(Re)Structuring Innovation:
Community-Based Wet Labs for Art-Science Collaborations.

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Collaborations between artists and scientists have yielded many notable innovations. Yet, such collaborations are generally underutilized, mostly due to the myriad obstacles faced by the partners entering into such collaborations. These obstacles include financial considerations (e.g., a lack of available grant funds), social and political tensions (e.g., between art and science, two communities that usually have distinct views about what constitutes valuable research), and professional standards (e.g., what the collaboration yields that is of professional value, such as publications or gallery showings). In this paper, the key issues and barriers to artist-scientist collaborations are detailed. Then, some tractable solutions are proposed.

This white paper is composed of three parts. The first part examines the barriers to collaboration via a dialogue between the two key stakeholders in an artist-scientist collaboration: the artist and the scientist. Since this paper is co-authored by one individual with scientific training (SJB) and one with artistic training (CC), and because we have been engaged in an ongoing artist-scientist collaboration, we felt this approach would be the best way of itemizing the issues involved in such work and revealing the essential tensions.

In this review we have decided to focus on those scientific disciplines that have been more resistant to collaborations with artists. For example, we are not interested in considering how we can improve collaborations between engineers or computer scientists and artists, even though we recognize that such collaborations have their own issues and obstacles, since such collaborations have a rich history (e.g., see Klüver, 1972). With the goal of determining why collaborations with other types of scientists, such as biologists, chemists and other 'wet-lab' scientists, are so challenging, the second part of this paper analyzes the differences between those scientific disciplines that have a more established history of art-science collaboration with those that do not. Such an analysis will reveal some of the shortcomings of current approaches to fostering art-science collaboration, and should also suggest some solutions.

The third and final part of this paper will present several lists of suggested actions for overcoming the various obstacles identified in the first two parts of the paper. Although that section puts forward many suggestions to deal with the specific issues raised in the earlier parts of the paper, our focus will be on suggestions that will have a long-term impact and address the major concerns of the stakeholders in art-science-collaboration. In addition, based on our analysis in the second part of the paper, we will focus on suggestions that foster better and more numerous collaborations between artists and wet-lab scientists.

Our most significant and overarching suggested action will be for the building of new semi-independent institutions that provide real physical spaces, furnished with the necessary relevant equipment, where art-science collaborations. We envision these as being community-based collective art-science organizations whose function is to serve as open access wet laboratories--not unlike the 'hacker spaces' that have appeared in many cities around the world, but with greater focus on the biological sciences, as opposed to engineering and computer science.

Though our focus is on discussing this open wet-lab scenario as a long-term goal, we ground our discussion by referencing our own personal experiences running a wet-lab-based collective in Vancouver, Canada. We will argue that although the formation of such autonomous organizations is critical for fostering artist-scientist collaborations, their ultimate success will depend on forming partnerships with academic and other cultural institutions, as well as an ethos of community participation.

Part I: Dialogue Between an Artist and Scientist on the Artist-Scientist Collaboration

While the issue of art-science collaboration as an institutional question has been address before (see Pearce, et al, 2003), for this first part of the white paper we have decided to address the question via a dialogue between two key stakeholders in an artist-scientist collaboration: the artist and the scientist. Because of our backgrounds and because we have each been engaged in several successful and unsuccessful artist-scientist collaborations, we, the authors of this white paper, have assumed the roles of scientist (SJB) and artist (CC). The dialogue is broken down into several subtopics, as appropriate.

Introductions: The Artist and The Scientist

CC: My background is in music and sound production. I later moved into other areas, that can loosely be defined as conceptual art, systems art and/or interactive art

CC: I am interested in art that emphasizes ideas, intellectual interpretation and critical judgment, rather than a pure focus on craft and object contemplation. I am also interested in cultural theory, philosophy, and analyzing/critiquing technology's role in society--this led me to the arts and technology. One of my primary motivations in this field is my belief that contemporary science and technology are radically transforming the world. I believe it is crucial that the arts address the questions and challenges presented by techno-scientific research. By doing so, the arts can expand its boundaries and reach.

