for NIAID, presented "Annotation and Filtering of Variants for Family-based Genetic Studies (NIAID Clinical Genomics Program)." Dr. Oler discussed how using sequencing to identify disease variants has led to functional validation in the clinical setting, particularly for rare diseases.

"Use of Bioinformatics to Address Antimalarial Drug Resistance in the Field" was presented by Dr. Abdoulaye Djimdé, Chief of the USTTB Molecular Epidemiology and Drug Resistance Unit. Dr. Djimdé discussed increased malarial drug resistance, parasite mutations, and how to use bioinformatics tools developed in the lab for real-life "messy systems" and continued improvement in global health.

Dr. Darrell Hurt, Branch Chief of the NIAID Bioinformatics Computational Biosciences Branch (BCBB), closed the Scientific Symposium with the presentation, "Computational Structural Biology Suggests Solutions to Otherwise Intractable Problems."

Prior to the ACE ribbon cutting and opening ceremony, NIAID computational biologists conducted a three-day, hands-on workshop to train USTTB faculty on the use of the BioCompACE, an appliance designed to handle computationally intensive data analysis. Training included use of UGENE, Galaxy, R, and other bioinformatics applications to aid in research and education. Instruction was provided by Drs. Mariam Quiñones, Vijayaraj Nagarajan, Andrew Oler, Kui Shen, Kurt Wollenberg, and Darrell Hurt, and by Ms. Olga Golosova. Drs. Shen and Wollenberg and Ms. Golosova made use of the state-of-the art telelearning facility by connecting remotely from Russia and the United States to provide instruction.

Building a World-Class Telelearning Center at the USTTB in Mali

Providing distance learning support for students and researchers is a significant component of the ACE program. The Mali ACE site required an optimized environment to receive training from international campuses. There are also a number of regional factors to consider, lighting, room acoustics, a lack of a stable utility power, the high number and duration of power outages, and insufficient technical support for equipment.

USTTB donated classroom space at the Faculty of Science, a 33 by 23-meter room with a ceiling height of three meters that is constructed from cement, with windows lining the outside walls. The room is shown here prior to modifications.

Since 2001, NIAID has been building video teleconferencing and web collaboration rooms in low- to middle-income countries. Experience has repeatedly proven that the typical concrete building construction in these areas creates a suboptimal video and teleconferencing environment. Several years ago, NIAID worked with specialists in video conferencing infrastructure optimization to develop a white paper on conference room design to help improve the experience for sites that require international infrastructure support. Outfitting the Mali ACE site presented an opportunity to put that experience and knowledge into practice.

The USTTB includes the Faculties of Medicine, Pharmacy, and Basic Sciences, an Institute of Applied Science, and the NIAID research laboratories focused on malaria, tuberculosis, and retrovirology. The Faculty of Science is on the opposite side of the Niger River from the Faculty of Medicine, where the new bioinformatics server, data center, and internet connection are housed. This infrastructure supports the primary labs and offices of the NIAID ICER. The ACE team donated and installed a high frequency microwave connection between the two sites to link the two campuses and provide internet access and connectivity. A line-of-site connection was relatively easy to establish as the two campuses face one another from the crest of the valley walls on opposite sides of the Niger river. The solution utilized AirFiber technology running at 24 gigahertz and at 33 watts of power to achieve a 1,000 megabits per second throughput. The radio on the dish antenna uses Power-over-Ethernet (POE) to reduce the signal attenuation through cables and can use the infrastructure power of the data center at the Faculty of Medicine to deliver the highest quality and greatest reliability possible.

The audio experience is the most important feature for distant communications, web collaborations, or video conferencing. Improperly designed acoustics result in echo or sound deadening that make communication difficult. The three measurable and adjustable features of room acoustics are absorption, reflection, and diffusion. The decibels (dB), the reverberation, and the dB ambient correction measurements are used to assess the room acoustics.

The iAudioTool smartphone application was used to test the room and collect these measurements. The telelearning room initially had baseline readings of 82 dB, .73 RT60 and after adding drop-ceiling tiles with a capture gap below the concrete ceiling and acoustic absorption wall panels, the reverberation readings dropped to 70 db .295 RT60. This reduced the amount of correction that the video conferencing equipment exerts in order to counteract the “echo” commonly interrupting voice and video conferencing.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African Center of Excellence in
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Sound

The selected speakerphones have a built in ten dB ambient noise filter that corrects for sounds such as air conditioners and fans, and features automatic voice level correction to compensate for different vocal pitches and volumes. The speakers also have a low power requirement; each unit needs only ten watts of power. This reduces the load placed on the battery backup during frequent blackouts and load-shedding incidents common in Bamako. A low-level current is conveyed using a special USB-to-POE adaptor and standard CAT 5E cabling, which is also used to connect to the conference station. The speakerphones are placed in the center of the room to simplify the cabling and to keep them equidistant from supplemental speakers on the desks on either side of the room.

