EMBO reports

Are scientists a workforce? – Or, how Dr. Frankenstein made biomedical research sick

A proposed plan to rescue US biomedical research from its current 'malaise' will not be effective as it misdiagnoses the root cause of the disease

Yuri Lazebnik

"You manage things, you lead people."
Grace ("Amazing Grace") Murray Hopper, a pioneering computer scientist and US Navy Rear Admiral

Some time ago, I was reading *Science*'s Careers and cringed at the title "Can NIH renovate the biomedical workforce?". The problem was the word "workforce", since its Russian equivalent was used by the Communist Party leadership to describe other citizens of the Soviet Union—where I grew up—whom they viewed as mere cogs in a machine at the Party's disposal. Hoping that my past confused me into misreading the meaning of the English word, I sought clarity from my daughter, who grew up in the USA and graduated *cum laude* from Columbia University with a degree in English and Comparative Literature: she did not like the word either. Michael Joyner, my American (born and raised) colleague, removed any doubt by suggesting that the title could have been composed by an apparatchik, another Soviet term, as the word "renovate" is usually applied to things, not people.

I then realized that despite these connotations, the term "scientific workforce" is increasingly becoming a part of the discourse, not only among scientific editors and administrators, but also among some scientists. Perhaps tellingly, a letter to *Science* from a scientist that discussed the "scientific workforce" was printed next to a letter reporting that "plantation workforce is hired on a daily ad hoc basis" (http://www.sciencemag.org/content/346/6212/929.full.pdf). Given the fate of the Soviet Union, I asked how equating scientists to the plantation workforce could be expected to benefit science and hence society as a whole.

A clue came from a recent article by a group of prominent scientists and administrators proposing a plan for "rescuing US biomedical research from its systemic flaws", which, they argue, manifests as "the widespread malaise" [1]. The authors call on the scientific community to "rethink some fundamental features of the US biomedical research ecosystem" because "no less than the future vitality of US biomedical science is at stake." Noting the mentioning of "scientific workforce" in the plan led me ask whether the systemic flaw that felled the Soviet Union—the leadership–workforce system, with its top-down chain of command—might also be related to the systemic flaws that are taking a shot at the US science. This commentary is an attempt at an answer.

The malaise is indeed increasingly incapacitating and embarrassing. Its symptoms include poor reliability (in one report [2], only six out of 53 landmark cancer research studies could be verified, with the reliability of less prominent studies also questioned [3]), insufficient funding [1], an outdated funding system [4], the scarcity of opportunities for growth in science, depression among scientists (in one study, 60% of graduate students said they feel overwhelmed, exhausted, hopeless, sad, or depressed nearly all the time and 10% contemplated suicide within the last year; http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2014_02_04/caredit.a1400031), and "doused passion" [5]. The severity of the malaise varies depending on the field of study, the institution, the individual laboratory, and individual scientist. However, the overall condition has invoked the image of the Titanic approaching its iceberg [6], a situation that indeed calls for a rescue plan. I would like to suggest, however, that the proposed plan is unlikely to be effective because it has misdiagnosed the disease.

> *"I asked how equating scientists to the plantation workforce could be expected to benefit science and hence society as a whole."*

According to the plan: "the root cause of the malaise is a longstanding assumption that the biomedical research system in the United States will expand indefinitely at a substantial rate. We are now faced with the stark realization that this is not

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the case. [...] the current system is in perpetual disequilibrium, because it will inevitably generate an ever-increasing supply of scientists vying for a finite set of research resources and employment opportunities" [1]. Hence, the plan proposes that supplying more money and slowing the "supply" of scientists should cure the malaise.

> *"Although the imbalance between money and scientists is indeed a problem, it is unlikely to be the root cause of the malaise."*

Although the imbalance between money and scientists is indeed a problem, it is unlikely to be the root cause of the malaise. First, the malaise began to develop before the recent rise in the NIH funding, which nearly doubled its budget (Fig 1). Second, funding had seen its previous periods of stagnation (Fig 1) without leading to malaise. Third, the malaise is not limited to biomedical research or to the USA, which suggests a more general cause. Finally, and most importantly, the plan does not explain *why* the heads of scientific institutions have assumed for so long that "the biomedical research system in the United States will expand indefinitely at a substantial rate." Indeed, the assumption that something tangible can expand exponentially endlessly is the foundation of market bubbles and is associated with crowd behavior, not with outstanding analytical minds.

There is an alternative diagnosis (Fig 2) not mentioned in the plan, but which is detailed in books with telling titles such as *University, Inc. The Corporate Corruption of Higher Education*, *The Fall of the Faculty: The Rise of the All-Administrative University and Why It Matters*, and *The Last Professors. The Corporate University and the Fate of the Humanities* (see Further Reading). These books argue that the root cause of the malaise is the attempt to apply business models of operation to basic science, clinical research, and clinical medicine. This diagnosis, which I will call the businessification of science, or businessification for short, is not marginal, as many scientists would confirm.

