OPINION

Expansion fever and soft money plague the biomedical research enterprise

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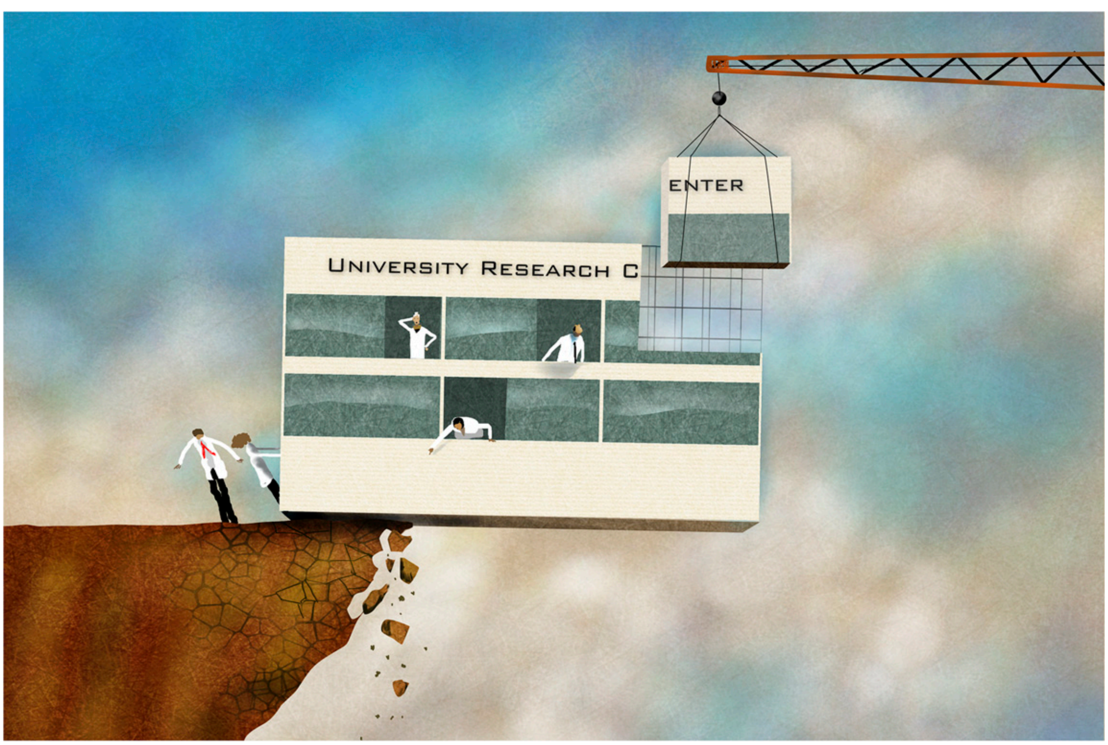
Academic biomedical science has had both a long boom in its funding and a subsequent scary bust. From 1970 to 1999, NIH budgets increased 9% per year (1); from 2000 to 2004, they doubled (2, 3). In 2005 came the unmistakable bust: flat-lined NIH budgets converted the doubling into a paltry 14% increase in inflation-corrected (4) dollars over 16 years (1999–2015; Fig. 1*A*). But during the bust, two stealthier dangers escaped notice, their quantitative details and significance masked or denied. Universities recklessly overbuilt laboratories to fill with more scientists, just when the bust removed funding increases they needed to do science. As diminished NIH dollars made research riskier, universities required principal investigators (PIs) to earn high proportions of salary from grants, transferring much of the risk to PIs: Universities in the 1970s paid PIs about 75% "hard" salary from their own coffers; those coffers in the 21st century pay PIs much less, forcing them to corral most salary as "soft" grant money.

As responses to specific circumstances, expansion and soft money seemed innocuous during boom decades, when increasing federal grants and indirect cost recovery (ICR) allowed expansion to pay for itself. Then flat-lined NIH budgets after 2004 turned formerly prudent policies into grave dangers, allowing stagnant funding to combine with ever-expanding research facilities and reliance on



Universities have recklessly overbuilt laboratories to fill with more scientists, just when lower funding from NIH eliminated the increases they needed to conduct science. Image courtesy of Dave Cutler.

