IBEST

INSTITUTE FOR BIOINFORMATICS AND EVOLUTIONARY STUDIES

2018 ANNUAL REPORT

COVER KEY

Celeste Brown - Common Marmoset

Larry Forney - #BinyourV Poster/P30 COBRE Sunset

James Foster - Beacon Lighthouse/Hot Tub

Luke Harmon - Phylogeny Building

Paul Hohenlohe - Tazmanian Devil

Paul Joyce - Pi in the Sky/Central Limit Tower

Chris Marx - LanthaNice Fertilizer

Scott Nuismer - “Intro to Coevolutionary Theory”

Barrie Robison/Terry Soule - Spacecraft

Terry Soule - TerryBot

Deb Stenkamp - Hidden Eyeball

Jack Sullivan - Chipmunk

Dave Tank - Tank

Eva Top - Plasmid Banner

Holly Wichman - Beaded Virus Earring

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Coastal wolf featured in BCB student Sarah Hendricks' study published in Nature Photo Credit Chris Darimont

EXECUTIVE SUMMARY

The Institute for Bioinformatics and Evolutionary Studies (IBEST) is a level III Research Institute at the University of Idaho. IBEST's Mission is to empower UI researchers to understand and apply the evolutionary process. To do this, we invest in *force multipliers*, which are personnel and infrastructure that allow students, postdocs, and faculty to maximize their research productivity. This report describes the accomplishments of IBEST for the 2018 fiscal year, as well as the Institutes' structure, resources, and strategic vision.

IBEST is a vibrant home for interdisciplinary research, with student, postdoc, and faculty participants from 7 colleges and 21 departments at the University of Idaho. These participants engage with IBEST in a variety of ways, including proposal support, grant management, and usage of genomic, bioinformatics, and computational infrastructure.

IBEST contributes significantly to the UI Strategic Plan Goal of scholarly and creative work with impact. In FY18, faculty submitted 19 proposals through IBEST, requesting $10,656,079. Of these requests, 11 proposals received notificaiton of funding, totaling $6,220,993. Total research expenditures from IBEST grants in FY18 were $2,215,877.

Faculty participating in IBEST report 183 peer reviewed publications (113 in 2017, and 70 so far in 2018), as well as 82 conference presentations and 87 invited seminars and keynote addresses. These faculty also represent a significant impact on the University of Idaho's training mission, mentoring 155 undergraduate researchers, 95 graduate students, and 36 postdoctoral scholars.

FY18 QUICK METRICS

Proposals Submitted	19	57.9% Funding Rate
Proposals Funded	11	
Funds Requested	$10,656,079	58.4% Funding Rate
Funds to be Awarded	$6,220,993	
Total Research Expenditures	$2,215,877	
Publications		
2018 to Date	70	
2017	113	
2016	114	
Since 2011	794	22,431 Citations
Trainees		
Undergraduate	155	
Graduate	95	
Postdoctoral	36	

Screenshot of Project Hastur, Polymorphic Games' upcoming evolutionary video game

LETTER FROM THE DIRECTOR

-Dr. Barrie D. Robison, IBEST Director

IBEST has been my intellectual “home” since my arrival as an assistant professor in 2003. My professional development as a scholar occurred almost exclusively in IBEST’s culture of interdisciplinary collaboration. I know no other model. I have observed, however, that when my colleagues visit our campus from other institutions, they marvel at what IBEST offers. They covet what we take for granted – that biologists, computer scientists, mathematicians, philosophers, and scholars from other disciplines often freely interact and collaborate. They admire our collegiality – that despite the many accomplishments of my colleagues, we count ourselves friends and disagreements are few. They respect the scholarship of the faculty who participate in IBEST, who are national and international thought leaders in their respective disciplines. The interdisciplinarity, collegiality, and productivity of IBEST was something I simply assumed to exist everywhere. It does not.

IBEST represents a collection of scholars who have had an undeniably significant impact on their fields. The scholarly impact of IBEST faculty is supported by administrative and scientific staff and state of the art infrastructure for genomics, bioinformatics and research computing. This support system for IBEST researchers was built over many years with significant investment (~$27 Million) by the National Institutes of Health, by commitments from the University of Idaho, and by the tireless work of many of my colleagues.

This annual report marks an important milestone for IBEST. The COBRE grant from the National Institutes of Health that funded the establishment of IBEST is sun-setting. The cover image of this report is an original piece of artwork by Cody Muir, our new communications coordinator, that symbolizes the end of the COBRE. Dr. Larry Forney, the Principal Investigator of the COBRE award and the founding Director of IBEST, has agreed to provide his reflections on the legacy of these awards as a preamble to this report. Larry’s perspective provides an important context in which this annual report should be viewed. IBEST represents a thriving, vibrant, and productive institutional legacy of a multimillion dollar investment by NIH.

I was appointed Director of IBEST in February of 2018 and am humbled to represent such an accomplished group of scholars. In my view, my mission as Director is to invest in these scholars, and find ways to maximize the impact of their research.

Dr. Barrie D. Robison

IBEST Director

LEGACY OF THE CENTER FOR RESEARCH ON PROCESSES IN EVOLUTION (CREPE)

-Dr. Larry J. Forney, Past IBEST Director

The Center for Research on Processes in Evolution (CRePE) is a Center of Biomedical Research Excellence (COBRE) that has been funded for the past 16 years by the National Institutes of Health (NIH). During this time the University of Idaho received more than $26.7 million dollars from NIH. As we draw near to the sunset of COBRE funding, this report provides a snapshot of what has been accomplished with NIH funding and institutional support from the University of Idaho.

COBRE Program Goals

Centers of Biomedical Research Excellence (COBRE) support thematic, multidisciplinary centers that augment and strengthen institutional biomedical research capacity. This is accomplished by expanding and developing biomedical faculty research capability and enhancing research infrastructure, including the establishment of core facilities needed to carry out the objectives of a multidisciplinary, collaborative program.

The COBRE has fundamentally changed the way biomedical research is done at the University of Idaho. This shift in culture is exemplified by the explosive increase in the use of next-generation sequencing technologies to explore biological diversity and evolutionary processes, and the ever-increasing demand for computational resources for biophysical studies, comparative genomics, phylogenetics, mathematical modeling, and statistical analyses.

This expansion of activity has been primarily driven by the coalescence of investigators around the scientific theme of the COBRE and the intellectual energy, enthusiasm and collegiality of participants, which is locally known as *frothiness*. In part this growth in interdisciplinary research has been made possible by ready access to sophisticated technologies available through COBRE supported core facilities in genomics and computation. The uses and applications of the core facility resources are becoming increasingly intertwined as sophisticated computer modeling informs empirical research, and data-rich genomic analyses and population genetics studies demand advanced computational capabilities for analyses. These interdisciplinary research projects are at the forefront of understanding fundamentals of host-pathogen interactions, adaptive evolution of organisms, and several other areas.

Since its inception the COBRE has mentored early career faculty to research independence, attracted new faculty into biomedical research, awarded pilot and technology access grants, developed undergraduate and graduate education programs, and formed important partnerships with investigators at other institutions throughout the nation. All this has resulted in national and international prominence in multiple disciplines that few expect to find at a small university in the sparsely populated Inland Northwest of the United States.

What's in a name?

We have consciously avoided referring to CRePE or COBRE because we wished to build a program (IBEST; the Institute for Bioinformatics and Evolutionary Studies) that transcends sources of funding and we saw no reason to add to the 'alphabet soup' that divides a whole into small parts. As a result, even people close to the program do not always know that so much has been made possible by COBRE funding (though they might know much more about IBEST).

This synopsis will help illuminate how much has been done to achieve the goals of the COBRE program, enable faculty and students to realize their aspirations, and to create the vibrant research community known to all as simply *IBEST*. It was from the beginning an effort to have a lasting impact on the University and, we dare say, it has achieved that end.

The Evolution of IBEST

The *Initiative* for Bioinformatics and Evolutionary Studies – which consisted of a relatively small number of investigators that shared fundamental research interests – was the kernel from which the *Institute* for Bioinformatics and Evolutionary Studies (IBEST) grew. The Institute, which was established in 2011, is one of only three research Institutes at the University of Idaho. It was built on the financial foundation provided by COBRE funding, while University of Idaho support to IBEST allowed us to broaden our scope to include research unrelated to human health. Here is how COBRE funding has been used.

INVESTMENTS IN PEOPLE

Faculty recruitment

COBRE funds have been strategically invested in the recruitment and retention of outstanding faculty. In some instances, this involved entirely funding their salaries for a few years and research start-up funds, while in other cases, COBRE funds were used in partnership with other units on campus to recruit faculty. The faculty who benefited from these COBRE funds include Drs. Buzbas, Fu, Harmon, Hohenlohe, McGowan, Parent, Remien, Ridenhour, Tank, Rosenblum and Top. These faculty have prospered at the University of Idaho and significantly contributed to IBEST and enabling other interdisciplinary activities on campus. The caliber of these faculty is amply demonstrated in their robust and productive research programs that are supported by extramural research funding. Three of these individuals (McGowan, Parent, and Tank) have been awarded much coveted NSF Career Awards.

Recruitment of other faculty

Over the years, the growing stature of IBEST, the high caliber of students and faculty, and its impressive core facilities have helped recruit faculty in a range of disciplines and academic departments. This 'snow ball' effect has broadly benefited the University though the magnitude of this effect is hard to quantify.

Faculty retention

Given the caliber of faculty affiliated with IBEST it is impressive that so many have been retained by the University. Only three faculty have decided to relocate, and two of these were largely decided by family issues and not because professional opportunities were better elsewhere.

In one instance, funds were used to retain a faculty member.

Graduate students

The graduate program in Bioinformatics and Computational Biology (BCB) was founded in 2003. It has attracted exceptional students from across the globe who were drawn by the faculty and their research programs. The BCB program has been nurtured by IBEST, and fellowships have been provided using COBRE funds. Since its inception the program has consistently grown and in recent years has remained at a steady enrollment of just over 20 students. This prestigious program has graduated about 50 students, many who have gone on to significant positions in industry and academia.

INVESTMENTS IN CORE FACILITIES

Using COBRE funding, IBEST has been able to provide access to advanced research infrastructure that is made accessible by partnering with exceptionally qualified technical staff dedicated to facilitating the success of investigators and their research projects. These core facilities, which are so extensively used today simply would not exist without COBRE funding.

Computational Resources Core (CRC)

With COBRE funding the CRC has developed from a minimal "proof of concept" beowulf cluster to the primary resource for high performance computing (HPC) at the University of Idaho. Initially offering compute accounts for free, the CRC has successfully transitioned to a Service Center model where user fees support the ongoing operating expenses of the core. Over the past three years, users have run 487,332 jobs on our primary cluster and now store 57.5 million objects in our primary storage. Our data center now includes over 280 servers and 30 network switches. In order to manage these resources with minimal staff the CRC uses configuration management scripts that now total more than 110 thousand lines of code. Total hard drive capacity of the data center is over 3.7 petabytes.

Genomics Resources Core (GRC)

COBRE funding was used to establish the IBEST Genomics Resources Core and to provision it with a suite of specialized instruments for the analysis of nucleic acids, totaling approximately $1.8 million in capital expenses. During the course of the COBRE grant period, the GRC has grown and adapted to keep up with the ever changing genomics technologies and the needs of researchers both on and off campus. The technologies and services have included Sanger capillary sequencing, microarray scanning and data analysis, Roche 454 sequencing, Bead Xpress genotyping, high throughput multi-locus amplicon library preparation and sequencing, Illumina sequencing, and most recently long-read sequencing on the Oxford Nanopore platform. During this time the GRC has developed a large customer base, serving a total of 167 different labs at 57 different public and private institutions since 2012. Researchers at the University of Idaho are the largest customer, accounting for about 50% of GRC revenue and receiving the benefit of hundreds of paid services per year, as well as many hours of consulting for methods development, trouble shooting, project design, and grant development support. External clients include researchers from Washington State University, USDA-ARS, UC Berkeley, and a wide variety of other institutions nationally and internationally making up the other ~50% of GRC revenue and services. Today the GRC is a central part of the University's commitment to interdisciplinary research and occupies two laboratory spaces in the University of Idaho's recently completed Integrated Research and Innovation Center, a world-class facility for interdisciplinary research and discovery.

INVESTMENTS THAT CREATE OPPORTUNITIES

Pilot Grants

COBRE funds entirely supported a Research Pilot Project Program that created a way to launch new research programs and increase the number and success rate of grant applications submitted to NIH and other federal and private funding agencies. These awards were for a maximum of $75,000 (each) per year for two years. Recipients of these awards include Drs. Hohenlohe, Heckendorn, Hrdlicka, Johnson, McGuire, Murdoch, Robison, Soule, and Top.

Technology Access Grants

IBEST used COBRE funds and partnered with the Idaho-INBRE to administer and fund the Technology Access Grant Program. This is essentially a pilot grant program that provides funding to investigators so they can conduct exploratory studies using the technologies and technical support of the IBEST Genomics Resources Core, Computational Resources Core, and Optical Imaging Core. These grants (typically $5,000 to $10,000) helped investigators produce preliminary or proof-of-concept data needed for competitive external proposals and overcome the financial hurdles met when launching a new area of research. Many of these led to extramurally funded grants. The recipients include Drs. Balemba, Foster, Fortunato, Fuerst, Karasev, Brown, Muira, Miller, Sullivan, Stenkamp, and Waits.

Other Research Funding

Startup funding was provided to Drs. Brown and Krone so they could launch a collaborative research project to explore the consequences of spatial structure on virus evolution.

Drs. Harmon, Rosenblum and Yterberg, received grants that were made possible as COBRE supplement awards and funding from the American Recovery and Reinvestment Act (ARRA) of 2009.

Bridge funding was provided to Dr. Stenkamp to provide continuity to her research program on the developmental biology of the retina, which in recent time has been awarded $1,870,140 by NIH.

OTHER INITIATIVES

IBEST became a founding partner in BEACON, an NSF Science and Technology Center for the Study of Evolution in Action whose investigators approach evolution in an innovative way to bring biologists, computer scientists, and engineers together to study evolution as it happens and apply this knowledge to solve real-world problems. BEACON is headquartered at Michigan State University with partners at University of Idaho (PI James Foster), North Carolina A&T State University, University of Texas at Austin, and University of Washington. NSF reports that BEACON is the model for what an NSF Science and Technology Center should be. They are particularly impressed with the extent and productivity (in terms of publications and funding) of collaborations fostered in BEACON.

Beyond the headline programs, more was made possible by COBRE funding, including a "Business for Scientists" workshop, the Travel and Collaborations Grant Program, the Inland Northwest Genomics Research Symposium, a seminar program, renovation of the zebra fish facility, and remodeling of collaborative workspace in MINES. Big and small investments have made a difference, and these were made possible by the flexibility of COBRE funding.

POSTSCRIPT

All that is described in this brief accounting of the past was made possible by the pliancy of the COBRE program, which has as its singular goal to strengthen institutional research capacity. Those affiliated with IBEST deserve credit for these achievements and for creating an interdisciplinary research community that knows no boundaries.

Dr. Larry J. Forney
University Distinguished Professor
IBEST Director '11–'15

Galapagos Snail photographed in the field by IBEST Principal Investigator Christine Parent's lab group.

IBEST's MISSION

IBEST empowers researchers to understand and apply the evolutionary process.

IBEST's VISION

We aspire to be a globally recognized center of excellence in evolutionary science that:

- Attracts and retains world renowned faculty
- Facilitates high impact research in evolutionary science
- Provides cutting edge infrastructure for genomics, bioinformatics, and research computing
- Houses exceptional administrative and scientific staff
- Is financially sustainable

HOW IBEST WORKS

The Institute for Bioinformatics and Evolutionary Studies (IBEST), a Level III Institute at the University of Idaho, facilitates research in evolutionary science, inclusive of all scholarly disciplines. IBEST faculty, staff, and students conduct basic research in evolution, as well as evolutionary modeling and applied evolutionary research in biomedical, agricultural, computational and conservation sciences. **IBEST provides an interdisciplinary, collegial and inclusive environment defined by a shared commitment to understanding and applying the evolutionary process.**

The process of evolution is the unifying principle of life sciences. Understanding evolution is essential to improving human well-being because evolutionary processes drive critical health challenges such as emerging infectious diseases, antimicrobial resistance, and even the origin and treatment of diseases such as cancer, mental illness, and obesity. Evolution also underlies agricultural challenges such as the emergence of pesticide resistance, the effects of invasive species, and improving the effectiveness of domestication. Understanding evolution also helps us protect our natural heritage by informing conservation policy and providing insight into adaptation to changing environments. Less obviously, computers can use evolution to solve complicated problems and to design both software and hardware. Evolutionary models have even proven important to understanding the diversity of languages and cultures.

IBEST empowers researchers to understand and apply the evolutionary process. These researchers represent diverse disciplines and come from 7 colleges and 21 academic departments across the UI campus.

IBEST seeks to maximize the RESEARCH IMPACT of participating faculty. We define research impact to be the degree to which the research changes how people think about the world. Thus, a high impact researcher is often described as a THOUGHT LEADER in their discipline. Their scholarship changes the hypotheses and methods of others in their field.

IDEAS TO IMPACT: ENVISIONING THE RESEARCH PROCESS

In order to maximize the research impact of participating faculty, we envision the research process using the following model:

IDEA ▸ **PROPOSAL** ▸ **RESOURCES** ▸ **DISCOVERY** ▸ **DISSEMINATION** ▸ **IMPACT**

In this model, we define the research process as a series of "states." These states are common milestones through which a research project can typically traverse. Most research begins as an idea. Over time, the researcher refines the idea until it can be formalized as a hypothesis within a research proposal. These proposals are often framed as requests for resources, which usually (but not always) come in the form of funding. Research resources, however, are merely the means to an end. The resources are spent on personnel, supplies, and equipment in order to collect data, which is then synthesized and disseminated to the research community. The most typical "state" at this stage of the model is a publication in a peer reviewed journal.

Ultimately, though, the point of the research is its intended IMPACT, whether it be solving a problem or illuminating the processes that govern the world around us.

This model of the research process is admittedly an oversimplification. However, by envisioning the research process in this way, we can identify investments that increase the rate at which faculty can move their research forward, transitioning between the states described above. We refer to these investments as "FORCE MULTIPLIERS." A second important advantage of this model is that each state is associated with quantifiable metrics that help us measure our progress toward our vision for IBEST.

RESEARCH FORCE MULITPLIERS

The concept of force multipliers originated in military history. In this context, a force multiplier is anything that increases the effectiveness of a fighting force. Examples include unique tactics, specialized equipment, or training. In more general terms, force multipliers allow an organization or individual to accomplish more with the same amount of effort.

