Symposium

Genetic Engineering and Life Sciences: Controlling Evolution

Graham T.T. Molitor*
Public Policy Forecasting, U.S.A.

Life sciences will become America's "economic mainspring" by 2100, then predominate well into the 22nd century. Biotech manipulation of plant, animals and eventually human beings will unleash divisive moral and ethical debates. "Blueprints of life" and a Brave New World create opportunities as well as problems. Cloning shakes the meaning of life to its very roots. Potentials for eradicating diseases, extending life expectancy, increasing food production, fashioning life-saving pharmaceuticals, enhancing resource recovery, resurrecting endangered species, and tapping "bio-factories" will prove too important to ignore.

The genetic revolution represents the "fourth" wave of advances in healthcare. The first major breakthrough occurred when it was established that natural forces, not supernatural ones, controlled health outcome. This led to recognition that contaminated water spread cholera which led, in turn, to public health and sanitation measures that suppressed devastating effects of infectious diseases. The second wave is attributed to anesthesia which made painless surgical intervention possible. The third wave, discovery of vaccines and antibiotics, enhanced pharmaceutical solutions.

Biometrics/Morphology

Older, Taller, Heavier, and Smarter Humans

People will be living longer: 100160 years; or, optionally, forever. They will grow taller, reaching 6 foot-2 inches by 3000. They will weigh more - 180-210 pounds by 3000. These changes, accelerated by bio-technologies, mean more "biomass" to feed, clothe, and care for.

* **Correspondence:** 9208 Wooden Bridge Road, Potomac, Maryland 20854, USA.
Email: gttmolitor@aol.com

Americans over 70 years of age will double in less than 30 years, rising from 24 million to 48 million, 1996-2030. By 2050 over 27 percent of all Americans will be age 65 or older. If, as in the case in trend-setting Netherlands, males retire at age 55, what will they do and how will they sustain themselves in retirement for up to 100 years or longer? "Ageism" is beginning to write new chapters in social codes.

Assumptions that population will stabilize are merely hopeful musings. Boosted by life sciences, population may reach 900 million in the US, and 30-60 billion worldwide by 3000.

Concerned about "burgeoning" population, there's a growing chorus of complaint about "crowding." Quick reference to cross-cultural comparisons recast that mindset. Comparing US population density of 75 persons per square mile (1996) to idyllic and luxurious Monaco's 40,812 inhabitants per square mile suggests the reality. There is plenty of capacity to accommodate vast increases in population. It's time to dash and set to rest the familiar age-old Malthusian complaint and Paul Ehrlich's contemporary hand wringing.

Increasing body size and mass already is influencing the tides of change. Increased girth and hip spread recently necessitated increased size standards for seating and furniture. The previous seating width standard of 18 inches has given way to 21-24 inches. The change-over is on-going. Ever wonder why those airplane seats feel to small? Think of reduced seating capacity in church pews, stadium seats, restaurant booths, and household furniture. Mattress loft and chair padding, along with supporting frames also have become heftier, comfier. Little-noticed though these changes may be to most, they highlight how groups, seemingly far removed from life sciences - manufacturers of furniture, office furnishings, stadium seating, church pews, as well as polyurethane and mohair suppliers, to mention a few - are all impacted.

Genomic Code - Human

Plotting the Genomic Code

The "holy grail" of life sciences involves decoding the human genome. Up to 90% of all genetic discoveries occurred within the past 30 years. The pace is increasing. These undertakings will begin to dominate US economic activity by 2100, then predominate well into the following century. Life sciences generically encompasses life-altering capabilities in its myriad forms. Far-reaching changes are poised to change the nature

of every living thing on planet Earth.

Plans for sequencing the human genome got underway in 1985, received National Research Council endorsement in 1988, and was formally launched by 1990. Government researchers projected completing mapping the human genome by 2005, 50 years after Watson and Crick elucidated the helical-shaped DNA structure.

On June 26, 2000 Celera Genomics and government researchers announced plotting a first draft of the blueprint of human life. Actually, the percent of genome letters identified amount to 97-99 percent of the total, and only 85 percent had been assembled in order.

One commentator compares the achievement to being confronted by a "data dump" far more difficult than deciphering Egyptian hieroglyphics without a Rosetta stone. Clearly, we have a long way to go. Filling in blanks, verifying and assembling correct assembly will require at least another two years time. Scientists estimate the total number of genes is most likely to total 66,000.

At least 96 percent of all gene functions remain unknown. Describing gene functions will require a minimum of 20 years, probably much longer. Bear in mind that it takes 10-15 years to get a new pharmaceutical product out of research, into animal and human testing and onto the market. Change is coming, but it won't be happening overnight.

Deciphering this first draft requires some concept of the enormous complexity involved. To begin with, the 24 human chromosomes, much too small to be seen by the unaided eye, each contain 3.12 billion molecular units (base pairs) that comprise the human genome. Immensity of these numbers hits home when one considers that simply reading this code would require 26 years non-stop! Another way of putting it is that the amount of data involved is equivalent to the contents of 200 telephone directories, each 500-pages long. Human life, of course, involves much more than a mere "cook book recipe." Great wisdom must be called up to answer life-giving, life-taking, or life-modifying questions.

Comprehending genetic patterns governing the 75 trillion constituent parts in the make-up of every human is an extraordinary undertaking. Making sense out of the Niagara of genetic information depends on bioinformatics and computer-inquiry programs that will take 50 years or more to fully develop. Answers will transform life and human activity as no other technological advance ever has.