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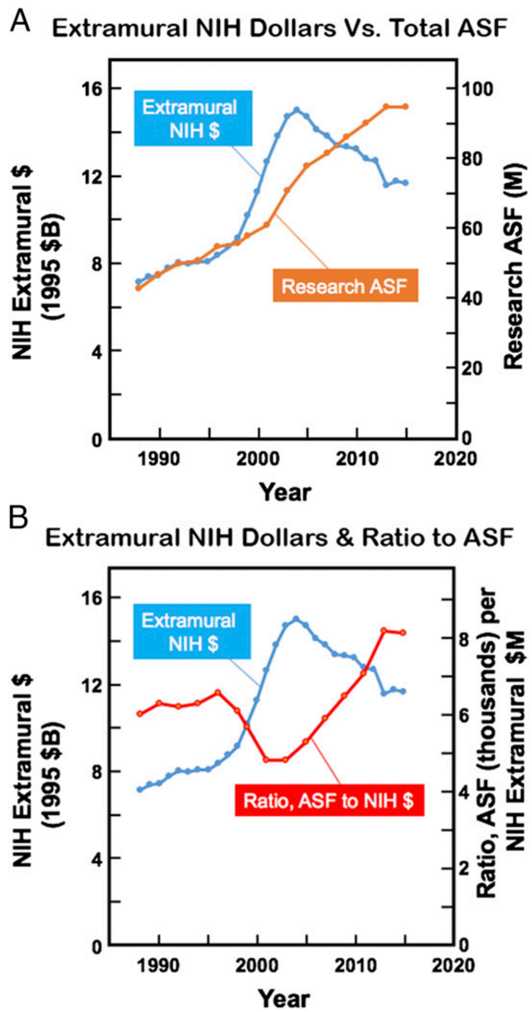

Fig. 1. **As these graphs show by tracking national academic research capacity and NIH extramural dollars from 1987 to 2015, infrastructure investments have come to represent a larger portion of available funds. (*A*) Annual extramural NIH dollars and national academic research capacity in biomedical sciences. (*B*) Annual extramural NIH dollars and ratios of research ASF to extramural NIH money. Dollars [that is, total research grant plus total research training (2, 3)] are corrected for inflation and expressed in 1995 dollars (4). The biennially tabulated ASF for biological and biomedical plus health and clinical sciences was from the National Science Foundation (see *SI Appendix*). Bienenstock et al. (5) denied overbuilding on the basis of an analysis similar to that of *B*, but wrote too early to include ASF data for 2013 and 2015.**

soft-money salary to corrode job security and opportunities for academic biomedical scientists. Although external funds remain scarce, research universities must act to protect science from soft money and expansion, both of which they control directly. Can academic institutions rescue biomedical research and the next generation of investigators? Yes, but the task will be hard and slow, and success will be piecemeal, not sweeping.

Overbuilding Is Real

In 2010, Alberts (6) warned that US biomedical research capacity was dangerously overbuilt relative to NIH funding. For lack of quantitative evidence, overbuilding's existence was denied (7), but new data (Fig. 1) show Alberts was right: The budget doubling lured schools to increase national biomedical research capacity [assignable square feet (ASF) of laboratory space] by 64% between 1999 and 2015 (see *SI Appendix* and Datasets S1 and S2). However, the bust devoured NIH dollars needed to fill new facilities with scientists, so NIH-supported research activity [extramural, inflation-corrected (4)] rose only 14% (Fig. 1*A*), whereas the ratio of capacity to activity rose 44% (Fig. 1*B*).

Three questions arise. First, did philanthropic or industry-derived grants make up for NIH's relative dollar shortfall after the doubling? Extrapolation from available data (8) indicates that these sources probably supplied about 15% of the shortfall (see *SI Appendix*). Second, why did evidence for excess research capacity not surface earlier? Baseline data are lacking, because the National Science Foundation first tabulated university research ASF in 1987, long after rising NIH dollars began to spur growth of research facilities. Third, how can universities continue to expand even when they face genuine financial risks? Recent construction of a university research facility* suggests how this can happen.