Lighting

Proper lighting is important for a quality video conferencing experience. If the room is too bright, faces wash out, too dark and they disappear into shadow. Optimum lighting specifications are color temperature, color rendering index, and lumens. The low power environment and the lack of access to replacement parts for bulbs, fixtures, and controls were also considerations. The lighting solution must be very low wattage and have an extremely long life cycle. We selected the Cree HD CR22 LED fixtures with a color temperature of 3500 kelvin and emit 3200 lumens at a color-rendering index of 90. They draw only 32 watts of power per fixture and have an expected life of 75,000 hours at 220v and 50Hz. The telelearning center has eight fixtures in the room.

Color

The paint on the walls has a direct impact on the lighting and therefore needs to be a specific shade and reflection. A slate blue paint was selected for its low reflective quality. The color offsets a wide range of skin tones and complexions so that the students are visible to remote instructors.

A common video conferencing and telelearning problem is the presence, or lack thereof, of the presenter. Most video conferencing platforms only display the presentation content while the presenter is an impersonal disembodied voice. To improve the interface experience, two displays were installed at the front of the classroom: an 85-inch LED LCD and a smaller 40-inch LED LCD on the side, mounted lengthwise. The side unit provides an image of the presenter. Together, the total power consumption of these two displays is less than 220 watts. WebEx is the preferred video conferencing platform, as it provides the ability to split the presenter from the content.

Workstations connect to the BioCompACE using a Microsoft Remote Desktop Protocol. The wireless network originates from the data center at the NIAID ICER. The data center also hosts the VMWare virtual environment and the BioCompACE.

Remote Desktop Protocol (RDP) is a simple tool that is commonly used by Microsoft servers and workstations. There are also clients available for Macintosh and Linux. By using RDP as a teaching platform, the remote professor can use the shadow feature to view the screens of the students. If a student is having problems with an assignment, the professor can look "over the shoulder" at the screen of the student to assist. The BioCompACE also uses XRDP to simplify the connection from the Zero Clients to the server for some applications such as graphical software used for protein folding and crystallography. Command line access to the BioCompACE for statistical programming with R and for analysis of sequencing data is also simplified in this manner.

The ACE telelearning room is an example of using design best practices in tandem with appropriate technologies tailored to a specific environment. It leverages knowledge accumulated over the years by sound and light engineers and by NIAID staff, while also optimizing power usage. Constructing a high quality telelearning training environment has enabled the seamless delivery of courses, reducing the costs associated with NIAID staff traveling to Mali in order to deliver the same seminars and courses.

Student Workstations

Each student seat is outfitted with a workstation. The workstations were selected with the same priorities: process, power, support, and cost. The HP t410 Zero Clients integrate the monitor and the client, reducing the electrical wiring requirements, as well as reducing the power consumption and keeping the support for the room as simple as possible. Using POE reduces power consumption and the need to install both power and network cabling.

While not part of the original specifications for the project, it was discovered that Zero Clients could not use USB flash drives when powered by POE. This feature serendipitously eliminates a leading cause of malware distribution in Africa.

204 Watts

The entire classroom computing infrastructure consumes only 204 watts with a peak use of 294 watts.

Proposal Submission Workflow System for the Mali BioCompACE

The BioCompACE Request Form leverages the existing Microsoft SharePoint server at the Mali International Center for Excellence in Research (ICER) site. The workflow provides a process through which ICER Mali staff, collaborators, USTTB students, and faculty can request access to the BioCompACE and support from the ACE program.

Scientific practice requires forethought and consideration; therefore, users are required to provide a justification that explains their research project and a list of programs they expect to run. A list of centrally installed applications is provided in the form for easy reference. Requesters can log in using the credentials of their collaborating institution since the NIAID Science Forum leverages the global research and education trust federations. The requester can also provide the names of additional team members requiring access, so that the system administrators can ensure that all collaborators have access through the NIAID Science Forum.

