

THRIVING IN AN ERA OF TEAM SCIENCE



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INTRODUCTION: TEAM SCIENCE

Advances in the technologies available to scientists, and in the subsequent generation of vast data sets, have enormously increased the range of questions one can hope to answer.



As the life and health sciences explore this expanded terrain, many researchers find themselves in new company, sharing the bench with physicists, computer scientists, engineers, mathematicians, chemists, demographers, anthropologists, and more. This new interdisciplinary set of colleagues and the techniques and perspectives they bring has triggered a revolution in the biological sciences.

Revolutions happen quickly and slowly. Biomedical science is changing rapidly, yet most academic scientists work in a system that has not yet defined how its historical and traditional methods for evaluating and rewarding scholars will adapt to a world in which important contributions are made not only by a principal investigator driving projects, but also by investigators whose most critical and valuable work occurs in the context of team efforts.

In this book, the Burroughs Wellcome Fund taps the experience of established investigators involved in team-driven science to provide some insight and advice on how to survive and thrive in collaborative science—how to make contributions, carve out signature elements that will help you define and communicate the role of your own original contributions, and get credited and rewarded for work that may only rarely feature your name.

BUILDING A CAREER IN TEAM SCIENCE

For many biomedical researchers in training, academic independence is the milestone that signifies you have “made it” within the scientific community. Independence implies a leadership role and recognition by one’s scientific peers for discoveries originating from your own research.



For decades, the academic incentive system has operated by rewarding independent thought and senior authorship on publications. But in the last decade there has been a significant shift from an incremental, independent approach toward the multidisciplinary team approach to tackling complex problems. The guiding concept is that diverse teams lead to dynamic, connective thinking and bring to bear solutions that may not have occurred to a single individual working in isolation. The government agencies that fund research have begun placing emphasis on collaborative team approaches, and that emphasis has begun shifting the center of gravity away from the individual principal investigator and toward a more integrated approach to problem solving. One could argue whether this shift will produce better solutions to the vexing scientific and medical problems we face, but regardless of your view, the shift is happening and it appears to have long-term consequences for career advancement.

What is “Team Science”?

Rapid growth of the biomedical research enterprise in the 20th century led to a branching of scientific specialization and even sub-specialization, with each field producing volumes of publications, and its own vocabulary, culture, and scientific norms. It has become clear that tackling the complex scientific and medical challenges of the 21st century will require a reassembly of these disparate fields into teams with a common purpose. Team science has been called by many names, including interdisciplinary science, multidisciplinary science, transdisciplinary science, and the catch-all phrase first coined in 1961: “big science.”¹ These terms imply an integration of two or more scientific approaches to solve a complex multifaceted problem. Teams can be formed for a finite amount of time, such as the National Institutes of Health grant cycle, or they can be a longer lasting collaboration that spans multiple projects over many years. Some approaches have become so integrated they have formed new disciplines, such as bioinformatics and nanobiotechnology.

Before Big Science

For much of the 20th century, biomedical science could be thought of as a cottage industry, with small groups working on tightly focused projects under the direction of a single lab leader. Even after World War II, when NIH’s budget and mission grew dramatically, the organizing unit of federal support remained the “principal investigator.” This system produced many of the scientific and medical advances we recognize as critical underpinnings of the modern biomedical enterprise. Some would

The success of the human genome project and its scientific offspring has bolstered the idea that much can be gained from assembling diverse teams to get things done.

argue that if the system works, why alter it? Indeed, it is unlikely that the individual investigator is in danger of extinction. However, as scientific and medical research has grown and borne fruit, it has become clear that many of the difficult problems still before us will require the combined efforts of many investigators with a variety of skills and experiences to solve. The success of the human genome project and its scientific offspring has bolstered the idea that much can be gained from assembling diverse teams to get things done. The current enthusiasm for team science might be considered to have sprung from of the era of “-omics.”

The Era of “-Omics”

By 1986, fervor around the concept of sequencing the entire human genome had reached fever pitch among geneticists. It had already been decided that the new study of genomes needed its own scholarly journal, but naming it became an issue. In a story that has now entered cultural lore, a small group of scientists that included Frank Ruddle of Yale University, Victor McKusick of Johns Hopkins University and Thomas Roderick of Jackson Laboratory, mulled the question late at night over beer and raw oysters. Roderick suggested the term “genomics” not just to name a new journal, but also to describe “an activity, a new way of thinking about biology.”² The massive accumulation of data that characterizes the era of “-omics” presaged bioinformatics and the integration of mathematics, the physical sciences and engineering into biological problem solving. The data deluge requires a variety of approaches to make use of all the tools available to biologists and medical researchers today.

The NIH Roadmap – What it means for you

The National Institutes of Health has been explicit in its support for scientists working in teams to solve complex problems. The NIH Roadmap, which has been guiding federally funded biomedical research since September 2004, explicitly sets research policy to encourage more cross-cutting and interdisciplinary research. According to the Roadmap, NIH “wants to stimulate new ways of combining skills and disciplines in the physical, biological, and social sciences to realize the great promise of 21st century medical research.”³

Essentially the NIH is providing incentives and funds specifically to move biomedical research in the United States away from individual, single principal investigator projects and toward multi-PI initiatives. The effect of this shift has yet to be felt, since many of the first Roadmap projects are still in their infancy, and the majority of NIH grants are still made to individual PIs. But NIH has made clear that interdisciplinary teams are the direction it is headed.


