Ethics and Biotechnology

After completing this chapter, you should be able to:

- Define bioethics and explain how it relates to biotechnology.
- Understand and apply different approaches to ethical thought.
- Identify potential ethical dilemmas associated with biotechnology.
- Pose questions and approaches that address the ethical problems identified in this chapter.
- Identify outcomes and pitfalls associated with different ethical approaches.
- Discuss interactions among science, economics, communication, and public policy.
- Understand and explain controversies and ethical issues surrounding genetic testing, stem cells, genetic modified organisms, cloning, and other bioethical topics.
- Describe possible pathways to a career in bioethics.

Bioethics considers topics such as human life. John and Lucinda Borden testified at a U.S. House hearing on embryo research. John holds their twins Luke and Mark; Lucinda holds a picture of the twins as embryos. Luke and Mark were adopted as frozen embryos.

Manny Ceneta/AFP/Newscom.

In some ways, **ethics** might seem like plain old common sense. Of course it is unethical to intentionally cause cancer in a group of people without their knowledge just to test your new anticancer drug. But in many cases the choices are not so clear-cut. Often the decisions must deal with potential trade-offs, compromises, or possibly even sacrifices. Bioethics deals with some of the most fundamental questions confronting our society. And in many respects the decisions made now can affect the future of science, humanity, and the world in which we live. The intent of this chapter is not to tell you what to think about bioethics. Instead, the intent is to get you to understand *how* to think about bioethics—to encourage you to ask questions, to think about how to ask the right questions, acquire all the facts, and make decisions based on information rather than emotional reactions.

FORECASTING THE FUTURE

Ethics and related issues in all areas of science are increasingly gaining attention among the public, scientists, politicians and others. In the future, as new biotechnology applications emerge, discussions and increased awareness of ethical concerns associated with these applications will almost always precede the actual development of the application. Using stem cells as an example, well before any stem cell applications were proven and ready to be implemented, ethicists were discussing *potential* ethical issues of stem cell applications. With the way information is rapidly communicated now, there will be few situations in which a biotechnology application or discovery is not preceded by ethical debate. So rather than trying to do the nearly impossible—that is, to forecast the most immediately pressing ethical issues that biotechnology will encounter over the next few years—we want to emphasis that, increasingly, ethical thinking and decision making will be important skills for the future. Almost every application you have learned about in this book, including those we forecast as hot areas in the future, will have significant ethical components to them.

1 What Is Ethics?

Ethics identifies a code of values for our actions, especially toward other humans. In simple terms, ethics could be considered a guide to separate right from wrong and good from evil. The area of ethics that deals with the implications of biological research and biotechnological applications, especially regarding medicine, is called **bioethics**. It considers social and moral aspects and potential outcomes of the use of biological and medical technologies.

It is important for you to appreciate that ethics is a *dilemma-based discipline*. Ethical dilemmas arise when an important problem or situation requires careful consideration and thought to make what one believes to be sound ethical decisions.

One fundamental question that should be asked in dealing with bioethical issues is not "Can this be done?" but "Should this be done?" And if something should be done, the question becomes "How can it be done in the right way?" Such questions are important for everyone to consider, especially in areas of biotechnology, where discoveries and their applications can have a great impact on human health and the environment. These questions get to the heart of not only society but also of science and its role in society.

For example, consider the photo shown in **Figure 1**. Scientists have implanted mouse cells into chicken embryos to demonstrate that the mouse cells could receive signals from the chicken embryo to induce development of teeth—something that does not normally occur in chickens. Chick embryos started to form teeth, but they were not allowed to develop into adults. But some people are outraged at experiments such as this because it creates images of "Frankenstein-like" mutant chickens with teeth that aren't normal. The rooster image shown in Figure 1 was created by photographers for shock value and headlines; it

FIGURE 1 Growing Teeth in Chickens. Should This Be Done? The image shown here is an artificial depiction of a rooster with teeth; no such animal actually exists. This is a deliberately inaccurate image presented for its shock value and to stimulate your thinking about bioethics.

Eric Carlson.

is not real. So just because technology is available to create a chicken embryo with teeth, should it be done in the first place? Should the embryo be allowed to grow into an adult chicken to see if it will develop teeth? Is this ethical? What do you think? For more information on the research we refer to here, see the paper by Mitsiadis et al. in the reference list on the Companion Website.

Approaches to Ethical Decision Making

Before we explore bioethical issues, we first examine some of the more important methods of ethical thought. The study of ethics is as old as humanity itself. Questions of our duties and responsibilities to other members of the human community have been with us for ages. Hippocrates (c. 460–361 B.C.) might be considered the first **bioethicist**. He emphasized the patient rather than the disease in his practice of medicine, viewing the worth of the individual and the sanctity of human life as of primary importance. For years, physicians have pledged to follow the central tenets of the **Hippocratic Oath**—"do not kill," "to help, or at least do no harm"—in their duty to patients and to their profession.

Ethical thought and methods to approach problems can often be divided between two main viewpoints (although there are certainly other approaches as well). The **utilitarian approach**, or consequential ethics, started with the Scottish philosopher Jeremy Bentham (1748–1832) and the English philosopher John Stuart Mill (1806–1873). This approach states that something is good if it is useful, and an action is moral if it produces the "greatest good for the greatest number." The second main approach—the **deontological (Kantian) approach**, or duty ethics—comes primarily from the German philosopher Immanuel Kant (1724–1804) and focuses on certain imperatives, or absolute principles, which we should follow out of a sense of duty and should dictate our actions.

Modern bioethics can be traced to much more recent times and is primarily the work of two ethicists in the 1970s: Joseph Fletcher and Paul Ramsey. These men refined the two primary approaches to ethical thought mentioned—Fletcher for utilitarianism (also termed "situational ethics") and Ramsey for deontology (or "objectivism").

Utilitarianism emphasizes consequences, not intentions. Another way to phrase this emphasis is that "the ends justify the means." The idea is to calculate what the consequences of an action would be and to weigh different consequences against one another. If we can analyze various courses of action to determine which will have the greatest positive effect on the greatest number of people, then we can provide an answer to the question of what we ought to do. In some ways, this is an elegant method for making decisions. All avenues can be assessed for potential benefit, and the decision becomes more quantitative. The disadvantage of this calculation is that we must assign a value to all of the things considered. How do we assign these values? Some would say that some of the most important things in life (love and family) are not easily quantified, whereas other things (material goods and life span) could be emphasized in the calculations because they are quantifiable. Another source of concern could also be the individual doing the calculating and assigning values. For example, the utilitarian calculation would be less than ideal if done by someone who believed that males are worth more than females or that the primary consideration should be the profit margin.

Deontology, or objectivism, starts from the point of view that there are at least some absolutes (definitive rules that cannot be broken) and that we have a moral obligation or commitment to adhere to these absolutes. One absolute usually mentioned is for the value of human life, expressed by Kant in this way: "Act in such a way that you always treat humanity, whether in your own person or in the person of any other, never simply as a means, but always at the same time as an end." Another way to say this is in terms of respect for others—that we ought to treat others as ends in themselves rather than as means to an end.

This approach has often been associated with religious traditions, but it is a mistaken notion to assume that an objective ethical approach is solely a religious approach or even that all religious approaches to ethical issues begin with the same absolutes. Deeply held convictions are just that—personal points of reference to which an individual adheres. An advantage of objectivism is that it gives firm guidelines in many situations in which ethical decisions are required, providing a clear-cut ethical formula for decision making. A disadvantage of this approach is that it may be, or at least may be perceived to be, too rigid in its decision-making process, not taking what may be important factors into account or considering possible changes in values. And there may be situations or issues where no clear conviction or absolute exists, requiring further examination of the issue to define the moral imperatives and discern the course of action.

To illustrate the difference between utilitarianism and objectivism, consider a situation in which a person is desperately hungry and has no money to buy food. Wandering by a store, the person sees a loaf of bread left out on a table. A utilitarian calculation might take into account the person's need, the available food, and the minuscule loss in value to the store and consider that it would be okay to take the bread. An objectivist

approach might have the absolute "it is wrong to steal" and consider it unethical to take the bread.