The SharePoint workflow automatically sends notification emails to a group of scientists at both the NIH and at the USTTB who review the BioCompACE request. They can return the request for clarification, approve, or deny the request. If approved, system administrators receive the approval and provision the platform for the tools needed. Consulting bioinformaticians from ACE work with the requester to ensure that they have the knowledge base needed to perform the data analysis.

The BioCompACE Model: High Performance Computing for ACE

Technical support and maintenance are critical components in building a sustainable model for bioinformatics research and training centers in low-resource settings. System administrators must be able to adapt to quickly changing and non-traditional requirements. Physically isolated from communities of support professionals who manage similar infrastructure and systems, administrators must develop solutions to the unique situations that they face such as reduced access to replacement parts and hardware support. Additionally, they must be able to adapt to changing tools and methods used in infrastructure management. As cloud technologies gain adoption in local data centers, Infrastructure-as-code (IAC) is the approach for configuration management and system administration in cloud platforms.

The ACE team has built a configuration management model for training and analysis that can be scaled for global distribution for similar or identical systems and compute platform needs in bioinformatics. The model integrates GitHub—the cloud-based code management and hosting service—with SaltStack, an open source configuration management tool. SaltStack provides a configuration management platform for Microsoft Windows or Linux system configurations using Python scripts. GitHub provides a central location for the Python scripts and a version control system particularly useful for sharing globally distributed open source projects. System administrators are working in the United States, at the USTTB in Mali, as well as in Uganda and India. SaltStack can pull the configurations directly from GitHub and deliver them to systems and applications running anywhere in the world. ACE can use this system to maintain the servers and to maintain Linux laptops used to deliver local hands-on training workshops for researchers and students. Overall, this model enables the ACE system administrators to provision customized instances, virtual machines, applications, and dockers into multiple cloud platforms.

The local compute at the Mali ACE consists of the BioCompACE server – currently a bare metal Ubuntu installation on a HP DL580 donated by Intel Corporation (with support from HPE). In future centers, the infrastructure will leverage cloud operating systems such as OpenStack, allowing the SaltStack configurations to provision not just to the African centers, but also cloud platforms such as Amazon Web Services, Google, or Microsoft Azure Stack. With this new infrastructure, ACE collaborators, students, and scientists will have the IT resources to develop and run scientific computing tools needed to keep local research current and competitive.

Developing a Secure Network for Visiting Faculty and Collaborators

Both academic and research communities stand to benefit from long-term cooperation. Collaboration between institutions, researchers, and even the private industry drives scientific advancement by allowing for greater access to cutting-edge research and scientific talent. The internet is making it easier to establish and continue such collaborations whether you are on opposite sides of the country, continent, or world through the development of open source tools. However, in many countries, there are restrictions on giving free unauthenticated internet access. This lack of easy access to the internet impedes the ability of researchers to access each other's tools and to work collaboratively.

NIAID has supported researchers through the ACE program and the ICERS by offering research solutions that help accelerate the translation of data. One such resource is eduroam. eduroam is a Wi-Fi network that provides secure internet access to students, faculty, and researchers both on campus and when visiting participating institutions. This extremely is a valuable service, especially for biomedical researchers who frequently travel to institutions with whom they collaborate. eduroam is sponsored by the European Union NREN for educational staff and researchers around the world at thousands of universities and research institutions.

eduroam

The eduroam initiative started in Europe in 2002 when SURFnet shared the idea of combining a RADIUS-based infrastructure with IEEE 802.1X technology to provide roaming network access across research and educational networks. eduroam is based on the most secure encryption and authentication standards available. Their system uses a network of servers run by the institutions, and the participation of National Research and Education Networks (NRENs) to securely route requests between institutions. In 2017, NIAID worked with Géant, the EU academic research and educational network organization, to extend this service to the NIAID ICERs in Mali, Uganda, and India.

Found in over 90 countries worldwide

Connected 1 billion authentications

Supports 25 active pilots and growing

eduroam expanded with assistance from

GÉANT

WACREN

Challenges

When NIAID began extending the eduroam networks to the ICERs, they faced serious challenges. None of the national education and research networks (NRENs) in the three countries had established the infrastructure to support the eduroam service. Additionally, they did not have any experience operating the RADIUS systems needed for the service to operate. ACE staff, supported by the NIAID, developed working relationships with the Géant operators in the Netherlands and were able to work with all three NRENs to provide this service and to become the first eduroam customer in both Uganda and Mali.