Faith That New Dollars from Somewhere Would Overcome Financial Risk. In the case of this major research university, construction costs ($447M) will be paid by the principal donor ($125M), unidentified donors ($50M), and bank loans to the university ($272M). Over the building's first decade, the university must also pay annual hidden costs I estimate at $21.7M per year ($217M total for hiring and paying new faculty, administration, utilities, maintenance, etc.). New PIs hired to fill the building will not earn sufficient ICR to pay these hidden costs—approximately 10% of the university's annual ICR from all its research grants. From loans and its own resources, the institution must pay $489M (74%) of the $664M total cost (construction plus hidden costs).* Well after construction began, sources for that 74% have not yet been identified, but paying it will probably inflict painful opportunity losses by consuming endowment payouts and ICR already committed to other PI salaries and research programs.

Academic Focus on Research Quality, New Knowledge, and Discovery Is Slighted When Universities Measure Success Primarily in Dollars and Buildings. Misguided metrics hurt PIs even more when successful expansion becomes increasingly addictive, leading to exclusive reliance on quantity to assess further success. At one large institution, a clinical department chair told me frankly that candidates for permanent faculty positions are judged by "Darwinian" selection based on obtaining NIH funding, because "by ourselves we can't judge quality or predict success well enough" (9).

*Choosing not to identify a single university among many that make plans and decisions in much the same way as this university did, I have not listed the scattered but accurate sources that specify this building's construction costs.

Secrecy.[†] Often well justified, secrecy can also prove toxic, if expansionist zeal produces a result that adversely affects future quality of the university's scientific mission. For example, commitments to pay millions of dollars for buildings make it prudent for the institution to consult, at an early stage, trusted university faculty who will not benefit from it directly but who can ask how the university will pay salaries of dozens of additional scientists. By preventing anyone from knowing whether that question was asked and answered, secrecy may have permitted an unspoken assumption—which would not be revealed until the scientists are hired—that the new faculty salaries would be paid from soft money. Measures to prevent such an outcome are presented below.

Soft Money and Expansion

Because universities carefully guard salary data, no one knows when the national shift to higher proportions of soft money began. In the only published account of soft-money distribution within a research university (10), 1,050 PIs received (on average) 65% of their salary from grants in 2014, whereas 500 others, mostly clinician scientists with large incomes from clinical activities, received 10%. This distribution is probably typical of most large academic research centers.

Universities derive huge dollar benefits from soft money. In 2014, the university alluded to above received $208M in soft money from NIH, including $148M in PI salaries it did not have to pay, plus $60M in ICR based on those grant-derived PI salaries (11). Although NIH does not reveal the amount of soft money NIH pays each year, it can be roughly estimated, based on the 23,629 reported person-years of "effort" by PIs and co-PIs reported (12) on NIH grants in 2009 and on reasonable assumptions.[‡] Thus NIH probably paid academic researchers and institutions $5–$6B in soft money plus associated ICR—or about 25% of its 2009 extramural NIH budget [$21B (3)]. If universities had paid those dollars instead, NIH could directly target them to research.

The huge boon of soft money for universities inflicts extremely toxic effects (Box 1) on scientists and research. Each toxicity directly reflects an inescapable fact: Soft-money salary transfers a hefty portion of the financial risk of supporting science from powerful universities to the vulnerable necks of PIs. Today's rampant expansion would be impossible without soft money, but many universities (and senior PIs with well-armored necks) argue—incorrectly, I suspect—that life-saving discoveries would also be slower. Expansion almost certainly produced more and better science when grants were more generous in the 1970s to 1990s, but increasing applications and limited NIH dollars now make grants much harder to get, gravely boosting toxicities inflicted by soft money and expansion on PIs and the academic research enterprise (Box 1).