How will careers advance if the principal investigator system fades away? NIH’s own tenure review committee revised its criteria for tenure to include team science in 2006. NIH’s clinical and translational science program explicitly promotes the formation of interdisciplinary teams among clinicians and basic scientists. In addition, since 2007, NIH has recognized multiple PIs on NIH grants. By “recognizing team leadership,

the NIH hopes to encourage institutions to reward and recognize successful science teamwork through career advancement.” But perhaps the most visible effort to assist team science has come in the form of a field guide, published in November 2010, that provides guidance for established investigators who are entering into a complex team project.⁴

For scientists who are at the start of their careers, learning the skills necessary to be a successful collaborator and perhaps a member of a larger team can only help aid the transition to independence. To that end, several large universities have begun to offer courses or professional development programs to encourage new or established investigators to put together effective teams.

Judith Ockene, professor of preventive and behavioral medicine at the University of Massachusetts Medical School in Worcester, Mass., has offered one of the first such team science workshops for graduate and medical students since 2003. Ockene says the most important outcome of her sessions is to get investigators to appreciate that engaging specialists in other fields can bring breadth to their own research and can stimulate creative thinking. For individuals still in training, beginning that process means seeking out a broad range of mentors outside your immediate specialty.

“We talk a lot about the importance of expanding the number of people they go to for mentorship to learn what they need to be able to work in teams,” says Ockene.



In November 2009, Stanford University launched its first team science training workshop, sponsored by NIH's Clinical and Translational Science Awards program. Hannah Valentine, senior associate dean and professor of cardiovascular medicine, worked with Margaret Neale, professor of organizational behavior at Stanford Graduate School of Business, to design a program around developing group cohesiveness and increasing creative thinking. The team dynamic approach involved exercises in building teams and leveraging the experience and expertise of team members to solve problems, says Valentine. Feedback from the 70 first-year participants suggested that while the exercises were worthwhile, the physicians and scientists in attendance would prefer a program designed specifically for their needs, according to Valentine.

By introducing the concepts that guide team science and the skill sets necessary to work well within a team environment, the Burroughs Wellcome Fund aims to spur thinking about what level of team science is right for you where you are now in your career. For those who are navigating a team environment while trying to establish an independent career, we provide examples of investigators who have successfully forged careers within a team science milieu and avoided getting lost in the crowd. Proactively addressing the role of teams within your institution and your own career goals will prepare you to be a stronger collaborator and team leader.

“We talk a lot about the importance of expanding the number of people they go to for mentorship to learn what they need to be able to work in teams.”

Judith Ockene
University of Massachusetts Medical School



PREPARING TO WORK ON A SCIENTIFIC TEAM


Just as you would take time and care in choosing a laboratory to conduct doctoral or postdoctoral research, it is crucial to evaluate the work environment and opportunities presented in any collaborative endeavor.



Teaming with a former advisor to extend already established work may seem straightforward. But, for a young investigator trying to establish him- or herself, working with a former advisor could be perceived as maintaining a “junior” role. In addition, there are critical differences between establishing a small two-lab collaboration and joining a large-scale, coordinated endeavor such as a distributed bioinformatics project or multi-institutional clinical trial.

“It might seem as if the decision to join a team should rest on whether the science is interesting, but if the goal is to be productive and publish in high impact journals, there is more to consider. Recent studies of the structure and productivity of scientific teams show that success correlates with group structure and dynamics.

The independent nature of academic research scientists has been well documented by social scientists studying team science efforts. According to Gary Olson and Judy Olson, cognitive scientists who study group dynamics and human-computer interactions at the University of Michigan, scientists must put in an extra effort when collaborating to maintain open communication channels, adopt shared toolsets, and keep groups focused on common, agreed upon goals.



The Olsons run one of a few research teams that have systematically examined large-scale academic research collaborations across many disciplines. After more than 15 years of research, including a National Science Foundation-funded study of its collaborative groups, they have developed a set of prerequisites that should be in place for a large-scale collaboration to be successful as evidenced by developing new, more efficient ways of working and/or forming new models that demonstrably move the field forward¹.

Efficient division of labor

Work should be divided so that it can get done without constant daily or even weekly communication across distance. For diverse scientific teams whose members are spread out geographically, it is helpful if the work can be divided into “modules” assigned to individual locations. The more modularized the work, the more successful it is likely to be. For example, scientists working on the malaria genome project, which involved sequencing centers on three continents, divided the chromosomes that need to be sequenced amongst themselves. While the project required intense collaboration to bridge technological hurdles, the day-to-day work required little contact among the groups. Leaders met face to face to compare notes and coordinate effort twice a year, according to Malcolm


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Joann Keyton
North Carolina State University

Gardner, a leading scientist in the project (see case study on page 44.) Even for projects within a single institution, dividing the work into self-contained units and devising a schedule of regular meetings to discuss progress helps keep everyone on track. For Julie Segre, a laboratory-based biologist, and Heidi Kong, a dermatologist and clinical investigator, both of the National Human Genome Research Institute (see case study on page 22), embarking on a large team project to identify the skin microbiome meant balancing clinical and laboratory arms of the operation. The two quickly realized that having one large meeting with all members present was an inefficient use of time. Instead, they opted for two meetings: one focused on clinical protocol development, patient recruitment, and details of specimen collection and storage; the other focused on technical laboratory issues and data analysis. Segre and Kong attend all meetings and negotiate problem-solving between the two groups.

Trust among all participants

While it may seem obvious, researchers who respect one another, share common goals, and just plain like each other make for more productive teams. Sometimes people lose sight of the fact that collaborating just to satisfy a funder's requirement, without first establishing mutual trust, can doom a collaboration to failure. In the case of Segre and Kong's



collaboration, while they hadn't worked together previously, they shared a trusted mentor, Maria Turner, who was at the time a senior clinician at NIH. It was important that Turner could vouch for the reliability and trustworthiness of the other.

