Hippocrates and Helices

The Importance of Integrating Genomics, Epigenomics, and Personalized Medicine into Systems of Medical Education

Johnathan Bowes
Dr. Doug Brutlag
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I. Introduction

Throughout history, from the age of Hippocrates and Galen to today, great minds have exalted preventative medicine as the best form of healthcare that a healer or doctor could provide. Doing so can, in many cases, spare patients from suffering through the physical symptoms of disease, the emotional strain imposed upon them and their loves ones by disease and treatment, and the economic hardship that they could experience if receiving medical care after developing a disease. Though legal efforts, like the Patient Protection and Affordable Care Act here in the United States, try to remove that last burden, such reforms cannot completely eliminate the financial costs of sickness—and no law could ever address the physical and mental costs that come with many of the world's most terrible maladies. Only preventing people from developing those illnesses in the first place removes all three.

Modern medicine now has access to some of the best methods of preventative medicine in history, thanks to the explosive growth of biotechnological knowledge and innovation in the near-decade since the completion of the Human Genome Project: personalized medical disciplines, particularly genomic medicine and epigenomic medicine. At this individualized level, with techniques like personal genome sequencing or analyzing the epigenetic factors that contribute to disease, doctors, nurses, and other clinicians have unprecedented capacities to discover the seeds of disease in a person and treat those seeds before they sprout.

But while those clinicians may have the capacity to use this new technology, relatively few currently have the ability or training to do so. Current requirements for "the continuum of medical education"[i]—premedical education for undergraduates, medical school education for doctoral students, and continuing medical education (CME) for practitioners—here in the United States and other industrialized nations include few if any stipulations about genetics in general,

much less the focused, personalized areas of medical epigenomics and genomics. If modern medicine is to continue advancing, expanding, and curing in the best possible manners for patients, modernization and reform efforts in medical education must include an increased emphasis on personalized medicine. Succinctly, medical educators should integrate genomics and epigenomics into their curricula at all levels.

II. Defining personalized medicine

The term "personalized medicine" can seem odd at first glance, since in theory, physicians should already personalize and tailor medical care to their patients' specific medical needs based on their specific medical histories. In practice, though, such specificity can only go so far without relying on either generalized recommendations or trial-and-error testing of various drugs and treatments—both with the potential for harmful side-effects and drug interactions that could jeopardize a person's long-term health.

As such, the modern concept of personalized medicine refers to a different process entirely. According to the Personalized Medicine Coalition (PMC), a think tank that "promotes the understanding and adoption of personalized medicine concepts,"[ii] personalized medicine "aims to achieve optimal medical outcomes by helping physicians and patients choose the disease management approaches likely to work best in the context of a patient's genetic and environmental profile."[iii] To do so, this fairly modern medical field "uses new methods of molecular analysis to better manage a patient's disease or predisposition toward a disease."[iv]

One of the core areas of personalized medicine is genomics, or the study of genomes. The usual medical applications of genomics (i.e. sequencing a person's genome and analyzing it for specific genetic markers with known associations to various ailments) often give practitioners

incredibly comprehensive pictures of their patients' medical risks. A close relative of medical genomics, medical epigenomics can do the same types of analysis with a person's epigenome, which "consists of chemical compounds that…mark the genome in a way that tells it what to do, where to do it, and when to do it."[v] While people do not experience many changes in their genomes in their lifetimes, their epigenomes "can be dynamic, influenced by environmental factors and extracellular stimuli, and [can] change in response to these factors."[vi] Epigenomic data can thus tell medical practitioners about the changing circumstances of their patients' underlying biological blueprints as a result of lifestyle, ageing, or other factors.

For the purposes of this paper, the term "personalized medicine," unless otherwise specified, will primarily refer to such genomic and epigenomic medical knowledge, technologies, and developments. Though other personalized medical fields, such as pharmacogenomics and medical proteomics, should also become more widespread in medical education, the foundational qualities of epigenomics and genomics (in relation to other areas of personalized medicine) make them more readily applicable across medical disciplines and more readily approachable for students from the undergraduate to CME levels.

III. Context: recent and current efforts at reform

According to Karen Malone and Salinder Supri, "medical education is in the throes of a revolution" thanks to several ever-growing movements for reform.[vii] But while medical educators and practitioners have often discussed this idea of reforming the teaching of medicine, only a minor portion of that discussion has dealt with the rapidly expanding fields of medical genomics and epigenomics. Much of the movement and debate instead has focused on general curricular reform or on addressing ingrained discrimination in medical education.

