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A Review of CIMIT: An Interdisciplinary, Inter-Institutional Enterprise

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Abstract

CIMIT, the Center for Integration of Medicine and Innovative Technology was founded in 1994 as an interdisciplinary entity devoted to the development of medical devices. CIMIT, is a multi-institutional organization committed to getting physicians, scientists, and engineers to work together on the development of medical technology. This organization recruits its members from four distinguished institutions: the Massachusetts General Hospital (MGH), Brigham and Women's Hospital (BWH), MIT, and the Draper Laboratories. Coordinated by an Operations committee led by a cast of top level researchers, CIMIT works as a network. How does CIMIT support its researchers to bridge institutional and disciplinary distances? How are interdisciplinary collaborations established? What kind of researcher is attracted to these interdisciplinary and inter-institutional ventures? Rooted in a content analysis of seven interviews with CIMIT members in this paper I examine organizational features that allow CIMIT to be successful in its pursuit, the nature of the collaborations that it promotes and supports, and the type of researchers who excel within its mission.

Introduction

"CIMIT is not an entity. It's an idea, if you will," explains CIMIT's Jonathan Rosen. The idea is an ambitious one: getting individuals with different backgrounds and ways of looking at the world and with different institutional cultures to work together, at the forefront of medical technology. CIMIT, the Center for Integration of Medicine and Innovative Technology is a multi-institutional organization committed to getting physicians, scientists, and engineers to work together on the development of medical devices. CIMIT recruits its members from four distinguished institutions: the Massachusetts General Hospital (MGH), Brigham and Women's Hospital (BWH), MIT, and the Draper Laboratories. Compared to other institutions carrying out interdisciplinary work, CIMIT is unique in its network-like structure. CIMIT researchers do not work under one roof. Rather they collaborate in long lasting part-time projects that coexist with their work as physicians, engineers, or biologists.

In this paper I examine this institution with three questions in mind:

1. How does CIMIT's particular organizational structures and characteristics facilitate or impede interdisciplinary efforts?

2. Which methods do members use to complete their work?

3. Which kind of researchers are attracted to and successful in these kinds of places?

My description stems from one-and-a-half hour, semi-structured interviews with seven members of CIMIT. Interviewees included, for example: Donald Baim, M.D., an interventional cardiologist; Reuben Mezrich, an M.D./Ph.D. radiologist with many years' experience as an engineer; James Muller, M.D., a cardiologist who, as a co-founder of the International Physicians for the Prevention of Nuclear War, shared the Nobel Peace Prize; Ronald Newbower, Ph.D., a physicist who devoted his research career to medical device development and who now serves as a senior administrator for CIMIT and Partners Healthcare; and Jonathan Rosen, Ph.D., an engineer who has also focused on device development throughout his career. All but one of the subjects we have interviewed thus far serve on CIMIT's Operations Committee, an important organizational structure which is described later in the paper.

Our interview protocol consists of approximately 40 questions and addresses the subject's early life, professional training, and beliefs and values. We also inquire into CIMIT's mission, organizational structure, and strengths and weaknesses. All the interviews were done in person and were audiotaped. The majority of quotations appearing in this paper were obtained from written transcripts of the interviews.

To provide some background on CIMIT's mission and work, in the coming section I begin with a historical account of this young organization and a brief portrait of one if its researchers. In section two I examine the organizational qualities to support and hinder interdisciplinary work at CIMIT highlighting the central role of the Operation's committee in recruiting researchers and supporting them in serious exchange across domains. Section three is dedicated to describing the nature of collaborations as envisioned by CIMIT members. Section four addressed the psychology of CIMIT workers including researchers, members of the Operations Committee and CIMIT's leader John Parrish.

I. Setting the foundations: CIMIT's history and CIMIT's work

A brief historical account

CIMIT was founded in 1994 as the Center for Innovative, Minimally Invasive Therapy (the acronym's meaning changed in 2001).[1] The concept of an interdisciplinary entity devoted to the development of medical devices originally emerged from the minds of leading physicians like surgeon David Rattner (now the Program Leader for CIMIT's Minimally Invasive Surgery project) and Steve Dawson (an MGH radiologist and Program Leader of CIMIT's effort in Simulation). Dawson has described the thoughts that led to the creation of CIMIT as follows[2]:

> Each of us will be a patient one day. CIMIT began with the premise that physicians from many specialties, working together and sharing ideas, could make the experience of being a patient less traumatic, safer, and equally effective to what we had accepted as "state-of-the-art." To create that reality, medicine must look beyond its traditional borders, grab what's good from other disciplines and apply those ideas to medical care. Revolutions in shared knowledge, communication, and biology-computer interfaces will profoundly change how we conceive, practice, and understand medicine. I want CIMIT to understand it first.

Supported by seed funding provided by MGH, CIMIT began to take shape. The organization's development has been driven in large part by the leadership of its dynamic Director, dermatologist John Parrish, who also serves as Chairman of the Department of Dermatology at Harvard Medical School and Director of both the Wellman Laboratories of Photomedicine at MGH (which he founded) and the MGH-Harvard Cutaneous Biology Research Center. In conjunction with colleagues like Ron Newbower (the Vice President for Research Management at Partners Healthcare and the Senior Vice President for Research and Technology at MGH), Parrish has implemented and expanded upon the team's vision of an organization which would

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[1] General information on CIMIT is available at the organization's website: www.cimit.org/about.html

[2] Quote taken from Steve Dawson's on-line profile, available at www.cimit.org/bios/dawson.html

capitalize on technological developments made in physics, engineering, and other sciences, and put them to use in a variety of medical specialties.

Parrish and colleagues' idea to combine technology and medicine was clearly not new. There are a large number of M.D./Ph.D. programs offered throughout the United States. In Boston, Harvard or MIT students interested in the intersection of medicine and technology can participate in the Health Sciences and Technology (HST) program. This program allows students to take classes and do research with professors at either institution, in pursuit of an M.D. or a Ph.D. in one of four scientific areas. Also, some students in HST graduate with an M.D./Ph.D.

However, HST, M.D./Ph.D. programs, and other, similar initiatives have rarely resulted in intense and lasting collaborations between physicians and engineers. According to the subjects with whom we spoke, the situation has been particularly frustrating with respect to Harvard physicians and MIT engineers. As Jonathan Rosen, the Director of CIMIT's Office of Technology Development, put it:

> For 30 years we've never really been able to get the hospital and MIT to work together because people's cultures are different. … There are very brilliant people that, when we first told them about CIMIT, they said this will never work. … not because they were pessimists, but it was because they knew all about what we're trying to do and they said this never works. You can never bring these people together and make it a success. It's just too hard, and the politics, the cultures, the institutional bureaucracies – everything's working against you. It's too hard. You can't do it.

