Chapter I

Introduction to Biotechnology and the Law

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Technology, or "tech," is a driving force in our culture and economy. Beginning in the late 1950s with the development of television, the invention of the transistor, and the launch of Russian satellite Sputnik, Americans evolved into a culture of technophiles. We drank Tang instant breakfast drink (supposedly a mainstay of the astronauts' space diet) while watching Walter Cronkite count down the minutes to the next nail-biting space launch. We listened to major news and sporting events, such as the Cassius Clay / Sonny Liston title fight, on our miniature transistor radios. Even our automobiles took on design elements of jet airplanes and rocket ships.

During this same time frame, advances in health care also leaped into our lives. The mass production of vaccines and the inoculation of millions of schoolchildren put to an end many devastating diseases that ravaged the previous generations. We witnessed the first heart transplant. And, increased medical sophistication gave women a new level of reproductive and economic freedom. It's no wonder that we began to believe in better living through chemistry.

These technological advances were, at least in part, driven by two foundational scientific events that foretold the future of the tech culture and the tech economy. The first was Bell Labs' invention of the transistor, which resulted in a Nobel Prize for the research team in 1956. That simple, almost inert, replacement for the vacuum tube was the initial and necessary step that made possible powerful microprocessors, each containing millions of circuits. Increasingly smaller chunks of silicon and copper, in turn, led to the development of the modern computer, the creation of the Internet, the invention of previously impossible scientific instruments and processes, and the mass production of electronic consumer devices that pervade virtually every aspect of our lives and have created a global tech economy.

The second, but equally breathtaking, scientific development was the discovery of the DNA double helix by two Cambridge University researchers, which earned them the Nobel Prize in 1962. This first glimpse at the source code of life fueled a research explosion in the biological and medical sciences. Biotech joined semiconductor technology as a potential driver of the new economy and culture.

While the semiconductor revolution (consistent with the tech "law" that microprocessor power doubles every 18 months) blazed along at geometric speed, biotech seemed to linger as the great unfulfilled promise. Even though biotech discoveries and developments continued to progress incrementally, at least from the consumer point of view, biotech did not seem to have the same raging momentum. There are many reasons for this perceived disparity in developmental speeds. Chief among these is that even the most sophisticated microprocessor does not approach the mysterious complexities of living systems. And, because biotech often involves direct or indirect application to human life, there is little room for error. It is one thing for an office computer to crash and quite another for an inadequately tested medical application to impair life and physical well-being. In other words, "Intel Inside" is much different from "Got DNA?"

While the benefits of biotech are too numerous to list, it has also been a source of great controversy. Most recently, developments regarding stem cell research (a biotech poster child), cloning, and athletic performance-enhancement drugs have created public debate that goes far beyond pure science into the realms of ethics, religion, and to the basic definition of

what it is to be human. At the concrete level, more serious are the examples of biotech innovation gone wrong, resulting in death and disabling conditions, such as the Thalidomide babies of the 1960s.

But while biotech research and development moves along at a more deliberate path, recent scientific and economic events have altered the potential, if not the pace, of biotech application. First, the mapping of the human genome, perhaps the greatest biological achievement since the identification of the double helix, has provided medical researchers with enhanced ability to study and treat disease. Second, the investment community, hungry for the addictive excitement and extraordinary profits of the 1990s electronic tech boom, now busted, is looking for a new fix, and biotech may be just the ticket. Third, individual, university, and corporate researchers, seeing what invention, innovation, and intellectual property licensing did for the Microsofts, Apples, and Sonys of the world, are working to build their biotech portfolios in anticipation of greater value, leverage, and profit.

If it isn't already obvious, the biotech boom is largely about money and the race for that money. True, the actual applications may be altruistic, such as creating vaccines to avoid pandemic outbreaks of deadly diseases. Even so, with an aging population of Baby Boomers who are determined to live forever, there is a great deal of money to be made by the successful competitors in the consumer market. As is true of most new technologies, such as the Internet, the initial commercialization that provides the necessary capital to go forward often does not come from the most sophisticated and erudite uses of the technology, but, instead, from consumer applications catering to more superficial wants and desires.

It is this potential for great riches that is causing biotech investors and inventors to seek each other out. One of the best examples of this trend is the relatively recent rise of the university technology transfer office mandated to increase university funding through the commercialization of academic research. Accordingly, investors are willing to take a risk with biotech development despite the high failure rate of new biotech ventures, and the great costs and exceedingly long time frames required to get a biotech product to market.

