
Commentary

Molecular Medicine and biomedical education: reshaping our mission

Gerasimos P. Sykiotis,¹ Panagiotis A. Konstantinopoulos,²
Athanasios G. Papavassiliou³

¹Department of Biomedical Genetics, University of Rochester Medical Center, Rochester, NY, ²Department of Medicine, Division of Hematology - Oncology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA, ³Department of Biological Chemistry, Athens University Medical School, Athens, Greece

The biomedical sciences are currently in transition between the bloom of fundamental knowledge and the fruition of specialized clinical application.¹ Following the success of the Human Genome Project, the roadmap is now in place for the description of physiology and illness in molecular terms. Through the advancements of the biosciences, medicine is being transformed from an empirical “art” to a rational (“ortho-molecular”) science. This is often viewed as a new medical “paradigm”, termed Molecular Medicine or Genomic Medicine. It can be argued that medicine has always been both “molecular” and “genomic”, because it employs drugs, which are molecules, that act on other molecules encoded by the genome. Yet, despite their long heritage, the terms “molecular” and “genomic” medicine today emphasize the importance we now attribute to understanding the role of molecular mech-

anisms and genetic information, respectively, in health and disease.

As biomedical research expands this understanding, medicine is expected to change (or to continue changing): hopefully, medical practice will soon become more *predictive* and *preventive*, and available treatments will be more *selective* (and ultimately *specific*). It is envisioned that linking genome-wide genetic information with disease predisposition will allow predictions of which disease(s) one might suffer from in the future. Genetic testing for *BRC1* mutations, which predispose to breast and ovarian cancer, serves as a good example.² Expanding this concept, it is conceivable that a DNA analysis performed at birth, at the outpatient office, in the emergency room, or during a hospitalization, could be the molecular equivalent of the “family history”. As information on the determinants (genetic, epigenetic and environmental) and molecular mechanisms of disease becomes available, focus could be shifted altogether from treating sickness to maintaining health. This is already adequately evidenced by the prevention of heart disease through cholesterol-lowering medications, and the prevention of breast cancer with Selective Estrogen Receptor Modulators (SERMs).³ When such approaches fail to preserve health, treatments could be tailored to the individual patient and their disease. Personal-

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Address correspondence and requests for reprints to:
Prof. Athanasios G. Papavassiliou, Head, Department of
Biological Chemistry, Athens University Medical School,
11527 Athens, Greece. Fax: +30-210-7791207, E-mail:
gpapavas@pat.forthnet.gr & papavas@med.uoa.gr

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ized medicine will entail sub- and re-classification of diseases based on their underlying molecular mechanisms. The Application of genetic and molecular testing, and of therapeutic agents that selectively target the molecular aberrations in a given patient will restore “molecular physiology”. As an example, patients with non-small cell lung cancers that harbor mutations in the tyrosine kinase domain of the epidermal growth factor receptor (EGFR) respond very well to EGFR tyrosine kinase inhibitors.⁴

The fact that there is proof-of-principle for the concepts of molecular medicine has warranted heavy investments in biomedical research, which are yielding novel information about biological systems at an unprecedented rate. However, the “translation” of scientific knowledge into innovative molecular diagnostics and therapeutics is proceeding much more slowly than desired.⁵ Reaching the goal faster depends in part on our ability to train researchers and health professionals in molecular medicine, and to inform and educate the public. Thus, there is now the opportunity and the need to institute the medical, research, and societal framework for molecular medicine in anticipation of its broad implementation.⁶ This imparts new educational responsibilities to all professionals as regards our functions in the academic field, the public or private health sectors, and the broader context of society.

In the academic setting, expanding the critical mass of the molecular medicine paradigm requires appropriate training of healthcare professionals and biomedical researchers. Curriculum reform remains a pressing issue. Rather than simply teaching the current advanced understanding of biological and biochemical phenomena, medical—including dental and nursing—education needs to embrace the integrative problem-based teaching of molecular medicine.⁷ Students must learn to integrate both traditional clinical and modern molecular approaches in clinical scenarios.⁸ This will equip physicians and other healthcare professionals with the knowledge required for a lifetime practice of molecular medicine. Training in computational biology and bioinformatics is indispensable for physicians and researchers alike to enable the study of complex bio-

logical systems in addition to clinical diagnosis, prognosis, and drug selection that will increasingly integrate clinical and genomic data.⁶ Basic scientists can benefit from an understanding of the biological foundations of disease and from a therapeutic mindset. Thus, the dialogue between clinicians and basic scientists must be institutionally encouraged as a way to bridge the gap between hypothesis-driven basic science and problem-focused medical research. Molecular medicine demands interdisciplinary research, ranging from genomic profiles and molecular interactions to clinical symptoms and therapeutic approaches. Individuals who can transcend both clinical medicine and molecular biology fields are therefore essential.⁹ It is important to identify potential researchers at an early stage of their careers and then entice them to and train them in molecular medicine so that they will increasingly populate the academic medical centers.

Translating academic progress into societal advancement is the optimal goal of molecular medicine. A crucial short-term approach to this goal is to educate established healthcare professionals. The formulation of ways to include them in the transformation of medicine will shorten and smooth the transition to the molecular paradigm. The Re-established Health Professional requires education about the interplay between genes and environment in health and disease, and about the emerging applications of genome science in clinical practice. The challenge for continuing professional education is to strike the right balance between depth and breadth of information for each discipline and professional group.⁶ Appropriately trained health professionals are also crucial for public education which, at least in the short term, will mostly take place during the clinical practice of genomic medicine. For example, lay people will be increasingly asked to make decisions about participating in studies that collect genomic data, or to make health-related choices and life-style modifications based on genomic information about themselves.⁶ At present, the public, though eager to benefit from the advances in biosciences, is fearful of the potential misuse of genomic data, most notably use of genetic information that could lead to discrimination in the granting of employment and insurance. If these fears can

be appeased through education and regulation, then the public could become molecular medicine's strongest proponent. It is therefore important to make people aware of the potential of genomics to identify the genetic basis of disease and of the usefulness of predictive genetic tests as they become available. In this respect, the Internet is a major public resource for information and education. The media can also help by accurately and responsibly presenting the prospects and limitations of molecular medicine. High-school students deserve special attention: they will be the future users of genetic information and the future researchers and/or health professionals. To adequately prepare this next generation for molecular medicine, high-school curricula can be adjusted and teachers given instruction and guidance.⁶

In conclusion, the education of researchers, physicians and the public is a priority for molecular medicine. In our opinion, molecular medicine is best portrayed neither as a new discipline nor as a component of all existing disciplines: it is simply the realization that health and disease can be defined in molecular terms and that better health is achievable through this new understanding.^{1,10} However, the overall effect of reductionist and synthetic biomedical approaches will be limited unless the dialogue between the medical and the biological sciences is accompanied by a broader dialogue between the life sciences and the social sciences and humanities, so that biomedical advances may be beneficial to everyone.¹¹

Finally and most vitally, the ethical issues raised by advances in molecular biology, when related to medical practice, must not be underestimated. These issues need to be taken into serious consideration

in view of the fast approaching application of the data of the genomic and post-genomic eras in preventive and therapeutic medicine.

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