1 Prologue

"As
vital as sex may be, it is a
glorious, glittering puzzle. Why do peacocks
drag around such grand tails, but not peahens? Why is
it that when Australian redback spiders mate, the male hurls
himself onto the female's poisonous fang, becoming a meal for her
at the end of the act? Why do ant nests contain thousands of sterile
female workers, all serving a fertile queen? Why do males
always have small mobile sperm, while females
have giant, immobile eggs? Why are
there males and females
at all?"

- Carl Zimmer, *Evolution*, 2001

► About the Title of the Book

Friends and colleagues are not only instrumental in shaping the contents of this book, but also the title.

Originally, I had decided on a more innocent title, "*Mother Nature, Father Time and Children Author*." While doing research for the book, I came across numerous mildly disturbing facts: –

- Fact One: In performing human cloning, a researcher needs an egg, which has been hollowed out, and a donor cell. The nucleus of the donor cell is then transplanted into the egg.
- Fact Two: The resulting embryo is then implanted into the uterus of a surrogate mother. After months of gestation, of course, the clone would be born the same sex as the donor. Since cloning involves no fertilization, but requires an egg and a uterus, in principle, the male population is redundant, provided no male clones were desired.
- Fact Three: In aquaculture or fish farming, in order to maximize feed-to-body-mass conversion, certain cloned fish have only female population. Male fish are too aggressive and spend too much energy fighting each other![1]

[1] Hwa A. Lim, *Genetically Yours: Bioinforming, biopharming, and biofarming*, (World Scientific Publishing Co., New Jersey, 2002).

- Fact Four: Someone at a company has actually succeeded in human parthenogenesis, that is, the development of an egg into an embryo without sperm fertilizing the ovum. The trick is to emulate chemically the environment for the egg to start cell division.[2]
- Fact Five: The whiptail lizard population in the western United States has no males. The way they reproduce is having one female mount another female and mimic what a "male lizard" would do while mating. The eggs simply start dividing and growing into embryos without being fertilized by sperm. In this way, the lizards invariably give birth to only females, all of which are identical to their mothers. The offspring is in all respect a clone. This reproduction process is a form of parthenogenesis.[3]

There are other facts, but these facts suffice to show that the male population plays a rather redundant supporting role. These facts were bubbling in my head for a while: would the male human population eventually become "extinct" if cloning and parthenogenesis techniques were perfected? Would the male human population eventually "die out" if they do not cut out the time they spend fighting and spend more time being intimate with their "significant other halves?"

On a business trip abroad in September 2002, while crossing a bridge, an inspiration struck and I changed the title to "*If Sex Is So Good, Why Clone?*" to highlight what has been going through my head, and to bring out the antimetabole – "procreation without sex" and "sex without procreation." I do not know what the significance of that bridge is, but I can tell you I was then in a country where all forms of pornography are forbidden.

At a function in Silicon Valley, California in December 2002, I met a famed octogenarian from the San Francisco Bay Area. He suggested "Why 'If'?" "If" was subsequently dropped. Then in January 2003, I met another famed Broadway octogenarian in Los Angeles, who suggested why "So Good" when it should be "Sooo… Good" with quiver on "Sooo…" which I do not know if he intentionally pronounced it that way or that it was because of his age. Out of respect, I dare not ask him to clarify. I thought it would have been better to add the 'o's to "Good" rather than the "So." But this is only a matter of age difference. After all, the famed Broadway octogenarian is about twice as intelligent in age as I am. Since I am not able to put the quivering effect in the title, I decided not to take the suggestion. Quivering effect will have to wait until we have a VCD or DVD version of this book.

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[2] Dan Vergano, "Technique might quell stem cell research concerns", *USA Today*, January 31, 2002.
[3] Carl Zimmer, *Evolution: The triumph of an idea*, (HarperCollins Publishers, New York, 2001).

During the months I had been tapping on the computer keyboard to complete this book, like other living things, I still needed to ingest but had inadvertently become more sedentary. One day, after a long day's work, I stood up to stretch. Just at the moment, an inquisitive seven-year old happened by. Innocently she asked, "Your stomach is so big. Are you pregnant?" I hope she was joking. As far as I know, male parthenogenesis is still not possible, even in the higher animal kingdom.[4]

When I was completing this book for submission to a publisher to publish into an imprint in 2003, a very intelligent eleven-year-old boy saw me busy tapping away on my computer keyboard. He approached and asked what I was doing. I told him I was putting finishing touches to a book. Out of curiosity, he took a peek at the cover, and then asked, "How much would this book cost?" I said, "This is for the publisher to decide." He then lamented, "My mom would never let me read this book."