A. The Biotech Primer

What does this all have to do with a primer on biotechnology law? The answer is this. Biotech has expanded from the largely exclusive realm of a few major corporations and research organizations to include a multitude of biotech start-ups and other entities looking for a stake in this next boom. As a result, legal practitioners who previously were unlikely to be faced with biotech issues are now finding themselves representing these new players. Biotech legal practice involves specialized subject matter and regulatory schemes that, generally, are not part of the business lawyer's repertoire and that can present many hazards for the uninitiated. Because of this expansion of the biotech practice beyond the traditional organizations and their representatives, the American Bar Association's Biotechnology Committee determined that the time was right for a biotech book to help lawyers find their way through the biotech maze.

This primer was never meant to be the last word on biotech law. Instead, it is intended to serve as a starting place for lawyers faced with the challenge of identifying the legal issues and processes that must be faced by their clients in building, marketing, and protecting a biotech business. The authors of the individual chapters, each of whom are experts in their respective fields, have endeavored to provide thorough, yet accessible, overviews of biotech subspecialties with an eye to practical application. We hope you will find this volume a useful and often consulted resource in your biotech practice.

B. Biotech Defined

Before going any further, it is necessary to attempt to come up with a working definition of "biotechnology." In its narrowest and most traditional sense, "biotech" is a term of art that encompasses the alteration and application of living matter—for example, the genetic manipulation of microbes—for a human use. With growth of the industry and the integration of many different technologies, however, a working definition becomes more elusive. As the field has grown, the term has evolved to include research, development, and application of medicines, devices, analytical aids, and therapies intended to contribute to the health and physical well-being of humans. The working definition must also include fields, activities, and

subject matter that indirectly impact or contribute to wellness or lifestyle. For example, the broader definition of biotech includes activities such the development of pesticides, altered or improved agricultural plants and animals intended for food or other uses, microbes engineered to perform specific tasks such as the breakdown of wastes and hazardous substances or the creation of chemical compounds, and even veterinary science aimed at the well-being of the family pet. It is this definition of biotech that is exemplified by the broad-based membership of many biotech industry groups. This is also the definition applied in this primer.

1. Three-Branch Approach

Because of the vastness of biotech development and application, it might be better to define biotech to encompass all things medicinal and/or biological, and then break the area down into three functional branches. The first branch is pharmacological, referred to in the industry as "pharma," which includes medicines, vaccines, and some diagnostic tools. The second branch is medical devices, used for research, diagnostics, and the application of medicines and therapies. The third branch might be described as the genetics, biologics or "Jurassic Park" branch and includes DNA technologies to create medical therapies, as well as agricultural plants and animals.

While this three-branch approach is a good starting point, the demarcation gets very fuzzy at the edges. So, for example, how do you characterize a therapeutic system involving a device that is implanted in a patient to dispense particular medications to specific cells or parts of the body? Or, what about a semiconductor designed to analyze a drop of a patient's blood (the "lab on a chip") to determine the genetic source of a disease? In the end, for the lack of a better taxonomy method, these examples all fall into the general category of "biotech."

C. The Biotech Company Life Cycle

To focus on the application of specific areas of biotech law, it is first necessary to understand the overall biotech company life cycle. Diagram I presents a somewhat simplistic, but generally accurate, depiction of that life cycle. Beginning with idea conception and corporate formation through

product development and marketing, next-level business development, and post-product sale, the lifecycle is intended to provide the reader with a frame of reference for the issues that arise at various points in the biotech business process. Accordingly, we have attempted to organize this primer in a manner consistent with the biotech life cycle. From a practical standpoint, the biotech company life cycle can be divided into four general phases.

1. Phase I: Start-up

The Start-up Phase is characterized by two distinct elements: idea inception and company formation, which are discussed in Chapters II-V. Biotech is an idea-driven industry dependent upon creative minds to come up with scientific discoveries that can be converted into new products. To be economically successful, however, those ideas and inventions must be backed by substantial financial investment within the context of a company structure. Therefore, representation of the start-up company requires expertise in both intellectual property protection and corporate formation and financing.

a. Intellectual Property

On the intellectual property side of the start-up equation, fortunes can be lost for failure to take the proper legal steps to protect discoveries and applications. This step in the legal process is the realm of the intellectual property lawyer with expertise in legal specialties including patent, trade secret, trademark, and copyright. Recognition of this representational need can go a long way toward building a foundation that will contribute greatly to acquiring adequate business development funding and achieving maximum profitability at the next major stage of biotech business development.