"She was the person who really connected Heidi and me in the beginning," says Segre. "There was a sense for both of us that if Maria vouched for the other one, then we could trust each other."

Shared goals and shared success

Before starting a new team project, it is critical to ensure that all participants are clear on the project's interim and ultimate goals, how they will be accomplished, and how credit, i.e. patent and/or publication authorship, will be apportioned. For trainees and junior faculty, it is especially important to be clear at the outset about what you need for professional recognition and career advancement and building mechanisms into the research plan to achieve those goals. If some members are clearly in an established position and some are in junior positions, misunderstandings and lack of motivation can undermine the endeavor. Everyone should be invested in seeing the project through to completion.

Likewise, if partners have competing goals, conflict is bound to ensue. The Olsons give an example of scientists collaborating with computer programmers to create a piece of software. In this case study, the scientists' goal was to create a reliable tool to further their research, while the computer programmer's goal was to extend knowledge about what the computer itself could accomplish. The programmers were content to continually modify the program, extending its capabilities, while the scientists became impatient for a finished product. Ultimately, the scientists decided to partner with program developers who were used to seeking input from users and modifying their program to meet specific requirements.

In another study of team productivity, a group led by business professor Brian Uzzi and Luís A. Nunes Amaral, a physicist who studies complex systems, both at Northwestern University, measured team productivity in the diverse fields of economics, ecology, astronomy, and social psychology. The study, published in the journal *Science*², demonstrated that the productivity of a given team, as measured by the impact factor of team's journal publications, correlates with how long team members have worked together and whether the team brings in new members. According to the study, prior experience working together increases team productivity, as does periodically bringing in new members to an established team.



Publication issues

Individuals working in interdisciplinary research may naturally seek to publish in journals influential in their own field of expertise. However, editors of some specialty journals may not readily see a multidisciplinary approach as falling within the scope of their publications. When getting ready to publish, a good idea may be to consider submitting to journals that expressly seek to publish research crossing disciplinary boundaries. Many publications now include an author contribution statement detailing each author's contribution to the work. For a publication with many authors, submitting to a journal that allows this level of authorial detail may alleviate discomfort over apportioning credit.

“I can’t stress enough spending time getting to know one another on a personal level.”

Joann Keyton
North Carolina State University

Putting it all together

If you are constructing a team to investigate a particular research question, it pays to work with people you know and trust, but as the work progresses, also to invite in new members who can contribute fresh ideas and perhaps expertise the team is currently lacking. If you are a new investigator and are asked to join a team whose members you have never worked with before, spend some time investigating what your role will be and how decisions about the direction of the project will be made.

“It’s important to know and understand your collaborators,” says Joann Keyton, professor of communication at North Carolina State University in Raleigh, N.C., and editor of the journal *Small Group Research*. Keyton studies how scientific teams work together and factors that contribute to success. “If you are planning to work with collaborators at another institution, I can’t stress enough spending time getting to know one another on a personal level. Then later when issues arise it will be that much easier to work through them. Science is often “star-driven” and the world is asking scientists to operate differently—to collaborate. Being able to take direction and give direction is important, and putting in place a system of consensual decision-making is critical.”

CASE STUDY:
HEIDI KONG AND
JULIE SEGRE


**Compatible goals and a trusted mentor
made for a smooth transition to team science
for Heidi Kong and Julie Segre**



An unexpected result led Julie Segre, an investigator at the National Human Genome Research Institute in Bethesda, Md., on a career-changing journey from studying the innate immune response in mice to examining the genomics of microbial communities that colonize human skin. In 2006, she discovered that injured skin cells in mice commonly produce antimicrobial peptides to prevent pathogenic bacteria from gaining hold and causing infection. This insight led her to wonder about the role of microbes in maintaining a healthy skin barrier. But to answer the new questions that arose from her work would require a momentous shift in research direction. That decision, reached after many discussions with senior researchers in her field and the acquisition of tenure, required her to form a team capable of analyzing normal and diseased skin samples, gathering samples, maintaining large databases, and doing high-throughput genomic analysis.

In short, Segre moved from running a lab to managing a diverse team. She knew that to make it work she would need a clinical partner who understood skin disease. But where to find such a partner? She didn't know. So she turned to "the connectors."

"There are certain people in fields who I think of as real connectors," says Segre. "Those people [who are experienced thought leaders] can put you in touch with someone else who has had a similar conversation with them, but from a different perspective. I talked with a few of those people and told them what I wanted to accomplish in some detail."



For Segre, it was a connection with Maria Turner, a senior clinician in National Cancer Institute's dermatology branch, that led her to Heidi Kong, an assistant clinical investigator in Turner's section. Kong had independently talked to Turner about her desire to ask deeper questions about the origin of skin diseases.

For Segre and Kong, having Turner as a trusted mentor was critical to making the decision to work together.

Segre recommends that individuals looking to start a team partnership find someone who is a good fit, not just professionally, but also personally. Prior to her collaboration with Kong, she had tried a similar team effort with another clinician scientist and it just didn't work. She says that it's crucial for each member of the team to be equally committed to the project and to remain 'on the same page.'

For Kong, a board-certified dermatologist and new investigator at NCI, the decision to collaborate with Segre was complex. Foremost, she had questions she wanted to ask about skin diseases in which microbes are thought to play a role. She knew that to answer those questions she would need a partner who could provide the expertise in microbial analysis and genomics, but as a brand new NCI clinician, she wasn't sure taking on a partner made sense. Her branch chief, the equivalent of a department chair in academia, had some concerns. To obtain tenure, she would need to show independence, and engaging in this partnership would have an impact on the tenure process.

