mechanics

Academia Americana de Mecánica • American Academy of Mechanics

Volume 32, Number 11-12 November-December 2003

(references in the form "M28(3-4)" indicate the last time the Journal was cited in *mechanics:* v. **28**, n. 3-4, in this case.)

mechanics

mechanics provides its readers with news in the field of theoretical and applied mechanics, and serves as a forum for the presentation and discussion of issues related to the development of the science and profession of mechanics. Opinions expressed are those of the authors and do not necessarily reflect official points of views of AAM or the institutions with which the authors are affiliated.

The *American Academy of Mechanics* is a non-profit corporation incorporated in 1969 under the laws of the Commonwealth of Pennsylvania. Its objective is to advance the science and profession of mechanics, with particular reference to the countries of North, South, and Central America. It aims to facilitate cooperation among mechanicists, to encourage recognition of achievements in mechanics, and to promote public understanding of the work of the mechanicist.

mechanics (ISSN 0076-5783) **POSTMASTER:** Send address changes to *mechanics*, Subscription and Membership, ESM, MC 0219, Virginia Tech, Blacksburg, VA 24061 (Tel. 540-231-6871: Fax 540-231-2290). Editorial and Advertising: Horacio D. Espinosa, Northwestern University, 2145 Sheridan Rd., Evanston, IL 60208-3111 (Tel. 847-467-5989, Fax 847-491-3915). Membership in the American Academy of Mechanics includes the subscription to *mechanics*.

American Academy of Mechanics
Academia Americana de Mecánica

LETTER FROM THE EDITOR

Dear AAM Member,

I am writing to bring to your attention a very provoking and insightful book on the current state of affairs at USA Universities concerning the commercialization of intellectual property. The book is entitled "Universities in the Marketplace: The Commercialization of Higher Education" by Derek Bok, ex-president of Harvard University.

You may remember that we published an excerpt of the book by Rosalind Williams, entitled *Retooling: A Historian Confronts Technological Change* in the January-February 2003 issue of *Mechanics*. Williams' book provided an excellent description of the changes in engineering education and the benefits arising from these changes. Bok's book is broader in scope but equally compelling.

I believe you would agree that university life is being transformed at a very fast pace. Many technological developments such as the Internet, wireless and instant communications are in part responsible for the globalization of education, research, and businesses. These in turn impact academic life in a profound way. Likewise, the potential of research and development in emerging areas such as Nano and Biotechnology, which is forecast to have a major impact on society, is a main driving force for universities to attempt to capture part of the emerging market. However, some of the changes resulting from these activities may have negative connotations that may be difficult to reverse. The challenge is identifying which changes are positive and what policies need to be instituted by faculty and administrators to resist the temptation for excessive and inappropriate commercialization of higher education. Bok provides an excellent and well-documented perspective in this regard. His book starts by defining the current and historical development of commercialization of higher education in the areas of education, research, and intercollegiate sports. Subsequent chapters provide an analysis and specific solutions based on his extensive experience and exposure to these aspects of academic life. His analysis and ideas could be invaluable to administrators that need to deal with conflict of interest, excessive research secrecy due to entrepreneurial activities, allocation of resources, etc. Likewise, they are very useful to the faculty that needs to contribute to emerging technologies within the framework of policies instituted by the federal and local governments.

In Bok's book a strong emphasis is placed on the history of commercialization at universities driven by intercollegiate sports and the drug industry, i.e., pharmaceutical companies. One could argue that a similar environment for commercialization arises from the establishment of the National Nanotechnology Initiative (NNI) of which mechanicians could play a significant role. The appetite for profit based on discoveries from nano science and engineering are clearly visible and will certainly impact the work experience of academicians. Essentially, different commercialization forces will be dominant in a given period; however, the issues, concerns and challenges remain unchanged over the years.

I found Bok's book extremely enjoyable to read, in part because it reaffirmed my understanding and convictions in relation to education, research and service, and in part because the book is written with simplicity and it is based on factual information. I hope the chapter we publish in this issue of mechanics will be equally appealing to you and will stimulate your desire for further reading. A review of the book, by David Baltimore, president of Caltech, is also published in this issue.

Sincerely,

Horacio D. Espinosa, *Editor*

SELECTIONS OF THE EDITOR

UNIVERSITIES IN THE MARKETPLACE: THE COMMERCIALIZATION OF HIGHER EDUCATION

Reprinted with permission from PRINCETON UNIVERSITY PRESS
Chapter 4, pp. 57-78, 2003, ISBN: 0-691-11412-9
By Derek Bok

Derek Bok is the 300th Anniversary University Professor and Faculty Chair of the Hauser Center for Nonprofit Organizations at Harvard University. He was formerly President of Harvard University and Dean of the Harvard Law School. His numerous books include *The Shape of the River* (Princeton, 1998, with William G. Bowen) and *The Trouble with Government* (Harvard, 2001).

CHAPTER 4: SCIENTIFIC RESEARCH

John Le Carré's latest novel, *The Constant Gardener*, tells of the murder of a young woman in Africa and her husband's valiant efforts to avenge her death. It soon appears that these events all grow out of a major pharmaceutical firm's campaign to develop a new drug for combating tuberculosis.[1] Discovered in a Polish laboratory, the drug looks very promising at first, raising hopes of earning hundreds of millions of dollars. As tests on human subjects begin in Kenya and other African countries, however, problems start to surface. There are side effects. Patients die. One of the scientists who discovered the drug has second thoughts and threatens to go public. Frantic, the company tries to suppress the unfavorable evidence and to buy off, intimidate, or even murder potential critics, such as the young heroine who dies trying to expose the deadly scheme. Meanwhile, the firm contrives to have several well-known academic scientists publish favorable reports about the drug in leading journals without disclosing that the reports were actually written by the company itself and that the purported authors are beneficiaries of lucrative research contracts from the very same source. A remote university in Saskatchewan is persuaded to offer the disaffected discoverer of the drug an amply funded post where she can be watched and induced to keep silent. When she finally speaks out, she is quickly vilified and ostracized by her university and its affiliated hospital, which just happen to have been promised large donations by ... that's right, the selfsame company.

Le Carré takes care to point out that his book is a work of imagination. He makes no claim that pharmaceutical firms resort to beatings and killings to get new drugs to the market. Still, the author does say that his account "draws on several cases, particularly in the North American continent, where highly qualified medical researchers have dared to disagree with their pharmaceutical paymasters and suffered vilification and persecution for their pains."[2]

This last remark is intriguing. Could such things really happen? If Le Carré's account is not wholly fanciful, how have corporate sponsors actually behaved, and how could universities and their professors get caught up in such compromising ways?

EARLY FEARS

Corporations have become much more involved with university scientists since 1980. Congressional initiatives, such as the Bayh-Dole Act, coupled with the sudden rise of the biogenetics industry, set off a surge of corporate funding for campus-based research and a sudden growth of contacts between professors in the life sciences and interested companies.

Although Congress may have gotten what it wanted, not everyone was pleased with the growing role of industry in supporting academic science. Corporate money, it was said, would subordinate the public aims of research to private ends. Critics warned that universities would impose secrecy and censor research findings to please company sponsors, while exploiting graduate students and corrupting appointments and promotions procedures for commercial gain. In the words of Leslie Glick, founder of Genex Corporation, "Not only will commercial considerations influence decisions about thesis topics and research proposals, but they will likely influence the employment and promotion of professors."[3]

Even more troubling were predictions that corporate money would cause a massive shift of research activity from basic science to applied problems of immediate economic interest. In 1945, Vannevar Bush, in his famous report to President Roosevelt on the future of American science, had pointed out how much the flow of new products and medical treatments depended on a vigorous program of basic research that only universities could provide.[4] Responding to this vision, the federal government came to invest billions of dollars every year in university labs, creating the strongest basic science capability in the world. Suddenly, forty years after the Bush report, critics such as Martin Kenney warned that commercialization was about to destroy the foundations of scientific progress by diverting professors from basic research to more lucrative applied work with high market potential. As he observed at the end of his book, *Biotechnology: The University-Industrial Complex*:

> Perhaps the greatest irony will be experienced by U.S. industry itself. As the university is bought and parceled out, basic science in the university will increasingly suffer. The speculative noncommercial scholar will be at a disadvantage, and the intellectual commons so important for producing a trained labor force and the birthplace of new ideas will be eroded and polluted. Industry will then discover that by being congenitally unable to control itself and having no restraints placed upon it by the public sector, it has polluted its own reservoir.[5]

To what extent have these dire prophecies come to pass? Certainly not to anything like the degree that critics such as Kenney and Glick predicted. There is little evidence that professors have steered a significant number of their graduate students into commercial research to promote their own financial interests. Nor have there been many documented reports of universities compromising their appointments and promotions standards to retain professors doing work of great commercial potential. Skeptics would even be hard put to show that research priorities have shifted in any substantial way to favor applied research at the expense of more fundamental inquiry.[6] The percentage of university R&D devoted to basic research has remained fairly constant since the late 1970s. While corporate support has grown, it still makes up less than 10 percent of all university research and hence does not significantly affect the overall balance of priorities. If certain valuable fields of basic inquiry receive less money than they should, such results are likely to reflect the shortsightedness of government authorities (or perhaps foundation officials) rather than the malign influence of business.

