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Establishing Genome Sequencing Centers, the Thematic Units in the Developing Nations and the Potential Medical, Public Health and Economic Implications

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Abstract

A detailed account of the overwhelming success attributed to the Human Genome Sequencing Project (HGSP) was examined. A comparison was made of the quality of life indicators between the G-8 nations and the other progressive developing nations, identifying the challenges involved in establishing viable genomic centers. Demographic data for the scientific workforce in Brazil, China and India and the frequencies of their IT and bio-engineering graduates will clearly out space those of G-8 nations in the next few years. This trend could leapfrog some of the developing nations into the status of highly industrialized countries. The lessons gleaned from the trajectory of their economic growth and development involve the ingenuity of their political administrators in advancing time-tested, cogent scientific policies, the generous funding and investment in scientific infrastructures to implement several biotechnological themes. They also advise their leaders of academic institutions to eliminate existing barriers among the sciences, behavioral disciplines and the practitioners of indigenous health care services.

Keywords: Human genome sequencing; Developing nations; Potential medical benefits; Public health implications; Economic implications; Genomic themes; National policies on science; Beijing Genomic Institute (BGI); Brazil Genomic Center; Quality of life indices

Inception of the Human Genome Project

In an effort to scientifically pinpoint the impact of radio- nucleotide on humans, after the use of atomic bomb by July 16, 1945 at Alamogordo, Mexico, Hiroshima and Nagasaki, Japan by August 1945; through the act of United States congress, the U.S. Department of Energy [1] was asked to study and analyze the genomic structure, replication, damage and repairs and the consequences of genetic mutation especially those caused by radiation and chemical by-products of energy production. From the plethora of scientific studies emanating from this official investigation grew the recognition that the most ingenious way to study the effects of radio-active agents on humans was to analyze the entire human genome to enable scientists have access to a reference genome [1-3]. Although planning began in 1986, regarding the Department of energy's human Genome Program, the National Institutes of Health (NIH) got involved in 1987. The joint initiative between The DOE-NIH, United States led Human genome Project formally began by October 1, 1990. The memorandum of Understanding was signed after the first joint 5-year plan was documented between the two United States federal scientific organizations. The accomplishment of human genome sequencing, mapping and declassification is practically incomplete without the imaginative vision of The Nobel laureate Dr. James D. Watson and his colleagues. In 1986, Dr Watson organized a special session to discuss the full ramifications of the human genome project, during that meeting at Cold Spring Harbor Laboratory, the idea was raised by Wally Gilbert that the project could consume a colossal sum of money to the tune of "3 billion base pairs, 3 billion dollars". This was perceived as an extremely expensive project that could only succeed with public funding. The role of Dr. Watson and his associates [4] in involving political leaders and soliciting funding for the accomplishment of the HGP can hardly be overemphasized. As the first biologist to serve as the director of the human genome unit at the National Institutes of Health, he cautioned both administrators and scientists about the enforcement of sanctimonious ethical principles in the practical implementation of genomics; discouraging the slightest elements of eugenics in the existing guidelines and protocol of conducting genomic research nationwide and internationally [3,4]. Currently even the comprehensive data on human genome are completely declassified and placed under public domain.

Recent trends

After the successful completion of the human genome sequencing project by March 2003, the International Human Genome Sequencing Consortium (IHGSC), and many organizations continue to publicize the impact of this global scientific breakthrough. In fact, genomics has created the momentum which could revolutionize the twenty-first century as the era of biological pre-eminence. The predictions are that everyone will be affected by the spin-off benefits of technologies associated with genomics. Besides, when on-going research and biotechnology developments are fully implemented, the current medical practice will become obsolete. Understanding of human genetics and genomic profile will create the foundation for intense research in innovative medicine, agriculture and the various biologic sub-disciplines which could illuminate the inner workings of the entire biological systems. Genomic researchers [5] admit that sequencing the human genome was a pioneering venture with risks and uncertainties. Researchers at the Wellcome Trust, remarked that the enormity of the Human Genome Project is unprecedented in biology and he praised the international vision and collaboration of the scientists who were involved in this global scientific breakthrough [6].

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An obvious benefit of the human genome project is bound to be a better understanding of human evolutionary history. By applying recent molecular tools scientists can now study polymorphic markers on different chromosomes to clarify the degree of similarity or differences between African populations, a process that will have profound implications for Blacks in the Western hemisphere whose ancestors are the survivors of forced migration out of African nations.

In the G-8 nations, the practical value-added impact of genomics are being realized in agriculture, forensics, identification science, microbial ecology, toxic waste management, and the mysteries of evolution, anthropology, sociology, and human migration patterns. The prediction by the international scientific community is that genomics and biotechnology will have profound impact on engineering, computer science, mathematics, ethics, religion, law, agriculture education, pharmaceuticals, instrumentation, nuclear medicine, forensic science, bioremediation, bio-fuels, and journalism.

As the enthusiasm about genomics surged, the promise of this unprecedented scientific feat was that everyone regardless of race, citizenship, national origin would reap the benefits of genomics and the multifarious applications. There would be increased life expectancy, low infant mortality rate, remunerative career prospects for young graduates and improved health status for newborns and their mothers. The trepidations in the developing nations are many and varied: they have echoed lack of scientific infrastructures to harness the benefits of research derived from genomics, they also confront the challenges of insufficient financial capital to establish viable comprehensive genomic sequencing centers and inadequately trained workforce to conduct rigorous and meaningful research in medicine, agriculture, plant genomics, bio-processing and other value added economic outcomes associated with genomics.

In view of these imminent challenges, the project described here was designed to:

- Assess the quality of life indices in the developing nations
- Assess the challenges involved in establishing genomic center in selected developing nations (Brazil and China)
- Analyze the potential medical and public health benefits associated in developing nations and
- Predict the potential economic benefits associated with research derived from genomics

The Biotech Industry within the last 5 years has seen a significant influx of capital into their firms due to their cutting edge technologies, the mapping of the human genome and a wave of new biologic drug products approvals by the FDA. This influx of capital, which has come from venture capitalists, private investors, off -balance sheet financial arrangements, convertible debt instruments, alliance revenue and product sales, has changed the Biotech business model.