CC: The truth is that my collaboration with SJB is probably my first "true" collaboration with a scientist. Although I have contacted scientists to ask them questions, I think two primary factors have prevented me from doing this until now:

1. Approaching a scientist can be difficult for an artist. I simply wasn't confident enough in my "crazy" ideas to contemplate asking a scientist to collaborate with me. I guess I felt I would be wasting their time somehow.

2. Second, the structure of MFA programs tends to hinder or obstruct collaborations of any kind. You are often supposed to explain what your personal motivation is or what you are trying to "express." Accordingly, a slightly more rational and exploratory approach, such as has been true for my work with SJB, is difficult to contextualize for a "traditional" art faculty. That said, I do feel that I had the backing my thesis committee to do art/sci work but didn't pursue it as much as I could have (probably because of point 1).

SJB: After some early training in the visual arts, I pursued several degrees and then a postdoctoral fellowship in Behavioural Neuroscience. During the course of my training I increasingly became (re)interested in the arts and how the technologies I was using in my scientific discipline might be employed in the arts. Yet, when I looked around my wet lab, there was a stark contrast between the lab and the arts world. I decided to leave the sciences to pursue artistic endeavors. I pursued training in new media in the form of a postdoctoral fellowship in interactive arts. Since then I have been developing my own art practice (traditional drawing and painting, as well as some computational pieces) and have been involved in several artist-scientist collaborations. In such collaborations, I have mostly served in the role of the scientist (often, to my chagrin), though there have been collaborations where I felt I was contributing as an artist as well (e.g., my work with CC).

SJB: My background, accordingly, is admittedly different from other scientists that might be entering into an artists-scientist collaboration. However, I believe these dual hats I have worn have both better prepared me for collaborative work and furnished me with insight into the collaborative process itself.

DPrime Research and *Biopoiesis*

CC: Over the past two years, SJB and I have been involved in the development of a nonprofit community-based organization that incorporates scientific research from many disciplines (e.g., biology, electrochemistry) that have not commonly been a part of artist-scientist collaborations. We have been working to build an organization that is in the spirit of the hacker spaces (which largely focus on electronics, robotics, and programming) situated in many cities around the world, but with greater emphasis placed on wet-lab sciences. It is our hope that we can develop a community of artist/scientist researchers that will be engaged in activities that spawn the same innovation that has been coming out of community-based hacker spaces. The name of our organization is DPrime Research (www.dprime.org).

SJB: DPrime Research is definitely a multifaceted organization. We are part research and development think tank, part science and technology start-up and part cultural and community organization. We are an assembly of artists and academics.

CC: The first significant projects to come out of DPrime Research is a project called 'Biopoiesis.' *Biopoiesis* (dprime.org/projects/biopoiesis/) is a series of experiments exploring the relationships between structure, matter, and self-organization, in what might be described as a computational "primordial soup." This work built on cyberneticist Gordon Pask's research into electrochemical control systems that could adapt to certain aspects of their environment (see Pask, 1960). Our experiments, undertaken by SJB and I, explored the artistic potential of Paskian-like systems. This work also examined the interactive and computational possibilities of natural processes, the potential for natural processes to serve as an alternative to the commonplace digital forms of computation--which might help (re)establish a dialogue between cybernetics, mainstream science, and the arts. In short, it was truly an artistic piece with solid scientific qualities.

SJB: Besides being a laboratory for explorations into electrochemical computing, *Biopoiesis* had at least two other purposes. First, we wished to feature and investigate alternative models of electronic arts practice (thus furthering the goals of DPrime Research). Second, by studying the growth and adaptation of an "inorganic" system, we wanted to question the traditional dichotomies of organic vs. inorganic and biological vs. non-biological. Based on the success of our public exhibitions of the *Biopoiesis* experiments, we felt that this body of work opened up new ways of thinking about sensing, intelligence (environmental, collective; not just cognitive), and memory (mutable electrochemical traces).