Individual scientists have also resisted rushing pell-mell into the arms of corporate sponsors. The share of all life-science faculty receiving at least some research funding from industry has stayed close to 25 percent since 1985 (and less than half of those who do receive such funding obtain more than one-quarter of their total support from business).[7] Comprehensive faculty surveys suggest that the percentage of life-science professors serving as scientific advisors to companies has not gone up appreciably.[8] Only 7 percent of the faculty members in a 1985 survey reported owning equity in private companies, and later fragmentary data do not indicate that the number is increasing.[9] It is true that faculty members with industry support are more likely than other scientists to be influenced by commercial considerations in choosing their research topics (35 percent v. 14 percent).[10] On the other hand, such researchers publish more than their colleagues in peer-reviewed journals and spend just as much time teaching students.[11] Overall, these findings bear out the conclusion of one team of investigators that canvassed life-sciences professors in leading universities: "there is little evidence in our survey to suggest that most life scientists are more interested in commercial activities than in traditional scientific endeavors ... or that a new kind of entrepreneurial scholar has taken over in universities."[12] If any tie with business proved to be a problem for research universities, one would have thought that it would be corporate consulting by the faculty. The prevailing rules on most campuses actually seem to invite faculty members to consult, since professors continue to receive their regular salaries during days spent far from the university earning extra money advising companies. The standard rule for outside activity-only one day per week-is open to several possible interpretations and is hard to enforce in any event, since faculty members will stoutly resist punching time clocks or handing in weekly timesheets.

Every campus has professors who do flout the rules and constantly spend much time away from their offices. Since cases of this kind attract attention, they can easily give the impression that most professors endlessly gallivant about making money at the expense of their teaching and research. Studies of the actual amount of paid consulting, however, fail to confirm this impression. Very few faculty members regularly consult more than the permissible one day per week, and the average compensation received by consultants in almost every field is less then one-tenth of their average academic salary.[13] Those who advise corporations teach as much, take on as many committee assignments, and publish more than colleagues who do not consult.[14] Contrary to what one might expect, one recent study found that life-science faculty members in highly ranked departments who consult with industry are *less* likely than their colleagues to be influenced by commercial considerations in choosing their research agenda.[15]

Apparently, then, the values that have traditionally inspired academic scientists have generally been strong enough to withstand the desire to grow rich. University researchers are not averse to making money on the side through consulting, and some may even decide at one point or another to work for a company where opportunities to do good science seem particularly promising. But if they have to choose between the kind of research they enjoy and earning large sums of money, they rarely prefer the latter. For almost all academic scientists, the respect of colleagues and the satisfactions that come from making important advances in knowledge continue to count above all else. In addition, it must be said, government funding agencies (and many corporate executives, too) understand the importance of basic science and have no desire to damage its vitality as the essential seedbed of future commercial applications.

Far from worrying that university scientists will be corrupted by business, some observers believe that active collaboration with colleagues in industry is actually useful in stimulating basic research. As Henry Etzkowitz has put it: “What is new in the present situation is that many academic scientists no longer believe in the necessity of an isolated `ivory tower' to the working out of the logic of scientific discovery.”[16] This sentiment is more than a rationalization on the part of university researchers eager to collect their consulting fees. It reflects a genuine sense that the process of scientific exploration has become a much more collaborative process, requiring input and stimulation from a wide variety of sources, of which some, at least, may reside in the more practical world of industrial science.[17] Today, talented scientists who are worthy collaborators are more likely than in the past to work for a company, at least for part of their professional careers. In certain fields of work, such as the development of new drugs, collaboration with industry is actually essential, since companies often have databases, vast libraries of relevant compounds, sophisticated computer models, and other research materials that university laboratories do not have and that scientists must be able to use to do their work.

As collaboration increases, giving rise to spectacular commercial successes such as Silicon Valley, the Research Triangle, or the Austin Miracle, voices can be heard urging more aggressive efforts to increase and improve technology transfer. Aiding business in this way is increasingly recognized as an explicit part of the mission of research universities. Some advocates would have campus officials acknowledge this responsibility even more strongly by counting contributions to technology transfer-obtaining patents, starting companies, serving on scientific advisory boards as a positive factor in appointments and promotions decisions. Others are not so sure. They worry about diverting talented scientists from basic research and other problems that could result from becoming too closely involved in commercial activities. This difference in outlook is far from resolved.

V

SECRECY

Although the worst fears of critics have not materialized, the rise of corporate funding has not been trouble-free. One of the most serious problems is increased secrecy. Firms that offer research support naturally want to keep any commercially valuable results from falling into a competitor's hands. Accordingly, company officials regularly insist that information concerning the work they support be kept in confidence while the research is going on and for a long enough time thereafter to allow them to decide whether to file for a patent. In addition, they may consider other bits of valuable information unsuitable for patenting and treat them as permanent trade secrets instead. For example, firms often share unpatented materials or techniques with academic colleagues only on condition that they be kept confidential indefinitely.

Although the results of university research may eventually be made public, companies continually press for more and more restrictions while the research they support is under way in an effort to keep any word of new discoveries from leaking prematurely to their competitors. Many firms try to prohibit the researchers they fund from speaking about their work at conferences. Some corporate agreements can be interpreted to require scientists to obtain clearance before merely talking on the telephone with colleagues. A few professors have actually declared their laboratories off-limits to colleagues and students in their own departments. While no one can measure the impact of such restrictions with precision, the likely effect is to inhibit scientific progress, at least to some extent, by limiting the flow of information and ideas that investigators need in order to advance their work.[18]

Surprisingly, many universities, their affiliated hospitals, and other biomedical research organizations have not done much to keep secrecy to the minimum necessary to protect legitimate commercial interests. In one comprehensive study, only 12 percent of these institutions had policies specifying clear time limits on keeping discoveries secret.[19] Some had no written policy at all. Others do not rigorously enforce their own rules. As a result, company research directors report that they seldom have difficulty obtaining as much secrecy as they want.

Survey results confirm that corporate funding has led to more secrecy than the strict necessities of business require. Although most observers believe that one or two months after completion of the research will give companies enough time to decide whether to seek a patent, 58 percent of corporate sponsors in one large study admitted to insisting regularly on delays of more than six months.[20] Nearly one in five life-science professors admitted that they had delayed publication by more than six months for commercial reasons.[21] Of course, scientists may refuse to talk about their work in order to preserve their lead over rival investigators or for other reasons having nothing to do with commercial gain. Nevertheless, the proportion delaying publication for more than six months was substantially greater (27 percent v. 17 percent) among researchers with industry funding, and the same pattern prevailed among faculty who refused to share research results and kept trade secrets.[22] A small but significant number of faculty members in the survey (12.5 percent) reported that they had themselves been denied access to research results or products by university researchers during the past three years.[23]

Scientists are also concerned over the time required to obtain permission to share cell lines and other research materials. The delays involved sometimes cause investigators to give up in disgust, especially when they need to borrow from several sources to proceed with their research. Companies, too, are up in arms. According to a report from a working group to the Director of the National Institutes of Health, “virtually every firm that we spoke with believed that restricted access to research tools is impeding the rapid advance of research and that the problem is getting worse.”[24] Ironically, universities were accused of being among the worst offenders. “Over and over again, firms complained to us that universities ‘wear the mortarboard’ when they seek access to [research] tools developed by others, yet they impose the same sorts of restrictions when they enter into agreements to give firms access to their own tools.”[25]

Apparently, universities often hold up requests for materials in an effort to obtain a slice of any revenue that grows out of the companies' research. When they share with universities, companies, for their part, insist on safeguards to keep their materials out of the hands of researchers under contract to rival firms. The net result is a far cry from the ideal community of scholars, freely sharing their ideas and materials in a common quest for greater knowledge and understanding.

CONFLICTS OF INTEREST

Conflicts of interest in science arise in "situations in which financial or other personal considerations may compromise, or have the appearance of compromising, an investigator's professional judgment in conducting or reporting research."[26] Such conflicts can easily result from the growing ties between corporations and university researchers. Faculty members, especially in the life sciences, may own a significant share of stock in a company for which they do research (perhaps a firm they founded to commercialize one of their own discoveries). Short of ownership, professors may test the products of a firm from which they have received significant amounts of research funding or obtained a lucrative consulting agreement. All these relationships provide reasons to favor the company involved and hence create conflicts that threaten the objectivity of scientists when they advise the government or publish research results on matters of financial significance to their corporate sponsor. Even if the scientists involved are completely honest and unbiased, their financial interests may give the *appearance* of bias and hence undermine the credibility of their work.