For the business lawyer representing the biotech client, and particularly the start-up client, it is very important to get intellectual property counsel involved early in the process. Patent lawyers, who by definition are required to have technical training in addition to a law degree, generally have backgrounds that mirror their clients' scientific disciplines. For example, semiconductor patent attorneys also tend to be electrical engineers ("Double E's") or chemical engineers ("Chem E's"), like their clients or their clients' inventors. Similarly, in the world of biotech, patent

lawyers tend to come from the life sciences disciplines and often hold Ph.D.'s in relevant areas such as biochemistry and molecular biology. Such team efforts help avoid the pitfalls inherent in the intellectual property protection process and also set the stage for a successful business strategy.

b. Company Formation

While company formation is important for any start-up business, it is particularly crucial for the biotech start-up. In contrast to the Internet start-ups, which seemed to move from inception to an individual public offering about as soon as the domain name was registered, the biotech company may take up to 10 years from idea inception before a product has been approved for sale. Because of this long lead time, strategic company formation is critical to keeping the company, its key executives, and its brain power together for the duration of the life cycle. Therefore, the business lawyer involved in biotech company formation must be able to think well into the future and to anticipate the types of corporate issues that might be triggered, including long-term corporate governance, key executive longevity, and the allocation of corporate equity.

c. Investment Capital

These business formation issues are further complicated by the fact that getting a biotech product to market is a costly enterprise that will not show a profit for years after idea inception. Therefore, the biotech start-up needs great amounts of outside investment capital from venture capitalists, sophisticated "angels," or the large biotech company seeking to purchase or partner with the start-up. Once money is at issue, the financial relationships between the start-up principals and the outside investors can become very complex as the start-up's equity begins to migrate away from the principals to those investors. Therefore, the start-up's lawyer has the challenge of helping her client form a company that protects the principals' interests while also being financially attractive to the essential outside investors.

Even though all of the players are focused, more or less, on the money, as with any tech speculation, there is a natural tension between investors and inventors. Typically, the outside money people are looking for speedy returns on investment. Inventors, on the other hand, and particularly aca-

demic inventors, are often driven by an obligation to complete fully the necessary research without shortcuts that could cause professional embarrassment. It is at this early intersection where biotech lawyers can work with their clients by creating business entities specifically tailored to address the need for speed while avoiding unnecessary research and development risks that could lead to exorbitant liability and business failure. By helping the client select a strong board of directors and the assignment of watchdogs, such as a science advisory board, the company can create a sort of business détente between investors and inventors that may allow them to survive the tumultuous early years of the relationship and see them through to business success**.**

2. Phase II: Early Development

Once the basic foundation of the start-up is in place, the new company is now on the long road to development, regulatory approval, and product sale. The early development phase is marked by continued financing issues, the search for development partners, the beginnings of the regulatory trials process, and the business issues faced by any tech company as it grows beyond a few principals to become a more complex organization. Chapters VI-IX address many of these early development issues.

a. Additional Investment

If there is one reoccurring theme throughout the biotech business lifecycle, it is financing and the virtually constant need for new capital. Financing issues are not as critical for the larger, established biotech companies with a diversified portfolio of products at different stages of maturity. For the start-up, however, finding capital and the right partners often means the difference between a successful business and early demise. These relationships can take different forms, both public funding and private investment, each of which presents strategic issues for the new company and challenges the biotech business lawyer in helping to shepherd his client to success.

b. The Regulatory Track

The early development phase is also marked by the all-important relationships between the company and the relevant governmental agencies, as well as the beginning of the years of scientific testing and trials necessary to ultimately achieve regulatory approval. Because biotech company development is based on an inherent tension between time and money, missteps in terms of damage to agency relationships or failure to comply with the required regulatory protocols can result in serious delays that strain the time/money critical path and endanger the company's chances for success. Here, the biotech lawyer, who will likely be better versed in regulatory compliance and relationship building than his science-driven client, can provide great value by helping the company to avoid the small missteps that often lead to business disaster.

c. Business Growth and Complexity

Once the fledging biotech company grows beyond the initial principals, it will become a more complex business organization, complete with employees and consultants who may have personal agendas different from those of the founders. As the principals move from the role of researchers to business managers, counsel can be invaluable in helping to set up these relationships in a manner that protects the company's assets and mitigates the inevitable tensions. For example, tech companies are typically havens for bright young scientists and engineers anxious to apply their training and make a name for themselves in their respective disciplines. It is also a well-recognized phenomenon that a disproportional degree of the actual idea advancement that occurs in tech companies is done by these young innovators fresh from academia and exposure to the most recent theoretical developments. When their ambitions motivate them to make their own ways and, perhaps, to start their own companies, there are often disputes about who owns the research and inventions. By anticipating these issues, the legal counsel can help his clients create employer/employee relations that may not stop the departure of brain power, but could prevent them from leaving with the family jewels.

