Title
A new conceptual framework for preclinical departments in schools of medicine: Maximizing groundbreaking work through thematic breadth

Journal
The FASEB Journal, 39(6)

ISSN
0892-6638

Authors
Santana, L Fernando
Barrett, Kim E
Murin, Susan

Publication Date
2025-03-31

DOI
10.1096/fj.202402439r

Received: 12 October 2024 | Revised: 23 February 2025 | Accepted: 5 March 2025
DOI: 10.1096/fj.202402439R

PERSPECTIVE

The FASEB Journal

A new conceptual framework for preclinical departments in schools of medicine: Maximizing groundbreaking work through thematic breadth

L. Fernando Santana[1] | Kim E. Barrett[2] | Susan Murin[3]

[1]Department of Physiology and Membrane Biology, University of California, Davis School of Medicine, Davis, California, USA
[2]Department of Physiology and Membrane Biology, University of California, Davis School of Medicine, Sacramento, California, USA
[3]Department of Internal Medicine, University of California, Davis School of Medicine, Sacramento, California, USA

Correspondence
L. Fernando Santana, Department of Physiology and Membrane Biology, University of California, Davis School of Medicine, Davis, CA, USA.
Email: lfsantana@ucdavis.edu

Abstract
Basic sciences form the foundation of medical knowledge and practice in medical schools. Since the 1910 Flexner Report, which led to the establishment of multiple basic science departments, faculty in these departments have been responsible for preclinical courses in the first 2 years of medical education. The basic science disciplines and their associated faculty have been crucial to medical education, fostering critical thinking and preparing physicians for rapid advancements in medicine. Importantly, they have grown as engines of innovation and influence to comprise hubs for fundamental and translational research. More recently, a convergence of influences, including the adoption of integrated curricula and other changes in the traditional medical education structure, as well as financial pressures and ongoing changes in research funding, has prompted many institutions to re-evaluate the organization of basic sciences, leading to a wave of departmental consolidations. While this may seem administratively and financially attractive, it could have the unintended consequence of consolidating scientific thought, with an attendant stifling of innovation. To sustain the institutional capacity for making the paradigm-shifting discoveries essential for transforming medicine in a shifting research landscape, we propose a new rationale for maintaining or even expanding the multi-departmental structure. Our model builds on recent research suggesting that thematic diversity and inter- and trans-disciplinary teams are fundamental features crucial for innovation. We propose a novel approach that involves the establishment of an institution-wide strategic theme, layered over a multi-departmental structure in which individual department chairs are recruited based on the extent to which their research agenda aligns with the strategic theme. This broad institutional strategy preserves the unique contributions of individual disciplines while fostering interdisciplinary collaboration, thereby maximizing thematic breadth and synergy. By balancing administrative efficiency with the imperative for innovative

The opinions expressed in this article are expressly those of the authors and do not necessarily reflect the opinions of FASEB or its constituent societies.

research, medical schools can establish a unique identity with an associated future vision. Importantly, the existing strengths that foster this vision provide the basis for explosive growth, with the capacity to shape the future of medical education while creating an environment conducive to groundbreaking discoveries and advancements in medical science.

1 | INTRODUCTION

Medical education has undergone significant transformation since its early apprenticeship days.[1] The journey from experiential learning to a scientifically grounded curriculum has been marked by several pivotal moments, perhaps none more notable than the Flexner Report of 1910.[2] This report revolutionized medical education by advocating for a standardized, science-based curriculum with a strong emphasis on preclinical science departments.

The Flexnerian model has long provided a rigorous, scientifically grounded framework that established robust standards for medical education at institutions.[3] This model enabled the integration of formal scientific inquiry with clinical training, producing generations of well-prepared physician–scientists. As detailed in Irby et al.,[3] its strengths include the systematic integration of basic science with clinical training and the establishment of a reliable educational structure. However, in their view, the experience at the University of California, San Francisco (UCSF), also exposed inherent weaknesses: a rigid 2 + 2 curricular format that leans heavily on didactic lectures and limited opportunities for early clinical immersion, ultimately constraining adaptability and responsiveness to contemporary healthcare challenges. In the light of these limitations, the 2010 Carnegie report proposed four areas of improvement: standardizing learning outcomes while individualizing the learning process, more seamlessly integrating formal knowledge with clinical experience, fostering habits of inquiry and continuous improvement, and emphasizing the progressive formation of professional identity. These proposals were designed to evolve the traditional Flexnerian model into a more dynamic, learner-centered framework that better addresses the complexities of modern medical education and practice. Accordingly, many schools have sought to improve the integration of theoretical knowledge and practical skills throughout the curriculum, recognizing the importance of both. New curricular styles, such as I-EXPLORE at UC Davis School of Medicine, represent a transition from the Flexnerian model and a move toward a more integrated approach to medical school teaching.