Conflicts of interest have attracted particular attention in research to test new drugs or medical procedures where human subjects are involved. Testing of this kind has become a major enterprise involving some 60,000 trials and 14 million human subjects per year at a total annual cost of several billion dollars. Such a large undertaking involving such high financial stakes is bound to give rise to instances of questionable behavior. In one highly publicized case, a research fellow in a Harvard-affiliated hospital, Scheffer Tseng, turned out to have minimized unfavorable results in a clinical study to test a dry-eye medication. It then came to light that both Tseng and his supervisor owned stock in the company that produced the medication, stock Tseng sold after his published test results had driven up the price but before the negative findings were revealed.

Conflicts of interest can turn up in more tragic circumstances. In 1999, Jesse Gelsinger, an eighteen-year-old patient in a gene therapy trial at the University of Pennsylvania Medical School, died in the course of the experiment. As it happened, the director of the institute conducting the research was the founder and a major stockholder in the company that funded the research. The university, too, was a stockholder, having been given an equity share by the company. Although the director did not participate personally in the trials, both he and the university stood to gain financially if the therapy being tested proved to be successful.

In most types of scientific research, any bias in the work performed is likely to be discovered sooner or later when other investigators replicate the studies. In clinical research, however, scientists with financial interests in the results may be too anxious to enroll patients in hazardous experiments involving the products or companies with which they have ties. In this event, human subjects may be put at risk before anyone is even aware of the conflicts involved.

Scientists with corporate ties naturally deny that financial interests will have any effect on their scientific work. Nevertheless, a number of investigators have shown that researchers reporting on the efficacy of drugs produced by companies in which they have an interest are more likely to report favorable results than scientists without such ties.[27] Other studies have shown that clinical trials funded by drug companies are far less likely than independently funded trials to arrive at unfavorable conclusions.[28]

In 1989, the National Institutes of Health proposed strict new rules to minimize financial conflicts of interest in research funded by the government. The proposals quickly came under heavy fire from university scientists. Eventually, the NIH retreated and produced a much weaker set of guidelines that merely required investigators to disclose financial conflicts to their universities but allowed the latter to decide what further restrictions to impose.

Opponents have made several arguments against stricter conflict-of-interest rules.[29] Some maintain that it is unfair to assume that scientists will be guilty of bias just because they have a financial interest. Others point out that there is no reason to single out financial conflicts for regulation, since scientists have always had to contend with temptations, such as the desire for fame or promotion, that can lead them to overstate or distort their findings. Still others insist that the best cure for biased results is the time-honored process in science of testing and replicating published research findings.

None of these arguments is persuasive, especially for research involving human subjects. Everyone agrees that it is wise to prohibit judges and government officials from making decisions on questions in which they have financial interests, even though many of these public servants could doubtless keep their investments from affecting their judgment. Since no one can tell whose judgment will be affected and whose will not, the standard practice is to remove all doubt by preventing conflicting interests from arising in the first place. By the same token, there is no unfairness in holding scientists to similar rules to reduce the risk of financial influence.

The other arguments against limiting conflicts are no more persuasive. The fact that all scientists face a human temptation to win fame by exaggerating their results is hardly a reason not to counter potential biases that can be easily removed or disclosed in advance. Although some inaccuracies and misrepresentations will eventually be detected by other investigators, not all of them will be found. Even if they are, discovering errors by investigators with undisclosed financial conflicts will still damage the credibility of university science. Worse yet, setting the record straight at some later date will do nothing for innocent patients whose health may have been put at risk by investigators using them as subjects to test some potentially lucrative new treatment.

Most people now agree that rules are needed to guard against conflicts of interest. But controversy continues over exactly what the rules should contain. Some argue that it is enough to require clear disclosure both to scientific journals and to human subjects before enrolling them in an experiment. Others strenuously disagree, insisting that the only way to eliminate the harmful effects of bias is to prohibit financial conflicts altogether.

Whatever the answer, academic institutions do not seem to be doing nearly enough to protect against the risks involved. According to one study published in 2000, only 3 of 250 medical schools and research institutions insisted that investigators disclose their financial conflicts to patients before enrolling them in clinical experiments or drug trials.[30] Only 7 percent of these institutions required their researchers to disclose such conflicts to journals publishing their research.[31] Only one of the ten leading medical schools receiving the greatest amounts of federal funding flatly prohibited investigators from doing clinical research on products of firms with which they had significant financial ties.[32] Most of these merely required disclosure to university officials.

In addressing these issues, universities do not come to the task with entirely clean hands, for they, too, may have financial interests that could conceivably bias the results. For example, Columbia, Duke, and several other medical schools have formed consortia to bid for contracts from pharmaceutical firms to test new drugs. In many cases, the principal purpose is not to secure opportunities for cutting edge research, but rather to earn money that can be used for other purposes. Schools that benefit in this way clearly have a financial stake in retaining the business of the companies whose products they test. To that extent, they have an incentive to avoid results that will disappoint their corporate sponsors. Nevertheless, like individual investigators, medical schools seem unwilling to admit that their financial interests could possibly affect the results of research performed within their walls.

CORPORATE EFFORTS TO INFLUENCE RESEARCH RESULTS

Efforts to test the effects of new drugs create additional risks not commonly found in university research. Clinical tests can enhance the value of a potentially lucrative product or destroy it. As a result, the sponsoring firm will often have a huge financial stake in the outcome of the research. Of course, companies will hardly want to market a drug that is actually dangerous to health. But no such inhibition exists in the case of trials to determine whether a brand-name drug is superior to generic substitutes or whether a medical device or procedure is truly efficacious or harmlessly ineffective. Even in the case of potentially dangerous products, corporate officials can be so blinded by the prospect of financial gain that they use poor judgment in working with academic researchers conducting tests.

Whatever the reason, drug companies sometimes employ highly questionable methods in an effort to gain the credibility of an academically run clinical trial while retaining control over the results.[33] Some firms insist on keeping all the data or helping to design the test. Some actually ghostwrite drafts of the final report for academic researchers to review prior to publication, a dangerous practice in view of the many subtle ways in which a study can be written up to place the company's product in a more favorable light. Other companies try to insert provisions in the research contract giving them the right to approve all material prior to publishing the results. None of these practices seems consistent with the standards universities need to protect the objectivity and accuracy of their research.

Even more troubling are a handful of cases involving heavy-handed attempts by drug companies to suppress unfavorable findings by university scientists. For example, Betty Dong of the University of California, San Francisco, received a grant from a pharmaceutical firm to determine whether its expensive drug Synthroid was in fact superior to cheaper generic alternatives. Against expectations, including her own, she found no significant difference (which meant that patients were paying several hundred million dollars more per year for Synthroid than they needed to spend). Informed of these embarrassing results, the company accused Dong of numerous methodological errors and unspecified ethical lapses and even hired a private investigator to look for conflicts of interest (which proved to be nonexistent). When Dong went ahead and submitted her findings to a professional journal, the company threatened suit, invoking a clause in the research agreement she had signed prohibiting publication without the firm's consent. Although the university had never reviewed the contract or warned her not to sign, it declined to assist her, leaving her to fight the company alone. Only after seven years did she finally succeed in publishing her paper.

Another professor, Nancy Olivieri, of the University of Toronto, met a similar fate, experiencing harassment much akin to the trials of the woman scientist in Le Carré's *The Constant Gardener*. In her capacity as university professor and researcher at the University's Hospital for Sick Children, Olivieri signed a contract with Canada's largest pharmaceutical firm, Apotex, to perform clinical trials on a drug to treat thalassemia patients. The contract contained a clause prohibiting her from publicizing results for a stipulated period without the company's permission. Despite the agreement, she insisted on making her findings known (with the approval of the hospital's Research Ethics Board) when they seemed to indicate that the drug she was testing was not only less effective than originally thought, but even potentially hazardous to patients.

As in the case of Betty Dong, the drug company accused Olivieri of deviating from the research protocol and tried to discourage her from reporting her findings by threatening legal action and canceling her research contract. In addition, a faculty associate sought to discredit her by sending disparaging anonymous letters to colleagues and the media and by publishing contrary findings without either informing her or disclosing that his work was being generously funded by Apotex. For her pains, she was falsely accused by her hospital of failing to observe hospital regulations, suspended from her position as program director, and directed, along with her supporters on the staff, not to discuss her problems publicly.

Throughout these controversies, the University of Toronto remained largely uninvolved, despite a flood of unfavorable publicity about the treatment of Olivieri by its affiliated teaching hospital. It then appeared that the university and Apotex had for some years been in discussions about a multimillion-dollar gift to the university and its teaching hospitals. Only after another firestorm of publicity and the intervention of distinguished scientists from Britain and the United States did the university finally intervene and mediate an agreement to have the hospital restore Olivieri's authority over patient care and research and acknowledge her academic freedom.