Note that there can be other ethical approaches and methods beyond the two main approaches mentioned here, and even these two approaches to ethical decision making can sometimes be blended. In approaching ethical decisions, a key objective is to gather information, consider the facts, and make a thoughtful, informed decision. And in debates on ethically contentious issues, it is neither wise nor polite to deride or belittle another person's decision. Be sensitive to the effects of your own conduct. Aim to understand and defend your own ethical decisions rationally, and strive to consider the decisions of others.

The idea of the likelihood of an event, the **statistical probability**, is another important concept to keep in mind in making ethical decisions. It is crucial to determine accurately what chance exists for a "bad" event to happen. Another consideration might be just how negative the effect of the possible event would be. Because many consequences take time to develop, the probability of an outcome occurring must be part of the consideration.

Bioethicists and scientists often use statistical measures to determine **risk assessments**, the likelihood that something harmful or unintended will happen. Risk assessment is part of your decision-making process every day. For instance, you know that each time you drive your car there is a risk that you might be in an accident. Assuming that you are not afraid of driving, your risk assessment probably tells you that the likelihood of an accident does not outweigh the need to get where you want to go. Cell phone use, air travel, drinking alcohol, the risk-benefit of taking antibiotics, cold medicines, vaccines or other drugs (versus the side effects) or making poor dietary choices are other good examples of risk assessments in your regular life.

Ethical Exercise Warm-up

What follows is a typical scenario regarding tough ethical decision making. Although the situation may seem a bit harsh because it deals with a life-or-death scenario, some of the biotechnologies being developed also deal with issues of life and death and have far-reaching consequences.

A family pulls up to the Grand Canyon in their car. The parents get out to check out a refreshment stand and lock the car doors, leaving three young children asleep in the back seat. But they do not set the brake well enough. After they've moved some distance away, the car slowly begins to roll toward the edge of the cliff. You are the only one who notices. A large man is standing close to where the car is headed. You could push him in front of the car, which would stop its rolling, although he would either be crushed or pushed over the edge himself. What would you do?

First, do you have all the facts in this situation? So far we have painted the scenario so you have only been given two choices: to let the car go over the edge or to sacrifice the one man for the three children. The question seems to be simply "Can you trade his life for theirs?" A utilitarian approach might consider this is an ethical trade, one life for three, and also consider

TOOLS OF THE TRADE

Careful Thought and an Open Mind Are Powerful Tools for Bioethicists

In contrast to the various laboratory and industrial applications of biotechnology, bioethics requires no specialized equipment. The main tools of the trade are logic and an open, inquisitive mind. Bioethicists must be able to assess a situation carefully, considering the possibilities from many different angles. They must include medical, religious, philosophical, legal, scientific, and social concerns and outcomes in their assessments. Bioethicists must be able and willing to consider many different viewpoints, which are often conflicting. Bioethicists must also be inquisitive, able to ask probing questions, and determine what the many factors that underlie the concerns. They may also find it necessary to do extensive literature searches, delving into the background of a topic from numerous perspectives. Language skills can be an additional asset, because not all perspectives or literature may be accessible in a single language. Sorting through possible outcomes and pointing out potential pathways for the resolution of concerns requires reason and logic as well as patience. In the modern world, knowledge of regulatory agencies and rules is also extremely important. This means that bioethicists must not only be able to understand the regulations and laws currently in place but be able to interact with policy makers to facilitate the creation of sound regulations and laws. Finally, good interpersonal and communication skills (both oral and written) are essential for making the concerns, questions, and outcomes clear to all involved.

YOU DECIDE

Right or Wrong?

The chief executive officer (CEO) of a small startup biotech company is involved in negotiating a multimillion-dollar merger of his company with a larger biotech company because of a promising stem cell cloning technology his company has developed. However, the CEO is also aware of a significant problem with this technology that has recently turned up. Does the CEO reveal the problem and risk jeopardizing the merger, or does the CEO allow the merger to move ahead without discussing the problem? You decide.

that the three are young lives; an objectivist approach might consider that it is wrong to endanger or kill any human life, no matter the eventual consequences. Are there other possible choices or alternatives?

2 Ethics and Biotechnology

Nature has been doing biotechnology experiments for much longer than humans have. Bacteria routinely swap plasmids and recombination and mutation occur, allowing the expression of new genes or new combinations of genes that were not present before. However, the game changes when humans get involved and create new genetic combinations. Because of concerns with recombinant DNA technology as a new method, scientists met at a conference in Asilomar, California, in 1975 and called for a **moratorium** (a temporary but complete stoppage of any research) until the safety of the technique and possible consequences could be assessed. Recall that a primary concern was that genetically engineered bacteria would escape from the laboratory into the environment, possibly creating new diseases, spreading old diseases in a more virulent manner, or creating ecosystem changes that might lead to decimation of some species.

In the end, scientists determined that recombinant DNA technology could be controlled in a way that would preserve safety for humans and for the environment while allowing the science to continue. In particular, guidelines were developed for different levels of biosafety containment depending on the inherent dangers of the experimental system used. For example, experiments with nonpathogenic bacteria and nonpathogenic gene sequences require only minimal safety equipment, whereas experiments with known pathogens, human cells, or potentially pathogenic genes require more stringent containment procedures.

Cells and Products

As we have discussed throughout this text, both bacteria and eukaryotic cells can be genetically engineered to express foreign genes and proteins. This has proven to be an indispensable approach for producing medically valuable products. Think about the ethical challenges involved with the genetic modification of individual cells and the products that have emerged as a result of these changes.

When a product concerns human application, such as a therapeutic recombinant protein, there is not only the obvious issue of safety but also the issue of **efficacy** or effectiveness in its intended use. This is obviously important for an intended patient because the patient wants an effective treatment. But efficacy is also important for the manufacturer; if the product is not effective, there can be tremendous economic waste. For any drug, an important consideration will be the dose at which the drug is effective, with minimal side effects and toxicity. Consequently it will also be important to establish whether the drug poses any **carcinogenic** or **teratogenic** hazards. These considerations prevent future problems—such as finding out that the drug cures the disease at one dose but kills the patient or causes cancer or birth defects at another dose—because they raise the ethical concern of harming rather than helping the patient and the potential problems involved in using the patients themselves as guinea pigs to test drug effectiveness.

We must be mindful of the **humane treatment** of animals in preclinical studies. We need to determine how many experimental animals will be the minimum needed to test the drug, what types of treatments will be necessary for the tests, and whether rodents or primates must be used. The choice of species can affect the action of the drug. One of the best examples of species difference in drug action occurred with the drug **thalidomide**, which was originally designed as a mild sedative. It was tested in standard laboratory rodents and found to be safe. However, many of the pregnant women who took this sedative gave birth to babies with severe birth defects. When the drug was tested on marmosets (a type of monkey), birth defects similar to those seen in humans resulted. It turns out that drug metabolism can vary among species. We consider the question of human experimentation in detail later, but the possible differences in effects on humans versus various animal species must always be kept in mind.

GM Crops: Are You What You Eat?

A key advance in genetic engineering, and also one of the biggest controversies, has come from the production of **genetically modified (GM) organisms**, particularly GM crops. The aim is to produce plants that can resist pests, disease, or harsh climates, facilitating the production of crops. Yet many people are opposed to GM crops and have an aversion to ingesting genetically modified food.

GM crops and other genetically modified plants present several areas of concern. The first area involves the plant itself. Scientists must determine whether the alterations in the plant's genetics provide a benefit to the plant or at least do not produce a less vigorous plant. One question that might be worth answering is whether the integrity of the species (maintaining the original genetic composition of a species without major change, so that it is still essentially the same species) is somehow preserved along with the alteration. You should seek to define for yourself whether such **species integrity** is important or whether creating a "better" plant species is more desirable than trying to maintain an "old" species. In doing so, determine for yourself whether the genetic modification of organisms, in this case plants, violates any ethical codes.