We consider force multipliers to be people or infrastructure that increase the rate or probability of moving research between the states in the conceptual model described above. At IBEST, most force multipliers are designed to save faculty time – allowing them to focus on the conception and execution of their research, rather than activities for which they weren't formally trained. Examples include budget preparation for grant proposals, post-award budget management, event management, graphic design, and media outreach.

Other IBEST force multipliers provide specialized expertise or equipment that allow researchers to do things they normally couldn't. These IBEST functions are commonly housed within our two service centers, the Genomics Resources Core and the Computational Resources Core. Examples of these types of force multipliers include next generation sequencing technology, bioinformatics analysis, and research computing infrastructure.

Idea to Proposal

- **Collaborator visits** - IBEST has funded the travel costs to send faculty to visit collaborators or bring collaborators to the University of Idaho. These visits typically focus on the development of a publication or grant proposal.
- **IBEST Seminars** - IBEST funds up to 4 seminar visitors per semester. Speakers are selected by the students in the Bioinformatics and Computational Biology Graduate program.
- **Proposal Support** - IBEST administrative staff support faculty in all phases of proposal development, including RFA review, proposal initiation, budget development, document management (such as current and pending support, biosketches, etc.), sub award coordination, Cayuse and Fast Lane support, and coordination with the Office of Sponsored Programs.

Proposal to Resources

- **Proposal Pre-review** - IBEST funds stipends to reviewers to pre-review some proposals prior to their submission. We generally reserve this process for new investigators or large programmatic proposals.
- **Faculty Development and Mentoring** - IBEST offers workshops that build faculty skill sets. Recent examples include "Business for Scientists," in which faculty learn the fundamental concepts of pitching ideas, business models, and team management skills. This October, IBEST is partnering with the College of Science to offer a grant writing workshop for new faculty.
- **Preliminary Data Generation** - IBEST has offered a variety of mechanisms that support the collection of preliminary data for grant proposals. The two most common are Technology Access Grants (TAGS), which fund the use of either of our core facilities, or Pilot Grants, which fund personnel and supplies. The BEACON Center for the Study of Evolution in Action has also funded many faculty with seed grants intended to collect preliminary data.
- **Teaching Release** - IBEST can support teaching buyouts for faculty working on large programmatic proposals that will be submitted through the institute.
- **Art and Graphic Design** - IBEST staff can support the development of high quality figures and artwork for publications and grant proposals.
- **Methods Development** - The staff in the GRC and CRC routinely help faculty develop new research methods and write relevant pieces of methods sections for both proposals and manuscripts.

Resources to Discovery

- **BCB Fellowships** - IBEST has funded many BCB fellowships, which allow graduate students to work full time on funded research projects.
- **GRC Infrastructure** - Fully described in the GRC section of this report, the GRC provides next generation sequencing and bioinformatics support.

- **CRC Infrastructure** - Fully described in the CRC section of this report, the CRC provides a variety of research computing infrastructure.
- **Collaborative Postdoctoral Support** - IBEST has co-funded postdoctoral scholars with the College of Agriculture and Life Sciences (currently Dr. Migrui Duan who works with Dr. Brenda Murdoch). This mechanism is meant to build stronger collaborative ties with targeted researchers.
- **Grants Services:** IBEST provides financial management of resources by overseeing all post-award grant functions such as early budget setups; advance funding requests; sub-award initiation and monitoring; sponsor pre-approvals for no cost extensions, re-budgets, expenditure reviews and compliance; budget transfers; payroll cost transfers; comprehensive financial reports and project closeouts. Administrative staff also collaborate with the grants managers of various sponsoring agencies to determine appropriate actions on matters regarding modifications to contracts, re-budgeting, funding carry-forward, time extensions and other contractual terms.

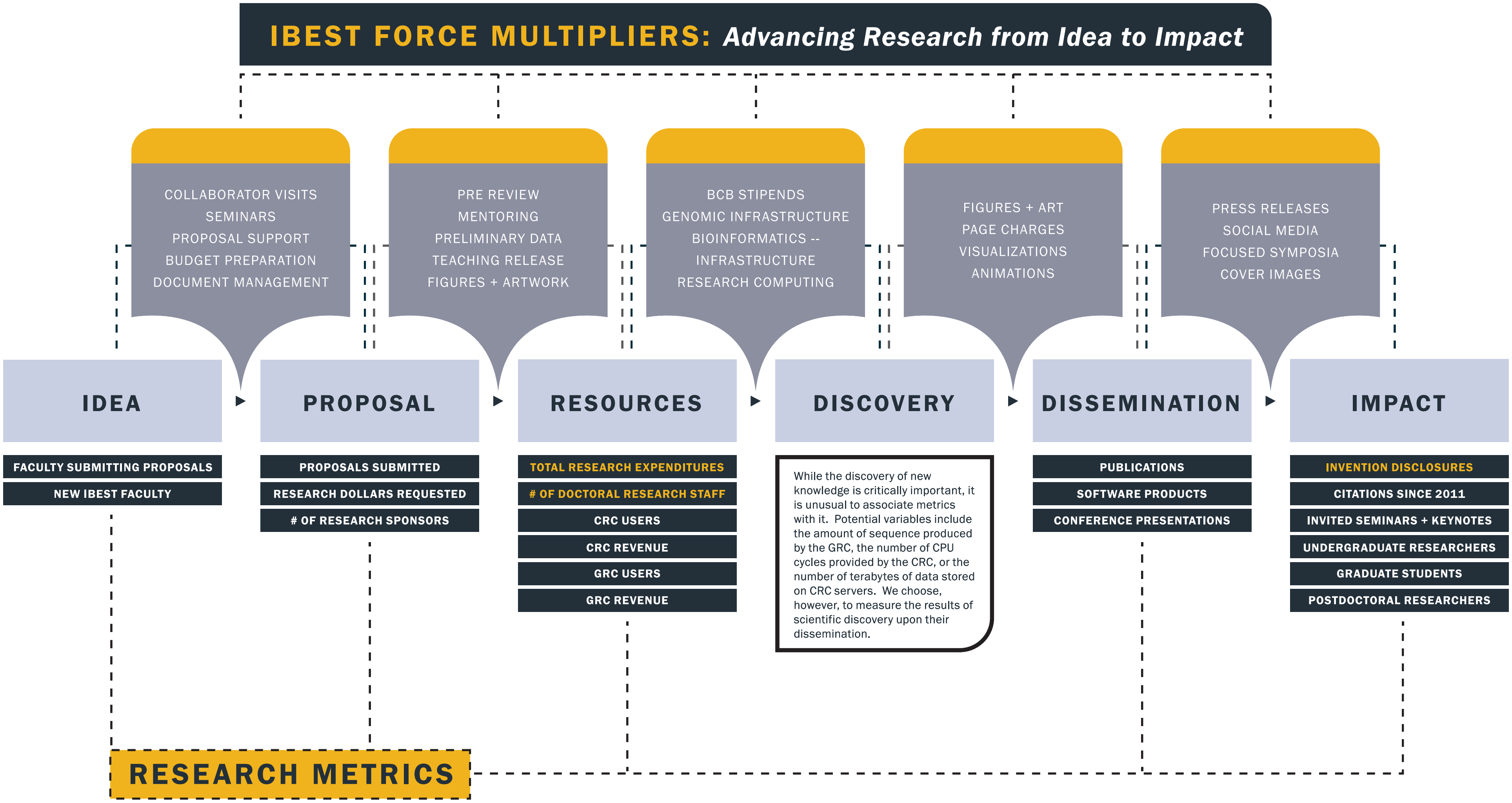
Working one on one with faculty researchers, IBEST staff proactively manage grant budgets by providing accurate projections and fiscal advice, and assuring compliance with institute, university, state and federal guidelines.

Discovery to Dissemination

- **Photography and Video** - IBEST staff are available for photography and video production to support the dissemination of faculty and student research.
- **Visualizations** - IBEST staff are available to collaborate with faculty on complex data visualizations, which can be deployed in print or online. Online visualizations can be interactive and can draw on dynamic data sets.
- **Animations** - IBEST has supported the development of animated visualizations, interactive displays, and virtual reality demonstrations that can be used for data exploration or outreach activities.

Dissemination to Impact

- **Press Releases** - IBEST Administrative Staff coordinate with faculty and UI Communications and Marketing to publicize important research discoveries. This includes writing of articles and production of visual collateral.
- **Social media** - IBEST publicizes events and research discoveries through social media channels.
- **Symposia** - IBEST has funded regional research symposia on genomics, as well as more focused symposia such as the 2016 symposium on Ecological and Evolutionary Drivers of Human Health and Welfare. We are currently considering co-offering with NKN a 2019 symposium on research computing and data science.



IBEST FORCE MULTIPLIERS: *Advancing Research from Idea to Impact*

COLLABORATOR VISITS
SEMINARS
PROPOSAL SUPPORT
BUDGET PREPARATION
DOCUMENT MANAGEMENT

PRE REVIEW
MENTORING
PRELIMINARY DATA
TEACHING RELEASE
FIGURES + ARTWORK

BCB STIPENDS
GENOMIC INFRASTRUCTURE
BIOINFORMATICS --
INFRASTRUCTURE
RESEARCH COMPUTING

FIGURES + ART
PAGE CHARGES
VISUALIZATIONS
ANIMATIONS

PRESS RELEASES
SOCIAL MEDIA
FOCUSED SYMPOSIA
COVER IMAGES

IDEA ▸ **PROPOSAL** ▸ **RESOURCES** ▸ **DISCOVERY** ▸ **DISSEMINATION** ▸ **IMPACT**

IDEA
FACULTY SUBMITTING PROPOSALS
NEW IBEST FACULTY

PROPOSAL
PROPOSALS SUBMITTED
RESEARCH DOLLARS REQUESTED
OF RESEARCH SPONSORS

RESOURCES
TOTAL RESEARCH EXPENDITURES
OF DOCTORAL RESEARCH STAFF
CRC USERS
CRC REVENUE
GRC USERS
GRC REVENUE

DISCOVERY
While the discovery of new knowledge is critically important, it is unusual to associate metrics with it. Potential variables include the amount of sequence produced by the GRC, the number of CPU cycles provided by the CRC, or the number of terabytes of data stored on CRC servers. We choose, however, to measure the results of scientific discovery upon their dissemination.

DISSEMINATION
PUBLICATIONS
SOFTWARE PRODUCTS
CONFERENCE PRESENTATIONS

IMPACT
INVENTION DISCLOSURES
CITATIONS SINCE 2011
INVITED SEMINARS + KEYNOTES
UNDERGRADUATE RESEARCHERS
GRADUATE STUDENTS
POSTDOCTORAL RESEARCHERS

RESEARCH METRICS

IBEST ORGANIZATION

Janet Nelson
VP for Research and Economic Development

ORED

IBEST STAFF

Dr. Barrie Robison
IBEST Director

Dr. Sam Hunter
Genomics Resources Core Director

Dr. Benji Oswald
Computational Resources Core Director

Rose Reese
Interim Grants Services Manager

Lisha Abendroth
Program Manager & Academic Director

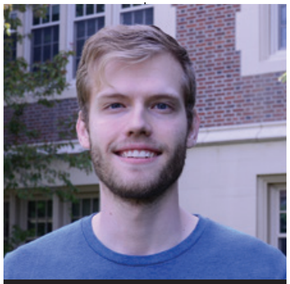
Vacant
System Administrator

Vacant
Financial Technician

Dan New
Genomics Lab Manager

Vacant
Data Scientist

Cody Muir
Communications Coordinator



Matt Fagnan
Research Technician

RESEARCH ADMINISTRATION

The Administrative Core of IBEST performs the research support functions for faculty, and is an important point of interaction between IBEST faculty and other administrative units on campus. Research grant proposals may be submitted through IBEST if they pertain to evolutionary science or if they rely on IBEST infrastructure (such as IBEST core facilities). In such cases, the IBEST Grant Services Manager assists the PIs in the development of proposal that support the scientific content (such as budgets, biosketches, and other documents). Once a grant is awarded, IBEST Administrative staff oversee purchases, travel, and other research expenditures.

- **Barrie Robison** – Director. Dr. Robison is a Professor in the Department of Biological Sciences. His research currently focuses on the modeling of evolutionary processes using video games. He was appointed Director of IBEST in February of 2018.
- **Lisha Abendroth** – Program Manager and Academic Director. Lisha manages and oversees the day to day operations of IBEST and the BCB graduate program.
- **Rose Reese** – Interim Grants Services Manager. This position is responsible for pre and post award support of grant proposals, and the fiscal administration of IBEST. Ms. MollyAnn Jones has accepted the permanent position and will begin in this role on September 24th.
- **Vacant** – Financial Technician. This position is responsible for transactional financial processes.
- **Cody Muir** – Communications Coordinator. Cody was hired in May 2018. He has extensive art and design training and is responsible for communication of IBEST activities and scholarship, as well as art and graphic design assignments that support IBEST researchers.

GENOMICS RESOURCES CORE

The IBEST GRC is the only comprehensive facility on the University of Idaho campus that houses all the equipment and personnel necessary to aid researchers in every aspect of high-throughput genomics research. It provides the molecular expertise and equipment needed for most high-throughput sequencing studies, and develops partnerships with other service facilities when additional capacity or other specialized equipment are warranted.

- **Sam Hunter** – Director GRC. Dr Hunter’s current duties as Director of the GRC include management of day-to-day operations, existing projects and client relations, outreach, identification of new opportunities, technologies, and clients, retaining and recruiting staff, data analysis, and advising students.
- **Dan New** – Genomics Manager. Dan is responsible for the day-to-day operation of the GRC “wet” laboratories which includes the DNA Sequencing Laboratory and GRC User Core.
- **Matt Fagnan** – Research Technician. Matt assists in day-to-day operations in the DNA Sequencing Laboratory.
- **Vacant** – Data Scientist. This position is responsible for bioinformatics and analysis of genomics data, and is currently vacant.

COMPUTATIONAL RESOURCES CORE

The mission of the CRC is to provide state of the art computing and data management services to our customers. The CRC contains an advanced mix of high performance computing clusters, powerful servers and reliable data storage components and is staffed by personnel with the knowledge and technical skills required to compress years of analysis into days. Our data center is a 1400 square foot facility in Room 124 in McClure Hall on the University of Idaho campus that has been specifically designed and renovated for our core.

- **Benji Oswald** – Director CRC. Dr Oswald is responsible for the day-to-day management operations, client retention and relations, cluster computing, data management and storage, and facility operations at the CRC.
- **Vacant** – System Administrator – This position is responsible for managing and providing high reliability and availability for IBEST production systems and software and for providing assistance to users.

PARTICIPATION IN IBEST

Any interested faculty, postdocs, or students may participate in IBEST activities. IBEST lunches, seminars, symposia, and other events are open to the public and provide a way for researchers to network and learn about the diverse research topics that touch IBEST in some way. While IBEST's intellectual focus is on evolutionary science, the bioinformatics, genomics, and research computing functions of our core facilities are available as service centers to all UI researchers. Faculty, postdocs, and students who rely on this infrastructure or who are interested in these areas are also welcome IBEST participants.

IBEST PRINCIPAL INVESTIGATORS

Faculty who are the most integrated in IBEST are those who submit grant proposals through the institute, and/or for whom IBEST administers their budgets. In order to submit a proposal through IBEST, the research must meet one of the following criteria:

1. The research is aligned with IBEST's intellectual focus on evolutionary science.
2. The research makes use of IBEST infrastructure, which may include the Genomics Resources Core, the Computational Resources Core, or IBEST's research support functions.

Currently, 17 faculty are classified as IBEST Principal Investigators:

Celeste Brown – **Professor**
Dept. of Biological Sciences
College of Science

Larry Forney – **Professor**
Dept. of Biological Sciences
College of Science

James Foster – **Professor**
Dept. of Biological Sciences
College of Science

Luke Harmon – **Professor**
Dept. of Biological Sciences
College of Science

Paul Hohenlohe – **Professor**
Dept. of Biological Sciences
College of Science

Samuel Hunter – **GRC Director**
Institute for Bioinformatics &
Evolutionary Studies

Brian Kennedy – **Assc. Professor**
Dept. of Fish and Wildlife Sciences
College of Natural Resources

Christopher Marx – **Professor**
Dept. of Biological Sciences
College of Science

Scott Nuismer – **Professor**
Dept. of Biological Sciences
College of Science

Christine Parent – **Asst. Professor**
Dept. of Biological Sciences
College of Science

Barrie Robison – **Professor**
Dept. of Biological Sciences
College of Science

Paul Rowley – **Asst. Professor**
Dept. of Biological Sciences
College of Science

Terence Soule – **Professor**
Dept. of Computer Science
College of Engineering

Deborah Stenkamp – **Professor**
Dept. of Biological Sciences
College of Science

Jack Sullivan – **Professor**
Dept. of Biological Sciences
College of Science

David Tank – **Professor**
Dept. of Biological Sciences
College of Science

Eva Top – **Professor**
Dept. of Biological Sciences
College of Science

CORE FACILITY USERS

The IBEST Core facilities support research of faculty from 7 colleges and 21 departments. The types of services and infrastructure provided by the IBEST cores are described more fully in their respective sections of this report.