The large and mid -sized biotech companies, have gone from reliance on large pharmaceutical partners for up front fees, milestone payments, and moderate royalties in funding their R&E endeavors (Platform Based of Tool Based Model), to a model whereby they can independently fund their own R&E activities and directly market their products, or enter into more lucrative co development and co promotion agreements with their large pharmaceutical partners (Composite Business Model). This new model has enabled a number of large and mid- sized biotech firms to significantly retain more of the fruits of their labor (i.e. profits and earnings). This is evidenced by the fact that in 1999, 55% of publicly traded biotech companies had less than two years worth of cash, and 35% had less than one year. As of 2001, 54% of biotech's had at least three years of cash and 42% had more than five years for funding their research activities. This financial strength presents an enormous challenge.

Biotech firms now need to put the money to work by continuing to effectively get products into the marketplace and get shareholders a return on investment. It also means they must advance existing projects in clinical trials, expand their R&E infrastructures, negotiate collaborations which retain maximum downstream value and possibly acquire other technologies or companies. Examples of biotech companies already making strides in these areas over the past couple of years are, Amgen in its acquisition of Immunex for $16 billion dollars, Millennium's acquisition of COR Therapeutics for $1.5 billion dollars, Medimmune's acquisition of Aviron, Elan's acquisition of Dura for $1.8 billion dollars, collaborations such as Imclone and Bristol Myers for $2 billion dollars, Cura Gen and Bayer for $1.5 billion dollars, Vertex and Novartis for $800 million dollars, Millennium and Bayer for $465 million dollars, Millennium and Aventis for $450 million dollars, and Millennium and Abbott Labs for $250 million dollars. This activity has allowed the large and mid size biotech companies to begin achieving their goal of becoming vertically integrated stand alone drug companies. Conversely, smaller biotechs with products still in early stages of development and who have not reached profitability must still rely on outside sources for capital (i.e.. Platform or Tool Based Business Model) such sources being large pharmaceutical or biotech companies. This has raised speculation that over the next few years there could be an increased M&A activity, not Pharma and Bio but Bio and Bio as biotech companies strive to acquire critical mass for achieving drug development independence. From a financial standpoint, Standard and Poor's expects industry wide revenue for public firms to increase from 25 billion in 2001 to 31 billion in 2002 with aggregate earnings to grow at approximately 24% a year. These revenues are currently fairly concentrated; estimates are that the six largest biotech drug developers in terms of sales (Amgen, Biogen, Chiron, Genentech, Genzyme and Immunex) will account for approximately two fifths of industry revenue. This revenue base will become more diversified as additional smaller firms grow their product portfolios (60 biotech companies report a profit for 2001 according to Ernst and Young's annual published revue of the Biotech industry "Focus on Fundamentals"). With this expected growth, come important income tax considerations. Some biotechs are deferring the reporting of their alliance revenues, other biotechs are using off balance sheet R&E financing vehicles to attract investment into their firms, while still other biotechs are looking to place their intangibles offshore. These activities will need to be monitored for compliance in the future [Easter, personal communication].

Developed and developing nations

Using economic indicators such as Gross National Product (GNP), life expectancy, low infant mortality rate, existing technologies, and nations of the world are characterized into developed, developing and least-developed countries. The most affluent nations are at the center of the global economy. Predominantly, they are responsible for promoting international trade and financing complex developmental projects in many of the least developing nations. These developmental indicators have been copiously discussed by Ebomoyi and Ebomoyi [7] and

Wright et al. [8] The percentage of their agricultural workforce is low, but through mechanized agriculture can feed their teeming population. Those nations currently described as the G8 include Canada, France, Germany, Italy, Japan, Russia, United Kingdom and the United States. Although their GNP is quite high, there are other nations (Norway, $87,070, Luxembourg $84,890, Channel Islands $68,640, Switzerland $65,330, Denmark $59,130, Sweden $50,940, Netherlands and Ireland $49,590) have higher GNP than that of the United States of $47,580 which is highest among the G8 nations [Figure1].

The developing nations

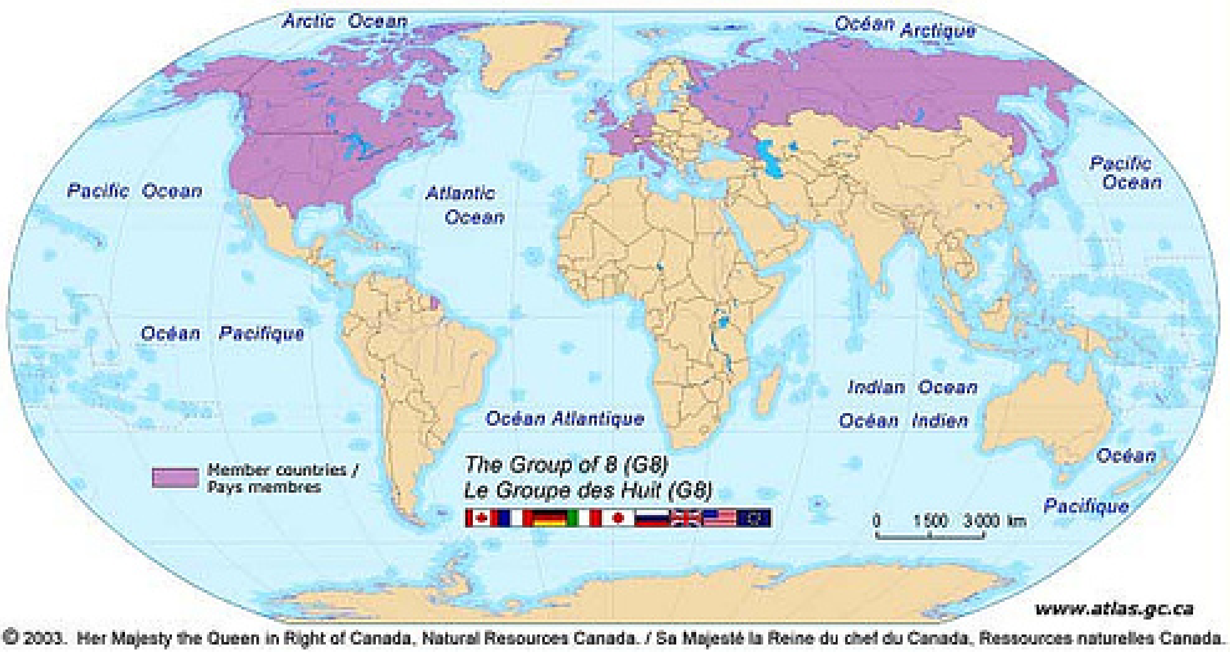
A list of developing nations are summarized in Table 1. These nations have demonstrated steady economic growth in terms of the Gross Domestic Products (GDP) life expectancy, and literacy level and ability to reduce their infant mortality rates. Table 1 presents the G20 nations which consist of the leading developing countries as China, Russia, Brazil, Mexico, Turkey, India, Poland, Ukraine and South Africa and their quality of life indices.

