UNIT 3

BIOETHICS AND THE NEW EMBRYOLOGY

Should We Select the Sex of Our Children?

The final aim of all love intrigues, be they comic or tragic, is really of more importance than all other ends in human life. What it turns upon is nothing less than the composition of the next generation.

A. Schopenhauer
(quoted by Charles Darwin, 1871)
Chapter 3 described the details of mammalian fertilization, the process that transmits genes from parent to child and which activates development in the newly fertilized egg. Fertilization is also the time when the sex of a child is to a large degree determined.

We learned in Chapter 3 that fertilization initiates the formation of a new organism with a unique genome of 46 chromosomes—two copies each (one from the male parent and one from the female) of 23 chromosomes. In all but one instance, the chromosomes are for the most part equal: the two copies of chromosomes 1 through 22 will contain the same genes no matter which parent provided them (although the information in the gene may be different; the genes that determine eye color, for example, may specify brown or blue). These 22 numbered chromosomes are the **autosomes**.

The “twenty-third chromosome,” however, is a different story—or, more accurately, two different stories. These **sex chromosomes** are not referred to by number but are designated X and Y. The genes carried on the X and Y chromosomes are very different, and some of them specify whether an embryo develops to be a male or a female.

**Primary Sex Determination**

Primary sex determination is the determination of whether an individual’s **gonads** (sex organs) become testes or ovaries. In humans, primary sex determination is genetic, based upon which sex chromosomes are present. In females, the two sex chromosomes are both X chromosomes (XX). Males have one X chromosome and one Y chromosome (XY).
Each of the haploid gametes formed via meiosis (see Figure 3.1) has only one sex chromosome. In eggs (the gametes formed by a female), the single sex chromosome will always be an X. When sperm (the male gametes) are formed, half the sperm will have an X chromosome and half will have a Y chromosome. When the sperm and egg unite, the conceptus will be female if the sperm that fertilizes the egg contains an X chromosome; the conceptus will be male if the sperm contains a Y chromosome (Figure 5.1). Thus, every human cell has at least one X chromosome, and the X chromosome is essential for cell function in both males and females. The Y chromosome, however, is strictly a sex chromosome: it carries genes that are needed for testis and sperm formation.

Formation of the gonads
The development of the gonads is unlike the development of any other organ. All other embryonic organ rudiments can differentiate into only one type of organ: a lung rudiment can become only a lung, and a liver rudiment can develop only into a liver. The gonadal rudiment, however, can develop into either an ovary or a testis. The path of differentiation taken by this rudiment determines the future sexual development of the organism. But before embarking on its sexual development, the human gonads first develop through a bipotential stage, during which time they have neither female nor male characteristics. The bipotential stage appears during week 4 of development and lasts until about week 7. At this stage, the gonadal rudiments are two pairs of genital ridges, one on each side of the lower abdomen. Each genital ridge is made up of an internal compartment of loose cells and an external compartment of tightly connected cells called the sex cords.

The formation of ovaries and testes are both active, gene-directed processes. At week 7, the primary sexual decision is made (Figure 5.2). If the gonadal cells have the genotype XY, testes are formed. The sex cords (the cells that will form the tissues that hold and nurture the germ cells) grow
FIGURE 5.2 Differentiation of human gonads. (A) Diagram of a 6-week embryo, showing the position of the undifferentiated gonads. The mesonephros is an embryonic excretory organ. (B) Transverse section through the genital ridge of the 6-week bipotential gonad. (C) In testis development, the primitive sex cords develop inwardly, losing contact with the outside. They differentiate, connecting to the Wolffian duct such that the sperm can leave the body through the penis. (D) Ovary development in an 8-week human embryo. The internal primitive sex cords degenerate, but new sex cords take their place on the outside of the genital ridge.
inwardly. Gamete precursor cells migrate into these tubules and will stay dormant until puberty. The internal male sex cords become the Sertoli cells of the seminiferous tubules and the loose tissue around them becomes the Leydig cells. At puberty the tubules will open up and the gamete precursor cells will differentiate into sperm.

If the gonadal cells have the genotype XX, the bipotential gonads become ovaries. The sex cords develop in the periphery of the gonad, and the germ cells migrating into them will become eggs. The surrounding cortical sex cords will differentiate into granulosa cells. The loose cells of the ovary differentiate into thecal cells. Together, the thecal and granulosa cells will form the follicles that envelop developing eggs. Each follicle will contain a single egg precursor cell. Thus, in females, the gametes (oocytes) will reside near the outer surface of the gonad (where they can be ovulated into the oviduct), while in males the gametes (sperm precursors) reside in the internal part of the gonad (and need sperm ducts to get them to the outside).