Another question, on a broader scale from the first, is the possible effect of altered plants on the ecosystem and on overall **biodiversity** (the range of different species present in an ecosystem). We must determine the effect of the introduction of a genetically modified plant on the local environment. Because we are focusing on crop plants, the desired effect will likely be not only to increase the growth and production of the GM crop plant but also to reduce the harm that might be caused by potential pests and diseases.

One example is Roundup-Ready soybeans. This soybean is genetically modified to resist Roundup herbicide, allowing a farmer to spray the crop and kill noxious weeds that would interfere with growth of the crop without harming the soybeans. Another example is Bt corn (**Figure 2**). Recall from Chapter 6 that this GM crop is engineered to produce a toxin from the bacterium *Bacillus thuringiensis,* which kills corn borer larvae and other insect pests that feed on the plant.

YOU DECIDE

Buyer Beware?

Because of public concern over the possible safety of GM foods, there have been proposals for conspicuous labeling of all GM foods, even if there is only a minute concentration of any GM product in the food. The cost of testing and labeling could add significantly to the price of these foods, and the actual need for labeling in terms of safety is disputed. Should public fears over GM foods require that all such foods be labeled for consumers? Is this a good marketing scheme? You decide.

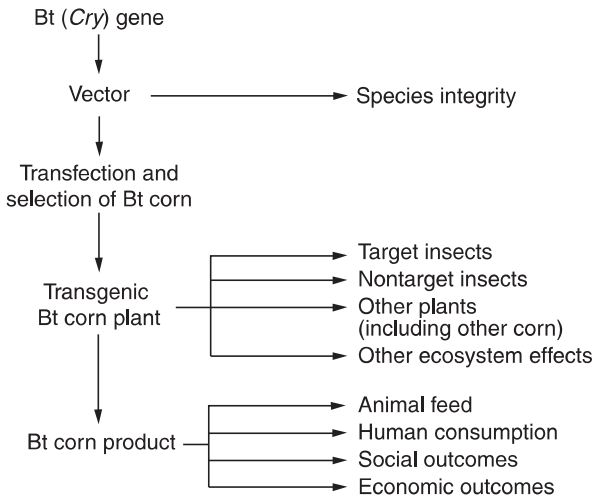

FIGURE 2 Possible Interactions and Considerations for a GM Crop, Bt Corn Bt-modified crops were designed to protect plants against pests such as the cotton bollworm (top photo) and corn borer; but soon after their use, concerns were raised about possible effects on nontarget insects such as monarch butterflies (bottom photo).

(a): USDA Forest Service., **(b):** USDA Forest Service.

Some research has suggested a possible toxic effect of Bt crops on monarch butterflies, even though they were not a target insect and do not feed on corn. It would thus be important to know if the toxin affects specific species or groups of insects and whether non-target insects can also be affected. One question that was considered was whether the toxin could be spread or was confined solely to the corn plant. Because corn is wind-pollinated, the pollen might be carried to other plants and be toxic to some insects at a distance. Researchers had to determine the likelihood of this happening. For the monarch butterflies, the study indicated that corn pollen could be spread by wind to milkweed plants (which are a food source for monarchs) located next to the GM cornfield. Monarchs feeding on the milkweed could then ingest the corn pollen (and the toxin). Scientists had to ask whether this was a likely occurrence and how much pollen and toxin it would take to kill a monarch butterfly. Think about the types of experiments you might design to test these questions. In recent years, several long-term studies have shown no adverse effects of monarch exposure to Bt crops.

There might be possible effects of cross-pollination between Bt corn and the transfer of engineered genes to other noncrop species (for example, other plants that might acquire the toxin gene and kill desirable insects, such as monarch butterflies). You would have to consider the likelihood of such an occurrence. The whole question of introducing GM plants into the natural environment needs careful scrutiny to consider possible long-term changes to the ecosystem and the effects on biodiversity. Another consideration is the spread of GM plants to other areas beyond where they are cultivated.

Another question to consider regards the product of the GM crop: we must consider how it will be used, whether it is safe to feed to animals, and whether it is safe for humans. We must also gather all the facts and make informed evaluations. Because the toxin is directed against insects, it seems unlikely that it would affect animals or humans. But making this assumption is not enough; evidence and tests are needed that could verify its safety. Think of some experiments you could do to test the safety of a GM product.

We should not focus only on the particular gene in question but also ask whether other genes or products present in the GM crop might have to be considered. For example, in many cases antibiotic-resistance genes are used as selection markers for genetically engineered cells. Are the genes still present in the GM crop? And if so, can these genes be transferred from ingested food to gut bacteria? You should again ask what the likelihood is that DNA or proteins would survive digestion. Figure 2 shows a some of the possible interactions and considerations. We must also determine whether the product from a GM crop should be quarantined after the crop has been cultivated. This again comes back to our question of safety, especially regarding human exposure to or consumption of the product.

One consideration to keep in mind is whether the Bt toxin would survive food preparation and still stimulate an allergic reaction. Some countries strictly limit the importation of GM crops, and there is a movement to label foods to designate their origin in terms of potential genetically modified plants. Some people believe that, based on the data, these restrictions are not valid and may unduly frighten consumers. What would be your reaction to finding a "GM" label on your pizza or cornflakes?

Social and economic questions also arise from the potential use of GM crops. The ability to modify plants for better, less costly production could drastically change

YOU DECIDE

Should the Public Be Consulted About the Release of Genetically Modified Insects?

In December 2010, some 6,000 GM mosquitoes were deliberately released into an uninhabited forest in Malaysia—to the surprise of locals and international followers. The Malaysian trial was an effort to control dengue fever, a virus-based disease transmitted by the mosquito *Aedes aegypti*. The dengue virus has spread to over 100 countries, and the World Health Organization (WHO) considers the at-risk population for dengue infection to comprise nearly 2.5 billion people. In some parts of the world, dengue fever is a major cause of death in children. Dengue fever causes severe and painful flu-like symptoms in adults, which can sometimes lead to lethal complications. British biotech company Oxitec had previously released 3.3 million GM insects in trials in the Cayman Islands in 2009 and 2010 in the world's first GM mosquito field trial designed to control dengue-carrying carrier insect populations. The company claims that their Cayman Island trials reduced that insect population by about 80%. In both cases the public and even researchers in the field were generally unaware of the releases until after results of the trials were announced. There are no policies on informing the public about such experiments. Should there be? Is it sufficient to simply inform the public that GM insects have been released? You decide.

YOU DECIDE

How Much Return on the Investment?

Monsanto, a company based in St. Louis, Missouri, created Roundup-Ready soybeans, which are genetically engineered to withstand Monsanto's Roundup weed killer, a commonly used herbicide that kills almost all plants. Roundup-Ready seed costs several dollars per bushel more than conventional soybean seeds. Monsanto has used private investigators to check out reports that farmers in New Jersey had been recycling seed harvested from Roundup-Ready soybeans planted the previous year. Using seed harvested from a previous crop is a common practice for many farmers and allows them to save money on seed for planting a new crop. Because Monsanto invested so much money in their technology, they wanted farmers to buy new Roundup-Ready seeds each year, but farmers claim they were never told their seed could not be replanted. Monsanto claims farmers are using their high-tech expensive product for free.

Should the farmers be allowed to continue their traditional practice of recycling seed? Or should biotechnology companies be able to enforce restricted uses of their products? You decide.

the agricultural industry. Potentially, more abundant food could be available at a reduced cost both to the farmer and to the consumer. These advantages may be offset by potential disadvantages, however, such as the safety concerns described previously. Other possible uses for GM crops include the production of medically useful compounds. Safety and efficacy again become key considerations in the ethical assessment for use of these compounds. Current U.S. policy requires not only the usual range of tests for safety and efficacy of medical compounds but also that growth of the GM plants be restricted. Fields must be surrounded only by other plants that should not cross-pollinate with the GM plant, all plant material must be removed at harvest, and the field cannot be used for a number of years after harvest.

Animal Husbandry or Animal Tinkering?