He was right. Certain books are for adults, but this one is definitely NOT one of those books. Do not let the title deceive you; or should I say, "Do not let the title tempt you." If you are purchasing this book for colorful pictures, you will be very, very disappointed. But if you are purchasing this book to learn more about the many ramifications – actual and perceived – of sex, reproduction, cloning, stem cell research and regenerative medicine, I hope you will enjoy reading this book as much as I enjoyed tapping away on my computer keyboard writing this book.[5]

► Risks of Writing this Book

No book on cloning, and the related issue of reproduction, will be complete without a discourse into sex. A dictionary defines "sex" as a noun, meaning 1. either of the two main groups (male and female) into which living things are placed according to their reproductive function, the fact of becoming one of these. 2. sexual feelings or impulses, attraction between members of the two sexes. 3. sexual intercourse.[6]

From these dictionary definitions of what "sex" is and the explanation of how the title of this book comes about, it is clear why I am taking some risk writing this book. The following two scenarios would help explain.

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[4] Fact Four mentioned above only led to the creation of an embryo of a few cells, not a complete organism.

[5] After HAL [HAL are the initials of the author] had submitted the book to the publisher to print into imprints, there was another suggestion for the title: why 'Sex is so good, why clone?' when it should be 'Sex is so great, why clone?' So the debate over the title continues.

[6] *Oxford American Dictionary*, Heald Colleges Edition, (Avon Books, New York, 1980).

Scenario One: Whenever I go to a bookstore to purchase books and walk up to a cashier to pay for the books, the cashier would always say smilingly while scanning one of the books over the barcode reader, "This is a great book. I have read it myself." I suspect nine out of ten times the cashier has not read the book. It is just a courtesy.

Scenario Two: Whenever I go to a bookstore to purchase books and one of the books happens to have the word "sex" in its title, the more conspicuous the word "sex" is the better. When I walk up to a cashier to pay for the books, the cashier would utter nothing, and even blush embarrassingly.

I am sure bookstore browsers can relate with such experiences. But what is the risk I am taking? Of course the risk has nothing to do with sex. Though purchasing books with the word "sex" in the title would create some awkward feeling, books with the word "sex" in the title are usually the most leafed books in any bookstore, a testimony to indicate that readers love books about sex (in its narrow third dictionary definition) – how to improve the technique, how to give and get pleasure, how to last longer, all that stuff.[7]

There is an anecdote in which a job applicant had to answer a list of questions. In one of the questions, the applicant was asked "sex:" the applicant's instinctive interpretation of the question was "human copulation" and wondered why the prospective employer would be interested in his or her lifestyle. So the applicant provided a rather reluctant, but honest answer "frequently" to indicate that he or she made love on regular basis. The question, as you may have guessed by now, asked whether the applicant was a male or a female, the first dictionary definition!

To avoid such uncomfortable situations, if I want to use the word sex to mean only "human copulation," I will say "coitus." It is precisely because most people interpret the word "sex" in such a narrow sense, that is, to mean coitus, that American sex researcher Shere Hite (1942-) writes, "I am suggesting we call sex something else, and it should include everything from kissing to sitting close together…" to indicate that sex encompasses more than copulation.

This anecdote and sexpert (or sex expert) Hite's redefinition of sex provide a hint of the risk I am taking: in this book I write about more than sex in its narrow sense. In the pages that follow you will find extraordinary wisdom on dozens of topics that go beyond copulation, the third definition in the dictionary. These topics merely dance along the periphery of sex. In fact

[7] Stephen C. George and Ken Winston Caine, *A Lifetime of Sex*, (Rodale, Inc., 1998).

sex in science encompasses a much wider scope than the dictionary definition of sex. "Sex" in science touches on coitus, sexual reproduction, asexual reproduction, altruism in sex, sexual attraction, the battle of the sperm in sexual reproduction, the role of sex in coevolution, disadvantages of sexual reproduction, evolutionary adaptations to sexual reproduction, maternal and paternal investments in sexual reproduction and many other topics related to sex and sexual reproduction.

In science, cloning is a form of assisted asexual reproduction; assisted with the help of technology. As such, when discussing the implications and ramifications of cloning, a thorough understanding of sex (in the scientific sense) will help. My discourse into sex thus does not qualify me to be a sexpert, but rather a necessity to make this book more complete.

For scientists to talk about sex and sexual reproduction in isolation is missing the point. Sex and sexual reproduction are intricately linked with all the other topics touched upon in this book. This takes us to one of the most important truisms: reproduction is more than just "the sperm meeting the egg" after some intimate moments. It is a simple concept, yet surprisingly few people have grasped it, even the experts. When you look at sex and reproduction books on the market, they treat sexual reproduction as sexual reproduction, or they deal with reproductive technology such as *in vitro* fertilization as reproductive technology, or they provide pros and cons of the very controversial cloning as ethical issues.

Then again these days, fundamentals in "the birds and the bees" are presented by a variety of instructors and learning institutions, including sitcom writers, school playground know-it-alls, Internet chat-rooms, magazines, and a seemingly endless faculty of sexperts (sex experts). Some of these are not necessarily bad places to get started, but they are not always credible.[8]

Hence the concept for a new book emerges: explain the basic concepts of all the related topics along the periphery of sex and reproduction, and interrelate them together in one volume. I take great pride in taking the risk of writing this book because over the years, I have given lectures on some of the topics and have on numerous occasions been accosted by people from different walks of life who ask questions on related topics while I was eating out, walking down a street or having a leisurely chat. This book provides many of the answers, and intends to help eliminate the misunderstandings.