As medical schools evolve and adapt to new educational paradigms and financial pressures, they face challenges in maintaining the traditional departmental structure. This has often led institutions to re-evaluate the organization of basic sciences, with many considering the consolidation of departments. While consolidation may seem administratively and financially attractive, recent research suggests that it may lead to a loss of thematic diversity crucial for innovation in scientific research. This insight provides a compelling rationale for maintaining, or even expanding, the multi-departmental framework in medical schools. By preserving distinct departments, each defined by its specialized subject matter and focus, institutions can create an environment that fosters paradigm-shifting discoveries and advances in medical science.

2 | THE CASE FOR THEMATIC BREADTH AS THE ENGINE FOR SCIENTIFIC DISCOVERY

A growing body of work suggests that thematic diversity is crucial for fostering innovation in biomedical research.[4–7] Collectively, this literature posits that diversity in research themes encourages the exploration of a broader range of scientific questions, promotes interdisciplinary collaboration, and prevents the intellectual stagnation that can occur when research themes become too narrowly focused. Enhanced collaboration across diverse research themes fosters integrative studies that address complex biological questions from multiple perspectives.

As an example of how thematic diversity can lead to groundbreaking discoveries consider the seminal work of Hodgkin and Huxley.[8] Seeking to understand how nerves conduct impulses—a question at the intersection of chemistry, physics, mathematics, and neurobiology—these researchers ultimately developed a mathematical model of the neuronal action potential. By applying an interdisciplinary approach, Hodgkin and Huxley not only revolutionized our understanding of neural signaling, they also laid the foundation for modern neuroscience, demonstrating how integrating diverse fields can open entirely new avenues of research.

Similarly, the work of Edwin G. Krebs[9] on reversible protein phosphorylation and the cAMP/protein kinase A pathway illustrates the far-reaching impact of thematic diversity. This work, encompassing biochemistry and molecular biology, has had profound implications for neuroscience and cardiovascular physiology, among many other areas. The elucidation of these signaling mechanisms provided crucial insights into synaptic plasticity in the brain and the regulation of heart function by the autonomic nervous system, showcasing how fundamental research in one area can have transformative effects across multiple disciplines.

The revolutionary impact of thematic diversity is further exemplified by the recent structural biology work of Drs. MacKinnon,[10] Kobilka[11] and Baker,[12] together with the Google DeepMind team behind AlphaFold.[13] These researchers and their teams have masterfully combined chemistry, physics, and computational modeling to solve the long-standing problem of predicting protein folding from primary amino acid sequence—the Holy Grail of protein biology. In so doing, they transformed our understanding of protein structures and their functions, profoundly impacting molecular biology and pharmacology.

These combined efforts, spanning traditional fields, have revolutionized structural biology, in the process providing pharmacologists with powerful tools for understanding drug-target interactions at an atomic level, allowing the development of more targeted and effective pharmaceuticals and potentially ushering in a new era of precision medicine. Importantly, these advances represent clear examples of scientific investigation that are not discipline-, domain-, or disease-specific.

3 | THE CONCEPT OF "CRITICAL MASS" OF RESEARCH TEAMS IS POORLY DEFINED AND CAN LEAD TO HYPER-SPECIALIZATION

A conceptual companion of thematic diversity in driving innovation is "critical mass" of research teams. As used here, critical mass refers to the optimal number of researchers needed to make significant progress in a scientific field and/or efficiently solve complex problems. This concept suggests a certain threshold, above which productivity and innovation increase dramatically and progress is rapid. Creating a critical mass of researchers is often cited as a rationale for the concentrated recruitment of faculty in specific areas of research. However, defining the optimal number of such researchers is inherently challenging, and the number itself varies with the nature of the discipline, problem complexity, and resource constraints.