Why did Parrish and his colleagues think CIMIT could succeed where others had failed? Parrish told us that he had two reasons to be optimistic about CIMIT's chances of success at the time it was founded. First, as Parrish and his colleagues were developing their ideas about CIMIT, MGH created a task force whose job was to find new and better ways to bring more bioengineering into the hospital; clearly, CIMIT would be created in a receptive environment. Second, the CIMIT founders had learned from their predecessors: they knew how difficult it was to create and support interdisciplinary collaborations between engineers and physicians. The combination of these two factors gave Parrish and his colleagues confidence that CIMIT would work.

Over time, members of the organization have continued to learn about what is effective and what is not with respect to supporting interdisciplinary work in the area of medical devices, and CIMIT now possesses structures and practices that will be crucial to its future success. These are discussed in later sections. For now, it is enough to note that early collaborations between physicians and engineers were successful enough, and the organization's promise was great enough, that in 1998 CIMIT was awarded $11 million by the Department of Defense.

Brief overview of CIMIT today

Three years after receiving major funding from the government, CIMIT continues to grow. Parrish is still at the helm, and he is joined at the top by Newbower, who serves as CIMIT's Director of Strategic Planning. In recent years, however, CIMIT has evolved into a multi-layered entity. Parrish and Newbower are now supported by the aforementioned Operations Committee. This committee consists of eight individuals who are broadly charged with overseeing CIMIT's development. The roles of particular committee members vary, but the group as a whole helps steer CIMIT by: developing its organizational infrastructure; reviewing proposed research projects; supporting or phasing out existing research projects; and helping to allocate CIMIT's funds.

All of these activities directly affect CIMIT's expanding network of active researchers, who are spread across the four institutions participating in CIMIT. These researchers devote their efforts to projects organized around CIMIT's eight "key scientific programs": endovascular device development, image guided therapy, minimally invasive surgery, simulation, stroke, tissue engineering, trauma and critical care, and vulnerable plaque detection and treatment.[3]

Profile of a CIMIT researcher: Joseph Vacanti, M.D.

A clear idea of how CIMIT works can be obtained by taking a closer look at a particular scientist. Joseph Vacanti is the leader of CIMIT's tissue engineering program and has been described by several of our subjects as a paradigmatic CIMIT researcher. Trained in general surgery, pediatric surgery, and transplantation in the late 1970s and early 1980s, Vacanti began work as a pediatric surgeon at Children's Hospital in Boston in 1983.[4] Shortly after his career began, Vacanti realized that the biggest obstacle he faced as a physician doing transplants was a lack of available organs. While other researchers were working on xenotransplantation (putting animal organs to use in people), Vacanti began to investigate the possibility of growing transplantable human organs in the laboratory.

Working with Robert Langer, a chemical engineer from MIT with special interest in medical matters, Vacanti began to explore the possibility of growing organs by first constructing an appropriately shaped biodegradable polymer scaffold and then seeding it with living cells[5]. Over time, the cells grow to fill in the gaps in the scaffold, which slowly dissolves away: the result is a bioengineered organ (of course this is an extremely simplified account of Langer and Vacanti's work). Since such an organ can be constructed using cells from the individual undergoing the transplant, the expectation

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[3] CIMIT's research areas are listed on its website: www.cimit.org
[4] Information on Vacanti's training can be found in his on-line profile at www.cimit.org/bios/vacanti.html
[5] The origin and evolution of Langer and Vacanti's partnership is described in Arnst, C. "The dynamic duo of tissue engineering." *Businessweek Online*, July 27, 1998. (www.businessweek.com/1998/30/b3588008.htm)

is that there should be no problems with immune system rejection when this approach is used.

Vacanti and his colleagues have had success creating several parts of the body utilizing the method described above, including skin cells, cartilage, and heart valves[6]. However, they have not yet been successful in engineering a large, complex organ along the lines of the liver or heart. One of the major challenges in making such an organ is its need for a blood supply: getting the vascular system in before all the new organ's cells die is difficult. Researchers had success engineering large blood vessels, but a major problem they ran into early on was trying to duplicate some of the body's smallest vessels — capillaries.

Vacanti and his research team used CIMIT's resources to tackle the problem of bioengineering capillaries[7]. Recently, Vacanti had the idea that the process used to etch computer microchips might be put to use in pursuit of a solution. He contacted engineers at Draper, and found that they customarily etch onto chips lines 10 times thinner than capillaries. In fact, one Draper engineer has been quoted as saying that etching capillary-sized lines is "like falling off a log for us." Working with Vacanti, Draper engineers have begun to etch capillary-sized lines. Using the same process described earlier, Vacanti and his colleagues have used the lines to create capillary beds on wafers of silicon or Pyrex. By stacking such layers on top of each other, Vacanti and his research team hope to create a vascular system that can sustain engineered lungs, hearts, and other organs.

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[6] Vacanti and Langer's progress is described in "The promise: transplantation research—hope for the future." *MGH Hotline online*, April 21, 2000. (www.massgeneral.org/depts/pubaffairs/graphics/042100sepromise.htm)

[7] Information on Vacanti's partnership with Draper engineers (including the direct quote from a Draper researcher) comes from Garr, D. "The human body shop." *MIT Technology Review*, April 2001. (www.techreview.com/magazine/apr01/garr.asp)

Achieving this goal will require continued hard work. Vacanti is currently trying to assemble a three-dimensional vasculature from the two-dimensional wafers his group has been able to create. Most importantly, for our purposes here however, is the fact that Vacanti's attempts to address this issue (and others that may arise) are occurring in close partnership with engineers from Draper and MIT. Working together, these researchers may make an important contribution to medicine; it is hard to imagine that they would have a chance of achieving such an outcome working as individuals.

However, one cannot deny the fact that Vacanti is an unusual individual. First, he is quite skilled: his position as the John Homans Professor of Surgery at Harvard Medical School and MGH testifies to that. Second, Vacanti possesses a broad-ranging mind. When we spoke with him, Vacanti told us that he originally thought Draper engineers might be able to help him design capillaries as a result of what he had read about silicon micro-machining, which Draper does. Vacanti told us that such mental excursions into technical fields outside of health care are not unusual for him; though he focuses on surgery, Vacanti has nurtured several other interests since his youth.

Vacanti's expertise in surgery and cell biology (he studied with noted cancer researcher Judah Folkman for two years, working on issues related to angiogenesis), as well as his willingness to make forays into disciplines like engineering, have thrust Vacanti into leadership positions within the world of tissue engineering. Having served in a variety of leadership roles for some time, Vacanti now also contributes an experienced point-of-view, for example, to the work of his laboratory. Over time, Vacanti has identified three factors that he believes are crucial to quality interdisciplinary work. Those factors are:

1. <u>excitement</u> – Vacanti believes that individuals must be passionate about their work if they are to be successful;

2. respect for others – in order to work productively in a team setting, people must be willing to minimize destructive interpersonal competition (e.g., trying to prove that they are smarter than one another) and instead work to develop an appreciation for each person's unique capabilities;

3. a common language – in order to bridge the gaps between disciplines (for example, between molecular biology and surgery), Vacanti told us that individuals must work out a common language. He tells his lab members that they must strive to speak about their work, no matter how technical it may be, in language a fifth grader could understand. I suggested to Vacanti that this must be a difficult goal to achieve. He replied by saying that if an individual is not willing to work towards it, he or she simply cannot remain a member of the research team.