RNA was discovered almost a century ago, in 1909. The double helix "staff of life," configured by Watson and Crick in 1953, was a pivotal

turning point in this genetic revolution. The double helix has come to symbolize the Life Sciences Era, just as the orbiting atom (or, more ominously, a mushroom cloud) symbolizes the Atomic Age. Complete synthesis of a gene was accomplished by 1970, followed one year later by transferring genetic material from one organism to another.

Creating, perfecting and directing forms of *animate* (organic) lifeforms as well as *inanimate* (inorganic) materials is at hand. Gene mapping provides biological blueprints for animate matter. Fathoming the "blueprints" of inanimate matter involving quantum particle physics holds for inanimate matter the equivalent promise of genomic codes. Mapping the nature of inanimate matter advanced rapidly following development of the periodic table of the chemical elements and its continuing elaboration. Scientists have discerned sub-atomic signatures or structures of 300 particles. They're still counting. Once understood, this new information will enable the manipulation of matter to perfect, create and design totally new and novel inorganic structures and materials. These twin developments mean that the two great "constructs" of our "apparent being" will be subject to conscious direction. One branch pertaining to "living" things, the other involving "non-living" things. Implications of these parallel developments stagger the imagination. The hand of the Creator has been exposed. Now the big question is whether humans can be responsible stewards of the basic secrets of the corporeal world which consists, fundamentally, of animate and inanimate matter. Spiritual dimensions are quite another matter. This host of questions also looms large on the future agenda.

Genomic Code - Plants and Animals

Genetic code of the first free-living organism was determined in 1995, the first whole animal (Caenorhabdits elegans, a worm) was plotted in 1998, and the initial draft of the human genome was accomplished in 2000. Genome code plotting by early-2001 was completed for 30 species. Most of them are bacteria, relatively simple constructs. In addition, another 100 are well along and nearing completion. Work proceeds apace to explicate genomes for a growing number of lifeforms. The mouse is the most studied human animal. It's importance is somewhat diminished by the fact that its genome is only 60 percent comparable to the human genome. Others can hardly wait for the principal test animal for drug studies - the rat - to have its genome laid out. Celera's J. Craig Ventner

insisted his company would complete the effort by December 2000. Federal government plans called for completing the job in three years.

Trump cards in profiling genomic codes of other animals include the great apes - chimpanzee, bonobo, and gorillas. The so-called "bio-medical imperative" here is attributable to the genetic match between great apes and humans which is 98.5-99% the same. Chimp anatomy is so similar to humans that veterinarians frequently use human medical textbooks to treat their patients.

Mapping the genomic codes entails the power to change the very form, structure, properties, and durability of living matter. Creation's schematics for lifeforms, translated by biotechnology and applied through genetic engineering, opens up almost unimaginable opportunities to control the evolution of plants, animals, and - eventually - human beings

Bio-inormatics (Iceland)

Genetic Profiling of Homogeneous Populations

Ascertaining genetic differences within homogeneous groups with lengthy and comprehensive medical histories vastly simplifies identification of genetic differences responsible for genetic diseases, defects or dysfunctions. One of the most promising examinations of gene profiling has been undertaken by a US company headquartered in Reykjavik, deCode Genetics. Iceland, a small country with a manageable 277,000 inhabitants is the target. This company paid the government $200 million to gain an exclusive 12-year license to "mine" genetic data in the country's careful and complete records. Icelandic stock, is derived almost exclusively from Norwegian and Celtic stock. The long, continuous, well documented, and homogeneous genealogy dates back to the ninth century AD. Well documented medical records date back a century or more. Life expectancy of 79 years ranks the nation fourth among all nations. Quality of life in the country is ranked ninth highest in the world, and per capita GNP at a comfortable $26,580 ranks eleventh in the world.

As genetic researchers delve into individual and family medical histories, protests involving invasion of privacy, breach of medical practitioner-patent confidentiality, and a host of other vexing problems arise. Privacy qualms in the Icelandic project are protected by elaborate cryptological coding, written consent is required for acquisition of sensitive data, breaching personal identities entails a two year prison sentence, and Data Protection Commission safeguards provide additional

protections. About 10 percent of the population were expected to decline participation, and by mid-2000 18,000 had opted out.

Proteomics

Plotting the Proteome

The next huge project involves identifying the human "proteome", the range of proteins encoded by DNA's genes. Complexity vastly exceeds that of the human genome. Genes are carriers, but proteins carry out bodily functions. The 80,000 -150,000 genes in the human genome are capable of churning out as many as one million proteins. So far, only 2,000 unique protein structures have been listed with the Protein Data Bank, the international structure depository.

DNA sequencing involves only four chemical markers, protein structures involve twenty different building blocks termed amino acids. To a large extent, a protein's shape determines its function, so techniques like x-ray crystallography, scanning tunneling microscopes, and other intricate probes will take many years to discern and elucidate the 3-D geometric patterns and possibilities.

Genetic Engineering/Eugencis

Implications Stemming from Life Science Advances

Life science benefits looming include an undeniable range of new capabilities. To begin with, keenly accurate diagnostics open up new arenas for life giving and quality of life improvements. Perhaps most beneficial - as well as most controversial - among these capabilities is the ability to discern genetic disease predisposition or affliction. Striking at fundamental root causes of diseases enables health care providers to treat causes, not merely deal with symptoms. New capabilities entail the ability toenhance life in ways that raise fears of creating a "super caste" and deepening traits that exacerbate rifts between haves and have-nots.

