

The new science of personalized medicine

The new science of personalized medicine:

Translating the promise into practice



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The heart of the matter

Personalized medicine is presenting new challenges and opportunities for players within and beyond the health industry. Collaboration will be a key to success.

Advances in genomic and proteomic science over the past decade have led to the development of “targeted” diagnostics and therapeutics that leverage knowledge of an individual’s genetic makeup to create a more personalized approach to healthcare. Genomic testing enables us to identify an individual’s susceptibility to disease, predict how a given patient will respond to a particular drug, and match patients with the right therapeutics. This new science of personalized medicine has the potential to eliminate unnecessary treatments, reduce the incidence of adverse reactions to drugs, increase the efficacy of treatments and ultimately, improve health outcomes.

Personalized medicine is often defined as “the right treatment for the right person at the right time.” The new science is embodied in an approach dubbed P4™ medicine by The Institute for Systems Biology and its co-founder, Dr. Leroy Hood, because of its four attributes: it is *personalized*, taking into account an individual’s genetic profile; *predictive*, anticipating health problems and drug reactions; *preventive*, focusing on wellness, not disease; and *participatory*, empowering patients to take more responsibility for healthcare decisions. Patient empowerment is part of a broader trend toward consumer-focused healthcare, enabled by easy access to health information that was once available only to medical professionals.

There are many other definitions of personalized medicine; the boundaries of this emerging market are fluid. PricewaterhouseCoopers defines personalized medicine broadly, as **products and services that leverage the science of genomics and proteomics (directly or indirectly) and capitalize on the trends toward wellness and consumerism to enable tailored approaches to prevention and care.** This definition encompasses everything from high-tech diagnostics to low-tech foods to technologies that enable storage, analysis and linking of patient and scientific data.

While the market for diagnostic tests and therapies that leverage this new science is growing, the biggest opportunities exist outside of the traditional healthcare sector. The U.S. personalized medicine market is estimated at about \$232 billion and is projected to grow 11% annually, nearly doubling in size by 2015 to over \$450 billion. The core diagnostic and therapeutic segment of the market—comprised primarily of pharmaceutical, medical device and diagnostics companies—is estimated at \$24 billion, and is expected to grow by 10% annually, reaching \$42 billion by 2015. The personalized medical care portion of the market—including telemedicine, health information technology, and disease management services offered by traditional health and technology companies—is estimated at \$4-12 billion and could grow tenfold to over \$100 billion by 2015. And the related nutrition and wellness market—including retail, complementary and alternative medicine offered by consumer products, food and beverage, leisure and retail companies—is estimated at \$196 billion and projected to grow by 7% annually to over \$290 billion by 2015.

Personalized medicine is a disruptive innovation that will require the development of new business models, particularly for health industry players. As the boundaries between traditional healthcare offerings and wellness products and services blur, and as the trend toward consumer-focused healthcare accelerates, companies outside the health industry are finding new opportunities. We believe that companies outside the traditional healthcare arena, from PepsiCo to Procter & Gamble, could be formidable competitors, due to their skills and experience in targeting consumers, who are contributing to the rapid growth of the wellness market. **To compete in this market, organizations will need new approaches, new relationships, and new ways of thinking.**

The move toward personalized medicine is inevitable, but the transition will not be easy. As companies search for sustainable models, one theme has emerged clearly: the need for collaboration. Personalized medicine is a complex undertaking. No player or sector with its current portfolio of capabilities can succeed in isolation.

In addition to collaboration, sustainable success will depend on technical expertise, a focus on the consumer, and a long-term vision and plan. Personalized medicine is a marathon, not a sprint.

Major Trends in Personalized Medicine

- Growing number of companies entering the space, but not without difficulty
- Entry of companies from outside the health industry
- Collaboration required in order to succeed

Where to begin?

Following are key recommendations for health industry players as they consider how to respond to the emerging personalized medicine market and explore sustainable business models.

Recommended Collaborative Efforts	Pharma, Biotech & Dx Cos.	Providers/ Provider Systems/ AMCs	Payers	Government
• Identify new pathways for approval of targeted diagnostics, therapeutics and theranostics	X	X		X
• Design regulatory, privacy and IP framework to support new product development	X	X		X
• Develop reimbursement strategies that encourage innovation and spread risk	X	X	X	X
• Jointly pursue tests and treatments for widespread (and costly) chronic conditions	X	X	X	X
• Accelerate translation of discoveries from “bench to bedside”	X	X	X	X

Additional Recommendations for Individual Players

Pharmaceutical, Biotechnology and Diagnostics Companies

- Articulate the benefits of products in the pipeline to payers and regulators as early as possible, to win their support and increase the odds of successful commercialization.
- Engage with academic medical centers and other research organizations with access to patient populations, to accelerate recruitment for clinical trials.
- Educate consumers about the need for, and benefits of, personalized medicine solutions.
- Explore new development models that use patient sub-groupings in order to enrich clinical trials, expedite conditional/ interim approvals, and reduce post-market label warnings or recalls.

Providers/Provider Systems/Academic Medical Centers

- Look to other industries, such as consumer products companies, to learn how to market directly to patients and deliver excellent customer service.
- Partner with experts in personalized medicine, and recruit physicians and administrators with expertise in the field.
- Adopt electronic health records and support industry efforts to create a system of interoperable EHRs to reduce costs and medical errors and support further advancements in personalized medicine.

Payers

- Become educated about the science and benefits of personalized medicine. Consult with experts and institutions at the forefront of advancing the new science.
- Set clear reimbursement criteria upfront, to help reduce R&D expenses for pharma and diagnostic companies, which ultimately will lower your costs as well as theirs.
- Redesign reimbursement models to focus on pay for performance.
- Work with pharma and diagnostics companies to maintain current, accurate information on the clinical efficacy of personalized medicine tests and treatments and use the information to inform benefits policies and coverage decisions.
- Analyze claims data to identify unmet needs that personalized medicine could address.

Government

- Provide funding, tax subsidies and other protections to diagnostic and pharmaceutical companies to develop new targeted tests and therapies.
 - Create public-private partnerships and fund collaborative private research efforts to accelerate personalized medicine solutions.
 - Invest in the interconnected IT infrastructure and create supporting legislation (privacy, etc.) to enable pooling and analysis of health data.
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An in-depth discussion

Personalized medicine
is redefining the health
industry and disrupting
existing business models.

Personalized medicine: the new science

In 1898, William Stewart Halsted, considered the father of American surgery, developed an innovative approach to the treatment of breast cancer: the radical mastectomy.¹ A century later, the Food and Drug Administration (FDA) approved an even more radical innovation: a biological compound called trastuzumab, which binds to the cells of some cancerous tumors, triggers the body's defense system to attack them, and may prevent the cells from replicating.²

Trastuzumab, better known by its brand name, Herceptin, was one of the first drugs to leverage the power of genetics to treat disease. It is prescribed only for patients whose genetic tests reveal an over-expression of the protein HER2 due to a gene mutation—an indicator of an aggressive form of cancer that is responsive to treatment by the drug. Unlike chemotherapy drugs, which attack any cell that is replicating rapidly, including healthy cells, Herceptin is customized to target only those cells associated with disease. As a result, the drug has none of the side effects associated with chemotherapy, such as hair loss and digestive problems.

Welcome to the new science of personalized medicine.

Over the past decade, advanced research into genomics (the study of an organism's genes) and proteomics (the study of the proteins that genes create or "express") has accelerated our understanding of individual differences in genetic makeup, opening the door to a more personalized approach to healthcare. "If you want to understand a disease, genetics gives you the opportunity to shine a bright light into the darkness of our ignorance so we can provide better ways to prevent and treat," says Dr. Francis Collins, the former Director of the National Center for Human Genome Research within the National Institutes of Health who is now Director of the NIH.³

Since Genentech's Herceptin and companion HER2 test were approved in 1998, they have been joined by a growing roster of "targeted" diagnostics and therapeutics that are tailored to the genetic makeup of the individual.

The science of genomics and proteomics has the potential to personalize healthcare, enabling providers to match drugs to patients based on their genetic profiles, identify who is susceptible to which health conditions, and determine how a given patient will respond to a particular therapy (a field known as *pharmacogenomics*). That could eliminate unnecessary treatments, minimize the potential for adverse events, and ultimately, improve patient outcomes.

Recent scientific discoveries have enabled a new view of disease that focuses on interactions at the molecular level, which differ from one person to the next. "Take into account that your genome and mine differ by 6 million nucleotides (which is the basic unit of organic acids found in all living cells). Then, therefore, we're susceptible to all sorts of combinations of diseases," says Dr. Leroy Hood, co-founder of the Institute for Systems Biology (ISB) and pioneer in personalized medicine. "We have to treat you differently than we treat me and everybody else. How we create an era of highly personalized

medicine will depend entirely on new diagnostic, therapeutic and ultimately... preventive techniques.”⁴

Personalized medicine often is defined as “the right treatment for the right person at the right time.” Some interpret this to mean that every person will receive a one-of-a-kind form of care. Others point out that we will never be able to predict perfectly the many types of medical responses possible among individuals, and that personalized medicine will need to emphasize the use of diagnostic skills and tests to guide selection of the treatment that is most likely to be optimal for each patient. The latter group includes Dr. Raymond Woosley, president and CEO of the Critical Path Institute (C-Path), a collaboration of government, industry and academia whose goal is to accelerate the development and commercialization of targeted diagnostics and therapeutics. “I don’t think personalized medicine means that we’ll have a different specific treatment for every individual,” says Woosley, “but that there are characteristics of each individual that can be better defined and incorporated into disease management once a diagnosis is made.”

The new science of personalized medicine is embodied in an approach dubbed P4™ medicine by ISB and Dr. Hood, because of its four attributes:

- It is **personalized**; it is based on an understanding of how genetic variation drives individual treatment.
- It is **predictive**; it is able to identify what conditions a person might contract in the future and how the person will respond to a given treatment, enabling the development of a tailored health strategy.

- It is **preventive**; it facilitates a proactive approach to health and medicine, which shifts the focus from illness to wellness.
- It is **participatory**; it empowers patients to make informed choices and take responsibility for their own health.

This last attribute of P4 medicine—patient empowerment—is part of a broader trend toward consumer-focused healthcare, enabled by easy access to health information that was once available only to medical professionals. According to search engine ask.com, 70% of adults use the Internet as a primary resource for medical and health information—only slightly less than the 72% who turn to their primary physicians for advice.⁵ This information access is creating educated healthcare consumers and shifting the traditional balance of power between patients and providers. “Access to information, and the growing education of the patient, are diluting the decision-making power, which used to be totally centered on health professionals,” says Dr. João Silveira, vice president of Portugal’s National Association of Pharmacies.

There are many definitions of personalized medicine; the boundaries of this emerging market are fluid. While the P4 approach focuses mainly on genomics and proteomics, for purposes of this paper PricewaterhouseCoopers defines personalized medicine more broadly, as **products and services that leverage the science of genomics and proteomics (directly or indirectly) and capitalize on the trends toward wellness and consumerism to enable tailored approaches to prevention and care.** This definition encompasses everything from high-tech diagnostics to low-tech foods to technologies that enable storage, analysis and linking of patient and scientific data.

Companies outside the health industry could be formidable competitors

Think of personalized medicine as a set of concentric rings, with the innermost rings representing medical applications of genomic and proteomic research, such as targeted diagnostics and pharmaceuticals, and the outermost rings representing health and wellness products and services far removed from the traditional healthcare arena, such as sports drinks and genomics-based cosmetics.

As the lines among these rings blur, so do the boundaries of the “healthcare” industry. Already, a number of non-traditional healthcare companies are marketing personalized medicine services to consumers—and posing new competition for traditional players in the healthcare space. We believe that many of the successes in the marketplace are likely to come from companies such as Google and Wal-mart, PepsiCo and Procter & Gamble as well as healthcare start-ups better able to operate under the new consumer-oriented paradigm. As the wellness market continues to expand and encroach upon traditional healthcare territory, such companies could be formidable competitors.