One more point about Vacanti should be made: his efforts in tissue engineering are the product of two core values. First, Vacanti believes strongly in the value of innovation; he enjoys taking creative risks to address areas of medical weakness. Second, Vacanti is totally committed to the well-being of his patients. He told us that he does everything with his patients in mind. Vacanti backs up these words with his actions: in addition to his lab work, he is still an active physician. The day before we interviewed him, for example, Vacanti had spent over 15 hours in the operating room, performing surgery on a child. Vacanti's work as a surgeon, and his obsession with helping his patients, clearly inform all his actions as a professional. His inclination as a risk taker at the forefront of medical innovation is grounded on a commitment to doing good through his profession that gives him a sense of purpose and sustains his efforts.

II. A deeper look into CIMIT: Organizational issues

The following four sections represent attempts to probe both the nature of CIMIT as an organization and how the organization's structure and mission affect the work done by

Vacanti and other collaborators. I have analyzed CIMIT along lines which I feel are particularly revealing: the first deals with organizational structure, the second and third deal with the dynamics of innovation at CIMIT, and the fourth addresses educational issues.

Spreading a good idea around: the intricacies of inter-institutional collaboration

Speaking about complications associated with product development and licensing issues, Jonathan Rosen told us, "CIMIT is not an entity. It's an idea, if you will." The idea is an ambitious one: in addition to the challenge of getting individuals with different backgrounds and ways of looking at the world to work together, CIMIT's leaders must deal with the fact that potential collaborators are physically separated. Though MGH, BWH, MIT, and the Draper Laboratories are close in the grand scheme of things, for people whose schedules are already full, the distances between each institution and the time required to negotiate those distances are barriers to collaboration. Members of CIMIT's Operations Committee have worked hard to minimize those barriers. Though there are drawbacks associated with CIMIT's diffuse nature, the power of inter-institutional collaboration is such that CIMIT members stand by their organization's structure.

Practical challenges

Reuben Mezrich has experience addressing the issues associated with CIMIT's diffuse nature. In fact, the position he holds on the Operations Committee was created in an attempt to facilitate interaction among CIMIT personnel: Mezrich spends much of his time at MIT, scouting out technological developments and encouraging promising engineers to work with CIMIT.

When Mezrich began working for CIMIT in this capacity, he expected that MIT engineers would be too busy to want to engage in collaboration with physicians. While that has sometimes proven true, Mezrich told us he has found many engineers eager to work with CIMIT, yet his and their hopes for collaboration have frequently been stymied by physicians who are too busy to leave their hospitals. According to Mezrich, sometimes a physician wants to work with CIMIT, but his chairman will not let him go. As he put it:

> the doctors are simply too busy. They don't have the time to sit down and think or — even if they have the inclination, their chairman won't let them do it. In fact, I've seen that a couple of times, that the chairman has a short staff and, 'I can't afford — you'd be gone for a day' or 'what are you wasting your time on this stuff? Do something useful — intubate somebody or something!' That's true, too. I mean, there is a problem … with declining reimbursements, people are working harder just to stay in place.

How does CIMIT address the challenges of time and distance? In two ways, one concrete and the other more philosophical.

First, Mezrich and the other members of the Operations Committee have realized that they must spend time convincing a potential CIMIT researcher's important associates at his home institution that CIMIT is a worthwhile endeavor. For Mezrich, that means working with doctors' supervisors so that they see that CIMIT might be of direct benefit to them:

> what I've started to do more lately, and with my colleagues, is spend more time at the hospitals talking to the chairman and saying, 'Hey, what are your problems? How can we help you?' to get them enthusiastic so they will … a) identify receptors to this and b) free them up, give them time … .

Mezrich and his colleagues then put CIMIT's money to work: they use it to buy the time of researchers who are interested in joining the organization. As Mezrich told us, "CIMIT helps and can help a lot by giving up money, by saying to a chairman, 'Here's some money to free up this guy's time. You're not going to lose any money on the deal.'" Furthermore, because he has ascertained the chairman's needs and desires, Mezrich can also say, "We'll go and develop something that will, in the long run, pay off." By creating personal relationships with a researcher's associates and then paying for that researcher's time, CIMIT has had success bringing interested researchers aboard.

However, that success is also the result of a piece of CIMIT's philosophy. I asked Ron Newbower if CIMIT ever had difficulty recruiting senior researchers. My question was informed by comments made by subjects at other interdisciplinary institutions our team has investigated. Those subjects indicated that senior researchers, tenured and secure in their environments, are sometimes hesitant to leave their professional homes, come to an interdisciplinary institution, and embark on a potentially bumpy ride. Newbower said he had heard of and understood such concerns, but he told me that CIMIT does not suffer from them. The reason CIMIT does not have trouble attracting senior researchers, Newbower explained, is that it consciously operates "on the margins" of the four institutions of which it is comprised. As Newbower put it:

> The secret recipe is that you don't try to change the whole world, or we're not trying — [MGH] is a huge medical center, the Brigham is almost as huge, and the whole Partners system is as large as they come. Trying to change that is not the point of CIMIT, but if you work around the margins of it, it's a great resource.

CIMIT's efforts to "lay low" may make it attractive to researchers who wish to contribute to the enterprise but who are unwilling to forsake their positions in order to do so.

The benefits of working across institutions

Though not always successful, the combination of Mezrich's direct approach (which is also used by other members of CIMIT's Operations Committee) and the indirect nature of CIMIT's philosophy has convinced and allowed individuals from all four institutions to join CIMIT. CIMIT benefits from the inter-institutional approach in two ways. First, CIMIT has access to many more talented individuals and more equipment than comparable organizations which are housed in a single institution. When the quality of the institutions involved in CIMIT is factored in, this truly is one of the strengths of the organization. Second, because it is situated outside of any departmental structure, CIMIT can focus solely on supporting and promoting the work of its researchers; it need not get involved in as much political wrangling as exists in some traditional departments. As Jonathan Rosen told us:

> we don't have conflict issues, and we don't have a conflicted agenda, which I think is a great strength. … We're not a department. We're not involved, for the most part, in [CIMIT investigators'] promotions as academic clinicians or researchers. So we're not their bosses. We're not their chiefs or chairmen and so on. We have a fairly huge role agenda, which is a great strength in promoting confidence.