Power to custom-tailor pharmaceuticals to a specific individual, will reduce dosages, thereby further limiting side effects. Germline therapies will cure patients by altering their genetic makeup passed along to their progeny. Cutting off and preventing inheritable disease from being passed along is a giant stride toward potential elimination of untold human suffering. These miraculous new capabilities provide new understandings concerning the mysteries of life - human, animal, plant and microbial.

Genetic Diagnostics

Diagnostic Genetic Screening

Thumbnail-sized diagnostic probes with 500,000 to as many as one million micro-tubules - equivalent to an enormous mini-lab on a chip - have been designed to assay genetic indicators of disease and profile DNA. Affymetrix (Santa Clara, California) uses a glass plate etched by photlithographic techniques to embed hundreds of thousands of probes to analyze DNA or RNA molecules.

At least 400 different genetic tests had been devised by 1999. A torrent more are imminent. Biochip slides and films coupled to portable labs can identify limited numbers of genes within minutes or hours. DNA diagnostic chips with limited functions cost $10, more complex and comprehensive versions range from $90-2,500 (1999). Prices will decline with technique refinement and mass production.

Genetic Therapeutics

New Genetically-modified (GM) Drug Development

Pharmacogenomics that compares an individual's gene profile with optimal genetic makeup, enables formulating person-specific "designer drugs." New strains of drugs will displace the old. "Smart bomb" GM drugs reduce "shotgun overdosing" and its side effects. Individually-tailored prescription drugs and lesser quantities of them needed to achieve desired pharmacological effects, will help to reduce rising health care and insurance costs. Over 100 bio-engineered drugs were on the market by mid-1999, and over 450 more were in clinical trials. Over 5,000 genes are linked to hereditary medical problems.

Genetic tinkering to eradicate cystic fibrosis, Tay Sachs disease or sickle cell disease deserve support without the hassle and heated debate that accompanied drugs and vaccines that obliterated smallpox, tuberculosis or polio. The resounding positive note, is that virtual elimination of genetic disease and disorders is within grasp. Careful understanding is essential before making the leap. Trade-offs will not always be clear cut.

Genetic-based therapies, after several decades of research have only begun to enter the markets. Experts believe that widespread gene therapies are at least a decade away from widespread clinical use. One promising development for sedentary post-industrial nations where obesity and overweightedness is widespread involves genetic fix for regulating appetites. Several such genes have been identified and patented. Research

on GM antibodies to eliminate bacteria involved in tooth decay are underway. GM technologies that increased antibiotic resistance in bacteria 32,000-fold, hold promise for humans.

Another line of primary activities involves genetically engineering animals or plants, and turning them into "bio-factories" producing drugs recovered and purified from their milk, urine, blood or other organs. Genetically engineered potatoes have been developed that carry bio-spliced vaccines protecting against cholera and hepatitis B. So-called "pharm-foods" are a God-send in countries where unsterile conditions, lack of refrigeration to store vaccines, cultural opposition, and prohibitive costs discourage life-saving vaccinations. Genetically modified plants yield genes that control blood clotting (coagulation factor VIII). A genetically engineered potato carries a vaccine against Norwalk virus, a major cause of infectious diarrhea. Produced at 10% the cost of traditional medical therapies, GM replacements may prove less costly and many will prove safer.

Genetics - Restoration of Senses

Replacing body parts commenced over 7,000 years ago! Today, hundreds of body prosthesis - form tooth fillings to hearts transplants - have created part machine/part human cyborgs. Advanced mechanical counterparts have been around for many decades. These developments build on work already accomplished to bio-engineer various key components - vessels, valves, muscles, organs.

Nanotechnologies provide a "bridging" technology reliant upon electro-mechanical components that accomplish what genetic engineering eventually will accomplish. Science is well along the way in restoring, rejuvenating and restarting sense of sight, hearing, taste, motor skills, neurological functions, among others. Great progress has been made in restoring hearing for the deaf or hearing impaired, sight to the blind, speech to stroke victims, restored motion for paralyzed, regulating bladder control for the incontinent , and so on. Diminutive electro-mechanical devices, some as small as a grain of salt, interface with nerves and are directly patched into the Brain. These are not biotech fabrications of individual cells or body parts, but rather manufactured prosthesis derived, at least in part, from inorganic sources. Large, clunky, and embarrassingly evident prostheses fall far short of replacing original organs. Fly-speck-size nanotech devices are to small, compact, lightweight, as to be

virtually invisible and certainly less uncomfortable for users. Artificial body parts prompt pundits to raise concern about "cyborgs" - a melding of man and machine. Turning back is not a realistic option.

Plant and Animal Bio-factories

Bio-factories supplant/supplement field runs

Industrial applications also are proceeding apace. DuPont has coaxed bacteria to yield adipic acid (a constituent of nylon), teraphthalic acid (constituent of polyester) and spider silk. Obviously, output of a bacterium, even a vast army of them, isn't very big. Realizing that a spider's spinneret gland is anatomically similar to that of goat's teat (a protein-producing bio-factory itself), scientists implanted spider genes into female goats and extracted silk from their milk. Goats each produce the equivalent of 10, 000 spiders.