The food industry is poised to capitalize on consumer-focused healthcare. The industry is creating a variety of “functional foods” (often called “nutraceuticals”)—nutrient-rich products aimed at proactive consumers who understand the role of diet in health and wellness, and who want to combat chronic disease through prevention. In 2003, Nestlé, a global leader in food products, declared that it was “moving from an agrifood business to an R&D-driven nutrition, health and wellness company.”⁶ Nestlé’s strategy is to add functionality to foods, such as

through its Branded Active Benefits—food components that are incorporated into existing products and provide consumers with a complementary health benefit, in addition to the good taste and normal nutrient content of the product itself. Other top food and beverage companies have signaled similar intentions, including Danone, Unilever, General Mills, Kellogg, PepsiCo, Coca-Cola, and Yakult.

As individuals gain greater appreciation for their unique disease risk profiles, they are demanding foods that address their specific health concerns, and the food industry is responding with more targeted products. In addition to chocolate bars, Nestlé offers nutrition products targeted to oncology and diabetes patients.⁷ As the burden of healthcare costs shifts to consumers, they may try to limit their exposure to co-pays and other costs. Consumption of functional foods may come to be seen as an alternative form of medicine.

Indeed, there is a growing grey area between nutraceuticals and pharmaceuticals. Less regulation of functional foods means more competition for regulated medicines just beyond the grey area.

Consumer products companies, too, are leveraging genomics and proteomics to target new products directly to consumers. For instance, Procter & Gamble’s genomics research identified differences in the reaction of older and younger skin at the molecular level. The results led to the launch of its Olay Pro-X line of skin creams, designed to make older skin “act” younger via active ingredients that stimulate molecular responses.⁸ The company also collaborated in a study to explore the human genome’s response to a common cold virus, in the hopes of developing new cold treatments.⁹

Technology companies also are capitalizing on the move toward personalized medicine. Some are providing the computational power to accelerate the process of genome sequencing, while others are exploring other business opportunities, from providing data storage, mining and analysis to developing the IT infrastructure and connectivity solutions to support research.

All players in the health industry, from pharmaceutical and diagnostics companies to hospitals and primary care providers, will have to change the way they

relate to consumers if they are to compete in an era of personalized medicine. Retailers, consumer product companies and other players accustomed to marketing directly to consumers may have an advantage in this regard over organizations that traditionally have targeted physicians or businesses. **The biggest opportunity in personalized medicine may lie in identifying new products, services and information targeted directly to consumers.** Success in this space will require new approaches, new relationships, and new ways of thinking.

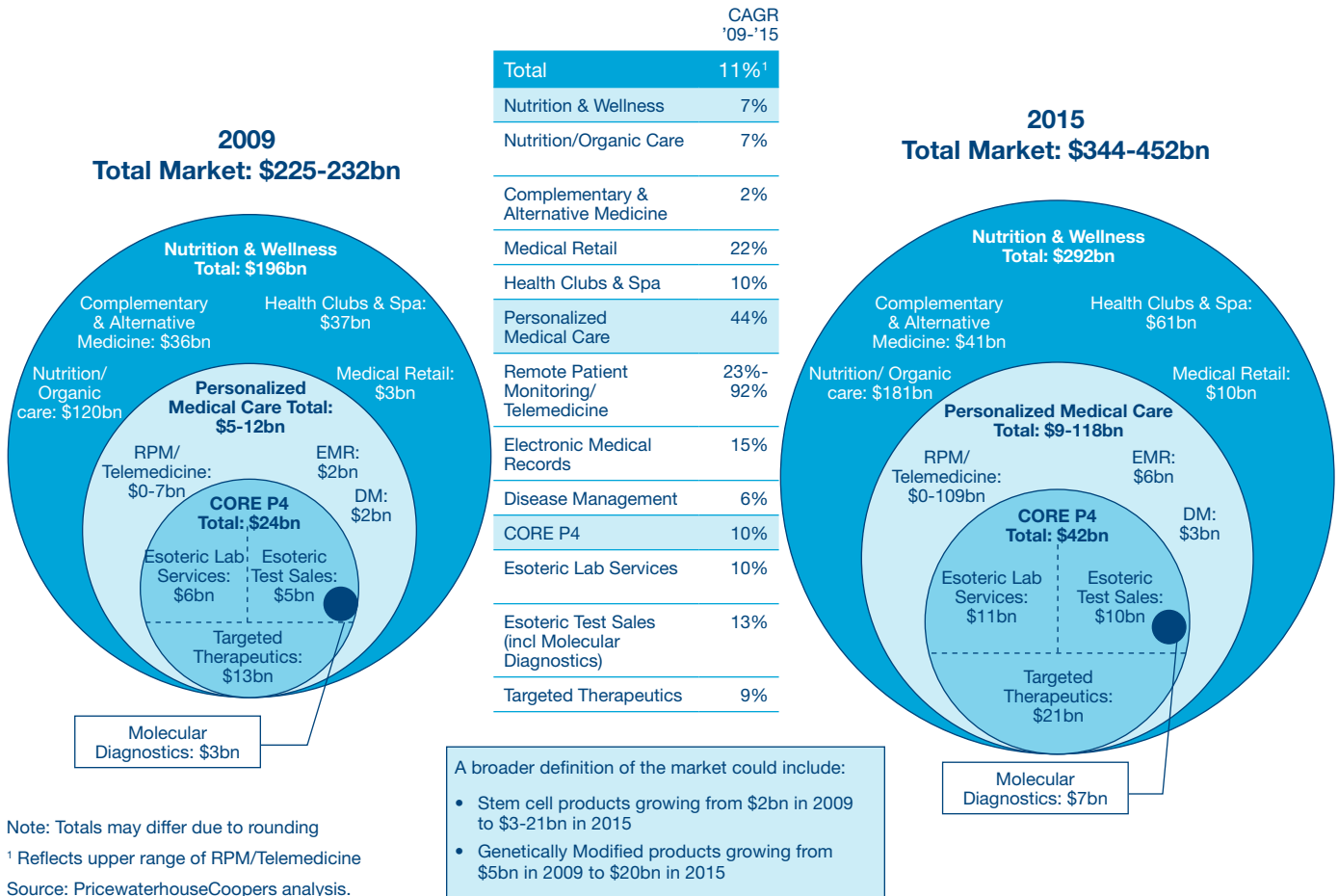
The Personalized Medicine Landscape

Industry/sector	Key Challenges	Key Opportunities	Key Barriers
Pharmaceutical, biotech and medical device companies	<ul style="list-style-type: none"> Moving from general to specific treatments, and from disease treatment to prevention 	<ul style="list-style-type: none"> Reducing time, cost, size and failure rate of clinical trials Capitalizing on preferential use of and premium pricing for drugs of proven effectiveness Reducing the number of drugs recalled due to safety concerns 	<ul style="list-style-type: none"> Changing research funding models and drug approval regulations Addressing pricing and reimbursement Identifying appropriate incentives for innovation Addressing changing revenue streams (i.e., shift from blockbuster model to smaller, targeted markets) Navigating the cultural shift required to work with diagnostics companies to match drugs with companion diagnostics Developing the ability to share R&D information internally and with external collaborators Recognizing the need to share “precompetitive data” to avoid redundant research
Diagnostic companies	<ul style="list-style-type: none"> Developing and validating new diagnostics to enable personalized medicine 	<ul style="list-style-type: none"> Capitalizing on a growing market driven partly by new, value-based reimbursement policies Creating new partnerships with pharmaceutical companies Capitalizing on new distribution models to create new businesses 	<ul style="list-style-type: none"> Addressing joint Dx/Rx approval processes / regulations, including the daunting cost of traditional randomized controlled trials Addressing pricing and reimbursement practices Determining if, when, and how to partner with drug companies Identifying and mobilizing resources needed to educate physicians about diagnostic tests Developing improved decision support tools to assist physicians in taking actions based on test results

The Personalized Medicine Landscape

Industry/sector	Key Challenges	Key Opportunities	Key Barriers
Technology companies (including medical device manufacturers)	<ul style="list-style-type: none"> • Developing new business models to capitalize on the value of data • Developing/embracing new technologies for measurement and visualization 	<ul style="list-style-type: none"> • Facilitating new, data-driven health care models • Facilitating new data mining models to make sense of vast quantities of data • Developing new product offerings • Creating new partnerships 	<ul style="list-style-type: none"> • Developing common data standards • Accelerating medicine / IT convergence • Understanding and influencing emerging regulatory standards • Protecting privacy and preventing genetic discrimination • Securing regulatory approval of combination devices • Overcoming a lack of domain knowledge of the health care space
Other non-healthcare companies (e.g., consumer products, food, beauty/cosmetics)	<ul style="list-style-type: none"> • Adapting to a new focus on wellness and the rise of consumerism • Developing effective strategies to broaden the definition of what is considered “health” • Addressing consumer demands for higher quality foods and products that contribute to healthfulness 	<ul style="list-style-type: none"> • Developing new products • Tapping new markets • Engaging in more precise customer segmentation 	<ul style="list-style-type: none"> • Educating the public about the multitude of wellness options available • Influencing and understanding emerging regulations • Developing better consumer metrics • Overcoming a lack of domain knowledge of the health care space
Health systems, AMCs and other providers	<ul style="list-style-type: none"> • Providing cutting-edge care while controlling health care delivery costs • Getting reimbursed for providing wellness and prevention services • Operationalizing a consumer-oriented business model 	<ul style="list-style-type: none"> • Developing new models of care • Increasing revenues • Improving quality / outcomes 	<ul style="list-style-type: none"> • Adapting to the “unbundling” of the hospital and to non-traditional competitors • Making operational changes • Correcting misalignment of incentives • Managing consumer/patient expectations for costly and potentially unnecessary diagnostic tests
Government and private payers	<ul style="list-style-type: none"> • Embracing innovation • Controlling health care reimbursement costs while improving health care outcomes to increase value per dollar spent 	<ul style="list-style-type: none"> • Influencing new reimbursement models • Identifying risk more precisely while delivering improved quality 	<ul style="list-style-type: none"> • Realigning provider incentives • Collecting and disseminating outcomes data

Personalized Medicine Market Size, 2009 and 2015



Personalized medicine market is growing rapidly

While still in the early stages, personalized medicine is steadily emerging as the new healthcare paradigm. In the U.S., the total market for personalized medicine currently is estimated at \$232 billion and is projected to grow 11% annually, nearly doubling in size by 2015, to a total of \$452 billion, according to PricewaterhouseCoopers' estimates. The core segment of the market—comprised primarily of diagnostic tests and targeted therapies—is estimated at \$24 billion, and is expected to grow by 10% annually to \$42 billion by 2015.¹⁰

While the market for personalized medicine diagnostics and therapeutics shows great potential, the biggest opportunities exist beyond these core products and services— particularly in less traditional, more consumer-oriented areas. The nutrition and wellness market—including retail health, complementary and alternative medicine, nutraceuticals and organic care, and health clubs and spas—is estimated at \$196 billion and projected to grow by 7% annually to \$292

billion by 2015.¹¹ The personalized medical care portion of the market—including telemedicine, electronic medical records, and disease management services—is estimated at \$4 billion to \$12 billion and could grow tenfold to over \$100 billion by 2015.¹² This segment is largely comprised of a range of healthcare players, as well as information technology companies that are starting to enter the space.

Such robust market size and growth potential will continue to attract many new players and require the development of new business models. A wide variety of organizations are entering this space, including consumer products, food and beverage, leisure and retail companies, as well as more traditional health companies that are successful in marketing directly to consumers.

There are other products and services related to the field of personalized medicine, such as genetically modified food and stem cell products. The growth of these newly emerging submarkets is difficult to predict.