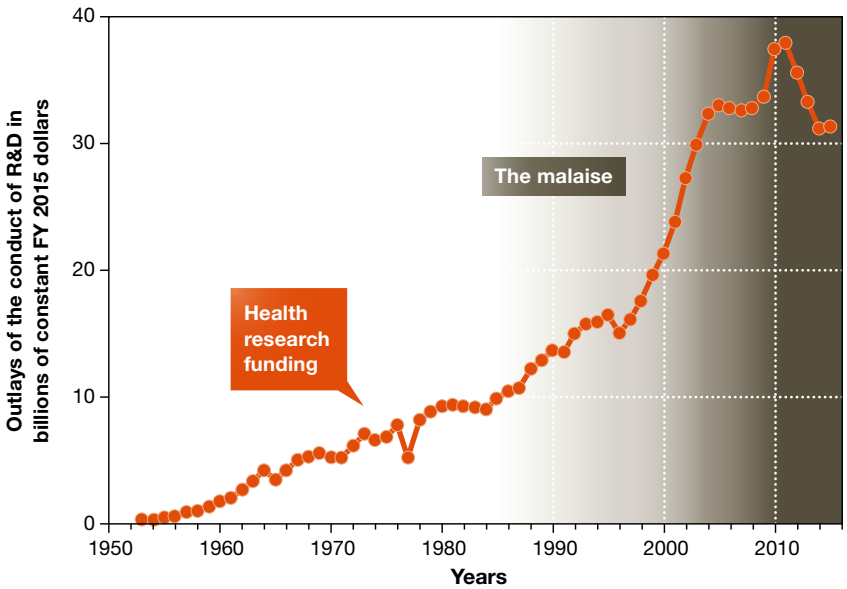

Figure 1. The increase of the federal funding for health-related research and the timing of the malaise.
The shading indicates the increased severity of the disease, the beginning of which is difficult to time precisely owing to the complexity of the condition. I placed it conservatively to the late 1980s–early 1990s based on the estimate of the rescue plan, other publications on this topic, conversations with scientists, and my own experience. Funding data are from: http://www.aaas.org/page/historical-trends-federal-rd#Overview (see "By Function: Nondefense Only, 1953–2016").

When symptoms can be caused by more than one disease—a headache can be caused by stress, vision problems, or a brain tumor—physicians do what they call differential diagnosis by systematically analyzing the signs supporting one diagnosis or excluding another. Otherwise, a doctor may end up prescribing new eyeglasses to a patient who needs brain surgery.

How can we differentiate between the two proposed diagnoses: the imbalance between the money and the number of scientists (the money imbalance), and the businessification of basic science? The money imbalance implies that a decrease in funds has caused the malaise precisely because the biomedical research ecosystem is organized according to traditional rules. Businessification implies the opposite: that the malaise resulted from deliberately abolishing the traditional rules of basic science and replacing them with the rules of business, thus making the system less robust. Keeping this in mind, I analyzed the plan beginning with the chapter "Supporting the Next Generation of Scientists", as one can tell volumes about a system by learning how it treats its most vulnerable members.

The plan summarizes a report prepared for the NIH by a committee co-chaired by one of the authors of the plan (http://acd.od.nih.gov/biomedical_research_wgreport.pdf). The report begins with a quote from *Science, the Endless Frontier* (http://www.nsf.gov/about/history/vbush1945.htm), a document widely credited for the success of US science over the past 70 years. It was prepared in 1945 for President Franklin Roosevelt by Vannevar Bush, an MIT professor, engineer, and science administrator who supervised most of the US military research during WWII, including the Manhattan Project and the mass production of penicillin. The quote reads: "The Government should provide a reasonable number of undergraduate scholarships and graduate fellowships in order to develop scientific talent in American youth. The plans should be designed to attract into science only that proportion of youthful talent appropriate to the needs of science in relation to the other needs of the nation for high abilities."

This quote was consistent with the main idea of the NIH report—the need to balance funds and scientists—which could explain the choice of the quote. However, by reading *Science, the Endless Frontier* in its entirety, I

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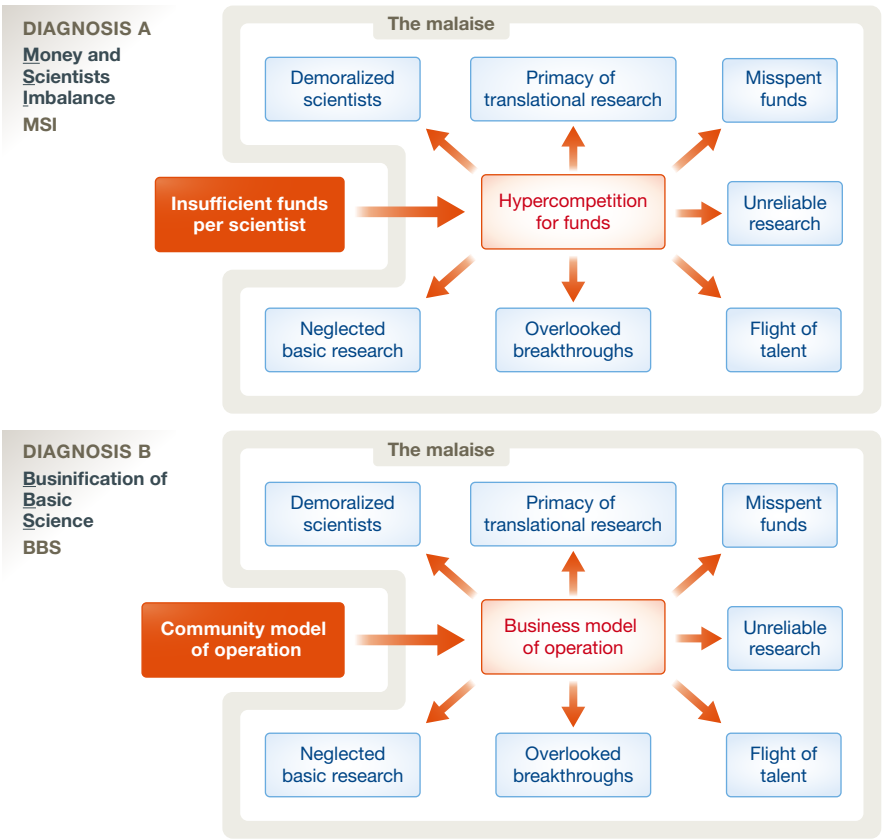