Bacterium, arachnids, mice or rats and the like may produce only minuscule yields or thimblefuls at most. Even choosing mammary output as the mode, limits choice to adult females. Genetically modifying the bio-factory to yield its valuable output from urine is not aesthetically pleasing. This route greatly increases potential yield since output comes from all ages, and both sexes. Furthermore, output is measured in buckets, not thimblefuls, or less. Far-fetched though this may sound, it is a fact that familiar pharmaceuticals such as premarin (estrogen) comes from horse urine.

Cosmetic Interventions

GM Cosmetics and Non-prescription Drugs

Accepting one's body "as is," has been giving way to cosmetic enhancement. Genetic enhancement transcending mere "surface" treatment is at hand. What cosmetics have done for "surface-effects," bio-engineers will be able to accomplish under the skin. Results, usually with permanent or very long-lasting effects will be revolutionary.

Bio-engineering to minimize - perhaps reverse - effects of aging, especially in nations where the numbers of elderly persons continue to swell, surely will be well received. "Body shops" acquire new meaning as an aging population seeks "body tune-ups" - resetting molecular clocks governing aging (telomeres thought to be regulated by an enzyme, telomerase); cloning or replacing body parts; "jump starting" senescent brains; "gas-

sing up" with genetically-engineered hormones; regenerating new cells and molecules; and reaming out tube-clogging plaque.

Gene researchers have succeeded in reactivating dormant hair follicles and successfully restoring hair - a potential boon to baldness or hair loss following chemotherapy. Other researchers are seeking genes controlling hair color. Some persons fret that genetic control of hair eventually may lead to masking racial origins by changing skin color. Carrying things much further, there is speculation that some individuals may change skin tint to fit their mood - blue or green, for example.

More difficult questions are posed by limiting health care funding to "worthy" cases. For example, should one genetically impaired patient costing millions of dollars to cure and sustain prevail? Alternatively, should funds be devoted to assist a far greater number of afflicted whose health problems could easily and inexpensively be treated? The fine line between therapeutic and cosmetic reconstruction poses questions of another sort.

Cloning - Humans

Life-extending Potentials

Cloning and organ transplants could usher in "immortality" of a sort for persons choosing that path. Routine cloning of body part replacements using one's own pluripotent (stem) cells is imminent. From this perspective, the fabled "fountain of youth," searched for in vain by Ponce de Leon, has resided within each of us right along!

Americans waiting for organs rose from 63,635 on June 2, 1999, to over 72,582 in October 2000. Median waiting time for US patients ranged from 962 days for kidneys (1995) to 207 days for a heart (1996). The number of US patients who died while awaiting an organ transplant exceeded 6,100 during 2000. The death rate (1997) ranged from 1.7 percent of those awaiting a pancreas (11 of 656 patients), to 15.2 percent of those awaiting heart-lungs (57 of 354 patients). And, it's costly. Organ transplant therapy is costly (1988): liver, $66,000-367,000; heart, $50,000-287,000; heart-lung, $135,000-250,000; pancreas, $51,000-135,000; and kidney, $25,000-130,000.

Later Resuscitation

Another approach for extending and possibly perpetuating lives involves cryogenically set asides and storage. Body parts or genetic components are placed in deep-freeze until the time when bio-technologies might be able to resurrect and effect newly found cures, thus enabling persons

to take up where they left off years earlier. Far-fetched, but not impossible. Costs currently run $120,000 for full bodies, and $50,000-60,000 for "neurosuspension" of just one's head. Responding to these developments, insurance companies already underwrite cryogenic suspension.

More down-to-earth, though still somewhat audacious, are services currently offered by funeral homes. Morticians will take DNA samples, secure genetic profiles, and cryogenically store samples for 25 years or longer. Costs range from $100-350. LifeTree Technologies Inc. (Greensboro, North Carolina) had contracted with over 100 funeral homes to provide these services by Spring 2000. The pitch is not overtly aimed at the problematic prospect of resurrecting the deceased life at some later time. Instead, the announced purpose is to provide a genetic store and template that might be used to help profile and pinpoint genetic diseases or dysfunctions in a family line, to prove paternity, or simply to avoid the emotionally difficult and costly procedure of exhuming a buried body.

Initial experiments in gene cloning date back to 1972. Ability to create new lifeforms by cloning, first realized by cloning a sheep (Dolly) from an adult (mammary) cell (1997), proved that duplication of genetic successors is possible. Cloning human life itself poses a much different kind of question. Cloning humans is expressly outlawed in a growing number of countries. In the US, cloning human life is declared illegal under existing regulations. These debates are far from being over.

Initial experiments in gene cloning date back to 1972. Ability to create new lifeforms by cloning, first realized by cloning a sheep (Dolly) from an adult (mammary) cell (1997), proved that duplication of genetic successors is possible. Cloning human life itself poses a much different kind of question. Cloning humans is expressly outlawed in a growing number of countries. In the US, cloning human life is declared illegal under existing regulations. These debates are far from being over.

These developments shake the meaning of life to its very roots. The secret of life itself, one of the most sought after mysteries of all time, is beginning to be revealed and capable of being manipulated. It's a Brave New World out there.

Cloning - Animals

Transgenic Animals

The cornucopian potentials of GM products are prodigious. Growth hormones have successfully boosted milk output of cows, and doubled

the growth of trout. The development and promotion of leaner and faster growing strains of pork - to the great benefit of growers and consumers - represents another important advance achieved through genetics. Sports fishermen now have more than mere hopes for catching "big ones."