An additional crucial consideration in applying the critical mass concept is the fluidity of this ideal number. This can lead to a drift toward homogenized thinking: As research teams grow, the need for coordination and consensus can overshadow individual contributions, creating an environment where dominant voices or ideas prevail and contradictory perspectives wither. The dominance of certain ideas or methodologies within a large group creates a normative pressure that promotes conformity, stifling the very creativity and innovation that larger teams are meant to foster and promoting groupthink, inadvertently limiting the diversity of thought essential for breakthroughs. This phenomenon can be particularly problematic in rapidly evolving fields or those tackling complex—or controversial—questions that benefit from diverse perspectives. Moreover, as fields become more specialized and require increasingly sophisticated equipment or techniques, the risk of concentrating resources and talent in the few centers that can afford them increases, further exacerbating the homogenization of ideas.

The pursuit of hyper-specialization in scientific research, while often seen as a path to expertise, may paradoxically hinder true innovation and mechanistic insights. As researchers delve deeper into increasingly narrow fields, they risk isolating themselves on "intellectual islands" where ideas circulate only among like-minded specialists. This insularity can block the influx of novel perspectives and alternative viewpoints from other disciplines. Consequently, the very depth of knowledge that specialization aims to achieve may become a barrier to breakthrough discoveries. By limiting exposure to diverse ideas and methodologies from seemingly unrelated fields, hyper-specialization can stifle the cross-pollination of concepts that often underpins paradigm-shifting insights and revolutionary advancements in scientific understanding.

Striking the right balance is key. While reaching a critical mass of researchers can accelerate progress, maintaining intellectual diversity and encouraging healthy scientific debate are equally important. This might involve fostering and/or incentivizing collaboration between different research groups, promoting interdisciplinary approaches, or deliberately incorporating researchers with varied backgrounds and perspectives. The goal should be to achieve a critical mass that enhances productivity and innovation while safeguarding against the pitfalls of intellectual homogeneity.

Chaos theory offers a useful lens for conceptualizing this balance. In complex systems, the "edge of chaos" is that unique space where elements do not settle into rigid, compacted structures but instead remain in a state of energetic suspension that maximizes adaptability, computation, and information-processing. Similarly, institutions that foster the right balance of thematic breadth can maintain a fluid intellectual ecosystem that encourages exploration and innovation, preventing the development of groupthink and ensuring that knowledge creation remains dynamic and responsive to emerging challenges.

4 | CONSOLIDATION OF BASIC SCIENCE DEPARTMENTS IN MEDICAL SCHOOLS

Many medical schools have moved toward consolidating their basic science departments. Ostensibly, this trend reflects an effort to streamline administration, foster interdisciplinary research, and adapt to evolving scientific paradigms. This widespread approach is exemplified by steps undertaken at several institutions.

At the University of Arizona, Phoenix, College of Medicine, diverse disciplines, including functional anatomy, cell and molecular biology, cardiovascular physiology, behavior, and medical education research, have been brought together in a Department of Basic Medical Sciences. Cedars-Sinai Medical Center in Los Angeles, CA, has similarly established a Department of Biomedical Sciences that encompasses multiple divisions and institutes.

The University of California, San Diego (UCSD) School of Medicine, has adopted a hybrid model that features two basic science departments—Cellular and Molecular Medicine and Pharmacology—but also includes clinical departments that house large numbers of basic scientists. Notably, UCSD has eschewed separate departments for most traditional disciplines, such as physiology and biochemistry. At its founding, it had no basic science departments at all, a strategy that was intended to increase research and teaching interactions with the main undergraduate campus, but one that has not proven wholly successful.

Other examples include the University of Rochester School of Medicine, which has a combined Physiology and Pharmacology department, recognizing the close relationship between these fields, and the University of Washington School of Medicine, which recently merged its Departments of Biological Structure and Physiology & Biophysics into a single Neurobiology & Biophysics department, reflecting the neuroscience focus of both original departments.