Sex-determining genes
The “testis-forming” gene of the Y chromosome has been identified as the SRY gene (SRY stands for “sex-related gene of the Y chromosome”). XY individuals with mutations in the SRY gene develop ovaries rather than testes. In females, the DAX1 gene on the X chromosome and the WNT4 gene appear to be important in forming the ovaries and preventing testes from forming.

In females, two X chromosomes (in the absence of a Y chromosome) are necessary for the production of ovaries. Individuals with only one X chromosome and no Y chromosome (designated “XO”) develop into sterile females whose ovaries fail to form properly.

The male and female germ cells
We mentioned in Chapter 1 that the germ cells—the precursors to the eggs and sperm—are set aside early in development. As the gonads are being formed, these gamete precursors migrate into the gonads. There are several differences between the male and female gametes as they reside in their respective gonads.

The female gamete precursor cells in the ovary initiate meiosis only once—while they are still in the embryo. They can stay in an immature state for decades, with one oocyte maturing to ovulate each month after menarche (the beginning of menstrual periods at puberty). Most of a woman’s oocytes die, however, and relatively few of them are ovulated.

The male gamete precursor cells of the human testis, on the other hand, become stem cells. A stem cell is a cell that can divide so that one of the products of division is a more differentiated cell type (such as an immature sperm cell), while the other product is another stem cell just like the origi-
nal cell. Thus, in human males, meiosis in the sperm begins at puberty, but new sperm are made continually throughout the man’s life.

**Secondary Sex Determination**

Primary sex determination, then, is concerned with the sexual specification of the gonads (testes and ovaries) and germ cells (sperm and egg precursors). **Secondary sex determination** involves the sexual specification of the rest of the body. In humans, secondary sex determination is accomplished through hormones secreted by the gonads. Human secondary sexual determination specifies the form of the external genitalia; it also specifies that men and women have different distributions of body fat and body hair, as well as differences in muscle mass, voice tone, and pelvic bone structure.

Secondary sex determination also specifies either a male or female duct system. The early human embryo not only has a bipotential gonad, but also has two potential duct systems. It has a **Wolffian duct** that can become the male epididymis and vas deferens (the tubes that carry sperm to the outside of the body); and it has a **Müllerian duct** that can differentiate into the oviducts, uterus, cervix, and upper vagina. Figure 5.3 summarizes the different development of these two duct systems.

**Figure 5.3** The development of the gonads and their ducts. Both the Wolffian and Müllerian ducts are present at the bipotential gonad stage. Without testosterone, the Wolffian duct and mesonephros degenerate, and estrogen causes the Müllerian duct (orange) to differentiate into the female genitalia (right). The testes make two major hormones. The first, anti-Müllerian duct factor (AMH), causes the Müllerian duct to regress. The second, testosterone, causes the differentiation of the Wolffian duct (blue) into the male internal genitalia (left).
**FIGURE 5.4** A simplified view of the cascade of events believed to lead to the formation of the male and female phenotypes in human sex organs. The bipotential gonad appears to be moved into the female pathway (ovary development) by the \textit{WNT4} and \textit{DAX1} genes. The ovaries make thecal cells and granulosa cells, which together are capable of synthesizing estrogen. Estrogen stimulates the development of the Müllerian ducts into the female genitalia. In the male, the \textit{SRY} gene (located on the Y chromosome) activates the \textit{SOX9} gene, which organizes the gonads to become testes. The Sertoli cells of the testes produce anti-Müllerian duct hormone (AMH), while the Leydig cells produce testosterone that stimulates the Wolffian duct into the male pattern.

If the embryo is XY, testes form and secrete two major hormones. The Sertoli cells secrete \textbf{anti-Müllerian duct hormone (AMH)}. AMH, as its name implies, destroys the Müllerian duct (which would otherwise become the female reproductive tract). The Leydig cells secrete a second hormone, \textbf{testosterone}. Testosterone promotes the differentiation of the Wolffian duct and its associated organs, such as the prostate gland. Testosterone also inhibits the development of breasts, stimulates the formation of the penis, and allows the testes to descend into the scrotum.

If the embryo is XX, the gonadal ridges develop into ovaries. The ovaries produce \textbf{estrogen}, a hormone that enables the Müllerian duct to develop into the uterus, oviducts, and upper end of the vagina. In the absence of adequate testosterone, the Wolffian duct of females degenerates. Estrogen also stimulates the onset of menstruation at puberty and, along with other hormones, regulates the cycle of ovulation. Figure 5.4 summarizes the interactions that result in physical and anatomical differentiation of the sex organs.