Genetic modification of animals raises many of the same questions posed by the genetic modification of plants. Early applications of biotechnology to animal husbandry have included antibiotic supplements in feeds and injections of growth hormone or steroids to increase growth of the animals. Consider the application of these supplements and injections from an ethical standpoint. First, because these are agricultural animals, the effects of genetic modification on the products from the animals (milk, meat, and so on) and the safety of these products for human consumption were the main concern. One consideration was the length of time the supplements (especially hormones) would persist within the animal—that is, whether they would still be present when the animal products were consumed by humans. If so, scientists must also determine whether there would be any effects on the consumer and whether the hormone, if present, would survive any cooking or the digestive process.

Little concern has been expressed about the effect of GM agricultural animals on the environment, but there are still questions about species integrity and the health of the animal as well as the safety of animal products for human consumers. Similar considerations are in order regarding animals that have been genetically engineered to produce medically useful products. These could include transgenic animals modified to produce a clotting factor in their milk, transgenic animals such as pigs engineered with human genes so their organs could be transplanted into humans without being rejected, or cloned cows to be used for meat. Chinese scientists have created transgenic cows that express human milk. At what point would you consider such alteration of an animal to be unethical?

Be sure to consider whether there is a point at which the animal might acquire enough human genes, cells, or attributes that you would consider it human and whether this would change your ethical viewpoint on using the animal for research. Refer back to Figure 1. Recently, English and French scientists implanted mouse cells into chicken embryos to demonstrate that mouse cells could recognize developmental signals from chicken cells to stimulate tooth formation. Biologists are interested in this in part because although the genes involved in these developmental signals are not active in birds (teeth were lost in birds about 70 to 80 million years ago), it indicates that these genes can be activated and can stimulate tooth development when the proper cells are present. So what? Who wants to make chickens with teeth? These are good questions, and you may certainly ask whether these types of experiments are ethical uses of animals. But also consider that information from these experiments can be fundamentally valuable to clarify tooth development and potentially in the future to develop novel treatments for tooth formation, replacement, and regeneration in humans—the main reasons for this research.

Genetically modified wild species of animals such as salmon present another set of ethical questions, including environmental concerns.

Synthetic Genomes and Synthetic Biology

Research on synthetic genomes has resulted in transplantation of a synthetic genome into a bacterial strain to change the recipient microbe into the organism of the donor synthetic genome. These and other future applications of synthetic biology are raising many ethical questions about what should and should not be done with synthetic genomes and their potential uses to create novel life forms.

The Human Question

Many of the thorniest questions regarding biotechnology, and some of the most contentious debates, revolve around humans. Even simple scientific procedures can evoke strong emotions and stir profound controversy when humans are the subjects. Why do you think the use or potential use of humans experimentally causes such strong reactions? Later we discuss how the mere definition of what is human has become an area for debate.

For now, we look at a simple example based on a potential anticancer drug generated through biotechnology. Suppose the drug has moved along to the point where it was ready for clinical trials. We must decide to whom we will administer the drug as a test. Because it is an anticancer drug, we will naturally give it to patients who have the type of cancer targeted by this drug. We must decide, however, whether to give it to all patients with that type of cancer or only to those in the most advanced stages of disease—those who may have exhausted all other means of treatment and for whom the new experimental drug is a last resort. The rationale is that, for this subset of patients, there is no other possible treatment; therefore the experimental treatment presents at least some hope. However, the drug may work better with patients who are earlier in the progression of the cancer and thus might be more effective. Nonetheless, the patients who are in earlier stages of the disease have other alternatives that have already shown safety and efficacy (at least to some extent).

After you have picked the patient group for the clinical trial, another dilemma arises. Patients have a right to be informed fully of the potential effects of the experimental treatment, both good and bad. Only when so informed can they be willing participants in the trial. This is termed **informed consent**. Patients give their consent to proceed with the experiment, fully informed of the potential benefits and risks that lie ahead. The concept of informed consent is vital to any procedure involving a human. If a patient is unable to give consent on her or his own (because the individual is too young or in a coma, for example), a family member or guardian can give proxy consent. Determine for yourself why informed consent is so vital.

Placebos present another problem as far as experimental procedures on humans are concerned. In a placebo-controlled study standard scientific practice involves using an experimental group (in this case, patients who would receive the drug) and a placebo-controlled group (in this case, patients who would receive a placebo, a safe but noneffective treatment

YOU DECIDE

Should Clinical Trial Data Be Public or Do They Belong to the Drug Company?

In 2002, the National Institutes of Health (NIH) launched Clinicaltrials.gov to help patients and physicians find information on nearby clinical trials. The current registry contains information on over 108,400 clinical trials in more than 174 countries. This registry has been voluntarily utilized by most biotech and drug companies because it excludes early-stage trials, where sensitive business information could be lost. For several years a congressional bill (S.467—the Fair Access to Clinical Trial Act; FACT Act) has been debated; it was to call for mandatory disclosure of the results of clinical trials in a public database. Some claim that the information could help patients determine whether to participate, but some in the drug industry say it is unnecessary and will stifle innovation.

The FACT Act was never passed as a law. The bill proposed to require open access to information from phase 1 trials, which enroll healthy patients in small numbers. According to some industry spokespersons, however, such information would be of little value to patients. The advocates for the bill claim that companies could benefit from sharing early-stage trials to prevent new drugs from repeating the same mistakes that had already produced negative results. In defense of the industry, biotech companies rely on venture capital funding, and if early data are shared with other companies, it is claimed that funding for innovation would dry up. Is the benefit worth the risk that it may reduce funding for drug research? Is there a better solution? You decide.

such as a sugar pill or saline injection). In a completely randomized **double-blind trial**, neither the patients nor the doctors administering the treatment would know who received the real drug and who received the placebo. Informed consent should play a role in this type of experiment. Using placebos is part of objective science, but we must look at whether it is ethical. Objective science may not always be the best approach or the ethical approach.

What Does It Mean to Be Human?

Many of the current ethical debates about stem cells and cloning revolve around the moral status of the human embryo. Stem cells may hold the potential for tremendous breakthroughs in **regenerative medicine**, making possible the repair or replacement of damaged and diseased tissue in many diseases such as heart disease, stroke, Parkinson disease, and diabetes. As you know, there are many possible sources of stem cells, including embryos, fetuses, umbilical cord blood, adult tissues, and even "tamed" tumor cells (**Figure 3**). These sources of stem cells are in addition to nuclear reprogramming options such as making induced pluriopotent stem cells from human somatic cells. Much of the stem cell debate has centered on the scientific question of the abilities of different stem cells to transform into other tissue types for the treatment of diseases; however, key elements in the debate have been ethical questions about embryos as a source of stem cells.

As a society, we have not been able to agree whether it is ethical to destroy early-stage human embryos for research that may potentially be of benefit to thousands of patients. Unlike organ donation, in which an individual may donate one of two paired organs while alive or after his or her death, the process of harvesting embryonic stem cells destroys the donor (the embryo; Figure 3). The use of human embryos as a source of stem cells is a very controversial topic, in part because it raises questions such as, "When is the embryo considered to be a person? Is it ethical to destroy a human embryo to harvest stem cells that may benefit many other humans?