GRC USER
CRC USER
USER OF BOTH CORES

John Abatzoglou
Geography, Science

Peter Allen
Chemistry, Science

Kimberly Andrews
Fish and Wildlife Sciences, Natural Resources

MD Badsha
Statistical Science, Science

Onesmo Balemba
Biological Sciences, Science

Soraia Barbosa
Fish and Wildlife Sciences Natural Resources

Jonathan Barnes
Physics, Science

Timothy Bartholomaus
Geography, Science

Jonah Bartrand
Geological Sciences, Science

Bert Baumgaertner
Politics and Philosophy, Letters, Arts and Social Sciences

Emily Bellis
Biology, Mathematics and Natural Sciences

Carolyn Bohatch
Food Science, CALS

Sarah Brooker
Bioinformatics and Computational Biology, Graduate Studies

Brittni Brown
Natural Resouces and Society, Natural Resources

Celeste Brown
Biological Sciences, Science

Ken Cain
Fish & Wildlife Sciences, Natural Resources

Dorothy Catey
Mathematics, Science

Camden Clark
Mathematics, Science

Katherine Cleary
Fish and Wildlife Sciences, Natural Resources

Heather Clendenin
Fish and Wildlife Sciences, Natural Resources

Erik Coats
Civil & Environmental Engineering, Engineering

Mark Coleman
Forest, Rangeland & Fire Sciences, Natural Resources

Courtney Conway
Fish & Wildlife Sciences, Natural Resources

Louise-Marie Dandurand
Entomology, Plant Pathology & Nematology, CALS

Kimberly Davenport
Animal and Veterinary Sciences, CALS

Travis DeVault
Computer Science, Engineering

Mariah Eckwright
Mathematics, Science

Clinton Elg
Biological Sciences, Science

Leo Epstein
Bioinformatics and Computational Biology, Graduate Studies

Anahi Espindola
Biological Sciences, Science

Joshua Faber-Hammond
Biology, Mathematics and Natural Sciences

Jake Ferguson
Center for Modeling Complex Interactions, Science

Peter Fetros
Biological Sciences, Science

Larry Forney
Biological Sciences, Science

Lee Fortunato
Biological Sciences, Science

James Foster
Biological Sciences, Science

Michael France
Bioinformatics and Computational Biology, Graduate Studies

Audrey Fu
Statistical Science, Science

Pete Fuerst
Biological Sciences, Science

Daniel Furman
Mathematics, Science

Fuchang Gao
Mathematics, Science

Alida Gerritsen
Institute for Bioinformatics & Evolutionary Studies, IBEST

Spencer Gomez
Biological Sciences, Science

Tawney Gonzales
Chemistry, Science

Andrea Gonzalez
Biological Sciences, Science

Scott Grieshaber
Biological Sciences, Science

Luke Harmon
Biological Sciences, Science

Kyle Harrington
Virtual Technology and Design, Art and Architecture

Patricia Hartzel
Biological Sciences, Science

Katherine Hegewisch
Geography, Science

Sarah Hendricks
Bioinformatics and Computational Biology, Graduate Studies

David Herndon
USDA - Agriculture Research Service, United States Dept of Agriculture

Paul Hohenlohe
Biological Sciences, Science

Sam Hunter
Institute for Bioinformatics & Evolutionary Studies, IBEST

Sarah Jacobs
Forest, Rangeland, and Fire Sciences, Natural Resources

Alexander Karasev
Entomology, Plant Pathology & Nematology, CALS

Bethel Kohler
Bioinformatics and Computational Biology, Graduate Studies

Rinu Kooliyottil
Entomology, Plant Pathology & Nematology, CALS

Joel Lafond-Lapalme
Globodera Alliance, United States Dept of Agriculture

Paul Lawrence
Newport Laboratories

Stephen Lee
Statistical Science, Science

Kevin Lewallen
Bioinformatics and Computational Biology, Graduate Studies

Rui Li
Statistical Science, Science

Bailey Lind-Trefts
Mechanical Engineering, Engineering

Mason Linscott
Biological Sciences, Science

Shirley Luckhart
Entomology, Plant Pathology & Nematology, CALS

Martyna Lukaszewicz
Bioinformatics and Computational Biology, Graduate Studies

Fenner MacRae
Biology, Mathematics and Natural Sciences

Louise Magbunduku
Virtual Technology and Design, Art and Architecture

Mark Margres
Institute for Bioinformatics & Evolutionary Studies, IBEST

Evan Martin
Bioinformatics and Computational Biology, Graduate Studies

Kyle Martin
Physics, Science

Chris Marx
Biological Sciences, Science

Samuel McCauley
Biological Sciences, Science

Armando McDonald
Forest, Rangeland & Fire Sciences, Natural Resources

Mark McGuire
Animal Veterinary Sciences, CALS

Conrad Mearns
Computer Science, Engineering

Marco Mesa-Frias
Statistical Science, Science

Craig Miller
Biological Sciences, Science

CONTINUED

Christopher Mirabzadeh
Physics, Science

Diana Mitchell
Biological Sciences, Science

Eric Mittelstaedt
Geological Sciences, Science

Tanya Miura
Biological Sciences, Science

James Moberly
Chemical & Materials Engineering, Engineering

Thomas Morrow
Geological Sciences, Science

Sebastian Mortimer
Biological Sciences, Science

Michelle Mousel
Veterinary Medicine, Veterinary Medicine

Brenda Murdoch
Animal Veterinary Sciecnes, CALS

Gordon Murdoch
Animal Veterinary Sciecnes, CALS

James Nagler
Biological Sciences, Science

Shawn Narum
Aquaculture Research Institute, CALS

Stacey Nerkowski
Fish and Wildlife Sciences, Natural Resources

Derek Neuharth
Geological Sciences, Science

George Newcombe
Forest, Rangeland & Fire Sciences, Natural Resources

Linh Nguyen
Mathematics, Science

Nuismer, Scott
Biological Sciences, Science

Kenetta Nunn
Bioinformatics and Computational Biology, Graduate Studies

Christine Parent
Biological Sciences, Science

Jagdish Patel
Center for Modeling Complex Interactions, Science

Matt Powell
Aquaculture Research Institute, CALS

Ben Price
Statistical Science, Science

Andrew Rankin
Bioinformatics and Computational Biology, Graduate Studies

Chris Remien
Mathematics, Science

Benjamin Ridenhour
Biological Sciences, Science

Barrie Robison
Biological Sciences, Science

Erica Rosenblum
Off Campus

Paul Rowley
Biological Sciences, Science

Megan Ruffley
Bioinformatics and Computational Biology, Graduate Studies

Dojin Ryu
Food Science, CALS

Malia Santos
Biological Sciences, Science

Sarah Schaack
Biology, Mathematics and Natural Sciences

Brenda Schroeder
Entomology, Plant Pathology & Nematology, CALS

Haiqing Sheng
Food Science, CALS

Matthew Singer
Biological Sciences, Science

Brian Small
Fish & Wildlife Sciences, Natural Resources

Amanda Stahlke
Biological Sciences, Science

Thibault Stalder
Biological Sciences, Science

Deborah Stenkamp
Biological Sciences, Science

Bryan Stevens
Fish and Wildlife Sciences, Natural Resources

David Streett
Institute for Bioinformatics & Evolutionary Studies, IBEST

Michael Strickland
Soil & Water Systems, CALS

Cheng Sun
Biology, Natural Sciences

David Tank
Biological Sciences, Science

Eva Top
Biological Sciences, Science

Juan Pablo Torres Florez
Institute for Bioinformatics & Evolutionary Studies, IBEST

Odbayar Tumendemberel
Bioinformatics and Computational Biology, Graduate Studies

Patric Vaelli
Department of Integrative Biology, Natural Science

James VanLeuven
Center for Modeling Complex Interactions, Science

Anne Veillet
Biological Sciences, Science

Kerri Vierling
Fish & Wildlife Sciences, Natural Resources

Margot Vore
Geological Sciences, Science

Lisette Waits
Fish & Wildlife Sciences, Natural Resources

Konstans Wells
Institute for Bioinformatics & Evolutionary Studies, IBEST

Stephen White
USDA - Agriculture Research Service, United States Dept of Agriculture

Kristopher Waynant
Chemistry, Science

Holly Wichman
Biological Sciences, Science

Janet Williams
Animal and Veterinary Sciences, CALS

Alexander Wixom
Center for Modeling Complex Interactions, Science

Marty Ytreberg
Physics, Science

Meijun Zhu
Off Campus

KEY PARTNERS

IBEST seeks to have a campus wide impact. To this end, we partner with other institutes and centers to leverage resources, identify shared opportunities, and enhance the research of participating faculty regardless of their home college or department.

Beacon

The BEACON Center for the Study of Evolution in Action is an NSF Science and Technology Center founded in 2010 with the mission of illuminating and harnessing the power of evolution in action to advance science and technology and benefit society. NSF STCs are multi-institutional consortia funded for up to 10 years at up to $5M per year. BEACON is a consortium of universities led by Michigan State University and includes IBEST at the University of Idaho along with the University of Texas at Austin, the University of Washington, and North Carolina A&T State University. BEACON unites biologists, computer scientists and engineers in joint study of natural and artificial evolutionary processes and in harnessing them to solve real-world problems.

BEACON promotes research on “Evolution in Action” that crosses academic areas (biological, artificial, engineering) and thematic boundaries (networks, communities, and behavior) by providing competitive research grants to participating institutions. Ideally the projects funded transcend geographic boundaries and engage investigators from multiple participating institutions. To date, IBEST has received over $4 million in competitive funding from BEACON. These funds have supported 48 projects, 18 faculty members from across campus, over two dozen graduate students and postdocs, and many undergraduate students. These projects are interdisciplinary, and many are cross-institutional.

IBEST was originally asked to help form BEACON in 2010 because of our established excellence in evolutionary engineering and experimental evolution. IBEST’s continued active involvement in BEACON remains a testament to the high regard in which our research activities are held by top universities nation-wide, and by NSF. Several IBEST faculty contributed large portions of text for the original BEACON STC proposal and for the subsequent funded application for renewal.

Center for Modeling Complex Interactions

The Center for Modeling Complex Interactions (CMCI) is an NIGMS-funded Center of Biomedical Research Excellence (COBRE). CMCI was awarded a $10.6 million 5-year grant in March 2015, with Dr. Holly Wichman as PI on the grant and the Director of the Center. CMCI funds projects led by three early-career faculty working in the area of viral co-infection. It also funds a Collaboratorium for modeling that houses four postdocs. These postdocs and participating faculty work with the three project directors on modeling for their projects and also do modeling for other biomedically-related research. One long-term goal is to extend this modeling paradigm beyond biomedical projects to other areas of research in at the university.

CMCI is an independent program, but it is complementary to and synergistic with IBEST. For example, the two programs have complementary pilot grant programs and technology access grants and have agreed to use the same formula for resource distribution to PIs and colleges. Furthermore, we have put protocols in place so that PIs can submit grants with shared credit (and F&A) between CMCI and IBEST when appropriate. In response to feedback from faculty, students and postdocs, CMCI and IBEST have merged our seminars. This provides greater opportunity for cross fertilization. Finally, the IBEST Computational Core houses and maintains CMCI’s high-end graphical processing node for molecular dynamic modeling.

Idaho Wheat Commission

The Idaho Wheat Commission (IWC) was established in 1959 by the Idaho Grain Growers Association to help maximize profitability for Idaho wheat producers by investing funds in market development, research, and information and education. The Commission recognizes that investing in new approaches to problem solving and into innovative ideas will help Idaho wheat growers adjust to changing situations. In recognition of this, IBEST, in collaboration with Dr. Arash Rashed (University of Idaho Aberdeen extension researcher) are studying the genomics of an emerging agricultural pest, the wire worm. Collaborations developed during this project are expected to lead to multiple new clients, opportunities for collaborative grant submission, and continued collaboration with the Idaho Wheat Commission. This collaboration grew out of an IBEST Technology Access Grant that funded sequencing of the wireworm genome.

Idaho EPSCoR

The State of Idaho recently submitted a $20M proposal to the EPSCoR RI competition. This pending proposal describes a 5 year project to study the adaptive capacity of two keystone species in Idaho – the rainbow trout and sagebrush. The project spans multiple Universities in the State and relies heavily on IBEST infrastructure. In particular, the services of the Genomics Resources Core and the Computational Resources Core are critical to the execution of the research.

Idaho INBRE

IBEST collaborates with the Idaho Idea Network of Biomedical Research Excellence to support faculty development and provide research infrastructure. IBEST and INBRE have co-funded Technology Access Grants in the past to support biomedical researchers as they collect critical preliminary data for grant proposals.

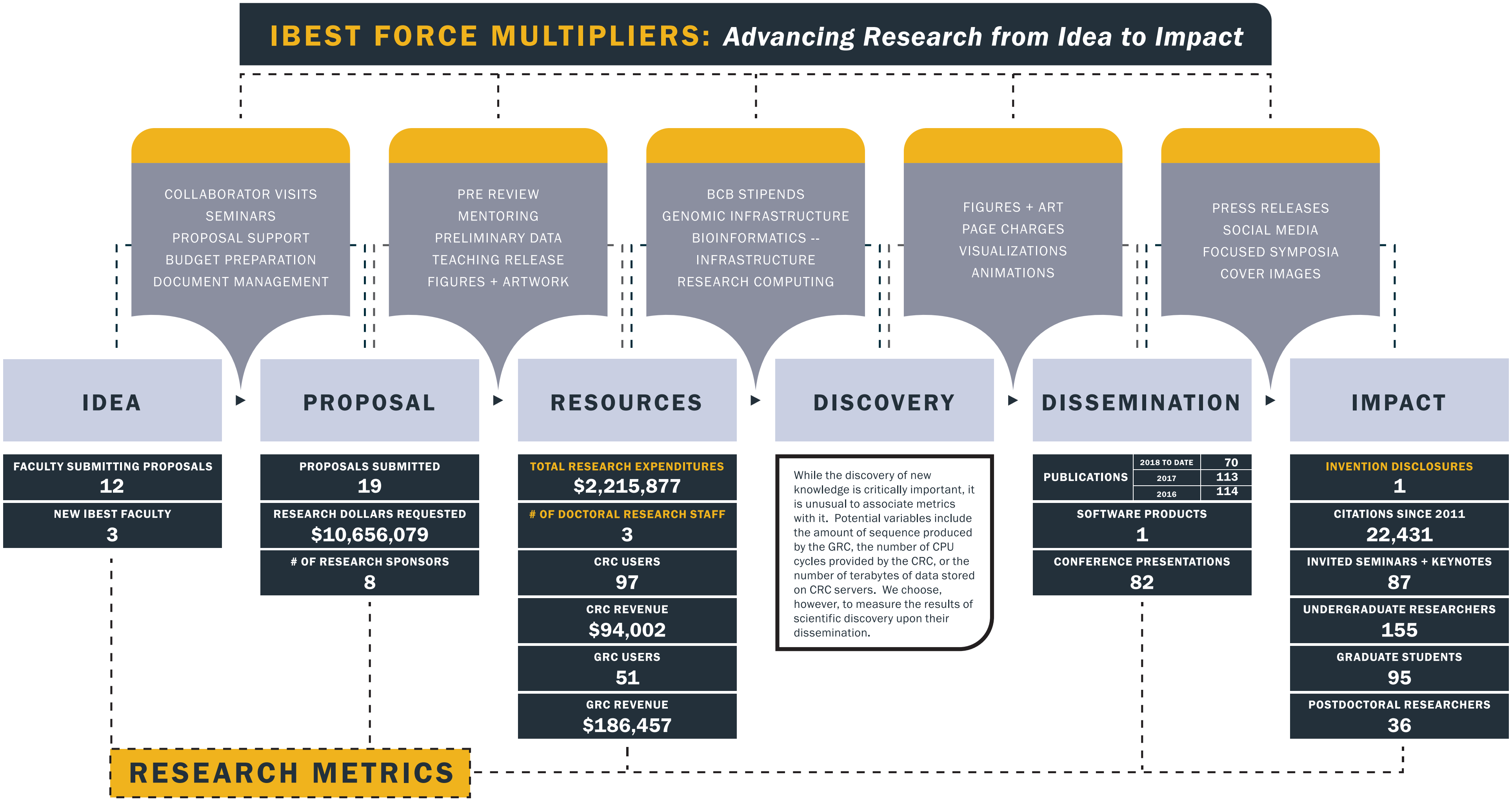
Northwest Knowledge Network

The Northwest Knowledge Network (NKN) enables data intensive research by offering research computing infrastructure at two data centers. NKN provides research data storage and management options, web and applications development, and also features an Unmanned Aerial Systems program. The majority of the UI research computation infrastructure is managed by either the IBEST CRC or NKN. IBEST and NKN are therefore working to better coordinate strategic partnerships that help invest in research computation.

2018 ACCOMPLISHMENTS AND PERFORMANCE METRICS

Each of the states in our model of the research process is associated with METRICS, variables that can be quantified and used to measure our progress toward our goals. Here, we define these metrics, describe our process for collection and measurement, and report them for Fiscal Year 2018. In some cases, our metrics do not align well with a fiscal year reporting window (publications in a calendar year being an obvious example). For these metrics, we report a "rolling window" to provide context for the 2018 partial calendar year.

In some cases, IBEST contributes directly to priority metrics that are used by the University of Idaho to measure progress in our 10 year Strategic Plan. These metrics are indicated in the diagram using gold text.



IBEST FORCE MULTIPLIERS: *Advancing Research from Idea to Impact*

COLLABORATOR VISITS
SEMINARS
PROPOSAL SUPPORT
BUDGET PREPARATION
DOCUMENT MANAGEMENT

PRE REVIEW
MENTORING
PRELIMINARY DATA
TEACHING RELEASE
FIGURES + ARTWORK

BCB STIPENDS
GENOMIC INFRASTRUCTURE
BIOINFORMATICS --
INFRASTRUCTURE
RESEARCH COMPUTING

FIGURES + ART
PAGE CHARGES
VISUALIZATIONS
ANIMATIONS

PRESS RELEASES
SOCIAL MEDIA
FOCUSED SYMPOSIA
COVER IMAGES

IDEA

FACULTY SUBMITTING PROPOSALS
12

NEW IBEST FACULTY
3

PROPOSAL

PROPOSALS SUBMITTED
19

RESEARCH DOLLARS REQUESTED
$10,656,079

 # OF RESEARCH SPONSORS
8

RESOURCES

TOTAL RESEARCH EXPENDITURES
$2,215,877

 # OF DOCTORAL RESEARCH STAFF
3

CRC USERS
97

CRC REVENUE
$94,002

GRC USERS
51

GRC REVENUE
$186,457

DISCOVERY

While the discovery of new knowledge is critically important, it is unusual to associate metrics with it. Potential variables include the amount of sequence produced by the GRC, the number of CPU cycles provided by the CRC, or the number of terabytes of data stored on CRC servers. We choose, however, to measure the results of scientific discovery upon their dissemination.

DISSEMINATION

PUBLICATIONS		
	2018 TO DATE	70
	2017	113
	2016	114

SOFTWARE PRODUCTS
1

CONFERENCE PRESENTATIONS
82

IMPACT

INVENTION DISCLOSURES
1

CITATIONS SINCE 2011
22,431

INVITED SEMINARS + KEYNOTES
87

UNDERGRADUATE RESEARCHERS
155

GRADUATE STUDENTS
95

POSTDOCTORAL RESEARCHERS
36

RESEARCH METRICS

Zebrafish act as the primary experimental model for Diana Mitchell and the Stenkamp Lab's research on vertebrate retinal development and regeneration. Photo Credit Benji Oswald

IDEAS

While research ideas are uncountable, IBEST plays an important role in helping researchers generate and refine their ideas. We invest in activities such as IBEST lunch and our seminar series precisely because they help faculty discuss their research, identify future collaborators, and get critical feedback. We are also keenly interested in growing participation in IBEST. To measure progress toward this goal, we track two metrics:

1. ***Number of faculty submitting proposals through IBEST:*** While participation can be measured at any number of IBEST events (lunches, seminars, symposia, workshops), the number of faculty submitting proposals most closely aligns with the University of Idaho's goal of increasing research expenditures.

IN FY18, 12 FACULTY SUBMITTED PROPOSALS THROUGH IBEST.