CC: Having provided that background about ourselves, our organization, and one of our projects, we will now talk about several topics related to artist-scientist collaborations.

Misunderstanding of the Other Discipline

CC: I think a major barrier to a successful artist-scientist collaboration is the existence of misconceptions of the other's discipline, a misunderstanding of what it means to be labelled (or self labelled) as an artist or as a scientist, or both. There is bound to be some level of miscommunication or misunderstanding, but insofar as the artist and/or scientist is not 'fixed' in their view of the other's discipline, the collaboration is much more likely to be truly collaborative in nature as opposed to being merely one sided.

SJB: The reason art-science collaborations are so challenging, or are never even initiated, is because the artist and scientist enter the relationship with two completely different conceptual models--both in terms of what they are trying to build, and how they should go about building it.

CC: I think that for an art-science collaboration to really work, it is not enough to merely throw an artist and a scientist into the same room. I would argue that the success of an art-science collaboration will depend on the appreciation that the artist and scientist have for each other's discipline. So, to maximize potential, each party must take steps to understand the world view and language of the other discipline, while leaving their preconceptions about art or science at the door.

SJB: In general, I think the common idea of 'collaboration' needs to be revised when applied to collaborations between artists and scientists. The common notion of 'collaboration' usually entails a worksite metaphor: If you bring your carpentry skills, I'll bring my masonry skills, and together we'll build a house. There is no need for me

to learn how to frame a house, and there is no need for you to learn how to mix and pour cement; there must be a certain level of communication between our disciplines, but as long as we agree on the blueprint we can essentially get the job done with minimal interaction. This approach will not work in an artist-scientist collaboration as understanding the others discipline is so critical to the success of the collaboration.

The Non-collaborative Nature of Artist-Scientist Collaborations

SJB: So the term 'collaboration' might in itself be a source of confusion. Artists have told me they have wanted to collaborate because of my scientific background, but the collaboration turned out to be largely one-sided (and, hence, not in a collaborative spirit): I would end up fielding questions about this scientific topic or that, rather than engaging in any real collaborating (at least it wasn't the sort of collaboration I am familiar with from my work in scientific laboratories). The problem, I think, is that in many cases the artist doesn't want to collaborate with a scientist; rather, they want a quick way of querying the scientific literature. This is, of course, tantamount to merely examining the products of science, rather than collaborating with a practitioner of science. On that note, I would assert there are far fewer examples of art-science collaborations than most would believe--most are probably just examples of an artist exploring the products of science.

CC: Artists (like scientists) are very curious. I know that I ask scientists many questions (I know I ask you a lot of questions SJB). Some artists will approach a science-based work (such as a residency in a hospital or at NASA) almost as if they are a "spy" or "infiltrator" (in the nicest possible connotations of those terms). It's a knowledge gathering or fact-finding expedition; they are almost acting like a reporter. They simply observe what the researchers do and sometimes will use their equipment as a basis for their "traditional" artworks (for example Susan Aldworth who used functional magnetic resonance (fMRI) images of epileptic patients (among others) to make films, etchings and aquatints; see http://susanaldworth.com). While there is significant interaction involved (in her case with both patients and doctors and researchers), it is not a collaboration (in the sense that we are talking about).

SJB: My own impression has been that collaboration within the sciences might be a truer form of collaboration--where all collaborators get a chance at credit for what they contribute to an experiment or series of experiments. This is not necessarily the case in the arts, where there is still the tendency to view the artist as a singular entity. In most of the artist-scientist collaborations that I have been involved as a scientist, my somewhat cynical perception has been that the artist objectified me as 'scientist,' and that objectification was usually based on a popular view of what a scientist is and does (e.g., information tome, conservative, an unwavering believer in the power of objectivity). Even when collaborations have been balanced, others (e.g., curators) can impose their own preconception of the artist as a singular entity on the outcome of the collaboration--giving more credit to the artist for the final piece than to the scientist. For example, in a recent exhibit of *Biopoiesis*, the curator adopted this stance: Not having information from CC and I about what names should be tied to our piece, the curator decided to credit the artist among us (CC) for the piece.