Reinventing the Traditional “Big Pharma” Model

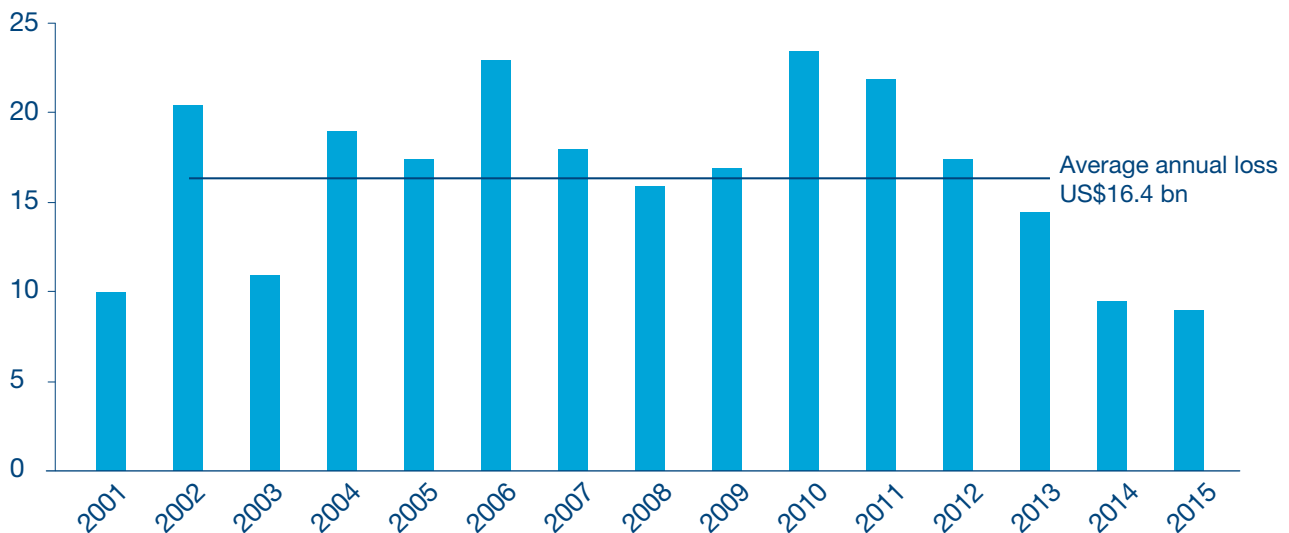
Rather than placing bets on blockbuster drugs that target broad populations, in an era of personalized medicine Big Pharma must discover and develop tailored therapies for smaller markets. The concept of tailoring is not new to the industry; for years, pharma companies have segmented customers by type of disease and used biomarkers such as cholesterol levels to guide treatment decisions. However, the development of new therapeutics based on genomics and proteomics will require an entirely new level of tailoring.

Many in the pharmaceutical industry view the prospect of smaller markets and shrinking revenues as the greatest challenge they will face over the next decade, as blockbuster drug patents continue to expire. Others are more sanguine, including John Lechleiter, chairman and chief executive officer of Eli Lilly and Company, who says “our business model will accommodate personalized medicine—in fact, it may

depend on it.”¹³ Lechleiter cites many benefits of pursuing what he calls “tailored therapeutics,” among them the ability to understand risks and benefits at the level of the individual. He also cites the expanded use of biomarkers to identify unpromising drugs early in the R&D process and to run smaller, accelerated clinical trials that can be modified in mid-stream as evidence emerges.

Lechleiter acknowledges his peers’ concern over replacing the revenues lost from blockbuster drugs, but he sees a viable new revenue model emerging: “Instead of getting a relatively small share of a really large pie—the traditional blockbuster model—a tailored therapy could expect to claim a relatively large share of a more segmented pie,” he says. “Repeat prescribing and patient compliance almost certainly would occur at a higher rate—further supporting the economic case. The net results, in terms of sales, actually look quite favorable.”¹⁴

Value of patent expiries 2001-2015 (constant USD billion)



\$157 billion sales exposed to generic competition by 2011
Source: IMS Health Midas

The jury is out on the impact of personalized medicine on adherence to medication regimens, but it's clear there is the potential for the emergence of "niche busters"—drugs targeted to small populations but carrying a high price tag—to replace some of the income lost as blockbusters go off patent. Educational efforts targeted to consumers could help to raise awareness of and demand for new personalized therapeutics.

Biotech is filling the pipeline¹⁵

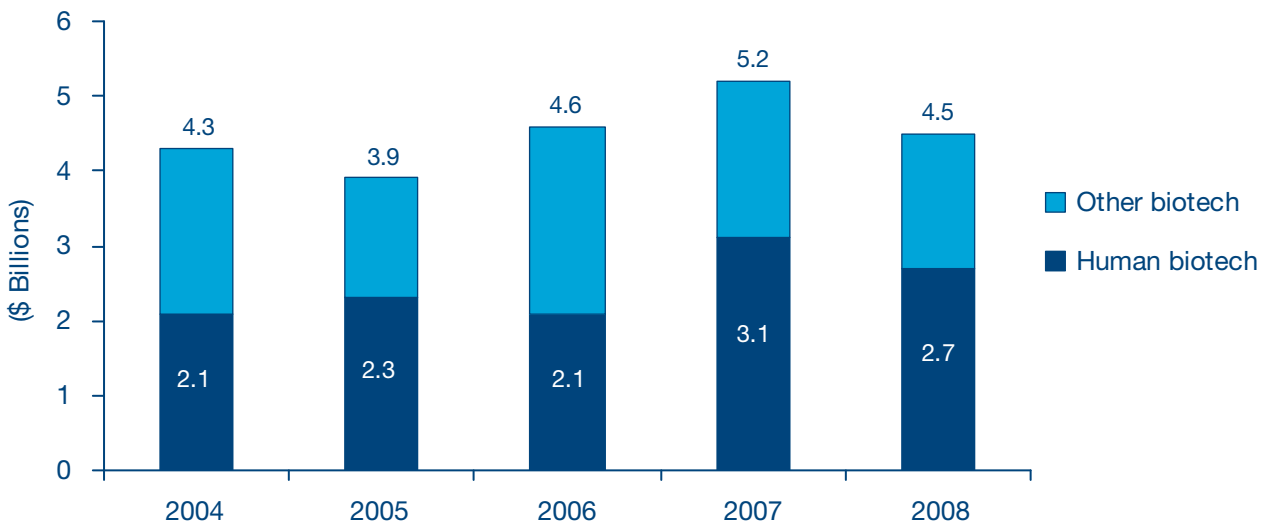
Rather than develop targeted therapeutics in their labs, most of the major pharmaceutical companies are turning to small biotech firms to fill the pipeline with new personalized medicines that could replace lost revenues. The venture capital (VC) community is looking to capitalize on Big Pharma's interest in biotech. Overall, venture capital investment in human biotech (excluding medical devices) companies totaled \$2.7 billion in 2008,

and 245 deals were closed. Those numbers represent a decline over 2007, thanks to a deep recession, but overall, VC investments have been trending upward since 2004.

Many recent deals have targeted oncology drugs, which have been at the forefront of advancing personalized medicine, for several reasons. The diagnosis of cancer is almost always based on a biopsy; subsequent examination of cells or tumor tissue is also common. The different slide-based technologies used in the pathology, such as immunohistochemistry, fluorescent in situ hybridization (FISH), and chromogenic in situ hybridization (CISH) have paved the way for pharmacodiagnostic testing.¹⁶

The bulk of venture capital investments since 2004 have been allocated to expansion and later stage companies, as VCs continue to hold firm—and expensive—positions in biotech companies with the brightest exit prospects. Smaller

Biotech Investment Trends



Source: PricewaterhouseCoopers/National Venture Capital Association MoneyTree™ Report (data: Thomson Reuters)

biotech firms that find it difficult to secure venture capital might turn to alternative sources of funding and support, including non-profit foundations. Some foundations are acting as investors, providing early stage funding for proof of concept and target validation as well as project management support and access to their network of scientific experts and research clinics needed to translate discoveries into the clinic.¹⁷

Nanotechnology devices will target medication delivery

The development of targeted therapeutics will bring new opportunities for medical device companies whose products can deliver personalized medications to specific parts of the body. For instance, Medtronic is investing in implanted pumps and other devices to target medications

directly to where they are needed. Philips has developed a technology to encapsulate drugs in biodegradable bubbles that are delivered via ultrasound to tumors. Selecta BioSciences is working on biodegradable nanoparticles targeting lymph nodes. And a company called MicroCHIPS is developing implantable silicon chips that store drugs in the body and release them on demand.¹⁸

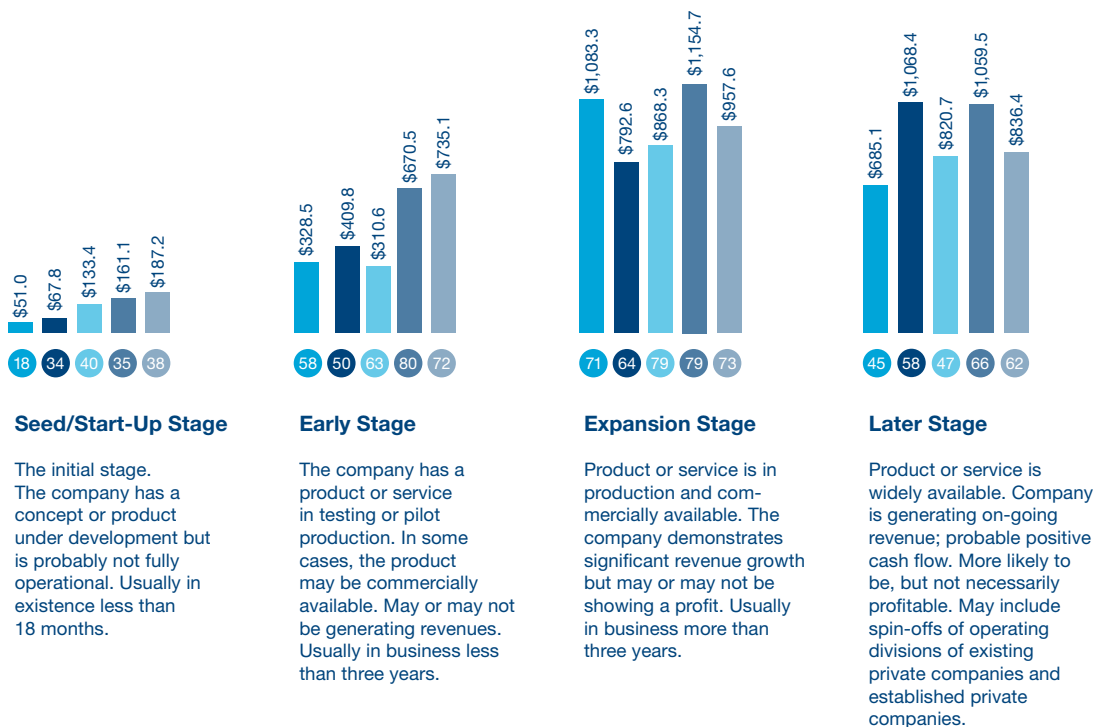
The convergence of medical devices, information technology and telecommunications is producing products that monitor patients and transmit data directly to clinicians. For instance, Corventis offers a wireless technology platform that gathers cardiovascular data, automatically detects clinical events and transmits the data to clinicians, and tracks long-term physiological trends—information that can be used to develop a more personalized treatment approach.¹⁹

Human biotech investments by stage of development

Amount invested

Number of deals

MoneyTree stage



2004 2005 2006 2007 2008

Source: PricewaterhouseCoopers/National Venture Capital Association MoneyTree™ Report (data: Thomson Reuters)

Molecular diagnostics: an early winner

One area of personalized medicine that shows early promise is molecular diagnostics—tests used to identify proteins and other biomarkers of disease, or disease susceptibility. “One of the innovation areas with the highest impact will be the whole field of early and correct diagnoses,” says Mars di Bartolomeo, Luxembourg Minister of Health. “More than anything else, we need objectivity and medical efficiency within therapy. By nature, this need will lead us to the approach of personalized medicine.”

Molecular diagnostics, which include imaging and lab tests, are used to guide treatment decisions and create prevention strategies. They can predict which patients are likely to have an adverse reaction to a drug and help a physician decide whether to use a particular drug, patient by patient. That can lead to better health outcomes and could prevent black box warnings or recalls for drugs that may be highly effective for a large population but can have severe—even fatal—adverse reactions for a small subset of patients.

Molecular diagnostics come with a high price tag—typically thousands of dollars per test—but many payers will reimburse for them if they can help to avoid even higher treatment costs by identifying patients who likely will or will not respond to a given drug. For instance, the majority of private payers provide coverage for the Oncotype DX Breast Cancer Test developed by Genomic Health because the test (roughly \$4,000—many times the average cost of a lab test) can help to avoid even higher chemotherapy costs, if test results indicate treatment isn’t warranted. Genomic Health estimates that by identifying those who would not benefit from treatment, the test can reduce chemotherapy use by 20% to 35% and yield a savings of approximately \$1900 per patient tested.²⁰ Aside from the cost savings, the test prevents needless pain and suffering.