“It’s crucial for each member of the team to be equally committed to the project and to remain ‘on the same page.’”

Julie Segre
National Human Genome Research Institute

“From a junior person’s standpoint, especially if you are going to work with someone who is senior, you’ve got to be able to be protected because it is very possible that you could potentially be overshadowed,” says Kong. “You have to make sure that you do things that ensure that you get tenure. You need independent projects.”

After some discussion, Segre and Kong decided to take it slowly and commit only to a pilot project, a kind of test, to see how well they meshed and whether the results were interesting enough to continue. In retrospect, they both recommend starting with a small pilot project to see how well you work together before committing to a major endeavor.

“In a sense it was testing out this relationship,” says Kong. “As in any relationship there are ups and downs, and we definitely hit some challenging parts. But if you have a sense that this is someone who is interested in working out problems, things can move forward.”

The research went well and they quickly completed a genomic survey of the microbial skin communities. They wrote that the work “provides a baseline for studies that examine the role of bacterial communities in disease states and the microbial interdependencies required to maintain healthy skin.” (*Science*, May 2009). The genomic study, which sampled normal healthy volunteers, found a remarkable diversity of bacteria living on the skin, far more than had been found using traditional laboratory culture techniques.



At the same time, Kong was invited to give a plenary talk at an investigative dermatology meeting and afterward was asked to write a review for a clinical journal. By this time the two investigators were working closely together, but Segre recognized that Kong needed to be able to do things on her own and after some discussion the two agreed for Kong to be sole author on the review. Besides, Segre had her own review to write for a basic science journal.

Thus was born what the two researchers say they expect to be a long-term team effort. With great determination and focus, they applied for a grant to be part of the NIH Human Microbiome Project and now are a part of a much larger big science effort to understand the role of microbes that inhabit our bodies.

But the relationship was not without some hurdles to overcome. For instance, it became clear fairly early on that Segre and Kong have different personalities and management styles. Segre's priorities were to make sure her trainees maintained some independence and sense of control over their portion of the research. Academic science, she points out, places a premium on creativity and problem-solving and a mentor's role is to inculcate those values and work ethic in graduate students and postdoctoral trainees. In Kong's clinical realm, the priority is on efficiency and competency. She was used to giving orders to her research nurse and technicians and having those orders carried out. Otherwise, she says, workflow would quickly grind to a halt.




Reconciling those different work styles took time and patience. To assist the process, the researchers looked to NIH Ombudsman Howard Gadlin, co-author of the NIH's field guide to team science, to guide the entire group through a "mission and vision" exercise in which the research team, about 20 people, met to discuss the overall goals of the team and the vision of where the project was headed. Then the group was able to discuss how to reach those goals and individual roles within the team.

After the exercise Segre realized that she needed to formalize her management style and to better articulate her expectations of laboratory staff. In addition Segre and Kong developed a contract that spells out requirements for authorship on any papers that resulted from the team effort.

"Because we are engaged in team science, Heidi and I did draw up a contractual agreement where we list our criteria for authorship, and we provide that document to every person who comes into either of our groups," says Segre.

At first Kong and Segre decided that to keep the team cohesive, they would regularly gather the entire group of about 20 for a single group meeting. But after some time, they realized that managing the clinical and laboratory ends of the enterprise had unique challenges that were best solved by those doing the work. They split into two weekly group meetings that the two senior investigators both attend, providing a link between



the smaller teams. To ensure that individuals on the team understand the other's roles, the researchers had each individual sit with the next person in the succession of sample handling to see what happened next. As a result, a number of time- and frustration-saving economies emerged. For example, Segre explains, Kong was breaking off the clinical swabs stick handles before dropping them in the sample tube such that the tube would close properly. Once the samples entered Segre's lab, a technician doing the initial DNA preparation was having great difficulty getting the tiny swab tip out of the tube while keeping it sterile. When Kong came to observe him, she said, "Well, we could just break them off longer so that the swabs are easier to remove."

"It's little things like that, if you understand what happens to the sample after you handle it that can save the next person a half hour of work," says Segre.


While Kong had to learn about the laboratory research enterprise, Segre developed a better understanding of what goes into clinical research. At first, writing a clinical protocol seemed like it should be simple process, but it didn't take long before she learned that you don't just fly through a process in which patients are asked to participate in the research process.

“I realize now that when it comes to patient privacy, you can’t make a mistake, and these things take time to get it right,” says Segre.

“It’s been an education for Julie,” continues Kong. “In the beginning, I’d say, ‘you don’t understand, you have to go through the IRB [Institutional Review Board].’ Now she’s had to live it. So she can appreciate that when one of her post docs comes in and says ‘I want to ask this question,’ and it’s a fabulous question, Julie knows that you have to write a protocol which could potentially take six months or more, then submit it to scientific review and then finally the IRB.”

“And for me,” she concludes. “It’s easy for me to say ‘I want this done, and can we do the analysis this way,’ But, again, understanding the effort that goes into it. It’s not just type, type, type, and out comes this beautiful graph. I understand that it takes a lot of training and it’s not trivial to be able to do that.”

Both Segre and Kong point out that being in close physical proximity has helped immensely when there were technical issues to address and misunderstandings arose. Kong maintains a small office space in Segre’s lab, and the two coordinate regular informal get-togethers for things like birthdays. Even those unplanned meetings in the hallway bolstered the sense of being on the same team, Segre says.



Segre and Kong are now true believers in the process of team science and have written an editorial for the *Journal of Investigative Dermatology*¹ describing their experiences as well as putting together a slide presentation. In one slide, Segre candidly lays out the bullet points in favor of team science:

- Because translational research is built into the project.
- To achieve a personal, professional goal.
- Because I do not have to work 100 hours every week.