CC: In fact, even in those cases where the scientist acts as mentor, or is otherwise integral to the realization of the piece, the artist will often not even mention that the scientist helped them (except perhaps in a credits listing which I believe belies the importance of the contribution). It struck me that most art/science (or art/engineering) collaborations generally fall into two broad categories: (1) scientist as mentor or even as a technician hired to a do a job (to help the artist realize his or her goals such as to make a glowing rabbit, or to program a self-organizing map algorithm (see Steinheider & Legrady, 2004)), or (2) artist and scientist as "clearly delineated specialists" in their fields (e.g., an artist wants to brainstorm with a scientist to make something interesting from the scientist's research, such as a plant that acts as a pollution sensor by changing color which presents an interesting research problem for the scientist (this also gets to SJB's point of each bringing his own skills and world views)). In my view (2) gets closest to a "true" collaboration.

CC: So there are really very few "true" collaborations (like ours?) where both parties are exploring a new area together (e.g. cybernetics, electrochemical learning systems) without knowing the outcome ahead of time, primarily through subjective interpretations and ongoing conversations; both in a sense working as artists and scientists. Ideally, this would lead to both an artistic and scientific contribution by each member.

SJB: Yes, I agree. I think our work has the elements of a true collaboration. And I think there is an interesting distinction arising from this discussion. Namely, that between true and not-true collaborations. In fact, I think we can fairly distinguish between two sorts of collaborations: (1) mentor-based collaborations, and (2) true collaborations. Though we should acknowledge that (2) might in some cases still entail a worksite metaphor in the collaboration, as CC pointed out. Employing a worksite metaphor in this sort of collaboration is not ideal. However, at least from an innovation standpoint, it is certainly a truer collaboration than (1).

CC: Given that distinction, it is probably a good idea to throw out some examples and see whether we can neatly divide those examples into one or the other categories. Here are some examples of art/science projects.

- Eduardo Kac: Green Fluorescent Protein (GFP) Bunny: www.ekac.org/gfpbunny.html
- Victoria Vesna: Blue Morph: artsci.ucla.edu/BlueMorph/main.html
- SymbioticA: MEART: www.fishandchips.uwa.edu.au/
- Beatriz Da Costa: Experiments in Biosensing: www.beatrizdacosta.net/sensing.php

CC: While I have incomplete knowledge of how these projects came to be, I would say that generally, the first two are of the mentor-based variety we are discussing while the last two are closer to true collaborations, though they still have some degree of worksite mentality about them. Of course these categories aren't mutually exclusive, there is likely elements of both in each project.

SJB: How often is it that a scientist approaches an artist to have a collaboration?

CC: The answer is of course is never or almost never. The real question of course is why. Here, I think that the generally accepted response might be that scientists are either not interested in art, don't know how their work might be useful in making contemporary art or are simply too busy with their research and the pressure of teaching, running research projects, applying for grants, getting tenure, etc.

SJB: I suspect that the career advancement issues are the most significant. Another big issue might be the culture of science. During my training as a scientist, I know that in most cases my artistic practices were frowned upon as either being a waste of time or simply a quaint past time--nothing 'serious.' There needs to be a concerted effort by people interested in art-science collaborations to collect and disseminate those important instances where art-science collaborations have yielded clear benefits to the participants and/or to society. People need to be shown what can be accomplished with a true artist-scientist collaboration; otherwise, I can understand their reasons for being skeptical and hesitant to engage in one themselves. I am not sure if this is possible yet, given that there has been so little in the way of true art-science collaboration.