**Sex-Linked Diseases**

Every female cell has two X chromosomes, whereas a male cell has only one. Moreover, the X chromosome, unlike the Y, contains genes that are used in all the cells of the body. Therefore, if there are mutant genes on the
X chromosome, men are much more likely to be affected than women. For instance, Duchenne muscular dystrophy (DMD) is caused by the mutation of a gene that is normally active in muscle cells. Because this gene is on the X chromosome, it is referred to as an X-linked gene. A woman can have the mutant DMD gene on one of her X chromosomes and yet not have the disease, because she has a “good” (i.e., normally functioning) copy of that gene on her second X chromosome. However, although half of her eggs will transmit the normal DMD gene, the other half will carry the mutant gene (Figure 5.5).

If an egg with the mutant DMD gene is fertilized by a sperm with a normal X chromosome, the resulting XX girl will be normal (although she will still carry the mutant gene, as her mother did, and can pass it on to her offspring). However, if the egg with a mutant DMD gene is fertilized by a sperm carrying a Y chromosome, the resulting boy, with only the mutated X chromosome, will have no “good” DMD gene to balance the mutant gene and will have muscular dystrophy. Therefore, most deficiencies of X-linked genes are seen only in males.

Because females have two X chromosomes in each of their cells while males have only one, each female XX cell will inactivate one of its X chromosomes. Thus each cell expresses the genes on only one X chromosome. This X-chromosome inactivation is random: each cell has an equal probability of inactivating its paternally derived or its maternally derived X chromosome. If a female is heterozygous for a mutant X-linked gene, her tissue will usually function normally, since the tissues (made up of many cells) can usually work fine with only half the “good” protein product (that is, the product made by the normal X-linked gene). So even though X-linked diseases are almost always expressed by males, a female can manifest the disease if for some reason too many of her “good” genes are inactivated (a rare situation), or if she inherited the mutant gene from both parents (which would mean her father expressed the condition and her mother was a carrier).

**FIGURE 5.5** A female may carry a disease-causing mutant gene on her X chromosome and yet be unaffected, because her second X chromosome has the normal variant of this gene and can compensate for the mutant gene. However, at meiosis, she makes two kinds of eggs, one whose X chromosome carries the mutant gene, and the other kind carrying the normal gene. If a sperm with a Y chromosome fertilizes the egg containing the mutant X chromosome, the boy will be affected by the disease.
Androgen Insensitivity Syndrome

One of the most interesting sex-linked conditions is androgen insensitivity syndrome. There is a gene on the X chromosome that makes a testosterone receptor protein—a protein that binds to testosterone and carries it into the cell nucleus. Without this receptor protein, testosterone cannot function.

Imagine an embryo that is XY, but with a mutation on its X chromosome in the gene for the testosterone receptor. This embryo makes testes (because it has a functional Y chromosome with a normal SRY gene); the testes in turn produce their two hormones, AMH and testosterone (see Figure 5.4). The anti-Müllerian duct hormone from the Sertoli cells functions normally: the Müllerian ducts disintegrate and the fetus has no cervix, uterus, or oviduct. But because of the mutation in the testosterone receptor protein, the testosterone made by the Leydig cells cannot function.

Now enter the influence of estrogen and related hormones. Estrogens are found in both male and female embryos; they are made by the adrenal gland, the testes, and the mother. In androgen-insensitive embryos, under the influence of estrogens the breast buds will be programmed to develop in the female manner, as will the hair and body fat distributions. Indeed, the testes (which are formed inside the abdomen and whose descent is regulated by testosterone) will not become external. When such a baby is born (and until she fails to have menstrual periods as a teenager), the individual looks and behaves like a normal woman; however, her anatomy prevents her from having children.

Persons with androgen insensitivity syndrome sometimes undergo surgery to extend the vagina and remove the nonfunctioning internal testes (which are prone to become cancerous if not removed).

If one views being “female” as a social category, then persons with androgen insensitivity syndrome are normal females, even though they carry a Y chromosome in every cell. If “female” is viewed as a strictly genetic category, however, these same people are abnormal males whose development has been arrested by a genetic mutation. If female-ness is viewed as a functional category, then these same people are abnormal females who lack a uterus and cannot bear children. Androgen insensitivity syndrome is thus one of several intersex conditions that make us ponder what we think of as “normal.” How biology and society interact in determining what is “normal” is discussed in Chapter 13.
Prenatal Diagnosis and Preimplantation Genetics

One of the consequences of in vitro fertilization (see Chapter 3) has been our ability to detect genetic mutations early in the embryo’s development. Many genetic diseases can be diagnosed before the baby is born; such prenatal diagnosis can be done by chorion biopsy at 8–9 weeks of gestation or by amniocentesis at around the fourth or fifth month of pregnancy. Chorion biopsy, or chorionic villus sampling, involves taking a sample of the placenta, while amniocentesis involves taking a sample of amniotic fluid. In both cases, fetal cells can be analyzed for the presence or absence of certain chromosomes, genes, or enzymes.