Modernizing the structure of medical curricula has usually served as the main focus of the reform debate, particularly over the area of 'competency-based education' (alternately, 'competence-based'). Generally speaking, a system of competency-based education enables "students [to] progress by demonstrating…that they have mastered the knowledge and skills (called competencies) required for a particular course, regardless of how long it takes."[viii] In terms of medical education, advocates of competency-based education say that "this methodological shift aims to increase the rigour and relevance of the medical curriculum, move students beyond…memorisation and regurgitation of scientific facts, and better enable them to understand scientific principles and apply them in practice."[ix] Instead of focusing on specific information that may quickly become outdated, this new teaching practice would try to prepare practitioners for any medical situation or technological innovation that could arise throughout their careers.

On the issue of discrimination, some recent reform efforts have sought to address the high attrition rate of students, especially at the premedical level, who identify as women and those who come from underrepresented minority (URM) backgrounds—specifically from Latino/a, black, or Native American racial or ethnic backgrounds; these attrition rates translate to fewer students from those groups successfully entering medical school or eventually becoming medical practitioners. Studies conducted among undergraduates initially planning to graduate as premedical students at UC Berkeley and here at Stanford quantified that trend: they showed that nearly fifty percent of women and URM students gave up on premedical education before completing the requirements, with many doing so due to "self-blame" for not performing well in introductory chemistry classes. Reformers have cited changing both the premedical curriculum

and culture of "prune and graft" (both of which have been essential to premedical education since the Nineteenth Century) as essential steps to begin closing the gender and cultural gaps in medical education that begin at the undergraduate level.[x]

With these two major areas of reform gaining traction in medical and academic circles, and thus the notion of reform in general becoming more palatable in those communities, the time seems ripe to push for greater incorporation of personalized medicine into medical education as well. While competency-based education will likely remain controversial for some time, adding training and knowledge about personalized medicine to either traditional or competency-based curricula inherently fits with the practice of updating teaching to match technological advancement. Increasing coverage of genomics or epigenomics in this sense is no different than transitioning from instructing medical students to vaccinate rather than inoculate patients against pathogens. And while efforts to reduce environments of discrimination in medical education will, if effective, take several years to begin closing the cultural and gender gaps in medicine, integration of personalized medicine can show profoundly positive impacts on the practice of medicine much sooner, particularly if CME-level integration occurs quickly.

The movement to incorporate genomics and epigenomics into medical education at the doctoral student level has fortunately already begun. In 2010, medical school faculty here at Stanford founded the Center for Genomics and Personalized Medicine, which "blends highly efficient, rapid sequencing technology with the research and clinical efforts of experts in genomics, bioinformatics, molecular genetic pathology…to bring advances from the laboratory to the patient" at Stanford Hospital & Clinics.[xi] Duke University in Durham, North Carolina, began the Duke Center for Personalized Medicine that same year with the goal of "bring[ing] the benefits of personalized medicine to patients at Duke Medicine and beyond."[xii] Few other

universities, though, have followed suit and integrated epigenomic and genomic medicine as completely into their medical schools. Additionally, general US requirements for premedical education at the undergraduate level still do not include those fields.

IV. Additional benefits of integration

Beyond the two benefits of educationally integrating personalized medicine discussed above—namely consistency with current curricular development and potential for rapid, positive results—proponents of such integration note several different benefits to the practice of medicine that genomics and epigenomics will bring. These include "eliminat[ing] trial-and-error inefficiencies that inflate health care costs and undermine patient care," determining "whether [patients] are susceptible to drug toxicities" that could prove extremely harmful or lethal, and "determin[ing] precisely which variant of a disease a person has" to better understand how to treat the disease effectively.[xiii] [xiv]

Perhaps the most compelling benefit of integration in this sense focuses back to the notion of preventative medicine as the best kind of medical care: early warning of a disease means either early treatment or effective prevention. A medical practitioner who has the knowledge and training to practice personalized medicine can thus more effectively practice preventative medicine. Markers for a disease in patients' genomes or epigenomes can allow their doctors and other clinicians to warn them of potential risks, hazards, and predispositions years before the onset of a disease or disease symptoms. Such advance notice can help "guide decisions about interventions that might prevent [a disease], delay its onset, or reduce its impact" on a person's health and wellbeing.[xv] In a case such as diabetes mellitus type 2, for instance, young individuals whose personal genomic analyses show a predisposition for the disease could

begin forming dietary and exercise habits that reduce their risks of actually developing the disease in later life. Teaching current and future practitioners to conduct and evaluate such personalized studies on their patients would expand access to this form of preventative medicine, which could, in many cases, save those patients' lives. On the other hand, as is often the case now, a doctor, nurse, or other clinician without the knowledge to use genomic or epigenomic data would not be able to expose their patients to the same opportunities for better health.