Career Implications of an Artist-Scientist Collaboration

SJB: The unfortunate reality is that although a singular scientist might appreciate one or more artistic endeavors, and may even be actively involved in them, the academic establishments within which they work usually do not recognize their efforts; thus, their collaborative efforts are not appreciated and may even be looked down upon by their scientist peers.

SJB: The artist has comparable struggles within their realm; for example, in the art world there has traditionally been less appreciation for the iterative, incremental work (that is much a part of a scientific practice), as opposed to the polished finished "masterpiece." This, of course, has been changing. Still, it is obvious that the issues extend well beyond the collaborators and includes the cultures within which each of those individuals work.

SJB: A key issue that stands in the way of artist-scientist collaborations is the disparity in the career benefits reaped from such collaborations. For the artist, such a collaboration is more likely to increase their academic and/or career stature through publications and gallery showings. For the scientist, such a collaboration is unlikely to yield comparable benefits. Some fellow scientists might even look down upon such endeavors. Moreover, such collaborative work, at least in its current form, is not likely to yield career advancement benefits in an academic setting for the scientist, where publications in scientific journals are the major indicator of making a significant contribution to their field of study. We need some mechanism of either changing the culture of science so as to

encourage scientists to engage in collaborations, or we need to change the way that collaborations are structured so that the benefits from such a relationship are more balanced.

Process vs. Product

SJB: In theory, scientific practice is much more focused on the process of achieving some result and not just the result itself: the documentation of the methods of a scientific experiment or investigation is just as significant as the outcome of an experiment. One of the pillars of the experimental method is the importance of replication; the idea that the results of a single experiment are fallible, but with replications (ideally by different research groups) information distills. Yet, in practice, there is good evidence that scientists (or at least the editors of scientific journals) are much more focused on the product. For example, positive results have a much greater chance of being published, and only a small fraction of published scientific experiments are ever replicated (see Lehrer, 2010).

CC: Traditionally, art's focus has been on the product. But this of course has been changing ever since the arrival of Conceptual Art in the 1960s, and the related practices of Systems Art and Process Art (all of which draw from Dada & Marcel Duchamp in some way). These practices, from which contemporary new media and interactive art derive, focus on the actual *doing* and how actions can be defined or understood as an actual artwork. So, in these practices, it's not so much about art as object but art as doing. But, as in science, the general bias toward "product" or the "object d'art" persists.

SJB: Yes, and it seems odd that the art world's move toward process over product has not been accompanied by the giving of credit to those individuals that an artists calls upon during the process of creating their work. Perhaps in conceptual art, the artist is still the key product? This is also not an uncommon part of the sciences. There are rock stars in both worlds.

CC: So there does seem to be some clear disparity between the methods of science and the methods of art. In science, there is objective detachment, in systems/process art there is (usually) a clear intention and desire to establish sets of patterns and associations - or at least set them in motion (even if, as in the case of John Cage for example, those patterns are not under the aesthetic control of the artist). There are differences as well: In systems/process art, replication and generalizability are generally not a concern. It can also be argued that traditional art-historical models of analysis do not apply; namely, appeal to the sublime or some aesthetic ideal (though I believe those are still there, just in a different form and with different emphases).

SJB: I agree, there should be an emphasis on exploration and discovery as opposed to merely following an existing line of research. For example, with *Biopoiesis*, we opened up some old abandoned work of the cyberneticists and explored those ideas in brand new contexts.

SJB: Despite science's focus on documentation for the purposes of replication, it seems very odd that science still largely relies on textual descriptions in journal articles as the primary method of disseminating the procedures used in an experiment. To the person that wants to replicate that experiment, there is nothing harder to decipher. Why aren't photos and videos used more commonly for the description of experimental methods? Indeed, there is only one journal that I know of that has employed a policy of documenting all research methods using video (i.e., www.jove.com/. Using video is probably seen as more demanding. But this is not a legitimate excuse.

CC: To be fair I've seen plenty of journal or conference articles in computer graphics, hci, tei, robotics, etc., where they at least link to YouTube videos.