Molecular diagnostics market is poised for rapid growth

Molecular diagnostics represents one of the fastest growing segments of the \$37 billion market for *in vitro* diagnostics, which includes test tube diagnostics such as glucose monitoring for diabetes care but excludes diagnostics for research use.²¹ This market segment is expected to grow 14% annually between 2007 and 2012, from \$2.6 billion to \$5.0 billion.²²

The diagnostics sector is more concentrated than the pharmaceutical sector. The 10 largest IVD players accounted for approximately 75% of the market in 2007, compared with 45% for the top 10 pharmaceutical companies. Some companies develop diagnostics products, while others are mainly service providers that perform diagnostic testing. Roche has the largest IVD market share, at 20%.

As the molecular diagnostics segment grows, Big Pharma is entering the space. Novartis is one example of a major pharma company that has launched a molecular diagnostics division.

Genetic testing accounted for \$580 million of the molecular diagnostics market in 2007, or roughly 21%.²³ The genetic testing segment is highly fragmented; nearly 40% of the segment is made up of niche players.²⁴ As the technology evolves, we expect to see more competition from diagnostics that test for multiple conditions and produce speedier results. For instance, a Colorado-based company, Beacon Biotechnology, is testing a device in the form of a disposable computer chip that can detect as many as 112 diseases or genetic conditions using just one drop of body fluid, and in some cases can generate results in just 15 minutes.²⁵

The sector faces regulatory and other challenges

While growth prospects for molecular diagnostics are bright, there is concern in some quarters that rapid growth is outpacing clinicians' ability to interpret test results. "There's a need to develop reasonable guidelines for the use of genetic test results, which requires understanding a staggering amount of information," says Dr. Troy Brennan, executive vice president and chief medical officer of CVS Caremark, a major integrated pharmacy services provider. "In addition, counseling for genetic issues is critical, but there are too few genetic counselors to handle the need. The biggest concern is that diagnostic tests will 'bleed' into the system without clear guidelines, without enough counselors to help patients understand the results, and without payers willing to reimburse for them."

The sector also faces challenges related to a potential change in the regulatory process for validating new tests. Before IVDs can be sold in the marketplace, they must either win approval from the FDA or be certified as compliant with the Clinical Laboratory Improvement Amendments (CLIA), a federal program designed to ensure the quality of laboratory tests. Under CLIA, if a test is deemed as a minimal risk to public health, FDA testing requirements can be waived.

So-called CLIA waivers are a popular pathway for genetic tests, but in 2006 the FDA announced its intention to increase the regulation of lab developed tests, and the subject has been debated ever since. In July 2009, Alberto Gutierrez, the FDA's new director of the Office of In Vitro Diagnostic Device Evaluation and Safety, signaled that the agency is prepared

to tighten regulations over diagnostics manufacturers, which could lead to the elimination of CLIA waivers for molecular diagnostics.²⁶ Such a move would increase the cost, time and complexity of developing new diagnostics and could stall growth in the sector.

In addition to regulatory hurdles, diagnostics companies face questions about the evidence required for reimbursement of diagnostics tests. A recent high-profile example of the industry's reimbursement challenges relates to warfarin, a widely used blood thinner. Determining the proper dosage of warfarin is tricky, and incorrect dosing can cause serious problems; too small a dose and blood clots could form, too high a dose and the patient may experience excessive bleeding. For many years, Medicare reimbursed the cost of genetic testing to determine the appropriate dosage of warfarin, but in 2009, the Centers for Medicare and Medicaid Services (CMS) said it would discontinue paying for the test because new research had revealed that it was not cost-effective. However, Medicare has agreed to cover the cost of tests (typically \$50-\$500) for participants in upcoming clinical trials designed to further evaluate the efficacy of testing.²⁷ The warfarin case raises questions about the government's requirements for demonstrating the effectiveness of diagnostics, and whether reimbursement, once established, might be denied at some future point.

The forecast for theranostics is mixed²⁸

One factor that could spur growth in the diagnostics sector is the trend toward "theranostics"—combinations of targeted

therapeutics and companion diagnostics. Genentech's Herceptin and companion HER2 diagnostic is a prominent example of a theranostics solution.

The push to develop theranostics is being driven in part by payers, who are increasingly demanding evidence of efficacy to support reimbursement decisions. Regulatory bodies also could accelerate the development of theranostics. The FDA, which has identified 28 valid biomarkers, has designated four that require a diagnostics test prior to prescribing the companion drug (tests for the other 24 biomarkers on the list are only "recommended" or "for information"). The European counterpart of the FDA, the European Medicines Agency (EMA), (an organization for the European Union with responsibilities similar to the FDA's), requires companion diagnostics for 11 targeted therapies.

Thus far, there is little evidence that diagnostics companies are embracing partnerships with pharma companies to develop theranostics. The development risk and time to market associated with drug candidates make the development of a companion diagnostic significantly less attractive to major diagnostics manufacturers than the revenues they generate from their traditional target market of clinical laboratories. That said, if government agencies increase the use of biomarkers and diagnostics in prescribing decisions, it's likely that pharma and diagnostics companies will increase their collaboration in this area.

The direct-to-consumer (DTC) diagnostic market is growing—and controversial

Genetic testing products for in-home use are empowering consumers with real-time information, enabling them to predict their medical risks, detect disease earlier, and

better manage their health status. Market research analysts estimate the size of the global market for genetic testing at \$730 million, with a 20% annual growth rate.²⁹ Though a relatively small portion of this market, direct-to-consumer (DTC) is expected to grow rapidly in response to consumer demands and declining prices. From companies such as DNA Direct, 23andme, Inverness Medical Innovations, and Navigenics, products start at a few hundred dollars. However, prices and services vary widely and may include supplements, access to telephone counseling, and other services, such as the development of personalized treatment programs.

Some industry watchdogs question the usefulness and security of DTC test results and are concerned that some of these companies may be side-stepping regulatory and third-party reimbursement issues. Companies that develop DTC tests may focus on testing hundreds or thousands of positions in the genome, but scientists do not yet understand the relationship between the vast majority of these sites and disease. In addition, most DTC testing is not diagnostic but prognostic—focused on determining genetic susceptibility, on probabilities rather than the presence of disease—which adds to the complexity. In effect, consumers may be paying for information that no one yet knows how to use. In addition, companies marketing DTC tests claim to protect privacy, but there is no guarantee that information won't be shared, as there is little oversight.

Because of such concerns, several states and some countries are regulating or prohibiting DTC genetic testing. Some DTC testing companies are using scientific expert advisors to help address these issues.

No Child Left Behind: How molecular diagnostics could improve the treatment of childhood cancer

Beth Baber is a woman on a mission. In 2005, Dr. Baber, a cancer researcher and mother of three, learned that her 15-month-old son, Nicholas Conor Boddy, had high-risk neuroblastoma—a malignant tumor that originates from the spine. After seven rounds of intensive chemotherapy, surgery and retinoic acid therapy, Nicholas remains in remission, but during the course of his treatment, Dr. Baber learned that children with rare cancers such as neuroblastoma are all given the same chemotherapy drugs; there is no personalization of treatment approaches.

Furthermore, because relatively few children get cancer, there's a dearth of therapies tailored for them. Instead, children often are treated with smaller doses of drugs originally designed for adults and which are harsh on young bodies. As a result, the majority of children that survive after chemo- and/or radiation therapy develop a plethora of long-term side effects, such as infertility, hearing loss, abnormal bone growth, secondary cancers, and a marked decrease in the functioning of the heart, lungs, and kidneys.

Renowned institutions such as St. Jude Children's Research Hospital, Memorial Sloan-Kettering and The Children's Hospital of Philadelphia have made great strides in developing new therapies for children. However, there is a gap between the

remarkable discoveries made in academic laboratories and the further development and commercialization required, simply because the market for children with cancer is small.

In 2006, Dr. Baber helped to launch The Nicholas Conor Institute (TNCI) (www.thenicholasconorinstitute.org) to address the challenge of developing more personalized treatment for childhood cancer. The Institute is working toward the development of treatment-specific, predictive molecular diagnostics to enable the customization of cancer therapies for each child. This strategy will reduce unnecessary exposure to highly toxic drugs, lead to better responses and longer survival, and minimize long-term (and costly) side effects.

The initial goal is to develop molecular diagnostics that will provide better guidance for the use of existing chemotherapy drugs rather than requiring the costly development of new treatments. "We hope to develop companion diagnostics that will determine in advance if a child is going to respond to a specific chemotherapy drug," says Baber. "A lot of drugs have been shelved because they were thought to be ineffective, but they may be effective if given to the right person. Companion diagnostics could help us to identify the 'right person,' so that drugs could be pulled off the shelf and commercialized for children."

To achieve that goal, TNCI is focusing on promising academic research that is not being translated into clinical practice because of the high cost of the R&D required. The Institute is collaborating with small biotech firms, filing joint grant

applications, and seeking supplemental funding from philanthropic organizations to move discoveries from the bench to the bedside. “Pediatric cancer is an orphan disease, and there are many rare diseases, not only in children but in adults,” says Baber. “If we can implement a lower-cost R&D model, it could serve as a model for other orphan diseases.”

The Institute is also collaborating directly with a diagnostics company, AltheaDx (www.altheadx.com), which is producing the first childhood cancer diagnostic panel for small round blue cell tumors—a category of tumors that look much the same under a microscope but are produced by a variety of cancers, each requiring a different treatment. The diagnostic can differentiate the types of small round blue base cell tumors with 99% accuracy so that the appropriate treatment can be given.

“The implication of giving a child the wrong treatment is that the child does not respond,” says Dr. Joseph Monforte, chief scientific officer of AltheaDx. “In the worst case scenario, that leads to tragedy, but more often it leads to unnecessary pain and suffering because the treatment for each form of cancer is so different. A definitive diagnosis provides the optimal chance that the child will immediately get placed on the right treatment and have the best chance of being cured.”

AltheaDx hopes that its new test will one day replace the current standard for diagnosing childhood cancer—or rather, the lack of a standard. “Today there is no defined protocol for diagnosing childhood cancer,” says Dr. Monforte. “Some pathologists are more thorough than others in their testing. And in cases where they are less aggressive, there’s a greater likelihood of a misdiagnosis. We hope to provide a uniform approach to making the cancer diagnosis, through a single, definitive test.”

In the meantime, Dr. Baber continues to work toward a future when cancer treatments will be more personalized to the individual child. “Every time I go to a doctor’s appointment with Conor I see children suffering from cancer, and it’s frustrating to me that they’re not getting all the help they could, when I know that the technology is available to improve their treatment,” she says. “Ten years from now, if we’re successful, we’ll be able to say that we can tailor existing therapeutics to produce better outcomes for children. And hopefully the industry will start to commercialize new cancer therapies for them, despite the small market size. I really want to make sure that no child is left behind.”

Technology-based opportunities

Technology companies, including some with no health expertise, are capitalizing on emerging opportunities to manage vast quantities of genetic and other health data. At the same time, they are driving down related costs. As an example, it took more than 13 years and \$2.7 billion to complete the Human Genome Project in 2003—the first successful effort to sequence a human’s DNA. Only four years later, a similar project took two months and cost less than \$1 million.³⁰ Currently, California-based Pacific Biosciences is working on a platform to sequence the human genome in less than 15 minutes at a cost of \$100. Sensing the potential, in 2008 Intel Capital, the venture arm of the technology giant, co-led a group of investors that injected \$100 million into the start-up.³¹

Expanding storage capabilities and processing power will create new business opportunities in personalized medicine. “Emerging technologies will allow us to gather data on individual patients that was otherwise impossible even five years ago,” says ISB’s Hood. “In 10 years’ time, we will have billions of data points on every individual, and we will need a substantial investment in IT for healthcare to address this.” A new breed of programmers and analysts will be needed to make sense of the data; our ability to generate data is rapidly outstripping our capability to understand and interpret it.