However useful the procedures of prenatal diagnosis are in detecting genetic disease, they carry with them a significant concern: If the fetus is found to have the genetic disease, the only means of preventing it is to abort the pregnancy. The waiting time between the knowledge of being pregnant and the results from the amniocentesis or chorion biopsy can create a “tentative pregnancy,” a stressful period during which many couples do not announce their pregnancy for fear that it might have to be terminated (Rothman 1994).

One way around this difficult choice would be to screen the embryonic cells before the embryo is even in the womb. Such screening is indeed possible during the period between in vitro fertilization and the implantation of the embryo into the uterus. This ability to test an in vitro embryo is the basis of a new area of medicine called preimplantation genetic diagnosis, or PGD. PGD seeks to test for genetic disease prior to the embryo’s entering the uterus.

Preimplantation screening procedures are performed on embryos created by in vitro fertilization while the embryos are still in the petri dish. At the 4- to 8-cell stage of the embryo, a small tunnel is made in the zona pellucida, and a micropipette removes two blastomeres (Figure 5.6). Since the

![Blastomere removed for genetic analysis](image)

**FIGURE 5.6** Preimplantation genetic diagnosis (PGD). This procedure is performed on one or two cells taken from an early (4- to 8-cell stage) embryo. Microscopy can tell whether the chromosomes are normal, and other lab tests reveal whether certain genes are present, absent, or mutant. (Courtesy of the Institute for Reproductive Medicine, Livingston, NJ)
mammalian embryo can easily replace these cells, their removal does not endanger the embryo. (This plasticity of early embryonic blastomeres was mentioned in Chapter 1 and will be discussed more fully in Chapter 7). The isolated cells can be tested immediately for the genes of interest, with results that are often available within two days. The presumptive “normal” embryos are implanted into the uterus, while presumptive defective embryos are discarded. For many couples, it is easier to consider implanting only those embryos that most likely will be healthy than aborting a fetus, even if the fetus is in all probability seriously impaired.

**Sex Selection**

Besides screening for genetic defects, preimplantation genetic diagnosis allows couples to know another piece of information that used to have to await the baby's birth: these tests can reveal the embryo's sex. Some parents want to know this information; some do not. Such knowledge raises the issue of parents choosing the sex of their offspring in advance.

There are probably very few people who would condone aborting a pregnancy simply because the embryo was the “wrong” sex (although this is known to happen, as discussed in Chapter 6). However, using PGD in conjunction with in vitro fertilization can allow a couple to choose their child’s sex by having only embryos of the desired sex implanted. Different countries and even different hospitals have varying regulations as to whether they permit preimplantation diagnosis solely for the purpose of sex determination.

Another way to accomplish sex selection is through sperm sorting. The basis for this procedure, which uses a biomedical technique called flow cytometry, is that the X chromosome is substantially larger than the Y chromosome. Unlike preimplantation diagnosis, sperm sorting is preconceptional: sperm selection occurs prior to fertilization and thus this method does not involve either the abortion or destruction of “wrong-sex” embryos. It is an expensive procedure, however, and is not likely to be covered by insurance; thus it is reserved for those wealthy enough to afford it.

Sperm sorting using flow cytometry was developed by a private laboratory in 1989. The technique exposes a sperm sample to a DNA-binding fluorescent dye. The female-producing sperm contains more DNA than male-producing sperm (because the X chromosome is much larger than the Y chromosome), and thus absorb more dye. The dye-injected sperm sample is then passed through the flow cytometer, a laser-based device that activates the dye and then separates sperm one at a time according to brightness density, separating the brighter (X-chromosome) sperm from the less fluorescent (Y-chromosome) sperm (Weaver 1999).

Sperm separation is not 100 percent effective, but it does result in a sperm sample that is significantly enriched for either X-bearing or Y-bear-
ing sperm. The enriched sample of choice can then be used for artificial insemination or in vitro fertilization, allowing a couple a significantly increased chance that the embryo produced will be of the desired sex. If the desired result is a girl, there is about a 90 percent success rate. Selection for a boy is less reliable, with about a 75 percent success rate (Ramachandran 1999). This disparity occurs because an X-carrying chromosome that appears even slightly dimmer than the norm will be sorted as an male-producing sperm.