As a result of inadequate economic growth in many of the developing nations, the funding of science and technological projects is usually accorded low priority. Owing to the comparatively low literacy level particularly among the females, the scientific workforce is not comprehensive enough to undertaken a gigantic scientific project such as the human genome sequencing. The effective coordination of multidimensional federal science institutes, the universities, the commercial and start-up enterprises are just being meticulously designed and implemented in many progressive developing nations such as Brazil, China, India, Cuba and a few other developing nations.

Quality of life indicators

The Physical Quality of Life Index (PQLI) recommended by M.D. Morris [6] of the Overseas Development Council which includes life expectancy infant mortality and adult literacy rate are summarized in Table 1. The G20 nations consist of the G8 and other emerging nations such as Brazil , China, India, Indonesia, Mexico, Saudi Arabia, South Africa, South Korea and Turkey. Characteristically low infant mortality rate, but higher life expectancy and literacy rate are obvious in the G8 compared to the developing nations. The electricity consumed is by far higher in the G8 than in the developing nations (Table 1) Energy consumption, literate workforce, human capital and cutting edge technologies are invaluable in establishing viable human genome sequencing centers. Therefore Brazil, China and India have become very committed in developing viable technological infrastructure to implement genomic programs.

Out of the twenty comprehensive worldwide human genome sequencing centers, the only laboratory from any of the developing nations is the Beijing Genomics Institute/Human Genome Center, Institute of Genetics, Chinese Academy of Science, Beijing, China. The HGSC located in United States were 13 (65%), and one in United Kingdom. The Wellcome Trust, Sanger Institute, the Wellcome Trust Genome Campus Hinxton, Cambridgeshire UK. Another sophisticated Laboratory is the Riken Genomic Science Center



G8 Nations	Developing Nations	Least-Developing Nations
Canada – Joined in 1976	Argentina,	Selected LDNs
France United States	Brazil, Cuba	Angola, Bangladesh, Benin, Burkina Faso Niger, Cambodia, Gambia, Guinea, Haiti
Germany	China	Senegal, Lesotho, Madagascar, Malawi
Great Britain	South Africa	Nepal, Rwanda, Senegal, Sierra Leone
Italy	India,	Chad, Togo, Uganda
Japan and Russia joined in1998.	Turkey	Solomon Island, Ivory Coast Zambia,
Russia – Formal member in 1998		
United States		

Figure 1: The Medical, Public Health and Economic Implications of Genomics in the Developing Nations.

Yokohama, Japan and the Department of Molecular Biology Kelo University School of Medicine, Tokyo Japan. From List 1, there are two centers located in Germany. Although the global sequencing centre is no longer in operation, in genomic community we realize, networking and mentoring of fellow scientists and collaboration with scientific colleagues continue to occur. To avoid complete brain drain, Diaspora scientists are provided the requisite incentives to return to their birthplaces to provide succinct scientific contribution to augment the technological development of their countries.

Challenges in establishing genomic centers

The opportunities for scientific advancement have never been so great as in this era of human genome project. Phenomena progress could be made in human health and primary prevention as scientists can now identify medical genomic, epidemiologic, anthropological and socio-economic indicators from several regions of the world which could serve as indicators for enhanced longevity and graceful living. However, establishing viable genomic centers which are sacrosanct to growth and development involves daunting challenges.

The prominent challenges confronting developing nations in establishing viable world-class genomic centers are lack of well articulated, time-tested policies on science, inadequate funding of national science initiatives and inability to objectively assess national science projects at federal level among others. The technological infrastructure for biotechnology and genomic research while adequate, specific cutting edge and sensitive technologies do not exist. The ability of administrators to convert ideas into new products suitable for commercialization so as to create gainful employment and profit yielding enterprises have not been competently fine-tuned. The G8 nations are experts in developing new ideas and systematically commercializing them. There are numerous economically affluent philanthropic organizations in the G8 nations willing to undertake viable scientific projects being cognizant of the risks and potential benefits associated with innovative ventures such as genomics. The Wellcome Trust and the Bill Gates Foundation are among such private non-profit organizations

In the same vein, in the G8 nations, there are world-renowned academic institutions, industries, venture capitalists and start-up companies that commit their resources to fund biotechnological and genomic projects so as to enhance the status of human health. In the developing nations, counterparts of similar private funding sources are at best committed but with limited resources. There is the problem of inertia and lag time to build biotechnological facilities, equip such centers, and employ competent interdisciplinary team that is endowed with talents. Leaders must motivate them to appreciate tolerance and they must be inspired to enable the center to evolve. A synopsis of the multidimensional linkage in the implementation of genomics and related biotechnology initiatives is illustrated in Figure 2.

List 1- The international human genome sequencing consortium

1. Whitehead Institute/MIT Center for Genome Research, Cambridge, Mass., U.S.
2. The Wellcome Trust Sanger Institute, The Wellcome Trust Genome Campus, Hinxton, Cambridgeshire, U.K.
3. Washington University School of Medicine Genome Sequencing Center, St. Louis, Mo., U.S.
4. U. S. Department of Energy Joint Genome Institute, Walnut Creek, Calif., U.S..
5. Baylor College of Medicine Human Genome Sequencing Center, Department of Molecular and Human Genetics, Houston, Tex., U.S.
6. RIKEN Genomic Sciences Center, Yokohama, Japan
7. Genoscope and CNRS UMR-8030, Evry, France