When asked if being able to aggregate and analyze electronic health information is critical to the expansion of personalized medicine, 86% of pharmaceutical companies surveyed by PricewaterhouseCoopers said that they “strongly” or “somewhat” agreed.³² Their responses highlight the importance of analytical and technological capabilities in an era of personalized medicine. A number of health analytics firms have been formed to capitalize on the opportunities presented by the glut of health data waiting to be mined.

Some companies are leveraging massive computing power to identify new personalized medicines. For instance, Gene Network Sciences, a private company based in Cambridge, Mass., is using supercomputers to mine biological data, gain insights into the causes of disease and identify potential new diagnostics and treatments.³³ The company is collaborating with cancer researchers at the University of Connecticut to model personalized medicines for cancer.³⁴

In 2009, Microsoft entered the space as well, acquiring a piece of Rosetta Biosoftware, a genetic data management software that enables gene analysis to identify compounds that have the most promising potential for developing into drugs.³⁵ The company plans to integrate the software into Microsoft Amalga Life Sciences, which helps researchers to integrate data from multiple internal and external systems.

Electronic health records (EHRs) could accelerate research

Interoperable electronic health records (EHRs) could enable the sharing of genomic, proteomic, and other health data related to personalized medicine data among research organizations, and pooling and analysis of data to identify trends and accelerate research efforts. “In the disaggregated, paper files of tens of thousands of doctors’ offices, we are squandering one of the greatest untapped resources in healthcare: namely, the knowledge of what works and what does not work in the treatment of patients based on their particular characteristics and medical histories,” says Sidney Taurel, former chairman of Lilly and an early advocate of personalized medicine. “Tapping this resource—in conjunction with the rise of genetic testing for individual patients—could yield a true wealth of insight on personalized

medicine, making treatments safer, more predictable, and more effective across the board.” Achieving this goal, he says, requires “an infrastructure for building and sharing health records electronically” and “a rigorous privacy code that prevents disclosure and discrimination.”³⁶

The American Recovery and Reinvestment Act of 2009 provides \$36 billion to create a healthcare IT infrastructure that will include a national, interoperable EHR system. Building such an infrastructure will be a major undertaking. With the exception of connectivity among cancer centers associated with the cancer Biomedical Informatics Grid® of the National Cancer Institute (caBIG®) and a handful of other local efforts, medical and academic research organizations operate in informational silos. Many have difficulty connecting information sources within their own walls, much less sharing it with other organizations.

However, connecting EHRs has many challenges because of the differing data types and formats; there is a need for agreement on common data standards to reduce complexity. A lack of consistent terminology adds to the complexity.

New businesses that leverage the web will emerge

As healthcare decisions and treatments are pushed closer to the patient, moved to the home and focused on the consumer, connectivity will be critical. Companies that play a connectivity role, including internet service providers (ISPs), social networking sites and emerging technologies such as

Twitter also could find opportunities in personalized medicine, for services such as home-based monitoring and patient-to-patient social networking. Some patient advocate sites enable social networking activities but there is the opportunity for niche providers to build new and enhanced models.

The potential of the web is illustrated by PatientsLikeMe, a social networking site where patients can form online communities and share resources and treatment information. The site has attracted communities of patients in a range of disease areas, from more common ailments such as Parkinson’s to rare diseases such as primary lateral sclerosis.³⁷ In April 2009, the company announced the launch of its specialized Genetics Search Engine for patients with ALS. Through the online platform, ALS patients can share their genetic information with one another and search for others in the community who share the same gene, or even the same gene mutation that caused the disease. The site may also enable researchers to accelerate progress in understanding the etiology of disease and the discovery of new treatments.³⁸

Social media sites also can connect healthcare professionals in diagnosis and treatment. For instance, Serma enables physicians to connect with their peers, corroborate or challenge the opinions of other physicians, identify trends and pool their knowledge to improve outcomes for their patients.³⁹ Networks such as this could enable physicians to jointly address the multidisciplinary challenges posed by personalized medicine.

Healthcare providers in flux

Will the family doctor be disintermediated?

For healthcare providers, personalized medicine offers the potential to improve the quality of care, through more precise diagnostics, better therapies, and access to more accurate and up-to-date patient data and sophisticated decision support tools. For example, advanced diagnostics potentially could be performed at home, with test data uploaded to the Internet for remote analysis and referral to a specialist if needed, bypassing the primary care physician completely. But such disruptive innovations could bolster competition and threaten family practitioners.⁴⁰

In this new environment, allied health professionals such as nurse practitioners and physicians' assistants may play a greater role. Physicians also could face competition from pharmacists. With additional specialized training, pharmacists may be well equipped to help patients navigate the personalized medicine landscape and understand the implications of potentially thousands of new targeted therapeutics.

Primary care providers may have to build new service lines around prevention and wellness in order to replace revenues lost from traditional medical procedures. When they do, they can expect to face low-cost competition from non-healthcare companies skilled in consumer marketing, and consumers armed with knowledge of their options.

Physicians will need training in genomics and proteomics

For primary care practitioners to remain relevant in an era of personalized medicine, they must become educated in the science and clinical application of genomics and proteomics. Doctors accustomed to one approach for all diabetic patients

might have to learn a dozen gene-based variations on the disease, each requiring a different treatment. They will need to interpret the results of sophisticated genetic tests and translate them into effective prevention and treatment strategies. Decision support tools will be essential to guide treatment decisions based on test results, but physicians will also require a solid background in genomics and proteomics to make the best use of these sophisticated tools. Without the right tools, and the training required to use them effectively, the personalized medicine market will not advance in the provider space or elsewhere.

In addition to educating themselves in genomics and proteomics, physicians will need to hone their communication skills to provide genetic counseling and address the delicate issues surrounding targeted tests and treatments. The physician accustomed to offering solutions may have to explain to a cancer patient why the drug that saved her brother won't work for someone with her genetic makeup. The doctor who is reimbursed for outcomes, not procedures, might have to decline the request for a diagnostic test, knowing the results won't change the patient's prognosis. (We're seeing this happen in the case of ovarian cancer. A test to detect a protein biomarker called CA125 is routinely used to identify whose cancer is likely to recur, so that early treatment with chemotherapy can begin. While patients may find the test reassuring, researchers in the UK have concluded that early treatment makes no difference in survival rates.)⁴¹

To educate the next generation of physicians and nurses in the complex issues raised by genomic and proteomic science, universities will have to update their programs. A handful of top medical schools, such as Baylor College of Medicine, are leading the way in developing new curricula to address this gap in knowledge.

Perhaps the physician of the future will be trained in engineering as well as medicine, to gain a greater understanding of new nanoscale medical devices used for personalized medicine drug delivery and diagnostics. Some physicians might be trained as genomics and proteomics specialists with holistic knowledge of many different diseases and an understanding of gene interactions, eliminating the need for patients to see a variety of specialists to treat their ailments.

Hospitals must find new sources of revenue

As the emphasis on wellness grows and payers and consumers seek alternative, less expensive forms of care, hospital admissions may shrink, and these providers will have to deliver new forms of care in order to maintain their revenue flows. The hospital model already is undergoing a major shift in parts of Asia, including Singapore, where some hospitals offer wellness, nutrition and even services such as botox treatments. By contrast, U.S. hospitals generally restrict the scope of their services to those covered by Medicare, Medicaid and private insurers. In the process, they risk defining themselves out of a viable role in the future, as more consumer-oriented service providers encroach on their business.

Hospitals linked to universities may have brighter prospects, as they are poised to take the lead in personalized medicine research. Academic medical centers (AMCs) in the U.S. are the main recipients of federal research grants and hold many patents in molecular diagnostics. Their unique combination of academic research, state-of-the-art technology, medical education and clinical care

makes them well positioned to identify unmet market needs and discover new targeted therapies.

Academic medical centers also have access to massive amounts of patient data, which accelerates the discovery process. At the start of the millenium there were more than 300 million biospecimens in storage at AMCs. This rich pool of samples could be mined for data to identify trends and correlations between outcomes and genetic profiles across subpopulations, accelerating research progress.⁴² Some AMCs are moving in this direction. For instance, Brigham and Women's Hospital, an AMC affiliated with Harvard Medical School, is planning to link patients' genetic data with the rich clinical information in its EHR system to enable analysis that could lead to new tailored treatments and prevention strategies. The ultimate goal is to expand the project to members of the Partners Healthcare System, to which Brigham and Women's belongs and which serves hundreds of thousands of patients.⁴³ While the potential for such initiatives is enormous, so are the costs and challenges related to linking, mining and analyzing genetic data, as well as to protecting patient confidentiality.

The NIH is creating an integrated network of leading AMCs through its Clinical and Translational Science Awards (CTSA) program, which eventually will link roughly 60 of the top institutions across the country to focus on clinical and translational science.⁴⁴ The CTSA program encourages multidisciplinary research and a collaborative approach that could accelerate advances in personalized medicine. Recipients of CTSA grants are well positioned to be winners in the academic research space.

Payers' actions will drive the business models of other participants

How payers approach personalized medicine is critical, as their reimbursement schemes will influence the business models of pharma and diagnostics companies as well as providers who depend on third-party payment. Payers that want to embrace the new science will have to rethink how they define coverage. Insurance premiums today are based on actuarial statistics that apply to large, predictable populations. By contrast, personalized medicine targets small populations, which are far less stable and predictable from an actuarial standpoint. Payers will need to develop new actuarial assumptions on which to base their reimbursement models.⁴⁵

Payers worry that the cost of personalized medicine could be unsustainable

Personalized medicine has the potential to reduce payers' costs in the long term by providing the precise diagnostics required to avoid unnecessary or ineffective treatments, prevent adverse events, develop prevention strategies, and deliver more effective, targeted therapeutics.

If personalized medicine succeeds in preventing or successfully treating widespread chronic conditions such as diabetes, the cost savings could be enormous. But this potential has yet to be realized, and many payers (and the employers who pay much of the health insurance tab in the U.S.) are concerned that the high costs of new targeted diagnostics and therapeutics could be unsustainable. They also worry that the costs could be additive, given the history of healthcare innovations, which typically supplement rather than replace existing tests or treatments.

Payers also worry that the investments they make could benefit competitors. On average, 25% of individuals change health plans each year, in part because most insurance is employment-based. As a result, one payer might invest in costly diagnostics and early intervention that might reduce or eliminate the need for surgery in the future, but by then the member may have changed plans, and the new insurer will benefit from the earlier investment.⁴⁶ Some consumers might even opt to purchase a health plan that covers personalized medicine diagnostics, then switch to a less costly plan for their ongoing care.⁴⁷ Despite the fact that all insurers face the same problem and any given one potentially could be affected by members switching plans, such potential scenarios make some payers reluctant to cover targeted diagnostics and therapeutics.

Major payers are leading the way

Despite such concerns, major payers are beginning to embrace personalized medicine. For instance, many plans of Aetna and Kaiser Permanente include coverage for genetic counseling. Aetna covers certain genetic tests where the result of the test will directly impact the treatment of that individual. Kaiser also has enrolled 400,000 northern California members in a long-term research program to identify the role of genes and the environment in health.⁴⁸ Geisinger Health System has gone even further with its members, asking them to provide DNA samples, and about 90% complied. Geisinger is linking this genomic information with its EHR system and biobank, in order to gain insights into patients' risks for various chronic health conditions, with the ultimate goal of improving health outcomes.⁴⁹

Such moves by major players likely will spur efforts by other insurers to make forays into personalized medicine. An IDC survey of 61 healthcare payers in the U.S. found that many payers are beginning to move toward implementing personalized medicine solutions, and are focusing in particular on targeted diagnostics and therapeutics.⁵⁰ When asked if they expect their organizations to reimburse for expensive therapies if they fill an unmet need, roughly 26% of survey respondents said yes, and another 59% said they might do so in the future.