We must resolve the focal question, which examines the moral or ethical status of a human embryo. Biologically the embryo is a human being, species *Homo sapiens*, just starting out on the developmental journey. We must weigh the relevance of different developmental milestones for being considered human against the simple biological fact that the embryo is a member of our own species. Biologically, an embryo is a member of the human species, but the question of the moral status of a human embryo goes beyond the biological and also revolves around what some have termed the status of **personhood**. This term has been used to define an entity that qualifies for protection based not on an intrinsic value but rather on certain attributes,

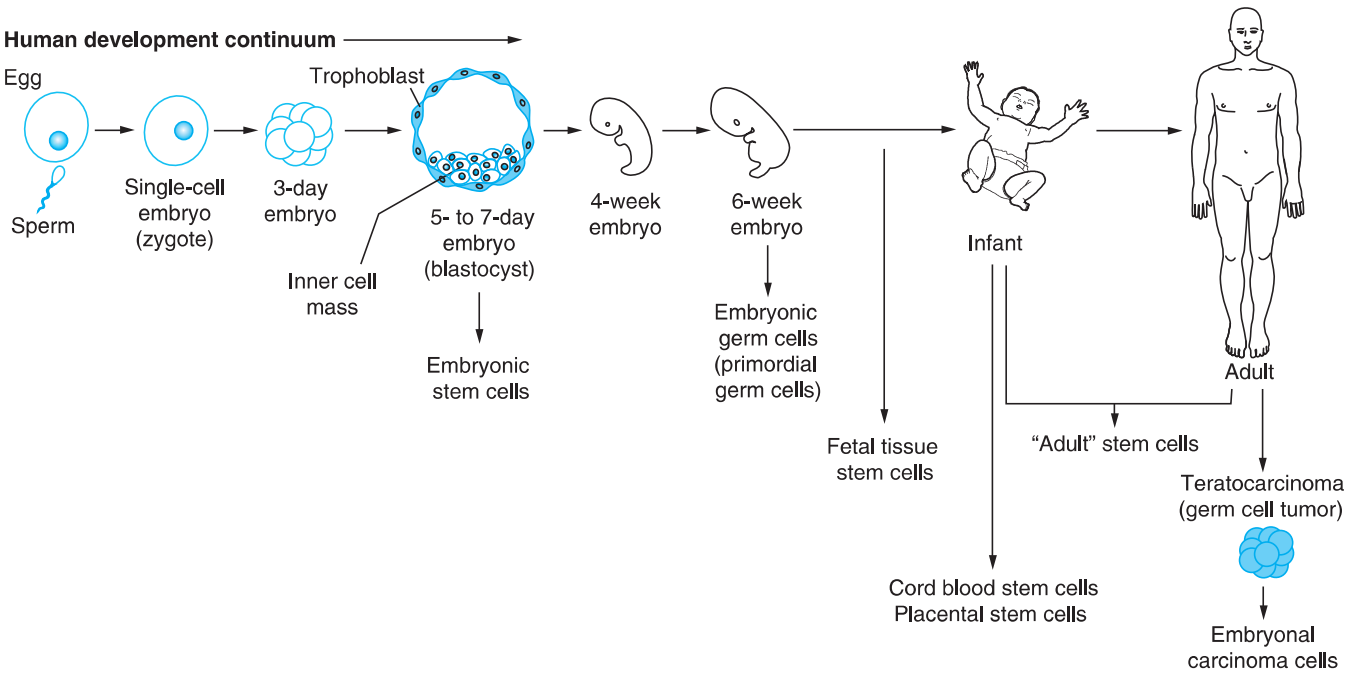

FIGURE 3 Sources of Stem Cells Human embryos, fetal tissue, infants, and adults are all potential sources of stem cells.

YOU DECIDE

Celebrity, Shame, and Stem Cells

Dr. Woo Suk Hwang of Seoul National University in South Korea was thought to be a pioneer in stem cell research. Dr. Hwang was treated to free airfare to travel around the world, high fees for speaking engagements, high-society parties, regular appearances on television, and other perks not typically associated with the life of a scientist. Hwang became a source of national pride in Korea primarily for claims that his research group had created the first cloned human embryo and stem cells derived from human patients. This work was published in 2004 and 2005 in highly heralded papers in the prestigious journal *Science*. But by December 2005, Woo Suk Hwang's celebrity and his career were quickly falling apart in disgrace and he resigned from his position. Current and former members of his own research team as well as a collaborating lab revealed evidence suggesting the falsification of data and allegations of unethical means for obtaining donated eggs. It was subsequently determined that data and figures had indeed been falsified and manipulated; the lab had not cloned an embryo or derived patient-specific stem cells as claimed. Among these issues of unethical actions was concern about how eggs had been collected for the work (initially Hwang reported that anonymous donors had provided the eggs) and lies about the number of eggs used. It turned out that junior researchers in Hwang's lab were among the donors and that donors were paid for their eggs. Women were also paid to take fertility drugs to provide eggs. Hwang's fall from grace was highly publicized around the world, and it served to further support the claims of groups speaking out against stem cell work—groups that were already skeptical regarding the highly lauded potential of stem cells.

Bioethicists claimed that Hwang failed to adhere to the West's ethical standards when he paid women for their eggs and used junior researchers who worked for him to provide eggs. But the South Korean Health Ministry deemed there was no ethical problem because the eggs were donated voluntarily, with no evidence that junior researchers were coerced to provide them. The ministry, in other words, determined that Hwang had not violated existing laws. The ministry further explained its conclusions by saying that Western-trained physicians and scientists considered donations from vulnerable junior researchers as unethical because they might feel pressured to satisfy their supervisors and donate involuntarily. The ministry went on to say that although researchers in South Korea abide by ethical procedures in conducting research, they generally do not focus on ethical issues as much as is common in the West. Was it ethical for Dr. Hwang to collect eggs from junior researchers? You decide.

such as self-awareness. List for yourself the advantages and disadvantages of this concept of personhood. One concern with it might be the question of who decides which attributes count in evaluating whether a particular human being can be valued as a person.

Regarding embryo research, some have taken this attitude: "Not a person, not a problem." They reason that a human embryo is microscopic, not yet possessing a beating heart, brainwaves, arms, or legs. Of course those things develop later, but at a very early stage the embryo lacks what we usually associate with our concept of humanity. There are obviously various views of the status of the human embryo, and no consensus. Some say it is simply a clump of cells, just like a chunk of skin. Others believe it is a form of human life deserving of profound respect—a potential person. Still others maintain that an embryo has the same moral value as any other member of the human species. Consider the question of whether *any* human cell deserves respect as a potential person. When combined, an egg cell and a sperm cell form an embryo, and any somatic cell can contribute a nucleus to form a cloned embryo. Consider, then, whether there is something special about having a complete human genome in an egg cell.

Considered in the context of using human embryos to isolate embryonic stem cells, the debate regarding the necessary destruction of the embryo is contentious. Certainly, embryonic stem cells can theoretically be used to form any tissue, with the potential for transplants to repair or replace damaged or diseased tissue. This might suggest that it would be ethical to destroy human embryos for research if, from that destruction, it meant that such research could lead to treatments for disease. However, based on current published evidence, one question that first must be asked is whether embryonic stem cells are as good for potential treatments as claimed. Another consideration that has both ethical and scientific components is whether other viable alternatives, such as adult stem cells or induced pluripotent stem cells, are just as good.

The ethical questions then take on a new form, asking, on the one hand, whether research on embryos is necessary if science is to explore all possible avenues for medical breakthroughs or, on the other, whether the calculation now indicates that the alternative makes ethically contentious research unnecessary. Of course one ethical position would be that even if there are no alternatives, the ethical cost is too high to justify the destruction of embryos.

Interestingly, even some people who view a human embryo as a potential person and not a realized individual oppose destruction of human embryos on ethical grounds. The concern is not directly with the embryo and its status but rather with how society views any human life. From their point of view, we are embarking on a slippery slope in which the destruction of human beings for medical use or experimentation might move from the use of embryos to the use of born individuals. Once again, we return to the question of personhood, especially as a societal construct that might rank different humans based on their quality of life and on their usefulness to society.

Spare Embryos for Research versus Creating Embryos for Research

As we consider the question regarding the moral status of the embryo, there are varying views based on the original purpose for which the embryo was created or on the method by which the embryo was created. Contrary to a common misconception that aborted fetuses are used for stem cell research, the primary source of embryos for this research is "excess" embryos from in vitro fertilization, or IVF. These embryos, left in frozen storage after a couple has used other embryos for implantation and ideally pregnancy and birth, may be donated (with the couple's consent) for research. Depending on the IVF clinic or the country, frozen embryos may be discarded after a certain period of time. List for yourself the necessary ethical considerations in this instance. Some say that it is ethically valid to use these embryos for research if they would otherwise be discarded—that some ethical good could be salvaged from their existence if they were to contribute to a potential therapy or new in scientific knowledge. Others say their destruction for research crosses an ethical line inconsistent with the purpose for which they were originally created.

Another potential source of human embryos is the specific creation of embryos for research purposes. Some have argued that the use of spare embryos for research is ethically valid (reasoning that this could be salvaging a potential good out of certain destruction) but that the specific creation of embryos for research is not. To determine whether this argument is ethically consistent, consider whether there is any difference in the embryos biologically or only in a view of the intent or use of the embryos.