2. ***Number of NEW faculty submitting proposals through IBEST:*** One of the stated goals in our new charter was to broaden interdisciplinary research in evolutionary science. An important metric in this regard is the number of new investigators that submitted proposals through IBEST. Investing in new researchers is also important because many of IBEST's key researchers are approaching retirement age.

IN FY18, WE RECRUITED THREE NEW FACULTY TO WORK WITH IBEST TO SUBMIT PROPOSALS

Paul Rowley - (Assistant Professor, Biological Sciences) – submitted NIH R21

Tonia Dousay - (Assistant Professor, College of Education) – CoPI on a pending NSF proposal

Diana Mitchell - (Assistant Professor, Biological Sciences) – PI on a pending R01

PROPOSAL ACTIVITY

Submissions Through IBEST

We measure proposal activity with three metrics:

- Number of proposals submitted.
- Total research dollars requested.
- Number of separate research sponsors.

IBEST PIs submitted 19 proposals in FY18, totaling $10,656,709 in requests. These requests were to 8 different sponsors.

Table 1: **Proposals Submitted Through IBEST**

PI	Sponsor	Title	Request	Status
Hunter , Samuel S.	Idaho Wheat Commission	Effects of the seed microbiome on alpha amylase activity	3,621	FUNDED
Rowley, Paul*	Dept. Health and Human Services	Genetic Determinants of Killer Toxin Efficacy against C. glabrata	356,961	SUBMITTED
Top, Eva M.	National Institute of Food & Agriculture/USDA	Tracking the spread of antibiotic resistance genes and plasmids in agricultural soils	500,000	FUNDED
Top, Eva M.	Dept. Health and Human Services	Plasmid-bacteria coevolution promotes the spread of antibiotic resistance	1,891,689	FUNDED
Tank, David C.	National Science Foundation	Collaborative Research: Patterns and processes underlying multiple transitions to wind pollination in Thalictrum (Ranunculaceae)	426,924	SUBMITTED
Marx, Christopher	Michigan State University	Enhancing sustainable agriculture by unraveling plant-microbiome interactions dependent on rare earth element	305,385	SUBMITTED
Top, Eva M.	Dept. Health and Human Services	Does pre-adaptation to antibiotic resistance plasmids result in pan-resistant pathogens?	414,179	SUBMITTED
Tank, David C.	National Science Foundation	Dimensions: Collaborative Research: The role of trait tradeoffs in creating functional strategies, adaptation, and diversification in a hyperdiverse plant clade	275,916	SUBMITTED
Harmon, Luke J.	National Science Foundation	Collaborative Research: Dimensions: The origin and maintenance of highly specialized co-evolved ecological networks: incorporating the geographic context for plants and pollinators	360,481	FUNDED
Marx, Christopher	National Science Foundation	Dimensions: An inordinate fondness for Methylobacterium- roles of phylogeny, genome content, and functional performance traits in the evolution and assembly of a diverse plant-associated community	1,777,711	FUNDED
Hohenlohe, Paul	National Science Foundation	Collaborative Research: Testing mechanisms of microgeographic adaptation	203,666	FUNDED
Tank, David C.	Society of Systematic Biologists	Phylogeographic Inference of Western Sword Fern (Polystichum munitum) Expands Capability of Predicting Cryptic Diversity	1,300	FUNDED
Tank, David C.	Society of Systematic Biologists	Pollination syndrome and biogeographic patterns of dispersal in the neotropical wildflower Lamourouxia: Exploring diversification and speciation in a phylogenetic framework	1,300	FUNDED
Kennedy, Brian P.	Bonneville Power Administration	Integrating evolving life history strategies and life cycle modeling for fall Chinook salmon (Oncorhynchus tshawytscha)	83,475	FUNDED
Parent, Christine	National Science Foundation	CAREER: Islands as Models to Study Effects of Multidimensional Selection	1,093,877	FUNDED
Forney, Larry J.	Weill Cornell Medicine	Analysis of the Vaginal Microbiome in Women with an Adnexal Mass	13,958	SUBMITTED
Soule, Terence**	National Science Foundation	THE EVOLUTIONARY ARCADE: A game based context for informal learning of evolutionary biology	2,641,822	SUBMITTED
Harmon, Luke J.	National Science Foundation	Collaborative Research: Framework: Software: HDR: Reproducible Visual Analysis of Multivaraiate Networks with MultiNet	303,812	FUNDED
Harmon, Luke J.	National Science Foundation	Biodiversity and Human Welfare Network (BioDAHWN)	0	SUBMITTED
			$10,656,079	

IBEST PIs submitted 19 proposals in FY18, totalling **$10,656,079** in requests.

11 proposals will receive funding, totalling **$6,220,933.**

Proposals featuring new PIs are indicated above with a *.
Proposals featuring new CoPIs are indicated with a **.
Requested amount may be different than awarded amount.

RESEARCH RESOURCES

At this stage, we can quantify the research activity of IBEST using metrics that measure either research expenditures, numbers of research personnel, or usage of infrastructure:

New awards: We track both the number of new awards that will be administered by IBEST each fiscal year, as well as their total dollar amount.

IBEST PIs received 11 new awards in FY18, totaling $6,220,933 (Table 1). These metrics do not include new awards from BEACON. IBEST received a total of 18 awards during FY18 plus 8 new BEACON seed grants.

In FY18, the total funds awarded to UI by external sponsors was $3,288,760. These funds, which are mix of previous grants and new grants are described in Table 2. Note that some awards listed as “FUNDED” in Table 1 do not distribute the total amount of the grant in the first year.

Research Expenditures: This metric, which is a priority metric for the University Strategic Plan, measures the dollars spent from sponsored grants and other activities related to research. In FY18, IBEST research expenditures amounted to $2,215,877.

Number of Doctoral Research Staff: This metric is also used in the University Strategic Plan. IBEST is the administrative home for 3 Doctoral Research Staff.

Computational Resources Core Users: The research computation infrastructure in the CRC had 97 unique users in FY18.

Computational Resources Core Revenue: Revenue by core facilities represents research activity that flows through IBEST, and is related to institutional research expenditures. The CRC Service Center Revenue for FY18 was $94,002.

Genomics Resources Core Users: The genomics and bioinformatics infrastructure in the GRC had 51 unique users in FY18.

Genomics Resources Core Revenue: The GRC Service Center revenue for FY18 was $186,457. Of this amount, 52.5% was from internal (UI) clients.

Table 2: FY18 Award Distribution

PI	Sponsor	Title	Award Amount	FA Rate
Forney, Larry	National Institutes of Health	COBRE III Year 5	$94,020	45.3%
Foster, James	Michigan State University BEACON	BEACON Center for the Study of Evolution in Action	$112,401	45.3%
Foster, James	Michigan State University BEACON	Robinson, Salmon Run: An Evolutionary Ecology Educational Game	$4,650	45.3%
Foster, James	Michigan State University BEACON	Marx, Stepwise evolution of growth on lignin-derived substrates by the biotechnological platform organism Methylobacterium extorquens PA1	$32,317	45.3%
Foster, James	Michigan State University BEACON	Marx, Going Global: Applying Tn-Seq technology to questions of pleiotropy and evolvability on a genomic scale	$30,838	45.3%
Foster, James	Michigan State University BEACON	Marx, Pleiotropy vs. evolovability within an enzyme	$15,486	45.3%
Foster, James	Michigan State University BEACON	Marx, Does selection for increased competitive ability result in bigger cells	$11,705	45.3%
Foster, James	Michigan State University BEACON	Top, Characterizing Unique Genomic Islands in Modern Pandemic Vibrio cholerae evolution	$7,499	45.3%
Foster, James	Michigan State University BEACON	Miller, Traversing multi-gene fitness landscapes in alternative phiX 174 hosts	$23,655	45.3%
Foster, James	Michigan State University BEACON	Top, Detecting unplanned evolution in the ADDgene plasmid repository	$11,430	45.3%
Foster, James	Michigan State University BEACON	Wichman, Rapid analysis of parasite dynamics and evolution in arthropod populations	$38,151	45.3%
Foster, James	Michigan State University BEACON	Marx, Deep sequencing and metabolomics analysis	$45,576	45.3%
Foster, James	Michigan State University BEACON	Marx, Adaptation in the face of ever-larger pulses of stress	$55,929	45.3%
Foster, James	Michigan State University BEACON	Mittelstaedt, Microbes and Microplastics: Is there evidence for selection in a novel deep ocean niche?	$39,551	45.3%
Foster, James	Michigan State University BEACON	Top, The evolution of plasmid persistence and host permissiveness and their effects on the emergence of multi-drug resistance	$34,486	45.3%
Kennedy, Brian	Bonneville Power Administration	Chinook Life Cycle Model	$129,522	26.0%
Top, Eva	National Institutes of Health	Plasmid-Bacteria Coevolution promotes the spread of antibiotic resistance	$363,870	47.5%
Hunter, Samuel	Idaho Wheat Commission	Effects of the seed microbiome on alpha amylase activity	$1,811	0.0%
Forney, Larry	University of Maryland (NIH)	Eludidating causes of vaginal symptoms using a multi-omics approach	$134,711	47.5%
Forney, Larry	University of Maryland (NIH)	Ecopathogenomics of sexually transmitted iInfections	$34,332	45.3%
Tank, David	Society of Systematic Biologists	Graduate Student Research Award: Western Sword Fern	$1,300	0.0%
Tank, David	Society of Systematic Biologists	Graduate Student Research Award: Neotropical Wildflower	$1,300	0.0%
Hunter, Samuel	Idaho Wheat Commission	Assessing genetic variation among geographically distinct sugar beet wireworm populations across the state of Idaho	$26,463	0.0%
Brown, Celeste	Texas Biomedical Research Institute	Research to improve & standardize Marmoset nutrition & dietary husbandry	$137,853	47.5%
Hohenlohe, Paul	National Science Foundation	Using experimental population genomics to test hpotheses and develop novel analytical tools	$699,389	47.5%
Hohenlohe, Paul	Colorado State University	The role of eco-evolutionary dynamics in an expanding biocontrol agent	$110,604	47.5%
Hohenlohe, Paul	Washington State University	Evolution of transmission in Tasmanian Devils and their infectious cancer	$24,098	45.3%
Robison, Barrie	Idaho State Board of Education	An Evolutionary approach for procedural opponent generations in video game	$67,600	0.0%
Hohenlohe, Paul	Washington State University	Evolution of cancer transmission	$118,401	47.5%
Parent, Christine	National Science Foundation	CAREER: Islands as models to study effects of multidemensional selection	$412,811	47.5%
Top, Eva	National Institute of Food & Agriculture	Tracking the spread of antibiotic resistance genes and plasmids in agricultural soils	$455,000	42.9%
Parent, Christine	National Science Foundation	Graduate Student Research Project - Linscott	$12,000	0.0%
			$3,288,760	

IBEST PIs received 18 awards in FY18, totalling **$3,288,760.**

NOTEWORTHY AWARDS ENABLED BY IBEST

Our metrics measure research that is administered by IBEST. However, these metrics fail to capture the research grants that rely on IBEST infrastructure but are not administered by IBEST. Examples of significant current grants that fall into this category include:

C. Miller and H. Wichman NIH R01

Title: Patterns of Adaptive Evolution
Award Amount: $1,306,334
Years: 2018–2023
Relies On:
Postaward:
Research Computing Infrastructure (CRC)

D. Stenkamp (Biological Sciences) NIH R01

Title: Patterning Genes in Retinal Development
Award Amount: $1,870,140
Years: 2018–2023
Relies On:
Preaward:

- IBEST provided bridging funds
- Sequencing or other molecular work by the GRC

Postaward:

- Sequencing or other molecular work by the GRC

S. Luckhart NIH R01

Title: The burden of malaria transmission due to asymptomatic HIV co-infection
Award Amount: $548,945 (2015)
Years: 2012–2019
Relies On:
Postaward:

- Sequencing or other molecular work by the GRC
- Bioinformatics by the GRC
- Large memory servers by the CRC
- GRC – other (methods development, protocol improvement)

S. Luckhart NIH R01

Title: Malaria and allergic inflammatory changes to the gut barrier
Award Amount: $1.94M
Years: 2018–2022
Relies On:
Preaward:

- Methods development by the GRC
- Proposal methods support

Postaward:

- Sequencing or other molecular work by the GRC
- Bioinformatics by the GRC

*S. Greishaber WSU R01 Sub**

Title: Genetic regulation of developmental transitions in Chlamydia
Award Amount: $1,066,933 Subaward to UI
Years: 2018–2022
Relies On:

- Sequencing or other molecular work by the GRC
- Methods development by the GRC

S. McGuire and M. McGuire NIH R01

Title: Mammary and milk microbiomes and metabolomes - Understanding early variation and impacts on risk for mammary inflammation and mastitis
Award Amount: $3,007,084
Years: 2018–2023
Relies On:
Postaward:

- Sequencing or other molecular work by the GRC
- Large memory servers and cluster computing by the CRC

L. Fortunato NIH R01

Title: HCMV infection downregulates nidogen 1 and myelin protein zero
Award Amount: $1,449,667
Years: 2018–2022
Relies On:
Preaward:

- Seed funding (from TAGS)
- Methods development by the GRC
- Preliminary data from the GRC

Postaward:

- Sequencing or other molecular work by the GRC
- Bioinformatics by the GRC

C. McGowan Career

Title: Establishing links between musculoskeletal morphology and the biomechanics of bipedal hopping in desert environments
Award Amount: $1,110,978
Years: 2016–2021
Relies On:
Preaward:

- Seed funding from 3 Beacon Grants

Proposals that have not yet been awarded are indicated with a *.

E. Middlestadt Career

Title: Moving into the 3rd Dimension: Quantifying the influence of Magmatism, Tectonics, Hydrothermal Cooling, and Hotspots on the Dynamic Evolution of Divergent Plate Boundaries
Award Amount: $599,643
Years: 2019–2023
Relies On:
Preaward:

- Preliminary data from the CRC

Postaward:

- Cluster computing by the CRC
- Polymorphic Games - game development

H. Wichman NIH COBRE

Title: Center for Modeling Complex Interactions
Award Amount: $10,572,579
Years: 2015–2020
Relies On:
Preaward:

- Seed funding through Beacon Grant

Postaward:

- Sequencing and bioinformatics by the GRC
- Large memory servers and cluster computing by the CRC

M. Ytreberg EPSCOR TRACK II

Title: Using Biophysical Protein Models to Map Genetic Variation to Phenotypes
Award Amount: $6,000,000
Years: 2018–2021
Relies On:
Preaward:

- Seed funding from BEACON, Preliminary data from the CRC, Proposal development support

Postaward:

- Cluster computing by the CRC
- CRC - other

C. Marx DOE

Title: Using gene editing and an accumulated bioproduct as a reporter for genotypic to phenotypic heterogeneity in growth-vs-production for Methylobacterium extorquens conversion of lignin-derived aromatics to butanol
Award Amount: $1,362,274
Years: 2018–2021
Relies On:
Preaward:

- Methods development by the GRC

Postaward:

- Sequencing or other molecular work by the GRC

S. Nuismer DARPA

Title: Prediction of Spillover Potential and Interventional En Masse Animal Vaccination to Prevent Emerging Pathogen Threats in Current and Future Zones of US Military Operation
Award Amount: 9.37 million (1.5 million to UI)
Years: 2018–2021
Relies On:
Preaward:

- Seed funding (from BEACON, pilot grants, TAGS, etc): Seed funding from two Beacon awards to J. Bull
- Proposal development support: Graphic Design for *Executive Summary Slide*

Postaward:

- Bioinformatics by the GRC
- Cluster computing by the CRC

$40,204,577 in active awards* rely on IBEST investments and infrastructure

*This is not an exhaustive list

DISCOVERY

While the discovery phase of the research endeavor is very important, it is unusual to associate metrics with it. This phase is most closely associated with the production of data. Potential metrics for tracking data production include the amount of sequence produced by the GRC, the number of CPU cycles provided by the CRC, or the number of terabytes of data stored on CRC servers. The amount of data produced, however, is less important than the quality of data. We therefore choose to measure the results of scientific discovery upon their dissemination.

DISSEMINATION

Publications are arguably the most important metric of scientific dissemination. Unfortunately, reporting the number of publications from a fiscal year isn't particularly sensible. We therefore report the number of publications in each year since IBEST became an institute. We also provide a bibliography of the three most recent years of publications in Appendix 1.

To track the publications of faculty participating in IBEST, we have partnered with the University of Idaho Library. The UI Library houses the VIVO database, which monitors publication indices and aggregates citations and other useful metadata. Using the VIVO database has the long term advantage of not constantly interrogating faculty for their research products, which they often must upload into a wide variety of reporting software. We have begun curating a database of IBEST publications that draws periodically from VIVO. Each year faculty log in to their IBEST account and indicate with a check box which publications involve IBEST (so that IBEST does not over-report). If any publications are missing, we then work with the UI library to refine the VIVO algorithms and integration with the IBEST database.

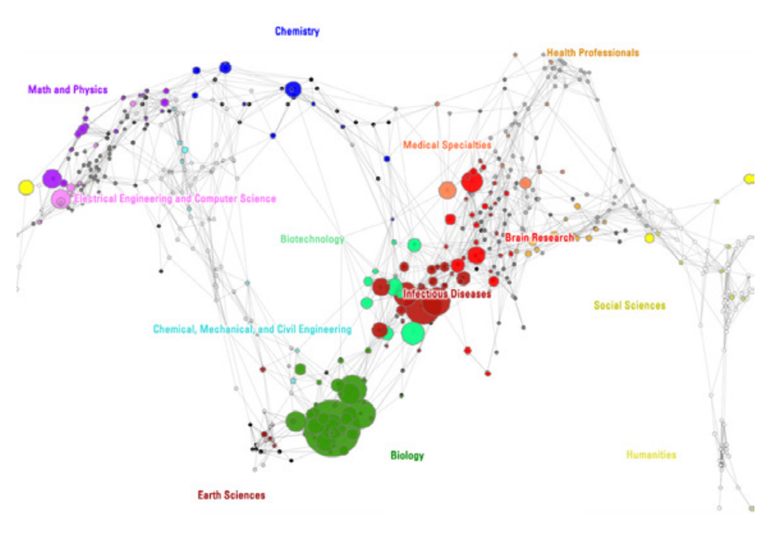
This approach only reports publications with a digital object identifier (doi). Thus, we may be missing some dissemination products that are not assigned dois.

Table of Publication Numbers

2011	87
2012	122
2013	103
2014	71
2015	114
2016	114
2017	113
2018	70

IBEST VIVO DISCIPLINE VISUALIZATION

This figure represents the mapping of IBEST publications since 2011. The colors represent the 13 major disciplines used by VIVO, while the size of the point represents the number of publications in that category.