Olivieri and Dong are by no means the only investigators who have been pressured by companies; there are plenty of anecdotes involving researchers threatened by lawsuits or attacks on their reputation in an effort to suppress unfavorable results. No one knows how extensive this problem is, since no one can be sure how many scientists have quietly succumbed to pressure and suppressed their findings rather than undergo the harassment and delay endured by Dong and Olivieri.[34] Still, the problems of undue influence and manipulation of research are great enough to have persuaded ten leading medical journals to take action. In 2001, they agreed not to accept any articles reporting the results of clinical trials unless the sponsoring company and the authors give satisfactory assurances that the sponsor has not tried to suppress unfavorable findings or otherwise influence the results.[35] Explaining the policy, the editor of the *Journal of the American Medical Association* declared: "I am not against pharmaceutical companies. What I object to is the use of my journal as an advertisement mechanism rather than a vehicle for the distribution of sound medical science."[36]

The Dong and Olivieri cases also raise questions about how willing medical schools and their affiliated hospitals are to resist pressure from corporate donors and how careful they are to protect their faculty from signing agreements with undue restrictions on publication. Faculty members rarely read the fine print of their research contracts, written as they are in the dense prose to which the legal profession is so famously attached. One contract officer for a group of major research hospitals estimates that 30-50 percent of all proposed agreements submitted by companies contain inappropriately broad secrecy clauses.[37] Without proper university oversight, many of these provisions are bound to find their way into the final contract.

Drug testing for pharmaceutical firms is not the only example of high-stakes research. Nutritionists investigating the health effects of particular foods can dampen the prospects of entire industries, just as epidemiologists changed the lives of tobacco manufacturers by demonstrating the link between cigarettes and cancer. Environmental scientists evaluating the effects of emissions can publish findings that bring about extremely costly regulations for manufacturers. Investigators studying the existence of global warming can drastically alter the future of the energy industry.

Unlike drug testing, however, most of the research just described is funded primarily by the government, not by industry. As a result, commercial interests do not have as much leverage over the results. But some companies try to influence the public debate by offering research funding to scientists who have views-or show promise of having views-that are favorable to the industry involved. Thus, investigators are often aware that if their work on controversial subjects turns out to be sympathetic to important corporate interests, money for their future work will be assured.

This state of affairs carries obvious risks for academic science. The clearest danger is that investigators who receive corporate funding for their research may be influenced in ways that favor the industry. They may not alter their findings deliberately to retain the favor of company sponsors. Having received such support, however, they may be subtly affected when they decide how strongly to word a conclusion, how much to emphasize possible qualifications and contrary interpretations, or whether to mention potential (but unproven) new risks. At the very least, industry funding can magnify the voice of those who receive it and encourage them to continue their research and be more outspoken and more vigorous in expounding their views.

Such tactics can confuse the public and distort the debate about important issues. For example, one survey investigating the wide divergence of views on the health effects of passive smoke found that 74 percent of the studies finding no adverse effects were written by authors with ties to the tobacco industry. Of the authors with tobacco ties, 94 percent found that passive smoke was not harmful to health, while only 13 percent of those without tobacco ties reached the same conclusion.[38]

Corporate efforts to influence public debate do more than muddy the waters. As the funding sources for the research become known, along with other links between the authors and interested companies, people become more skeptical of what they read from supposedly disinterested scholars. Eventually, confidence in all academic research may suffer, especially if the investigators who join the debate and testify before Congress fail to reveal the identity of their sponsors.

LESSONS LEARNED AND NOT YET LEARNED

Looking back, the record of commercializing academic research over the past twenty years is instructive in several ways. Now that efforts by universities to patent scientific discoveries have become well established, the financial results are reminiscent of intercollegiate athletics. Most universities have not earned much money from royalties; the odds of making anything substantial from patenting a new discovery are extremely small. Still, the extraordinary success of a few patents and the many millions of dollars in royalties earned each year by a small minority of schools are enough to keep scores of institutions scouring their labs for commercially valuable innovations. In this respect, commercial incentives have succeeded in encouraging universities to do a much better job of serving the public interest.

At the same time, using the promise of financial gain to bring about socially useful results is a risky enterprise. While Le Carré may have engaged in flights of fiction by having pharmaceutical companies resort to murder and beatings, most of the other transgressions he described have their counterparts in real life. Universities have paid a price for industry support through excessive secrecy, periodic exposes of financial conflict, and corporate efforts to manipulate or suppress research results. No consensus has yet emerged on how to contain these threats to academic science. Differences of opinion persist over how best to deal with conflicts of interest arising from the financial ties of investigators or of the university itself. Rules relating to secrecy are often lax, weakly enforced, and seldom applied to restrictions companies attach to research done through consulting agreements or corporate gifts. In the face of pressure from corporate sponsors to influence the results of high-stakes clinical research, institutional safeguards have proved inadequate in a disturbing number of cases.

Most universities have not done all they should to protect the integrity of their research. Many have not even shown that they are seriously concerned about doing so. As in athletics, officials have been willing to cut corners and wink at potential problems in an effort to gain additional resources. Unlike athletics, however, commercialization of research is still relatively new, and universities are not yet bound irrevocably to indefensible policies. Only time will tell whether they manage to do a better job of maintaining appropriate standards for science than they have done in upholding academic values on their playing fields.

CHAPTER 4 REFERENCES

1. John Le Carré, *The Constant Gardener* (2001).
2. Ibid., p. 491.
3. Quoted in Martin Kenney, *Biotechnology: The University Industrial Complex* (1986), p. 130.
4. Vannevar Bush, *Science: The Endless Frontier* (1945), *http://wwwl.umn.edu/scitech/assign/vb/V.Bush1945.html.*, p. 16.
5. Martin Kenney, *Biotechnology: The University-Industrial Complex*, p. 246.
6. David C. Mowery, Richard R. Nelson, Bhaven N. Sampat, and Arvids A. Ziedonis, "The Effects of the Bayh-Dole Act on U.S. University Research and Technology Transfer," in Lewis M. Branscomb, Fumio Kodama, and Richard Florida, eds., *Industrializing Knowledge: University-Industry Linkages in Japan and the United States* (1999), pp. 269, 300. There are still critics who claim that academic scientists have shifted their activities heavily from basic to applied research, for example, Linda Marsa, *Prescription for Profits: How the Pharmaceutical Industry Bankrolled the Unholy Marriage Between Science and Business* (1997), pp. 7,143. But these accounts seem to be based on anecdotal evidence rather than a careful review of overall funding for scientific research.
7. Eric C. Campbell and David Blumenthal, "Relationships in Biotechnology: A Primer on Policy and Practice," *Cloning 2* (2000), p.103; see also Karen S. Louis, David Blumenthal, MichaelE. Gluck, and

Michael A. Stoto, “Entrepreneurs in Academe: An Exploration of Behaviors among Life Scientists,” *Administrative Science Quarterly 34* (1989), pp.110,115.
8. David Blumenthal, Eric G. Campbell, Nancyanne Causino and Lauren S. Louis, “Participation of Life Science Faculty in Research Relationships with Industry,” *New England Journal of Medicine* 335 (1996), p. 1734.
9. Ibid.
10. David Blumenthal and Eric G. Campbell, “Academic Industry Relationships in Biotechnology, Overview,” in Thomas J.Murray and Maxwell J. Mehlman, eds., *Encyclopedia of Ethical, Legal and Policy Issues in Biotechnology* (2000), pp. 1, 6.
11. Ibid.
12. Karen S. Louis et al., “Entrepreneurs in Academe,” p. 127.
13. U.S. Department of Education, *National Center for Educational Statistics, Background Characteristics, Work Activities, and Compensation of Faculty and Instructional Staff in Postsecondary Institutions: Fall 1998* (April, 2001), pp. 46 et seq.
14. Ibid.
15. Lisa-Marie Jones, *The Commercialization o f Academic Science: Conflict of Interest for the Faculty Consultant*, Ph.D. diss. UMI Pro Quest Digital Dissertations, AAT9986421 (2000), pp. 73-74.
16. Henry Etzkowitz, “Bridging the Gap: The Evolution of Industry-University Links in the United States,” in Lewis M. Branscomb, Fumio Kodama, and Richard Florida, eds., *Industrializing Knowledge*, p. 208.
17. See more generally Michael Gibbons et al., *The New Production of Knowledge* (1994).
18. For some interesting findings along these lines, see Eric G. Campbell et al., “Data Withholding in Academic Genetics,” *Journal o f the American Medical Association* 287 (2000), pp. 473,478.
19. Mildred K. Cho et al., “Policies on Faculty Conflicts of Interest at U.S. Universities,” *Journal of the American Medical Association* 284 (2000), p. 2203.
20. David Blumenthal, Eric G. Campbell et al., “Withholding
Research Results in Academic Life Science,” *Journal of the American Medical Association* 277 (1997), p. 1224.
21. Ibid.
22. David Blumenthal and Eric G. Campbell, “Academic Industry Relationships,” pp. 1, 6.
23. Ibid. See also, Eric G. Campbell, Joel S. Weissmann, Nancyanne Causino, and David Blumenthal, “Data Withholding in Academic Medicine: Characteristics of Faculty Denied Access to Research Results and Biomaterials,” *Research Policy* 29 (2000), p. 303.
24. *Report of the National Institutes o f Health (NIH) Working Group on Research Tools* (June 4, 1998), p. 18.
25. Ibid.
26. Association of American Medical Colleges, “Guidelines for Dealing with Conflicts of Commitment and Conflicts of Interest in Research,” *Academic Medicine* 65 (1990), p. 491.
27. See, for example, H. T. Stelfox et al., “Conflict of Interest in the Debate over Calcium Channel Antagonists,” *New England Journal of Medicine* 338 (1998), p. 101; P.A. Rochon et al., “A Study of Manufacturer-Supported Trials of Nonsteroidal Antiinflammatory Drugs in the Treatment of Arthritis,” *Archives of Internal Medicine* 154 (1994), p. 157; and Deborah A. Barnes and Lisa A. Bero, “Why Review Articles on the Health Effects of Passive Smoking Reach Different Conclusions,” *Journal of the American Medical Association* 279 (1998), p. 1566.
28. For example, a recent review of clinical studies of new drugs to fight cancer revealed that 38 percent of the studies financed by nonprofit organizations reported unfavorable results, whereas only 5 percent of studies funded by pharmaceutical companies reached unfavorable conclusions. See Mark Friedberg et al., “Evaluation of Conflict of Interest in Economic Analyses of New Drugs Used in Oncology,” *Journal of the American Medical Association* 282 (1999), p. 1453. In fairness, it should be pointed out that factors other than financial bias could help to account for these differences. For example, drug companies may be