Should Humans and Other Animals Be Cloned for Any Reason?

Creation of embryos by somatic cell nuclear transfer cloning raises many of the same questions encountered with stem cell research, with the added complexity of the technique and the potential "identity" of the clone (**Figure 4**). A cloned embryo created for transfer into a uterus and implantation faces many risks and safety

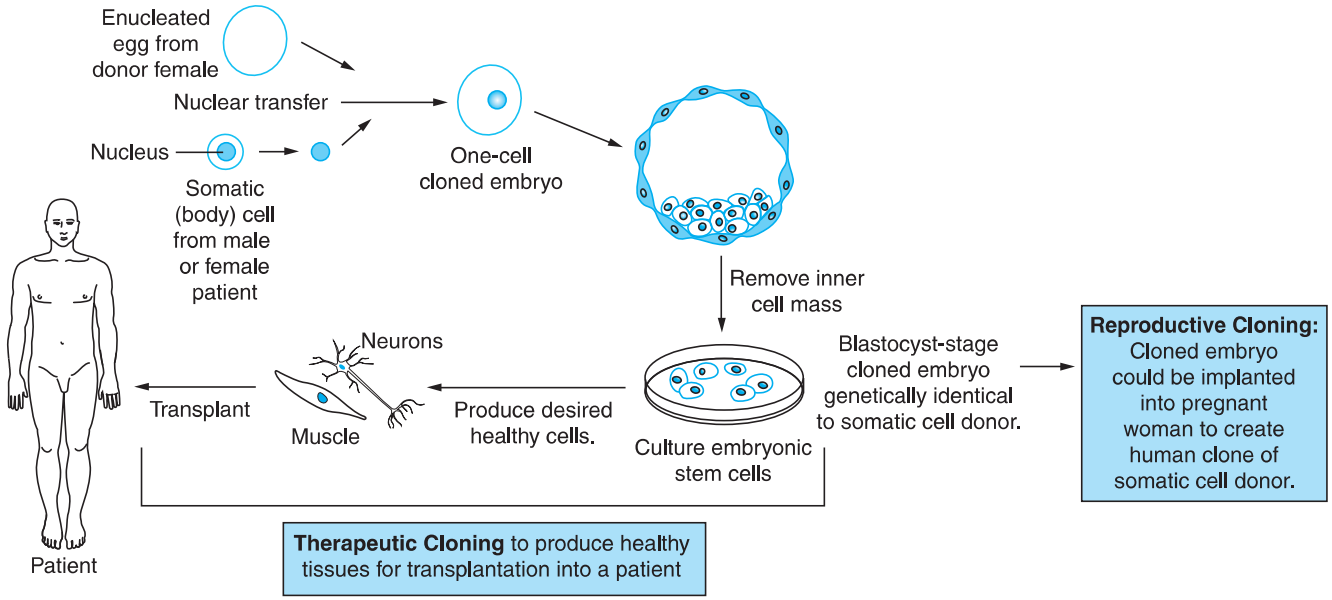

FIGURE 4 **Theoretical Scheme for Human Cloning or Therapeutic Cloning to Produce Tissues for Transplantation**

YOU DECIDE

The Same or Different?

Consider the following scenario. An embryo is created by in vitro fertilization for a couple who want a child. However, it is known that the couple carry a genetic disease, and there is a 100% certainty that the embryo will have the disease. Scientists working with the couple isolate embryonic stem cells from the embryo. In culture, they are able to repair the genetic problem in the cells. Some of the embryonic stem cells are then packaged in the form of tetraploid embryonic cells, creating an embryo that is implanted into the woman and carried to term. The infant that is born does not have the genetic disease, and neither will any of that child's offspring. In addition to the several ethical questions that can be discussed regarding this scenario, consider this one: Is the born child the same human/individual/person as the original embryo? You decide.

factors for its own development and growth, both before and after birth. The success rate for live births and the subsequent survival of the clones is extremely low. We know that there can be a number of problems, some subtle and some very severe, with the health of clones.

One consideration is whether creating a cloned human embryo with the intent of initiating a pregnancy and live birth should be considered another type of assisted reproductive technology similar to IVF or whether (because of the safety risks and low success rates) it should be considered unethical human research. Societal questions regarding the identity of a born human clone must also be taken into consideration. For example, if a couple decided to create a cloned child using a donor cell from the wife, the clone would not be a genetic daughter but rather the wife's sister, a late-born twin, and would not be related to the husband at all. Ethical considerations related to the clone include how the lack of relatedness to one parent might change kinship and family relationships. Given that the clone is a "copy" of one of the "parents," the clone, once born, might be expected to "live a better life" than the person who was cloned. Another potential concern arises if a previously existing person, now deceased, had been cloned. The genetic makeup of the clone would already be known, already dictated, because the process of cloning reproduces a previously existent individual. A clone may be expected to live up to that genetic legacy, with heightened expectations by the parents and others based on what was achieved by the donor of the clone's genetic material.

The cloned cat "cc" (**Figure 5**) looks very similar to the cat that donated her genetic material, but her coat pattern differs slightly from the donor's. These differences occur because of subtle epigenetic changes during development. Our genes determine many of our physical characteristics and predispose us to various diseases or behaviors, but after we are born there are many experiences and environments that make us who we are and who we will become. Those experiences cannot be duplicated, so the clone will grow up differently than the one who was cloned and may behave quite differently. A clone of Einstein might become an artist instead of a scientist. A great deal more affects us and our makeup than just our genetics, including our environment and experiences.

So far we have considered the creation of a cloned human embryo with the intent of producing a live-born child. However, this is not the only proposal for the creation of cloned human embryos. Creating human embryos for **therapeutic cloning** could lead to matched embryonic cells for patients (Figure 4) and to valuable human research models for the study of genetic diseases and cancer. Although this might sound like a potentially valuable and ethically valid reason for creating cloned human embryos, others argue that such embryos should not be produced.

FIGURE 5 The First Cloned Cat, "cc" (the Carbon Copy Cat)

Richard Olsenius/National Geographic Image Collection.

One argument against the creation of cloned human embryos is not based on the embryo's inherent value as a human or person but on the argument that the creation of human embryos for such purposes could lead to human commercialization, making any human life a commodity to be bought, sold, and used, thus cheapening life in the process. Still others have argued that we should not be creating human embryos in a manner that manufactures human life, the so-called designer embryos.

One argument in favor of creating cloned human embryos relies on the assumption that if an embryo is not created by normal means (in this case meaning by fertilization), it is not human. Each of these arguments is based on different definitions of what it means to be human and the value placed on human life. Interestingly, nearly 30 years ago, similar ethical debates about what it means to be human arose when Louise Brown, the so-called test tube baby, was conceived by in vitro fertilization. And now even the most conservative groups, including many religious sects, consider in vitro fertilization to be a completely ethical way in which to conceive an embryo.

Patient Rights and Biological Materials

Consider how you would feel if the following scenario happened to you. You are being treated for a disease such as leukemia and you donate blood, bone marrow, and spleen cell samples for analysis as part of your treatment. You later learn that the physicians treating you developed cell lines from your tissues, which they patented and then used to bring substantial financial rewards. Such situations have in fact occurred and resulted in a number of patients' lawsuits. In these cases, patients have claimed that prior to providing their **informed consent** to extract the cells, not told that their physicians would conduct research on their cells and that they would benefit financially. Patients and lawyers have claimed that these examples represent a breach of the doctor–patient relationship and an example of a "principle of unjust enrichment."

In most of these cases, patients have sought a share of financial compensation for their cells. In several high-profile cases, courts have ruled that physicians do have a duty to disclose their personal interest in research and potential economic matters unrelated to patient treatment. But courts have also ruled that donors of cells and other biological materials do not have ownership rights of their biological materials, and physicians and scientists who develop patents and receive financial benefits from these materials are not liable for patient compensation.