V. Potential drawbacks of integration

Despite the overwhelming amount of benefits and positive aspects of personalized medicine, some drawbacks do exist that must factor into the debate of educational integration of that discipline. One of the more obvious drawbacks of genomic and epigenomic technologies in general is their age. The fields only really developed in the decade or so since the late 1990s and early 2000s, a period coinciding with the final stages of the Human Genome Project; that project, in fact "created the field of genomics" by the fact of its existence and nature as a public enterprise.[xvi] While safety and reliability normally constitute the main concerns with new technologies, lack of information often overshadows those in the cases of medical epigenomics and genomics. Only a finite number of diseases have been associated with genomic marker or epigenetic regulation changes that a medical practitioner could find and evaluate in a patient's DNA; for the illnesses and maladies that have not yet had the proper study, clinicians can only utilize current methods of detection and treatment. While that information gap continues to close over the next several years, too heavy a focus on teaching personalized medicine in the interim could leave physicians unprepared to handle disease cases outside the currently limited scope of personalized medical tests. A solution to that situation, though, could be to begin integration

genomics and epigenomics into medical curricula by supplementing rather than supplanting current teachings on disease diagnosis. As genome-wide association studies and other academic research projects determine more links between specific genes, epigenetic regulations, and diseases, personalized medicine could assume a more central role in the curricula of medical education.

Here in the United States, another potential drawback to promoting personalized genetic and epigenetic medicine could come with loopholes in the Genetic Information Nondiscrimination Act (GINA) of 2008. For instance, while GINA does protect most individuals from denied coverage or higher premiums for health insurance based on the results of a genomic or epigenomic test, that protection excludes "members of the military, veterans obtaining care through the Veteran's Administration, or individuals receiving care through Indian Health Services" as well as "life, disability, or long-term care insurance."[xvii] Unless those loopholes close, practitioners who have been taught to rely on those tests for diagnosis and treatment may accidentally saddle their patients with huge economic burdens that neutralize the cost-saving effects of personalized medicine. Broadening the protections of GINA would come as the most straightforward solution to that potential problem, though teaching current and future clinicians to warn patients about potential economic risks could also reduce the effects of the problem before such amendment occurs.

VI. Conclusion

In final analysis, the potential advantages of promoting the proliferation of personalized medical practices by incorporating them into the curricula at all levels of medical education far outweigh the potential (and more unlikely) disadvantages of doing so. Those drawbacks do still

exist and should ultimately factor into the discussion, but they must not overshadow the fact that sending out cohort after cohort of clinicians trained to use medical genomic and epigenomic technologies will ultimately transform modern healthcare for the better.

As knowledge and availability of such technologies spreads, the potential exists for personalized medicine, in the forms of genomics and epigenomics, to save millions of lives each year through preventative measures alone. Studies have already linked sufficient numbers of preventable diseases to specific epigenetic methylation patterns or genetic nucleotide sequences for use in many screenings; such screenings can usually detect predispositions for disease long enough in advance for physicians and other practitioners to recommend effective preventative measures to their patients. When also considering the opportunities to predict harmful or lethal reactions to drugs and the myriad other physical and physiological benefits of expanding personalized medicine, the number of lives saved each year can only increase.

Even from a purely academic standpoint, integrating genomic and epigenomic knowledge into the curricula of the various levels of medical education makes sense. This knowledge comes as both a continuation of the general principles of genetics taught in many undergraduate courses and as a new technological improvement that doctoral students can learn and CME students can relearn to further their own specific abilities as medical practitioners.

As the ultimate form of preventative medicine currently known, personalized medicine should not remain excluded from medical education whenever possible. Though the medical world remains years from reaching this point, the integration of genomic, epigenomic, and other reliable forms of personalized medicine—in other words, modern knowledge of the wealth of information stored in the helices of DNA—must eventually become as crucial and essential to medical practice as Hippocrates' ancient command to keep patients from injustice and harm.

VII. Endnotes

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