Country	Per Capital GDP	GNP	IMR (per 1000)	Life Expentancy (M/F)	Literacy Rate (%)	Electricity Consumed (bil. kwh)
Austria	$39,200.00	321.8 bil	4.1	75.8/81.7	100	58.4
Brazil	$2,710.00	2.0 tril	23.3	68.2/75.5	90.5	411.7
Canada	$39,100.00	1.3 tril	5.1	78.7/83.8	99.0	594.6
China	$6,000.00	8.0 tril	21.2	71.4/78.2	93.3	2717.5
France	$33,200.00	2.1 tril	3.4	77.7/84.2	99.0	542.4
Germany	$35,400.00	2.9 tril	4.0	76.1/82.3	99.0	594.6
India	$2,900.00	3.3 tril	32.3	66.9/71.9	66.0	703.3
Indonesia	$3,900.00	914.6 bil	31.0	68.0/73.1	91.4	125.7
Italy	$31,300.00	1.8 tril	5.6	77.1/83.2	98.9	291.2
Japan	$34,000.00	4.3 tril	2.8	78.7/85.6	99.0	1032.7
Mexico	$14,200.00	1.6 tril	19.0	73.0/78.8	92.4	236.4
Russia	$16,100.00	2.3 tril	10.8	59.2/73.1	99.5	940.6
Saudi Arabia	$20,500.00	576.5 bil	11.9	74.0/78.2	85.0	189.0
South Africa	$10,000.00	491.0 bil	45.1	49.8/48.1	88.0	227.7
South Korea	$27,600.00	1.3 tril	4.3	75.3/82.2	97.9	379.7
Turkey	$11,900.00	902.7 bil	37.0	70.7/75.7	88.7	167.9
Great Britian	$36,500.00	2.2 tril	4.9	76.4/81.5	99.0	372.0
USA	$46,900.00	14.3 tril	6.3	75.3/81.7	99.0	4071.3
European Union*						
Source: World Almanac and United Nations 2010						

Table 1: The G20 Nations and their Quality Indices.

8. GTC Sequencing Center, Genome Therapeutics Corporation, Waltham, Mass., U.S.
9. Department of Genome Analysis, Institute of Molecular Biotechnology, Jena, Germany
10. Beijing Genomics Institute/Human Genome Center, Institute of Genetics, Chinese Academy of Sciences, Beijing, China
11. Multimegabase Sequencing Center, The Institute for Systems Biology, Seattle, Wash., U.S.
12. Stanford Genome Technology Center, Stanford, Calif., U.S.
13. Stanford Human Genome Center and Department of Genetics, Stanford University School of Medicine, Stanford, Calif., U.S.
14. University of Washington Genome Center, Seattle, Wash., U.S.
15. Department of Molecular Biology, Keio University School of Medicine, Tokyo, Japan
16. University of Texas Southwestern Medical Center at Dallas, Dallas, Texas, U.S.*
17. University of Oklahoma's Advanced Center for Genome Technology, Dept. of Chemistry and Biochemistry, University of Oklahoma, Norman, Okla., U.S.
18. Max Planck Institute for Molecular Genetics, Berlin, Germany
19. Cold Spring Harbor Laboratory, Lita Annenberg Hazen Genome Center, Cold Spring Harbor, N.Y., U.S.
20. GBF - German Research Centre for Biotechnology, Braunschweig, Germany

The theoretic construct of diffusion of innovation

The theory of innovation was originally developed by Rogers [9]. The innovation research was conceptualized by Everett M. Rogers as the diffusion of innovation. This construct involves the Bell-shaped curve and the various adopter categories. The diffusion theory provides succinct explanation for the diffusion of innovations in populations. Genomics applications are innovations that have not been made ubiquitous in United States and even highly educated scientists are still skeptical about the successful applications of genomics to improve the economic benefits people worldwide.. Rogers [9] efficiently categorized adopters based on when they adopt innovations. They consist of innovators, early adopters, early or late majority and the laggards. The rate at which they assimilate innovations was depicted by the perfect bell-shaped curved with -4standard deviation to +4standard deviation.

Innovators are the first to adopt an innovation. The G-8 nations having well-established technological infrastructure and the workforce to harness the economic benefits of genomics are the innovators. The second group consists of the early adopters. This group is very interested in innovations, but they do not want to be the first involved. This category is where we find very progressive developing nations that have appreciated the benefits of genomics and have invested their resources to translate both theories and intellectual vision into practical realities. Early adopters are respected by others in the social system and perceived as opinion leaders. The next group is the early majority. This cohort of nations include those in many of the developing nations who are interest in genomics but do not have the financial capital and the competent workforce to participate in genomic research ventures. They may be interested in innovation but will need external motivation to get involved in innovative activities. The Late majorities are comprised of nations that have the resources but are very skeptical and will not adopt an innovation until other nations have tried and possibly succeeded in innovative activities. The last group is characterized as the laggards. The Laggards are usually the last people to get involved