Figure 2. Two diagnoses for the malaise.
(A) Insufficient funding causes hypercompetition for money, which leads to the malaise: increased emphasis on medical-related research at the expense of fundamental research, poor reliability of results, insufficient support for breakthrough ideas, doused passion of young researchers, the reluctance of new talent to join biomedical research, etc. (B) The malaise is caused by reorganizing basic science according to business models.

learned that the quote was an afterthought to Bush's main argument about the primacy of science and that his vision reached far beyond counting scientists. I also understood that this old governmental document was so successful not only because it outlines a plan for developing US science, but also because it inspires by explaining how scientists and science work.

Bush emphasized that "Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown…" and noted the complexity of developing scientific talent because "no one can select from the bottom those who will be the leaders at the top because unmeasured and unknown factors enter into scientific, or any, leadership. There are brains and character, strength and health, happiness and spiritual vitality, interest and motivation, and no one knows what else, that must needs enter into this supra-mathematical calculus." This language might be considered fanciful by today's standards, if not for the reputation of the author and the success of his vision.

The language of the NIH report, to which I now return, is different, beginning with the title: "Biomedical Research Workforce Working Group Report." I learned that the committee "was tasked with developing a model for a sustainable and diverse U.S. biomedical research workforce" because "successful biomedical research relies on the talent and dedication of the scientific workforce", and found that "the level of PhD *production* in 1998 exceeded the availability of jobs" [emphasis mine]. The "conceptual frameworks were developed to provide static models of the workforce—one each for the PhD and the MD and MD-PhD workforces…" that it "is absolutely essential to creating a well-prepared pipeline of individuals for NIH's programs." After finishing reading the NIH report, I felt that merging "scientific talent" with "workforce" created "scientific workforce" by leaving out "talent".

But does language matter? Can it be used to evaluate a community? I share the view that it can, because it can reveal what we actually think and explains how we influence others. If reading *Science, the Endless Frontier* left me proud that I am a scientist and taught me how a vision can turn problems into lasting success, the NIH report has left me confused. On the one hand, the authors are clearly concerned about the fate of their younger colleagues. On the other hand, I could not avoid the impression that the report considers young scientists not as unique creative individuals with "brains and character, strength and health, happiness and spiritual vitality, interest and motivation, and no one knows what else", but as colonies of laboratory mice that need to be maintained at a low cost, propagated in needed quantities, and trained for use in the laboratory. The sense of detachment, if not alienation, between the report and the people whose fate it discusses was reinforced by my failure to find graduate students or postdoctoral fellows among its authors or reviewers. Two representatives of the National Postdoctoral Association did attend a meeting of "stakeholders" and the "perception of being perceived as cheap labor" was noted in the responses to the request for information issued by the committee. Was this perception justified?

What kind of perception would young scientists have if their role models describe them not as colleagues in exploring the endless frontier, but as an economical workforce that should be *produced* through a yet-to-be-improved pipeline in the quantities required to satisfy the demand of the stakeholders without disturbing the balance of supply and demand? Would they not realize that viewing them as a workforce—cheap labor, as they might read it—is now an official policy, not the personal view of an odd laboratory head? Would they find this confirmation inspiring, or would it douse their passion? How would the absence of passion, the resentment for having it extinguished, and a sense that their purpose has been stolen from them affect the biomedical ecosystem and the reliability of research at a time when

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the heads of laboratories are forced to spend most of their time writing grant applications and are thus absolutely dependent for their livelihood on what, how, or whether the "workforce" discovers or imagines?

> *"... I felt that merging "scientific talent" with "workforce" created "scientific workforce" by leaving out "talent"."*

Overall, it was difficult to avoid the conclusion that a key link that holds the biomedical ecosystem in balance—the relationship between the senior and young scientists—has changed, and not to the better. Could this change be explained solely by the money imbalance? I doubt it, as the change was already underway when funding was still increasing (http://acd.od.nih.gov/biomedical_research_wgreport.pdf) and because depending on people and their relationships difficulties can bring people together, not only pull them apart. However, the diagnosis of businessification also seemed unlikely, as I thought that treating people as a workforce might work in a diamond mine, but not if diamonds are ideas, observations, and discoveries. Why would anyone use such a model?