SJB: It's interesting the disciplines you list as examples of properly documenting their process and methods. They are precisely those disciplines that have a richer history of art-science collaboration. Might this commonality in the proper documenting of process be one of the reasons for their heavy involvement with artists? Or maybe part of the reason the sciences you didn't list are not more involved in artist-scientist collaborations is because those sciences are seen as much more technically demanding and thus inaccessible--only by virtue of their methods being described in jargon-ridden journal articles, rather than through the use of video and images.

SJB: On a related note, it seems quite odd that scientists have not employed or sought guidance from artists how to better represent their methods (and to a lesser extent, their results) so that dissemination is more accessible, and replicability is improved.

CC: In general, I think what we are arguing for here is the establishment of autonomous zones of research where modes of exploration--highly speculative, without clearly defined goals, other than perhaps some loosely defined artifact or system (that is both an artifact of exploration and a vehicle for further exploration, as opposed to simply an art object in the traditional sense)--are brought to the fore.

CC: So the very models we are proposing in this paper (and exploring in current and future DPrime work) is itself an artwork or a research "artifact" or "result." The collaboration itself is the medium (see Slayton, 2002).

Part II: What Makes a Scientific Discipline Amenable to Successful Artist-Scientist Collaborations?

This second part of this white paper examines the qualities of those scientific disciplines that have had a significant history of working with artists and compares those disciplines with other scientific disciplines that have not had such a history. The purpose of this section is to achieve some assessment of what makes a scientific discipline more or less amenable to artist-scientist collaborations, or at least determine why certain scientific disciplines have seen more collaborations with artists. The question we hope to answer in this part of the paper is this: Why has computer science (in addition to certain engineering disciplines) seen such a relatively large number of artist-scientist collaborations when compared to wet-lab sciences?

Though there are of course exceptions, at least at an institutional level, the majority of artist-scientist collaborations in recent history have been between computer scientists and/or engineers and artists. The successes (and failures) of collaborative endeavors such as the Xerox PARC Artist in Residence Program, Interval Research Corporation and Experiments in Art and Technology (EAT) have been well documented.[1] This has likely been shaped by a combination of several factors, three of which we feel are the most important and warrant some discussion.

1. **Access:** First and perhaps most significant is the rapid and significant impact that computing and information technology has had on society. This does not entirely answer our central question, since there are many other scientific disciplines that have had a marked impact on society, such as the biomedical sciences. However, the advances made by computer science and allied engineering disciplines have the unique feature of having become very pervasive in the daily lives of most westerners. We are constantly exposed to digital media. It shapes our patterns of communication, our consumption and our social relations. By contrast, our exposure to biomedical advances has been less pervasive, or at least we are less aware of its presence day-to-day. This pervasiveness can, in part, be attributed to the relatively low-cost and accessibility of sophisticated digital technologies, in comparison to biomedical technologies which are often quite expensive and less accessible. This goes a long way in explaining why so many artists have explored the creative potentials of these technologies. Simply put, more artists can get their hands on sophisticated digital technologies than can get their hands on technologies of the wet-lab sciences (not to mention those of astronomy and particle physics). Although, at least in the case of the wet-lab sciences, there are many alternatives available to the technologies used in scientific laboratories--many of them in our own backyards, literally. However, those alternatives are often unknown.

[1] The Xerox PARC Artist in Residence Program included renowned artist and scholars such as Stephen Wilson, Joel Slayton and Pamela Z (see Harris, 1999). Interval Research Corporation was a research think tank and technology incubator founded by Microsoft co-founder Paul Allen. It employed well known new media artists such as Brenda Laurel and Golan Levin among others (see Interval Research Corporation, 1998 for select publications). Experiments in Art and Technology (EAT) was a non-profit organization established to develop collaborations between artists and engineers and helped developing technology-based artworks that included such well-known artists as John Cage and Robert Rauschenberg among others. Notable engineers included Billy Klüver and Max Mathews among others (see Klüver, et al, 1972).