3. Phase III: Later-Stage Development and Product Approval

In reality, the early stages of the biotech regulatory process are only a warm-up for the real race, which is clinical trials and final agency product approval. Only after this stage is completed is the biotech company positioned to reap the rewards from years of investment and hard work. But, successful navigation of this phase requires a high level of legal proficiency in the respective regulatory disciplines. As a result, this is another point in the process where the lead biotech lawyer will likely want to partner with other lawyers with specialized expertise—this time, experienced biotech regulatory lawyers.

The unknown wonders of biological systems are yet to be revealed, in addition to the potential for great harm associated with human tampering. It is no wonder that biotech is subject to an exceedingly complex set of federal and state laws and regulations. These regulatory schemes dictate virtually every aspect of biotech development from research protocols to product testing, clinical trials, record keeping, marketing, labeling and packaging. Given the number and levels of agencies regulating some aspect of biotech, it is no wonder that the field is a virtual sea of acronyms comparable only to the rise of environmental regulation in the 1980s. Any given biotech regulatory analysis might include references to the FDA, USDA, EPA, and so on, as well as to the procedures prescribed by each, also referred to in their acronym form. The biotech business lawyer or general counsel charting an efficient and effective course through the agency morass needs at least a conversational familiarity with the language and an understanding of the scope and reach of the respective agencies. Chapters 10-15 will provide the business lawyer with a strong and accessible first-reference source.

4. Phase IV: Challenges Facing the Now Mature Company

While successful completion of clinical trials is the last major step to getting a product to market, the biotech company's business and legal challenges continue as the company shepherds its products, builds its capital, and looks for the next innovation, application, or market. As with any mature company, these related issues involve future business development, additional regulatory strictures, and potential liability.

a. Commercialization

On the business development side, the ownership of an approved product can result in a biotech company becoming much more attractive to outside investors and other large established biotech companies. Therefore, if the biotech company has not already entered into such partnerships, it is now in a position to seek additional investment and commercialization relationships aggressively, thus creating a new role for legal counsel. In addition, the biotech company will likely want to seek other markets for its product beyond the United States. Entry into the international marketplace will require the company and its legal counsel to engage in and comply with the separate regulatory schemes in each new jurisdiction. Finally, while the biotech company may possess an exclusive right to produce and market its product, that right is limited to a term of years. Consistent with the business adage of "stand still and die," the biotech company will want to explore ways to extend that limited monopoly through additional product applications and new "follow on" products that may not require the same level of, and time for, regulatory scrutiny.

b. Regulatory Oversight

Regulatory requirements do not end with product approval. The biotech company is required to monitor the performance of its product, report any side effects or dangers that are discovered in the course of its use, and take the actions necessary to avoid or mitigate those dangers, including issuing warnings, recalling product, and, possibly, termination of sales. In addition, there are strict regulations governing how a product may be marketed and for what purposes. Marketing a product for purposes beyond the scope of the agency approval can subject the biotech company to severe financial penalties and additional regulatory limitations.

c. Litigation

Success, however, often attracts opportunists, competitors, accusers, and thieves, against whom the biotech lawyer must be ready to defend her client. In addition to the typical civil litigation experienced by other businesses, the types of disputes most often faced by biotech companies are

those relating to intellectual property rights and the safety of their products. The lure of a commercially successful product often entices infringers, both domestic and international, to take advantage of the biotech company's years of research, investment, and marketing to achieve quick and ill-gotten profits. A strong intellectual property enforcement program, although often expensive to fund, can send a strong message to potential infringers while, at the same time, providing investors and public shareholders with a sense of security that can result in increased company value. Likewise, continuous monitoring of product performance coupled with a willingness to take responsible action can go a long way toward deflecting potentially crippling product liability suits and protecting the brand.

D. Conclusion

This introduction merely provides an overview of the world of biotech law. The real value of this primer is in the pages that follow, which provide the expert analysis and recommendations of the biotech practitioners who have graciously contributed to this effort. We are all greatly indebted to these legal experts. We would also like to thank the American Bar Association for its vision and continued support of this project. Biotech law is a dynamic subject matter, and this primer provides a snapshot in time of this rapidly growing and evolving area. What is particularly noteworthy about this effort is that it represents what we believe to be the most comprehensive resource on this highly diverse and increasingly pervasive area of law, for which our authors must be thanked.