Three additional toxicities will be substantially mitigated if scientific judgment manages to redirect priorities toward quality and away from expansion and soft money. "Unsustainable hypercompetition" for jobs, grants, publications, and trainees forces PIs to compete fiercely for scarce NIH dollars and use trainees as a cheap laboratory workforce, eventually producing more soft-money investigators with federal support than is compatible with high-quality science in times of reduced NIH support (13, 14). Continuing expansion of the hypercompetitive system leverages relative advantages of older over younger PIs (in salary, competition for grants, and attention from institutional leaders), thereby enhancing older PIs' control over distribution of university resources (15). Also, PIs in basic science departments of academic health centers inevitably become more financially vulnerable than clinician PIs: The latter can earn clinic-derived salary, so basic scientists need almost twice the proportion of soft-money salary (on average) needed by clinician scientists (16). Job security and less reliance on soft money will furnish biomedical scientists

Box 1. Toxicities of Expansion and Soft Money

Effects on PIs

- Soft money makes PIs less loyal to their institutions and colleagues, just as it makes institutions care less about the welfare and futures of its PIs.
- PIs write myriad time-devouring grant applications.
- NIH reviews of more grant applications become increasingly arbitrary, because requests graded in the top 10% may not be better than those in the next 10%.
- Schools cede the task of evaluating PIs and their research to funding agencies.
- These effects, plus the stress of living on soft money, sap PIs' job security.
- Job insecurity drives PIs to seek hard-money academic jobs in other countries.
- Worse, job insecurity drives many more PIs to avoid tackling hard questions.

Effects on academic biomedical research

- Overbuilt facilities waste money and tempt institutions to hire many more scientists than external funds can support.
- Bright students choose against insecure futures in science.
- Senior PIs are favored over younger PIs, whose work must drive discoveries when today's older PIs are gone.
- Together, these effects can make this research appear expressly designed to extirpate scientific curiosity.

[†]For 2 years, plans and decisions for the building referred to here were known only to a top university official, two department chairs, and the principal donor. These four then consulted university researchers in the field to be explored in the new facility, but 3 years passed before anyone else learned the building's planned location, size, and purpose. This secrecy was confirmed in conversations between two high officials of the institution and the author.

[‡]The assumptions: (*i*) $192,000 is the average annual total salary plus benefits for all PIs/co-PIs who received some NIH-derived salary, (*ii*) ICR dollars based on PI/co-PI salary reimbursed at an average rate of 41% of the actual salary and benefits, and (*iii*) top and bottom estimates of NIH dollars paid in association with soft-money salaries ($5.12–$6.0B) reflect payment from NIH grants of either 80% or 100% of all PI/co-PI person-years (percentages are hypothetical).

more time and energy to improve the workforce's composition and future prospects, training, nurturing of young colleagues, and research excellence in both clinical and basic science departments.

Reform: Barriers and Tactics

We seek to strengthen the ability of academic biomedical research to create new knowledge and nurture new researchers, thereby enhancing its quality and sustainability. To do so, reformed institutions must (*i*) stop expanding research capacity, (*ii*) provide more hard-money salary for superb young and midcareer PIs, and (*iii*) tap their best researchers' scientific judgment to promote better decisions regarding research.

To be blunt, interlocking barriers stymie progress toward this goal. NIH cannot and will not tackle the job for fear of devastating pushback from large institutions. Similar pushback in 2012 constrained recommendations of an NIH working group to change the research workforce (13) and in 2017 prevented the Grant Support Index from helping young PIs by limiting big grants awarded to senior PIs (17, 18). Universities steadfastly reject limits on both expansion and their annual boon, the yearly NIH gift of $5–$6B in soft money plus ICR.

Because institutions directly control both soft money and expansion, they could limit growth of their

They understand that expansion without adequate salary support for new scientists cannot continue forever, that savings from renouncing expansion help them pay higher proportions of PI salaries from endowments, and that hard-money salaries magnetically attract superb scientists.

biomedical research and forego that soft-money gift. Caltech, Rockefeller University, and the Massachusetts Institute of Technology have done so: They have not expanded numbers of biomedical research PIs for years, pay all or most salary of tenure-track PIs, and produce abundant high-quality research.[§] They understand that expansion without adequate salary support for new scientists cannot continue forever, that savings from renouncing expansion help them pay higher proportions of PI salaries from endowments, and that hard-money salaries magnetically attract superb scientists. Similar prudence and enlightened self-interest should persuade additional "pioneer" schools to follow their examples.