2. **Cultural Attitudes:** The lack of access to the equipment and technologies of wet lab sciences general can, in addition to cost factors, also be attributed to a general cultural attitude of fear of wet lab sciences as potentially dangerous, toxic or life-threatening. The words 'bio,' 'biological,' 'genetic,' and 'chemical' all carry certain negative connotations that are related to their portrayal and usage in popular media. This might explain the rather byzantine labyrinth of concomitant policies and procedures that one must adhere to undertake many sorts of wet-lab sciences--often, when the hazards are trivial or non-existent. This includes the general difficulty in obtaining wet-lab equipment and resources when one does not have University-administered grant account or an industry account. While these barriers exist in all research areas, they are especially present in the wet-lab sciences.

3. **Computation as a Medium:** A final reason why computer scientists have been so involved in artist-scientist collaborations is perhaps because computation is seen as a medium. A computer has a more clearly defined set of input/output relations that simultaneously provide great variability and complexity (which is attractive to artist) but is also (in most cases) easily grasped by a non-technical user. Computer Science and Engineering are disciplines wherein the products (and process) are definite. There is no probability associated with the development of an algorithm. It either works or it doesn't. The answers these disciplines produce may be complex, but at the same time they are simpler in that they rest on firmer ground. Computer science and engineering have also produced tools that new media artists have used for quite some time now. It is perhaps more difficult to view the products of biological or chemical sciences as mediums that can be used by artists. Sciences that produce results that are attached to probability statements (e.g., $p < .05$) are perhaps harder to envision as being a fertile ground for collaboration. These results after all, do not *do* anything. If the reason that computer scientists are more commonly involved in artist-scientist collaborations is because their discipline has created a new medium for artists, then it should be the case that artists view their partner in such collaborations as technicians. Indeed, we feel that this is a common phenomena in artist-scientist collaborations. This is perhaps what distinguishes between the mentorship-based and true forms of collaboration discussed above.

Part III: Suggested Actions

Given the issues identified in the previous parts of this paper, we would now like to suggest several lines of action. In this part of the paper, actions are presented in subsections; each subsection is targeted at one of the many stakeholders identified for artist-scientist collaborations.

The most significant and overarching suggested action will be for the building of new semi-independent academic/industry/community institutions that provide real physical spaces, furnished with the necessary relevant equipment, where art-science collaborations can take place. We envision these as being community-based collective art-science organizations whose function is to serve as open access wet laboratories--not unlike the 'hacker spaces' that have appeared in many cities around the world, but that are focused more on the biological sciences, as opposed to engineering and computer science (though obviously a certain amount of crossover would be expected and encouraged).

I. For All Stakeholders

1. Support the creation of semiautonomous institutions--community-based wet labs--that provide support for artist-scientist collaborations and permit academic researchers to work outside their comfort zone, while free from significant worries about career advancement. Such institutions should ideally be situated in a neutral space and be outfitted with the equipment necessary for the artist and scientist collaborators to be able to draw from their disciplines and associated technologies. We propose that current hacker space organizations are a suitable model, but that there should be comparable organizations to support collaboration with all the scientific disciplines. For example, wet-lab hacker spaces for artist-biological scientist collaborations.

2. Pursuant to the above suggestion, limit as much as possible bureaucratic and institutional barriers to the founding and continued development of these institutions. Support decentralized, horizontal and community-focused organizational models.

II. For The Artist and Scientist Collaborators

1. Realize that your impression of your partner's discipline is probably incorrect, and enter the relationship as free of opinions and preconceptions as possible.
2. Realize that, although there may currently be career-advancement conflicts in many artist-scientist collaborations, such collaborations have historically been a great source of innovation. Innovations that you can carry you through their subsequent research career.
3. If you are engaged in an artist-scientist collaboration, take it upon yourself to educate your partner about your discipline and sub-discipline through readings and discussions. Educating your partner in the collaboration is critical to furthering the general goals of collaboration.