These examples illustrate a growing trend in medical education and research, where institutions are breaking down traditional departmental boundaries to create more integrated research teams.

5 | STRATEGIC VISION FOR INNOVATION VIA EXPANSION OF THEMATIC BREADTH IN THE BASIC SCIENCES

It is important to acknowledge that the optimal implementation of our proposed framework is not a one-size-fits-all solution. Variations in institution size, funding levels, governance structures, and historical context mean that each institution will need to tailor these strategies to its unique circumstances. Our proposal is intended to provoke thoughtful discussion and encourage institutions to critically evaluate how best to integrate thematic diversity within their existing structures, rather than to prescribe a definitive model.

To maximize thematic diversity and enhance the impact of preclinical research, we propose a strategic vision that emphasizes distinct but complementary thematic areas within each department or recruiting unit. In many institutions, faculty recruitment is primarily conducted by departmental chairs, who often hire faculty with specializations that align with their own. While this approach can be beneficial, as chairs are well-positioned to identify and mentor top recruits in their field, it may also lead to hyper-specialization and a consequent loss of thematic diversity, potentially hindering innovation.

An important question arising is whether thematic diversity and departmental consolidation are mutually exclusive. We believe the answer is a qualified no. Maintaining diversity within consolidated structures can be accomplished by decentralizing hiring decisions to divisions or centers or by having department chairs who are committed to recruiting diverse faculty. However, our experience suggests that the latter scenario is relatively uncommon.

The risk for institutions where multiple basic science departments have chairs with similar research interests is that faculty recruitments lead to thematic similarities both within and across departments. In this scenario, the rationale supporting separate departments weakens and the likelihood of their fusion increases. This underscores the necessity for a new approach that emphasizes strategically recruiting chairs—and thus faculty—who are aligned with diverse thematic areas.

To address these challenges, we propose a deliberate, strategic approach for the recruitment of chairs that recognizes the benefits of allowing these individuals the independence to recruit new faculty in areas they know well and can therefore judge effectively. To counterbalance this tendency toward similarity within departments, institutions will need to promote diversity among departments, strategically realigning them to focus on distinct but complementary thematic areas that are derived from a broader institutional strategic vision. This process involves recruiting new department chairs with expertise in the respective research areas and ensuring that their faculty hires align with the departmental thematic focus. By implementing this approach, institutions can foster a rich, diverse research environment that promotes innovation and interdisciplinary collaboration.

This strategic vision for thematic diversity aims to strike a balance between the efficiency gained through departmental consolidation and the innovation fostered by diverse research interests. It recognizes the importance of thoughtful, strategic hiring practices at both the chair and faculty levels in maintaining a vibrant and multifaceted research ecosystem within the basic sciences. Importantly, this approach also affords maximum independence to each department in recruiting decisions, leveraging the expertise of chairs while ensuring overall institutional diversity.

While every institution should debate how to implement a version of our framework, we advocate for the formation of a multilevel consultation model that preserves and enhances thematic diversity across the basic sciences within an overarching institutional vision. At the apex of this structure is the Dean of the School of Medicine, who would receive advice from a strategic committee composed of senior academic leadership (e.g., Vice Dean for Basic Sciences and Vice Dean for Research) and cross-disciplinary representatives. This group would be responsible for proposing a cohesive institutional strategy that defines the broad thematic vision and provides direction for the entire organization. Complementing the work of this group, regular departmental and cross-departmental meetings would facilitate ongoing dialogue, allowing departments to share insights, address challenges collaboratively, and continuously refine their approaches. Together, these layers of consultation serve to create a dynamic and flexible framework that fosters innovation while safeguarding the unique contributions of each department.

By developing institution-specific thematic criteria, the strategic committee would identify specific areas of focus in each basic science discipline to ensure that new chairs are recruited based on their potential to foster complementary research areas that enhance a vibrant, interdisciplinary research environment. In addition, the committee would review best practices from both academic and external sectors, ensuring that recruitment practices are innovative, adaptable, and responsive to current trends in research funding and collaboration. Regular dialogue among departments would facilitate continual reassessment of recruitment strategies, preventing the risks of hyper-specialization and intellectual homogeneity. Ultimately, this strategic preparatory process would not only safeguard the institution's commitment to thematic breadth, but it would also ensure that new chairs contribute to a robust ecosystem of interdisciplinary collaboration and innovation, adaptable to institutions of various sizes, funding levels, and governance structures.