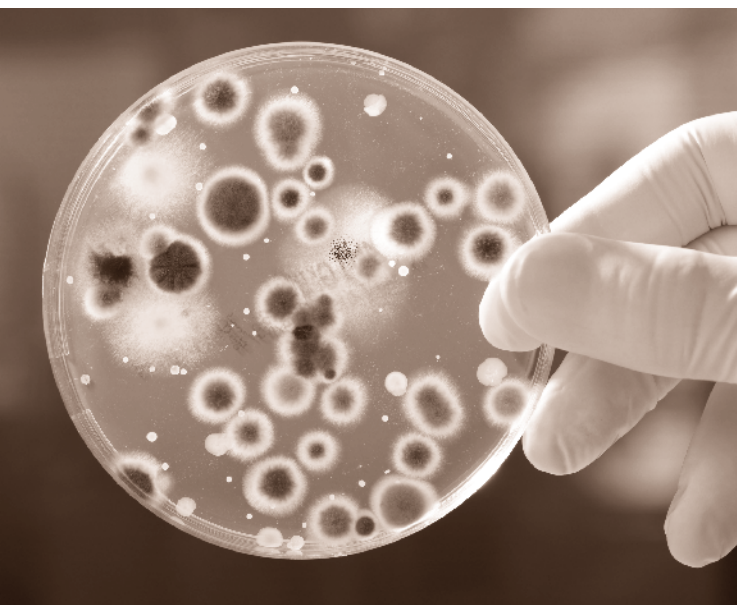
And last, but not least,

- Free skin care advice is great!

“Even those unplanned meetings in the hallway
bolster the sense of being on the same team.”

Julie Segre

National Human Genome Research Institute



CASE STUDY: JIM MORAN

Biological research is transitioning from its late 20th century emphasis on genomics to an integrated analysis of biological systems using genomic tools combined with techniques from the physical and chemical sciences. This transition has made scientists who offer technical expertise, combined with a willingness to collaborate, especially marketable to employers.




When a collaborative team of scientists from Michigan State University and Pacific Northwest National Lab (PNNL) started a project exploring the use of microbes to generate hydrogen as a renewable energy source, the group realized they need to add a scientist trained in both microbiology and the earth sciences. What's more, they needed a scientist with experience in stable isotope ratio mass spectrometry, a useful tool for tracking the movement of nutrients during metabolism.

Scientists at PNNL were establishing a stable isotope mass spectrometry (MS) group and were looking for a broadly trained scientist to join the group.

"Jim Moran's expertise, his collegiality and his willingness to jump right into the team effort really stood out," says Helen Kreuzer, senior scientist at PNNL.

Moran joined the PNNL group and immediately began working as part of the collaboration in 2009. Using the model organism *Shewanella oneidensis*, the group is examining two potential metabolic pathways to hydrogen production.

"This organism has two routes for making hydrogen," says Moran. "We are trying to prove that with these stable isotopes we can distinguish between the two routes," he says. "The long-term goal is to develop a tool that can help us optimize hydrogen production."



Team members at PNNL include the MS group, microbiologists who culture the organism, and an RNA group that is synchronizing the stable isotope data with the appearance of RNA messages encoding metabolic proteins. Scientists from Eric Hegg's group at Michigan State are conducting biochemical experiments.

Moran says his graduate work at Pennsylvania State University's National Science Foundation-supported biogeochemistry program helped prepare him for the highly integrative work he is doing now. Moran's graduate work combined knowledge of biology, chemistry, and geology to examine how archaea and a sulfate-reducing bacteria work together to consume isolated pockets of deep-sea methane. The discovery of microbes that work together to feed on methane deposits is relatively recent, and little was known about how they interact.

"No one really knew how they interplay with each other, so I was focusing mainly on those two groups," says Moran.

His graduate work, published in 2008, showed that the archaea oxidize methane to produce methyl sulfide, which is then consumed by sulfate-reducing bacteria. The work helped explain why only 10 percent of the greenhouse gas, which is produced in large quantities in the ocean, escapes into the atmosphere.



Throughout his graduate training Moran cultivated relationships among faculty in geology, chemistry, and microbiology, learning the lingo of each group and making research among different specialties second nature to him.


“In many ways I was pretty interdisciplinary before I got here and was used to working in teams,” he says.

Perhaps more important though, upon reflection, Moran says the intellectual openness of his program was a major influence in his development and the search for an open, team-oriented career stemmed from that early experience.

“I had a lot of interaction with most of the lab groups in our department,” he says. “Versus some grad schools where there is not even an exchange of resources between one lab and the lab across the hall.”

Moran said he observed that cloistered attitude at other laboratories he worked with, which stood in stark contrast to what he experienced in graduate school.

Moran says his training taught him to think broadly when approaching a research question and not place limits on the research because he doesn’t have the tools or techniques in place.



“I think, do I know anyone who has this capability or expertise that I can tap into,” he says. “My training made me much less wary of asking for help, which fits very well with how the system works at the national labs.”

Moran says that the applied research mission of the national labs lends itself more to goal-directed research in which teams with different areas of expertise work within a project-driven framework with everyone having defined roles and deliverables. But Moran says there is room for professional development within the structure and he has learned how to use lasers and tie his laser work into his stable isotope work. In addition, he has been encouraged to attend conferences and present his work.

Moran says the best part about jumping into an established group where he brings a new skill set is that he has been able to quickly contribute and has been an author on four research publications, including one first-author work, in the 18 months since he joined the lab.

“There are a lot of opportunities to do new things,” says Moran.