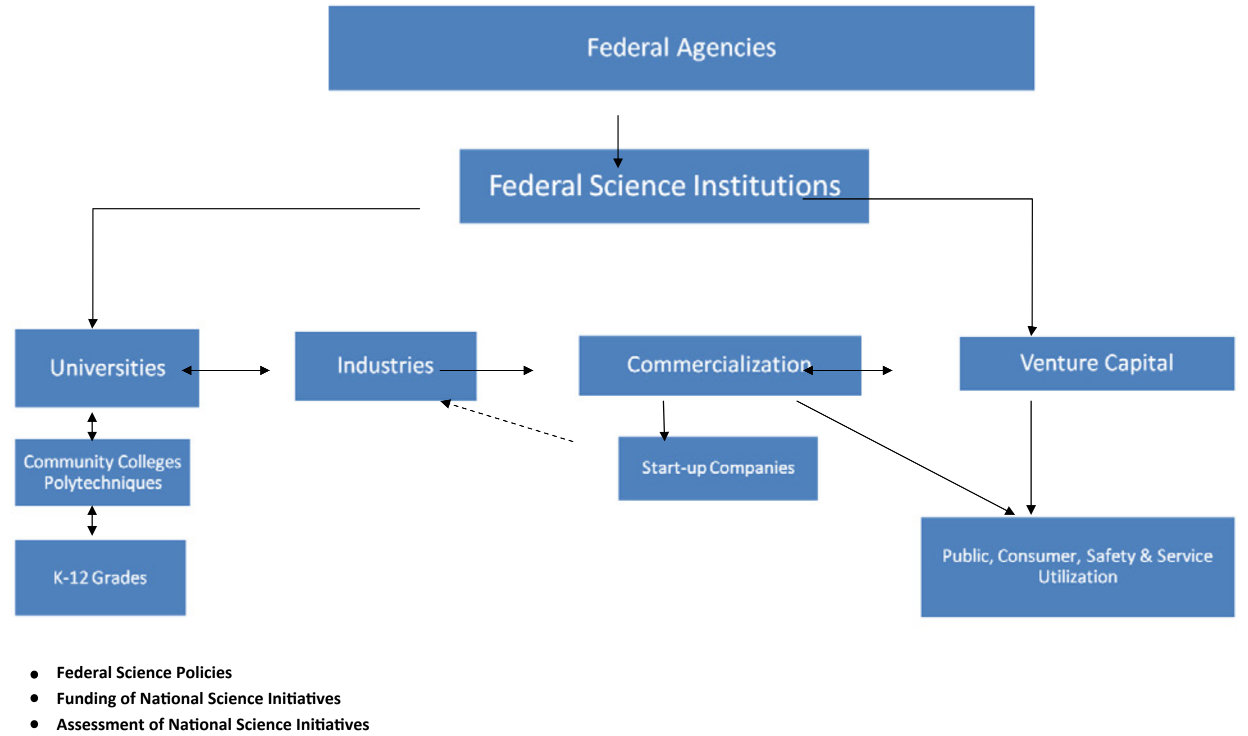


Figure 2:

in any innovation. In this model, most of the least-developing nations may never get involved in genomics; they lack the resources and the motivation even if they ever get involved at all.

Practical applications

The major outcomes of the innovative and genomic technologies in creating economic opportunities in United States has begun, but quite slowly. Advances in genomic technologies have led to increased life expectancies, resulting in annual net gains of over $2.4trillion in United States economy. Scientific research report have confirmed how new bio-agriculture technologies have created the potential to reduce hunger around the world, through genomic interventions which continue to increase crop-yields by up to 25% and reducing reliance on herbicide and pesticides, which is conducive for improved health status and good for the environment.

Genomics, and bioinformatics continue to create more energy-efficient and educational technologies and applications to improve the way we learn. The National Science Foundation (NSF) predicts that market for nanotechnology products and services will reach over $1 trillion by 2015 in the United States NSF expert committee has also predicted nanotechnology will create economic impact which is similar to the significant breakthrough as antibiotics. Knowledge development and commercialization of genomic technologies to the developing nations have become the drivers of economic growth in the United States. Genomic science and technologies will promote innovations, support entrepreneurs, improve infrastructure and empower most people in United States Genomic sciences and technologies will create increased market opportunities for those who breed knockout mice, that is transgenic mice which are crucial in conducting various scientific experiments The other potential economic benefits associated with genomics and the associated genomic technologies are the utilization of genomics in bio-archaeology, anthropology, evolution and human migration by studying evolution through germ line mutation in lineages [10].

Creativity in adaptation of Innovative theories- The Brazilian experience

The collaborative research efforts of Rafael Tello, Ana Luiza, Larade Araujo et al. [10] demonstrated the application of innovative theory in the development of technological capabilities in a typical developing nation. At inception, the team not only had mutual understanding engendered by trust, confidence and common vision about the relevance of organizational relevance of structure in collaborative innovative network, but applied the concept of innovation to accomplish their genolyptus project. For the first time in Brazil, this team could involve twelve companies and seven major universities and government agencies in Brazil to discover, sequence, map, and determine the functions of the genes with economic benefits from Eucalyptus. As an original initiative in the agricultural sector which involves keen competition in Brazil, the team was extremely meticulous in translating theoretical innovations into practical economic realities [11].

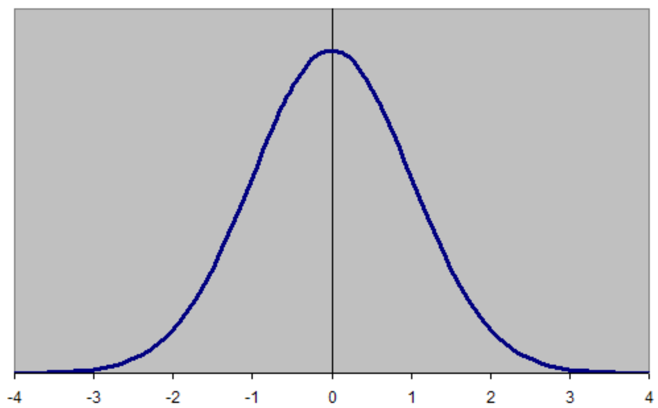


Figure 3: The Innovation Diffusion Model.

Although an in-depth analysis of integrating genomics into Eucalyptus breeding is beyond the scope of this project, it must be stated that interaction among the key agents for innovation is the bedrock for success. In network literature, special importance must be accorded to learning, interaction with colleagues, sharing of knowledge carried out in an atmosphere of mutual trust and collective vision.

The project also revealed the singular importance of innovation with the potential to enhance entrepreneurship, the connections between technology and market dynamics, capacity to change techniques of doing things in companies, and the clarity of thought created between structural and institutional linkages in organizations. Effective communication must reinforce the element of social capital which was defined as a valuable concept for understanding the emerging growth potential and operation of network connection. Also, trust is unique as a fundamental asset built from experience, accumulated by service agents during a process of mutual confidence.

This innovative process which was accomplished through the collaborative initiative of scientists has elevated the status Brazil to that of a world leader and top exporter of short-fiber cellulose. Besides, it currently has the largest forest productivity as a result of genomic science [11].

The brazilian and chinese experiences

Brazil with a population of 201,103,330 people has become the leading industrial power in Latin America. The agriculture output has soared just as its economy has become one of the largest in the world. Brazil information technologies and associated enterprises have attracted ventures capitalists from both domestic and foreign entrepreneurs. As reported by Global Services [11], CapGemini's, a Paris based company has announced its intent to invest $298 million in Brazilian IT services provider. CapGemini is not only visionary but has become involved in Brazilian IT services before its global competitors. This exemplifies the Brazilian company's financial outlook for the Latin American market for outsourced services. The Forrester researcher predicts IT venture is expected to grow 12 percent in 2010 to $8 billion. This fund can augment the $19 billion that local companies are expected to spend on IT consulting initiatives [12].

Based on the existing Brazilian workforce of 250,000 IT professionals, 23,000 annual IT graduates, scientists, and infrastructural capabilities to establish genomic centers could become an achievable project. Generous investments in IT infrastructure have enabled Brazilians to perfect the use of communication technology, wireless graphic high speed computer, voice over IP digital media high speed computers, health informatics (NRC) E-commerce, E-health global health high speed computers. The other IT associated technologies are photonics high speed computers, population high speed computers software engineering bioprocessing, medical photonics, computational biochemistry and bionanotech high speed computers. As a result of aggressive investment in Biotechnology, Brazil currently leads the world in biofuels and prevention of citrus diseases [13].