Software Products

Many IBEST researchers are associated with computational disciplines. Thus, we have begun tracking software products. This year, IBEST researchers commercially released one piece of software – the evolutionary video game Darwin's Demons, and the GRC has released the bionformatic pipeline HTStream.

Conference Presentations

Faculty participating in IBEST report delivering 82 submitted conference presentations in FY18.

IMPACT

The most important component of the research process is also the most difficult to quantify. In fact, some research might not fully realize its impact until decades after it is first published (Mendel's work being a significant example).

- Citations: Working with the UI Library, we have used the web of science database to quantify the total number of citations of publications that faculty self-report as associated with IBEST. We include only works published since 2011, the year IBEST became an Institute. This obviously omits the many publications associated with the COBRE grants (Larry Forney, PI) that initiated IBEST. As of August 2018 IBEST publications had been cited 22,431 times.
- Invited Presentations: An indication that researchers are considered thought leaders in their disciplines is invitations to speak at conferences, department seminars, or deliver keynote or other prestigious addresses. IBEST faculty report delivering 87 such presentations in FY18.

TRAINING METRICS THAT SUPPORT THE UI STRATEGIC PLAN

Training of undergraduates, graduate students, and postdocs is an important component of research in a University setting. In fact, these activities are classified as "broader impacts" by the National Science Foundation. We therefore report the numbers of these trainees that are mentored by faculty participating in IBEST.

Terminal Degrees

The number of terminal degrees is a priority metric in the University of Idaho's strategic plan. While IBEST does not confer degrees, the Institute does make investments that support graduate students. The most significant of these investments is the funding of competitive fellowships to BCB graduate students. The following students received IBEST funded BCB fellowships:

2017-2018 BCB Fellowship Recipients:	**2018-2019 BCB Fellowship Recipients:**
Sarah Brooker (PhD, Mcguire)	Clinton Elg (PhD, Top)
Brenda Hanley (PhD, Dennis)	Sarah Hendricks (PhD, Hohenlohe)
Sarah Hendricks (PhD, Hohenlohe)	Kenetta Nunn (PhD, Forney)
Andrew Rankin (PhD, Sullivan)	Megan Ruffley (PhD, Sullivan/Tank)
Siavash Riazi (PhD, Marx/Remien)	Siavash Riazi (PhD, Marx/Remien)
Robert Week (PhD, Nuismer)	Robert Week (PhD, Nuismer)

In addition to the students directly supported with IBEST funds (above), faculty participating in IBEST report a total of 95 graduate students mentored in FY18. In terms of institutional calculations, these students will be reported by their graduate programs. This metric is intended to track the involvement of IBEST faculty in graduate education.

Undergraduate Researchers

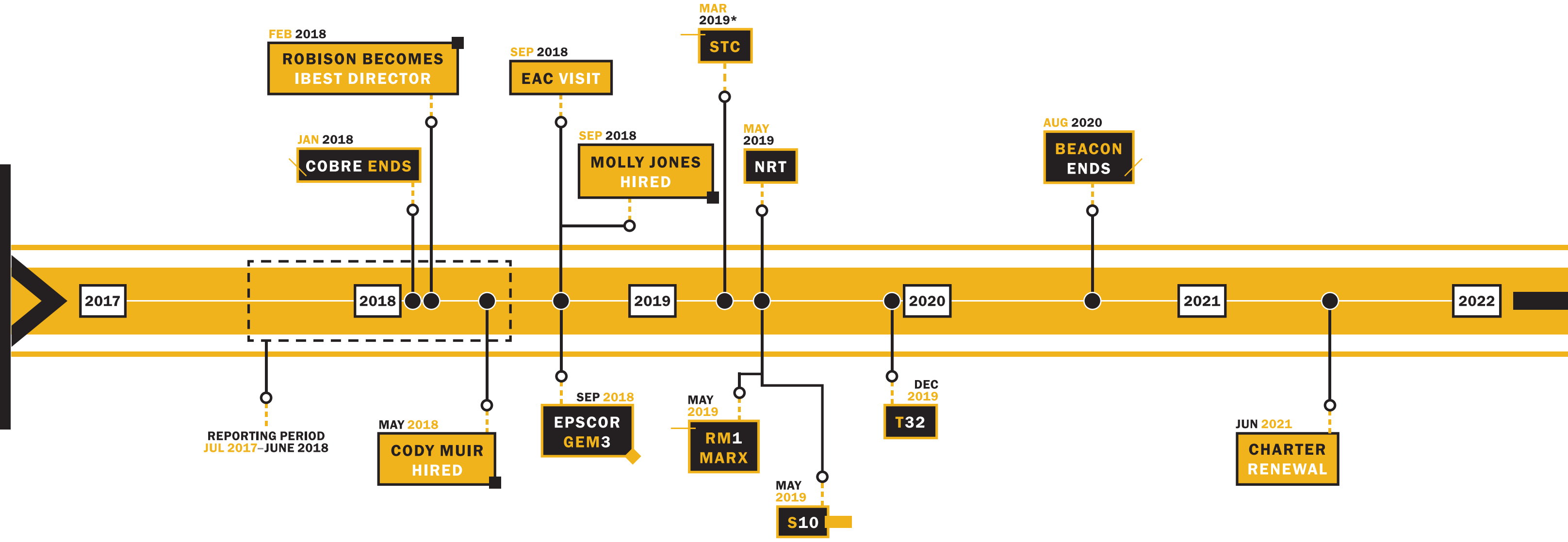
Undergraduates participating in research is an institutional metric in the *Innovate* section of the UI Strategic plan. Faculty participating in IBEST report mentoring 155 undergraduate student researchers in FY18. In terms of institutional calculations, these students will be reported by their academic departments. This metric is intended to track the involvement of IBEST faculty in undergraduate research.

Postdoctoral Scholars

IBEST faculty report mentoring 36 postdoctoral scholars in FY18. These postdocs are supported by a wide variety of extramural funds, most of which resides outside IBEST administration. This metric is intended to track the involvement of IBEST faculty in the mentoring of postdoctoral scholars.

PROSPECTUS

The following figure delineates the key strategic dates prior to submission of the next IBEST charter renewal. We include targeted programmatic grant proposal submissions for IBEST and our key partners, as well as sunset dates for existing major grant programs.



EPSCOR GEM3

(Genes, Environment, Modeling, Mechanism, and Mapping) is a large cooperative agreement between NSF and the State of Idaho. The objective of this $20M program is to identify the genetic, physiological, and ecological factors that determine adaptive capacity and ecological resilience in two keystone species in Idaho. GEM3 relies extensively on IBEST genomics, bioinformatics, and computational infrastructure. Several IBEST faculty (Hohenlohe, Waits, Robison, Wichman, Abatzaglou) are participating in the research objectives.

NSF STC Proposal

A team led by Drs. Harmon and Sullivan have been approved to submit a pre-proposal to the NSF Science and Technology Center program. They are currently awaiting the new program announcement. The theme of their pre-proposal is Ecological and Evolutionary Drivers of Human Welfare. We represent our estimate of the proposal deadline in the timeline.

NSF NRT Proposal

Dr. Harmon is leading a proposal to the NRT program. The proposal describes innovative changes to the Bioinformatics and Computational Biology graduate program.

NIH S10 Proposal

We are targeting a May 2019 deadline to the S10 program. We will request, funds to invest in long read genome sequencing technology.

NIH RM1

IBEST and CMCI are partnering to support an RM1 proposal by Dr. Marx. The two institutes will jointly support teaching release, proposal development, and infrastructure for this project.

NIH T32

We will resubmit an NIH training grant proposal that was originally crafted by Dr. Foster. We are working to strengthen the weaknesses in the proposal identified during the review process.

GOALS FOR FY19

Personnel:

1. Transition our ORED budget from an aggregated amount labeled "Miscellaneous Group" to defined Position Control Numbers. This will align our financial model with the other two Tier III institutes.
2. Hire a new Grant Services Manager, allowing Rose Reese to re-enter retirement. (New Hire starts 9/24/18)
3. Hire a bioinformatician (postdoc or staff) to support the Genomics Resources Core.
4. Hire a systems administrator to support the Computational Resources Core.
5. Explore a stronger strategic partnership with the Northwest Knowledge Network to support research computation infrastructure at the UI.

Performance Metrics:

1. Increase the number of new investigators submitting grants through IBEST from 3 to 5 by:
    a. Communicating the advantages of IBEST participation to new hires
    b. Communicating the advantages of IBEST participation to chairs and deans
2. Increase the number of new awards from 11 to 13 and the dollar value of new awards from \$6.2m to \$7.4m
    a. Strategically identifying new programmatic proposals (RM1, Track II, AISL, STC)
    b. Investing teaching release and other support into these large proposals
    c. Fully deploying the new proposal support capabilities of IBEST (including art and design, pre review, and document management) to existing and new PIs.

STRENGTHS, WEAKNESSES, OPPORTUNITIES, AND THREATS

Strengths:

- A highly productive group of core faculty with internationally recognized research programs.
- An inclusive, energetic, and collaborative culture.
- Strong synergy with the College of Science and the Center for Modelling Complex Interactions.
- A newly re-organized and revitalized staff.

Weaknesses:

- Most participating faculty are fully (or over) committed, which limits programmatic growth.
- The CRC Director has no backup staff, and represents a "single point of failure" for CRC users.
- Significant research grants that rely on IBEST infrastructure are not administered by IBEST undermining the IBEST F&A return model intended to pay for infrastructure.
- The service center model limits the potential of the GRC and CRC to help UI researchers reach their potential.

Opportunities:

- An emerging partnership with the Northwest Knowledge Network, that may result in a unified voice and strategy for institutional investment in research computing infrastructure.
- Strengthening relationships with the College of Agriculture and Life Sciences and the College of Natural Resources to meet their growing genomic, bioinformatics, and computational needs.
- A potential partnership with the Center for Health and Human Ecosystem.
- Developing Polymorphic Games studio as a resource for IBEST researchers.

Threats:

- Staff positions at IBEST are not sufficiently funded.
- Operations are being partially funded with reserves.
- Faculty are sometimes reluctant to submit grants through IBEST because of an erroneous perception that it will "count against them" during promotion and tenure.

COMPUTATIONAL RESOURCES CORE

MISSION AND VISION The mission of the CRC is to provide state of the art computing and data management services to our customers. Our vision is to remain technologically current in hardware, software and services while partnering with customers to help them perform and disseminate their research, in a fiscally sustainable way. Our guiding principles are to maximize the reliability, availability, and effectiveness of our services while minimizing administrative costs.

Infrastructure

The CRC contains an advanced mix of high performance computing clusters, powerful servers and reliable data storage components and is staffed by personnel with the knowledge and technical skills required to compress years of analysis into days. Our data center is a 1400 square foot facility in Room 124 in McClure Hall on the University of Idaho campus that has been specifically designed and renovated for our core. This room has a dedicated Uninterruptable Power Supply (UPS) with three-phase power and four-forced air handlers attached to redundant university chilled water systems. Optical fiber and copper interconnects provide high-speed data transfer for server and storage intercommunication and communication to the University backbone that is connected to the high-speed Internet 2 network. The features of our primary systems are described below.

High Performance Computing

CRC has one main compute cluster for research and genomic data analyses. We have continued to add computational capacity, the main cluster now provides 1592 processor cores (up from 1490 processor cores last year) and over 8 terabytes of system memory. Along with the new nodes, we have transitioned fully to new cluster scheduling software that is better able to allocate jobs to our now more heterogeneous cluster. We added four additional GPU nodes to make GPU accelerated computing accessible to all our users, enabling research involving machine learning. Cluster nodes are connected with 40Gb/s QDR Infiniband connections, providing fast, low latency data transmission for increased performance of HPC bioinformatics applications. We also replaced four ‘standalone’ servers, for a total of twelve servers (608 total cores and over 4.7 terabytes total system memory) for applications that require large amounts of memory on a single system but do not take advantage of the parallel cluster resources. Three of our most powerful servers in this group contain 256 times the system memory of a standard desktop (1TB or 1024GB) and are used primarily for sequence assembly of next-generation sequencing data.

Data Storage

The CRC has historically maintained two tiers of primary storage, and last year introduced a third distributed file system. The first tier is comprised of fast but more expensive disk arrays, which we have expanded from 130TB to 200TB. Testing over the past year has demonstrated the superiority of the third distributed file system. As such we are in the process of transitioning data from the old second tier (16 servers with over 600TB of hard drives) to the new third tier of storage – which now has 30 servers and nearly 2 PB of hard drives. This third tier provides greater performance, and has better self-balancing and healing properties. After the data is successfully moved, the old second tier of storage will be added to the third and we will be back to two tiers. Additionally, we have approximately 300TB disk available for data archiving and backup storage within the McClure data center. In 2016 and 2017 we set up a robust offsite backup system working with UI ITS to co-locate three IBEST data servers with 630TB combined capacity in the UI Library datacenter. In addition the core provides in-house developed solutions to maintain data integrity and restoration.

Support Systems

The CRC maintains its own support infrastructure because this scale of core operations falls well outside that of the University of Idaho Information Technology and Enterprise Computing services. Our support infrastructure includes several servers for data storage and authentication of user accounts, domain name resolution, Internet address assignment, and secure connections to our private networks. The core also provides web and database services for online documentation and data sharing.

Education and Training

To support educational programs and inter-institutional collaborations we maintain three teleconferencing enabled conference rooms and a state of the art technology classroom. The classroom is frequently used by instructors from the College of Science and the College of Natural Resources. The classroom also has teleconferencing system, which allows us to offer workshops and classes from and to collaborating institutions such as Michigan State University, University of Texas at Austin, University of Washington, and North Carolina Ag and Tech.

Power

Providing the energy demands of the CRC systems is a challenging task. The energy needs to be clean and uninterrupted for proper operation of the systems and supporting infrastructure. This challenge is met by our 3-phase 80KV power supply battery backup system. This system was purchased in 2008 and we replaced the batteries in the fourth quarter of 2015, and the capacitors in the first quarter of 2018.

New Infrastructure

To increase the capacity, throughput, and reliability within the CRC for our users, we have over the past year:

- Added 6 computational nodes 160 processor cores and 28,672 GPU cores to our main cluster.
- Replaced 4 standalone servers with support from an ORED infrastructure award.
- Continued to improve our in-house developed billing system.
- Increased the the capacity of our Lustre (1st tier) file system by 53%
- Completed the new Ceph distributed file system, which will provide over 2 petabytes of total disk and increased performance and fault tolerance, reducing down time.
- Added two new 100Gb Ethernet switches for the Ceph storage system.
- Added two new 10Gb Ethernet switches to data center network.
- Continued to improve the security of compute systems.
- Installed a new computation and network attached storage (NAS) server for a researcher in Geology.
- Replaced web hosting infrastructure with a Docker container based solution.

Planned infrastructure

- We intend to continue adding additional data storage capacity to accommodate increasing numbers of users and their increasing data requirements.
- Add new cluster nodes with additional co-processors and/or GPUs for increased computational efficiency.

Innovation

Continuing Innovation in Technology and Services

The primary function of the CRC is to facilitate the innovation of our customers. We have deployed existing technology in innovative ways, offer services that are not available from most other computational core facilities, and developed unique in-house solutions to address user needs.

Examples of our innovative use of existing technology include:

- We use configuration management systems (the modules environment) to provide customized software services, including versioning. Most cores provide only one version of software, which makes it difficult to replicate prior work or to test new user-developed software. This mechanism is uniform across over 120 systems, so the learning curve for users is very shallow. This mechanism also makes it possible for us to install and test new software without disrupting system availability.
- Some of our hardware, such as the very large memory servers, are not commonly available. These enable users to pursue specialized applications such as alignments of very large genomic datasets, intense agent-based simulations, and visualization rendering.
- Our existing data backup system was developed in house.
- Internal Software development – We employ several technologies and write a significant amount of code to maintain our complex infrastructure with a small staff.

Examples of our innovative services include:

- The tight integration of the CRC and GRC in terms of personnel, hardware, software, and administration is highly innovative relative to most other computational core facilities.
- We provide a high level of support for customized software installation, configuration, script development, and ad hoc user services.
- We offer a local, secure file-sharing system as an alternative to DropBox and similar cloud storage services.
- We offer our own web-based account management, poster printing, and online documentation systems. These systems were developed in-house, and offer streamlined interfaces to our services and documentation and are easier for CRC staff to maintain. Thorough documentation of our services allows novice users a consistent reference, and reduces CRC staff user support load.

Sustainability

To sustain the level of service required by investigators we must continually update hardware and software to remain an attractive option for researchers. There are two dimensions to sustainability in the CRC: maintaining our current services and updating services to remain on the cutting edge.

Maintaining Current Status

In June 2014, we implemented a fee for service model with a single user fee for access to all systems. A single standard user subscription currently costs $1500 per year, down from $2000. We have been able to control costs through the extensive use of automation, commodity hardware, university support, and a stable user base. We currently have 63 paid users (45 standard accounts, and 18 satellite accounts) across 20 UI departments, and 4 Condominium accounts.

The bulk of the CRC equipment was purchased using COBRE funds, and so pursuant to federal guidelines, user fees fund personnel costs associated with administering the CRC, not hardware. Over the past two years we have been a self-sustaining service center, and in fact had to reduce our rates to comply with carry-forward guidelines. We are now in a position to support our staff on user fees (40 standard accounts, and 30 satellite accounts) provided that: 1) the significant salary support from the Dept. of Biological Sciences for the CRC Director position continues, and 2) we continue to use undergraduate students to fill the role of systems administrators.

We introduced a new model last year to complement our existing fee for service model. This ‘Condominium’ model will allow researchers to purchase dedicated computational hardware, which the CRC will manage. This hardware will be incorporated into our main cluster, and unused compute cycles will be available for all CRC users. In this way, researchers are freed from the burden of system administration, and CRC users benefit from additional computational capacity. Along with the condominium model, we introduced a tier of free accounts for undergraduate and graduate students. These accounts have access to a limited set of the CRC’s computational resources, but with all the software available. The undergraduate accounts are not time limited, and are intended to help the University achieve its strategic goal of increased research productivity on the way to becoming an R1 institution. The graduate accounts are limited to 90 days, and are intended as an introduction to high performance computing, and to see what the CRC can offer without monetary commitment.

We have continued to increase our campus wide impact and overall number of paid accounts and now have users in 20 different UI Academic Departments (Figure 1). We continue to support external users from Reed College, and Washington State University, and a private company out of Wisconsin (Figure 2). We intend to continue to court external users, while keeping our core user-base on the University of Idaho campus.