Prior to joining the national lab, Moran considered teaching or getting into environmental consulting work, but his two biggest priorities were to make sure he had opportunities for professional growth, and to be at a place where his wife, an engineer, could also find work. PNNL provided both.

He had considered university research, but found that it was difficult to find an academic “home,” a problem that often faces scientists with such broad cross training.

“In terms of academia, there is no biogeochemistry department,” he says. “The question is: what am I? Am I a biologist or a geologist or a chemist? And that’s something I still kind of struggle with. I don’t know how to classify myself, which can be a little bit challenging professionally.”

“But these are man-made constructions,” he adds. “In reality, nature doesn’t exist in ‘biology world’ or ‘chemistry world.’ As science gets more integrated, it’s a good background to have.”

CASE STUDY: MARCUS BOSENBERG

Marcus Bosenberg wasn't looking to join a large scientific team. Instead, one found him.




In 2007, Marcus Bosenberg was within weeks of obtaining tenure at the University of Vermont. He had enough publications, and his research studying mouse models of melanoma was humming along. He had a thriving dermatopathology practice. Aspiring clinician-scientists might picture Bosenberg's life as having "made it." But an invitation to give grand rounds at Yale University's melanoma research group made him re-think his career. Unbeknownst to him, the group was putting together a package to apply for a National Cancer Institute Specialized Programs of Research Excellence (SPOR) grant in melanoma.

"It became pretty clear at that visit that I might be able to contribute or add to some of the things they were doing," says Bosenberg. "There aren't that many skin pathologists that run labs, especially with a strong interest in melanoma. We realized that my work might be a good fit for some of the translational things that go on in a SPOR project."

As excited as he became about the research possibilities at Yale, professionally it was a giant leap to move from a nearly tenured, single-investigator lab to an untenured position at Yale.

"As a physician-scientist it is often difficult to strike a balance between the clinical work, running a research enterprise and being able to support yourself while doing all of those things," he says. The Yale group was willing to put together a hiring package that allowed Bosenberg to relinquish some of the constant pressure of applying for grants. But what really got his attention was the sense of collegiality and a shared goal of patient-centered melanoma research.




He said that a key for him in his decision to move was the incredible contrast in the Yale group from other institutions he had observed who do not meeting or interacting on a regular basis. “It was very clear that people here actually liked each other and wanted to work together,” he says.

The 80-member Yale melanoma research group consists of 12 research groups, along with clinical and research staff. Group leader Ruth Halaban, a molecular biologist by training, says that the group is organized to maximize interaction while allowing each group to carve out its own niche. In addition, the group has developed common resources that benefit everyone. For example, Yale has one of the nation’s largest melanoma tumor banks. For research investigators, having access to patient samples can be a key element to discovery. But organizing and running a tumor bank is a massive effort that requires coordination and cooperation from surgeons and nurses who obtain informed consent, through to technicians and database processors. As Bosenberg points out, organizing a cooperative group willing to contribute to the tumor bank requires listening to everyone’s perspective and maintaining good relationships with the clinical staff.

“If a surgeon is not interested in calling your tumor-banking person you will never receive a single specimen,” he says. “They really have to be on-board because it is extra time and effort for them.”

What maintains that camaraderie is an inclusiveness and the engagement of the surgeons in the research enterprise, says Halaban. The entire group meets regularly for research talks from students, postdocs, clinicians and invited speakers. A steering committee gets together quarterly to review progress and make decisions about resource allocation. All team members have avenues for input and the group encourages entrepreneurship from within. Junior faculty are encouraged to apply for career development awards, which come from the SPORF funds, to gain protected time to try new ideas. For Bosenberg, becoming a member of such a large group has opened up avenues of research that would have been beyond his means and resources at Vermont.

“I think the clearest evidence of how things have changed is that I am a co-PI on four grants now,” he says. In one of the grants, co-PI with David Stern in Yale’s pathology department, he says, “we are trying to find combinations of drugs that work in particular subsets of melanoma patients, which is something I never would have done or never would have thought of doing before I came to Yale.”



Another grant, in which Bosenberg is the principal investigator, but which has five additional investigators, will focus on tumor immunobiology, an area that Bosenberg says he had no experience with before he came to Yale. Next year the group is looking to coordinate a next-generation bioinformatics platform that will allow them to integrate biological sampling with genomic and proteomic data to open up even more avenues of research.

“If I look at the research direction where I was headed before I came here and compare it to what I am doing now, I never would have even been able to imagine all the exciting types of things I am doing now,” he says. “And those are just the funded things. There are probably 10 others I am doing where reagents are being shared, where I am crossing mice with other people’s mice in pilot projects.”

When he came to Yale, Bosenberg chose a non-tenure-track clinical position so that he could be free from the tenure clock.

“It was very clear that people here actually liked each other and wanted to work together.”

Marcus Bosenberg
Yale University

“I have the security in my current position because of my clinical efforts,” he says. “As long as I practice dermato-pathology, and that’s a day a week, I feel secure in my job. One of the reasons why I have chosen to shape my career as I have is so I wouldn’t have to worry about those kinds of tenure decisions. I wanted to concentrate on what was worth discovering and what was worth pursuing.”

CASE STUDY:
MALCOLM GARDNER

**“Big science” led to professional recognition
and advancement for Malcolm Gardner.**




Malcolm Gardner is familiar with rejections.

With his newly minted Ph.D. from Oak Ridge Graduate School of Biomedical Sciences, at Oak Ridge National Laboratory in Tenn., he looked in vain for postdoctoral work. He was trying to move from studying the basic biology of retroviruses into a more clinically oriented research area. After sending lots of queries, Gardner received a number of rejections, including his favorite: a one-sentence letter that simply stated “Your application has not been successful. Sincerely, Dr. X.”