The increased funding in Research and Development in Brazil has facilitated the nation's global leadership in bio-fuel technology. The lesson gleaned for other developing nations is the involvement of political leaders in innovative scientific projects. Since 2003, funding for science has increased tremendously from 1.26 to 1.56 percent of the gross domestic product with US$400 million allotted to science and technology, specifically the development of technology training center, scientific museums and science journalism. The perceived challenges include difficulty in judicious assessment of scientific impact, excessive bureaucracy, fragile infrastructure and the replacement of seasoned retirees [14].

Recently, the Brazilian consortium unveiled a multi-billion-dollar initiative to advance the nation to the status of a global leader in biotechnology. The forum on biotechnology consists of government agencies, the private sector and the academic institutions. The investment of US$530 million has been earmarked for health-related biotechnology, drug and vaccine production for neglected diseases and research on genomics, proteomics, nano-technology and stem-cell research activities. With these funds judiciously utilized, Brazil is expected to be among the most progressive developing nations in public health, agriculture, horticulture and industrial biotechnology [14].

Progress in Latin America

The increased application of polymerase chain reaction (PCR) test has improved the diagnosis of Leishmaniasis and dengue fever which are endemic in many Latin American nations. According to the research findings of Eva Harris of the sustainable science Institute at San Francisco, California, the technology when applied in Nicaragua, Ecuador and Guatemala, PCR and nonradioactive DNA probes are more rapid, sensitive, specific, safe and inexpensive compared to the arduous detection of pathogenic organisms [14]. Many innovative genome-associated techniques such as PCR, microarrays, bioinformatics, pharmacogenomics, functional genomics, high precision liquid chromatography and capillary analysis do not involve the genetic modification of organisms [14].

Chinese Experience

China with a population of 1,330,141,295 people is the largest in the world. The poly-ethnic groups, diversified, and complex economic growth have endowed China with a GDP of $8.7 trillion and as per capital GDP of $6,600. Today, China's current investment in innovative technology has enabled the nation to establish viable infrastructure for national genome sequencing institutes for over three decades [15].

Beijing genomic institute (BGI)

The BGI is China's world class primier research scientific institute. As a superior public research center, it is committed to excellence in genomic science. The predominant fields of excellence include bioinformatics, genome dynamics, and genotyping. BGI's being the largest and most equipped genomic center in China and the center has achieved significant reputation for its scientific breakthrough as the only developing nation to participate in the sequencing task of the IHGSC. In fact the BGI sequenced 1 percent.

Professor Songgang Li is among the scientists who established the large-scale sequencing and high performance computing platform in the institute [16]. The BGI innovative scientists have invaluable experience in large-scale genome projects involving rice, silkworm, pig and chicken. BGI is also an external collaborator of the Human cancer Genome project and the centre plans to participate in high throughput sequencing-based microbial profiling. They are challenged to conduct 260 full analyses involving 40 million short sequences [14]. As the most populous nation in the world, food security was paramount in its scientific innovations. Therefore, BGI participated in the International Rice Genome Project led by Japan [16,17].

Progress in china

The International Rice Genome Sequencing Project (IRGSP) is a consortium of publically funded scientific laboratories which was established in 1997 to provide high quality, map-based sequence of rice genome by applying the cultivar Nippon base of Orryza sativa ssp. japonica. The ten member nations involved in this project are United States, Japan, China, Taiwan, Korea, India, Thailand, France, Brazil, and United Kingdom. The IRGSP used the clone-by-clone shotgun sequencing technique so that each sequenced clone can be associated with a specific position on the genetic map. This facilitated the process of adherence to the policy of spontaneous release of the sequence data to public domain. With this project completed by December 2004, the Chinese Academy of Sciences (CAS), and the Shanghai local government have been focusing on the sequencing of the rice genome and many other organisms since 1998. In fact, the NCGR has been involved and works painstakingly on the chromosome 4 sequencing in close collaboration with the IRGSP members [17].

China's regenerative medicine

China recently emerged as the stem cell research proponent poised to commit its funding on this thematic unit in genomics. The nation is committed to investing in stem cell research so as to provide clinical therapies to patients with chronic and degenerative diseases worldwide. Currently 47 researchers from academia, hospitals, research institutes, and venture capitalists are collaborating in the development of regenerative medicine [17] Just as in Brazil, China in eliminating the barriers among federal science institutions, commercial companies, universities and start-up companies have been able to implement many viable genomic projects such as sequencing the rice genome and other projects.

Although we have exemplified the involvement of two developing nations in biotechnological innovations, there other progressive nations as India, Cuba, and South Africa who are currently pursuing competitive investment in the sciences. Fragile infrastructures can be an impediment. For example in Bangalore, India, there are twin giants of IT industry namely, Infosys and Wipro Limited. The other high-tech companies in India are the Siemens, General Electric and Hewlett Package and the Tata consultancy companies [17,18]

In the view of Dr B. Joseph White former president of the University of Illinois, cyber-infrastructure is the digital age equivalent of the interstate highway. Just as the network of high-speed roadways accelerates communication and commerce, cyber-infrastructure accelerates innovations and discovery. Computation has augmented observation and experimentation as an integral component of the scientific process and added modeling and simulation to the scientific arsenal. Comprehensive application of modeling and simulation range from the mechanisms underlying how the body functions at the molecular level to how the universe evolved in the moments after the Big Bang to how atmospheric forces create deadly storms [19].

Human genome sequencing

At present, existing molecular data indicate less than 25 percent of the DNA are in the genome. The remaining portion is characterized as "Junk". The function of this "nonsense" component is at this time unknown. With the existing technology, the whole genome cannot be sequenced at once, therefore with the shot gun technique; medical technicians break the genome into pieces, sequence the pieces and then reassemble them into proper order to complete the entire genome. This clone by clone approach involves breaking the genome up into large clones about 150,000base pair (bp). Genome mapping techniques are used to sort out the location in the genome that the clone belongs [20]

By 2007, complete genome sequencing had been mapped for several different species consisting of 400bacterial, 30 archaea, 20 protists, 6plants and 20 animals. Today, modern genome sequencing utilizes the technique called whole genome shotgun sequencing. This process involves isolation of the DNA from the entire genome shared into smaller (e.g. 2000 base pairs) and large (50,000bp) fragments and cloned into vectors. The insert is sequenced at both ends. This technique is known as the double-barrel shot gun sequencing. The sequencing of both end is a relatively new development and it facilitates the spacing of alignment since the spacing of the particular DNA is about the same [20,21]. The HGP which began in 1990 was a 13 years project of NIH and the U.S Department of Energy. From inception, there were seven major goals which were to:

- Obtain a genetic linkage map of the human genome
- Obtain a physical map of the human genome
- Obtain the DNA sequence of the entire genome
- Develop technology for the management of human genome information
- Analyze the genome of other model organisms
- Develop programs focusing on understanding and addressing the ethical, legal, social implications
- Assess the results emanating from HGP and
- Develop technological advances in genetic methodologies [21, 22].