less inclined than other funders to support clinical trials unless they have reason to believe that they will be successful.
29. The arguments are discussed in Roger J. Porter and Thomas E. Malone, eds., *Biomedical Research: Collaboration and Conflict of Interest* (1992). For a vigorous exposition of the arguments against efforts to regulate conflicts of interest, see Kenneth J. Rothman, "Conflict of Interest: The New McCarthyism in Science," *Journal of the American Medical Association* 269 (1993), p. 2782.
30. S. Van McCrary et al., "A National Survey of Policies on Disclosure of Conflicts of Interest in Biomedical Research," *New England Journal of Medicine* 343 (2000), pp. 1621, 1623.
31. Ibid., p. 1625.
32. Bernard Lo, Leslie E. Wolf, and Albiona Berkeley, "Conflict of-Interest Policies for Investigators in Clinical Trials," *New England Journal of Medicine* 343 (2000), p. 1616.
33. Thomas Bodenheimer, "Uneasy Alliance: Clinical Investigators and the Pharmaceutical Industry," *New England Journal of Medicine* 342 (2000), p. 1539. For a detailed analysis of how studies can be manipulated to arrive at more favorable findings, see Lisa A. Bero and Drummond Rennie, "Influences on the Quality of Published Drug Studies," *International Journal of Technology Assessment in Health Care* 12 (1996), p. 209.
34. One author, Thomas Bodenheimer, seems, on the basis of his informal survey, to imply that such cases are not uncommon; see note 33.
35. Susan Okie, "Journals Decide to Help Fight Firms' Influence on Research," *International Herald Tribune* (September 11, 2001), p. 3.
36. Ibid.
37. Quoted in Bodenheimer, "Uneasy Alliance," p. 1541.
38. Deborah A. Barnes and Lisa A. Bero, "Why Review Articles," p. 1566.

ON OVER-WEIGHTING THE BOTTOM LINE

Reprinted with permission from SCIENCE
Volume 301, Number 5636, 22 August 2003, pp. 1050-1051
by David Baltimore

The following is a review of the book *Universities in the Marketplace: The Commercialization of Higher Education* by Derek Bok (Princeton University Press, 2003). The reviewer is president of the California Institute of Technology, Mail Code 204-31, Pasadena, CA 91125, USA. E-mail:baltimo@caltech.edu

Most universities are nonprofit institutions and like to think that makes them fundamentally different from profit-making ventures. They are and they aren't. Their goal is not maximizing a bottom line but rather serving the public interest with education and research. But financially, they need to at least break even, which generally requires that they maximize their multiple sources of income. So they are businesses, and when viewed financially, they often are hard to distinguish from profit-making enterprises.

This perspective was, I believe, at the heart of the recent judgment in the case of *Madey v. Duke University*. In that October 2002 decision, a federal appeals court reversed a lower court and held that a university is not generally entitled to an ex-emption from obtaining licenses to patents that affect its research endeavors. The appeals court found that all of the research activities of a university serve to further its "legitimate business objectives" and therefore are no different than the activities of a for-profit company. The appellate decision explicitly stated that the lower court had "attached too great a weight to the nonprofit, educational status of Duke University." It said, "The correct focus should not be on the nonprofit status of Duke but on the legitimate business Duke is involved in." Just recently, the U.S. Supreme Court refused to hear the case, so the judgment will presumably stand, although the lower court still has to interpret it.

Derek Bok, a former president of Harvard University and previously dean of its law school, provides a similar perspective in *Universities in the Marketplace: The Commercialization of Higher Education*. He focuses on four activities of universities that have significant commercial rationales: competitive athletics, scientific research undertaken to enhance net revenues, technology transfer, and what I will call "non-core education" (continuing education and distance learning). Bok's concern is that the magnitude of these activities either distorts or threatens the mission of universities. His is a purist stance: anything that distracts from the primary goals - education and research - of a university is suspect. A cynic might say that although that's a fine stance for the president emeritus of Harvard, lesser institutions are living on a thinner edge. Nonetheless, Bok is speaking for the high vision of the university world, a perspective all institutions should hold dear.

It is hard for universities to keep their financial picture in order. Tuition is one of the few sources of hard money, and for institutions that have a need-blind admissions policy, that source is not constant. Other sources of revenue - such as endowment income, gifts, technology-transfer revenues, and ancillary activities - are inconsistent. With a downturn in the economy, all of these suffer. Running a university to break even is a constant struggle, so Bok's purist stance can be seen as a denial of the realities of university administration.

Bok constantly refers to revenue-enhancing activities over and above tuition increases or attraction of research dollars as making a "profit." Because a non-profit institution, by definition, makes no profit, this is clearly his attempt to color revenue-enhancing activities with a commercial brush. As I noted above, universities are not uncommercial, but it is important to see their budgets as a whole and not to denigrate particular aspects as "commercial."

Bok's noirest bête is athletics. Here he sees major dangers for the university with little real up side. In his analysis, he draws heavily on the seminal study by James L. Shulman and William G. Bowen, *The Game of Life: College Sports and Educational Values* (Princeton University Press, 2001). Shulman and Bowen document the pernicious effects of athletics in great detail, and Bok reiterates many of the points they make. Their study is clearly the touchstone of his thinking on the subject, and it colors his view of the other issues he tackles. It is my opinion too that big-time athletics, as practiced both in large universities and small colleges, is a foreign body of professionalism inserted into what should be an amateur environment. And I agree that it is in need of serious rethinking. However, the major uproar from alumni that ensued when Swarthmore College struck football out of its programs shows how hard it is to attack this problem, even at elite, small colleges.

Bok does say that in the realms of re-search, technology transfer, and non-core education, the universities have generally been more aware of the potential conflicts with their traditional values. He is basically afraid that these areas of revenue enhancement will go the way of athletics, becoming so ingrained into institutional practice that there is no way to govern them within the framework of such values. This is a real worry and one against which the academic world needs to be constantly vigilant. For instance, technology transfer, which admittedly only generates net revenue in a few schools, could become an end in itself for a university and thus lead to external guidance of the research directions of the faculty. Or the university might lower the bar covering corporate review of research, maximizing corporate funding of research while compromising core university values of openness and access. A particular danger is that marginal research activities and investigators can become overvalued at the expense of more solid investigations.

Bok is quite skeptical of the promise of non-core education (what he calls education for profit) as a revenue generator for major universities. He notes "all the brave talk of rendering residential campuses obsolete seems definitely premature." But he is also worried about how poorly students at major universities are often treated by faculty. He asks the rhetorical but provocative question, "might not competition and the lure of profit be the only forces powerful enough to break through the thick crust of faculty inertia and bring about some real progress in university teaching and learning?"

I have been watching the university scene for more than 40 years and have tried to be alert to universities compromising their core values. I have been impressed that, at least at the major research universities, their revenue-enhancing activities have not seriously distorted such values. Universities have become more complicated, but the administration, faculty, and students have been aware of the need for vigilance and have exercised it. Not to say that there have not been people taking advantage of the generally permissive atmosphere of universities - that has certainly happened. But it is the exception, not the rule.

Universities in the Marketplace is well written, even eloquent at times. It presents interesting history as well as contemporary analysis. However, the book is short on data and misses the chance to put the issues within the context of the overall picture of university finances. It also does not give a wide view of the diversity of universities and colleges that exist in the United States. I would recommend the book for laying out important issues, but I wish Bok had given them deeper consideration. He has lived with many of these issues at Harvard, notably in the early days of biotechnology, and he could have drawn more on his personal experiences.