Ultimately, this book is about sex in its broadest sense, reproduction, reproductive technologies, and new breakthroughs in stem cell research and regenerative medicine. If these are what you get out of the book, I will be very

[8] Felicia Zopol, *Let's Talk About Sex*, (Running Press, Philadelphia, 2002).

satisfied. But if I am truly successful in taking the risk, decades from now, people will still be reading this book or use it as a reference. This will make me feel very rewarded indeed.

► The Title Revisited

Just before the imprint came out, in late 2002, I had the opportunity to give a lecture to the public in California on stem cell research and related topics. I cited this forthcoming imprint. At the conclusion of the lecture, someone came up to me, after the Q&A session and told me in private, why "*Sex Is So Good, Why Clone?*" when it should be "*Sex Is So Great, Why Clone?*"

A few months later, in 2003, a flyer came out featuring the imprint. A fellow author (on tour books) saw the flyer. Jokingly, he said, "Dr. Lim just wrote a book on '*SISG*'…" In November 2005, I was at a university lecturing on a topic not related to cloning. During the introduction, my host introduced my background, and then went on to say, "…Dr. Lim had recently written a book. The title is '*If Sex Is That Good, Why Clone?*'…" There was laughter from the audience.

Now you see, when it comes to sex, people not only like to do it in different ways, but also like to say and express it in their own ways! Some awkward situations arose. In 2004, when I presented a copy of the imprint to an official of a Middle Eastern country, he decided to cover the word "Sex" when we posed for a photograph. When I presented a copy of the imprint to a chief minister of a Southeast Asian country, he looked at the title and said, "A very interesting book."

In order to avoid further confusions, and after consulting the marketing department of the publishing house, I decided to change the title to *Multiplicity Yours: Cloning, stem cell research, and regenerative medicine*. This not only brings us closer to a very successful book I have had with the publisher, *Genetically Yours: Bioinforming, biopharming, and biofarming* (published in 2002), but also begins a "Yours" series of books.

In a Webster dictionary, "multiplicity" is defined as: the quality of being multiple, or various; a state of being many. There are also technical definitions of "multiplicity" in mathematics and physics, a computer program of the same name, or a disease with the same name (but also variously known as multiple personality disorder or dissociative identity disorder). These are of less relevance to us. Of more relevance is a 1996 film starring Michael Keaton (as Doug Kinney) and Andie MacDowell (as Laura Kinney). In the movie, *Multiplicity*, Doug is a stressed-out family man. He meets up with a cloning

enthusiast and makes a clone of himself in order to take over himself at work while he tries to spend quality time with his family. The clone turns out to suffer from residual quirks of the cloning process. More clones have to be made. Eventually Doug's cloning misadventures end up complicating rather than simplifying his life.

Now it is obvious why the project to clone a beloved mutt named Missy is called the Missyplicity Project. The project was backed by entrepreneur John Sperling and was based initially at Texas A&M University.

Of most relevance is this book is actually a collection of answers to questions raised at the end of my lectures, asked by friends and acquaintances in leisurely chats, over the phone, received in postal and electronic mail. I thus decide it is appropriate to title the book in a correspondence format, just like we usually pen off a letter with "Affectionately yours," or "Truly yours."

This book thus has a longer gestation period than the three years since I keyed in the first word on my laptop. During this period, my laptop has been replaced twice, and the contents of the book changed, and were revised and updated many times. The title has also evolved from "*Mother Nature, Father Time and Children Author*" to "*Sex Is So Good, Why Clone?*" to "*Multiplicity Yours: Cloning, stem cell research, and regenerative medicine*." This book was first published in 2004. This is an updated, revised and expanded new book.

What Has Gravity Got To Do with This Book?

This book may be a little heavy; gram for gram (we have to get metricated here, otherwise it should be "pound for pound") you are getting a great deal. But this is not I am getting at.

Albert Einstein (1879-1955) is by far the most famous and beloved scientist of all time. We revere him not only as a scientific genius but also as a moral and even a spiritual sage whose enduring aphorisms touch on matters from the sublime (such as "Science without religion is lame, religion without science is blind") to the playful (such as "Gravity cannot be blamed for people falling in love"). There is a guesstimate of 500 books about Einstein in print, of which at least a dozen were published in 2005.