Sex selection, almost always using preimplantation genetic diagnosis, is widely used therapeutically as a way of preventing X-linked diseases. It is a boon to women who know, or who have reason to believe (from family medical history), that they carry an X-linked mutation. However, the wider potential for sex selection is in fact its use as a method of family balancing: if a couple can have children of the desired sex in the sequence they prefer, proponents argue, it will result in smaller families (a good thing in an overpopulated world) and thus less economic and emotional burden for many. Opponents of sex selection, however, point to its probable use to prevent the birth of girls in cultures where women are regarded as less important than men. This concern and other issues are the subject of the next chapter.
Arguments For and Against Sex Selection

Discussions of cloning and stem cell research involve setting limits on technologies that do not yet exist. However, the debate on whether sex selection is an ethical practice concerns technology that is already perfected. It is possible, through preimplantation genetic diagnosis (PGD), to determine which 4- or 8-cell human embryos are male and which are female, and to implant into the uterus only embryos of the desired sex.

Preimplantation diagnosis is widely used to prevent the birth of sons in women known to be carriers for X-linked lethal or debilitating diseases (see pages 88–89). For instance, a woman who is a carrier for the X-linked conditions hemophilia or muscular dystrophy may not want to suffer through the “tentative pregnancy” associated with amniocentesis or chorionic villus sampling, and then have to decide whether or not to abort the male fetus should it prove to have the disease. Such women can instead undergo in vitro fertilization and have only XX embryos implanted; the female infants should be unaffected by X-linked diseases (although they have a 50 percent chance of being carriers).

Using PGD for the diagnosis and prevention of serious medical conditions seems appropriate to most people (especially if they are not morally opposed to IVF in general; see Chapter 4). However, if a couple have a son and now want a daughter, should they be allowed to use the new sex selection technologies to assure the outcome? If a couple has three daughters and the husband desperately wants a son to “carry on his name,” should this family be allowed access to the technology? Empires have fallen from the lack of a male heir; even today there is debate in Japan about how far the royal family should go in trying to produce a male to sit on the Chrysanthemum Throne, since the Crown Prince and Princess have only
daughters. Moreover, there are some societies where the cultural pressures favoring males are so strong they can drive parents to abandon or kill their female offspring. What would be the result of readily available, reliable sex-selection technology in such countries?

**A Brief History of Sex Selection Practices**

Throughout history, couples have made attempts to control the sex of their offspring. In almost all cases, males have been preferred due to social circumstances favoring the male's greater ability to earn money for the family, provide manpower to armies, work the fields, care for aging parents, inherit possessions, and carry on the family name.

There seems no end to the techniques that parents have tried in order to influence the sex of their child. Aristotle, who believed that high temperatures produced male children, counseled men (especially elderly men) to have intercourse in the summertime if they wished male heirs. Ligating testicles (the right one was believed to contain the male-producing semen), eating certain foods, mating at particular times in the woman's menstrual cycle, and wearing boots to bed have all been promoted as ways to influence the sex of one's offspring. Such folkloric solutions can still be found on today's Internet, and these are every bit as reliable as the ancient prescriptions—that is to say, they produce the desired result about 50 percent of the time.

As twentieth-century scientists learned more about the intricacies of reproduction, scientifically founded but still marginal techniques were proposed to increase the odds of conceiving one sex or the other. In 1970, David Rorvik and Landrum Shettles proposed a technique based on the swimming speeds of sperm. Because male-producing sperm carry a Y chromosome, which is smaller than the X chromosome carried by female-producing sperm, Rorvik and Shettles reasoned that the Y-bearing sperm should be able to swim faster along the female reproductive tract. Therefore they recommended that to have intercourse close to the time of ovulation would give the faster, Y-bearing sperm the advantage and increase the odds of conceiving a son. Conversely, their theory holds that having intercourse several days before ovulation tips the scales in favor of conceiving a girl. A second hypothesis from Rorvik and Shettles claimed that using a weakly acidic douche to wash out the vagina and cervix just before having intercourse would increase the chance of having a girl, whereas using an alkaline douche would increase the chance of a boy (Rorvik and Shettles 1970). These maneuvers give, at best, a minute statistical advantage to one type of sperm or the other; couples using them often end up with a child of the unintended sex.

When recipes for sex determination fail to produce the desired results, couples throughout history have turned to more direct methods of sex selection—namely, infanticide and abortion. There is evidence that infanticide was practiced in ancient Greece, throughout the early Roman Empire,
and in the Arab world to select for male children (Warren 1985). And there is evidence that both infanticide and sex-specific abortion occur in modern countries such as India and China, where extreme cultural pressure to give birth to males collides with increased governmental and economic pressure to have small families; this dilemma will be discussed at length in the next section.