The *Madey* decision and Bok's book together remind us that our vaunted higher educational system sits within the same capitalist framework as the rest of American life. It serves a high ideal—the discovery and dissemination of understanding and skill - but it does so facing the same strains as any business striving to stay solvent.

UNIVERSITY LICENSING AND THE BAYH-DOLE ACT

Reprinted with permission from SCIENCE
Volume 301, Number 5636, 22 August 2003, p. 1052
by Jerry G. Thursby and Marie C. Thursby

The Bayh-Dole Act of 1980 allows universities to patent and exclusively license federally funded inventions. With dramatic growth in university licensing, the Act has become controversial and the subject of policy review. For the 84 U.S. institutions responding to the Association of University Technology Managers' (AUTM) 1991 and 2000 surveys, inventions disclosed increased by 84%, new patent applications by 238%, license agreements by 161%, and royalties by more than 520% (*1*). Bayh-Dole advocates argue that in its absence many results from federally funded research would remain in the laboratory; critics say exclusive licenses are not needed for technology transfer and universities are chasing profits (*2*). Amid the rhetoric, what are the issues and evidence?

Would technologies be transferred in the absence of Bayh-Dole? Technology can be, and obviously is, transferred to industry without patents or licenses. Historically, publications, meetings, and consulting were the primary ways for industry to learn about academic research, and recent evidence suggests they remain so (*3-5*).

If and when exclusive licensing is needed to augment these channels is an important issue. Exclusive licensing may be needed when inventions require further development before use (*6*). A survey of 62 U.S. universities suggests that much university research fits this profile, with 45% of inventions no more than a "proof of concept" and only 12% "ready for practical use" at the time of license (*7, 8*). The failure rate for these inventions is high, 46% for all inventions and 72% for those that are only a proof of concept (*9*). Exclusive patent rights provide an incentive for firms to invest in costly development, but only to the extent that patents are effective in protecting intellectual property (IP), which varies by industry (*10, 11*).

Many university inventions are research tools, in which case exclusivity may limit use by future researchers. Although Bayh-Dole permits exclusive license, it does not require it, and surveys show many licenses are nonexclusive (AUTM reports half) (*2, 12*). How often research tools are exclusively licensed is not known, but known examples, such as the OncoMouse, have exacerbated the controversy. Restricted use of such tools is more detrimental the broader their patent claims (*13*). Regardless, NIH guidelines for sharing research tools are helpful (*14*).

Are technology transfer offices "profit centers"? In the 2000 AUTM survey, 156 U.S. respondents reported $1.24 billion in income from royalties and cashed-in equity net of unreimbursed legal fees (*1, 15*). This income was about 4.7% of their research expenditure. For every dollar of income, there is about $0.20 in sponsored research tied to a license. The average income per active license is $66,465, but only 43% earned royalties and 0.56% earned more than $1 million in 2000.

Although average income per respondent was about $8 million, 79% earned less than $5 million, and half reported income less than $824,000. On average, technology transfer offices below the median had four employees, which made it likely that many spent more than they received in income. While more offices have become profitable over time and this trend may continue, the current picture suggests that profits are not the sole goal of licensing. Survey research highlights the complexity of university goals, which also include sponsored research and Bayh-Dole's mandate to commercialize federally funded research (*8, 16*). Further, many in the university community recognize the need to balance IP rights and the public good (*17*).

Does licensing restrict dissemination of academic research? A survey of industry licensing executives shows 27% of their university licenses include clauses that allow deletion of information from papers before submission, and 44% ask for publication delay (3.9 months on average) (*18*). Life science faculty involved in commercial activity often deny requests by other scientists for research results, although multiple factors are involved (*19*, *20*). This problem is more likely related to research that is company sponsored rather than federally funded, because companies can protect IP with secrecy, whereas Bayh-Dole requires eventual disclosure through patents.

Have financial incentives from licensing diverted faculty from basic to more applied research? Evidence on the direction of faculty research is limited, but suggests that the answer is no. A survey of firms that license from universities indicates that the prime reason for increasing their collaboration with universities was receptivity to licensing rather than a change in faculty research (*18*). Studies of technology transfer from the University of California, Stanford, and Columbia find little evidence of either changes in research direction or financial return as a major motive for the research (*6*, *21*). Our study of over 3400 faculty at six research universities from 1983 to 1999 suggests that the portion of research that was basic has not changed even though licensing increased by a factor greater than 10 (*5*).

There is evidence to suggest that university licensing facilitates technology transfer with minimal effects on the research environment, but the issues are complex and there are unknowns. Further study is needed, particularly as to whether faculty involvement in licensing complements or substitutes for open publication. The environment is also evolving. The explosive growth of licensing cannot continue forever - the final equilibrium, however, remains to be seen.

References and Notes

1. Association of University Technology Managers, *AUTM Licensing Survey* (FY 1991 and FY 2001).
2. E.Press and J.Washburn, *Atl. Mon.* **285**, 39 (March 2000).
3. W.Cohen, R.Nelson, J.Walsh, *Mgt. Sci.* **48**, 1 (2002).
4. A.Agrawal, R.Henderson, *Mgt. Sci.* **48**, 44 (2002).
5. J.Thursby, M.Thursby, unpublished data.
6. J.Colyvas *et al.*, *Mgt. Sci.* **48**, 61 (2002).
7. R.Jensen, M.Thursby, *Am. Econ. Rev.* **91**, 240 (March 2001).
8. J.Thursby, R.Jensen, M.Thursby, *J. Tech. Trans.* **26**, 59 (2001).
9. J.Thursby, M.Thursby, in *Buying In or Selling Out: Commercialization of the American Research University*, D.Stein, Ed.(Rutgers Univ., New Brunswick, NJ, in press),
10. W.Cohen, R.Nelson, J.Walsh, working paper 7552, National Bureau of Economic Research (NBER) (2000); www.nber.org/papers.
11. E.Dechenaux *et al.*, working paper 9735, NBER (2003); www.nber.org/papers.
12. M.Henry, M.K.Cho, M.A.Weaver, J.F.Merz, *Science* **297**, 1279 (2002).
13. A.Rai, R.Eisenberg, *Law Contemp. Prob.* **66**, 288 (2003).
14. S.Nass, B.Stillman, Eds., *Large-Scale Biomedical Science: Exploring Strategies for Future Research* (National Academy Press, Washington, DC, 2003), p.168; www.nap.edu/openbook/0309089123/html.
15. Some respondents report for several units (e.g., the University of California System).
16. R.Jensen *et al.*, *Int. J. Ind. Org.*, in press.
17. R.C.Atkinson *et al.*, *Science* **301**, 174 (2003).
18. J.Thursby, M.Thursby, *Mgt. Sci.* **48**, 90 (2002).
19. D.Blumenthal *et al.*, *JAMA* **277**, 1224 (1997).
20. K.Louis *et al.*, *J. Tech. Trans.* **26**, 233 (2001).
21. D.Mowery *et al.*, *Res. Pol.* **30**, 99 (2001).
22. Supported by the Alan and Mildred Peterson Foundation and National Science Foundation.

CHAMPIONING A 17th CENTURY UNDERDOG

Reprinted with permission from SCIENCE
Volume 301, Number 5630, 11 July 2003, p. 152
by Richard Stone

LONDON - A quick quiz: Through meticulous observations with a 20-meter-long telescope that vibrated in the slightest breeze, this 17th century scientist was the first to describe the shadow that Saturn's ring cast on the planet and to make detailed maps of the moon's craters. He was an accomplished surveyor and architect who helped rebuild London after the Great Fire of 1666 and an avid inventor whose creations include the balance spring watch and the compound microscope. This "Leonardo da Vinci of England" was also a maverick thinker who was one of the first to articulate the concept of extinction and who suggested evolution 2 centuries before Charles Darwin. Who was this polymath?

If you guessed Robert Hooke (1635-1703), you know your history better than many of your peers. Scholars have long argued that Hooke has received far less credit for his insights and inventions than he deserves. Set against the brilliance of his contemporary, Isaac Newton, Hooke has tended to shine like a 60-watt light bulb. It didn't help that Newton, upon Hooke's death, set out to destroy his reputation. Newton "denied many of Hooke's contributions and did all that he could to obliterate them from history," says science historian Michael Cooper, a leading Hooke scholar at City University of London.

But Hooke is undergoing a remarkable rehabilitation. A clutch of new books about his life and achievements have appeared in the past few years or are about to be published. "Hooke is fashionable," says physicist Robert Purrington of Tulane University in New Orleans. And as indicated at a conference* earlier this week to mark the tercentenary of Hooke's death, scholars are gravitating to him for a variety of reasons, from the philosophical underpinnings of his work to his bitter quarrels with Newton and subsequent downfall. "Hooke was one of the most prolific and inventive scientists of all time," says Michael Nauenberg, a physicist at the University of California, Santa Cruz.