I turned for answers to the book *Zero To One: notes on startups, or how to build the future* by Peter Thiel, as I thought that his main advice, to create something entirely new (Zero to One) rather than replicate something known (One to *n*), also applies to science. The author's reputation makes his advice worth considering. Thiel has degrees in philosophy and law from Stanford University, cofounded PayPal at the age of 31, sold it 4 years later for US$1.5B, and cofounded Palantir, a $20B company at the time of writing. He was the first outside investor to put money into Facebook, has invested in hundreds of businesses, and founded the Thiel Foundation to support "bold thinkers who pursue unrecognized truths." His PayPal cofounders went to start companies such as Tesla, SpaceX, LinkedIn, Yelp, and YouTube, testifying to the exceptional talent Thiel attracted.

Given such track record, I was pleasantly surprised to find no mention of "workforce" in the book and thought that this term may be not as mandatory in business as the writings of biomedical scientists have led me to assume. Instead, Thiel's language is not unlike Bush's when it comes to the value of talent. The book advises that "talented people don't *need* to work for you; they have plenty of options [emphasis Thiel's]" and suggests to attract talent by offering people "the opportunity to do irreplaceable work on the unique problem alongside great people" and by explaining "why your company is a unique match for him personally [emphasis mine]". Thiel concludes that, "for the company [PayPal] to work, it didn't matter what people looked like or which country they came from, but we needed every new hire to be equally obsessed." Hence, according to Thiel, treating people as mere tools was not a recipe for success in an innovative and highly profitable business.

This advice led me to ask what kinds of models were used to businessify basic research. I noted that the word "pipeline", which was often used in the NIH report, is part of pharmaceutical corporate jargon, although there it refers to prospective drugs, not people. If pharmaceutical corporations were chosen as a role model to businessify science, which is what some books suggest, then Thiel has some cautionary advice. He reminds us that pharmaceutical companies live by the Eroom Law (Moore spelled in reverse; the Moore law roughly states that the computer power *doubles* every 2 years). The Eroom law states that the number of drugs approved by the FDA has *halved* every 9 years since 1950 [7]. If we consider the facts that some recent drugs are barely better than placebo (http://www.nybooks.com/articles/archives/2009/jan/15/drug-companies-doctorsa-story-of-corruption/) or require a search for a disease they can help, and some succeed by accident rather than by design (http://archive.cosmosmagazine.com/features/how-i-discovered-viagra/), the trend is even more worrying. Although multiple factors are likely to contribute, Thiel contrasts "committed entrepreneurial hackers" of software companies to "high-salaried, unaligned lab drones" of biotech. It is not a pleasant comparison, but does the insulting "lab drones" differ much from the matter-of-fact "laboratory workforce"?

One can argue that I am painting an overly dark picture, as there are still many laboratories where young scientists "live their dream" in the best sense of this expression. The key word is "still". If the malaise continues, people will come to view this disease as normal. The key question is whether someone who has been treated as cheap labor for a decade of apprenticeship can remain an independently thinking and adventurous scientist. Perhaps those in whom the brilliance of mind is coupled to the hardness and resilience of their character can make it, if they decide it is worth it. Others would drop out, embrace the malaise, or lose their minds. Who, then, will find the cure for cancer?

To summarize the first stage of my differential diagnosis, I found that the relationship within the ecosystem changed from one of advisors, trainees, and colleagues to that of a workforce and its users. This change is difficult to explain solely by money shortages, but it can be explained if we assume the advisors adopted a new behavioral model, likely of corporate origin; a possibility that favored the diagnosis of businessification. I began to suspect, however, that the diagnosis could be more complex because business models are not all alike, as Thiel demonstrates. Hence, I continued my diagnosis by turning to the relationship between the senior scientists (the faculty) and their superiors and thus to the chapter of the plan entitled "Damaging Effects of Hypercompetition".

> *"The key question is whether someone who has been treated as cheap labor for a decade of apprenticeship can remain an independently thinking and adventurous scientist."*

The plan suggests that an immediate consequence of the imbalance between funding and the number of scientists is "hypercompetition for the resources and positions", which "suppresses the creativity, cooperation, risk-taking, and original thinking required to make fundamental discoveries [...] The system now favors those who can guarantee results rather than those with potentially path-breaking ideas that, by definition, cannot promise success" [1].

Indeed, Brian Silver, a professor at Technion, noted in his book, *The Ascent of Science*, that "The struggle between old and

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new has rarely been dignified. Scientists come in many colors, of which the green of jealousy and the purple of rage are fashionable shades. The essence of scientific history has been conflict." Maybe this is why the legend that Pythagoras had a member of his school drowned for revealing a fundamental flaw in Pythagoras' model has endured throughout millennia. Has anything changed lately to explain the emergence of the malaise? Is it only the scarcity of money, which would indeed increase the intensity of the competition, or is it that the rules of the competition also changed? Indeed, a championship basketball game is more intense than a game at a park, but either would look different if played by the rules of American football. To find an answer, I again compared then and now.

Vannevar Bush advised that, "At their best [medical schools and universities] provide the scientific worker with a strong sense of solidarity and security, as well as a substantial degree of personal intellectual freedom. All of these factors are of great importance in the development of new knowledge, since much of new knowledge is certain to arouse opposition because of its tendency to challenge current beliefs or practice." Does this description fit the current environment in our scientific institutions?