Why 2005? The year 2005 was the "World Year of Physics." That year celebrated the centennial of the "miraculous year" when a young patent clerk in Bern, Switzerland, revolutionized physics with five papers on relativity,

quantum mechanics and thermodynamics. With other scientific giants, Einstein contributed greatly to the science of the twentieth century.[9]

For the first half of the twentieth century, physics yielded not only deep insights into nature – which resonated with the disorienting work of creative visionaries like Pablo Picasso (1881-1973), James Joyce (1882-1941) and Sigmund Freud (1856-1939) – but also history-jolting technologies like the atomic bomb, nuclear power, radar, lasers, transistors and all the gadgets that make up the computer and communications industries. Physics also contributed greatly to the invention of tools that would prove essential for probing studies of life science today. Physics mattered.[10]

These days, biology has displaced physics as the scientific enterprise with the most intellectual, practical and economic clout. Biology has given us thrilling, chilling technologies like genetic engineering, cloning, stem cells, and regenerative medicine. Many of our most pressing problems are also biological: AIDS, SARS, avian flu and other epidemics, ailments, overpopulation, environmental remediation, species extinction, even warfare (particularly after September 11, 2001). We naturally look for answers to these problems not from physicists, but from scientists grounded in biology.

It is fair to say no modern biologists have come close to Einstein's extra-scientific reputation. Einstein took advantage of his fame to speak out on nuclear weapons, nuclear power, militarism and other vital issues through lectures, essays, interviews, petitions and letters to world leaders. When he spoke, people listened. After Israel's first president, the chemist Chaim Azriel Weizmann (1874-1952), died, the Israeli cabinet asked Einstein if he would consider becoming the country's president. Einstein politely declined – perhaps to the relief of the Israeli officials, given his avowed commitment to pacifism and a supranational government.[11]

It is hard to imagine any modern scientist, physicist or biologist, being lionized the way Einstein was. One reason may be that science as a whole has lost its moral sheen. We are more aware than ever of the downside of scientific advances, whether nuclear power or genetic recombination; moreover, as science has become increasingly institutionalized, it has come to

[9] John Horgan, "Einstein has left the building", *The New York Times*, January 1, 2006.
[10] Hwa A. Lim, "Bioinformatics and cheminformatics in the drug discovery cycle", in: *Lecture Notes in Computer Science, German Conference on Bioinformatics*, Leipzig, Germany, September/October 1996, Ralf Hofestädt, Thomas Lengauer, Markus Löffler, and Dietmer Schomburg (eds.), (Springer, Berlin, 1997), pp. 30-43.
[11] While awaiting Einstein's answer, David Ben-Gurion, then prime minister of Israel, reportedly asked an aide, "What are we going to do if he accepts?"

be perceived as just another guild pursuing its own selfish interests alongside truth and the common good.

Why this digression about Einstein? Gravity certainly has nothing to do with cloning, stem cell research, and regenerative medicine. As you will see, we shall be mentioning Einstein again in the chapter on cloning: will we get an Einstein if we clone Einstein? In discussing ethical and moral implications of cloning, stem cell research and regenerative medicine, we will find Einstein's aphorism "Science without religion is lame, religion without science is blind" pertinent.

Sir Edward Tylor introduced the concept of survival (NOT the same "survival" as in "survival of the fittest"). In this case, survivals are ancient customs or habits that had persisted long after their original purpose had been lost or forgotten. Many of our instinctive reactions and emotions are on occasions at odds with this modern age, but they continue to shape the way we live. As you will see, in cloning, stem cell research and regenerative medicine, science and religion will clash head on. In parts of the world (surprisingly, the U.S. tops the list) where modern mores often collide with ancient traditions and customs, what constitutes progress can be debatable, and in some cases, even divisive. The U.S. government has been debating on the issues for decades, with no definitive conclusions; political candidates and Supreme Court nominees have to answer tough questions on these issues; and these issues become platforms of political parties, stand of interest groups. These are also the issues debated in recent U.S. presidential campaigns. Once elected, the president usually takes a certain stand, at times counter to the campaign promises.

This is yet the greatest risk of writing this book, for when drafts of more controversial chapters of this book were posted on the Internet I received electronic email offering diverse opinions, suggestions and criticisms. I am not running for any public office. This makes writing this book a little easier. But I have to emphasize that this book is not a systematic inquiry of any kind. I possess no special wisdom, nor am I peddling a policy.

One-Handed Scientist

At the dawn of the twentieth century, science was recognized as the dominating force of the age. Objective scientific analysis promised to open everything to human control. This is when science and technology began to become key issues in public decision-making.

Harry Truman (1884-1972) is the 33rd President of the U.S. After listening to his scientific advisors propose a well-argued hypothesis, and then escape

from it with an "on the other hand," he is reputed to have pleaded for a "one-handed scientist" and said that he could solve the world's technical problems if he could just find a "one-handed" scientist.

The 34th U.S. President, Dwight D. Eisenhower (1890-1969), not to be outdone, is known to have made the statement, "I'm a physicist and I just can't resist saying, 'on the one hand… but on the other hand'…"

Or was it U.S. Senator Edmund Muskie (1914-1996) who first pleaded for a "one-handed scientist?" It was a time when supersonic transport was first coming into the U.S. and the senate was trying to decide whether it would create giant holes in the ozone layer. Senator Muskie had a big hearing on Capitol Hill and he called expert scientists together. A blue ribbon panel presented their findings and said, "Our findings show this, that the preponderance of data is that it won't cause any danger. On the other hand, our data shows just the opposite, also, that we need to do more research." It was at this point that Senator Muskie got up and quipped, "Will somebody please find me a one-handed scientist?"