Hooke made his mark early. As a student at Oxford in the late 1650s, he joined the laboratory of Robert Boyle, where, working with springs, he discovered that stress is directly proportional to strain - Hooke's law. He also devised an air pump and performed experiments on gases that led to the formulation of Boyle's law. Hooke so impressed his Oxford colleagues that in 1662 he was named Curator of Experiments at the newly formed Royal Society of London, tasked with demonstrating experiments at the society's weekly meetings.

In 1665, at the age of 30, Hooke published *Micrographia*, a bestseller based on his observations and intricate drawings of the natural world through his compound microscope. Along with the drawings, he made striking insights into the processes of nature. Based on his observations of the cliff shores of the Isle of Wight, where he grew up, Hooke believed that the biblical flood could not be taken literally. "He knew that erosion needed more time," says Ellen Tan Drake of Oregon State University in Corvallis. Even more profound were his insights into extinction. In the mid-17th century, fossils and minerals were thought a trick of nature, formed by magic, although a handful of scholars believed that fossils were relics of Noah's flood. After examining seashore fossils, he wrote in 1667: "There have been many other Species of Creatures in former Ages of which we can find none at present." He even anticipated Charles Darwin, suggesting that new species could arise from the pressure of environmental change.

A year after *Micrographia* appeared, fires ravaged London; during the 1670s, Hooke, trained as a surveyor, worked with his best friend, architect Christopher Wren (far more famous than Hooke

* "Hooke 2003," sponsored by the Royal Society and Gresham College, 7 to 8 July.

Acta Materialia 51(14) 2003

Acta Materialia 51(15) 2003

Acta Mechanica 163(3-4) 2003

Acta Mechanica 164(1-2) 2003

AIAA Journal 41(8) 2003

AIAA Journal 41(9) 2003

Applied Mathematical Modelling 27(9) 2003

Applied Mathematics & Mechanics 24(6) 2003

Applied Mathematics & Mechanics 24(7) 2003

Archive for Rational Mechanics & Analysis 169(1) 2003

Archive of Applied Mechanics 73(1-2) 2003

Communications on Pure & Applied Mathematics 56(10) 2003

Computational Mechanics 31(5) 2003

Computational Mechanics 31(6) 2003

Computer Methods in Applied Mechanics & Engineering 192(28-30) 2003

Computer Methods in Applied Mechanics & Engineering 192(31-32) 2003

Computer Methods in Applied Mechanics & Engineering 192(33-34) 2003

Computer Methods in Applied Mechanics & Engineering 192(35-36) 2003

Computer Methods in Applied Mechanics & Engineering 192(37-38) 2003

Computer Modeling in Engineering & Sciences — 4(3-4) 2003

Computers & Structures — 81(18-19) 2003

Computers & Structures — 81(20) 2003

Computers & Structures 81(21) 2003

Earthquake Engineering & Structural Dynamics 32(10) 2003

Earthquake Engineering & Structural Dynamics 32(11) 2003

Engineering Fracture Mechanics 70(16) 2003

Engineering Fracture Mechanics 70(17) 2003

Engineering Fracture Mechanics 70(18) 2003

Engineering Structures 25(10) 2003

Engineering Structures 25(11) 2003

Engineering Structures 25(13) 2003

European Journal of Mechanics A-Solids 22(4) 2003

European Journal of Mechanics B-Fluids 22(4) 2003

Experimental Mechanics 43(3) 2003

Experiments in Fluids 35(1) 2003

Fatigue & Fracture of Engineering Materials & Structures 26(8) 2003

Fatigue & Fracture of Engineering Materials & Structures 26(9) 2003

Finite Elements in Analysis & Design 39(11) 2003

Finite Elements in Analysis & Design 39(12) 2003

Finite Elements in Analysis & Design 39(13) 2003

International Journal for Numerical & Analytical Methods in Geomechanics 27(9) 2003

International Journal for Numerical & Analytical Methods in Geomechanics 27(10) 2003

International Journal for Numerical & Analytical Methods in Geomechanics 27(11) 2003

International Journal for Numerical Methods in Engineering 57(12) 2003

International Journal for Numerical Methods in Engineering 57(13) 2003

International Journal for Numerical Methods in Engineering 57(14) 2003

International Journal for Numerical Methods in Engineering 57(15) 2003

International Journal for Numerical Methods in Engineering 58(1) 2003

International Journal for Numerical Methods in Engineering 58(2) 2003

International Journal for Numerical Methods in Engineering 58(3) 2003

International Journal for Numerical Methods in Engineering 58(4) 2003

International Journal for Numerical Methods in Fluids 42(10) 2003

International Journal for Numerical Methods in Fluids 42(11) 2003

International Journal for Numerical Methods in Fluids 42(12) 2003

International Journal for Numerical Methods in Fluids 43(1) 2003

International Journal for Numerical Methods in Fluids 43(2) 2003

International Journal of Engineering Science 41(16) 2003

International Journal of Engineering Science 41(17) 2003

International Journal of Engineering Science 41(18) 2003

International Journal of Engineering Science 41(19) 2003

International Journal of Fracture 119(4-2) 2003

International Journal of Heat & Fluid Flow 24(5) 2003

International Journal of Heat & Mass Transfer 46(21) 2003

International Journal of Heat & Mass Transfer 46(22) 2003

International Journal of Heat & Mass Transfer 46(23) 2003

International Journal of Heat & Mass Transfer 46(24) 2003

International Journal of Impact Engineering 28(10) 2003

International Journal of Plasticity 19(12) 2003

International Journal of Pressure Vessels & Piping 80(6) 2003

International Journal of Pressure Vessels & Piping 80(7-8) 2003

International Journal of Solids & Structures 40(20) 2003

5353	Electro-elastic interaction between a piezoelectric screw dislocation and circular interfacial rigid lines	Liu YW. Fang QH.
5371	Initial tension in randomly disordered periodic lattices	Karpov EG. Stephen NG. Liu WK.
5389	Crack parameter estimation in structures using finite element modeling	Dado MHF. Shpli OA.
5407	Analysis for polycrystal nonproportional cyclic plasticity with a dissipated energy based rule for cross-hardening	Peng X. Fan J.
5423	Comparison of dynamic response of structures with uncertain-but-bounded parameters using non-probabilistic interval analysis method and probabilistic approach	Qiu ZP. Wang XJ.
5441	Modelling paper as a two-dimensional elastic-plastic stochastic network	Bronkhorst CA.
5455	Experiments on the penetration of thin long-rod projectiles into thick long-cylindrical borosilicate targets under pressure-free polycarbonate, aluminum and steel confinements	Doyoyo M.
5477	Free and forced vibration of repetitive structures	Wang DJ. Zhou CY. Rong J.
5495	Elastic wave propagation in anisotropic spherical curved plates	Towfighi S. Kundu T.
5511	Theoretical model of piezoelectric fibre pull-out	Liu HY. Qin QH. Mai YW.

International Journal of Solids & Structures 40(21) 2003

5521	Mechanisms of stress transfer and interface integrity in carbon/epoxy composites under compression loading. part ii: numerical approach	Goutianos S. Galiotis C. Peijs T.
5539	A general failure criterion for spot welds under combined loading conditions	Lin SH. Pan J. Tyan T. Prasad P.
5565	Elastic constants for granular materials modeled as first-order strain-gradient continua	Chang CS. Shi Q. Liao CL.
5583	Interaction of thermal contact resistance and frictional heating in thermoelastic instability	Ciavarella M. Johansson L. Afferrante L. Klarbring A. Barber JR.
5599	Orthotropic elastic-plastic material model for paper materials	Makela P. Ostlund S.
5621	The use of graded finite elements in the study of elastic wave propagation in continuously nonhomogeneous materials	Santare MH. Thamburaj P. Gazonas GA.
5635	Elastic buckling of i-beams under linear moment gradient	Lim NH. Park NH. Kang YJ. Sung IH.
5649	Electrical nonlinear anti-plane shear crack in a functionally graded piezoelectric strip	Kwon SM.
5669	Finite polycrystalline elastoplasticity and damage: multiscale kinematics	Clayton JD. McDowell DL.
5689	Alternative state space formulations for magnetoelectric thermoelasticity with transverse isotropy and the application to bending analysis of nonhomogeneous plates	Chen WQ. Lee KY.
5707	Design of metallic textile core sandwich panels	Zok FW. Rathbun HJ. Wei Z. Evans AG.
5723	Periodically supported beam on a visco-elastic layer as a model for dynamic analysis of a high-speed railway track	Vostroukhov A. Metrikine A.
5753	The non-homogeneous biharmonic plate equation: fundamental solutions	Manolis GD. Rangelov TV. Shaw RP.
5769	Influence of plasticity on interface toughness in a layered solid with residual stresses	Tvergaard V.
5781	Edge dislocation interacting with an interfacial crack along a circular inhomogeneity	Fang QH. Liu YW. Jiang CP.
5799	Non-homogeneous displacement jumps in strong embedded discontinuities	Alfaiate J. Simone A. Sluys LJ.
5819	A cohesive plastic and damage zone model for dynamic crack growth in rate-dependent materials	Zhang X. Mai YW. Jeffrey RG.
5839	The plane elasticity problem of an isotropic wedge under normal and shear distributed loading - application in the case of a multi-material problem	Stampouloglou IH. Theotokoglou EE.
5861	"work-conjugacy between rotation-dependent moments and finite rotations" by manuel ritto-correa and dinar camotim [vol. 40, no. 11, pp. 2851-2873]	Teh LH.