While some faculty consider young scientists as an economical workforce, the irony is that the advisors themselves have become viewed as a workforce by their superiors, the administrations of the institutions (Fig 3). Accordingly, top administrators now officially call themselves the leadership to emphasize that they no longer merely manage the institution to support research, but lead scientists, which implies telling them what to do. The leadership includes administrators who supervise finances, information technology, recruitment, public affairs, buildings and grounds, and other parts of the infrastructure, which means that the people whose job previously was to *serve* scientists are now leading them. With all due respect to these much-needed services and their providers, this change does put the cart before the horse, a rearrangement that stalls both.

Such a system, in which the chain of command is a familiar term, is naturally prone to becoming a matryoshka doll of "us" and "them", with the inevitable of "us" vs "them", in which only the outermost layer is not in the dark. Economists call this process dualization, which "is the strengthening of this divide between insiders in secure, stable employment and outsiders in fixed-term, precarious employment" (http://blogs.lse.ac.uk/impactofsocialsciences/2013/12/11/how-academia-resembles-a-drug-gang/). The outsiders now increasingly include faculty. During the past three decades, the number of administrators at the institutions of higher education grew 16 times faster (369 to 23%) than that of tenured or tenure track faculty, the salaries of top executives grew two-to-three times faster than that of professors, and the institution of tenure, which provided job security for faculty, has been steadily driven into extinction (http://www.aaup.org/reports-publications/2013-14salarysurvey). An extreme example of this dualization was the case of Professor Stefan Grimm, who committed suicide not because he failed as a scientist, but after his administrators at Imperial College London, UK, not the abstract "system", informed him that he either had to raise more money or look for work elsewhere (http://www.timeshighereducation.co.uk/news/stefan-grimm-inquest-new-policies-may-not-have-prevented-suicide/2019563.article). Is dualization a recipe for success for an activity that requires the utmost concentration of the mind and spirit? I learned about dualization from an article by an economist, who introduced the concept by comparing the structure of academia to that of a drug gang (http://blogs.lse.ac.uk/impactofsocialsciences/2013/12/11/how-academia-resembles-a-drug-gang/). Where are we going if we are inviting comparisons to lab drones and drug dealers? Is it merely because we do not have enough funding?

How did it happen that the self-organizing and self-maintaining system of *Science, the Endless Frontier* was replaced with the chain of command (Fig 3)? The transition had to be deliberate, as institutional policies are designed and implemented by people with authority, not by an abstract system or spontaneous evolution. Indeed, the cited books and articles provide examples of how it happened, but even without reading these books, one can identify the role model by asking why some directors of scientific institutions rebranded themselves as CEOs with the titles such as CFO, COO, and CIO assigned to their immediate subordinates? Could this change in appearances and the underlying thinking be explained by the

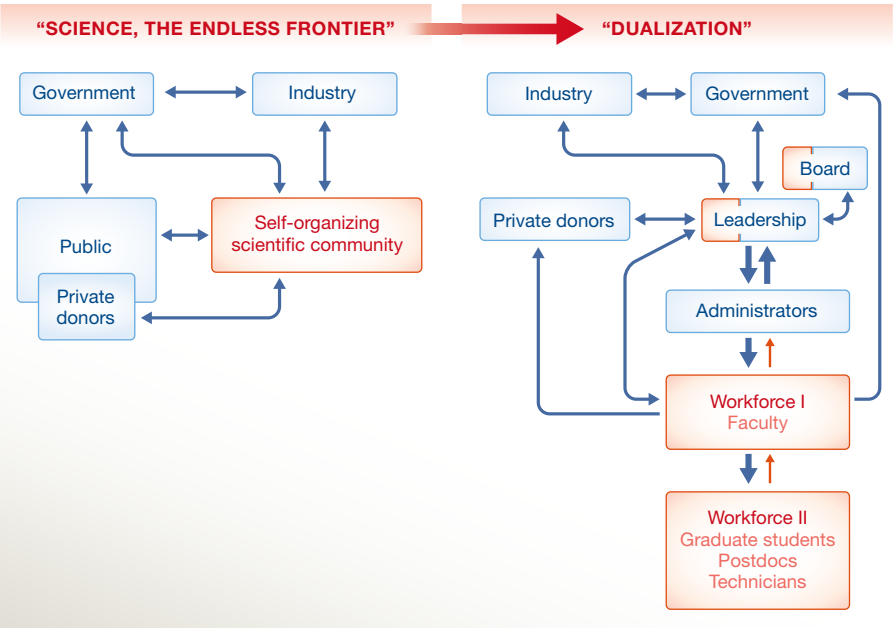

Figure 3. Two models for organizing basic science research: the traditional model (left) and the current model (right).
The arrows indicate the interactions between the parties, with the thickness of the lines proportional to the extent of the interactions. The red boxes indicate the parties composed primarily of scientists. Note that the representation of scientists in the "leadership" and "board" varies from a majority to a minority (depicted).

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imbalance of money and scientists, or does it reflect a wish to run scientific institutions as a business? I favored the latter explanation and proceeded to analyze the next symptom of the malaise, the prevalence of translational research.

> *"While some faculty consider young scientists as an economical workforce, the irony is that the advisors themselves have become viewed as a workforce by their superiors . . ."*

The plan suggests that the imbalance and the consequent hypercompetition lead to "the inflated value that is now accorded to studies that claim a close link to medical practice", which "is detracting from an equivalent appreciation of fundamental research of broad applicability." This statement describes the problem, but leaves unexplained who, when, and why inflated the value. Some answers can be found in the studies that date the emergence of the problem to the times preceding the latest crunch of NIH funding by decades.