Enabling Bioinformatics Research and Education in Mali

The increasing diversity of data and the computational nature of research across all scientific disciplines make networking as critical for scientific discovery as the physical laboratory or clinic. National research and education networks (NRENs) provide universities and scientists with the computational and communications tools they need to compete in education, research, collaboration, and funding.

The Mali Research and Education Network (MaliREN) provides interconnection between national research and academic institutions with their regional, African, and international counterparts via its points of presence (POP).

The long-running collaboration between the USTTB and the NIH is uniquely suited to facilitate MaliREN's mission and is supporting the installation and organization of a network operations center at the Faculty of Medicine's (FMOS) Point G campus. The USTTB-NIH collaboration has dedicated technical staff with extensive computing/networking experience, as well as facilities capable of hosting the radios, routers, switches, and servers comprising a POP. The campus itself is uniquely situated at the edge of a plateau overlooking the city of Bamako and it features a tower already built for metropolitan microwave circuits. This location makes the FMOS campus the ideal location for the MaliREN POP because of the clear lines of site to many of the MaliREN members in the city.

The MaliREN fiber backbone allows the ACE to connect the telelearning center at the Faculty of Science to the data center at the Faculty of Medicine. The two campuses of USTTB are separated by 5 km and the Niger River. The network serves as a conduit that does far more than connect faculty and students to the internet; it helps to build local collaborations and capacity within the research community in Mali and the West African region.

Data Center Supports Clinical and Genetic Studies of Hereditary Neurological Disorders in Mali

Despite the genetic diversity of the continent, genetic studies have been limited in Africa, particularly those of hereditary neurological disorders (HNDs). In other populations, several genes have been associated with HNDs; however, the genetic basis of many others is still not established. The high consanguinity and fertility rate of the African population offers a unique opportunity to discover new genes that can be studied in other populations.

This area of research is the focus of one of ACE's research collaborators, Dr. Guida Landoure. Dr. Landoure is a principal investigator at the USTTB. Trained in Mali, the United States, and Great Britain, Dr. Landoure is a neurologist specializing in rare hereditary neurological disorders. His research aims to characterize families with HNDs and to identify the underlying genetic defects. Patients participating in the study underwent a thorough clinical and laboratory evaluation. DNA was extracted for genetic analysis including candidate gene testing, exome sequencing, and homozygosity mapping.

Dr. Landoure has faced several challenges with conducting his research. First is the lack of a data manager and dedicated bioinformatician. In addition, data storage and internet access are significant issues. Together these challenges are slowing productivity. Recent collaboration with the Mali ACE has set the stage to mitigate these deficits and increase his data management and analysis capability. ACE provides high computing resources to process Dr. Landoure's genomic data. Currently, 5 TB of genomic data is stored on the BioCompACE (this is the 378 TB of direct attached storage provided by Intel and HP) for NGS data analysis. Additionally, Dr. Landoure has a bioinformatics student assigned to him through the ACE to assist him with his research and data storage. Dr. Landoure has also received bioinformatics consultation through the Center.

The data center at Mali ACE serves as a centralized resource for providing data analysis solutions and expert bioinformatics consulting. The services are available to students and researchers on both grant-funded and school-assigned research projects. Data analysis performed by the local community of researchers will lead to larger gains in health and lower the incidence of disease and death in participating African countries. That is one of the many reasons ACE aims to be a long-term resource in Africa.

The mission of the data center is to build and maintain an infrastructure that supports and enables the application of strong bioinformatics analysis with a measurable impact on the ability of researchers to publish their work and obtain funding. We are looking to our stakeholders—existing and new—to help us fulfill this mission in the years to come.

Dr. Guida Landoure

A Digital Future for Research in Mali

The Master's program at the USTTB is divided into four semesters. The fourth semester is dedicated to a research project on a topic of the student's choosing. Dr. Mamadou Wele of the USTTB Faculty of Science and Dr. Seydou Doumbia of the USTTB Faculty of Medicine developed the program curriculum in coordination with the Human Heredity and Health in Africa consortium (H3 Africa). The curriculum covers nearly every modern approach to computational biology. For the inaugural cohort of students, both USTTB faculty and NIAID bioinformaticians provided instruction for the courses. NIAID staff also provided weekly supplemental seminars to reinforce content on genomics, molecular modeling, and simulation.

The African Bioinformatics Curriculum Development Task Force was a part of the first cycle of the H3ABioNet. The international working group developed a framework for specific modules and topics that would comprise a Master's in Bioinformatics for African institutes of higher education.