III. For Educators and Academic Administrators

1. Treat time spent within an artist-scientist collaboration as a criterion for career advancement in academic settings--both for artists and for scientists. Reward such risk taking, so that eventually it will no longer be risky and will be a standard element in career advancement schemes.
2. Universities should set up residency programs with established and to-be-established community-based wet labs, so that participants are given a clear record of their participation in the program (e.g., 'artist-in-residence' and 'scientist-in-residence' programs).
3. Acknowledge that much current innovation is occurring outside traditional laboratories, in (for example) community-based hacker spaces. Such existent organizations should be targeted as partner organizations, and new organizations should be founded to further innovation in those scientific fields where innovation is seen to be languishing.
4. Rework the assessment of academic accomplishment so that career advancement is not solely based upon numbers of publications in one's chosen field. Current career advancement mechanisms seem to favour non-innovative approaches (i.e., those approaches that yield higher publication numbers). Risk taking, exploration and innovation, in the form of artist-scientist collaborations or other activities, should be rewarded and not punished.
5. Support the creation of new academic journals (or the expansion of existing ones), based on the Leonardo model and the *PLoS* online publishing model (see www.plos.org/). Given that *Leonardo* (www.leonardo.info/) is already an excellent venue for general new media and art/science work, those new journals should be targeted at specific types of artist-scientist collaborative research.
6. Reward time spent in art-science collaborations with reduced teaching loads or comparable rewards, as is already done in certain universities to reward research productivity (usually measured by numbers of publications).

IV. For Foundations, Government Agencies, and Other Funders

1. Support the creation of new academic journals, as described above.
2. Allocate funds for the development of innovation through the support of specific art-science collaborations as well as the infrastructure to support those collaborations (e.g., community-based wet labs, new journals)
3. Institute granting programs that specifically call for artist-scientist collaborations--both at early and late stages of their careers. These grants could be used to fund residency programs in community-based wet labs, as described above.
4. Institute granting programs that reward time spent in art-science collaborations with reduced teaching loads or comparable rewards, as is already done in some current granting schemes.
5. Many grants are currently restricted to tenure-track University faculty. This restriction makes sense if one believes the tenure system to be an accurate means of assessing research ability. However, since the tenure system is biased against riskier forms of research that might not generate larger numbers of publications, this approach needs to be questioned. Accordingly, grants should be opened up to individuals and non-profit societies.
6. Review any current regulations and laws that might be restricting or hindering wet-lab experimentation outside of the traditional University laboratory to determine if those rules still have any merit or are justified. It is quite likely that these restrictions and laws are slowing innovation.

V. For Industry

1. Provide funding, in the form of grants, for artist-scientist collaborations, and for the the formation of community-based wet labs. Understand that such funding will lead to innovative approaches to problems that you, as an organization, can set forth as the topics of grants. Also realize that your specified "problem space" has not been fully explored and that new problems (or the re-casting of old problems) may sometimes be the results of these endeavors.
2. Engage with the semi-autonomous institutions we are proposing. For example, by allocating time for employees to participate in the management of these institution or as a members of an art-science collaboration.

VI. For the National Academies, Scientific and Artistic Societies

1. Undertake or fund a comprehensive review of the works created through art-science collaborations and evaluate the outcomes of those works. It would be good for those involved in art-science collaborations to be able to provide evidence to support any claims that such collaborations serve as a significant source of innovation. As discussed earlier in this paper, it is our suspicion that collaborations that we have labelled as "true" collaborations are more likely to be the source of innovative outcomes; this assertion needs to evaluated.
2. Undertake or fund initiatives (e.g. conferences, community events, etc) that foster further discussions and knowledge sharing between artists, scientist and local communities.
3. Fund resources that provide information to aspiring wet-lab hackers about alternate and cheaper sources of wet-lab equipment, and alternate forms of items commonly used in wet labs (e.g., many chemicals that are expensive when obtained from chemical suppliers can be obtained quite cheaply through garden and home centers).

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