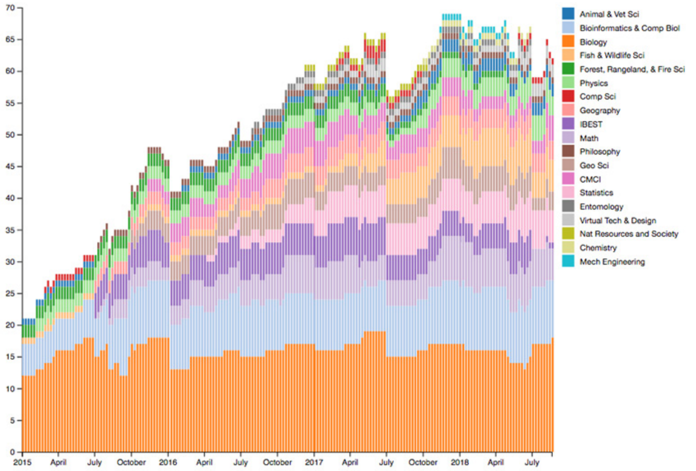


FIGURE 1: The number of University of Idaho users with active accounts for each week since 2015, *colored by department.*

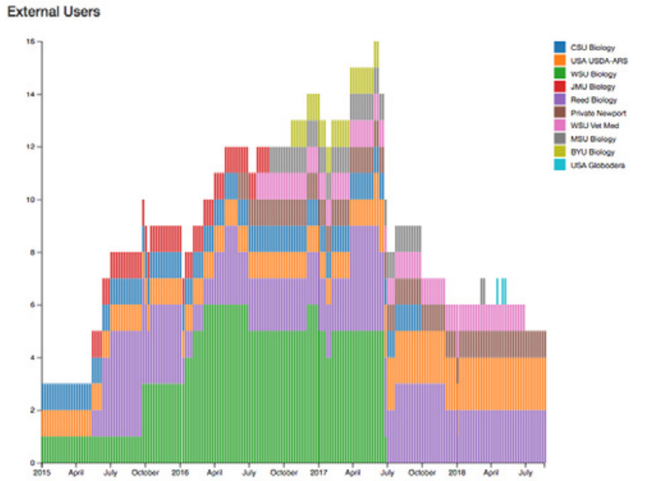


FIGURE 2: The number of external users with active accounts for each week since 2015, *colored by institution and department.*

Usage pattern trends and prospectus

In the fast-paced and intensely competitive research environment now common to higher education, our users tend to pick the shortest path to quick results rather than spend the time required to learn complex application programming interfaces. Thus, being able to simply log onto a powerful server and immediately run several threads of a bioinformatics application has historically proven more attractive for our users. Over the past year we have seen increased demand on the main cluster. To help CRC users overcome the intimidating knowledge barrier presented by job-scheduling software, we offer regular workshops where researchers can get one-on-one help converting their scripts and application calls to cluster enabled scripts.

This year we have continued to see increased demand for GPU enabled computational infrastructure to be used for machine learning and neural network simulation. We purchased a further four new cluster nodes with GPUs, in order to meet the need.

Keeping Current

Maintaining current hardware is a continuous challenge. Academic and corporate data centers assume a half-life of about two years for high-end equipment like ours. Thus, after approximately four years, the equipment is fully depreciated. Two of our most powerful systems were purchased 6 years ago (Nov 2012) and the bulk of our cluster nodes are now 10 years old (purchased Nov 2008). As the older cluster nodes fail, it has not been cost-effective to repair them, but to simply replace them with refurbished nodes. At this time, 8/64 of the original cluster nodes have failed and been replaced with more modern hardware. The purchase of over 40 new cluster nodes since 2015 has helped keep our current user base satisfied, but new demands for GPU enabled servers have exceeded our current capacity.

As the data storage needs of our users have grown even faster than their computational needs, we have focused our new equipment purchases on ever-larger data storage capacity (Figure 3). However, as we add additional users, we will now need to continue to update our computational infrastructure as well.

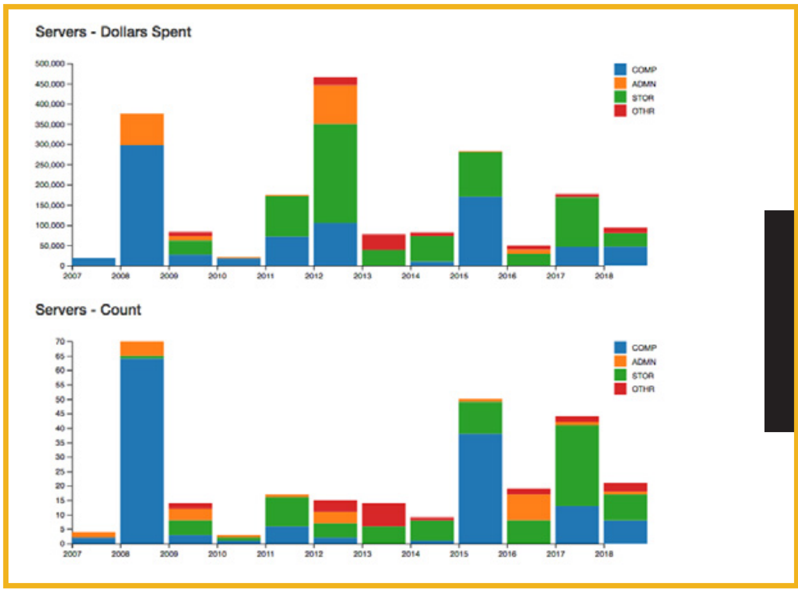


FIGURE 3: The number of servers and total amount spent each year, colored by their primary purpose.

Because our primary user data storage is a distributed file system composed of several individual servers that each store a part of the overall file system, a high-speed network is necessary to ensure adequate performance. As the amount of data stored and accessed by our users has increased, the standard networking technologies employed have struggled to deliver consistent performance. We therefore purchased higher speed network interfaces (Infiniband) to decrease latency and increase throughput by 4000% and installed that equipment in late 2015. Additionally, working with UI technology services, we updated our external facing switches from 1G to 10G so that our servers will be able to connect to the campus 10G network at full speed instead of the final link being only 1G. This increased bandwidth makes an offsite daily backup feasible, and we implemented such as system in 2016.

Plans

The sustainability of the CRC over the long term will require that we maintain self-generated revenue and retain institutional financial support. User fees alone cannot maintain centers such as the CRC given their high capitalization and maintenance costs. Therefore, institutional support will always be part of the core's revenue. Our goal is to support the bulk of salary expenses with self-generated revenue, and rely on future grant funding to continue to replace aging hardware.

In order to avoid costly maintenance contracts with hardware vendors, we rely heavily on commodity hardware with warranties included at the time of purchase. However, we keep hardware in service well beyond typical warranty periods (3-5 years), and so ongoing maintenance costs will likely increase.

Besides relying on commodity hardware, we also rely on open-source software almost exclusively. While this reduces overall operating costs, it places a greater burden on our staff in both time and education. Previously, due to non-competitive compensation levels at the UI, we found it impossible to attract systems administrators with previous experience in HPC and configuration management tools. Thus, we have historically settled for systems administrators with little experience - but high aptitude - and trained them up over the period of a couple years. However, these now experienced systems administrators have then promptly moved on to private industry or higher education institutions that can compensate them at market rates. Over the past year, the university has made progress towards compensating employees at market rates, and it may be time to search again for a permanent systems administrator. A complementary path is to focus on our undergraduate staff. The amount of training necessary to get a talented undergraduate to the level of competency required for systems administration in our environment is comparable to the amount required for an individual with a bachelor's degree. The undergraduate students get the benefit of hands-on systems administration experience, and the CRC benefits from a simplified hiring process and reduced salary expenditures.

Training up inexperienced system administrators requires a hardware environment tolerant of inevitable errors – which our production environment is not. We therefore built a unique 'classroom cluster' which has nearly all the complexities of our production cluster – but fits nicely in the IBEST classroom. This classroom cluster uses modern hardware similar to that used in our production environment, and provides an ideal environment for testing new technologies and software. Solutions developed for the classroom cluster can be translated directly to our production environment. We intend to offer undergraduate classes for credit on HPC administration using the classroom cluster. These classes will serve as a talent pool for future CRC staff.

Outreach

Do to staffing constraints, the CRC is less active with outreach than the other cores within IBEST. We provide workshops every Fall semester for CRC users and non-users. We hope to expand our educational reach with the undergraduate HPC administration class. The outreach activities described by the GRC are often facilitated by the tight integration between the Computation and Genomics Resources Cores.

Opportunities

There are many on campus resources, both current and potential, that could increase the CRC user base or simplify CRC operations.

- The COBRE Center for Modeling Complex Interactions includes a modeling collaboratorium and several potentially computationally intensive projects which has led to 20 user accounts, and computational nodes for the HPC cluster.
- We are now supporting other research units within the College of Science, including Geographical Sciences, and Geology Researchers. With the required software for these users now installed, we are in a better position to offer services to other faculty members. Additionally, with our free undergraduate accounts – we anticipate being able to impact even more departments on campus.
- Federal grants increasingly require data management plans to be submitted with any large grant. The CRC has the expertise to offer data management services for researchers, but would need to invest in additional hardware and formalize a service center category to offer this service.

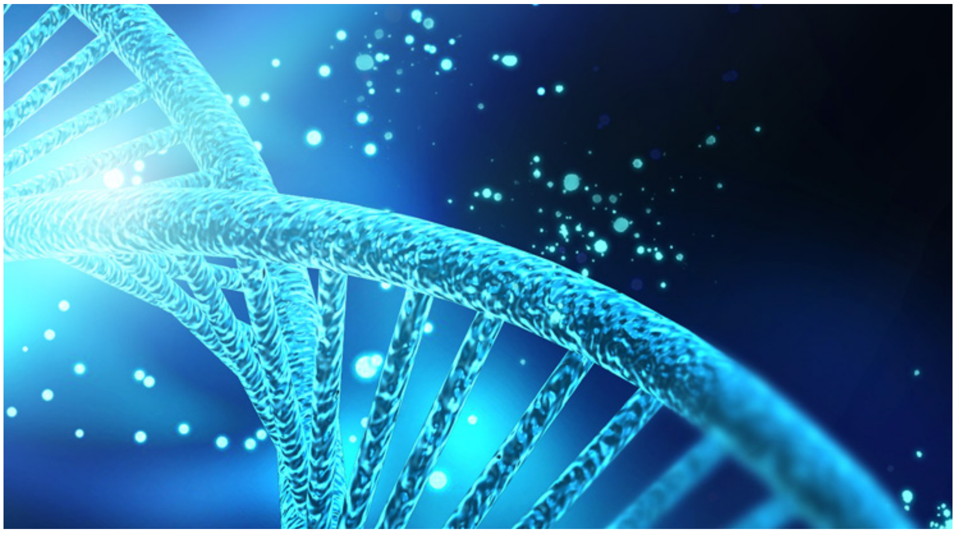
We are also considering other opportunities to take advantage of existing on-campus resources. For example:

- We have expanded the use of undergraduate assistants for tasks such as inventory, classroom and communications support, hardware installation, and systems monitoring. In the past, this has been a reliable pipeline for developing and training future CRC staff.
- Tap existing users to recruit new customers, for example at IBEST lunches or new faculty orientation.
- Include a university-funded CRC “gift certificate” as part of the startup package for new faculty.

We could also consider expanding our mission to support educational activities such as undergraduate research, courses, and workshops, or to support research from non-evolutionary scientists such as physicists and computer scientists.

GENOMICS RESOURCES CORE

MISSION AND VISION The mission of the IBEST Genomics Resources Core (GRC) is to provide researchers at the University of Idaho access to cutting edge genomics technology and the bioinformatics tools needed to acquire, analyze, and visualize data. The vision of the GRC is to stay current in genomics technology and bioinformatics, remaining agile with respect to new techniques and approaches, and to build partnerships with research groups and other regional core facilities.



Infrastructure and Personnel

The IBEST GRC is the only comprehensive facility on the University of Idaho campus that houses all the equipment and personnel necessary to aid researchers in every aspect of high-throughput genomics research. It provides the molecular expertise and equipment needed for most high-throughput sequencing studies, and develops partnerships with other service facilities when additional capacity or other specialized equipment are warranted. The real benefit of the IBEST Genomics Resources Core facility, however, has been the integration of bioinformatics data analysis with data generation. The GRC offers consultation on experimental design, appropriate and best use of technologies, and bioinformatics support to perform analysis, quality assurance, interpretation, and visualization. Through a unique strategy known as "the triangle of collaboration," an investigator, molecular scientist, and bioinformatician meet regularly as a team to discuss the goals and objectives for a project. This strategy helps improve the success rate of GRC projects, and reduces costs by generating informative data on the first attempt for a given experiment.

The GRC also maintains equipment that is accessible to faculty, staff and students of University of Idaho. This equipment, collectively called the "GRC User Core", is primarily designated for high throughput sample preparation and quality assurance. Users are trained by GRC laboratory staff before scheduling time to use the equipment, and are responsible for any reagents needed to run their samples. When needed, GRC staff are available to help troubleshoot.

Existing Infrastructure

The Genomics Resources Core Facility has the equipment necessary for applications of DNA sequencing technology, high throughput sample preparation, quality assurance, and bioinformatics analysis. The Core facility occupies two laboratory spaces in the IRIC building. IRIC 210 houses the controlled access component of the GRC which includes desk space for wet-lab staff and equipment required for preparing libraries and sequencing nucleic acid. The GRC Common User Core is located in IRIC room 142. The GRC has two offices, IRIC rooms 224 and 226 which house the bioinformatics scientists and are located a short distance from the wet-lab facilitating easy communication. The IRIC building is centrally located on the University of Idaho main campus in Moscow, Idaho. The Core facility infrastructure is described in more detail below.

GRC DNA Sequencing Laboratory

DNA sequencing has become an indispensable tool for basic biological research, biomedical research, diagnostics, and molecular systematics. Current applications using DNA sequencing include whole genome shotgun sequencing, for de novo sequencing of previously unknown genomes; transcriptome sequencing; targeted re-sequencing; transposable element enrichment; single nucleotide polymorphism (SNP) discovery; metagenomics and amplicon sequencing for studies on microbial community composition; and many other applications. The Core facility also has equipment and robotics for high throughput sample preparation associated with activities upstream of DNA sequencing, such as library preparation. This equipment enables researchers to streamline sample preparation, thereby reducing the costs of operating the core. Presently, the core has the following equipment in its DNA Sequencing Laboratory:

DNA Sequencing

- Illumina MiSeq Sequencing Platform: Paired-end sequencing of up to 600bp per library-fragment and 15Gb of DNA sequence per run.
- Illumina HiSeq Sequencing Service: Paired-end sequencing for projects requiring higher-than-MiSeq read-density; libraries prepared in the GRC, but outsourced to collaborating facilities (this process is transparent to clients at the University of Idaho because the GRC handles billing and data transfer).
- Oxford Nanopore Sequencing Platform: Due to the experimental nature of the Oxford Nanopore platform, the GRC does not yet offer this type of sequencing as a standard service. However the GRC has developed the expertise necessary to partner with collaborators interested in utilizing this technology on an experimental basis.

Library Qualification and Quantification

- Life Technologies StepOnePlus: Quantification of sequenceable libraries via qPCR.
- Advanced Analytical Technologies Fragment Analyzer: Capillary array based high-throughput quality assessment of all DNA and RNA samples.
- Agilent 2100 Bioanalyzer: Sizing, quantification, and quality control of DNA, RNA, proteins and cells in low-throughput fashion.

Library Preparation and Size Selection

- Fluidigm Juno: Creates sequencing libraries of up to 2400 amplicons per 192 sample chip for targeted-resequencing. Highly automated for minimal hands-on time and high throughput.
- Fluidigm Access Array: Creates sequencing libraries of up to 480 amplicons per 48 sample chip for targeted-resequencing.
- Wafergen Apollo 324: Automates next generation sequence library preparation workflows for Illumina, Ion Torrent, and 454.
- Sage Biosciences BluePippin: Automated and customizable PFGE-based size-selection of DNA fragments between 90bp and 50kb with no cross-contamination.
- Covaris M220: Highly reproducible DNA-shearing between 150bp and 5kb.
- Coastal Genomics Light Bench: Size seleciton and vizualization of DNA using gel cartridges.

Sample Quantification

- Molecular Devices Plate-Reader and Invitrogen Qubit 3.0: Fluorometric quantification of DNA and RNA (hundreds of samples or single samples depending on device) yielding more accurate and reliable concentrations than NanoDrop.

GRC User Core: High Throughput Sample Preparation and Quality Assurance

By acquiring new instruments in the GRC User Core for high-throughput sample preparation and quality assurance, the GRC provides researchers with the ability to increase sample quality while simultaneously reducing sample-to-sample variability and the time required for procedures. Equipment in the GRC User Core used for high sample throughput and quality assurance include:

DNA, RNA, and Library Qualification

- Qiagen QIAxcel: Providing “digital gels” for all DNA and RNA less than 3000 bp in high throughput fashion.
- Molecular Devices SpectraMax Paradigm: Multimode modular microplate reader currently capable of high-throughput quantification of DNA & RNA.

Sample -prep DNA & RNA purification

- Thermo Scientific KingFisher Flex: Automated high speed purification of nucleic acids, proteins, and cells in a 96well format using agnostic reagents and kits.
- Boreal Genomics Aurora: Gel based isolation, purification, and concentration of DNA from highly contaminated sources using Boreal’s proprietary SCODA electrophoresis.
- Diagenode Bioruptor Plus (UCD-300): High-volume sonication/

shearing of DNA, chromatin, cells, and tissue.

- BioRad T100: Basic touch-screen thermal-cycler for labs lacking this capability.
- Qubit 2.0 Fluorometer: Fluorometric quantification of DNA and RNA single samples yielding more accurate and reliable concentrations than NanoDrop.

GRC staff continuously monitor current technological methods and trends for potential new equipment that will contribute to the mission of the GRC, both in the DNA sequencing laboratory and the GRC User Core. Each piece of equipment is evaluated for its ability to increase potential service offerings, improve the quality or reduce the price of existing services, increase automation and throughput, and/or augment the existing equipment in the GRC User Core.

Personnel

The IBEST Genomics Resources Core facility operates as a "turnkey" facility in which project design, sample preparation, data generation, and data analysis are integrated within a single facility. Therefore, the GRC has two main components: the "wet" lab and the "dry" lab, with the GRC Director overseeing both laboratories. The "wet" laboratory is staffed by professionals with molecular biology expertise and is where data are generated from samples provided by investigators. The "dry" laboratory is staffed by bioinformatics data scientists and is where data generated in the "wet" lab (and in other facilities) are analyzed, summarized and interpreted. A significant amount of communication and coordination occurs between the "wet" and "dry" laboratories.

The GRC stays nimble by continuing to develop new partnerships with other service facilities and by purchasing equipment to automate molecular methods, allowing a small staff to perform the same quantity and quality of work as a core facility with a larger staff that lacks as many automated workflows.