Researchers learn early in their careers about the fine line between cautious explanation and avoidance; this is especially so when it comes to the demand for simple answers to complex scientific questions. In the policy arena, for example, elected officials dream of the "one-handed" scientist. Researchers offering scientific expertise often state a likely option based on analysis of data, and quickly follow with "but on the other hand," proceeding to describe layers of factors that might rule out science's best guess at the moment. But people want answers, and become frustrated by responses that are a long list of options, potential factors and qualifiers.

Even Leon Kass, President George W. Bush's choice to head his council to monitor stem cell research, on August 10, 2001 National Public Radio's "All Things Considered" said:

> "I have opinions, but you cannot work in the field of ethics and be neutral. In fact, it's a disservice to have spent your time thinking about these things and say, 'on the one hand, on the other.' I mean, what you really want are people who have thought these things through and have a position."

Two days later, on CBS's "Face the Nation," he said:

> "I don't have a firm position on stem cell research myself. I think it's a terribly difficult and vexing question."

Now you see why Einstein is by far the most famous scientist. He was not only a genius, but also a "one-handed" speaker. When he spoke out on vital issues through lectures, essays, interviews, petitions and letters to world

leaders, he spoke with "one-handed" authority. Recall that Truman was the U.S. president who decided to drop the two atomic bombs in Nagasaki and Hiroshima during World War II. Einstein had written Franklin D. Roosevelt (1882-1945), President Truman's predecessor, and warned him of the danger of atomic bombs. President Truman could not be referring to Einstein when he was pleading for a "one-handed scientist."

Uncertainty, probability, change and refinement are inherent aspects of science. The popular view of uncertainty, however real, carries images of bumbling, ineptitude, indecisiveness, weakness, and almost subversive, but all the word really means is that there is something we do not know. It may be an unknowable like the future, or it may be easy to find out like a phone number. Whether or not someone else knows it, if you yourself do not know it, you are harboring uncertainty. Find someone who claims to know everything, and you will have found someone to avoid. Someone once said that life can be understood backwards, but unfortunately it must be lived forwards. Probability goes both ways.[12]

Scientists are generally much more patient with the progress of knowledge – continually self-correcting, building on prior knowledge but never absolute – than nonscientists. Other activities, particularly politics and business, call for quick and definitive answers. In the legal profession, most laws – being an accumulation of unchanging law – are in fact irrelevant in a society that is constantly changing. Time-tested circumlocutions in the legal profession are also not uncommon. This tension between science, legal profession and non-scientific activities may be irreducible.

The journalist is often in the position of posing questions to which the research world can offer no authoritative answer, but can offer just a cautious account of the current state of informed belief, including the "on the one hand… on the other hand…" type of answers. Inevitably, some members of the public will ignore all the caveats (such as "this is just a preliminary study," "the sample isn't representative of the population," "we won't know for at least two more years," "it's only been tested on mice") and believe whatever they want to believe, or believe in one hand more than the other. Sensationalism will always build an audience in the short run. Responsible journalists recognize this tendency and resist the temptation to abet it.[13]

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[12] H.W. Lewis, *Why Flip a Coin? The art and science of good decision making*, (Barnes & Noble Books, New York, 1997).

[13] Kenneth K. Goldstein, "Training for the medical information complex", *21st C*, Special Section: Medicine and the Media, Issue 4.2, Columbia University, Fall, 1999.

Information Cornucopia

As most of us have noticed, with joy and some dread, we now live in an information-rich era, with abundant print and digital media clamoring to get our attention. Data, information, news and "facts" flash endlessly across pages, computer and TV screens, battering our minds with the flotsam flowing at us in the information river. Some of them credible, perhaps even true, but how is one to tell the difference? Often web logs, chat rooms and news groups snatch them up and soon they are all over the place, physical and cyber. Some of the sites and reportage are legitimate, but others may be specious and dangerous, or at least with insufficient verification.

The torrents of data and information include a special flow dealing with new scientific breakthroughs in biotechnology, healthcare and medicine. Such material is often given to the general public via the conduit we call the science journalist. The job of the science journalist is to evaluate that information mass (may as well be information mess) and translate it into user-friendly language appropriately balanced with what is and is not true, as far as we know.[14]

Who goes into this particular profession of science journalism? Quite a few science writers start as practicing scientists but find that scientific work holds less fascination than the chance to consider research from an outsider's vantage point. The traffic may also go the other way – some science journalists end up going back to get an advanced science degree. However, there is often an expertise gap between professional researchers and journalists without advanced scientific training. The journalist cannot always expect to grasp technical topics on the same level as the specialist. But being a layperson also carries a practical advantage: the journalist can be more fluent than the scientist in communicating to the general public.[15]

The information complex has grown powerful, and this power can be used either for beneficial or venal purposes. Infomercials may run with the news and stretch the claims, and the media communication may reduce all subjects to caricatures and sound bytes. In some cases, Hollywood will immaturely take breakthroughs or discoveries a step further to make them into movies, further sensationalizing them. As certain notorious instances have borne out, a distorted story can do a great deal of harm to the public, to the scientists

[14] Kenneth K. Goldstein, "Training for the medical information complex", *21stC*, Special Section: Medicine and the Media, Issue 4.2, Columbia University, Fall, 1999.