6 | POTENTIAL THEMATIC AREAS

Maximizing thematic diversity across independent departments can be achieved through a strategic approach that begins with identifying broad areas of strength within the institution's basic science programs. This deliberate approach allows each department to develop a distinct research identity, minimizing overlap while enhancing synergies across disciplines. The thematic focus of individual medical schools may vary, reflecting their unique research profiles and institutional goals.

For instance, a school might choose a unifying theme, such as precision medicine, regenerative biology, or molecular therapeutics to guide its overarching strategy. Using the chosen theme as an organizing principle, each basic science department could focus on specific areas that are aligned with its strengths, ensuring a balanced portfolio of research efforts that complement each other and collectively drive innovation.

A department focused on cellular and molecular biology could explore cell dynamics through advanced cell modeling, genetic editing, or computational approaches. Another department might focus on bioinformatics and genomics, leveraging high-throughput technologies to study gene–environment interactions or metabolic pathways. A department with strengths in pharmacology could specialize in drug discovery, pharmacogenomics, or molecular mechanisms of drug resistance. Meanwhile, physiology-focused departments could adopt integrated approaches to study human systems, from molecular to whole-body levels, using patient-derived models or bioengineering techniques. Departments centered on microbiology and immunology might emphasize host–microbe interactions or immune modulation as part of the broader research ecosystem.

By recruiting department chairs with expertise in distinct yet complementary fields, institutions can ensure that each department contributes uniquely to the school's overall research mission. This approach also allows for departmental autonomy in faculty recruitment, while simultaneously aligning with the institution's broader strategic objectives. Such a model promotes both specialization within individual departments and a diversity of research themes across the institution, creating an environment conducive to interdisciplinary collaboration and groundbreaking discoveries.

In the light of anticipated reductions in NIH and NSF funding, an essential thematic pillar that all basic science departments should adopt is bolstering computational capabilities. Advanced computational tools can streamline experimental design, enhance data analysis, and reduce costs through optimized resource allocation, thus sustaining innovative research even in financially constrained environments. By integrating these methodologies into traditional experimental paradigms, departments not only enhance research efficiency and output, they also equip the next generation of scientists with critical, cost-effective skill sets. Rather than replacing conventional approaches, this strategy fosters a synergistic environment where computational biology helps us do more with less, ultimately reinforcing a dynamic and competitive research identity.

7 | THEMATIC BREADTH IN BASIC SCIENCE DEPARTMENTS AND THEIR RECIPROCAL RELATIONSHIP WITH CLINICAL RESEARCH

Our model emphasizes thematic diversity in basic science departments as a key driver of innovation, with direct benefits for research in clinical departments. By aligning diverse scientific themes with clinically relevant areas, we aim to foster a robust, bidirectional flow between basic and clinical sciences. This can be achieved through incentivized collaborations, including joint faculty recruitment focused on institutionally prioritized areas, cross-departmental mentorship, targeted symposia, and collaborative projects between researchers in basic and clinical departments.

The premise is that thematic diversity allows basic scientists to explore a broad range of fundamental questions, while collaboration with clinical researchers generates new hypotheses, tools, and approaches for investigating disease mechanisms and treatments. Clinical observations, in turn, guide basic science by revealing new challenges and questions that require deeper mechanistic insights. This reciprocal relationship ensures that basic science departments are fully integrated with medical practice, serving as innovation hubs essential for translating foundational discoveries into clinical advances. By continually responding to and informing clinical needs, basic science departments can maintain a crucial role in medical schools, countering national trends that might otherwise diminish their significance.

8 | CONCLUSIONS

In conclusion, the proposed organizational changes are designed not only to spur research innovation through enhanced interdisciplinary collaboration and thematic diversity but also to create a transformative educational environment. By reorganizing departmental structures and fostering a strategic, multilevel governance model, institutions can stimulate groundbreaking scientific inquiry while also enriching the academic experience. Medical, dental, and undergraduate students stand to benefit from an environment where critical thinking is actively nurtured, scientific exposure is broadened across diverse fields, and mentorship is deeply integrated into the research process. These changes ensure that students are not merely passive recipients of knowledge but are engaged as active participants in a dynamic ecosystem that bridges theory and practice, preparing them to be the next generation of innovators and leaders in their respective fields.