Inverse Problems in Engineering 11(5) 2003

359	Optimal geometric representation of turbomachinery cascades using nurbs	Ghaly WS. Mengistu TT.
375	Upper bound of experiment informativeness	Romanovski M.
391	An inverse mass transfer problem in solid-liquid adsorption systems	Vasconcellos JFV. Neto AJS. Santana CC.
409	A downhill simplex method for computation of interfacial heat transfer coefficients in alloy casting	Pohanka M. Woodbury KA.
425	The use of model reduction and function decomposition for identifying boundary conditions of a linear thermal system	Girault M. Petit D. Videcoq E.

Journal of Biomechanical Engineering 125(4) 2003

Journal of Biomechanics 36(9) 2003

Journal of Composite Materials 37(16) 2003

Journal of Composite Materials 37(17) 2003

Journal of Computational Physics 189(2) 2003

Journal of Engineering Materials & Technology 125(3) 2003

Journal of Engineering Mathematics 46(3-4) 2003

Journal of Engineering Mathematics 47(1) 2003

Journal of Engineering Mechanics 129(9) 2003

Journal of Fluid Mechanics 487 2003

Journal of Fluid Mechanics 488 2003

Journal of Fluid Mechanics 489 2003

Journal of Fluids Engineering 125(4) 2003

Journal of Intelligent Material Systems & Structures 14(4-5) 2003

Journal of Intelligent Material Systems & Structures 14(6) 2003

Journal of Intelligent Material Systems & Structures 14(7) 2003

Journal of Microelectromechanical Systems 12(4) 2003

Journal of Non-Newtonian Fluid Mechanics 112(2-3) 2003

Journal of Non-Newtonian Fluid Mechanics 113(1) 2003

Journal of Non-Newtonian Fluid Mechanics 113(2-3) 2003

Journal of Reinforced Plastics & Composites 22(11) 2003

Journal of Reinforced Plastics & Composites 22(12) 2003

Journal of Reinforced Plastics & Composites 22(13) 2003

Journal of Reinforced Plastics & Composites 22(14) 2003

Journal of Sound & Vibration 265(2) 2003

Journal of Sound & Vibration 265(3) 2003

Journal of Sound & Vibration 265(4) 2003

Journal of Sound & Vibration 265(5) 2003

Journal of Sound & Vibration 266(1) 2003

Journal of Sound & Vibration 266(2) 2003

Journal of Strain Analysis for Engineering Design 38(4) 2003

Journal of the Mechanics & Physics of Solids 51(9) 2003

Journal of the Mechanics & Physics of Solids 51(10) 2003

Journal of Thermal Stresses 26(9) 2003

Journal of Thermal Stresses 26(10) 2003

Journal of Vibration & Control 9(8) 2003

JSME International Journal Series A-
Solid Mechanics & Material Engineering 46(3) 2003

Mathematics & Mechanics of Solids 8(4) 2003

Mathematics & Mechanics of Solids 8(5) 2003

Mechanics of Materials 35(10) 2003

Mechanics of Time-Dependent Materials 7(2) 2003

Mechanics Research Communications 30(5) 2003

Medical Engineering & Physics 25(8) 2003

Nonlinear Dynamics 32(4) 2003

Nonlinear Dynamics 33(1) 2003

Probabilistic Engineering Mechanics 18(3) 2003

Proceedings of the Royal Society of London Series A-Mathematical Physical & Engineering Sciences 459(2036) 2003

Proceedings of the Royal Society of London Series A-Mathematical Physical & Engineering Sciences 459(2037) 2003

Quarterly Journal of Mechanics & Applied Mathematics 56(Part 3) 2003

Quarterly of Applied Mathematics 61(3) 2003

485	A new weber-type transform	Thambynayagam RKM. Habashy TM.
495	Asymptotic behaviour for a partially diffusive relaxation system	Escobedo M. Laurencot P.
513	Analysis of a class of nonlinear integro-differential equations arising in a forestry application	Kreamer MA. Kalachev LV.
537	L-derivative of an approximate solution to phi ' = a(t)phi: series and product formulae for left corrections	Najfeld I. Lakin W.
565	On an elastic dissipation model for a cantilevered beam	Van Horssen WT. Zarubinskaya MA.
575	Surface waves of non-rayleigh type	Kuznetsov SV.
583	On similarity solutions and blow-up spectra for a semilinear wave equation	Galaktionov VA. Pohozaev SI.

SIAM Journal on Applied Mathematics 63(5) 2003

1475	Time reversal and refocusing in random media	Bal G. Ryzhik L.
1499	Heat-induced stretching of a glass tube under tension: application to glass microelectrodes	Huang HX. Miura RM. Ireland WP. Puil E.
1520	Periodic travelling wave selection by dirichlet boundary conditions in oscillatory reaction-diffusion systems	Sherratt JA.
1539	Solitary waves in layered nonlinear media	Leveque RJ. Yong DH.
1561	Formal asymptotic models of vehicular traffic. model closures	Sopasakis A.
1585	A periodically forced wilson-cowan system	Noonburg VW. Benardete D. Pollina B.
1604	Oscillatory flow near a stagnation point	Blyth MG. Hall P.
1615	System of phase oscillators with diagonalizable interaction	Nishikawa T. Hoppensteadt FC.
1627	Nonlinear coupling near a degenerate hopf (bautin) bifurcation	Drover JD. Ermentrout B.
1648	Singular perturbations in option pricing	Fouque JP. Papanicolaou G. Sircar R. Solna K.
1666	Chemotactic cellular migration: smooth and discontinuous travelling wave solutions	Landman KA. Pettet GJ. Newgreen DF.
1682	Formal asymptotics of bubbling in the harmonic map heat flow	Van den Berg JB. Hulshof J. King JR.
1718	Backscattering and nonparaxiality arrest collapse of damped nonlinear waves	Fibich G. Ilan B. Tsynkov S.
1737	The radio-frequency driven plasma sheath: asymptotics and analysis	Slemrod M.
1764	Acoustic pulse spreading in a random fractal	Solna K.
1789	Orthonormal polynomial wavelets on the interval and applications to the analysis of turbulent flow fields	Frohlich J. Uhlmann M.
1831	Initiation of free-radical polymerization waves	Ritter LR. Olmstead WE. Volpert VA.

Structural & Multidisciplinary Optimization 25(2) 2003

67	A unified reanalysis approach for structural analysis, design, and optimization [review]	Kirsch U.
86	The normalized normal constraint method for generating the pareto frontier	Messac A. Ismail-Yahaya A. Mattson CA.
99	The use of metamodeling techniques for optimization under uncertainty	Jin R. Du X. Chen W.
117	Boundary perturbation method applied to optimal plastic design of beams under bending with shear	Egner W. Zyczkowski M.
128	Managing approximation models in multiobjective optimization (vol 24, pg 141, 2002)	Yang YS. Jang BS. Yeun YS. Ruy WS.
129	Using surrogate models and response surfaces in structural optimization - with application to crashworthiness design and sheet metal forming	Jansson T. Nilsson L. Redhe M.
141	A nlp approach for evaluating storey-buckling strengths of steel frames under variable loading	Xu L.

Studies in Applied Mathematics 111(3) 2003

269	Classification of discrete symmetries of ordinary differential equations	Laine-Pearson FE. Hydon PE.
301	Modulations of deep water waves and spectral filtering	Kliakhandler IL.
315	Linearizable hierarchies of evolution equations in (1+1) dimensions	Euler M. Euler N. Petersson N.
339	Infinite interval problems modeling phenomena which arise in the theory of plasma and electrical potential theory	Agarwal RP. O'Regan D.
359	Continuous families of embedded solitons in the third-order nonlinear schrodinger equation	Yang J. Akylas TR.

Theoretical & Applied Fracture Mechanics 40(2) 2003

Thin-Walled Structures 41(9) 2003

Wave Motion 38(3) 2003

Wave Motion 38(4) 2003

Zeitschrift fur Angewandte Mathematik und Mechanik 83(7) 2003

Zeitschrift fur Angewandte Mathematik und Mechanik 83(8) 2003

Zeitschrift fur Angewandte Mathematik und Mechanik 83(9) 2003

Zeitschrift fur Angewandte Mathematik und Physik 54(4) 2003