Bush presciently warned that: "Basic scientific research should not, therefore, be placed under an operating agency whose paramount concern is anything other than research. Research will always suffer when put in competition with operations." To put it in contemporary terms: if earning money gains priority, and the director of a scientific institution becomes its Chief *Operating* Officer, basic research suffers. From the operational perspective, a patent related to medicine can bring millions if not billions of dollars to the institution, while wondering why petunias have colored patches may appear to be a waste of much-needed resources (to note, the petunia led to the discovery of RNA interference, a breakthrough that has affected many areas of medicine, from viral infections to cancer). From the operational perspective, funding from the pharmaceutical industry is a gift from heaven, but this gift comes with an implied or explicit focus on research related to medicine. Do we need to look for other explanations for the primacy of translational research beyond those indicated by Bush in his warning?

After reviewing this symptom, I felt that sometimes what is not mentioned can tell more about a problem than what is, and concluded that the prevalence of translation research can be easily explained by businessification. The next symptom—an unsatisfactory reliability of biomedical research—was more difficult to understand.

> *"The leadership of scientific institutions realized that using these bonuses to construct buildings would allow them to hire more researchers to bring more bonuses to build more buildings and so on."*

According to the plan, the hypercompetitiveness and the consequent pressure also cause a decline in the reliability of biomedical research, a problem that has come to the attention of the federal government [8] and even the mass media (http://www.nytimes.com/2014/01/21/science/new-truths-that-only-one-can-see.html). But can the pressure alone explain this problem? Although high pressure does contribute to mistakes and increases the temptation to cut corners, is it the primary cause? The projects that Bush supervised during the war show that scientists can work under pressure and may even enjoy it if it has a meaningful purpose. Hence, I thought that the money imbalance was an unlikely explanation for this symptom of the malaise. The businessification also seemed unlikely because why would a business model promote the production of faulty products? The suspicion that I miss a yet-to-be-identified cause, a third diagnosis was reinforced by analyzing what is called in the plan "Perverse Incentives in Research Funding".

The US federal government and many other funding agencies complement each research grant with a "bonus" of 20%–85% of the grant amount, to cover the so-called indirect costs of research, including construction and the maintenance of buildings, utilities, and administration [9]. The leadership of scientific institutions realized that using these bonuses to construct buildings would allow them to hire more researchers to bring more bonuses to build more buildings and so on. The opportunity to hire more administrators and to increase their salaries was an additional benefit. Once funding decreased, revealing that "[…] the building boom is now costing the scientific enterprise by creating space that cannot be paid for." [9], the bonuses were renamed into "perverse incentives" [1,9] "because they encourage grantee institutions to grow without making sufficient investments in their own faculty and facilities" [1]. One can argue, however, that an incentive does not imply an obligation to use it, as otherwise someone who spends food money on alcohol could complain that the liquor store had a sale. Hence, using the federal incentive could hardly be explained by businessification, as pouring money into buildings at the expense of the people on whom the business depends indicates poor management rather than a particular operational model. Indeed, as a management consulting firm concluded after inspecting the institutions of higher learning, "In no other industry would overhead costs be allowed to grow at this rate—executives would lose

Sidebar A: Further reading

Bruner RF (2005) *Deals from hell: M & A lessons that rise above the ashes.* Hoboken, NJ: Wiley

Chase S (1959) *The tyranny of words.* New York: Harcourt, Brace

Hall N (2012) Why science and synchronized swimming should not be Olympic sports. *Genome Biol* 13: 171–172

Comroe Jr JH, Dripps RD (1974) Ben Franklin and open heart surgery. *Circ Res* 35: 661–669

Donoghue F (2008) *The last professors: the corporate university and the fate of the humanities*, 1st edn. New York: Fordham University Press

Ginsberg B (2011) *The fall of the faculty: the rise of the all-administrative university and why it matters.* Oxford: Oxford University Press

Shelley MW (2008) *Frankenstein, or the modern Prometheus.* Oxford: Oxford University Press

Silver BL (1998) *The ascent of science.* New York: Oxford University Press

Thiel PA, Masters BG (2014) *Zero to one: notes on startups, or how to build the future.* New York: Crown Business

Washburn J (2005) *University, Inc.: the corporate corruption of American higher education.* New York: Basic Books

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their jobs" (http://www.bain.com/Images/BAIN_BRIEF_The_financially_sustainable_university.pdf). This conclusion led me to the final diagnosis, which I will call the hybrid system dysfunction, or the Frankenstein problem.

Business and basic science are complex systems that have evolved over centuries side by side in continuous and often unpredictable interaction. The discovery by Galvani that a dissected frog leg twitches when it simultaneously touches two metals led Volta to develop the first practical generators of electricity. These devices enabled research into electricity and electromagnetism, and their practical applications, from the light bulb to the computer. More recently, asking why some cobs of corn have a mixture of differently colored kernels led Barbara McClintock to discoveries that enabled a revolution in agribusiness. In turn, business owners founded and funded scientific institutions named after them—Johns Hopkins, Yale, Stanford, Carnegie, and others—and have sponsored research in other ways, a tradition that continues. The heroes of innovative business and science share a knack for identifying key problems and an obsession with finding a solution, testifying to the commonality of how creative people, whatever they do, think, and act.