Although the essential goals advocated for HGS have been achieved, the information derived from sequencing, and the promise that genomics could revolutionize the diagnosis of diseases, prevention and treatment of single-gene and complex diseases have not been completely realized. For example, sickle cell diseases, neurofibromatosis Bruguda disease and hemophilia do not at present have any known cure [23].

However, epidemiologists, and physicians are now better able to assess the precursors of many diseases and recommend unique and appropriate treatment for patients. There are many invasive and non-invasive technologies that will enable the physicians and other medical scientists to visualize and screen the body of their patients and advise them about pre-symptomatic testing of many diseases. The problematic ethical, legal and social implications are exposing patients to the presence of diseases without cures. The diagnosis of such single gene diseases can create unnecessary stress for the patient.

In the United States and other G-8 nations, comprehensive genomic and biotechnology centers are being established with myriad thematic programs. These genomic institutes involve colossal sum of money, scientific workforce, human capital management and legal experts. In anticipation of genomic revolution some of the comprehensive full-fledged universities in the G-8 nations established genomic institutes with well-furnished thematic research centers. Currently such research establishments exist at the University of California, Harvard University, Massachusetts Institute of Technology, and the University of Illinois, at Chicago and Urbana-Champaign, University of Chicago, and University of Connecticut, USA among others.

Prototypes of thematic research area

Although many developing nations are poised to establish biotechnological centers with comprehensive genomic research units, the themes which have been successfully developed in the G-8 nations include biomedical genomics; this component focuses on the enduring promise of genomics/proteomics to ameliorate the prediction, prevention, and treatment of their leading causes of death. To illustrate, in genome scientific community, so much progress in research has occurred in understanding the etiological agents and precursors of heart disease, cancer, cerebrovascular disease, with stroke being significantly being controlled, chronic lower respiratory disease, diabetes, over seven gene-chromosomes associated with diabetes have been sequenced, pneumonia, Alzheimer, kidney disease and septicemia [23].

Many academic institutions also focus on pharmaco-genomics, genomics of complex diseases, microbial pathogenesis, immune-genomics, stem cell genomics, structural genomics/proteomics and the bioethical , social and legal implications(University of Illinois , Institute of Genomic Biology [23,24].

The IGB [24] conducts rigorous interdisciplinary research on many thematic areas such as regenerative and tissue engineering genomic ecology and the ethical, social and legal implications of genomics. In regenerative and tissue engineering, the challenge involves the mechanism by which genomic information can lead to effective treatment for chronic conditions as diabetes, rheumatoid arthritis and osteoporosis. In one of the ecological units, researchers investigate the molecular bio-engineering of biomass conversion and the relevance of plant genomics on agriculture. Molecular scientists believe it could have relevance in creating added value in agricultural productivity and the use of food crops to combat malnutrition and the control of insect pests. The genomic ecology of global change deals with how changes in the networks of genes alter the ecosystem metabolism when challenged by such elements as greenhouse gases, atmospheric pressure, drought, and the interaction between insects, herbivores, and plant pathogens. The University of Illinois is the only institution in the world which has successfully established genomic center that investigates the interaction of effects of increased level of carbon dioxide and ozone with biotic and a biotic factors on plants under open-air conditions [24]. The economic and legal themes focus on the ELSI of genomics. At such centers, lawyers, economics and ethicists are employed tackle the issues of intellectual property protection, patients' rights and the mechanism of improving institutional linkage with industries, investors, start-up companies and the process of commercialization. This is a synopsis as other academic institutions in many G-8 nations have also established viable genomic thematic centers in their respective nations to meet the ecological, economic and political needs of their societies.

Human genome epidemiologic centers

This thematic area investigates the application of epidemiological methods and approaches in population-based studies assessing the impact of genetic variations and their haplotype characteristics on the onset and trajectory of diseases or longevity. Genomic epidemiology is the link uniting the intersection between genetic and molecular epidemiology. The adopted spectrum of cases is individual and group susceptibility to identifiable genetic-related diseases. For example, which environmental factors predispose Europeans and North Americans to Alzheimer's diseases? In South Sahara Africa, why are the alleles of sickle hemoglobinopathies most frequent in this region compared to other geographical parts of the world?

Medical informatics: A comprehensive genomic center must have the informatics units to focus on the investigation, invention and implementation of structures and algorithms to enhance communication, understand, explain, and manage innovative medical information. Also, this technology is applied to improve copious data in decision making and the manipulation of algorithms to collate essential biomedical data.

Neuroinformatics: in genomics investigates data structures and the use of software tools to analyze, model, and integrate and disseminate information in all areas of neuroscience, involving ontologies, modeling approaches, and meta-analysis of data-bases, computational simulation of models and the organization of complex data. Neuro-engineering methods include hardware, robotics, information and advanced theoretical studies (http://www.genomics glossaries, 2011).

Biotechnology and cyber-infrastructure

The United States National Center for Computational Sciences (NCSA) is the only center in the world to successfully manufacture the "Jaguar", a Cray X-15 super-computer which is the fastest in the world. Located at the US Department of Energy at Oak-Ridge Tennessee, this expensive hardware is used for conducting genome-related scientific investigations for mundane and uncharted field of "petascale" scientific supercomputing. The Jaguar cyber-infrastructure with over 355million combined processor hours has been applied by interdisciplinary research team to accomplish breakthrough scientific discoveries in climate science, chemistry, material science, nuclear energy, physics, bio-energy, astrophysics, geosciences, fusion, and combustion activities [25].