Glossary

University of California – Berkeley*
Division of Agricultural and Natural Resources
Statewide Biotechnology Workgroup
www.ucbiotech.org

Agrobacterium Microorganism (bacterium) that produces crown gall disease in the wild; it does so by introducing a part of its genetic material into the plant to direct it to make compounds it needs to live.

Agro-ecosystem A complex mixture of pastures, farm fields, businesses, home sites, natural habitats, and cities and towns.

Agronomy The science and economics of crop production; management of farm land.

Antibiotic Chemical sometimes synthesized by other organisms, sometimes manufactured, that is a deterrent to other organisms.

Antibiotic resistance Resistance mechanisms to antibiotics exist that render cells "immune" to the antibiotic; the genes for these characteristics are found in certain organisms. The genes are used in some genetic-engineering experiments as tools to identify cells that have received new DNA.

Antibody Protein produced by humans and higher animals in response to the presence of another protein, termed an antigen. The interaction of the antigen and the antibody can cause certain human health problems, like allergies or autoimmune diseases.

Antigen Substance, usually a protein, that when introduced into the body causes the body to make an antibody, usually specific to the antigen.

Autoradiography Technique used to visualize DNA that is labeled with radioactivity. It can be used to determine the presence or absence of certain DNA fragments and the length or number of DNA molecules.

Bacillus thuringiensis See Bt.

Bacteriophage Virus that infects bacteria, sometimes causing the death of the host organism.

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* Special Thanks to the University of California – Berkeley Division of Agricultural and Natural Resources for its permission to use this glossary. See www.ucbiotech.org for updates of this site.

Bacterium/pl. bacteria Simplest form of life that exists as a single cell without a distinct structure called a nucleus that contains the genetic information of the cell. Also known as a prokaryote.

Base pair One unit of DNA composed of two complementary nucleic acid molecules (nucleotides) on opposing strands of DNA. The base adenosine always pairs with thymidine; the base guanidine pairs with cytidine.

Biodegradable Capable of being broken down by microorganisms. Breakdown products can often be re-used by other organisms as food and energy sources.

Bioinformatics Assembly of data from genomic analysis into accessible and usable forms.

Biomass Total weight of all organisms in a sample after drying.

Biomining Use of living organisms (e.g., bacteria, plants) to accumulate in their cells precious metals, like gold, silver, platinum, from mine tailings. Organisms can be collected and the metal recovered.

Bioreactor Vessel or container in which a biological reaction occurs. Often used in manufacturing efforts to produce pharmaceuticals.

Bioremediation Use of organisms (e.g., bacteria, plants) to remove environmental contaminants from soils and water. The contaminants can include organic molecules, like PCPs, or metals, like mercury, selenium and lead.

Biotechnology See "Know GMOs" Basics section. Historically means use of an organism to perform a function, like making cheese or wine. Contemporary meaning includes the use of the new genetic tools of recombinant DNA to make a new genetically modified organism.

BST/BGH Bovine somatotropin or bovine growth hormone. This is a hormone produced by cattle naturally. The genetic information for this hormone was cloned and can now be made in microorganisms for injection into cattle to increase milk production.

Bt Bacillus thuringiensis. A naturally occurring microorganism that produces a toxin that only kills organisms with alkaling stomachs, namely insect larvae. As a whole killed organism, this toxin has been used for biological control for decades. The genetic information that encodes the toxin was identified and moved into plants to make them insect tolerant.

"Bug" Colloquial or slang term for bacterium.

Callus Undifferentiated plant cells resulting from cell division of differentiated organs, such as leaves, roots, seeds. The undifferentiated callus can be triggered by hormones to develop into a whole plant.

cDNA DNA that is synthesized to be complementary to an mRNA molecule. By definition a cDNA represents a portion of the DNA that specifies a protein (is translated). If the sequence of the cDNA is known, by complementarity, the sequence of the DNA is known.

Cell Basic unit of life, the smallest living structure that is able to function independently. The human body is composed of trillions of cells; bacteria are a single cell.

Centimorgan Unit of measurement for studying genetics. One centimorgan is equivalent to a 0.01 chance that a particular genetic location (locus) will be separate from a particular marker in a single generation. In humans a centimorgan is about 1 million base pairs.

Chromosome Spring-like structures of tightly coiled DNA that contains the genetic information (genes) that instructs the cell on its function. Genes are present on chromosomes. Organisms contain differing but characteristic numbers of chromosomes; humans contain 2

Clone Exact genetic replica of a single unit of the genetic information in the form of DNA (e.g., gene) or of an entire cell or organism.

Cloning Means of isolating particular parts of the genome in small fragments of DNA and making copies of and studying the sequence in another organism. Can also mean the process of producing by nonsexual means an identical copy of an organism.