Yet, business and basic science have operated by different rules that are determined by the primary purpose of each system.

The primary purpose of a business is to generate monetary profit for its owner(s) (Fig 4). This purpose has defined the basic rules of business. First, profit is the universal and quantitative measure of how or whether a business serves its purpose. However noble its goal, however committed its owners, or whatever the prior achievements of management, the business dies unless it produces a profit or finds a subsidy. Second, the universal model of operation is to sell whatever can be sold for a profit, be it virtual powers in a video game or real power plants. Third, within the law, the owners have the final say on how their business is run and what it does.

The purpose of scientific research is to make verifiable discoveries, whether they have a commercial value or not (Fig 4). The primacy of discovery has defined how basic science is organized as a system. First, scientists are measured by the discoveries they made and by their perceived potential to make more of them. This measure, known as reputation, was the glue that held the components of the system together. Second, the reputation of scientific institutions has been measured by their ability to enable discovery, both by attracting discoverers and by providing a helpful environment.

> *"As systems theory suggests, and as Dr. Frankenstein belatedly learned, merging complex systems is inherently prone to produce unexpected results"*

The question is, what would happen if someone decided to switch the purpose in either system? To give an example, let us assume that the captains of industry decide that profit is no longer the primary purpose of business; it is discovery. What would happen to the market forces that determine what is produced, how, and when? What would the people who are in it to make money think and do? The entire system would look ridiculous and horrifying at the same time. This is not an abstract example, as this is exactly what happened in the countries subjected to communism, an ideology that makes profit, private property, and private enterprise illegal. It is enough to mention that when my family was leaving the Soviet Union in 1991, each person in our city had ration stamps to buy ten eggs, two kilos of meat (bones included), a kilo of sugar, and 200 g of butter per month. The rest had to be found in the empty stores. It

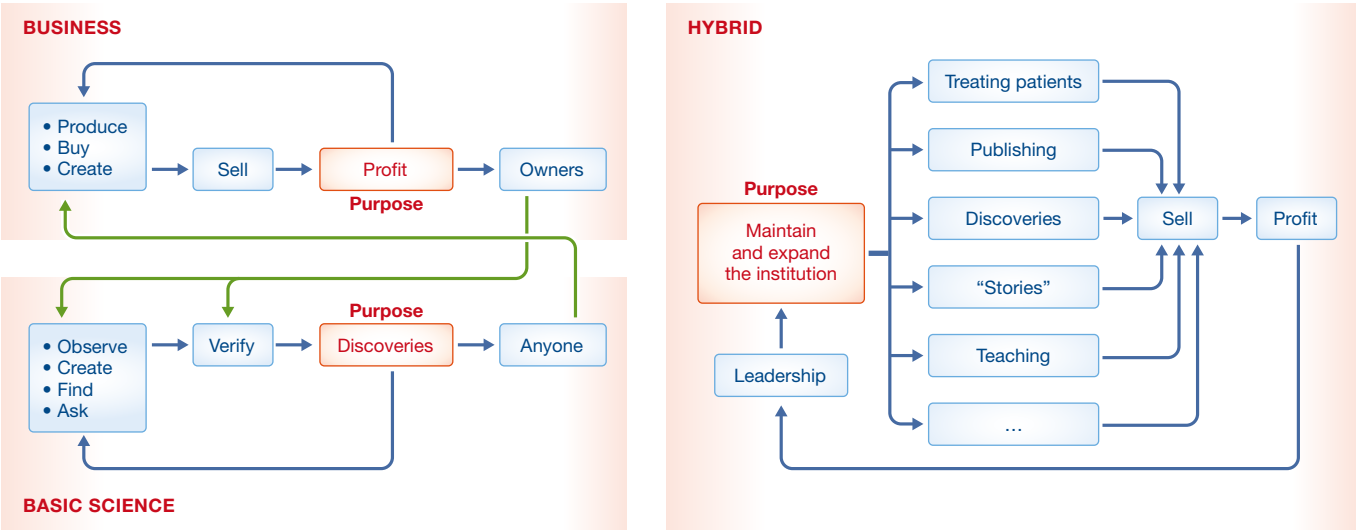

Figure 4. The current operational model of scientific institution as a hybrid of business and basic research models.
The flow charts depict basic organization of the three models and its main components, with the purpose of each highlighted in red. The green lines show the traditional interconnection between business and basic science. Note that both the purpose of the hybrid and its structure are different from that of either of the parental systems, a phenomenon observed in hybrid systems.

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took just a few years of legalized profit to make these shortages history.