But getting his resume out there eventually paid off. He received a hand-written note from the well-known parasitologist Iain Wilson, who at the time worked at the MRC National Institute for Medical Research in London, UK. Wilson offered him a postdoctoral position to study malaria, a move that would eventually lead to being first-author on the October 2002 *Nature*² paper announcing the complete sequencing of the malaria parasite, *Plasmodium falciparum* genome.

Gardner says moving from retroviruses to malaria happened because he had gotten his resume out there, taken his rejection lumps, and jumped on a promising opportunity when it presented itself.

“I knew nothing about what we now call global health, back then called tropical medicine,” says Gardner.



“Moving from the cancer field and the retrovirus field, which was completely overcrowded, to the malaria field, I thought ‘Hey, this is really interesting. Very little molecular biology had been done on this parasite and wouldn’t that be a good area for a new person to make a mark in,” he says.

Gardner worked for six years on characterizing what he thought was the malaria parasite’s mitochondrial DNA, but which turned out to be from a previously unknown organelle now called the apicoplast. Because the apicoplast does not exist in human cells, it became an attractive target for new malaria drugs, an interest that Gardner continues to work in his current position at Seattle Biomedical Research Institute.

But in 1991, the malaria field was still small and relatively obscure to the larger scientific community. Gardner felt he needed to broaden his scientific horizons. After working two years at Walter Reed Army Medical Center in Washington D.C., Gardner was approached by Stephen Hoffman, then director of the malaria research program at the U.S. Naval Medical Research Center in Bethesda, Md.

“I was never aiming at any particular place, but at some point I wanted to run my own lab,” says Gardner. “At the time I had no inkling I would get involved in something as big as the [malaria] genome project, I had no clue.”

“You have to know enough about what the other person does ... that you can explain your objectives and your desires in a way that they will be able to understand and help you.”

Malcolm Gardner
Seattle Biomedical Research Institute

At the Naval Research Center, Hoffman, a well known immunologist who was well connected in the research community, mentored Gardner. “Getting the right mentors is critical,” says Gardner. For him, moving to Stephen Hoffman’s lab was a critical stepping stone because Hoffman ran a large, productive research enterprise and had lots of contacts within the scientific community. “I learned a lot from Steve, about writing proposals, and about networking.”

If you have a successful mentor, more opportunities present themselves, he adds.

“The genome project is a perfect example of that, an opportunity came by that might not have presented itself if I had been somewhere else,” he says. “You have to jump at chances when you get them.”

Hoffman started a collaboration with scientists at The Institute for Genomic Research (TIGR) to attempt to sequence the malaria parasite’s complete genome and Gardner moved to TIGR shortly thereafter. The group knew it would be difficult to get good sequence. The organism’s genome was difficult to clone, and had long repeated stretches of “A” and “T” which made it difficult from a technical standpoint to correctly count repeats of the sequence.



“There were people in the malaria world who said it was impossible, that we’d never be able to do it, and some of them were quite prominent, so it was somewhat risky,” says Gardner.

The project was a massive undertaking with three major funders: the U.K.’s Wellcome Trust, the U.S. federal government (National Institute of Allergy and Infectious Disease and the Department of Defense) and the Burroughs Wellcome Fund. The work was divided, by chromosome, among three sequencing centers: the Wellcome Trust Sanger Institute in the U.K.; The Institute for Genomic Research (TIGR) in collaboration with Gardner’s mentor Hoffman at the Naval Medical Research Institute, and Stanford University. It was one of the first examples of “big science” being brought to bear on what was thought to be an intractable biological problem.

Logistically, it required intense cooperation and regular meetings to discuss progress, problems and policy. Gardner describes the effort as a true collaboration with no designated leader. The scientific and technical hurdles provided the way forward, he says.

TIGR announced the completed chromosome 2 sequence in 1998, followed by chromosome 3 completed by the Sanger Institute in 1999.

As the project was drawing to a close, the group met to discuss the drafting of a paper to announce the full genome had been sequenced. The scientists working at the Sanger Institute shocked Gardner by offering him the role of lead author in writing the paper.

“Biggest lesson learned: Not being closed to things outside your comfort zone is important. You never know where it will take you.”

Malcolm Gardner
Seattle Biomedical Research Institute

“It was a dream come true,” he says.

Gardner’s many years of basic research work and vaccine development work served him well when it came time to write the genome paper. He served as a liaison for the many authors of the paper and often found himself acting as a mediator between the various authors to make sure all the relevant implications of the genome were represented in the final draft.

“You have to be a bit of a generalist,” he says. “You have to know enough about what the other person does and what their point of view is that you can explain your objectives and your desires to them in a way that they will be able to understand and help you.”

Today he has come full circle and is now studying proteins that are essential for apicoplast function in the hopes that its unique biology will present a target for new antimalarial drugs. His group is also currently evaluating a new malaria target, the indirect aminoacylation pathway, which they identified using bioinformatics and comparative genomics.

His biggest lesson learned: “Not being closed to things outside your comfort zone is important,” he says. “You never know where it will take you.”

LOOKING TO THE FUTURE: CHALLENGES AND OPPORTUNITIES IN TEAM SCIENCE

Success in biomedical research is becoming increasingly dependent on the ability to work in teams with specific, targeted goals.



As we've seen with the case studies presented here, becoming comfortable with the give-and-take that accompanies this kind of work can lead to professional rewards that would be unattainable working within the confines of a small lab group.

In fields such as sports and business, the benefits of working as a team are well known and well studied. An analysis of success in World Cup soccer revealed that in 2010, national teams whose members had experience playing together in club soccer won more matches. In fact, beginning with the quarterfinal round, teams with more club members won every time. Take home message: Teams that function well rely on trust and know how to work together to achieve goals.