[15] Science journalists are hybrid communicators – part journalist, part technologist or scientist – who may be self-trained or trained in a journalism school's science and technology writing curriculum.

involved, to the field itself, or to other parties unjustly accused of irresponsible conduct.

As we shall see later in the book, the Hwang Woo-suk clone-gate is one excellent example in which the media had played both the role of the spinmeister to take the breakthroughs and ran with them, and the role of a detective to unravel the scandal down to the last thread. But here as a sidebar, we will present the case of sex chromosome study as a case in point.

Will the Y Chromosome Decay and Take Men with It?

Down to the genomic level, the genomic sequences of the sex chromosomes can shed light on the behavioral and biological differences between the sexes (male and female).

Besides the 22 pairs of autosomes, a human male has an X and a Y chromosome, while a human female has two X chromosomes. Genetic mutations and diseases such as color blindness, autism and hemophilia that are linked to the X chromosome tend to affect males because they do not have another X to compensate for the faults.[16]

Containing 1,098 genes, or about 5% of the human genome, the X chromosome is linked to more than 300 human diseases. Its genetic code may help to explain why women are so different from men, along with information that may help to improve the diagnosis of illnesses ranging from hemophilia, blindness and autism to obesity and leukemia.[17]

The Y chromosome is an eroded version of the X chromosome, with only a few genes. The X chromosome is also bigger than the Y chromosome. Because females have two copies of X chromosomes, one of them is largely switched off or inactivated in each cell so that, like men, they operate with just one copy functioning. But scientists have long known that the inactivation is not complete, i.e., not all of the genes on the silenced chromosome are inactivated.[18]

A study has found that 15% of the genes on the inactivated copy continues to function, sending out chemical orders for the cell to manufacture specific proteins. A more surprising fact is that about another 10% of the genes, in which the activity level varies widely among woman, from zero in some to varying levels in others. This should be contrasted with the more consistent activity levels in X chromosomes from men, or in other chromosomes in either

[16] Patricia Reaney, "X chromosome shows why women differ from men", *Reuter*, March 16, 2005.
[17] Mark T. Ross, et al, "The DNA sequence of the human X chromosome", *Nature*, 434, March 17, 2005, pp. 325-337.
[18] "Study reveals new difference between the sexes", *The Associated Press*, March 17, 2005.

sex. The effects of these genes from the inactive X chromosome could explain some of the differences between men and women that are not attributable to sex hormones, and the variability in activity levels could explain the differences among women.[19]

Some 300 million years ago, the Y chromosome used to carry the same 1,100 or so genes as its partner, the X chromosome. Because the Y cannot exchange DNA with the X and update its genes, in humans, over time, it has lost all but 16 of its X-related genes through mutation or failure to stay relevant to their owner's survival. Over time the Y, however, has gained some genes from other chromosomes because it is a safe haven for genes that benefit only men, since the Y never enters a woman's body. These added genes, not surprisingly, all have functions involved in making sperm.

This evolutionary decline has led to predictions that the Y chromosome will be completely bereft of functional genes within ten million years. Although there is evidence of gene conversion within massive Y-linked palindromes which runs counter to this hypothesis, most unique Y-linked genes are not situated in palindromes and have no gene conversion partners. The "impending demise" hypothesis thus rests on understanding the degree of conservation of these genes.[20]

David Page of the Whitehead Institute in Cambridge, Massachusetts and an expert on the Y chromosome has been seeking to understand whether the Y will lose yet more genes and lapse into terminal decay, taking men with it. The idea of the Y's extinction is so tantalizing from the perspective of gender politics. But before you leap into conclusion and declare "death to the men," think DNA, and never underestimate the DNA.

In 2003, Page discovered a surprising mechanism that protects the sperm-making genes. These genes exist in pairs, arranged so that when the DNA of the chromosome is folded back on itself, the two copies of the gene are aligned. If one copy of the gene has been hit by a mutation, the cell can repair it by correcting the mismatch in DNA units. The 16 X-related genes are present in only single copies, and similar protection mechanism has not been found.

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[19] Laura Carrel, and Huntington F. Willard, "X-inactivation profile reveals extensive variability in X-linked gene expression in females", *Nature*, 434, March 17, 2005, pp. 400-404.

[20] Jennifer F. Hughes, Helen Skaletsky, Tatyana Pyntikova, Patrick J. Minx, Tina Graves, Steve Rozen, Richard K. Wilson, and David C. Page, "Conservation of Y-linked genes during human evolution revealed by comparative sequencing in chimpanzee", *Nature*, 437, September 1, 2005, pp. 100-103.