The drawbacks of working across institutions

As beneficial as it is, working across four institutions is not easy, and CIMIT's efforts to do so are not always successful. The problems CIMIT has had illustrate the main drawback of being a diffuse organization: convincing a number of institutes that a new and unfamiliar agenda is worth supporting is difficult, especially when that agenda represents a departure from their normal modes of operation. Jonathan Rosen spoke to us about some of the difficulties CIMIT has experienced:

> This is one of the last bastions of academic medicine. This is also, recognizably, one of the most conservative environments left in the world. The long history associated with the institutions — we're working with MIT, Mass General — these places have been around a long time. They have really deep roots, and making change in that environment is challenging. … The organizational structure that we work in is not conducive. We are here fighting against a history of not ever getting the

> clinicians and the engineers together. So the opportunity is there, but the challenge is there at the same time.

Conclusion

As Rosen's comments suggest, CIMIT's strengths and weaknesses — at least with respect to its organizational structure — constitute two sides of the same coin: MGH, BWH, MIT, and Draper provide CIMIT with a large pool of talented individuals, but they also set up barricades to those individuals' participation in CIMIT. However, the organization's leaders are confident that, in time, the strengths will outweigh the weaknesses. In fact, some of CIMIT's leaders are so confident that they predicted CIMIT would soon take advantage of another strength of working without a particular institutional home: ideas, if not people, are easily transported from one locale to another. Because CIMIT is "an idea," it could easily be spread to other institutions, and some CIMIT members expect that it soon will be. Rosen told us:

> CIMIT will begin to be exported. There will be a national CIMIT. There will be connections to other CIMIT-like activities around the country. There will be a national stroke center that CIMIT will coordinate from here ... what we've learned here about managing stroke will be applied locally around the country. An international CIMIT will happen…. In general, if we can quantitatively and qualitatively demonstrate CIMIT as a "success"…. it will be extremely interesting to a lot of people and a lot of institutions.

Disciplinary dynamics at CIMIT

One distinction that separates truly interdisciplinary institutions from the rest of the pack is the balance between the disciplines at those institutions. When we set out to identify institutions for inclusion in our study, we looked for places where two or more disciplines were used to inform one another in a deep way. By contrast, we were not interested in places where one discipline was clearly, consistently, and solely used in service of another. It is difficult to summarize all the possible ways in which such a condition might manifest itself; hopefully, it is enough to say that an important question for us has been, "To what degree are medicine and engineering (and closely related disciplines, e.g., physics) balanced at CIMIT?"

Because we are still studying CIMIT, the reader has probably already assumed (correctly) that CIMIT is well-balanced with respect to these two disciplines. Through our interviews, we have learned why that balance is important to individual collaborators, how the balance affects CIMIT's output, and how changes in CIMIT's mission (related in part to the balance between medical and engineering concerns) have led to one of the few critiques of the organization we have heard thus far.

The importance of disciplinary balance to collaborators

The challenges that CIMIT tackles require input from both physicians and engineers, but that does not mean that the contribution of each discipline to a particular project must be equal. Either engineering or medicine could be the dominant discipline and could set CIMIT's agenda with respect to the problems the organization would address, the methods researchers would use, and the standards by which CIMIT's work would be judged.

However, we have found that neither engineering nor medicine outshines the other at CIMIT, in large part because the organization's personnel strive to ensure that the two disciplines are emphasized roughly equally. This is more than a matter of professional courtesy: many collaborations have failed (not only at CIMIT) because one of the collaborators felt like he or she was not a full partner in the enterprise. Reuben Mezrich, in his position at MIT, is conscious of the fact that the way a potential collaboration is presented to an MIT scientist can have a big impact on whether or not he or she will participate. Mezrich told us:

> One of the problems that has to be overcome, and I'm conscious of trying to overcome it, is a lot of the doctors here have a problem and say, 'Ah, this guy [an MIT scientist] can fix it for me.' The problem is … the doctor treats an engineer as a technician. 'I got this little problem, make me this gadget, thank you very much, good-bye.' No collaboration.
>
> And, in fact, that does work, but not at MIT. The MIT guys are not interested in someone else's problems, and they surely don't want to be a technician. They have enough independence, enough smarts, and enough going on that they don't need to solve my problem. So, that approach doesn't work, unless it's a really interesting problem. So, 'I don't want to test this little gadget, but to cure cancer? All right, that's a little better." If it comes from the doctor, the challenge has got to be a really interesting problem, not a 'one of,' and the MIT guys have got to get the sense that there is in fact a collaboration, that they're going to work as equals.

Mezrich is not alone in his concerns: all of the CIMIT personnel with whom we spoke were cognizant of this issue, and they all characterized CIMIT collaborations as two-way streets.

Balance on an organizational level

One can observe the importance of disciplinary balance at CIMIT on an organizational level as well. A good example concerns a recent shift in CIMIT's structure. Until several months ago, CIMIT researchers worked on one of two large enterprises: either they were addressing issues in one of CIMIT's Clinical Focus Areas (CFAs) or they were innovating on one of CIMIT's Advanced Technology Teams (ATTs). This division has been discarded and replaced by CIMIT's current structure, which is centered on the eight scientific focus areas listed earlier.

There appear to have been several reasons behind this re-organization. Some ATTs and CFAs did not develop as expected, and economic considerations probably played a role in CIMIT's decision to streamline. However, comments by Jim Muller, the Chairman of the Operations Committee, suggest that another impetus for the rearrangement may have been a sort of disciplinary imbalance: the greater number of ATTs (there were nine ATTs as opposed to five CFAs) and the idea that they would at least sometimes function outside of collaboration with physicians may have led to their abandonment. Muller told us:

> There is a portion of the ATT concept that failed that could be of interest for your study of structure. The ATTs were conceived of as … technology experts who would develop their technology and then share it with everybody and make it available — a core function for the whole investigative group. That really never developed, partly because people don't work that way … and partly because the receptor sides, the needs weren't there for the technology by everybody.

By restructuring CIMIT along the lines of eight collaborative enterprises, CIMIT's leadership may have been trying to achieve a disciplinary balance that had previously eluded the organization.

Looking at all the pairing and projects under way at CIMIT, one can characterize the organization as a whole with respect to disciplinary balance and dynamics. Jim Muller did this during my interview with him. When I asked Muller whether CIMIT ever harmed itself by straying too far towards medicine or engineering to the neglect of the other, he replied (in part) by saying:

> CIMIT is a push and a pull situation. There is some technology we're pushing because we think it will be good, like MEMS [micro-electromechanical systems] sensors, and then there are some problems like stroke and vulnerable plaque [where] we're pulling technology.

To restate Muller's idea in more abstract terms, CIMIT "pushes" when it develops technology for which there is no pre-identified medical application, and CIMIT researchers are "pulled" into developing technology when a medical problem cries out for a solution.