The pharmacy benefit managers (PBMs) also are getting involved, adding genomics-related products to their menus of benefits and collaborating on genomics research. In 2008, Medco Health Solutions, one of the nation's largest PBMs, announced a two-year research partnership with the FDA to explore the link between genetics and the efficacy of prescription drugs.⁵¹

Pay for performance could accelerate adoption of personalized medicine

As payers search for ways to reduce costs, they are moving away from paying for procedures—the traditional reimbursement paradigm—and toward outcomes-based reimbursement or “pay for performance” (P4P). The number of P4P programs in the United States is increasing rapidly. The compound annual growth rate (CAGR) for such programs, from a variety of sponsors (mainly government, employers, and commercial health plans) between 2003–2009 is estimated at 26.5%, from 39 in 2003 to an estimated 160 in 2009.⁵²

The trend toward P4P could accelerate the adoption of personalized medicine, if clinical data shows that targeted diagnostics and therapies reduce payers' costs. Until there is evidence to show that a targeted diagnostic, therapeutic or theranostic solution will save money, payers are not likely to provide reimbursement. Genomic Health offers a good example. Initially, consumers had to pay out of pocket for the company's Oncotype DX test. Only when sufficient clinical data was gathered to quantify potential cost savings did payers begin to reimburse for the test.

Government must be an enabler, not an obstacle

As major funders of healthcare, governments worldwide play a key role in advancing (or impeding) the progress of personalized medicine. Government can be an enabler of the new science by funding research, implementing appropriate reimbursement and regulatory policies, and addressing key issues such as data privacy and IP rights to genomic discoveries. As many parts of the world look to U.S. policies and initiatives in the area of personalized medicine at this stage, we will focus largely on the role and activities of U.S. government agencies in the personalized medicine space.

Government actions in four areas will be critical in driving the progress of personalized medicine: reimbursement, regulation, privacy and intellectual property (IP). We noted earlier that current, volume-based reimbursement models do not support personalized medicine, and there is no viable regulatory path for targeted diagnostics, therapeutics, and theranostics. If personalized medicine is to move forward, these critical issues must be addressed.

The FDA's Critical Path Initiative is tackling translational challenges through collaboration

In 2004, the FDA launched the Critical Path Initiative to improve the process by which new medical products are developed and approved. In 2005, the FDA and the University of Arizona formed the Critical Path Institute (C-Path), an independent, non-profit organization, to implement the initiative. C-Path is forging collaborations among the FDA, academia and industry to shorten the path for bringing new drugs, diagnostics and medical devices to market.

One goal of C-Path is to accelerate the development of approved biomarkers and related diagnostics. As C-Path president, Dr. Woosley is motivated to achieve that goal by his own experience in the design of Roche Diagnostics' AmpliChip CYP450 test, which analyzes two genes that influence drug metabolism and is used to guide dosing decisions and prevent adverse events. "In 1995 I went on sabbatical and helped develop the Amplichip, but it was ten years before it went to the FDA," he says. "It's frustrating to see it not move more quickly, because the science that was approved in 2008 had been available since 1996." To accelerate the approval process, C-Path collaborates with the FDA, EMEA, and multiple pharmaceutical companies to jointly address translational challenges.

By working with EMEA, C-Path could explore the development of global standards, so that a drug approved in Europe would be automatically approved in the U.S., and vice versa. Global standards could reduce or eliminate duplication of effort and streamline the approval process, which will become even more critical as the number of new diagnostics and therapeutics continues to grow.

The FDA is engaged in other collaborations that could advance personalized medicine. Among others, these include the two-year research partnership with Medco cited earlier, and a partnership with the NIH and the Pharmaceutical Research and Manufacturers of America (PhRMA) to test tools that can mine databases of information about health outcomes, with the goal of improving monitoring of pharmaceuticals for safety.⁵³ For instance, the ability to mine and correlate patient data could enable clinicians to identify adverse drug reactions more quickly.⁵⁴

Government must balance privacy needs with research requirements

To bolster privacy in response to the growth of genomics research, in 2008 Congress passed the Genetic Information Nondiscrimination Act (GINA), which is designed to protect consumers against discrimination by employers or healthcare insurers based on genetic profiles that could indicate they are at risk of contracting a particular disease or condition. GINA may ease concerns of many consumers about participating in clinical trials and maintaining EHRs. Some advocates refer to GINA as a civil rights bill for an era of genomics.⁵⁵

Protecting consumers' privacy is essential, but if privacy laws are too restrictive they could impede research by prohibiting access to patient data and tissue samples. Some state privacy laws are creating barriers to the adoption of EHRs. According to a study by researchers at MIT and the University of Virginia, in states that adopted stricter privacy laws, the adoption of EHRs by hospitals was up to 30% lower than in states without such restrictive legislation.⁵⁶ This argues in favor of national legislation in order to accelerate research efforts.

Some argue for an "opt out" approach to privacy under which patients' health records and biospecimens, with identifying information detached, would be used for research unless the patient declines. That would enable the research to progress even if some consumers opt not to participate. As one respondent to the

FasterCures survey noted, "We don't want the politics of fear of privacy breaches to get in the way of the needed advances."⁵⁷

Government must strike a balance, establishing policies and writing legislation that provides financial incentives for the private sector while protecting the public's interest in furthering genomics research. Federal legislators are debating the appropriate length of patent protection for new biotechnology drugs. While some lawmakers want to limit exclusive IP rights to five years, the biotech industry is arguing for protection for 12 to 14 years in order to break even and encourage the development of new therapeutics.⁵⁸

The IP battle also is being fought in the courtroom. In May 2009 the American Civil Liberties Union (ACLU) partnered with a group of leading researchers, health organizations and cancer patients to bring a lawsuit against the U.S. Patent and Trademark Office and Myriad Genetics, challenging the validity of two of the company's patents for gene sequences associated with breast and ovarian cancer risk.⁵⁹ Myriad's business model is built around its IP for all testing related to the BRCA1 and BRCA2 gene sequences—a monopoly that enables the company to charge a premium price for BRCA tests. Myriad's patents have been ignored by some health systems in Europe and Canada and the patents were invalidated in Europe in 2004, on the grounds that the company hadn't invented anything new. The plaintiffs in the ACLU lawsuit may not prevail, but the case highlights the financial stakes involved and hints at the obstacles that lie ahead for personalized medicine.

The impact of comparative effectiveness is unclear

The economic stimulus package passed under the Obama administration includes several provisions that could impact the advancement of personalized medicine. In addition to the \$36 billion for creation of a healthcare IT infrastructure noted earlier, the package provides \$10 billion in biomedical funding for the National Institutes of Health (NIH), and \$1.1 billion for comparative effectiveness research to identify which drugs perform best and ensure that government and patients get the most for their money.

Funding of comparative effectiveness research is a controversial component of the stimulus package. Critics, including many in the pharmaceutical industry, view it as a cost-cutting initiative that

could remove access to viable drugs that are effective for small populations but might not be chosen as “best in class.” That would shrink the market for those drugs and could discourage research and development of new, and potentially costly, personalized medicines. Critics in the U.S. point to the UK, where a similar approach has resulted in claims of “rationing of care.” A 2009 report on the National Institute for Health and Clinical Excellence (NICE), the gatekeeper for the UK’s efforts at cost-effective medicine, recommended raising the price ceiling on some innovative drugs for two or three years.⁶⁰ This signals the willingness of the government to experiment more broadly in the personalized medicine space. Industry observers will be watching closely, as the U.S. government’s implementation of comparative effectiveness will influence the reimbursement decisions of private payers.

How government can help

Government can have a profound influence in shaping the future of personalized medicine by taking actions in four key areas:

- **Regulatory:** Create clear and reasonable pathways for approval of personalized medicine diagnostics and therapeutics, and for co-development of drugs and diagnostics (i.e., theranostics).
- **Reimbursement:** Change reimbursement models from volume- to value-based, from rewarding for treatment/disease to paying for outcomes/wellness.
- **Privacy:** Implement policies that enable sharing of patient data and biospecimens needed for research while ensuring the privacy and security of patient data.
- **Intellectual property (IP):** Create IP policies and legislation that provide financial incentives to develop new drugs and diagnostics while balancing the need for sharing of scientific information to advance research.

Government agencies shaping personalized medicine

Four organizations in the U.S. and Europe will play a key role in shaping the future of personalized medicine.

Centers for Medicare & Medicaid Services (CMS)

As the largest healthcare payer in the U.S., CMS could have a profound impact on the advancement of targeted diagnostics and therapeutics and the adoption of a proactive healthcare model that emphasizes health, wellness and the prevention of disease. Reimbursement models developed by CMS tend to be adopted by most private insurers. CMS is expected to move forward in the direction of adopting a more outcomes-based reimbursement model that could spur the development of targeted diagnostics and therapeutics.

Food and Drug Administration (FDA)

As the federal agency responsible for approval and regulation of drugs and diagnostics, the FDA faces a major challenge to develop a clear, viable pathway for the approval of new targeted diagnostics, therapeutics, and theranostics. Efforts such as the Critical Path Initiative are paving the way for collaborations with industry to address the challenge and accelerate progress in personalized medicine. The FDA also could speed progress by supporting conditional approvals—allowing smaller and less expensive clinical trials for personalized medicines, then utilizing personal mobile devices (smart phones) to monitor patient compliance and performance to determine if problems are emerging, thereby enabling quality and safety.

National Institutes of Health (NIH)

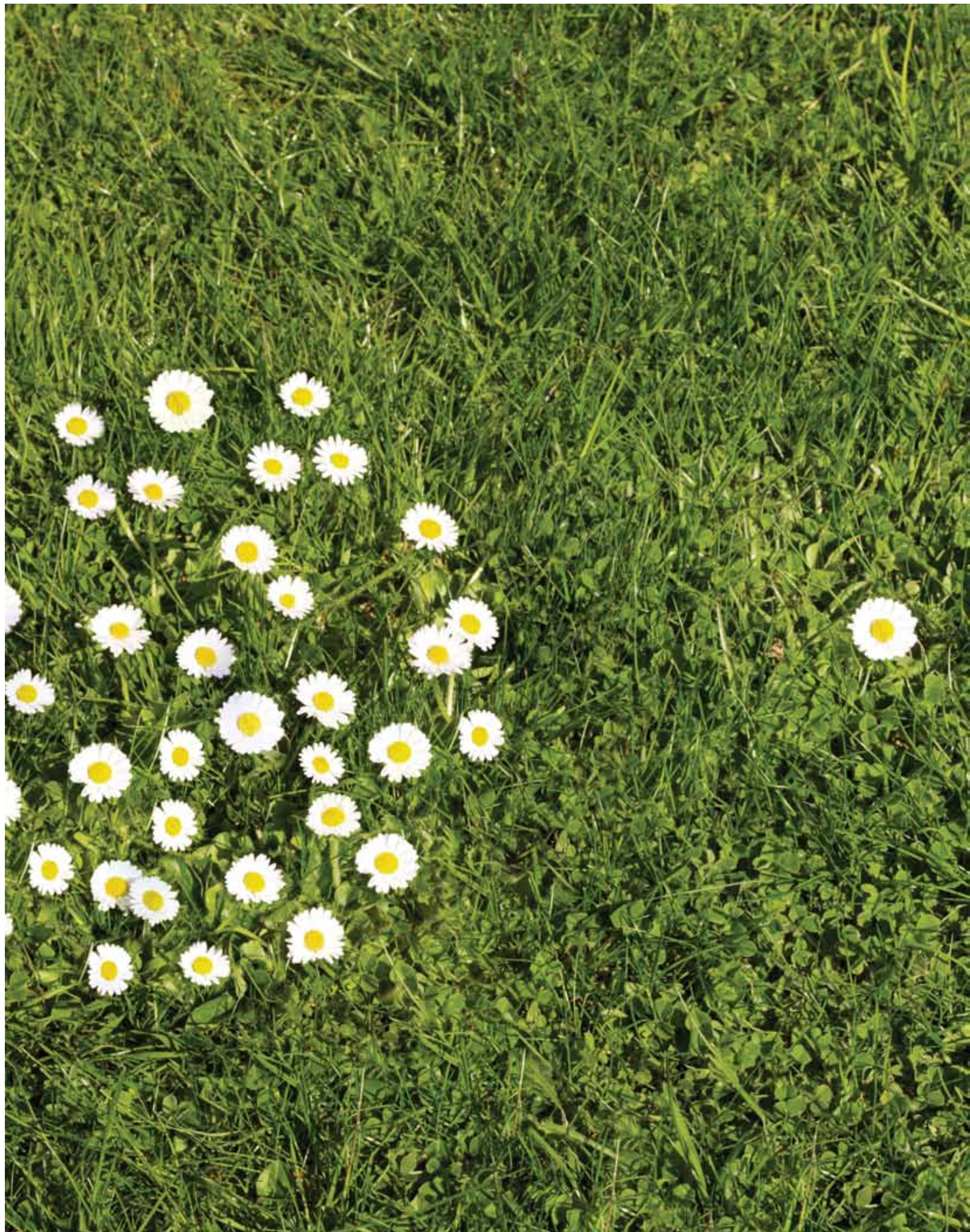
The NIH, which is responsible for U.S. medical research in the public domain, is guided by its NIH Roadmap for Medical Research, which includes funding for research into systems biology,

genomics and proteomics, and other aspects of personalized medicine. Bolstered by \$10 billion in funding from the economic stimulus, the NIH can enhance its research into biomarkers of disease and the development of targeted diagnostics and therapeutics. The NIH also is creating an integrated network of leading AMCs through its Clinical and Translational Science Awards (CTSA) program. These institutions will likely be at the forefront of scientific research to advance the science of personalized medicine.