> *"A correct diagnosis might help to understand what these interests are and help scientists, funders, administrators and policy makers act accordingly, using both therapy and surgery."*

Now, imagine what would happen if the captains of science decided that the primary purpose of basic research is not discovery, but profit. The system would also look ridiculous and horrifying. What would those who grew up dreaming of becoming great discoverers think, feel, and do? If reputation based on discovery is no longer the currency, then how should funding be allocated? Hence, the search for surrogates to fill the void—the number of papers published, the number of citations, citation indexes, impact factors, formulas to calculate their relative values, and all other administrative inventions to keep the system operating—with the ultimate measure being the money that scientists can bring in. If discovery is no longer the primary purpose and finding true answers to nature's questions remains as hard as it is, would the people who accept the first convenient finding for the answer have an advantage in securing funding? Would the people who cannot trade their integrity leave science or decide not to come in? If discovery is secondary, is it surprising that the traditional model of operation—discover something, verify, convince colleagues (including reviewers) with evidence, publish to secure your credit as the discoverer and letting others know about it, use your credit to get grants, repeat—would change to something different: come up with a nice story, sell it to the reviewers and editors, use the publication as a voucher to get grants to produce more nice stories. If science is a business, why would it matter what is sold? A loss of the sense of purpose can send a person into a tailspin. The same can happen to an institution, to a part of a society, or to society as a whole.

However, I could not see the current scientific institution as a business. What I saw was a creature not unlike that made by Dr. Frankenstein and which turned onto its creator: neither traditional science nor business, as it is made from incompatible parts taken from both bodies with good intentions but not much forethought (Fig 4). Indeed, if this creature is a business, does it make a profit? If it does not, why is it still in business? If it is a business, why are some of its workers engaged in non-commercial research? If it is an institution of basic science, why does it put money before everything else? If it is a business, who owns it? If it is a scientific institution, why has the management assigned itself the role of owners? If it is a business, what does it sell? If it is a scientific institution, why is it involved in selling something? If it is a business, why are the CEOs fired so rarely? If it is a scientific institution, why does it have a CEO? If it is a business, why does the CEO keep his job if the company makes unreliable products? If it is a scientific institution, why does it no longer strive to produce only truth? To avoid the word "Frankenstein", I would call this hybrid entity pseudo-business, by analogy to pseudoscience, which is an activity that pretends to be science but does not follow its basic rules. If this hybrid has any purpose, it is to maintain and expand itself.

As systems theory suggests, and as Dr. Frankenstein belatedly learned, merging complex systems is inherently prone to produce unexpected results [10]. An example outside of fine literature is business mergers, which have a failure rate of 80–90% despite all the planning, managing, good faith of the parties, and the scores of previous examples to study. As a general rule, the more different the systems are, the more likely their hybrid would have unexpected properties. The differences between business and basic science are difficult to miss, making the malaise a predictable outcome. To put it broadly, merging love and profit has a danger of leading to prostitution.

Is my differential diagnosis of any practical use? I hope so, because as in medicine, solving social and behavioral problems—and the malaise is one of them—depends on a correct diagnosis. The recommendations of the current rescue plan tell the parties involved what they should do, using the word "should" 21 times [1]. However, people tend to refuse, ignore, or stall a request unless they perceive it as consistent with their interests. A correct diagnosis might help to understand what these interests are and help scientists, funders, administrators, and policymakers act accordingly, using both therapy and surgery. If my diagnosis is correct, the preamble to a successful rescue plan would say: "The root cause of the malaise was our decision to run basic science as a business. This approach has failed. Perhaps high fences do make good neighbors. Let's learn from our mistakes and start building the basic science of the future."

Will the scientific community ever hear this announcement? I do not know. The ship is titanic in size, the inertia is comparable, the captains' quarters are comfortable, and the crew and passengers have come to assume that they have as much leverage as they would on a military ship. I hope they will reconsider. I also hope that the Carnegies, Stanfords, and Hopkinses of today, perhaps with some help from the government, will build new ships, perhaps smaller, but more agile and steered by crews who are not afraid to sail in uncharted waters. Vannevar Bush has proven advice on how to do it right and there is plenty of outstanding young talent ready to come aboard. Finally, I hope that you will also do something. Otherwise, we might end up carrying smartphones that are more powerful than the supercomputers of the recent past, but keep dying of cancer or turn senile prematurely, whether we are part of the workforce, leadership, scientists, or successful investors.

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Conflict of interest

The author declares that he has no conflict of interest.

References

1. Alberts B, Kirschner MW, Tilghman S, Varmus H (2014) Rescuing US biomedical research from its systemic flaws. *Proc Natl Acad Sci USA* 111: 5773 – 5777
2. Begley CG, Ellis LM (2012) Drug development: raise standards for preclinical cancer research. *Nature* 483: 531 – 533

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3. Begley CG (2013) Six red flags for suspect work. *Nature* 497: 433 – 434
4. Nicholson JM, Ioannidis JP (2012) Research grants: conform and be funded. *Nature* 492: 34 – 36
5. Kern SE (2010) Where's the passion? *Cancer Biol Ther* 10: 655 – 657
6. Bourne HR, Lively MO (2012) Iceberg alert for NIH. *Science* 337: 390
7. Scannell JW, Blanckley A, Boldon H, Warrington B (2012) Diagnosing the decline in pharmaceutical R&D efficiency. *Nat Rev Drug Discov* 11: 191 – 200
8. Collins FS, Tabak LA (2014) Policy: NIH plans to enhance reproducibility. *Nature* 505: 612 – 613
9. Stephan P (2012) Research efficiency: perverse incentives. *Nature* 484: 29 – 31
10. Koulakov AA, Lazebnik Y (2012) The problem of colliding networks and its relation to cell fusion and cancer. *Biophys J* 103: 2011 – 2020

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