Genomics Resources Core Director

The current GRC Core Director, Dr. Samuel Hunter, joined the core in January 2016. Dr. Hunter earned a Ph.D. in Bioinformatics and MS in Statistics from the University of Idaho after earning a B.S. degree with a double major in Biology and Computer Science from the College of Idaho. Dr. Hunter worked for the GRC as a Bioinformatics Data Scientist from 2011 to 2014 focusing on Microarray data analysis and high throughput sequencing analysis, especially genome assembly, variant calling, and methods development. In 2014 Dr. Hunter left the GRC to work as a Computational Biologist at Dana-Farber Cancer Institute in Boston, Massachusetts. While there he focused on methods development for clinical cancer sequencing, creating a software tool for CNV detection which was integrated into the Dana-Farber/Brigham and Women's Hospital personalized cancer sequencing pipeline to aid in clinical diagnosis. His current duties with the GRC include management of day to day operations, existing projects and client relations, outreach, identification of new opportunities, technologies, and clients, retaining and recruiting staff, data analysis, and advising students.

Bioinformatics Data Scientist

This position is responsible for bioinformatics and analysis of genomics data, and is currently vacant. It was previously occupied by Dr. Alida Gerritsen who served through June 2017.

Genomics Laboratory Manager

Mr. Daniel New is responsible for the day-to-day operation of the GRC "wet" laboratories which includes the DNA Sequencing Laboratory and GRC User Core. Dan earned a B.S. degree in Microbiology and Molecular-Biology/Biochemistry from the University of Idaho in 2005 while concurrently working as an undergraduate researcher to learn basic molecular techniques from 2003-2005. Prior to joining the Core in 2010, Mr. New was a Research Associate at Washington State University in the College of Veterinary Medicine where he gained experience in RNA extraction, relative-qPCR, mammalian cell-culture and transfection, microarray printing/processing, Sanger sequencing/instrumentation, PFGE, MLVA, and Kirby-Bauer assays. Starting in early 2016, Mr. New has worked closely with Dr. Gerritsen to learn basic bioinformatics skills necessary for routine data delivery.

Genomics Laboratory Scientist

In May 2016 the GRC hired Matthew Fagnan as a temporary employee. Mr. Fagnan completed a B.S. in Bioengineering at WSU in May 2016 and spent the summer working closely with Mr. New and Dr. Gerritsen to gain the necessary skills for working in a high-throughput sequencing laboratory. These skills include training and familiarity with Qubit, TBS-380, Fluidigm 48.48 Access Array, Fluidigm Juno, Fragment Analyzer, APCR, Wafergen Apollo, Ampur Bead cleaning, Linux, as well as experience with customer service and research and development. Following this successful evaluation/training period, the GRC hired Mr. Fagnan as a permanent employee to fill the Genomics Laboratory Scientist position. As part of an ongoing GRC objective to address recruitment and retention difficulties, as well as to improve redundancy and stability, Mr. Fagnan will continue to work with Mr. New and Dr. Hunter to develop more advanced wet lab and bioinformatic skills. Additionally, Mr. Fagnan has chosen to pursue an MS in Statistics (with a focus on biostatistics) at the UofI while continuing to work in the GRC.

Interns

During the summer of 2017, the GRC experimented with hosting undergraduate interns. The interns Neale Ellyson and James Styer worked with GRC staff to learn molecular techniques and gain experience working in a sequencing core. James continued working with the GRC during the Fall 2017 semester to fulfill lab-rotation requirements for his degree.

Bioinformatics Post-Doc

During the summer of 2017, the GRC worked with Dr. Haiqing Sheng in the College of Agricultural and Life Sciences to hire a temporary employee to complete a bacterial genome assembly and annotation project. The GRC identified a candidate (Dr. Mingrui Duan) for this position, and she was hired with funding from Dr. Sheng. The GRC provided desk space, access to computational resources, and training for Dr. Duan during this project. Following completion of the genome assembly project, Dr. Duan was hired as a postdoc through a collaboration between IBEST and Dr. Brenda Murdoch in the College of Agricultural and Life Sciences. Dr. Duan has worked with GRC staff and Dr. Murdoch's team to develop an ovine genotyping platform with research and agricultural applications for marker assisted selection and parentage analysis. Dr. Duan has an MS in Biochemical Engineering and a Ph.D. in Molecular Biology.

Bioinformatics Analysis Resources

The GRC does not maintain any specialized equipment for data management or bioinformatics analysis; instead, it maintains a strong partnership with the University of Idaho IBEST Computational Resources Core facility. This tight integration between the GRC and CRC has numerous advantages. First, the CRC provides the storage and computational power necessary for the analysis of the large-scale genomic data sets that are produced by the GRC. Second, the collaboration between the cores provides a great deal of agility with regard to the development of new bioinformatics techniques and analyses. This fosters innovation and creative activity that are the hallmark of IBEST, and differentiates the GRC from other more "traditional" genomics core facilities around the US and the world.

Services and Innovation

The Genomics Resources Core offers "genomics project management" to customers by integrating services in all three phases of genomics research: project planning and consultation, genomic data generation, and bioinformatics data analysis. In contrast, most core facilities around the country focus mainly on data generation, leaving investigators to struggle with immense data sets with little help. Our integrated approach is very unusual, and a key component to our continued success. This has led to a large amount of off-campus clients (both U.S. and International) through "word-of-mouth advertising" which is balanced with our on-campus workload (see Figure 1). To track and manage the growing GRC user base, the Core iLab project management and billing system in late FY2014. Over the past three years, the Core has been able to use iLab to accurately track usage data from internal and external users and effectively bill for bioinformatics time.

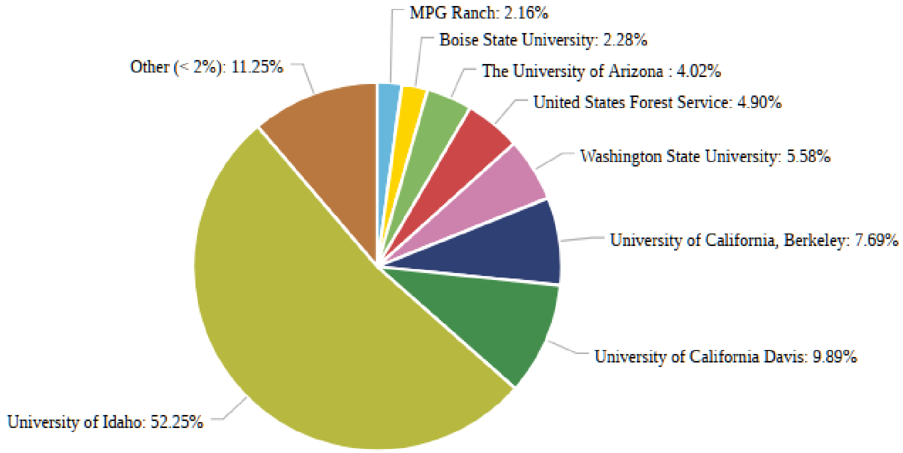


FIGURE 1: The top 10 institutions (by total revenue) in billed work from the GRC during FY18

Project Consultation

Core facility staff consult with investigators to discuss project aims, expectations, experimental design, appropriate and best use of technology, sample quantity and quality issues, and data analysis needs. During consultation, a project time line is formed, expected costs are discussed, deliverables are identified, and a user agreement is reviewed. Having these discussions early in a project provides an opportunity for Core personnel to offer their expertise, advice, and assistance to enhance the proposed project and sidestep potential problems. Initial consultation is a service that the GRC currently provides free of charge.

This service is especially important to researchers developing grant proposals, where a detailed quote and sophisticated understanding of the protocols and analysis are likely to increase chances for funding and ensure accurate budgeting. In 2017, the GRC has provided letters of support and/or consultation for several researchers seeking funding including Dr. Onesmo Balemba (UofI), Dr. Diana Mitchell (UofI), Dr. Ryan Driskell (WSU), Dr. Sanford Eigenbrode (UofI), Dr. Eva Top (UofI), Dr. Daolin Fu (UofI), Dr. Jianli Chen (UofI), Dr. Jeff Langman (UofI), Dr. Shirley Luckhart (UofI), and Dr. Paul Rowley (UofI) among others. At the end of this section, we describe several projects that exemplify this type of collaboration. This approach helps keep overall costs low, expectations realistic, and potentially costly problems minimal in the latter stages of a project.

Genomics Data Generation

The Genomics Resource Core facility operates and maintains equipment (described above) that allows high throughput sample preparation, quality assurance, and generation of high throughput DNA/RNA sequence data. While the Genomics Resources Core operates much of the equipment necessary to perform the work proposed by its clients, there are instances when projects require technologies that are not present in the facility. In these cases, the GRC facilitates access to the technology through cooperation and collaboration with other regional core facilities. For example, when investigators require the additional capacity provided by the Illumina HiSeq platform, the GRC staff prepares Illumina libraries that are sent to other institutions for sequencing (such as University of California Berkeley or the University of Oregon), and the data are then sent back to the GRC for processing and analysis. The GRC has also developed a relationship with the University of Washington PacBio sequencing core in expectation of the need for long-read sequencing in the future. The fact that the sequencing was done “off-site” is seamless and causes no additional work for the investigator. This expands the range of services the GRC can offer without incurring additional capital expense. A time series of expenditures by type is shown in Figure 2 and and top ten services by total cost in Figure 3.

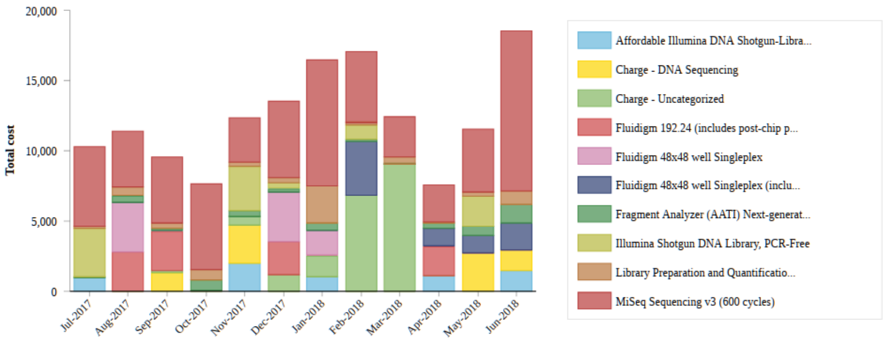


FIGURE 2: Time series of expenditures by type of service, FY18

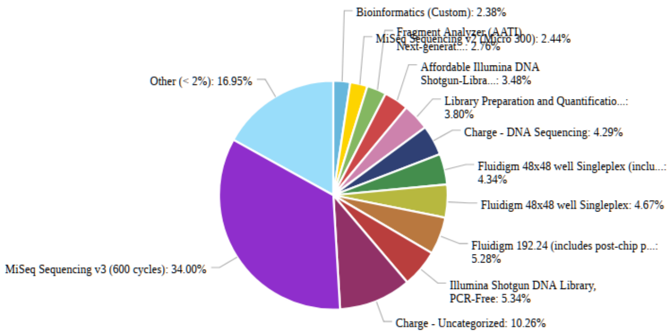


FIGURE 3: Summary of top ten types of service by cost, FY18

Bioinformatics and Data Analysis

The GRC continues to increase its user base for genomic data generation and as a result has increased charges associated with bioinformatics analysis. Bioinformatics data analysis is often the most challenging aspect of any experiment, and until very recently was often overlooked in budgeting for experiments. The current system accurately tracks personnel hours on independent projects and reflects the effort that is expended for analysis.

The GRC offers bioinformatics services through staff bioinformaticians and can perform a full range of analysis tasks to address questions in areas such as population genetics, genomics, microbial community dynamics, functional genomics and systems biology. GRC bioinformaticians begin with raw output from genomics equipment and proceed through quality assurance, data processing and analysis, data interpretation and visualization. Analyses are conducted using pipelines in the public domain or those developed by Core staff members. Core personnel have developed analytical techniques and pipelines for microbial community analysis, genome assembly, transcriptome assembly, population variant analysis, SNP/INDEL detection, and RNAseq analysis. These pipelines transform and manipulate raw data into a form and format that can be mined by investigators. Data processing occurs through a feedback loop with investigators. The GRC bioinformaticians seek feedback from investigators after preliminary data analysis, so that adjustments in output content, form, and format can be made. Data are then re-analyzed or additional analyses are performed until the project's goals are met, figures are generated, and summary tables are provided to the investigators in a form that is useful to them. The Core staff provides investigators with detailed knowledge of the laboratory protocols and bioinformatics methods used so they can be included in reports and publications as needed. As a result, core staff members are often included as co-authors on publications because of their significant intellectual contributions to research projects.

Innovative New Methods

GRC staff has participated in the design and development of new methods and techniques for genomics research. Example projects are briefly described below.

Assembly by Reduced Complexity (ARC)

As a part of his PhD dissertation, Dr. Samuel Hunter developed Assembly by Reduced Complexity (ARC), a software package for targeted assembly of homologous sequences. The algorithm works by comparing reads to a set of reference targets and bins them based on the results of these comparisons. Assemblies are then performed on sequences from each bin. ARC works effectively with divergent references, functions well with short sequence reads, and compares favorably to de novo assembly in terms of CPU and memory requirements.

A Modular, Highly Multiplexed Design for Illumina Amplicon Sequencing

Dr. Matthew Settles, in collaboration with Mr. New and Dr. Gerritsen, developed a laboratory protocol and data analysis platform for performing highly multiplexed Illumina amplicon sequencing. PCR amplicon sequencing is an important tool used to query genetic variation and structure in individual samples and ecological communities. Applications range from determining the composition and structure of bacterial and fungal communities to determining allele frequencies in a set of genes across many individuals. This methodology provides a way to simultaneously sequence and analyze hundreds of samples across one or many targeted regions in the same sequencing reaction while significantly reducing experimental costs.

The analysis platform is a comprehensive application that starts with raw sequence reads and ends with abundance tables of taxonomically assigned sequences for community analysis. Additionally, the application is able to prepare reads for input into phylogenetic tree building software. The software project is ongoing, relying on user comments and feedback to continue improving the functionality and efficiency of the program.

HTStream

HTStream is a toolset for preprocessing Illumina data to remove various forms of noise common in this type of data. It consists of a set of algorithms implemented in C++ as standalone programs which can be easily chained together to form custom pipelines, tailored for specific project needs. HTStream was developed by David Streett as part of his master's thesis while he worked for the GRC.

Sustainability

Service center fees are established based on the estimated costs of consumables, instrument maintenance agreements and personnel time associated with each service and updated on a semi-annual basis. Clients who request custom bioinformatic analyses or new method development are provided a cost estimate based on the amount of time expected to complete the proposed work.

During FY 2013-2014 there was a significant shift in the types of services the GRC offered. Specifically, the GRC phased out equipment for DNA microarrays (purchased 2011), DNA genotyping (purchased 2011), and Roche 454 Pyrosequencing (purchased 2009). Each of these technologies was displaced by new, less expensive technology (such as the Illumina MiSeq). These upgrades produced a 'more data for lower cost' effect, which resulted in a decrease in GRC annual revenue from $369,314 in FY2013 to $203,198 in FY2014. A slight increase in demand for services was reflected by a total revenue of $219,688 in FY2015, however the GRC was severely understaffed during much of this fiscal year, limiting the amount of time that could be spent on outreach developing new opportunities. Ongoing R&D efforts and new acquisitions continue to be targeted at decreasing reagent costs and improving efficiency to offer updated services while maintaining competitive pricing for existing and new clients. Outreach efforts and a renewed focus on identifying new opportunities for collaboration are expected to result in further improvements towards sustainability.

Additionally, GRC staff have continued to focus on supporting the generation of preliminary data, and grant writing efforts by UofI Faculty. Successfully funded grants provide future work and revenue for the GRC, as well as overhead return increasing the sustainability of IBEST and ensuring continued support from IBEST staff.

Plans

IBEST successfully completed a search for a new GRC Director in late 2015. The new director has continued to transition the Core towards a business model focused on long term sustainability. Included in this transition is continued investment in key strengths such as multi-locus targeted amplicon sequencing. Based on extensive research online, discussions with Fluidigm, clients, and other core directors, this service is offered for non-model organisms by only one other sequencing center in the country. Limited availability, in combination with presentations at conferences and publications by early adopters has led to increased demand for this service. This increased demand will be met by the acquisition of the Fluidigm Juno platform which will significantly reduce reagent cost per sample and hands-on time by quadrupling throughput as compared to our existing Access Array system (a close collaboration with Fluidigm research scientists has enabled us to maintain backwards compatibility with assays run on the Access Array improving redundancy of key service).

Another key strength of the GRC, metagenomic community analysis using 16s and other targets, has also been an area of continued focus. As well as continuing to invest heavily in training clients to prepare libraries using our custom set of dual barcode indexes, we have launched an initiative to improve reproducibility and consistency across runs by developing a set of positive controls consisting of an internal (standardized library) and external (mock community) control which will be sequenced at low depth on each amplicon run. These controls will allow us to monitor for run-to-run variations within the GRC, as well as simplify trouble shooting library prep for new clients as well as variation between library preps for existing clients.

The GRC has continued to look for new ways to expand the applications of this targeted amplicon strategy by identifying researchers at WSU and the UofI who can employ this strategy to characterize mutations generated by the exciting new CRISPR/Cas9 gene editing technology. Collaborations with Drs. Jim Nagler (UofI), Deb Stenkamp (UofI), and Michael Varnum (WSU) were successful in all cases, producing data that was included on a poster and in two manuscripts.

Additional research and development objectives aimed at increased sustainability include adopting new protocols for decreasing costs and increasing efficiency of shotgun and RNAseq library preparation, both of which are currently in progress. Finally, increasing the user base continues to be a major objective. Efforts on campus have included consulting, sequencing, analysis and grant writing support for members of the College of Agriculture and Life Sciences as well as members of the College of Natural Resources. Fostering collaborations with off campus researchers has included collaborations with faculty at UofI extension offices and USDA facilities in Idaho, as well as with researchers in neighboring states. Although "word of mouth" advertising continues to bring us many new clients, our collaboration with the Idaho Wheat Commission has also increased our visibility, opening many opportunities to work with a variety of agricultural researchers across the Northwest.

A second component of sustainability is recruitment, retention, and minimizing the damage caused by losing a staff member. The increasing popularity of next generation sequencing methods has led to high demand for experienced staff. This represents a serious concern for the GRC which has a small staff and has traditionally had little redundancy in skills and significant risk associated with losing a staff member. A major objective of the new Director has been to address these problems through a combination of strategies.