Codon Unit of three nucleotide bases contained in the DNA and mRNA that specifies the information for one of the 20 amino acids; the entire array of codons is known as the genetic code. Strings of codons form genes and strings of genes form chromosomes.

Contigs Group of DNA sequences that are overlapping or contiguous on the genome. Such sequences are necessary to obtain the entire, uninterrupted sequence of the genome.

Cosmids Vehicles that are used to separate out discrete sections of the DNA for cloning purposes. These vehicles contain bacterial phage lambda DNA to allow them to make copies of themselves in their bacterial host and also DNA fragments of about 40,000 base pairs from the source being studied.

Cross-infection The simultaneous infection with different types of viruses.

Culture A particular type or subset of organisms growing under controlled conditions in the laboratory; a cell culture.

Cytoplasm Liquid portion inside of a cell in which other parts of the cell reside, e.g., ribosomes, mitochondria.

Dietary supplement Food product ingested to correct a perceived deficit in the overall diet; typically not a whole food.

DNA Deoxyribonucleic acid. The chemical building block of the genetic information in the cell, genes; it specifies the characteristics of most living organisms. The DNA is usually in the form of two complementary strands.

DNA probe Short piece of DNA that is complementary to a specific piece of DNA in the cell. By marking the probe, it is possible to visualize whether the DNA is present in the genetic material. This forms the basis for DNA diagnostics.

E. coli/Escherichia coli Specific single-celled organism or bacterium that lives in the intestinal tract of most vertebrates; some strains of this bacteria are harmful to humans, e.g., E. coli 0157. This organism has been used to do much of the genetic manipulation with recombinant DNA methods because it is well-characterized genetically.

Ecology Study of interaction of organisms with the physical environment and with one another.

Ecosystem Living system that includes all organisms in a "natural community" that live and interact with their environment.

Electrophoresis Method using an electrical field which leads to the separation of proteins or DNA fragments based on their size. Smaller proteins or DNA fragments move faster; larger ones slower. Samples are normally placed in the electrical field loaded in a gel-like substance, called agar or agarose.

Endophyte Organism living inside another organism. In some cases the endophyte cannot live outside its host, an "obligate endophyte"; in other cases the endophyte can live outside its host, "facultative endophyte."

Enzyme Protein that facilitates or speeds up certain chemical reactions. Enzymes are used inside of cells to aid in cell growth and reproduction. Enzymes have also been isolated from organisms and used in products like cheese and laundry detergents.

Eucaryote/eukaryote Organism that contains a defined nucleus; includes all organisms except viruses, bacteria, and blue-green algae, which are known as prokaryotes.

Exons Portion of the DNA sequence that codes for the protein parts of the gene.

Explant Portion of living tissue that is removed from the organism (e.g., plant) and cultured independently in the laboratory.

Fermentation Conversion of one substance into a more desirable substance through the actions of microorganisms under controlled growth conditions.

Functional food Food that provides health benefits beyond energy and essential nutrients (e.g., yogurt, which promotes beneficial microflora in the gut).

Fungicide Some agent, like a chemical, that kills fungi.

Fungus/ pl. fungi Type of microorganism that lacks chlorophyll used for photosynthesis, for example, yeasts and molds.

Gene Segment of DNA specifying a unit of genetic information; an ordered sequence of nucleotide base pairs that produce a certain product that has a specific function.

Gene flow The incorporation of genes from one organism into the complement of genes in another population of organisms.

Gene mapping Determination of the relative locations of genetic information (genes) on chromosomes.

Gene pool The combination of all genes and gene variations of a specified group, e.g., species.

Genetics Study of the patterns of inheritance of genetic information in organisms.

Genome Entire genetic material in an organism, comprising all chromosomes.

Genomic library Collection of DNA clones that represent the entire genome.

Genomics Molecular characterization of all the genes and gene products of a species.

Genotype Collection of genetic material in an organism that gives rise to its characteristics.

Germplasm

GMO Genetically modified organism, term used to refer to organisms modified by the new methods of genetic engineering.

Herbal supplement The subset of botanical supplements derived from herbaceous plants.

Hybridization 1. Joining of two complementary strands of DNA, or of DNA and RNA, to form a double-stranded molecule. 2. Process of sexual exchange between two plants to produce hybrid plants.

Intellectual property Intellectual property rights include patent rights, plant variety protection certificates, unpublished patent applications, and inventions that may or may not be legally protectable.

Intron DNA sequences that interrupt the protein-coding sequence of a gene; introns are transcribed into mRNA but the sequences are eliminated from the RNA before it is used to make protein.