The first class of students accepted into the USTTB Master's program graduated last August. The NIAID team recently interviewed those students to learn more about their research projects and their plans after graduation, as well as to collect constructive feedback about the ACE pilot. The theme expressed consistently throughout the interviews was the pride the students shared in being a part of the inaugural degree program. They felt that bioinformatics was important to medical research and improving the health of the Malian people, as well as to contributing to the global body of knowledge. The students provided the following recommendations for improving the program for future participants:

1. Increased instruction time for programming languages
2. Additional practical theory exercises
3. Structured opportunities for peer learning

Nine students were accepted into the inaugural class of students in 2015, eight of whom graduated or are currently finishing their Master's thesis.

Mr. Kangaye Diallo has received a grant to pursue his Ph.D. at the USTTB Faculty of Science with funding from the United States Agency for International Development (USAID). Ms. Fatoumata Fofana and Ms. Assetou Diarra completed their Master's theses in Tunisia under Dr. Alia Benkhala. Mr. Almamy Koita is working in Nigeria in Dr. Ezekiel Akintunde's lab to finish his Master's thesis. Mr. Sibiry Samake is working in Dr. Seydou Doumbia's lab at the USTTB Faculty of Medicine. Mr. Modibo Kouyate is working with Dr. Modibo Sangare, who received support from the NIH for his research on autism.

Whether looking for autism biomarkers, creating a national database of microorganisms, or looking at a potential vaccine for Leishmaniasis, these students have bright futures and are ready to make their mark on scientific research and on the world.


MALARIA

Collaborations

The DELGEME Project

Funding from the Wellcome Trust helped to establish the program for Developing Excellence in Leadership and Genetics Training for Malaria Elimination in Sub-Saharan Africa, also known as DELGEME. The USTTB is one of eleven preeminent African research institutions to receive this innovative grant. The DELGEME Program was established at the USTTB with support from the Alliance for Accelerating Excellence in Science in Africa (AESA), Wellcome Trust/DFID, and collaborations with the African Centers of Excellence (ACE), Medical Research Council (MRC) in the Gambia, the United States Army Medical Research Directorate (USAMRU-K) in Kenya, the Noguchi Memorial Institute for Medical Research in Tanzania, and the Kumasi Center for Collaborative Research (KCCR) in Ghana.

ACE is collaborating with Dr. Djimde and DELGEME to provide logistical support, consultations, and training in configuration management and system administration. The center is working to connect the faculty leading the DELGEME Program with similar programs in Africa, including the next ACE. Students in the DELGEME program will have access to the telelearning facility and existing computing infrastructure as they build the infrastructure for large data sets in malaria research.

The mission of the DELGEME project is to enrich the pool of African scientists working in local institutions with relevant expertise for the exploitation of big genetics and genomics data for malaria elimination in sub-Saharan Africa. DELGEME is helping African scientists to gain advanced technical and analytical skills in relevant areas of bioinformatics, next generation sequencing, population genetics, epidemiology, biostatistics, and cellular and molecular biology. DELGEME works in collaboration with local and international partners for malaria control and elimination in sub-Saharan Africa.

The program includes both a series of short-term courses and in-depth degree training (M.Sc., Ph.D., and post-doctoral). This summer, DELGEME launched the first set of short courses focused on advanced scientific writing, oral communication, and ethics training. Current enrollment is around 50 students, two of whom are enrolled in the USTTB Master's program. ACE is currently providing infrastructure support for three of the DELGEME collaborative sites: the USTTB in Bamako, the Medical Research Council (MRC) in the Gambia, and The United States Army Medical Research Directorate in Kenya.

The main objectives of the DELGEME program are:

1. To train, retain, and develop graduate, doctoral, and post-doctoral fellows in genomics and bioinformatics across malaria endemic countries
2. To develop programs that enhance the understanding and dissemination of genetic data relevant to malaria interventions and eradication
3. To deliver short trainings for various audiences on genetics, clinical studies, ethics, grant writing, grant management, and leadership development
4. To design and implement a formal long-term curriculum with contribution and oversight from local and international faculty and advisory boards

Introducing the Mali ACE Stakeholders

Dr. Adama Keita
Rector, University of Sciences, Techniques, and Technology of Bamako (USTTB)

Professor Adama Keita attended the National School of Medicine and Pharmacy in Bamako from 1983 to 1990. Keita then participated in the National Youth Service before being appointed Deputy Chief Medical Officer, then Chief Medical Officer of the Health and Social Services of Djenné in the Mopti region.