Coordinating a multi-institutional research effort requires scientific, technical, and management expertise. Some of the factors that contribute to success of such endeavors can be gleaned from the study of teams in general, but other intangibles can only be understood by studying scientific teams in action.

Science of Team Science

The study of scientific teams—the Science of Team Science—or SciTS is in its infancy, but is gaining interest and momentum on a number of fronts. The annual International Science of Team Science Conference brings together researchers, funding agencies, and those developing tools to make collaboration more efficient and effective.

The inclusive meeting has drawn interest from those involved in communications research, business, complex systems studies, and other fields not traditionally associated with biomedical research. The meeting’s goal, according to organizer and champion of team science Holly Falk-Krzesinski is to serve as a neutral forum for sharing empirical findings about team science and acting as a “bridge between the science and praxis of team science.”

Based on the results of the first annual meeting and discussions among a small group intimately involved in SciTS, Falk-Krzesinski, and colleagues recently published a framework intended as an introduction to existing knowledge and a jumping off point for future lines of SciTS research.¹

Another instructive resource on team science can be found in a special series of articles published in a supplement to the *American Journal of Preventive Medicine* in 2008. The articles cover topics including management issues, readiness for team science, transdisciplinary and interdisciplinary team science, models and strategies for training and evaluating team science, the series provides in-depth evaluation and recommendations based on the current understanding of best practices.

On-line Tools for Team Science

But in the fast moving landscape of team science, more immediate knowledge-sharing channels are also emerging. The National Cancer Institute has developed a “Team Science Toolkit” to provide a web-based, interactive repository of team-science resources.

[www.teamsciencetoolkit.cancer.gov/public/Home.aspx]

Other groups are developing web-based tools to introduce a wide audience to team science concepts and enhance communication among those engaged in team science. For example, researcher Bonnie Spring and her colleagues at Northwestern University’s Clinical and Translational Science Awards (CTSA) have launched the Online Assistance for Leveraging the Science of Collaborative Effort website at www.teamscience.net to provide online modules that guide researchers through a simulated experience in forming a team, identifying and securing funding, managing conflict, and evaluating team success. Indiana University, Bloomington has developed the Cyberinfrastructure for Network Science Center as a portal to shared resources, databases, large-scale network analysis, modeling, and visualization tools for team science. cns.iu.edu/cyber.html

Promotion and Tenure

This trend toward team science may be good for advancing research, but even after you have developed all the necessary skills to be an excellent team member and leader, the academic promotion and tenure system still rewards individual effort. As some who have examined the impact of team science pointed out, “training and mentoring with the expectation that the trainee will have a successful career in such a team environment are virtually nonexistent.”² What’s more, the impact on the tenure system has not been explicitly addressed. Tenure track investigators are justified in wondering what having the majority of their research conducted as part of a large team means when the tenure committee critically examines the tenure package.

For a scientist on the verge of independence, navigating the new world of team science can pose a dilemma. Becoming part of a team that includes established investigators can open doors and provide professional references, but it can also strand you in the role of perpetual “junior investigator.” The challenge for many scientists suddenly becomes establishing independence while operating within the new paradigm of team science. There is a clear disconnect between the traditional reward system and the new funding priorities.

Since the trend toward collaborative research seems likely to march on, it is up to those now in training to gain the skills necessary to prosper in research teams.

“Everything about our traditional career advancement structure in academia focuses on individual achievements and accomplishments,” says Falk-Krzesinski, director, research team support, Northwestern University Clinical and Translational Sciences Institute. “In the absence of individual accomplishment, you’re not getting tenure. Most colleges and universities do not have language about the value of collaborative accomplishments in the promotion and tenure policy. If collaboration is not one of the activities that is rewarded, what do you do?”

For those on the tenure track, Ockene recommends keeping your department chair informed about your team activities and about the importance of your contribution to the overall team effort and to cultivate relationships with senior scientists outside your institution who can attest to your importance to the team effort.

“Promotions committees need to get educated about the importance of team science,” says Ockene. “It’s still an education process both for our promotions committees and for our scientists.” After all, having those letters to support the promotion process is still paramount.

Since the trend toward collaborative research seems likely to march on, it is up to those now in training to gain the skills necessary to prosper in research teams. We hope this resource will be a first step on that road.

Notes

Building a Career in Team Science

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Preparing to Work on a Scientific Team

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- 2) Disis, Mary L. and John T. Slattery. “The Road We Must Take: Multidisciplinary Team Science.” *Science Translational Medicine* 2.22 (2010) : 22cm9.

Further Resources

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Web Resources

The Office of the Ombudsman at the National Institutes of Health maintains a web site to serve as a jumping off point into team science. From here, you can download NIH’s Guide to Team Science and find other resources:

ccrod.cancer.gov/confluence/display/NIHOMBUD/Home

Northwestern University maintains a Science of Team Science (SciTS) web site containing the proceedings of the Annual International SciTS meetings and a host of links to other resources:

scienceofteamscience.northwestern.edu

Also based at Northwestern, on-line modules that provide an introduction to the basic concepts of team science, showcasing examples of team-based research from experts in the field. Major topics include: team conflicts and resolutions, incentives and disincentives to collaborative research, communication techniques, and evaluation methods:

www.teamscience.net

The National Cancer Institute has developed a “Team Science Toolkit” to serve as a clearinghouse for resources on team science:

www.teamsciencetoolkit.cancer.gov

The Science of Science Infrastructure portal provides links for research teams working in distributed environments and seeking to share resources:

sci.slis.indiana.edu

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