A challenge associated with the balance between push and pull

From an outsider's point of view, it appears that the dynamics between push and pull have changed since CIMIT's early days. To be sure, there was always a focus on bringing specialists from various disciplines together to work on medical problems. Yet, when CIMIT stood for the Center for Innovative, Minimally Invasive Therapy, the problems it was addressing seem to have been more circumscribed. For certain, the expansion of the organization's mission (reflected in the change of the meaning of its acronym) has caused some observers to criticize CIMIT. Jim Muller described the situation to us as follows:

> We have been criticized for losing our focus. The name changed; it used to be the Center for Innovative, Minimally Invasive Therapy. That is what it funded in the beginning — you know, new ways to take out gall bladders. But then we realized, as we gave out more money, that we were giving out money for broader issues than just minimally invasive therapy. … So we were stuck with a name that lagged our mission … .

Accordingly, CIMIT updated the meaning of its acronym. However, minimally invasive therapy is still prominently mentioned in the organization's mission statement, in part, one subject we interviewed suggested, because of the pointed critiques of individuals who believe CIMIT has overextended itself.

I would not argue that all those who have criticized CIMIT for going beyond its mission focused on the inclusion of more engineering (or more diverse innovation, generally) as the source of the problems they perceived. In fact, those critics may have been concerned with the simple fact that CIMIT was doing *anything* besides investigating minimally invasive therapy. However, I think it is fair to suppose that some critics would argue that CIMIT is more "push" than it set out to be, or than it should be. Even if this assertion is incorrect, there are certainly people — within CIMIT as well as external to the organization — who would argue that the balance between disciplines and between push and pull is not yet optimized. Individuals would make such an argument because these balances are important: as we have seen, they affect the character of the organization as whole.

Conclusion

Though CIMIT is not perfect, to me it appears to have achieved a fine balance. If pressed, I would say that as a whole, the organization is more "pull"-oriented: after all, every instrument put forth by CIMIT will be a medical device. As innovative as a particular engineer may be, if he or she is working within one of CIMIT's eight scientific focus areas, he or she is working on a project organized, however loosely, around a medical issue. Generally though, I would not push this point very far. As indicated in the quotations from Reuben Mezrich earlier in this section, CIMIT works very hard to keep physicians and engineers on equal terms.

III. A deeper look into collaborations: CIMIT researchers working together

Interdisciplinary work can be done in many different ways. A basic question which interdisciplinary institutions must answer is whether they will pursue their work via collaborations between disciplinary specialists, or by supporting the work of "hybrids" — individuals who have mastered two or more disciplines themselves (of course, these two categories are not really mutually exclusive: an institution could support collaboration between hybrids).

Though it is very important for CIMIT investigators to be interested in disciplines other than their own, the organization relies on a collaborative model. CIMIT pursues this strategy because of a firm belief on the part of its leadership that the type of thinking and the information needed to do good work in medicine differ dramatically from those needed to do good engineering. Accordingly, pairing up specialists from each discipline is much more time-efficient and effective than trying to develop hybrid physician/engineers, and CIMIT features structures designed to facilitate and support collaboration between these two types of individuals. Using these structures, CIMIT has managed to address successfully many of the challenges associated with collaboration.

Why collaboration?

We have asked every CIMIT member with whom we have spoken why the organization favors collaboration over attempts at hybridization, and we have gotten a similar answer from every member. Jonathan Rosen (actually speaking in response to a question pertaining to another issue) put forth CIMIT's position on this issue:

> certain types of research, particularly pharmaceutical research and certain types of cancer research, really benefit from single-minded dedication of very bright scientists and others working in a lab by themselves over a long period of time, and really understanding science or biology at the highest level. … But I think there's a whole other class of problems, and particularly ones that are more in the technology/medical device area, where the very nature of the problem requires a breadth of appreciation and knowledge that's rarely captured by one person.

Reuben Mezrich, who was a Ph.D. engineer for RCA/Sarnoff Labs and Johnson & Johnson for 17 years before entering medical school, is especially qualified to speak about why that "breadth of appreciation and knowledge" is so rarely seen in one individual. He commented extensively on this issue during his interview with us:

> A good physicist, a good mathematician will memorize nothing. He'll derive everything from first principles, right? … in medicine, there are very few unifying theories. In engineering, there are unifying theories and so, therefore, you can derive things. In biology and medicine, or at least medicine, there's nothing to derive. Not yet at least. Maybe ultimately there will be genetics where you can actually figure out why [a particular illness] happens, but at the moment, what you have [in medicine] is a compilation of data and effects [such] that: if you have this [condition],

> then these are the possibilities that led to that. Its called a differential diagnosis.
>
> And so, what you've got to know is, what are all the differential things that can lead to this [condition]? … [because] if you don't think of it, you'll never diagnose it. That's why doctors amass all this trivia, almost because they need to.
>
> … I think you need both people [doctors and technologists] there because there aren't that many people who, in themselves, have enough a) knowledge of what the medical world is like and b)know what the technical possibilities are. … To get to be a good doctor, you've got to learn a lot of this stuff and gain the experience because, again, there's no underlying theory. So the more disease you see, the more you get to understand disease. It sucks up time, and so you don't have the time to learn enough mathematics or enough engineering to be able to fashion a solution. That's why I think it's much more efficient, instead of trying to grow one [disciplinary hybrid], to put [two specialists] together.

Putting two specialists together can be more challenging than it sounds. Mezrich told us about some of the difficulties he has faced, as well as about a time when he participated in the creation of a bridge between physicians and engineers:

> CIMIT is not interested in pharmaceuticals — that's not in our charter — nor in genomics. Many of the medical types, because they come to medicine through a biology background and not an engineering background, and they're more comfortable in biochemistry and biology and stuff like that — to get some of them enthusiastic about devices, it takes a little bit of training. They're afraid of physics. It's amazing how many physicians are scared of physics and engineering. … the engineers — very bright people, inventive and bright — know nothing about how we work, about medicine, about biology. It's just wonderful, their views of how things happen are no different than laymen's views and yet these people are far smarter than what we call laymen. They're really bright people.
>
> So part of the task is simply to educate them [both groups, but in the following example Mezrich focuses on the engineers]. … We're starting a project on an artificial sphincter. … These wizards over at MIT have developed what they call an artificial muscle. It's a conductive polymer,

> and if you apply voltage to it, it contracts; if you turn the voltage the other way it expands. … You can think of a lot of things [to do with this material], but think of … an artificial sphincter for people who have had … prostatectomies or diabetes or whatever, and simply can't control their urinary sphincter….
>
> Well, the first thing we have to do is teach these guys [the engineers] what a bladder is and how it works. And it was actually a great culture shock because the urologist came over and sat with the group at MIT — a group of mechanical engineers — and he started out drawing pictures … explaining what a bladder is, what the function of the sphincter is. … And then he started getting wonderful questions — they wanted the numbers: What is the flow velocity? What are the pressures? There was a great interchange. …That was a great example of the cultures being bridged on both sides.