Immunoassay Diagnostic assay that uses antibodies to confirm the presence/absence of certain compounds.

In vitro Direct translation is "in glass." Describes biological reactions that take place in laboratory containers, such as test tubes. Although they attempt to achieve conditions in living organisms, such reactions only simulate real-life situations.

In vivo Direct translation is "in life." Describes biological reactions taking place inside living organisms.

Library Collection of fragments of the genome in an unordered array. Relationships of fragments can be determined by physical (sequencing, RFLP maps, ESTs) or genetic means.

Linkage Physical relationship between markers on a chromosome; the linkage number gives an estimate of the probability that two markers will be inherited together. The closer together the markers, the lower the probability that they will be separated during chromosome pairing after fertilization.

Locus Location of a gene on a chromosome.

Marker Identifiable physical location on a chromosome, the inheritance of which can be monitored.

Marker gene Gene used during genetic engineering attempts that helps to identify cells that have received new DNA. Genes usually include either a selection advantage, e.g., antibiotic or herbicide resistance, or visualization advantage, e.g., beta glucuronidase (GUS) or green fluorescent protein (GFP) expression.

Metabolites Substances that are used by or produced by enzyme reactions or other metabolic processes.

Microbe Any small, microscopic organism.

Micrometer Unit used for measurement, equivalent to 10-6 meters or one-millionth of a meter; abbreviation um.

Molecular breeding Identification and evaluation of useful traits in breeding programs using marker-assisted selection.

Monoclonal antibody Highly specific, purified antibody derived from only one subset of cells and which recognizes only one antigen or epitope.

Morphology Form and structure of organisms, like plants and animals; their structural appearance.

Mutagen Agent or process that causes mutation, like chemicals, radiation or transposable elements.

Mutant Variant organism that differs from its parent because of mutation.

Mutation Genetic change caused by natural phenomena or by use of mutagens. Stable mutations in genes are passed on to offspring; unstable mutations are not. From latin word for "change."

Mycorrhiza/pl. mycorrhizae Fungal microorganisms that form close, symbiotic relationships with the roots of higher plants. Such relationships often provide the plant with micronutrients.

Nanometer Unit used for measurement, equivalent to 10-9 meters or one-billionth of a meter; abbreviation nm.

Nitrogen fixation Change of atmospheric nitrogen into nitrogen compounds by certain microorganisms, usually living in close relationship with plant roots. Nitrogen compounds can be used by plants as food. See **rhizobia**.

Nodule Swelling or enlargement of roots of plants, predominantly legumes, due to the presence of nitrogen-fixing microorganisms.

Nutraceutical Food or food product that decreases the risk of disease establishment or progression.

Nucleic acids Long chains of molecules known as nucleotides, that perform important functions in the cell; two kinds of nucleic acids function in the cell, i.e., DNA and RNA.

Nucleotide Building blocks of DNA and RNA. Nucleotides are composed of phosphate, sugar, and one of four bases, adenine, guanine, cytosine and uracil (RNA) or thymine (DNA). Three bases form a codon, which specifies a particular amino acid; amino acids are strung together to form proteins. Strings of thousands of nucleotides form a DNA or RNA molecule.

Nucleus Central compartment in cells of higher organisms (eukaryotes); it houses most of the heritable genetic information in a cell in higher organisms.

Oligonucleotide probe Short piece of DNA that is complementary to a specific piece of DNA in the cell. By marking the probe, it is possible to visualize whether the DNA is present in the genetic material. This forms the basis for DNA diagnostics.

Pathogen Any organism capable of producing disease.

Peptide Two or more amino acids, building blocks of proteins, that are chemically linked to each other.

Phage Virus that infects bacteria, sometimes causing the death of the host organism.

Phenotype Visible characteristics or traits of an organism, like a plant or an animal.

Phytochemical Substances found in plants and plant-derived products.

Plasmid Independent, free-floating circular piece of DNA in a bacterium, capable of making copies of itself in the host cell. Plasmids can be used in recombinant DNA experiments to clone genes from other organisms and make large quantities of their DNA.

Polymerase chain reaction Commonly used technique that leads to the selective amplification of a nucleotide sequence of interest. The amplified DNA becomes the predominant sequence in the mixture upon PCR amplification. Often used to make nucleotide probes for diagnostics.

Polymeorphysm A visible or molecular difference between two contrasting individuals.

Prion A small protein found in the brain cell membrane. The distorted form of this protein is responsible for mad cow disease and causes new Creutzfeld-Jakob disease in humans.