A Goal of This Book

The X chromosome study can be put to venal ends as a gender politics; or it can be beneficially used to understand why women make higher doses of certain proteins than men, which could result in differences in both normal life and disease. This example – differences of the sexes – will serve to exemplify many of the touchy issues we will encounter in this book. The controversy surrounding the issue, in fact pales when compared with the controversies over cloning, stem cell research, and regenerative medicine.

To see human reproduction purely as a gift from God overlooks the many dangerous strings attached to that gift. Similarly, to see stem cell research, reproduction technology, and regenerative medicine as just a commercial evil would be to overlook the undeniable good that accompanies that evil. Failing to recognize both sides of these issues – the potential vast benefits and the ethical cost – misses the essential and complexities of these issues. This is an exemplary case that has all the earmarks of the always-Byzantine intersection of science, technology, business, religion and politics.

Particularly in this era in which sound bytes substitute for news, docudramas for history, and book reviews for books, one area where scientific and technological breakthroughs (for example, in biotech and medicine), journalism and scientific writing can act together to great social benefit is in reaching the curious and inquisitive populations – whether intelligent, or technologically and medically underserved populations – with accurate information. This is what I intend to achieve as the author of this book. I am not a journalist; this book offers my diligent notes as a scientist and a fascinated observer.

► Inside This Book

Do you know that:

- Humans have been tinkering with heredity for thousands of years?
- Infanticides of the past were ceremonially elevated to be a form of human sacrifice to dissimulate the main purpose?
- Shadows of our savannah past cast over our modern mores and ways of life?
- Sexual reproduction is evolutionarily inefficient?
- There is an invisible hand guiding the current commercialization of human body shop and human reproduction?
- Animals have been cloned with regularity?

- The cat has been cloned, and so has the dog?
- More than 100,000 assisted reproductive procedures are carried out each year, in the U.S. alone?
- Some thirty human "clones" are born each day, in the U.S. alone?
- Clones will never grow up to be exactly identical to their progenitors?
- Parts of our body can regenerate?
- Legally a clone can run for the U.S. presidency?
- Our first reaction to a human clone can be stranger than you might think?
- …

To find answers to these and many other fascinating and tantalizing questions, we note that on the one end of the human reproduction spectrum are sex and sexual reproduction; on the other end of the spectrum are cloning and stem cell research, and their applications in regenerative medicine. I will now take you for a leisurely "sightseeing" tour between these two extremities of the genetic world.

Unlike sexual reproduction, cloning reproduces identical copies using a form of reproductive technology rather than reproducing naturally. In between the two extremes there are a number of reproductive technologies, including *in vitro* fertilization. In sexual reproduction, we leave the outcome to genetic roulette; with the help of technology, for many people it means having a baby is much safer – for most people – more within their control. But whether technology always brings more good than harm is one big question; and whether the current state of reproductive technology is ready for cloning is yet another issue? Whether our current technological quests into the human body shop and human reproductive system "are imprisoned by the twin gods of technology and profit, a doleful tale of Faustian bargains wrapped in commercial paper, of promissory notes extolling the benefits of a coming technological utopia…" is an issue for the intelligent readers to decide.[21]

To be able to discourse on all these issues, I begin with a primer on genetics to bring all readers up to speed. I start by differentiating living and nonliving things and show that reproduction is very much a part of living things. Of note in this chapter is how our knowledge of genetics and heredity has been accelerating in the past century and a half since the seminal works of Charles Darwin (1809-1882) and Gregory Mendel (1822-1884). Particularly, in the past three decades technological breakthroughs in genetic manipulations

[21] Jeremy Rifkin, In: the Foreword of Andrew Kimbrell, *The Human Body Shop*, (HarperCollins Publishers, New York, 1993).

have been coming forth with breathtaking pace. As a sidebar, I present a case in history where genetics played a critical role to bring out its significance. Readers who are familiar with the fundamentals and timeline of genetics may skip this chapter without loss of continuity.

In Chapter Three I discuss the role of evolution in sexual reproduction by citing supporting evidences from nature and from computer simulations. I also discuss the advantages and disadvantages of sexual reproduction, including sex persists to purge of mutations or sex persists to fight diseases. Sex is also a means to pass on genetic materials. But if passing on genetic materials is the sole purpose of sex, then asexual reproduction will be more effective; cloning, another reproductive technique is also relatively more effective in passing on genetic material than sexual reproduction. In certain sense, our primal sexual instinct can be traced to our ancestral lives on the savannah.

Chapter Four delves into the mating dance, Cupid's chemicals, matrimony, and household arrangements.