Many donors are unaware that they do not own their own cells and they relinquish a large degree of control over their tissues when they donate them. Related to this, there have even been situations where donated sperm samples were used to fertilize eggs and produce children without the consent of the individual who donated the sperm, thus making men fathers without their consent. Overall, U.S. regulations are increasingly favoring written, informed consent without coercion for any donor subject. As stem cells and regenerative medicine technologies become more common, undoubtedly the issue of patients' rights regarding biological materials will become even more complex and require greater scrutiny and ethical consideration.

Genetic Information

The Human Genome Project has led to the identification of genes responsible for or contributing to many disease states. This knowledge has also led to new strategies for genetic testing and treating genetic disease. But because the story told in our DNA could become so easily read, there is a growing concern over the privacy of that information. One's DNA sequence can be a truly unique identifier. Researchers especially must take care to guard the confidentiality of those who have donated DNA for sequencing and testing. Because a free flow of scientific information ensures rapid dissemination of ideas and facilitates scientific advances, we next look at some of the ways in which scientists can safeguard genetic information to assure individual research subjects or groups of subjects that their privacy will be maintained. This is important not only to reassure research subjects but also for scientists to maintain the continued trust of people and their willingness to participate in research projects. A sampling of some of ethical questions about genetic information include the following:

- Should we test people for genetic disorders for which there are no effective treatments?
- What ethical obligation do physicians and scientists have to divulge genetic testing results if analysis of a person's DNA reveals mutations unrelated to the original reasons for the test?
- A negative result from a genetic test does not always rule out the future development of certain diseases, nor does a positive result always mean that an individual will develop a disease. How do we effectively communicate the results of genetic tests and actual risks to the person being tested?
- Should it be possible for someone to be tested for non-disease-related genes affecting such traits as intelligence, skin color, height, or weight?

- *Identifiability*, the potential for disseminated genetic data to be associated (or reveal the confidential identify) of specific individuals, is a major concern. How can electronic medical record keeping prevent identifiability even when patients agree to share or release certain aspects of their medical records?

We have discussed controversies associated with direct-to-consumer genetic tests. As the identification of genetic traits becomes more routine in clinical settings, physicians will have to ensure their patients' privacy. There are significant concerns as to how genetic information could be used negatively by employers, insurance companies, government agencies, or through perceptions acquired by the general public. Genetic privacy and the prevention of genetic discrimination will be increasingly important in the coming years. In 2008, the U.S. House of Representatives passed bill H.R. 483, the **Genetic Information Nondiscrimination Act (GINA)**. The Senate also passed an identical bill (S. 358), and shortly thereafter President George W. Bush signed the GINA into law. This act prohibits discrimination based on genetics or the improper use of genetic information in health insurance and employment.

More or Less Human?

The first successful example of gene therapy involved children suffering from severe combined immunodeficiency syndrome (SCID). Individuals with SCID are born without an effective immune system, primarily because of one defective gene in their immune cells. Successful treatments have used adult stem cells from the children's bone marrow, using genetic engineering to add the correct gene and replacing the engineered stem cells back into the patients.

Think about some of the ethical considerations associated with gene therapy technology. Gene therapy treatments such as those used to correct SCID seem wildly successful, so one might think there should be no concerns. However, because these are experimental medical procedures, there are certainly issues of informed consent, safety, and efficacy. One safety issue that has arisen is the potential for cancer formation. An adenovirus vector used for gene therapy has led to leukemia in several children. This consequence has aroused considerable concern about future genetic therapies, especially using this particular viral vector. So one ethical consideration might be the risks associated with altering an individual's genetics, especially the specificity of the targeting for insertion of the replacement gene.

Current and proposed somatic gene therapies involve the treatment of existing genetic diseases. However, we should consider the possibility of genetic treatments for conditions where there is only a genetic *tendency* toward a particular disease and there is no certainty that the disease will occur. One possibility is breast cancer, in which genes (such as mutations in *BRCA1* and *BRCA2*) have been identified that can increase the risk for development of the cancer. We must consider the difference between a genetic disease and a genetic attribute. For a genetic disease such as SCID, it is known that an individual with such a genetic problem will definitely develop the disease. However, a genetic *attribute* does not mean that the disease condition already exists or that it will inevitably develop. If we consider attributes that may not necessarily lead to a disease or may not even be associated with an increased risk for disease, we extend our considerations of genetic engineering beyond the therapeutic and begin to contemplate whether we will consider other potential genetic modifications as ethically acceptable, going beyond treatment for an existing condition to alterations and even enhancements of the human genetic composition.

Consider whether enhancing our individual genetics, perhaps to increase muscle mass or the oxygen-carrying capacity of red blood cells, might also be considered medically necessary for the health of the individual, even if it were really just a personal preference. The prohibition of such genetic alterations could be regarded as an infringement of individual rights. Because this individual's genome would be altered to something other than the normal, we must reconsider the question of whether he or she would still be considered human as well as just what we might include in that definition. Many questions surround the possibility of **gene doping** in athletes; that is, using gene therapy for genetic modification to enhance human traits important for sports. Genetic techniques applied to animals have demonstrated enhanced muscle function, increased blood cell production and oxygen content, and enhanced metabolism and endurance performance.

The question of what makes an organism human becomes more pressing when we look at the potential of **germline genetic engineering**. In this case, the genetic alteration is done in the sperm, egg, or early embryo. This can actually make the manipulation more effective than somatic genetic engineering because the genetic modification can affect every cell in the individual's body, making the genetic alteration inheritable. Potentially this could mean the elimination of some genetic diseases, because those genes could be removed from the human gene pool. Of course, any

problems resulting from the genetic alteration could also be inheritable, as could any genetic enhancements. Consider whether this type of genetic modification, which would affect not only the treated individual but also future generations, might be ethically acceptable. Some of the potential outcomes of removing or adding genes in the human gene pool could include the elimination of genetic diseases or disease susceptibility, enhanced human performance, increased or decreased human life span, and increased cancer risks.

One Nobel laureate has been an advocate of this type of research because it could lead to the development of a "better human being"; but we might pause to consider just what constitutes "better" and whose definition should be utilized in these decisions. Another potential outcome sometimes mentioned for germline genetic alteration could be the creation of a new, superior species of human—the basic concept behind **eugenics**. One potential negative associated with this outcome could be splitting humans into different genetic social classes.

YOU DECIDE

What to Treat Using Gene Therapy

There are many ethical concerns about gene therapy and the risks associated with it. Do the patient and his or her family members understand the risks associated with gene therapy trials? For instance, Jesse Gelsinger (Jesse died as a result of his gene therapy) had a relatively mild form of a disease that was being successfully treated with medication. Should he have been a gene therapy trial participant? Gene therapy is currently very expensive. Should everyone have access to gene therapy treatments regardless of the cost? What types of disease and conditions should be subject to gene therapy (for example, only deadly diseases)? What about treatable diseases for which gene therapy would be used so patients would not have to take daily but effective medications? What about cosmetic conditions such as baldness? You decide.

3 Economics, the Role of Science, and Communication

We cannot escape the fact that money plays a major role in research decisions. Private investments as well as government funds fuel research and development, and individuals and companies alike seek to use biotechnology for discoveries that will be profitable. Biotechnology is a business, after all.

Not only is scientific research expensive, but projects, companies, and careers may live or die depending on the funding for and profitability of the research. There is clearly not enough money to fund every scientific proposal, whether the proposal is from a university faculty member doing research or a company working to develop a new product. Research funding is often evaluated based on whether it will increase our knowledge about fundamental aspects of science or produce a discovery or product that improves our lives.

Many college and university researchers seeking funding submit research proposals to funding agencies. These proposals are then reviewed by panels of scientists who make recommendations to the funding agencies about which projects should be funded. But the amount of money and even some of the decisions on funding direction also come from those providing the money, especially the U.S. Congress. Most of the decisions are based on the potential success of the science, its novelty, and its potential application to health and general knowledge. However, some of the decisions may also be affected by how well the scientists are known by the reviewers or by political pressure from members of Congress.