Structural supports for collaboration

An important point to make with respect to the example above is the active involvement of Mezrich in facilitating the collaboration between the engineers and the physicians. The members of CIMIT's Operations Committee are all charged with this role to a greater or lesser extent. So, in a way, the committee serves as the organization's "interdisciplinary mind": its members identify, create, and nurture promising interdisciplinary collaborations (though oftentimes researchers come to the committee with their own ideas for collaborative research).

Jonathan Rosen gave us insight as to how he performs this facilitating role. When he tours MGH and BWH, Rosen encounters CIMIT physicians who do not conceive of themselves as inventors; many have good ideas for innovations but do not know what to do with them. Rosen said that a typical conversation with a new CIMIT physician in his or her hospital often goes something like this:

> I sit down saying, 'What are you working on? That's a really cool idea. Have you written it down in a notebook?' [Physician speaking] 'Do you think it might be novel?' 'Oh, yes. Have you filed for an invention?'

> [Physician speaking] ‘No, I never got around to it. It’s still in my notebook.’

In his role as the Director of CIMIT’s Office of Technology Development, Rosen will help the physician 1) get his or her invention recorded properly and 2) get the invention patented and licensed by a company.

Rosen’s work has been incredibly valuable to CIMIT. According to him, two years ago, there were eight invention disclosures filed at CIMIT; this year, there were 80. Rosen describes this increase as the “result of going around and interviewing [people about their inventions]. I interviewed over 200 investigators this past year.” Each new invention that Rosen identifies and prods into development is the potential subject of another CIMIT collaboration.

Such collaborations are strengthened by another CIMIT structure: its weekly forum. Jim Muller told us that the forums are largely where the physicians and engineers who participate in CIMIT educate one another. Muller said, “Ron Newbower likes to call it the ‘special sauce’ of CIMIT. … You’ll have a bunch of physicists, a bunch of doctors there. It’s usually about 50 to 100 people that show up. They are very exciting seminars. There are often new ideas generated … .”

The forum provides a safe haven for physicians and engineers to get acquainted with one another. Participants can ask the “dumb questions” that many subjects characterized as incredibly important to an effective collaboration: CIMIT leaders feel collaborators must be so comfortable with one another that they can admit areas of ignorance — otherwise, the pairing will not be productive. Furthermore, by being open about gaps in their knowledge and areas of misunderstanding, physicians and engineers can begin to form a common language that bridges the differences between their disciplines and that allows them to work together on problems.

Conclusion

CIMIT is committed to collaboration. Reuben Mezrich, Jim Muller, Jonathan Rosen, and the other members of CIMIT's Operations Committee devote a great deal of their time and resources to finding areas of overlap between physicians and engineers, educating each group of specialists, and supporting the partnerships that form. As a result of all this work, CIMIT gets the benefit of having (at least) two minds address each problem it tackles, instead of one. CIMIT leaders feel this is the most efficient way to achieve the organization's goals, and they expect to be served well by the collaborative model in the foreseeable future.

IV. The psychology of CIMIT personnel

CIMIT has a bold mission and is committed to a collaborative model. It also has structures in place to support its mission and make those collaborations work. All those things are worthless, however, without good people. One might ask whether there are particular characteristics that distinguish CIMIT personnel from individuals at other institutions. The answer is yes.

While broad generalizations about these researchers' cognitive strategies would be unfounded, subjects repeatedly mentioned four attributes as particularly important to CIMIT investigators. When arranged in dyads these attributes seem to stand in creative tension: *Problem-focus* and *lateral thinking*, and *risk-taking* and *humility*.

Problem-focus

As mentioned earlier, in an interdisciplinary enterprise there is the possibility of one discipline dominating the other(s). For example, CIMIT projects could be designed almost solely with engineering concerns in mind (e.g., devices could be re-worked over and over again with an eye towards engineering perfection, even if many of the elements being worked on would not substantially affect its medical performance).

One of the reasons CIMIT tends not to have this type of difficulty is that CIMIT researchers are extremely problem-focused: the disciplines involved in their work, though important, take a back seat to the issue at hand. Jim Muller told us, for example, "I'm problem-oriented. If it takes the technology to solve the problem, then I like the technology. When I was trying to prevent a nuclear war [Muller was a co-founder of the International Physicians for the Prevention of Nuclear War], if I had to learn Russian better to do it, I'd study Russian."

Similarly, Don Baim (the Director of CIMIT's Research Awards program and CIMIT's liaison at BWH) told us that he relies on the needs of the patient to keep his mind appropriately balanced between clinical concerns and engineering requirements when doing device development for use in cardiological procedures.

Lateral thinking

However, CIMIT researchers are also open-minded, lateral thinkers. This should come as no surprise: if they were only problem-focused, they would be extremely single-minded physicians and engineers and their creative powers would probably be much less apparent. Lateral thinking allows CIMIT investigators to orient themselves on the edges of engineering and medicine.

I should emphasize that CIMIT researchers do more than think broadly. Though he admitted he was being facetious, Ron Newbower's characterization of a good CIMIT member's mind was revealing: he told us that most CIMIT researchers have such a wide range of interests that it is "almost to the point of attention deficit disorder." Jim Muller lent credence to Newbower's statement: Muller credited a mentor with focusing his interests. Muller told us:

> Eugene Braunwald [the famous research cardiologist who currently serves as the Vice President for Academic Programs at Partners Healthcare System] was my mentor for 20 years. … for someone like me that's always bouncing off the walls and going in, he was highly structured. He would tell me, 'Stop doing that; do this,' and it would keep me focused enough that I would accomplish something. So he was great, and that was a good experience for me.

By being open-minded within the framework of a clear problem, CIMIT investigators are able to develop innovative solutions. Don Baim described the problem spaces he works on as lying between two planes: one plane is the discipline of engineering, the other is the discipline of medicine, and the problem Baim is focusing on at any particular time rests directly in between the two planes. For the most part, Baim keeps his attention in this center area. He's aided in solving the problem, however, by being able to draw on skills and technology from both planes. Baim feels he has a creative advantage over other scientists, who can only draw on one of the two disciplines to solve problems.

<u>Risk taking</u>

Lateral thinking pre-supposes excitement about interdisciplinarity on the part of an individual, as well as the willingness to risk a foray away from disciplinary shores: these elements are the motivational fuel for lateral thinking. They are not found everywhere, but they are a virtual necessity at CIMIT. As Reuben Mezrich told us:

> We need people who are willing to try something even if it's stupid. … If you want to try an idea that will be a new way of treating somebody, you

> need that kind of person who's willing to take that kind of a risk. And, sometimes, it's a real risk. It'd be a risk to their career because, if they're junior and they try something, spend a lot of time on some new idea and it doesn't work out, time's gone by and they haven't advanced their career. So, again, for a lot of people the safe thing is to analyze one more compound.