Bovine growth hormone research got underway an Monsanto during the 1960s but concluded when the effort was determined not to be cost effective. During 1980 Genentech helped express BST gene in Esherichia coli, and the renewed efforts took off. BGH eventually was approved by 30 countries. Protests based on dubious scientific observations and surmises, and prodded along by a Luddite mentality, thwarted progress. Several countries banned BGH, including Canada and the EU.

Artificial insemination played a key role in boosting bovine milk output. Milk production per cow rose from 4,622 pounds yearly (8,600 pounds on well-managed US dairy farms) in 1940, to 16,915 pounds in 1997. The world record milk output from a single cow, 55,691 pounds, in one year, indicates that there's plenty of room for further increases. Genetic enhancements are certain to bring about further increases.

The jump to genetic-based animal husbandry and cloning is a small one. Already, 60 percent of calves in the US are conceived by artificial insemination. A mature prize bull produces enough sperm to fertilize every cow in the world in a single day. One champion bull, over a 12-year lifetime, sired 2 million cows!

Cloning prize livestock will be a boon to animal husbandry, to zoos interested in perpetuating scarce species, and for environmentalists concerned about preserving bio-diversity. Livestock segments, such as beef producers with 1998 sales totaling $30-35 billion, are keenly interested in these developments. Japanese scientists recently cloned prized cows whose meat is valued at $100 per pound, and sells in the US for as much as $100 for a 3-4 ounce serving.

Cloning pets, undertakings somewhat less controversial than cloning a human, may be the way station to mass applications of bio-genetics. Who would have thought, not so many years ago, that "pet cemeteries" would become a big business? Thanks to a Silicon Valley tycoon (named Mr. E), a company named Genetic Savings & Clone affiliated with Texas A&M University, invested $2.3 million to clone a billionaire's pet dog. Though the first efforts at cloning dogs was unsuccessful, the company speculates that cloning pets may become the first line of activity opening the way for human cloning. Recently, the company offered to save and store a pet's cells for $1,000 until such time as cloning becomes feasible.

Japanese genetic engineers, reportedly have succeeded in cloning kittens. Dogs and other pets can't be far behind. Little know is the fact that the first animal to be cloned was the carp (an ornamental fish prized by Japanese), also accomplished by Japanese scientists.

Fertility, Stem Cells

Human Embryo Stem Cell Research

Human embryo, fetal and adult stem cells have extraordinary capacities to rejuvenate and cure defective organs or tissues. Tinkering with embryonic components that could grow into a human being poses more difficult problems.

As debate surrounding experimentation with embryos and stem cell research grew, Congress passed a law in 1996 that outlawed federal funding for such purposes. As life-giving potentials associated with this research became clearer, government lawyers found a loophole. They contended that because stem cells from human embryos cannot grow into a human being, this line of research was permissible. NIH, with encouragement from the President, issued new guidelines in December 1999 permitting somewhat constricted go-ahead for federally funded research in this important area. Presidential hopefuls have taken opposite positions on this issue: Gore favoring federal funded research, Bush opposing. President Bush recently approved at least some limited lines of stem cell research. The battles aren't over yet!

Opponents fear that a green light for embryo research may induce women to abort fetuses for money-making purposes (sale of discarded materials), or abort for the more benevolent purpose of providing genetic materials to aid or cure a designated donee. Scientists are careful to point out that embryos are not "carved up" to obtain stem cells because retrieval is undertaken at the one-week stage when the embryo is still a microscopic mass of undifferentiated cells, and a long way from beginning to form organs, limbs and the like.

British rules are considerably more permissive than those in the US, permitting research on embryos up to 14 days - the blastocyst stage - when nerve cells first appear. Up to that time embryos could be used for research purposes, but only in five research categories linked to infertility.

Organized religion, typically the conservative stalwart of the status quo regarding questions of life, has variant positions regarding interfering with the "hand of the creator." Catholics believe life starts when the

sperm and the ovum merge, or earlier. Eastern Greek Orthodox belief opposes tampering with embryos. Islamic beliefs hold to the belief that moral-legal being is not formed until 120 days when "ensoulment" occurs. Judaism, liberally interpreted, countenances embryo and stem cell research based on discarded embryos; views embryos as simply water during the first 40 days; maintains that genetic materials outside the uterus are without legal status, and not part human until implanted.

Cast in broad terms, genetic interventions, particularly undertakings involving embryos and stem cells are considered by some as just another element in the erosion of respect for human life. Pluripotent cells that can be directed to mature into 200 types of specialized cells - blood, liver, brain cells, and the like - suggest the basic dimensions of this possibility. Some observers fear a "commoditization" of human life. The irony is that such accomplishments actually are targeted at improving and enhancing life, making fuller lives possible for the afflicted, and saving millions more from premature death.

Steps toward "designer babies" are long underway. Until recently, women passively accepted the number of children "willed by God." The situation changed as contraceptives were begrudgingly introduced, after being outlawed for centuries. Amniocentesis, available since 1952, and enhanced visualization techniques, are among procedures that can detect developmental and genetic problems, as well as to enable sex determination. Sex selection, although officially restricted, has become a factor in life-giving. Abortion also became a somewhat limited right that still remains in contention. Abortions reported in the US doubled between 1972-1996, rising from 586,760 to 1,221,585. Large-scale resort to abortion markedly alters the way society thinks about sustaining life.