Prokaryote/procaryote Microbial or bacterial cell lacking a true nucleus. Its genetic information is usually in the form of a single long strand of DNA; plasmids exist separate from the primary DNA strand. Contrast with eukaryote.

Promoter A control region of a gene that determines in which tissue and at what time points a gene product is produced.

Proteomics The study of proteins.

Protoplast Cellular material, cytoplasm, mitochondria, nucleus, etc., remaining after the cell wall has been removed.

PST Porcine somatotropin. Version of growth hormone or somatotropin produced by swine.

Recombinant DNA (Abbr. rDNA) As a process: broad range of techniques that involve the manipulation of the genetic material of organisms, also known as genetic engineering or biotechnology. As a product: fragments of DNA from two sources or organisms joined together.

Regeneration Process of triggering the formation of whole plants from cells

removed from the plant and grown in the laboratory under controlled growth conditions. One of the steps involved in the process of demonstrating **totipotency**.

Restriction enzymes Class of enzymes that cut DNA at specific locations identified by the sequence of the nucleotides. At the site of the cut, other pieces of DNA, sometimes sharing the same recognition sequence, can be inserted.

Rhizobia Microorganisms or bacteria belonging to the genus Rhizobium, which are commonly involved in fixing nitrogen; normally reside in close relationship (symbiotic) with roots of leguminous plants.

Rhizosphere Area of soil near the plant roots, normally the location of large populations of microorganisms.

Ribonucleic acid (Abbr. RNA) Chemical chains made up on the sugar ribose attached to nucleic acid molecules. Different types of RNA exist in cells, some of which serve as the immediate code for proteins, some of which are involved in the physical process of protein synthesis. RNA can also serve instead of DNA as the only genetic information in certain viruses.

Sexual reproduction Process in which two cells, termed gametes, come together to form one fertilized cell that contains genetic information from both parental cells.

Somaclonal variation Genetic changes that occur within non-reproductive cells, often during the process of culturing the cells in the laboratory. Some of these changes are heritable and result from actual changes in the genetic code and some changes are only present for a si

Species Term used to describe the group of like individuals. Classically, species were defined as organisms that share certain characteristics.

Somatotropin Protein hormone secreted by a special organ in mammals, the pituitary gland, and each animal produces its own specific version of the hormone that is active in its own species and in species of lower order but not higher. The hormone directs milk production.

Spore Particular form of certain microbes that allows the organisms to survive in a dormant stage until conditions improve, at which time the spores can germinate and the life cycle resumes.

Sterile Free of living organisms; the term usually refers to lack of microorganisms or bacteria. Process of sterilization refers to killing all life forms by heating, chemical treatment or other means.

Strain Different organism within same species.

Substrate Material or substance acted upon by an enzyme.

Symbiosis Two or more dissimilar organisms living together in close association with one another. Includes parasitism, where one of the organisms harms the other(s), mutualism, where association is advantageous to all, and commensalism, where association is advantageous to one organism but doesn't affect other organism(s).

Tissue culture Process of introducing living tissue into culture in the laboratory where tissues or cells can be grown for extended periods of time.

Totipotency Capability of certain cells to be cultured in the laboratory and undergo sustained cell divisions. Application of hormonal and other signals triggers the tissue to undergo a programmed, developmental pathway that leads to the re-formation of the entire organism.

Transformation Process of introducing into an organism new genetic information that can be stably maintained.

Transgenic Organism that contains genetic materials introduced through recombinant DNA techniques. Usually implies that organism contains DNA from another organism.

Transposon Naturally occurring DNA sequence that is capable of moving its location within the genome; movement is due to the presence of an enzyme that can mediate the movement and which is encoded within the transposon itself. Transposable elements are responsible

Vaccine Utilization of a killed or debilitated organism or a part of its contents that is capable of inducing protection against the disease caused by that organism.

Value-added Trait introduced into an organism/plant that gives that organism added value, like the addition of a valued trait or the capability to produce a new, valued substance, like a pharmaceutical or a biomaterial.

Vector Agent, such as an insect, virus or plasmid, that is able to mechanically or biologically transfer itself or its contents from one organism to another. In genetic engineering this refers to any virus or plasmid into which a gene is introduced and which is

Virulence Degree or severity of disease-causing potential of an organism.

Virus Small genetic element composed of either DNA or RNA that is protected by a protein coat. Virus is capable of existing either inside a cell (intracellular) or outside a cell (extracellular). Viruses cannot make copies of themselves without invading another cell and using some of its machinery.

Wild-type Organism as discovered in nature.

Yeast Kind of fungi or microbe. Yeasts are used in bread-, wine-, and beer-making to produce fermentation.