Part of the hard money necessary for reform must come from more and bigger endowments. But note also that if expansion fever had not committed $489M in university funds for the new research facility and 40–50 additional PIs described above,* the dollars saved could generate $100,000 in hard-money salary plus benefits every year for more than 245 PIs.[¶] Finally, most schools already pay some hard-money PI salary, so gradual reduction of a small proportion of faculty slots could provide dollops of hard money to attract outstanding PIs.

In practical terms, reform will necessarily proceed piecemeal, achieving successes in individual pioneer research universities after years of hard work. It will begin in pioneer schools only if unhappy faculty press hard for reform and leaders hear them. Too strapped financially to risk the pioneer route or already infected with expansionist zeal transmitted from their health-care affiliates, other schools will simply dismiss the idea. Prospective pioneer schools will first assess costs and benefits, financial and scientific, of their soft-money and expansion policies. Making those assessments public will subject pioneers to attack for betraying cabalistic secrets, but it is crucial for implementation. For reform to succeed, this hard nut must crack.

To implement reform, each pioneer will craft tactics to fit its needs, first designating its core reformers—a director, deputy director, and steering committee. This core, respected PIs with active research programs, who represent a broad spectrum of research in multiple departments, must devote substantial energy to the project and merit trust of school leaders, who can provide necessary dollars, staff, and judicious facilitation. The core's scientific judgment will help the school distribute internal resources for research, resolve research construction and renovation issues, and attract philanthropy for endowment to pay hard-money salary. In this role, the core can counter potential toxicities of secrecy in planning new construction as noted above. As implementation begins, NIH must provide valuable but inexpensive help by assuring the pioneer's leaders and reformers that—providing the proposed budget for a grant application is justified—its peer review will not arbitrarily reduce total funding for PIs who receive the school's extra hard money. Indeed, a grant that pays little or no PI salary but instead replaces a trainee with an expensive, highly qualified PhD staff scientist, could produce better research, leverage the school's hard money to strengthen the national biomedical workforce (13, 14), and justifiably recover institutional ICR otherwise lost by not reducing a PI's soft money.

In implementing reform, the core's most critical long-term task will be to supervise substitution of hard for soft money. Substitution must be gradual because enough hard money to achieve the ultimate goal—every PI gets at least 75% of his or her salary in hard dollars—will be hard to find. Selecting the right PIs for supplementary hard dollars will be critical because proper selection criteria and judicious choice of new

[§]Based on written or telephone communications with high officials at these institutions. Other institutions may do the same, of course, but most do not.

[¶]In the expansion-fever episode described, the university has committed $489M for building's total costs (construction plus hidden costs; see text). A similar-sized endowment with an annual payout of 5% per year would produce $24.5M per year, or $100,000 of hard-money salary plus benefits for 245 PIs. Caveats abound, but they are too numerous for discussion here.

hires and outstanding early- to midcareer PIs will greatly boost quality of the institution's research. Within universities, that selection will be the hardest task, because PI X will merit a hard-money award, whereas PIs Y and Z, at the same professorial rank, do not. Such decisions must be fair with criteria clear to all.

To preserve and enhance creation of new knowledge, we seek to husband our scarcest resource: energetic, creative scientists. Piecemeal curbing of expansion and soft money in a few research universities will require 20 years or more. Dramatic approaches will not work, but slow, careful reform in pioneer universities can achieve local success: (*i*) job security for pioneers' PIs need no longer depend solely on arbitrary grant reviews, (*ii*) enhanced quality will make pioneer institutions better places to do science and attract excellent colleagues and students, (*iii*) successful pioneers will create an archipelago of scientific opportunity in a roiling sea of overbuilt institutions with frazzled scientists who wish they could work for a pioneer, and (*iv*) once enough pioneers succeed, NIH and the biomedical research community will eagerly help others follow.

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