On the life-giving side of such questions, infertile couples and those at high risk in conceiving or bearing children resort to fertility clinics. Surgically removed ovum and sperm can be carefully screened for gene-based defects, and then combined in the laboratory to create a perfect zygote (fertilized ovum before cleavage). Selected blastocysts (multi-celled developing embryos) can be implanted in the biological parent or a third party female surrogate. Defying nature, these techniques enabled a 63 year old female to bear a child! Lab-assisted fertility and genetic screening open up new opportunities for assuring "sound stock." Germ-line manipulation, involving manipulating genes in sperm and ovum, ensure that genetic flaws are eliminated from individuals and family trees. Modern fertility technologies make it possible for females to bear babies without males, using artificial insemination. Reciprocally, males soon may be

able to father children without females, relying upon cloning. The Brave New World is upon us.

On another front, in utero surgery (first reported in 1981), creates opportunities for dealing with fetal abnormalities. Genetic therapies also can repair certain problems - both in utero and at later stages of human development (first successfully accomplished in 1990).

Eventually, a "menu" of traits would-be parents can pick and choose from might be possible. Parents, having the option to control genetic defects, will not fail to take steps to avoid passing them along - and to pass along the most advantageous genetic predispositions possible. "Normal" sexual reproduction without genetic profiling or engineering will come to be deemed as foolhardy as foregoing prenatal care is today.

Genetic technologies used on animals and crops already are being applied to humans. Scientists in South Korea, reportedly, have cloned a human embryo. However, terminating the experiment at the second cell division stage, clouds significance since the first four divisions occur automatically. Only at the 16-cell stage do embryo genes begin to drive further development. The significance is that "the genie is out of the bottle". A Bahamas-based company, a forum or venue of least resistance, already offers human cloning services for $200,000. Apparently money can, literally, buy anything. Genetic technologies denied in one jurisdictions, simply will become established elsewhere.

Detecting and Treating Genetic Defects

Detecting genetic abnormalities affords new opportunities to correct defects. Gene therapies can be used prior to or at early stages of conception, during gestation in utero, or after birth and later on during life. The importance of shifting from a corrective to a preventive approach to health care cannot be underemphasized. The shift will relieve untold suffering and reduce surgical and drug therapeutics needs and costs.

Pre-birth detection of defects escalates the abortion debate to new levels. Great wisdom will be required, lest a false move terminate another Lou Gehrig, Babe Ruth or Stephen Hawking. On the other hand, spending millions to treat genetic impediments that might have been avoided - had irresponsible parent-healthcare givers taken proper screening/therapeutic stops - could become too burdensome on limited taxpayer-funded health care. "Sky is the limit" health care costs could reach the point that social consensus and taxpayer reluctance clamors for a halt.

Genetic testing is far more prevalent in the US than many think. Clinical labs perform approximately 4 million genetic tests annually. Laws in most every state mandate newborns be tested for phenylketonuria, a simple

metabolic disorder that, left untreated, leads to mental retardation. Newborns are routinely checked these days for sickle cell anemia and congenital thyroid disease.

There are many other lines of research and development that strive to improve human life. Among them are on-going efforts to determine whether genetic engineering techniques may be able to "re-start" processes that would enable humans to regenerate a severed limb or body parts. Certain animals, including starfish, newts and a few others have this innate capability. Sounds simple. It isn't. Consider, for example, that growing an adult-sized leg required about 18 years - would you want to wait a full 18 years for a new leg to regenerate? Scaffolding techniques provide another approach surmounting such "time lags."

Lawsuits have been lodged by children injured by genetic therapies gone wrong. Suits have been filed against fertility clinics for passing along genetically flawed sperm or ovum, medical practitioners that failed to detect genetic defects or omitted mentioning the availability of genetic screening (that might have prevented of an afflicted baby). Sooner or later, gene-impaired individuals may sue parents and/or health care providers who failed to take advantage of genetic screening or therapies that could have eliminated genetic flaws. This line of cases leads to a "slippery slope" into conscious culling out or eugenic cleansing of the "unfit." If bringing into the world a person with a genetic disorder or disease that was diagnosable before birth is actionable, how close are suits brought for trifling cosmetic imperfections or minor differences that might have been corrected?

Health Insurers object to constraints against disclosure of family history, physical exams or medical records that have crucial bearings on actuarial experience ratings. Actuarial rates, based on risk factors - higher rates for smokers, alcohol abusers, accident-prone drivers, and so on - suggest that risk, not flat-rate universal (and more costly), rate structures will prevail. Health insurance providers are barred or otherwise limited by statute in 39 states from discrimination based on genetic tests.

Genetically Modified Crops/Foods

Bio-tech Green Revolution

Genetic technologies will boost crop yields far beyond those made possible by the Green Revolution. Bio-engineered crops not only will boost yields, but create new varieties that thrive in hostile environments, survive without irrigation, flourish in brackish/arid soils, withstand frost,

tolerate herbicides, fend off viruses, increase nutrient composition, minimize fertilizer, reduce pesticide use, cut agri-chemical needs, heft plant stems (to withstand ravaging weather), and diminish energy inputs overall. Contribution to worldwide goals of "sustainable" agriculture will be enormous.

Over 4,500 GM crops have been developed and tested. Consumer-oriented genetic enhancements target flavor, sweetness, color, acidity, texture, size, shape, and so on. Nature's chemistry is exquisite, but can be improved upon. By a stretch of the imagination, crops may be redesigned for bio-reactors to yield only the most useful and valuable component desired: orange juice sacs without roots, trunk, branches, leaves, rind or seed, for example!