European Medicines Agency (EMA)

The European Medicines Agency (EMA) is the governing body of the European Union that is responsible for promoting public health and safety and has regulatory approval and oversight of new diagnostics and therapeutics. It is roughly equivalent to the FDA in the United States but is a decentralized organization. EMA could accelerate the spread of personalized medicine through its approval process, under which only a single application is required to secure approval of a drug or diagnostic in all EU countries.

One major objective of the EMA is to make safe and effective medicines available to patients. Better medicines need to reach the market in a timely manner and be evaluated using state-of-the-art methods. A key goal of the EMA Road Map 2010 is to foster research and innovation in the pharmaceutical industry across the European Union. To this end, an “EMA/CHMP think-tank group on innovative drug development” was created. The group comprises EMA staff and several members of different scientific committees/working parties of the Agency acting as an internal focus group. These experts aim to identify scientific bottlenecks to the development of innovative medicines, both in the industry’s R&D and in the academic environment.⁶¹



Much progress has been made but many challenges remain

We have described the activities of various players who are moving into the personalized medicine market—some aggressively, others cautiously. We also have highlighted the key scientific, business, and regulatory hurdles they face, and the progress that has been made. Additional challenges in all three areas must be overcome before personalized medicine can fulfill its promise.

Tremendous progress has been made in genomic and proteomic research, but scientists still have much to learn about the precise biological mechanisms that predict or trigger disease in a given individual, the interaction of multiple genes and proteins with the environment, and how to translate that knowledge into prevention and treatment strategies. Some businesses have experienced success in the personalized medicine market, but there are few viable business models for other organizations to follow. Indeed, one of the more uncertain aspects of personalized medicine is whether the anticipated benefits will be realized at an acceptable cost. Recently released analyses suggest that the returns on investment depend on the particular scenario and are different for different stakeholders. The federal government has taken steps to address the regulatory issues surrounding targeted tests and treatments, but pharmaceutical and diagnostics companies still face uncertainty over the evidentiary requirements for approval of new diagnostics, therapeutics, and theranostics.

Consumer behavior is another obstacle to personalized medicine, one that is often overlooked or underestimated. Targeted diagnostics and therapeutics are not a panacea for medical conditions that drive healthcare costs. Lifestyle habits play a key role in disease and disease management, and they are notoriously difficult to change. The late anthropologist Margaret Mead famously declared that it is easier for a man to change his religion than his diet. (More recently, Bill Gates has noted that bathroom scales have not curbed the rise in obesity.⁶²) For providers and patients, shifting the healthcare paradigm from treatment to prevention of disease, from illness to wellness, will not be easy.

Other key challenges include needs related to information gathering, sharing and interpretation: for universal standards for managing genomic information in electronic medical records; improvement in the collection and interpretation of clinical data; and development of new strategies to educate practitioners and patients/consumers. The reality is that personalized medicine is upon us; open discourse and periodic reality checks will be necessary as we confront the issue of costs versus benefits.⁶³

Beyond the challenges highlighted above, there is the inevitable resistance to change that must be overcome before any major innovation can become widely accepted. The implementation of personalized medicine on a large scale will require a major restructuring of the healthcare infrastructure to become more consumer-focused, and a radical shift in the thinking and culture of the medical establishment. Such a shift is bound to require years, if not decades, to occur.

What this means for your business

Sustainability will require
a long-term strategy,
cross-industry collaboration,
and technical expertise.

Based on our observations of the emerging personalized medicine market and experience in helping clients to capitalize on the potential it presents, PricewaterhouseCoopers has identified four lessons that will be critical to the success of market participants.

Organizations will profit together, not alone

Personalized medicine is a highly complex field, and no one organization or industry has all the resources, knowledge and tools needed to implement solutions in this space. This is driving organizations towards “open innovation” networks that allow them to collaborate with others, within or outside their industries, to create the next generation of innovations.

Unless regulatory and reimbursement models are aligned with the requirements of personalized medicine, the new science is not likely to advance far. Pharmaceutical and diagnostics companies, payers and regulators can work together to create an economically viable, sustainable process for commercializing targeted diagnostics and therapeutics.

More broadly, we expect to see complex networks of collaboration emerge, within and across industries and between the public and private sectors, as individual players grapple with the complicated challenges of participating in a new market where the lines between health and wellness, and between industries, are blurring. For example, collaboration could be accomplished by leveraging social media technologies in innovative ways to bring diverse groups together, and bundling payments to such groups in order to provide an incentive to work together.

As personalized medicine advances and the boundaries between healthcare and wellness products and services blur, organizations are experimenting with a wide variety of collaborations within and across industries. Following are a few examples of the many flavors of collaboration emerging through open innovative approaches:

- Lilly began sharing the results of clinical trials online with its competitors and the public in 2004, and other pharma companies have followed suit, allowing them to learn from one another.⁶⁴
- Procter & Gamble has established a \$325 million joint venture with diagnostics company Inverness Medical Innovations to market DTC diagnostics.⁶⁵
- The Michael J. Fox Foundation for Parkinson’s Research is partnering with DTC diagnostics firm 23andme to design web tools for gathering data for clinical trials.⁶⁶
- Intel launched a joint venture with General Electric to market health devices that connect to the internet, enabling remote monitoring of patients in their homes.⁶⁷
- Google is collaborating with the Cleveland Clinic, Quest Diagnostics, Walgreens Pharmacy, Longs Drug Stores and others to advance its PHR platform, Google Health.



- A unit of Abbott Laboratories that develops genetic tests will partner with Pfizer to develop a new diagnostic for screening of non-small cell lung cancer (NSCLC) tumors, to identify patients who are likely to respond to a new cancer therapy Pfizer is developing.⁶⁸
- Merck and AstraZeneca have forged an unusual agreement to combine two experimental cancer drugs, one from each company, to create a cocktail that could be far more effective than each treatment administered separately.⁶⁹
- Swiss biopharma development specialist Debiopharm in-licenses promising new drug candidates from academic institutes and biotech companies, develops them and then out-licenses them to Big Pharma.⁷⁰
- Lilly is teaming up with other organizations to create virtual R&D programs to gain better access to innovation, reduce its costs, manage risks more effectively and enhance its productivity.
- Diagnostics firm LabCorp formed a research collaboration with Medco, the PBM giant, to evaluate genetic variations in how people metabolize the cancer drug Tamoxifen.

A core skill for the future will be managing these complex alliances to ensure that all parties benefit from the innovations that emerge. For instance, Lilly has developed a collaborative network approach to R&D designed to share risks and rewards with research partners. In one such arrangement, Lilly contracted with a partner to develop molecules from its discovery pipeline, retaining the option to bring them back into its portfolio. The partner would receive milestone payments at key development transition points, and a royalty if the product made it to the market. In the future we can expect to see more such creative arrangements.

Profiting Together in an Era of Personalized Medicine

Collaborative pharmaceutical business models

To succeed in an era of personalized medicine, pharmaceutical companies will have to transition from profiting alone to profiting together through open innovation. To this end, Johnson & Johnson, Pfizer and Eli Lilly announced their commitment to an open innovation business model in 2009.

PricewaterhouseCoopers has identified two principal collaborative business models that could help pharma companies to achieve sustainable success through greater innovation: federated and fully diversified.⁷¹

Under the **federated model**, a pharmaceutical company creates a network of separate entities—universities, hospitals, clinics, technology suppliers, data analysis firms and lifestyle service providers—with a common supporting infrastructure (funding, data, and access to patients and back-office services). Network participants share the goal of managing outcomes in a given patient population, and each player is rewarded in proportion to its contributions. This model provides a framework for creating integrated packages of products and services, and thus diversifying beyond a company's core offering.

Under the **virtual version** of the federated model, the pharma company outsources most or all of its activities and acts as a management hub, enabling the company to reduce its initial capital outlay, convert fixed costs into variable costs, utilize resources more efficiently, become more flexible, and expand more easily into new product and service areas or geographic markets. Under the **venture version** of the model, the pharma company invests in a portfolio of companies in return for a share

of the intellectual assets and/or the capital growth they generate. At the end of the investment period, the pharma company claims its share of the IP generated or out-licenses it to a third party.

Under the **fully diversified model**, a pharmaceutical company expands from its core business into related products and services, such as diagnostics and devices, generics, nutraceuticals and health management. Johnson & Johnson is the leading exponent of this model, which enables companies to:

- reduce their reliance on blockbuster drugs
- spread their risk by moving into other market segments with the potential to act as a bulwark against generic competition
- move into outcomes management by offering combined product-service packages and playing to the growing emphasis on prevention
- develop more powerful brands and acquire a better corporate image
- supplement products with wellness services.

The two models are not mutually exclusive. A fully diversified company might choose to use a federated model for certain aspects of its business, and vice versa. PricewaterhouseCoopers believes that the federated model will dominate because it can be implemented easily, rapidly and at a lower cost than the fully diversified model. Furthermore, the latter model requires the ability to manage complex networks of partners in order to succeed—a difficult challenge.

Public-private collaboration drives economic development

Collaboration between public and private sectors can generate advances in personalized medicine that go beyond what industry alone could achieve. One prominent example is the application of open innovation to the creation of the Arizona-based Translational Genomics Research Institute (TGen).

TGen was established in 2002 as a public-private partnership that included the state of Arizona, the city of Phoenix, three Arizona universities, and local hospitals. It was driven by government leaders in Phoenix, who visualized their city as the next locus for biomedical research and related economic development. PricewaterhouseCoopers helped to launch TGen, tapping into resources of the institute's advocates and working with Arizona's public universities, philanthropic organizations, and local and national research and clinical organizations that wanted to explore professional relationships with the institute. Within five months, financial backers committed over \$100 million in seed funding and other support.

Launching a major biomedical research institute is a huge undertaking, and doing so in a location not known for biomedical research adds to the complexity. Without close collaboration between the public and private sectors in Arizona, TGen's success would not have been possible.

After the launch, TGen quickly forged collaborations with other key leaders in personalized medicine, and rapidly achieved worldwide renown. The organization has spawned a number of successful for-profit ventures that have helped to boost the Phoenix area economy.

Disease franchise model

To replace revenues generated by blockbuster drugs, some pharmaceutical companies might focus on providing a comprehensive suite of products for a particular disease area—for instance, developing a franchise in diabetes, whose treatment involves diagnostics and drug delivery devices as well as pharmaceuticals and diet and exercise resources. Disease franchises could be accomplished via collaborations or licensing rather than via acquisitions of companies that produce “best in class” complementary products, or developing the full set of products and services in-house. It remains to be seen what impact, if any, lawsuits such as the one against Myriad will have, or if access to IP in the area of genomics will become so restricted that it will prevent access to targeted diagnostics and therapeutics needed to implement a disease franchise model.

Successful organizations will keep their eyes on the prize: consumers

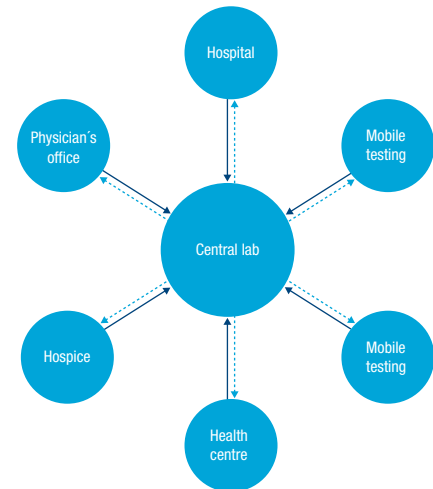
Focusing on consumers will be critical for traditional health industry players, who face competition from consumer products and other industries with skill and experience in targeting consumers and delivering high-quality customer service. For providers and other healthcare players, learning to view patients as consumers with many alternatives will be a key to success.