We should consider not only how research proposals are evaluated and their chances of success but also the possibility of their contributing to the breadth of scientific knowledge (because in science, it is difficult to know where the next major breakthroughs might come from and what background knowledge might lead to such breakthroughs). Additional considerations are the costs of and access to any treatments that might be produced. Funding for research might be so costly that only the rich would be able to benefit from it, or it might prove to be a colossal waste of money and time; it might simply suggest that other avenues of research would have a better chance of producing useful results. Because the possible sources of funding for research are limited, funding decisions may have to be weighed in terms of whether funding one type of research might decrease the funding of another, potentially more successful line.

A biotechnology company with a potentially profitable idea typically has to seek funding from venture capitalists and other investors willing to fund the R&D necessary for product development. If such investors are risk-averse but seeking a profit, who will fund risky experimental research that is expensive but has great potential for saving lives or leading to some new and useful technology?

We could even extend the discussion of economics to ethical issues such as whether it is acceptable to pay women to donate eggs for stem cell research. The lack of quality eggs left over from IVF coupled with the increased demand for eggs as stem cell research becomes more common is driving a need for human eggs. In June 2009, New York became the first state to allow public money to be used in this way—up to $10,000! Some of the ethical issues here revolve around the risk associated with hormonal stimulation, potential complications, and the invasive approaches required to harvest eggs. Many economic and noneconomic questions revolve around this issue:

- Should women be paid as egg donors?
- If so, should there be limits on such payments?
- Should there be a limit on how many times a woman can donate eggs over a particular period of time or should she be allowed to serve as a "serial" donor, giving dozens of eggs over time?
- Will paying for eggs create a market wherein women use egg donation as a form of employment?

Intellectual property rights are also important as we consider the ethical implications of research and its funding. The **patenting** of intellectual property—whether it be isolated genes, new cell types, GMOs, or even embryos—can be lucrative for the discoverers but may also pose ethical and scientific dilemmas. For example, consider the possibilities for a human gene that has been isolated and characterized—and then patented by the discoverer. The person or company holding the patent could require that anyone attempting to do research with the patented gene pay a licensing fee for its use. Should a diagnostic test or therapy result from the research, more fees and royalties might be required. This could make it difficult or expensive to carry out research on some genes or limit the clinical use of the patented gene. In 2011, a federal appeals court ruled that human genes can be patented, reversing a lower court's ruling involving a test for breast cancer (i.e., the *BRCA1* and *BRCA2* genes). It is expected than an appeal will be filed by the American Civil Liberties Union to challenge this ruling.

Some physicians have already complained that they cannot afford to pass on the charges of certain genetic tests to their patients owing to licensing restrictions. However, limiting or preventing patents for genes or genetic tools could remove the incentive for pursuing such research, especially for companies that hope to profit from their research. Compile a list of potential ethical problems associated with patenting of genes or cells and consider possible alternatives or compromises that might be reached to allow research to continue.

Ethical questions regarding biotechnology also touch on science's role in society (**Figure 6**). Science and technology have provided discoveries and inventions that make our lives happier and healthier. But it is important to consider whether scientists should have unlimited freedom for research. It is often difficult to know what the source of the next major breakthrough will be, and sometimes, new discoveries arise from unexpected sources and paths that many scientists may not even consider worth following. We must determine how science can best serve society. The whole concept of regulating something as unpredictable and free-flowing as scientific discovery is difficult. It is also hard to know who should decide these questions—scientists because they know how science works, policy makers because they must set the rules, or society because it is most affected by the decisions. Consider what types of regulations might best serve the needs both of science in furthering discovery and of society in furthering health care and ethical interests. Bioethics becomes critically important to the biotechnology industry because ethical discussions and debate are often the driving force for making laws in general (laws that govern

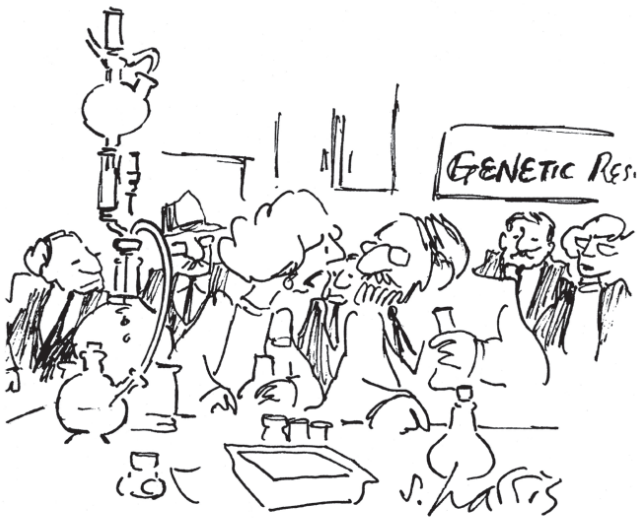

FIGURE 6 Ethical Decision Making Is an Essential Part of Science

Sidney Harris.

the population's behavior and certainly laws that will regulate the biotechnology industry) once it becomes a general consensus of a particular population that a law is necessary.

Accurate, honest communication is vital to the success of science in general and biotechnology in particular. Scientists must be willing and able to communicate openly and candidly with other scientists but also and more importantly with the general community. A public that cannot understand and appreciate the importance of the contributions that science makes to their daily lives will not support its endeavors. Straightforward communication is necessary, without overstating the potential of the research or the imminence of the results and without using confusing terminology. If the public and the policy makers believe they have been misled, the outcomes might be disastrous for both science and society. If the public believes scientists are insensitive to ethical questions in their research, scientists will have a hard time earning the public's trust. Consideration of all the facts is important. Integrity in research is essential, but so is integrity in the communication of science.

Many of these ethical questions involve difficult decisions affecting not only yourself but other lives as well, both now and into the future. It would always be easier if the decisions, especially the tough ones, could be made for you. But the latter approach assumes that the decision maker has all the facts or has objectives that match your own. It also involves giving up your individual freedom in making those decisions, as well as your individual responsibility. With freedom comes responsibility—if you make

CAREER PROFILE

Career Paths in Bioethics

There are over 100 academic bioethics research centers around the world. Public interest in bioethics is at an all-time high, and there are many exciting career opportunities in this field. Traditionally, medical ethics has been a concern from the time Hippocrates swore to "First, do no harm"; but bioethics became a discipline only in the 1980s. As concerns over issues such as abortion and euthanasia were raised, doctors consulted with religious scholars, priests, rabbis, and philosophers to develop the field of bioethics. In the late 1980s, there was increasing consultation and involvement from lawyers and scientists. All these pathways (medical, religious, philosophical, legal, scientific) have contributed to the development of the discipline of bioethics, and there is still no very clear path to follow for a bioethics career.

Many people working in bioethics train in science or medicine initially and then pursue a master's degree in bioethics. Some begin in law school, some start with a Ph.D. in philosophy, and now there are Ph.D. programs in bioethics. Other starting points may be in medical anthropology, medical sociology, the history of medicine, or nursing. There is still much controversy over the best training to develop proper credentials for bioethics. One nearly universal agreement is that training should be interdisciplinary: It should include a broad knowledge base, language skills, and the ability to communicate across such multiple disciplines as religion, science, and medicine.

Choosing the right path of training depends to a great extent on a person's interests. Start by assessing your own interests and skills as they relate to bioethics. You should also investigate what possible jobs are available so you can anticipate the necessary training. A good place to start is the NIH "Careers in Bioethics" website (see the Keeping Current list of websites on the Companion Website).

Skills in this area can convince employers of your potential. When biotechnology employers look at potential employees, they do not simply look at academic credentials and work experience. Meeting the specifications in the job description is essential, but possessing some of the intangible skills that can make prospective employers call you for an interview is often more important. Employers often look for well-rounded employees who not only will work well in teams but also are diplomatic, resourceful, and able to build networks among their peers. Let employers know that you possess these skills, even if you have acquired them over the years in other work experiences than those called for in the application. Employers also want to know that their workers can tackle complex issues with integrity and appropriate ethical consideration.

Be prepared to defend any so-called soft skill you possess with clear examples, but don't be afraid to sell yourself or your abilities.

Adapted from P. Watson (2003), Transferable Skills for a Competitive Edge, *Nature Biotechnology*, 21: 211.