Acceptance of GM Crops

Controversy surrounding genetically modified (GM) or transgenic crops abounds that are derisively referred to as "Frankenfoods" or "Mutant Crops." Such enmity is misplaced. Former President, Jimmy Carter put it simply but eloquently when he stated: "Responsible bio-technology is not the enemy; starvation is."

The twisted irony of all this is that genetic modification has been underway for at least 10,000 years! Around 8000 BC, when natural crops became domesticated, selective breeding actually got underway. It was followed by cross-breeding and eventually hybridization (early 1900s). Genetic modification simply involves more conscious and directed refinement of previous "hit-or-miss" approaches at a more precise molecular and cellular levels.

GM Food Restrictions

The regulatory and voluntary efforts controlling GM foodstuffs. Are significant. Nations have acted to ban imports or sales (Sri Lanka). Others require labeling disclosure (Japan, Korea - effective 2001; Australia, effective 2001). At least one nation requires GM seed labeling (PRC). Court rulings ban GM farming (Brazil - ruling essentially ignored). Signatories representing 38 nations circulate a letter to all government urging imposition of a 5-year moratorium against GM crops.

EU policies have required label disclosure for GM foods (with GM components in excess of 1 percent) since 1997. The European Union suspended regulatory approval of GM crops, June 26, 1999. European Union rules call for labeling of GM foods in its 15 member nations. The initial Novel Foods Regulation (No. 258/97), applied to foods and food

ingredients produced from but not containing GM components. Subsequent developments included: labeling exemption for listed products, exemption for products containing less that 1 percent GM constituents. Regulation 50/2000 mandates labeling of food products containing GM additives or flavorings, and also establishes a de minimis threshold for exemptions. Forthcoming EU regulations will deal with "GM-free" claims which may or may not include exemption for products produced from but not containing GM components.

Genetics - Industrial Applications

Industrial Applications of GM Crops

Monsanto bio-engineered cotton to produce tinted cotton bolls on the plant. DuPont developed a soybean that yields triple the oleic acid content of conventional varieties. Scientists are working on GM corn, wheat, and treestocks that can be used as a feedstock for plastics. Companies pursue three different approaches to bio-engineer plastics: conversion of phyto-sugars into plastics; production of plastic within the plant itself; production of plastics inside organisms. Other companies seek to bio-engineer synthetic lumber using lignin (polymeric glue) and cellulose to self-assemble woodlike cells. Turf grasses genetically engineered *not* to grow beyond a fixed height will revolutionize lawn care. GM bacteria designed to eradicate corrosion of conduits, cooling systems, sewage treatment plants and so on are under development.

Bioethics

Genetic Engineering Fears and Obstacles

As early as 2020, use of genetic know-how to create life will unleash the most divisive moral and ethical dilemmas of all time. Eugenics, humans taking conscious control of their evolution, is certain to become the most controversial center of these debates. Threats of genocide, creating a "super race," and contending with the gargantuan geriatric problems introduced by increasing life expectancy to 125-160 years (or even immortality) pose new realities.

Attempts to encumber advances in bio-technologies, genetics and life sciences will be surmounted. Eradicating genetic diseases, extending life expectancy, increasing food production, creating life-saving pharmaceuticals, enhancing resource recovery/remediation, providing synthetic lumber, generating industrial enzymes, providing new fuel/energy sources, producing bio-degradable plastics,

creating computer bio-chips - all of these advances, and so many more, will prove far too important to be stifled or denied.

Similar confrontations accompanied most every major advance in bio-science. Not so many years ago, hybridizing plant life by Luther Burbank was denounced as blasphemous by church leaders. Centuries earlier, human dissection was blocked on grounds it was sacrilegious, cruel, immoral and obscene. Medical and public health measures, introduction of antiseptics, immunizations and nutrition therapies encountered similar opposition. Religious groups, to this day, oppose female egg donation and artificial conception. As it eventually turned out, each one of these advances saved countless lives, eliminated untold suffering, and vastly enhanced quality of life. Denying new knowledge and understanding that can alleviate suffering and improve lives is, simply put, foolhardy. The task will not be easy. Iron resolve will be.

Gene Patenting

Patent Protection

Patent protection has covered genetically engineered plant microbes since 1980. Chakrabarty's bio-engineered bacterium (Pseudomonas), designed for mopping up four principal components in oil spills, set the pattern. The patent was filed in 1972 and upheld 5-4 by a Supreme Court decision during June 1980. Next, a patent was granted for a technique to produce recombinant DNA. This patent awarded to Cohen and Boyer was filed in 1974, but not granted until 1981. The pattern had been cast by that time. Patent grants for multicellular organisms followed in 1987, and genetically-engineered animals in 1988.

Gene patents (covering human, animal, plant and microbial gene sequences) filed between 1990 and 1999 rose an impressive 14-fold. Biotechnology patent applications in FY 1997 numbered 10,500, second only to those for computer sciences. Another tabulation asserted that bio-tech patent applications rose from 5,977 to >8,000, 1998-1999. However counted and whatever the numbers may be, the salience of this rapidly growing technology is evident.

Give-aways to Poor Countries

A classic example of the good that can and will be done involves so-called golden rice. Rice is a staple for over one-third of the world's population. Genetically altered rice, modified to carry a bountiful supply of beta carotene (a vitamin A precursor), has the potential for enhancing and saving lives. Not just a few lives. The number of persons worldwide

who die each year from afflictions associated with vitamin A deficiency number 1-2 million persons. In addition, "golden rice" has the potential to eradicate the annual incidence of 300,000 cases of blindness caused each year by vitamin A.