As we move across the spectrum of reproduction, from natural sexual reproduction towards cloning, we come across the reasons why people seek the help of reproductive technologies and the various types of reproductive technology available. Thus in Chapter Five, I discuss the quest for perfection as reasons why some people seek the help of reproductive technology. I also go back in time to see that the search for perfection is not something of late, but rather something that had been practiced since antiquity. Nonetheless, "What is perfection?" "What is beauty?" are contestable issues. In this chapter, I also explain infanticides were practiced in ancient times to cull imperfect infants and the founders of Rome were actually survivors of exposure! Having shown that we are beginning to tinker with the genetics of reproduction, I warn of the potential rise of eugenics. In Chapter Six, I discuss *in vitro* fertilization (IVF) as a means to help infertile parents. I also go into detail of the human life cycle development to see how birth defects can be inflicted during the various critical stages of development in the womb.

Just as when I mention "sex," very likely the first thing that comes to mind is copulation; similarly, when I mention "clone," very likely the first thing that comes to mind is reproducing identical copies. In fact, there are at least two types of cloning: reproductive cloning and therapeutic cloning.

In Chapter Seven I provide examples of successful reproductive cloning efforts from the barnyard, from before the time of the celebrated Dolly the sheep to recent cases. Chapter Eight continues the successes of animal cloning to talk about reproductive cloning of something closer to our hearts, pet cloning. The reproductive physiology of each animal can be rather unique.

Thus, the cat has been cloned, and the dog only recently, but the cloning of some other animals is an ongoing quest.

This paves the way for Chapter Nine, which surveys the currently available cloning techniques that have been used for cloning these barnyard animals and pets. This chapter also compares and contrasts these techniques. Unbeknown to many people, twins are natural clones!

Chapter Ten is perhaps the main chapter of the book. It touches on the very controversial issue of human reproductive cloning. This chapter attempts to survey all pertinent aspects of human reproductive cloning, all the way from human development, how the male and the female are formed during development, the key players in human cloning, to health issues with human reproductive cloning. Not surprisingly, the rather successful cloning technologies used in the barnyard are being modified for human cloning. Current cloning technologies, as applied to humans, are still not perfect and human clones are believed to likely have health problems at birth or later in life.

Chapter Eleven returns to therapeutic cloning – a cloning effort much more acceptable than reproductive cloning. I discuss the significance of therapeutic cloning in curing human ailments, concentrating particularly on stem cell research and regenerative medicine. In Chapter Twelve I also take a cursory survey of the different social and political climates in different parts of the world to see why certain countries have laws that are more progressive than others when it comes to guiding therapeutic cloning. I will also dissect a cloning shenanigan of scandalous proportion.

Having discussed the current state of the art of cloning and the potential uses of cloning, I enumerate the legal and ethical issues of cloning in Chapter Thirteen. Issues arise not only within the family, but also in the wider circle of public acceptance. As far as cloning is concerned, our current laws are still wanting. But when the law and ethical concerns are very clear, scientists can always come up with innovative ways to overcome the legal and ethical impasse.

The book closes with Chapter Fourteen to trace the reason why technology has made such great inroads into our lives. It has not only thrown open the gate of natural resource commons, but also the gates of genetic commons and now bodily commons for potential commercial exploitation. The international effort to convert the genetic blueprints of millions of years of evolution to privately held intellectual property represents both the completion of almost a millennium of commercial history and the enclosing of the last remaining frontier of the natural world – the final frontier where no life scientists have

gone before.[22,23] Along the envelope of this final frontier are bodily commons, and activities on the bodily commons such as genetic manipulations, reproductive technologies, cloning, stem cell research, regenerative medicine…[24]

► Best Use of This Book

Despite the fact that the chapters in this book have been organized in a certain logical flow, the chapters can be read or consulted independently. Interested readers will also find the index useful for looking up topics of interest. If you find that the topics of interest to you are spread among different chapters, congratulate yourself because this means that you are a complex, active, thinking, and living reader who has been able to interrelate the pertinent topics.

So without further fellatio and foreplay, I invite you to take this ecstatic odyssey to see why if sex is so good, people still attempt to clone. And why not? All sorts of people from all walks of life have their own perspective on the subjects: cloning, reproduction and sex, stem cell research and regenerative medicine, as well as an insatiable curiosity to read what others have to say about reproduction, the controversial cloning, and the world's oldest obsession – sex.

This is the first book that addresses all these issues all in one volume.

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Sunt bona, sunt quaedam mediocria, sunt plura mala, quae legis hic:
aliter non fit, Avite, liber.[25]

If you are wondering what the sentences mean, they are just a Latin quip to say:

"Here are some good things, some so-so, and some bad.
There's no other way to make a book."

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[22] Andrew Kimbrell, *The Human Body Shop: The engineering and marketing of life*, (Harper, San Francisco, 1993).
[23] Jeremy Rifkin, *The Biotech Century: Harnessing the gene and remaking the world*, (Tarcher/Putnam, New York, 1998).
[24] Hwa A. Lim, *Genetically Yours: Bioinforming, biopharming, and biofarming*, (World Scientific Publishing Co., New Jersey, 2002).
[25] Marcus Valerius Martialis (40–104 AD), *Epigrammata*, XV, 16.

Read on…