Inverness Medical Innovations provides a good example of how a consumer focus can lead to success. Inverness is a leading global developer, manufacturer and distributor of rapid diagnostics, including molecular tests. The company also offers consumer-focused health management services, such as home monitoring, patient education and nurse relationships (call center services) for patients who have chronic illnesses, who are acutely ill and/or have clinically complex conditions, or who are pregnant. Inverness is in the process of developing a communication infrastructure that will link patients, caregivers, providers and payers to instantaneous results and a longitudinal clinical record, thus empowering consumers to improve their health.

Inverness acquires companies and products moving towards consumer-centric healthcare. It emphasizes near patient point of care (POC) products—tests that are performed at or near the site of patient care, including at home. Inverness markets its diagnostics products to physician office labs and directly to consumers. Products are designed for physicians and patients and don't require sophisticated technical training to use.

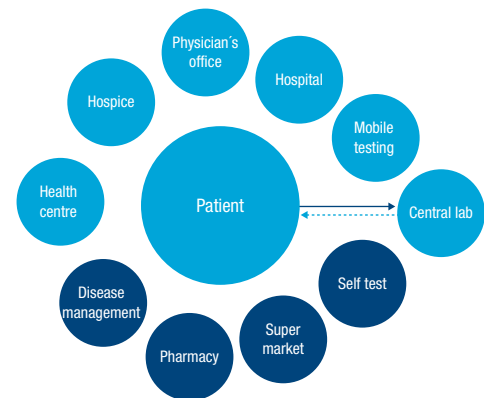
Central Lab Model

Lab centric



Point of Care Model

Patient centric



- Sample
- Results
- New market
- Old market

Inverness' emerging point of care (POC) model illustrates a potential shift in the diagnostics market away from centralized labs and toward the patient/consumer.

Inverness' emerging Point of Care model illustrates a potential shift in the diagnostics market away from centralized labs and towards patients/consumers. After several years of acquisitions, the company has a 30% POC market share in the U.S. and a leading position in many of the global markets; the rest of the market is relatively fragmented. Inverness' consumer-focused strategy is supported by industry growth projections: The global POC market is expected to grow at 5% CAGR through 2012, when it is projected to reach nearly \$20 billion.⁷²

TGen is another example of a health organization succeeding in part by focusing on patients. Dr. Jeffrey Trent, President and Research Director of TGen, said his organization's goals for personalized medicine are to take scientific discoveries

made in laboratories and—as quickly as possible—translate them into more effective treatments for patients, while striving for the most cost-effective patient benefit.

To accelerate the process of translating discoveries into practical applications for patients, TGen sought out clinical partners, including several hospitals in Phoenix and a branch of the Mayo Clinic in Scottsdale, Arizona. In addition, three of TGen's spinoffs are focused on applying research findings to patients quickly. One spin-off, Molecular Profiling Institute (subsequently acquired by Caris Diagnostics) analyzes tumors. Another, TGen Drug Development Services (TD2), conducts clinical trials of new drugs. A third organization, MedTrust Online, enables oncologists to obtain information about the best available treatment for their patients.

Expertise matters

Many of the organizations and initiatives that have succeeded thus far have leveraged the expertise of leading scientists in personalized medicine. For instance, Dr. Trent, TGen's president and research director, is the founding scientific director of the National Human Genome Research Institute and recognized nationally and internationally as an industry leader. Dr. Leland Hartwell, President of the Fred Hutchinson Cancer Research Center, won a Nobel Prize in 2001 for identifying genes that control cell division. And before he became the leader of ISB, Dr. Leroy Hood created the DNA sequencer, which enabled rapid automated sequencing and the success of efforts to decode the human genome.

The expertise of these three men was essential to the government of Luxembourg when it established a bold initiative to diversify its economy by building a health sciences and technology sector. PricewaterhouseCoopers brought TGen and ISB into the collaboration with Luxembourg along with another world-class biomedical research organization led by Dr. Hartwell: the Partnership for Personalized Medicine (PPM), which focuses on the development, validation and clinical application of new molecular diagnostics.

Personalized medicine is a marathon, not a sprint

Business models will require a long-term strategy and great flexibility to succeed in a fast-moving market that could evolve in unpredictable ways. For example, in Luxembourg, the government was open to a broad range of potential strategic partners but required that partners be willing to develop a lasting relationship. PricewaterhouseCoopers worked with the government to flesh out an economic development plan that focuses on sustainable, long-term economic growth rather than transitory, short-term gains. The strategy called for Luxembourg to implement an integrated model of economic development that will link biomedical research with education, healthcare and the national economy. Each of these four elements will mutually reinforce one another and create broader economic diversification. For instance, cutting-edge biomedical research will improve healthcare by attracting world-class physicians, and clinical activities will support new research discoveries. Investments in training and education will also support the research effort, which, in

turn, will generate high-skill, high-paying jobs that will attract talent and research funding from foreign investors.

If such a vision seems implausible, consider that Luxembourg has succeeded in the past, implementing another bold strategy that transformed the country into a world-class financial center and a nation with the highest per capita income in the world. Its vision of reinventing the country as a global bioscience center could help to ensure that it maintains that status. Other nations and multinational corporations have expressed interest in the Luxembourg initiative, and private investors are sensing its potential to offer investment opportunities.

While few forays into personalized medicine will be as complex as the Luxembourg initiative, its lessons could apply to any organization that wants to achieve sustainable success: Keep the long-term vision in mind. Personalized medicine is a marathon, not a sprint.



Conclusion

We have described the many challenges involved in translating the promise of personalized medicine into practice, and the importance of taking a long-term view. A future that seems distant and unattainable may seem inevitable in hindsight.

The 20th century was marked by extraordinary advances in technology that would have seemed beyond the imagination at the start of the century. When the Wright Brothers took flight off the sands of Kitty Hawk in 1903, few could imagine that in the space of less than 70 years a man would set foot on the moon. Similarly, we believe the 21st century will give rise to advances in genomic and proteomic science that cannot yet be envisioned, and will yield results on a similarly grand scale.

While the scientific potential of personalized medicine is enormous, delivering a high quality of care also will be a key to the success of this emerging field. “Personalized medicine should result in better patient outcomes, not only in how disease is treated, but in how patients are treated as individuals,” says TGen’s Dr. Trent.

Dr. Trent is optimistic about the prospects for personalized medicine. “As we look ahead to the next few years and move from ‘one size fits all’ medicine toward precision medicine, there will be a remarkably more personal nature to clinical care,” he says. “Using each individual’s own genetic fingerprint to define both the disease and treatment will transform the medical profession. All of what we know about medicine will indeed be defined by what we know of the human genome. There are great surprises ahead, and I believe the overwhelming balance will be positive.”

Where to begin: recommendations for the health industry and consumers

Following are recommendations for health industry players as they consider how to respond to the emerging personalized medicine market and explore sustainable business models.

Pharmaceutical and diagnostics companies

- Articulate the benefits of products in the pipeline to payers and regulators as early as possible in the R&D process, to win their support and avoid the time and expense of developing a drug or diagnostic that cannot be commercialized.
- To help make the business case for reimbursement, develop health economic models that project the potential cost savings of products in development.
- Work proactively with regulators to educate them about the need for a reasonable period of IP exclusivity as well as new pathways for approval of targeted diagnostics, therapeutics and theranostics. Assist in offering novel solutions.
- Collaborate with payers in developing novel reimbursement strategies that minimize your risks and costs, such as an accelerating schedule of reimbursements as products progress through their lifecycle and demonstrate their efficacy.
- Discuss with payers the potential to secure funding for R&D efforts in areas of interest to them, and address their concerns in your R&D efforts.
- Collaborate with academic medical centers and other organizations with access to patient populations, to accelerate recruitment for clinical trials.
- Create an open innovation business model to support all these collaborative relationships that will create networks of talent within and outside the boundaries

of the organization and be aligned towards developing and commercializing innovation.

- Educate consumers about the need for, and benefits of, personalized medicine solutions. The success of blockbuster drugs and diagnostics such as Oncotype DX test was driven in part by consumer awareness.

Providers / Provider Systems

- Become educated in genomics and proteomics to educate patients, respond to their concerns, and develop effective prevention and treatment plans.
- Identify health and wellness products and services to potentially offer to patients.
- Look to other industries, such as consumer products companies, to understand how to market directly to patients and deliver excellent customer service.
- Collaborate in research efforts, including initiatives and pilot projects to accelerate translation of discoveries from the bench to the bedside.
- Encourage patients to become educated in personalized medicine and take steps to advance it—for instance, by contributing genetic information for research, participating in clinical trials and/or social networking sites such as PatientsLikeMe, and donating biospecimens for biobanks.
- Partner with experts in personalized medicine, and recruit physicians and administrators with expertise in the field.
- Adopt electronic health records, capture genomic data to populate them, and support industry efforts to create a system of interoperable EHRs across the industry, to reduce costs and medical errors and support further advancements in personalized medicine.

Payers

- Become educated about the science and benefits of personalized medicine. Consult with experts and institutions that are at the forefront of advancing the new science.
- Invest in personalized medicine early, to win initial market share and strengthen your image as an innovative market leader.
- Set clear reimbursement criteria upfront, to help reduce R&D expenses for pharma and diagnostic companies, which will ultimately will lower your costs as well as theirs.
- Explore R&D collaborations with pharma and diagnostics companies that could benefit all parties, such as the development of new tests and treatments for widespread chronic conditions such as diabetes and obesity, which could improve health outcomes, boost workforce productivity and reduce claims costs.
- Work with pharma and diagnostics companies to maintain current, accurate information on the clinical efficacy of personalized medicine tests and treatments and use this information to inform benefits policies and coverage decisions
- Design novel reimbursement models that encourage innovation and spread risk, such as accelerating reimbursement as products progress through their lifecycle and demonstrate their efficacy.
- Redesign reimbursement models to focus on pay for performance rather than rewarding for the number and type of procedures performed.
- Analyze claims data to identify unmet needs that personalized medicine

could address. Consider funding R&D for development of identified target diagnostics and therapeutics.

- Collaborate with peers and with other industry players (pharma and diagnostics companies, non-profit disease foundations, etc.) to understand and apply best practices in personalized medicine.

Government

- Collaborate with pharma and diagnostics companies to ensure that the appropriate regulatory, privacy and intellectual property (IP) framework is in place to support the development and commercialization of new products.
- Provide funding, tax subsidies and other protections to diagnostic and pharmaceutical companies to develop new targeted tests and therapies.
- Create public-private partnerships and fund collaborative private research efforts to accelerate personalized medicine solutions, particularly in important areas of public health that have limited profit potential for commercial companies.
- Identify and support potentially “disruptive innovations” (via tax subsidies and/or other incentives) that could advance the science and practice of personalized medicine while reducing healthcare costs.
- Invest in the interconnected information technology infrastructure and create supporting legislation (including privacy legislation), to enable pooling and analysis of data.
- Provide and/or fund development of educational materials about personalized medicine for the general public, to cultivate well informed healthcare consumers.

About PricewaterhouseCoopers

PricewaterhouseCoopers (www.pwc.com) provides industry-focused assurance, tax and advisory services to build public trust and enhance value for our clients and their stakeholders. More than 163,000 people in 151 countries across our network share their thinking, experience and solutions to develop fresh perspectives and practical advice.

Health Industries

PricewaterhouseCoopers Health Industries serves as a catalyst for change and the leading advisor to organizations across the health continuum, including payers, providers, health sciences, biotech/medical devices, pharmaceutical and employer practices in the public, private and academic sectors. With a distinctive approach that is collaborative, multidisciplinary and multi-industry, PricewaterhouseCoopers draws from its broad perspective and capabilities across and beyond the health industries to help solve the array of emerging complex problems health organizations face, lead cultural and clinical transformation, and create a new, sustainable model for care delivery that is quality driven, patient centered and technology enabled.

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