Concluding Statement

With hopes to "grow where nobody has grown before," to heal, to improve the quality of life overall drive bio-tech sectors in all their might and fury. Forecasts for swift implementation to resolve age-old specters will come step-by step. Fell-swoop change and acceptances are unlikely - at least for the present. Over the course of time, as the footing becomes surer and sounder, virtually every aspect of society will literally be transformed by the life-sciences. A brave new world of a very positive and upbeat sort stands in the offing. Advances in the human condition will be remarkable, and welcomed.

References

Anderson, Walter Truett Anderson. 1987. *To Govern Evolution: Further Adventures of the Political Animal.* New York: Harcourt Brace Jovanovich Publishers.

____. 1996. *Evolution Isn't What It Used To Be: The Augmented Animal and the Whole Wired World.* New York: W.H. Freeman and Company.

Andrews, Lori B. 2001. *Future Perfect: Confronting Decisions About Genetics.* New York: Columbia University Press.

Blank, Robert H. and J. C. Merrick. 1996. Editors-in-Chief. *Encyclopedia of U.S. Biomedical Policy.* Westport, Connecticut: Greenwood Press.

Bylinsky, Gene. 1981. *Life in Darwin's Universe: Evolution and the Cosmos.* Garden City, New York: Doubleday & Company, Inc..

Chaisson, Eric. 1981. *Cosmic Dawn: The Origins of Matter and Life.* New York: W.W. Norton & Company, Inc.

____. 1987. *The Life Era: Cosmic Selection & Conscious Evolution.* New York: The Atlantic Monthly Press.

Cooper, David K.C. and R. P. Lanza. 2000. *Xeno: The Promise of Transplanting Animal Organs Into Humans.* Oxford: Oxford University Press.

Davies, Paul. 1999. *The Fifth Miracle: The Search for the Origin and Meaning of Life.* New York: Simon & Schuster.

Fox, Michael W. 1999. *Beyond Evolution: The Genetically Altered Future of Plants, Animals, the Earth...and Humans.* New York: The Lyons Press.

Gosden, Roger. 1999. *Designing Babies: The Brave New World of Reproductive Technology*. New York: W.H. Freeman and Company.
Gottweis, Herbert. 1998. *Governing Molecules: The Discursive Politics of Genetic Engineering in Europe and the United States*. Cambridge, Massachusetts: The MIT Press.
Johanson, Donald and B. Edgar. 1996. *From Lucy to Language*. New York: Simon & Schuster Editions.
Johanson, Donald and M. Edey. 1981. *Lucy: The Beginnings of Humankind*. New York: Warner Books, Inc.
Johanson, Donald and J. Shreeve. 1989. *Lucy's Child: The Discovery of a Human Ancestor*. New York: William Morrow and Company, Inc.
Keller, Evelyn Fox. 2000. *The Century of the Gene*. Cambridge, Massachusetts: Harvard University Press.
Kolata, Gina.1998. *Clone: The Road to Dolly and the Path Ahead*. New York: William Morrow and Company, Inc.
Margulis, Lynn and D. Sagan. 1995. *What Is Life*? New York: Simon & Schuster.
Morrison, Reg. 1999. *The Spirit in the Gene: Humanity's Proud Illusion and the Laws of Nature*. Ithaca, New York: Comstock Publishing Associates/Cornell University Press.
Ponnamperuma, Cyril. 1972. *The Origins of Life*. London: E.P. Dutton & Co., Inc.
Rifkin, Jeremy. 1998. *The Biotech Century: Harnessing the Gene and Remaking the World*. New York: Jeremy P. Tarcher/Putnam.
Rothblatt, Martine. 1997. *Unzipped Genes: Taking Charge of Baby-Making in the New Millennium*. Philadelphia: Temple University Press.
Ruse, Michael and A. Sheppard. eds. 2001. *Cloning: Responsible Science or Technomadness*? Amherst, New York: Prometheus Books.
Silver, Lee M. 1997. *Remaking Eden: Cloning and Beyond in a Brave New World*. New York: Avon Books.
Smith, John Maynard and Eors Szathmary. 1999. *The Origins of Life: From Birth of Life to the Origin of Language*. Oxford: Oxford University Press.
Stock, Gregory. 1993. *Metaman: The Merging of Humans and Machines into a Global Superorganism*. New York: Simon & Schuster.
Taylor, Michael Ray. 1999. *Dark Life: Martian Nanobacteria, Rock-Eating Cave Bugs, and Other Extreme Organisms of Inner Earth and Outer Space*. New York: Scribner.
Thompson, Larry. 1994. *Correcting the Code: Inventing the Genetic Cure for the Human Body*. New York: Simon & Schuster.
Turney, Jon. 1998. *Frankenstein's Footsteps: Science, Genetics and Popular Culture*. New Haven: Yale University Press.
Walter, Malcolm. 1999. *The Search for Life on Mars*. Cambridge: Perseus Books.

Ward, Peter D. and Donald Brownlee. 2000. *Rare Earth: Why Complex Life Is Uncommon in the Universe*. New York: Copernicus/Springer-Verlag New York, Inc..

Wilmut, Ian, et al. 2000. *The Second Creation: Dolly and the Age of Biological Control*. New York: Farrar, Straus and Giroux.