In view of the multi-dimensional applications of genomics; two renowned administrators, B. Joseph White [26] former president of the University of Illinois, and Dr. Elias A, Zerhouni [27] former director of the US National Institutes of Health, have emphatically recommended the importance of breaking down the barriers among the sciences. They also encouraged researchers to adopt interdisciplinary team effort because in the age of genomic science, multi-disciplinary strategy is the bedrock for studying the complex human, environmental, ecological and behavioral dimensions of human existence on this planet.

In spite of the enormous funding and the workforce required to establish full-fledge genomic centers, there are many developing nations poised to face this daunting biotechnological and scientific challenge. Although this uncharted territory involves some risks, according to Zerhouni [27] a more ominous risks is not to take any risk at all.

It is quite evident that the ten great public health achievements [28] were completely implemented in in the G-8 nations, but these initiatives were either partially implemented in some of the developing nations or completely eluded the least-developed nations. These achievements include immunizations, motor-vehicle safety, workplace safety, control of infectious diseases, safe and healthier babies, family planning, fluoridation of drinking water, and tobacco as a health hazard. In the geographically isolated villages of many the developing and least developed nations, portable water supply is very rare. In the same vein, the twenty great engineering achievements [29] of the twentieth century were only fully implemented in Europe and North America. These developments which were from scientific manufacturing of civilian infrastructure included electrification, automobile, airplane, water supply and distribution, electronics radio and television, agricultutural mechanization, computers, air conditioning and refrigeration, highway, spacecraft, internet, imaging, household appliances, health technologies, petroleum and petrochemical technologies laser technologies and high-performance materials. The intellectual merits of the various policies proposed by the secretary of State Mr. George C, Marshall [30] plan were translated into practical realties in emancipating Europe from the wanton destructive impact of the Second World War. Many of the affected nations, only sixty six years ago, are now among the enviable G-8 nations. In the 21st century, genomics could spur the wealth of nations if congenially implemented.

Potential Medical Implications

In developing nations

In many developing nations, the leading causes of death are the broad spectrum of parasitic diseases which complicate the provision of clinical care in addition to the chronic and degenerative diseases In fact in some of the developing areas, vast geographical areas are medically isolated. Consumers in these communities are dependent solely on traditional herbal remedies. Basic public health infrastructure such as water supplies, environmental sanitation facilities, electricity and well-paved roads to facilitate medical referral services either do not exist or create tortuous thoroughfare. As Brazil, China, and India continue to emerge as industrialized nations, efforts are being made to extend public health services to hitherto geographically isolated rural area. In fact among the undeveloped and developing nations, vast geographical areas are medically isolated. In the developing and undeveloped nations many people suffer parasitic infections, complications in reproductive health. The overall health status in these areas in inadequate. Diseases such as malaria, schistosomiasis, filariasis, trypanosomiasis, leishmaniasis, hookworm and guinea worm further complicate healthcare delivery in under-developed nations and malaria and schistosomiasis expose people to HIV infections in these societies. Lacks of basic health infrastructures, weak capacity building, corruption among government officials, and ignorance have created the proliferation of these diseases in epidemic proportions.

Scientifically, primary preventive measures such as provision of safe water supply, installation of an effective efficient sewage disposal and treatment system, could impede the prevalence of diseases such as amoebiasis and eliminate over 75 percent of the infectious diseases which plague people in developing nations. The human immunodeficiency disease also create major upsurge for infant death and emerging infectious diseases with alarming case fatality rate. Worldwide, genomics should be considered in all facets of public health. It is relevant in environmental health, infectious, chronic diseases, occupational health and mental health.

Public health implications

From scientific research studies, it has become self-evident that the public health benefits derived from genomics by the industrialized G-8 nations could be different from those anticipated for the developing nations. Besides the elimination of parasitic diseases, concerted efforts are required for a paradigm shift in reverting the culture of consanguinity, excessive fecundity, gender disparity, very high female literacy rate, and the high infant mortality rate in developing nations.

Consanguinity and endogamy are the precursors for the high prevalence of genetic diseases in the developing nations. Genomics has improved the ability of medical and clinical geneticist and pediatricians to promptly detect the onset of genetic diseases in the newborn. Many of the single gene diseases which follow the Mendelian pattern occur in epidemic proportions in the developing nations. Currently, in United Arab Emirate alone, 260 new genetic diseases were recently reported. The prevalence of sickle hemoglobinopathies and Down syndrome is double the global average at 21.4babies per 100,000 populations [31].

Genomics has enhanced the ability of most clinicians or gynecologists to quickly detect the onset of genetic diseases in the unborn fetus. Many of the single gene diseases which follow Medelian pattern of inheritance include sickle cell anemia, cystic fibrosis, hemochromatosis, hemophilia, neurofibromatosis, Duchene muscular dystrophy, Tay-Sachs disease, and phenylketonuria.

The complex genetic diseases are the congenital heart disease, neural tube defects, cleft lip/palate, and congenital primary hypothyroidism. The chromosomal aberrations include Down syndrome, fragile-x syndrome, klinefelter syndrome and trisomy13 among others. Although the technology for screening and detecting these diseases were developed quite a few years ago, the high precision liquid chromatography and hemoglobin electrophoresis are found to be quite effective. In the developing nations public health initiatives are required to focus on the control of genetic diseases through trait counseling and comprehensive health education of the public. However, it seems axiomatic that primary preventive techniques can reduce the very high infant mortality rate and low life expectancy which are the characteristics of underdevelopment. These genetic tests can be used to diagnose, and confirm genetic diseases, even before the symptoms of the disease begin to appear. DNA test can effectively predict or provide relevant information about the progression or prognosis of a disease. It can also predict the risk of future onset of specific diseases in apparently healthy individuals.

Economic implications

The prominent employment opportunities which could occur in the developing nations involve the recruitment of traditional healers, barefoot doctors and indigenous farmers, botanists and agronomists from local institutions and the new generation of trainable journalists in the science of precise genomic reporting with the intricate caveats. The services of the traditional healers will be invaluable in identification of plants with healing properties and the ecological biome, when, and where to harvest such plants. Botanists will be recruited to scientifically identify and classify such cash crops. Ayuvedic doctors will be required to identify the "material medica" of their practice and how physicians can collaborate with them to test the validity of their claim of authenticity through rigorous resting. New generation of journalists and health educators will be recruited and retrained to effectively educate the public about the benefits and limitations of genomics.

Although the US Department of Energy and NIH, have compiled myriad employment opportunities derived from genomics, many of the employment prospects might not be applicable in the technologically underdeveloped countries.

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