In the 1970s, Gametrics, a Montana-based lab under the aegis of Roland Ericsson, developed a method of sperm separation for use in livestock breeding. (In dairy farming, for example, male cattle are superfluous and expensive, since nearly all commercial cattle breeding is through artificial insemination.) Like that of Rorvik and Shettles, Ericsson’s method relied on sperm swimming speed: sperm containing Y chromosomes presumably swim slightly faster than those bearing X chromosomes.

Gametrics separated the X- from the Y-bearing sperm by passing the sample through viscous (sticky) materials such as albumin, Percoll, or complex carbohydrates to create a “chemical obstacle course” that exaggerated the difference in their swim speeds (“Unnatural Selection,” 1993). This method of sperm separation, the only one available until a few years ago, was only capable of “enriching” semen, or offsetting the ratio of X-bearing to Y-bearing sperm, by about 10 percent.

In the early 1990s biotechnology laboratories in the United States developed the flow cytometry technique of sperm sorting (see pages 92–93). Sperm sorting, for those who can afford it, can now be quite effective. And using the preimplantation genetic diagnostic procedures described in Chapter 5 allows one to choose an embryo’s sex with virtually 100 percent certainty. Sex selection is now possible, but to what extent is it a good idea? There are a number of serious issues to be considered.

**Pressures for Sex Selection**

Many factors play into a parent’s desire for children of one sex over the other, and these factors vary in different parts of the world. In most of the world—and particularly the Far East—cultural, personal, and economic issues merge to drive the balance in favor of male babies (Robertson 2001). Much of this attitude is deeply ingrained in the cultures that share it, and many regions have long histories of preferring males. On the other hand, many Westerners who promote sex selection see it as a way to achieve what is known as family balancing, since in these countries it appears the preference in most families is to have children of both sexes (Kalb 2004).

**Economic and cultural pressures and the gender gap**

Matters of finance and family economics are perhaps the most overt forces working around the globe to drive sex selection. In India, for example,
daughters are viewed as an expense, while sons are seen as a financial asset (Ramachandran 1999). Daughters need to be provided with dowries when they marry,* and patrilineal tradition ensures that many women join their husbands' families upon marriage and thus are no longer available to care for their own parents. Indian culture is also influenced by Sanskrit literature, which is interpreted as saying that the main purpose of marriage is to give birth to a son (Mudar 2002). In some parts of India, particularly poor rural areas, it is not uncommon for the midwife, or dai, to hold a female newborn upside down by the waist, give it a jerk to snap the spinal column, and pronounce a stillbirth (Carmichael 2004).

Among the Chinese, the kinship system emphasizes paternal descent. Patrilocal residence is the norm, and Chinese parents rely on their sons for support in their old age. Because the perceived need for a son is so high, and because the Chinese government places heavy financial burdens on families with more than one child, infanticide of females is believed to be relatively common. Female infants are often left in the streets or on doorsteps of orphanages (Li 1991; Vines 1993; Winkvist and Akhtar 2000).

In the Malay culture of Southeast Asia, on the other hand, matrilocal kinship is practiced in some areas, while bilateral kinship appears in others. In these regions there is no consequence of surnames for lineage, and girls are thought to take better care of their parents, so if any sex preference arises, it is slightly in favor of females (Pong 1994). The Second Malaysian Family Life Survey in 1988 examined Chinese, Indian, and Malaysian populations living together in Malaysia. The survey found that Indians had the strongest preference for boys, followed by the Chinese with a moderate preference, and the Malays, who had no preference for one sex over the other (Pong 1994).

The overwhelming preference for male children among parents in India and China has had sobering results. The technologies of amniocentesis and ultrasound, vital medical technologies for the health of many women and infants, both allow sex identification within the first trimester of pregnancy—well within the legal limits of abortion in most countries. If a woman requests an abortion, it is impossible in most cases to differentiate whether she does not want a baby at all, or does not want a baby of that particular sex.

In wealthy areas of India, where ultrasound and amniocentesis are available, abortion rates of female fetuses is disproportionately high, even though sex selection by any means is illegal and the Hindu religion predominant in the area strictly proscribes abortion (see Chapter 2). In Bom-

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*The government of India, recognizing the severity of the sexism the dowry system has engendered, has begun instigating policies to create a movement away from dowries and toward “bride money.” Bride money is paid by the groom to the bride’s family, and by encouraging this tradition, the Indian government hopes to combat the idea that daughters are a financial liability (President’s Council on Bioethics 2003).
bay, a 1985 survey found that 96 percent of aborted female fetuses were aborted after amniocentesis revealed their sex (Ramachandran 1999). One study found that out of 8,000 reported abortions, 7,999 of them were of female fetuses (Roberts 2002). In 1994, the Indian government passed the Pre-Natal Diagnostic Techniques Act, which attempted to regulate prenatal testing such as sonography and made it illegal to use such procedures for sex selection. However, it seems that, in spite of the act, sex-selective abortion following sonography remains widespread (Shete 2005).