The GRC currently (and historically) has been staffed entirely by members who gained a large portion of their training in High Throughput Sequencing techniques within the GRC. Although recruiting highly skilled staff members is always a possibility, the rapid growth and popularity of High Throughput Sequencing has created consistent demand for experts in this area. Rather than relying on recruitment of such skilled staff, the GRC will continue the strategy of developing capacity by hiring entry level positions, investing in professional development and training, and promoting when appropriate. As mentioned earlier, this model was used for the current Director and Genomics Laboratory Manager as well as the new Genomics Laboratory Scientist (who was hired as a summer intern with no previous HTS or genomics experience).

To reduce the threat posed by loss of a staff member, redundancy in job roles has been improved by training wet-lab staff in basic bioinformatic and data delivery procedures, ensuring that a subset of services would continue to be available even in the absence of bioinformatic staff. Redundancy in wet-lab procedures has been improved by hiring a Genomics Laboratory Scientist who has been trained in nearly all critical wet-lab procedures. Redundancy in administrative tasks is ensured by continued involvement of Mr. New and Mr. Fagnan in developing new business, billing, and other administrative decisions where appropriate.

Concerns about retention have been partially addressed by somewhat reducing workload and stress through hiring additional core staff and by working with IBEST and University administration to provide above baseline salary increases for existing staff members. A recent Market Based Compensation initiative within the University has also led to significant salary increases for some GRC staff members, helping to address salary levels which were significantly below market levels. Unfortunately these changes did not go into effect until after the GRC lost one staff member to a better paying position.

Outreach

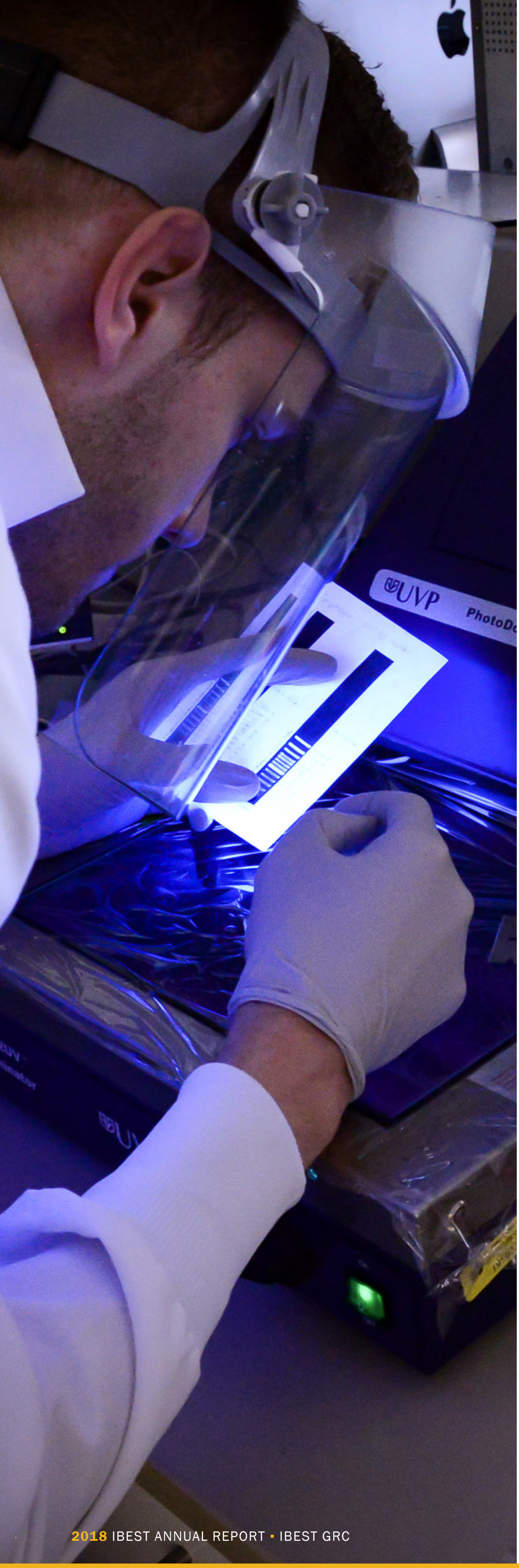
The Genomics Resources Core engages in several outreach activities across the University of Idaho campus, the state of Idaho, across the nation. Examples of outreach activities include:

Professional associations

Genomics technology partnerships and consultation with service centers and researchers at the University of Oregon, University of California-Berkeley, University of California-Irvine, University of Montana, Washington State University, and the University of Washington.

Conferences

Travel to technological and administrative conferences developed for service centers and core facilities, including the Association of Biomolecular Resource Facilities and the Western Association of Core Directors. Novel approaches to analysis, budgeting, customer service, sustainability, and technological innovations are all topics that are encountered at these conferences.



Challenges

Maintaining a balance between accessibility and financial sustainability continues to be the biggest challenge for the GRC. The GRC operates under a unique structure that integrates all three phases of genomics project management - combining data generation and bioinformatics like few other facilities in the United States. This is both its greatest strength and its greatest ongoing challenge. Because the GRC is so unique, there are few (if any) other facilities that can serve as a model for growth and sustainability. In addition, the scope of research facilitated by the GRC is complex and highly varied, working with a wide variety of data types, non-model organisms, and a range of experimental protocols. This challenges staff to develop expertise pertinent to a wide range of technologies and methodologies, and can limit the ability to develop high volume standardized work flows. Despite these challenges, the integrated approach remains the GRC's signature characteristic and is a key component to continued success.

Another challenge for the GRC that is related to financial sustainability is the lack of recognition the GRC receives for molecular and bioinformatics work. Many clients assume that because GRC services are paid, the GRC staff should not receive recognition as part of the publication process. However, because of the investment of time through multiple, (typically free) consultations with researchers, the GRC staff has a significant intellectual impact on many of the projects submitted to the core. These intellectual contributions often result in completely redesigned projects which take better advantage of modern technologies and more effectively address the research question. These impacts should be attributed and will help favorably increase the core's reputation amongst the scientific community, and will also justify the continuing University investment into this shared resource. The GRC has taken steps towards addressing this problem by requesting that new and existing clients review and sign a document acknowledging these contributions, and reminding clients of the necessity of citing the COBRE grant which has supported development of the core facility. These reminders are included every time the GRC delivers data to a client.

Perhaps the most significant threat to the Genomics Resources Core continues to be its ability to hire new staff and retain them. Classification and pay scales at the UI have undergone significant revisions, largely addressing the difficulties in offering competitive salaries. However, the bioinformatics field continues to grow, creating many opportunities for qualified staff and maintaining high demand in the job market.

Future Directions

The IBEST Genomics Resources Core will continue to offer state-of-art services in genomics and bioinformatics that will enable University of Idaho investigators to overcome the “barriers to entry” posed by their own lack of expertise in these fields. Collaborating with the GRC will allow them to pursue new avenues of research that leverage the resources available within IBEST. The goal is to continue to provide integrated services to IBEST researchers – facilitating cutting edge research in genomics and real time evolution.

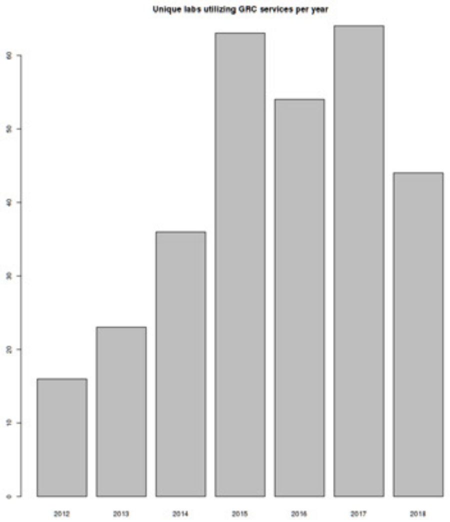
The GRC constantly evaluates the portfolio of offered services, a critical activity because the field of genomics changes quickly. New technologies emerge every year, and the capacity for data generation is outpacing the capacity to store, analyze, and interpret these data. Staying on top of emerging technologies and trends enables the GRC to continually identify novel business and collaborative opportunities while focusing on key existing services ensures financial stability, at least in the short term. Balancing these two competing interests will ensure that the GRC is sustainable, and adaptable as old technologies are replaced by new ones. The GRC’s most important offering is in identifying and developing solutions to facilitate scientific discovery, particularly in areas where less integrated or more entrenched cores may be unwilling to innovate. To this end, the intellectual capital, expertise, and adaptability represented in the GRC are its biggest asset. So, while purchasing new equipment may be necessary to stay current or increase capacity, continued investment in personnel is the best way to ensure long-term viability of the core.

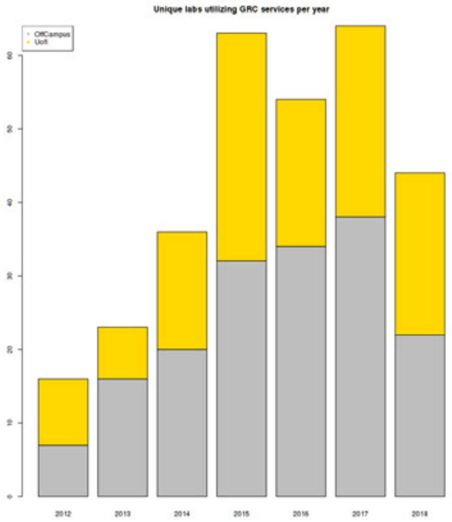
Unique Labs Utilizing GRC

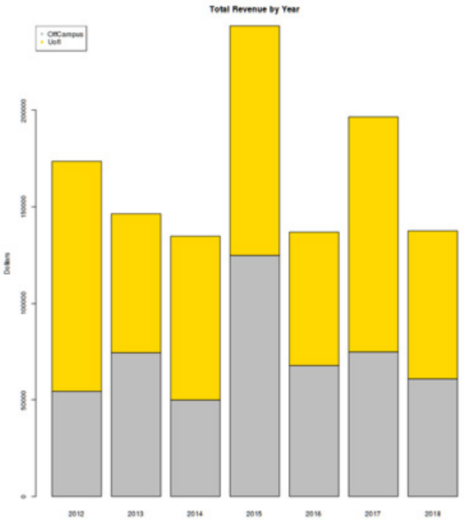
	Off Campus	U of I
2012	7	9
2013	16	7
2014	20	16
2015	32	31
2016	34	20
2017	38	26
2018	22	22

Revenue by Year

	Off Campus	U of I
2012	$54,415	$119,224
2013	$74,457	$71,861
2014	$49,879	$84,974
2015	$124,712	$118,979
2016	$67,693	$69,282
2017	$74,862	$121,532
2018	$61,004	$76,658







Case Studies

While a large fraction of the GRC's contribution to the research effort at the UofI can be reflected in revenue generated and the number of invoiced services, this does not fully capture the expertise and support that GRC staff provide. Much of this service is provided in the form of email or phone support, and in conversations with collaborators who drop by the lab or office.

1) Potato and Grape Viral Sequencing

Jennifer Dahan and Alexander Karasev
College of Agricultural and Life Sciences: Entomology, Plant Pathology and Nematology

When various established protocols for identifying viruses in potatoes and grape vines proved ineffective, Jennifer and Alexander approached the GRC about trying to sequence some samples in order to determine what might be causing an infected phenotype in their samples. The GRC assisted with sequencing and developed a custom bioinformatic pipeline to assemble viral sequences, allowing the researchers to identify viruses present in the samples. These results and additional results from a second project are in preparation for publication. In addition to completing the project, GRC staff provided detailed step by step instruction on analysis, scripts for the analysis pipeline, and training so that Jennifer could carry out a similar analysis in the future.

2) Squirrel Fecal Amplicon Sequencing

Kim Andrews, Dave Tank (Biological Sciences), Lisette Waits (CNR)

GRC staff provided extensive support for trouble shooting development of a method for sequencing amplified markers from squirrel fecal material.

3) Long read Bacterial Genomic Sequencing

Eva Top (Biological Sciences), Haiqing Sheng (School of Food Science), Larry Forney (Biological Sciences)

The field of Next Generation Sequencing continues to evolve rapidly. Currently long-read sequencing technology is revolutionizing genome assembly and other sequencing strategies. The GRC has partnered with various collaborators on campus to keep up with this emerging technology, and ensure that UofI researchers do not fall behind. In this project samples were provided by three collaborators: 1) Eva Top provided a pool of plasmids carrying antibiotic resistance genes, 2) Haiqing Sheng provided DNA samples from shiga toxin producing (*Escherichia coli*), 3) Larry Forney provided metagenomic samples collected from healthy, and cancerous tissue. In order to test the Oxford Nanopore MinION sequencer, and our ability to multiplex samples on this sequencer, the GRC produced long-read libraries for all samples, barcoded them, sequenced them on the MinION, analyzed the resulting data, and delivered the data to each collaborator. In all three cases, the data was informative. The long reads enabled resolution of genome assemblies for Haiqing, and plasmid assemblies for Eva Top. The data from Larry Forney's samples produced a number of interesting assembled contigs, including an apparently closed bacterial genome for Lactobacillus crispatus.

4) Bighorn Sheep Mitochondrial Sequencing

Brenda Murdoch and Kim Davenport (Department of Animal and Veterinary Science)

Brenda wanted to genotype a number of samples collected from sheep horns to determine whether the horns had been collected from domestic sheep or illegally poached wild bighorn sheep. GRC staff helped in developing an amplicon panel to genotype these animals, and also suggested preparing a low-depth shotgun library from the wild bighorn sample. Reads from this library were assembled into a complete mitochondrial genome sequence, which was submitted

to NCBI (MH094035.1) and represents the second published mitochondrial sequence for this species, and first for an animal from the United States.

5) Rapid congenics for mice

Shirley Luckhart (Entomology, Plant Pathology, Nematology, and Biological Sciences)

The GRC is working closely with Shirley to develop a strategy for genotyping mice in a high resolution and cost effective manner. In collaboration with the Lab Animal Research Facility, this collaboration with enable "speed congenics" on the UofI campus, making it unnecessary to use a similar service provided by The Jackson Laboratory at a much higher price (https://www.jax.org/jax-mice-and-services/breeding-and-rederivation-services/speed-congenic#).

6) Targeted capture for Dwarf Bunt resistance

Jianli Chen (Plant Sciences)

The GRC is working with Jianli in order to develop a targeted capture panel to genotype, and hopefully identify the causative mutation underlying resistance to dwarf bunt. Dwarf bunt is a wheat disease caused by a fungus. It results in costly reduction in yield and contamination of healthy wheat, and is a concern for Idaho wheat growers. This projected was funded by the Idaho Wheat Commission as the result of a competitive grant.

7) Metagenomics of lake Coeur d'Alene sediment

James Moberly (Chermical and Materials Engineering)

Lake Coeur d'Alene contains high levels of heavy metal contamination. The bioavailability of this contamination is thought to be mediated by various species of bacteria. Potential future changes in management of the lake may increase available carbon, potentially impacting the microbiome and increasing the danger of heavy metals within the lake. The GRC worked closely with James to develop a multi-pronged approach for characterizing the bacterial communities within the sediment layers of the lake. GRC staff provided training, primer design, and extensive trouble shooting and support for difficult PCR reactions for targeted amplicon sequencing of 16S rRNA from samples. GRC suggested and coordinated Hi-C sequencing of representative samples with the company Phase Genomics. The GRC continues to work with James to build shotgun libraries from contaminated samples.

8) Environmental DNA sequencing – Monitoring Idaho's Lakes and Streams

Anahi Espindola (Biological Sciences), Michael Lucid (Idaho Department of Fish and Game)

The GRC worked closely with Anahi in developing primers to amplify eukaryote CO1 mtDNA sequences from environmental samples. After sequencing the resulting amplicons, GRC staff are developing an analysis approach for classifying amplicons and monitoring rare or endangered species, many of which are native to Idaho streams, and which have not previously been sequenced. If successful, this project may impact the way that Idaho streams are managed, making it possible to comprehensively assess the species present in a minimally invasive and low-cost way.

9) Wheat Endophytes and their relation to Low Falling Number: Does wheat carry the seeds of it's own destruction?

Mary Ridout (Department of Forest, Rangeland and Fire Sciences), Juliet Marshall (Entomology, Plant Pathology and Nematology), Hui-Mei Lin (Food Science), Cathy Wilson (Idaho Wheat Commission)

In collaboration with Mary Ridout, the GRC was awarded funding from the Idaho Wheat Commission to carry out a pilot study investigating whether low falling number in wheat (a problem which cost Pacific Northwest growers between $30 and $130 million in 2016 and a major concern for Idaho farmers) might be associated with the microbiome contained in the wheat seeds themselves. The GRC helped design the experiment, an undergrad from the Biology department who had previously trained in the GRC to carry out two-step PCR did the lab work, and the resulting libraries will be sequenced by the GRC in an upcoming sequencing run. The results may lead to new strategies for controlling low falling number, as well as elucidating the cause of this phenomenon.

APPENDIX 1: BIBLIOGRAPHY

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APPENDIX 2: IBEST SEMINAR SERIES

2017

Seminar Series

Fall 2017

Co-Sponsored by IBEST and CMCI
Seminars are Thursdays at 12:30 in EP 122

August 31	Dr. Kathleen Kay, UC Santa Cruz Pollinator driven speciation in plants — insights from Neotropical gingers and California Clarkias
September 14	Dr. Laura Kubatko, Ohio State University Coalescent-based phylogenetic inference using site pattern probabilities
September 21	Dr. Terry Hwa, UC San Diego A surprisingly simple link between the transcriptome and proteome of exponentially growing bacteria
October 12	Dr. Zachariah Gompert, Utah State University Causes and constraints on the evolution of ecological specialization in herbivorous insects
October 19	Dr. Forest Rohwer, San Diego State University How Phage Create an Immune System
November 09	Dr. T. Trevor Caughlin, Boise State University Quantitative Spatial Ecology
November 30	Dr. Miriam Barlow, University of California Merced Making statistically powerful evolutionary predictions using an antibiotic resistance model

For course credit register for BCB 501 CRN 31371

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2018

Seminar Series

Spring 2018

Co-Sponsored by IBEST and CMCI
*Seminars are held on **Thursdays** at **12:30 p.m.** in **JEB 104***

For course credit register for BCB 501 CRN 31371

February 15	Dr. Doug Fowler, University of Washington Making and measuring the effects of mutations on a massive scale
February 22	Dr. Catherine Linnen, University of Kentucky From mutations to species: causes and consequences of phenotypic variation in pine sawflies
March 8	Dr. Mark Kirkpatrick, University of Texas Austin Evolution of genome structure by sexually antagonistic selection
March 29	Dr. Terry Hwa, University of California San Diego A surprisingly simple link between the transcriptome and proteome of exponentially growing bacteria
April 19	Dr. Neil Carter, Boise State University Modeling human-wildlife coexistence
April 26	Dr. Zev Kronenberg, Phase Genomics Building *de novo* reference-grade genomes

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