Humility

In order to get those risks to pay off in CIMIT's collaborative environment, researchers must be willing to work with each other. Jim Muller described problems he has seen with respect to this requirement:

> I have seen some troubles where there's a lack of humility on the part of the specialist in terms of respecting the problems outside his or her specialty. That, just because it works in their specialty doesn't mean that the things are wired in the same way in the other specialty.

Jonathan Rosen seized on the solution to this type of problem in his description of the one factor that is common to all good CIMIT researchers:

> The overwhelmingly consistent feature that I can see … is a willingness to allow others to win, to promote the others on the team over yourself. It's a humility. The greatest researchers we work with are the most human beings and the least interested in promoting themselves. … It is partly a humility; it is partly a genuine sense on their own part that they're trying to help other people be successful. They are successful themselves, also, as a result.

Conclusion

Being an effective CIMIT investigator is a tall order. Individuals must be both adventurous and humble, as well as intellectually equipped to both think broadly and focus all their attention on a particular problem.

As they do their work, CIMIT researchers are supported by members of the Operations Committee. While they possess the four traits described above, members of the Committee show additional characteristics which help them in pursuit of their mission. These traits are described below.

Traits of members of CIMIT's Operations Committee

Nearly all of our interviews at CIMIT to date have taken place with members of the Operations Committee. These men (we have not interviewed the lone woman on the Operations Committee, Janice Crosby) play an important role in scouting out prospective interdisciplinary pairings — often spurring their creation — and they support the pairings that form. They are aided in their tasks by three common attributes: seniority, accomplishment/security, and strong technical backgrounds.

<u>Seniority</u>

All of the members of the Operations Committee with whom we spoke are over 50 years old. They are experienced scientists, and their experience allows them to recognize opportunities that younger scientists might not.

<u>Accomplishment/security</u>

The men on the Operations Committee have used their years well; these are people who have achieved a great deal in their lives. For example: Jim Muller, in addition to being an outstanding cardiologist, was awarded a Nobel Peace Prize in 1985; Reuben Mezrich is a radiologist who holds over 25 patents; Don Baim has published more than 250 papers and is an internationally renowned interventional cardiologist. Several of our subjects told us that achieving such success within their area of expertise has left them with a feeling of disciplinary security: they no longer need to prove themselves or advance their careers. Consequently, they are immune to the risks that can come with interdisciplinary ventures and so can focus on CIMIT's goals.

Technical background

Every Operations Committee member with whom we spoke has some background in engineering or physics. Reuben Mezrich and Jonathan Rosen both worked as engineers for many years, and Kirby Vosburgh (a CIMIT Operations Committee member we did not interview) has degrees in engineering and physics and managed research and design labs at General Electric before coming to CIMIT.[8] Speaking about his interest in using near infrared spectroscopy to characterize atherosclerosis, Jim Muller told us, "I was a physics major in the first two years of college at Notre Dame, so I have enough background and enough information to understand spectroscopy, to understand lasers. These things are not frightening to me. I actually enjoy the technology … ." Don Baim majored in physics as an undergraduate at the University of Chicago.

Of course, each of the Operations Committee members also has a wealth of experience in medicine. Of the men with whom we spoke, only Rosen does not have an M.D., and he has spent his adult life working on medical devices. Though "regular" CIMIT investigators are broad thinkers, based on the accounts we have been given, most of them do not have the breadth of formal training that is characteristic of members of the Operations Committee. As emphasized earlier, CIMIT relies on collaboration between specialists. Perhaps being on the Operations Committee and

[8] Details of Kirby Vosburgh's career obtained from his on-line profile at www.cimit.org/bios/vosburgh.html

serving as CIMIT's "interdisciplinary mind" requires that an individual be "hybridized" to an extent unnecessary for CIMIT collaborators.

How does CIMIT attract such people?

Given the practical skill, intellectual sharpness, and psychological complexity required to be a CIMIT researcher or Operations Committee member, a natural question to ask is: how did so many outstanding people end up involved with CIMIT? According to our subjects, the answer is: via self-selection. Ron Newbower told us that attracting exceptional workers is not a problem for CIMIT:

> The people who have the personality, who want to do this, are so frustrated by their inability to find willing partners in the process, that they are drawn towards the platform of CIMIT. You don't have to look real hard — it's amazing — to find just world class individuals.

The ease with which CIMIT attracts such people does not imply that there are many such individuals. When speaking to us, Don Baim estimated that maybe 25% of the medical personnel in the world are currently inclined to pursuing the research CIMIT pursues in the way CIMIT pursues it. Baim thinks that CIMIT currently has a small fraction of those people on board: in the next few years, he hopes the organization will attract the rest.

Though CIMIT relies primarily on self-selection, it also uses the Operations Committee's powers to spur the development of the cognitive factors important to CIMIT researchers. Jonathan Rosen, in particular, is focused on this. Though in Rosen's opinion, CIMIT's best researchers possess some un-teachable qualities, he does spend time trying to improve every CIMIT investigator's innovative abilities. Rosen told us:

> a lot of what I do is take anybody and make them better. I hand out notebooks, and I teach people how to write down their ideas. I interview

> them actively to get their ideas onto paper, and I can move their thinking closer to the front edge of intellectual property in that field. If I can work with an individual investigator for a year, I can move them from ideas that other people had ten years ago to five years ago to one year ago to brand new ideas with novelty. I can teach that process to anybody that has ideas.

Rosen made it clear that he could not "create a DaVinci out of anybody," but he clearly has had success stimulating the development of traits important to CIMIT's enterprises.

An outstanding leader: John Parrish

According to our subjects, a major key to CIMIT's success has been the leadership of John Parrish. In fact, Jim Muller said Parrish has been *the* key to CIMIT's success: Muller referred to him as CIMIT's greatest strength. This sort of praise is not unusual; all the subjects we interviewed spoke glowingly of Parrish. Several referred to him as a visionary figure — the man who "thinks the big thoughts" at CIMIT. Muller said, "85 percent of the creativity here [at CIMIT] is because of him." Subjects also often mentioned Parrish's ability to attract outstanding people. Muller said Parrish is "like a pied piper." Jonathan Rosen told us:

> unequivocally, John Parrish's leadership is very much a strength of CIMIT. I am here because of it. I think a lot of us have accepted the invitation [to come to CIMIT] mainly because we're intrigued with working with him … . Clinicians have come from across the country to be a part of CIMIT, and Dr. Parrish has just an uncanny ability to convince the best people that this is the place for them. It's not just superficial or recruiting skills — it's a genuine sense of an opportunity that he can convey [to] people. The people that are looking for it, like myself, find it and say, 'Yes, this is where I want to be.'