Because of the overwhelming preference for boys in most Eastern cultures, the gender gap—the extent to which the sex ratio of males to females deviates from the theoretical norm of 100:100—has become a major issue in many countries (Macklin, 1995; Satpathy and Mishra 2000). The 2001 Indian census showed that the country’s sex ratio rose to 108:100 during the 1990s (Mudar 2002). In China, as of 1996, males outnumbered females by 36 million (Cardarelli 1996).

In some regions (most often rural areas), gender gaps have led to a generation of young, single males who have no prospects of marrying. This demographic group has been around long enough in some countries to earn its own term. In China, the young men are known as guang gun-er ("bare branch") because they represent "branches of a family tree that would never bear fruit because no marriage partner might be found for them" (Hudson and Den Boer 2004). Studies have shown that the guang gun-er commit a disproportionately high fraction of the crime in their respective areas.

The cultural situation in countries like India and China presents a real dilemma for proponents of sex selection technologies. Even if it were economically feasible to make the current (expensive) technologies widely available there, and even if large numbers of people in these cultures could be brought to accept the loss of privacy and invasiveness of these techniques, would the results really be beneficial? Parental choice would certainly help curb infanticide, abandonment, and the huge number of sex-based abortions. But would the technology allow the gender gap in these countries to skew even more strongly and dangerously to an overabundance of males?

**Family balancing**

Gender gaps in the Western world are not nearly as pronounced as in Asia. Indeed, a 2001 article in the British Medical Journal claimed that "there are studies [in England] which show universally that there is no preponderance of one gender" and that "in Western society there are as many couples who want the girl as there are who want the boy" (Gottlieb 2001). Similarly, a 1993 study by the American Association for the Advancement of Science and a 1999 report in Canada found that just as many women preferred girls as boys, and that most had no preference one way or the other (Vines 1993; McDougall et al. 1999).
Although different studies reveal slightly different statistics, it seems likely that in many Western countries, the preferences for girl-versus-boy would balance out over the long run. The goal of sex selection in these countries would be family balancing—the ability to choose to have a family of a desired composition (often perceived to be two children, one of each sex, with a slight preference given to the boy being born first) (Silver 1998; McDougall 1999).

Where biases have been found, they are often tightly linked to the number and sex of children already born to the family. For example, an extensive study done in the U.S. between 1970 and 1975 showed the strongest sex preferences to be in women who already had two children of the same sex (Figure 6.1; Pebley and Westoff 1982). A 2005 study appears to confirm that, in the United States at least, the majority preference is not for one sex over the other, but for a family with children of both sexes (Jain et al. 2005). And the 1999 Canadian study showed Canadian women to prefer sons as first-born children; however, when Canadian couples were interviewed as a unit, the preference disappeared, indicating that studies targeting only women may not accurately represent gender preferences of entire populations (McDougall et al. 1999).

With the widespread use of sex-selection technology, a slight gender gap might initially be created, but some predict that over time the gap would close (Smith 1993). Rather than an overall change in numbers of males and

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<th>For first child</th>
<th>Prefer a boy</th>
<th>No preference</th>
<th>Prefer a girl</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>45.5</td>
<td>34.2</td>
<td>20.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>For second child</th>
<th>Prefer a boy</th>
<th>No preference</th>
<th>Prefer a girl</th>
</tr>
</thead>
<tbody>
<tr>
<td>If first was a boy</td>
<td>15.0</td>
<td>12.7</td>
<td>72.3</td>
</tr>
<tr>
<td>If first was a girl</td>
<td>68.4</td>
<td>17.7</td>
<td>13.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>For third child</th>
<th>Prefer a boy</th>
<th>No preference</th>
<th>Prefer a girl</th>
</tr>
</thead>
<tbody>
<tr>
<td>If first and second were: Both boys</td>
<td>14.9</td>
<td>9.5</td>
<td>75.6</td>
</tr>
<tr>
<td>Were different</td>
<td>28.1</td>
<td>40.4</td>
<td>31.5</td>
</tr>
<tr>
<td>Both girls</td>
<td>79.8</td>
<td>10.7</td>
<td>9.6</td>
</tr>
</tbody>
</table>

**Figure 6.1** Preferences of married women in the United States for the sex of their next child. The women were surveyed over a number of years (1970–1975). The numbers are the percentages of women preferring a boy (blue bars) or a girl (red bars), and those expressing no preference one way or the other (yellow bars). (Data from Pebley and Westoff 1982.)
females, some predict that “there would be a significant increase in the probability of the first-born being male and the second child being female, and a large drop in the probability of both being the same sex” (Westoff and Rindfuss 1974). Even this, however, could have a major impact on a society’s structure.