However, the framework we propose is only the beginning. Future studies should rigorously test the relationship between thematic diversity and innovation in schools of medicine to validate our hypothesis. Empirical evidence will be essential to determine whether maintaining or expanding basic science departments truly accelerates innovation and thought leadership, as suggested by our preliminary analysis. This work will help guide the strategic organization of basic science departments, ensuring they remain integral to the advancement of medical science and education.

AUTHOR CONTRIBUTIONS

L. Fernando Santana conceptualized and designed the perspective. All authors contributed significant input, shaping the recommendations and conclusions presented, and also were actively involved in the manuscript revision process.

ACKNOWLEDGMENTS

We would like to thank Dr. Rose E. Dixon, Dr. Coleen E. Clancy, and Ms. Dorinda L. Santana for their insightful feedback on the manuscript.

FUNDING INFORMATION

None.

DISCLOSURES

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

DATA AVAILABILITY STATEMENT

All relevant data are contained within the article, and data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

L. Fernando Santana https://orcid.org/0000-0002-4297-8029

Kim E. Barrett https://orcid.org/0000-0002-6704-998X
Susan Murin https://orcid.org/0009-0000-0619-6815

REFERENCES

1. Fulton JF. History of medical education. *Br Med J*. 1953;2:457-461.
2. Flexner A. Medical education in the United States and Canada. From the Carnegie Foundation for the Advancement of Teaching, bulletin number four, 1910. *Bull World Health Organ*. 2002;80:594-602.
3. Irby DM, Cooke M, O'Brien BC. Calls for reform of medical education by the Carnegie Foundation for the Advancement of Teaching: 1910 and 2010. *Acad Med*. 2010;85:220-227.
4. Hong L, Page SE. Groups of diverse problem solvers can outperform groups of high-ability problem solvers. *Proc Natl Acad Sci USA*. 2004;101:16385-16389.
5. Yang Y, Tian TY, Woodruff TK, Jones BF, Uzzi B. Gender-diverse teams produce more novel and higher-impact scientific ideas. *Proc Natl Acad Sci USA*. 2022;119:e2200841119.
6. Hall KL, Vogel AL, Huang GC, et al. The science of team science: a review of the empirical evidence and research gaps on collaboration in science. *Am Psychol*. 2018;73:532-548.
7. Uzzi B, Mukherjee S, Stringer M, Jones B. Atypical combinations and scientific impact. *Science*. 2013;342:468-472.
8. Hodgkin AL, Huxley AF. A quantitative description of membrane current and its application to conduction and excitation in nerve. *J Physiol*. 1952;117:500-544.
9. Reimann EM, Walsh DA, Krebs EG. Purification and properties of rabbit skeletal muscle adenosine 3′,5′-monophosphate-dependent protein kinases. *J Biol Chem*. 1971;246:1986-1995.
10. Doyle DA, Cabral J̃M, Pfuetzner RA, et al. The structure of the potassium channel: molecular basis of K+ conduction and selectivity. *Science*. 1998;280:69-77.
11. Rasmussen SG, Choi HJ, Rosenbaum DM, et al. Crystal structure of the human beta2 adrenergic G-protein-coupled receptor. *Nature*. 2007;450:383-387. doi:10.1038/nature06325
12. Krishna R, Wang J, Ahern W, et al. Generalized biomolecular modeling and design with RoseTTAFold all-atom. *Science*. 2024;384:eadl2528.
13. Abramson J, Adler J, Dunger J, et al. Accurate structure prediction of biomolecular interactions with AlphaFold 3. *Nature*. 2024;630:493-500.

How to cite this article: Santana LF, Barrett KE, Murin S. A new conceptual framework for preclinical departments in schools of medicine: Maximizing groundbreaking work through thematic breadth. *The FASEB Journal*. 2025;39:e70482. doi:10.1096/fj.202402439R