What makes John Parrish such an effective leader? The answer is, largely, experience. As a young dermatologist, Parrish designed a treatment for psoriasis called PUVA (Psoralen and Ultraviolet A, the key components in the therapy). PUVA was dramatically more effective than previous treatments for psoriasis had been; in fact, it was a revolutionary breakthrough in dermatology. Parrish realized that the treatment's success was due largely to the fact that he had borrowed from several disciplines in order to create it. By utilizing developments in molecular biology, photochemistry, and physics, Parrish was able to develop a multi-facetted treatment that worked.

Proud of his achievement, Parrish sought to duplicate it by forming a team of researchers from a variety of disciplines — including disciplines as diverse as cutaneous photobiology, experimental pathology, and gastroenterology — at the Wellman Laboratories of Photomedicine, located at MGH. His effort has been successful: the Wellman Labs have produced a number of treatments which have been important to skin care and medicine more generally.[9] In the late 1980s, Parrish became the Director of another multidisciplinary enterprise devoted to improvements in skin care, the MGH-Harvard Cutaneous Biology Research Center (CBRC). In short, by the early '90s, Parrish had established himself as a leader of interdisciplinary ventures.

In his positions at the Wellman Labs and the CBRC, Parrish developed a sense of what leadership of an interdisciplinary institution demands. The most important, Parrish told us, is energy: leading an interdisciplinary institution successfully means devoting a lot of energy to it. At disciplinary institutions, individuals generally focus on their own projects and on advancing their own careers. By contrast, for CIMIT to be successful, individuals must set aside their personal agendas and work for the benefit of a team. As mentioned earlier, CIMIT holds promise in part because it has been able to attract individuals who are predisposed to taking such actions, who come to CIMIT willing to make personal sacrifices. Even so, Parrish told us that the natural tendency for motivated individuals at any of CIMIT's four participating institutions is to break off from the group to go and do their own work. Even as CIMIT's potential has begun to

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[9] See "Overview of the Wellman Laboratories", available at the Wellman Laboratories' webpage, www.mgh.harvard.edu/wellman/history.html

materialize, this sort of centrifugal force away from the organization's center has continued. Consequently, Parrish spends a great deal of time extolling the virtues of collaboration, reminding CIMIT researchers of the organization's teamwork-oriented mission, and trying to bring like-minded individuals together in the hope that collaborations will form. Judging by the comments other subjects have made, Parrish has been successful in performing these actions.

Parrish's success stems from a deep commitment to CIMIT: he told us that he truly believes CIMIT's model has the potential to improve healthcare dramatically. Because of his experiences with PUVA, the Wellman Labs, and the CBRC, Parrish has faith in the value of interdisciplinary work. However, he also believes CIMIT can play a role in making sure that important technology gets put to use in patient care. Parrish told us that over the course of his career, he has seen a number of important, novel ideas fail before they actually became products because of many barriers which impede the development of products. To name two, a product must be approved by the FDA and attract the interest and confidence of third party payers if it is to have a chance at ever being used by a patient. While FDA regulations and the need for payment plans are not bad in and of themselves, they can be frustrating obstacles to clinician-researchers who have little experience in product development. If a physician does not know how to deal with the FDA, or how to pitch his or her ideas to a third party payer, the value of his or her idea will be lost. At CIMIT, Parrish and his colleagues have created multiple teams of experts — for example, those in Rosen's Office of Technology Development — whose job it is to see that CIMIT researchers do not get stopped by these barriers.

Parrish's experience is helpful to CIMIT, as is his belief in the value of the organization. Both have emerged from a common source: Parrish's commitment to improving healthcare. Much of Parrish's adult life has been devoted to organization building, rather than to the practice of medicine. However, like Vacanti, Parrish's overarching goal is to take care of the sick: Parrish simply feels he can affect more people by creating and directing medical organizations than he could by practicing dermatology. When we asked Parrish to whom or what he felt most responsible in his work, his answer was revealing. He said, "my boss is a future patient."

V. To conclude: on challenges and possibilities

CIMIT is a complex institution with an ambitious mission. As such, it is not immune to problems. The biggest challenge on CIMIT's horizon concerns funding. Everyone at CIMIT is anxious for the organization to get its first "win" — a breakthrough, profitable medical device whose creation stemmed from work done under CIMIT's auspices. Such a breakthrough would put CIMIT on the road to financial self-sufficiency. Reuben Mezrich described the situation in the following way:

> The goal is that, you know, a company will come out [based on the success of a medical breakthrough made at CIMIT], we'll get rich like crazy, we'll have some equity and, therefore, have money. And, now, we'll have money to turn it back in to fund the next company that goes out the door. Well … it's a problem till you get to the first one. Once you've got the first one, you're home free. But, we're not there.

Several subjects mentioned that although it is off to an auspicious start, CIMIT could close or be shut down if it does not prove able to sustain itself financially relatively soon.

As pressing as pragmatic problems like this are, CIMIT must also deal with more abstract issues that are a consequence of its unique nature. The most prominent problem of this type centers around career development: there is no clear career path available for a young researcher who becomes involved in CIMIT's enterprises. As one of our subjects put it:

> we have a lot of talented, young people, and we can't say to them, 'Come work with CIMIT; do X, Y, and Z; and you'll have enough money to pay your mortgage, and you'll get promoted.' It's hard to say that.

Traditionally, academic institutions (including the ones which are collaborating via CIMIT) have rewarded individuals, not teams, for their work. Furthermore, those awards have typically been handed out for work done within a department, along disciplinary lines. Consequently, a young person could do a great deal of good, hard work at CIMIT and not see their career advance as rapidly as it might elsewhere. CIMIT is working to develop ways around this problem. Operations Committee members are designing awards intended to support young people who wish to be involved in the organization's interdisciplinary work.

One last concern is also somewhat abstract. As mentioned at the beginning of this paper, CIMIT has grown dramatically since its inception — what once was a promising idea is now a multi-layered organization. Some of our subjects expressed concern about that growth. They are worried that CIMIT may lose sight of its focus and evolve into an increasingly burdensome bureaucracy. Balancing excitement and dynamic ideas with the organizational structures needed to support interdisciplinary work is a difficult task that CIMIT will probably have to continue working on throughout its existence.

Despite these natural challenges, one leaves an examination of CIMIT with a prevailing sense of having visited an organization with a clear goal: to stimulate breakthroughs in medical device development by supporting collaborations between outstanding doctors and engineers from four leading Boston institutions. With respect to the three questions posed at the beginning of this paper, we have learned: (1) That the organization devotes a great deal of time and energy to identifying, nurturing, and supporting those collaborations, largely through the work of its Operations Committee.

(2) Those researchers rely on collaboration (and the CIMIT forum) to get their work done; (3) that the organization attracts researchers who display a number of cognitive and dispositional characteristics which contribute to their ability to work together in using the tools of engineering and medicine to solve pressing problems.