After being admitted to the National Radiology Diagnostic and Medical Imagery Assistantship Competition and achieving the rank of Assistant Chief of Clinic in 1996, Professor Keita moved to Brest, France, where he worked as Chief Clinical Associate at the University of Western Brittany. He returned to Mali in 1998 to serve as a clinician at the national Hospital of Point G and as a professor at the University of Bamako Faculty of Medicine, Pharmacy and Dentistry (FMPOS), where he eventually became Head of the Department of Education and Research (DER) of Medicine and Medical Specialties.

Since 2011, Professor Keita has held the position of Rector of the USTTB. He is also part of the multidisciplinary research team on schistosomiasis, which is tasked with achieving parasitic imagery, morbidity control, and praziquantel treatment efficacy. Additionally, he is part of the ICER Mali filariasis research team, with which he performed the imagery of lymphatic lesions and the identification of adult worm nests. Professor Keita is an author on over thirty articles in national and international scientific journals, and is considered an expert in parasitic ultrasonography.

Dr. Seydou Doumbia
Dean of the Faculty of Medicine and Odontostomatology, University of Sciences, Techniques, and Technology of Bamako (USTTB)

Professor Doumbia, MD, has experience that covers infectious disease, particularly malaria, neglected tropical infectious diseases, HIV, emerging infectious diseases, and community-based interventions. His experience as PI or Co-Investigator of several NIH intramural- and extramural-funded grants includes the International Center of Excellence in Malaria Research as Project Leader and the Tropical Medicine Research Center as Program Director. In his work with the USTTB University Clinical Research Center, Professor Doumbia laid the groundwork for developing sustainable infectious disease research training and career development programs for scientists and health research professionals. Additionally, he contributed to the creation of the Mali ACE and the Master's in Bioinformatics at the USTTB.

Dr. Mamadou Wele
Director of African Center of Excellence in Bioinformatics, University of Sciences, Techniques, and Technology of Bamako (USTTB)

Professor Wele attended the Belarus State University in Minsk to study Biochemistry. He later earned his Ph.D. from the University of Bamako, Mali in Biochemistry and Molecular Biology. His Fulbright post-doctoral work focused on drug development.

Wele has authored a number of papers on malarial molecular drug resistance and the role of the *pfcrt* gene in severe malaria. He has also worked on the development of antimalarial drugs from Malian medicinal plants.

Professor Wele was instrumental in the launch of the Mali ACE and provides oversight of the Master's program in Bioinformatics.

Moving Forward

Collectively, as a public-private-partnership and research consortium, ACE has developed an innovative organizational model for supporting access to bioinformatics tools and for building research capacity for U.S. research in Africa. The partnership of private companies, academic institutions, governments, and non-profit organizations through in-kind donations of materials and expertise has paved the way for building bioinformatics capacity and expertise in Africa. We are grateful for the long-term relationships we have built with Intel, HP, BioTeam, USTTB, RENU and others to make this possible. The outcomes and successes from the center in Mali would not have been possible without our private and public partners and have led to plans to open a new Center in Kampala, Uganda in partnership with Makerere University, RENU, and the Infectious Diseases Institute (IDI). Together we are building a data center, telelearning classroom, virtual reality visualization lab, and a modern library and workspace for local researchers, students, and faculty. As we look at our efforts in Mali, we recognize that to expand and continue to meet the needs of our stakeholders, we need an infrastructure upgrade. To accomplish this, we need partners—existing and new—to contribute compute infrastructure and expertise so that the local research communities and student bodies will have the resources to conduct research at a competitive level and expand human understanding of disease both in their communities and around the world.

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The ACE founding partners receive the 2016 NIH Director's Award on Tuesday, July 19, 2016. From left to right: Hugh Auchincloss, NIAID; Gregg Mahdessian, EMC; Vicki Zagaria, Intel; Christopher Whalen, NIAID; Alexander Rosenthal, NIAID; Michael Tartakovsky, NIAID, Adama Kieta, USTTB, Darrell Hurt, NIAID; Stan Gloss, BioTeam; Ari Berman, BioTeam; and Francis Collins, NIH.

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Page 25 – *Malaria Insectarium*. Photo from the National Institute of Allergy and Infectious Diseases, National Institutes of Health. Retrieved from https://www.flickr.com/photos/nihgov/21147127551/in/album-72157656890787872/.

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AFRICAN CENTERS OF EXCELLENCE IN BIOINFORMATICS

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