**Ethical Views on Sex Selection**

Aside from serious questions about the impact widespread practice of sex selection might have on the gender composition of different societies, many people question whether or not it is really a good idea for people to exercise this kind of control over choices that have heretofore been out of human hands. Some think the technology would be beneficial, insuring smaller families in an overpopulated world and less tension in certain family situations. Others think see the practice as sexist, antisocial, or otherwise immoral.

Attitudes toward sex selection vary among and within countries. In the United Kingdom a recent survey found that 69 percent of interviewees thought sex selection should be restricted in some way, and 80 percent thought that sex selection for nonmedical reasons should not be permitted at all (Ethics Committee 2001). Similarly, the authors of a 2003 German survey reported in *Human Reproduction* concluded that, even if they did not condemn the use of prenatal sex selection by others, most Germans (92 percent of those surveyed) would not use it themselves (Dahl et al. 2003). In the same survey, 58 percent of the respondents stated that they didn’t care which sex their offspring were, while 30 percent preferred a family with an equal number of boys and girls. About equal numbers wanted a preponderance of one sex (4 percent wanted more boys, 3 percent more girls) and 2 percent preferred only girls or only boys (1 percent each).

The idea of sex selection seems slightly more popular in the United States. A 2005 survey of women being treated for infertility found that 41 percent of them said would make use of preimplantation sex selection if it were offered to them (Jain et al. 2005). However, many people still disapprove of the ability to choose the sex of one’s child. Indeed, in response to the *Human Reproduction* survey, Brent Waters, a Christian theologian, wrote that “most respondents have no intention of using sex selection techniques, reflecting, I believe, a moral intuition that there is something inherently wrong with the process itself” (Waters 2003).

**Religious viewpoints**

The question of sex selection using preimplantation diagnosis is inextricably tied with religious beliefs on when life begins, as addressed in Chapter
2. If the religious view is that life begins at conception, then PGD, which involves the manipulation and disposal of zygotes and early embryos, is usually proscribed.

There is no definitive viewpoint among the various Christian denominations about the morality of sex selection. The Roman Catholic doctrine of strict interdependence between the acts of marital union and procreation eliminates any potential for sex selection. The benefits of PGD in certain circumstances are certainly acknowledged and often supported among some Protestant denominations, although the use of this technology for nonmedical purposes is generally eyed askance.

Another perspective found in Western religions is apparently rooted in opposition to pagan practices of sex selection through infanticide. Infanticide was practiced widely in the pre-Christian Roman Empire, but was outlawed as Christianity came into power (Warren 1985). Similarly, the emergence of Islam in the Arab world suppressed infanticide as a means of sex selection in the Middle East. Prior to this point, bearing a female child was considered shameful; however, Muhammad, the prophet of Islam, attempted to convince the Arab people that the killing of any soul created by God was a sin, and that the souls of women are as valuable as the souls of men (Giladi 1990).

In 1983, Islamic scholars convened a seminar to discuss human reproduction (Islamic Organization for Medical Sciences 1983). At the time there was agreement among the participants that sex selection on a national level was unlawful; however, there was a split among the scholars as to whether PGD practiced on a case-by-case basis should be legal. Some thought the wishes of individual couples should be met, while others feared the skewed sex ratio that might result from the practice. There is still no unanimous decision among Muslim religious leaders regarding sex selection technology, with some being of the opinion that family balancing offers a valid point to support the practice (Al-Serour 2000).

However, the political and social differences between men and women in much of the Arab world continue to result in boys being the more desired offspring. For example, a recent decision in Dubai concluded that married men (but not married women) could legally be cloned (Andrews 1999). And Arab physicians confronted with a baby having ambiguous genitalia (see Chapter 5) have refused to perform surgery that would render the child a girl rather than a boy (Fausto-Sterling 2000). Thus sex selection in this culture retains the potential for population imbalance.

Jewish tradition maintains a very strong relationship with the field of medicine, in which it is thought that “he who saves one human life, is as if he saved an entire world” (Shalev 2003). For this reason, genetic screening, genetic engineering, and other genetic manipulations are allowed and even encouraged by Jewish teachings if undertaken to prevent disease and save lives (Rosner 1998). In fact, a campaign to screen potential parents for Tay-Sachs (a recessive mutation that is lethal to the child when both parents...
transmit the trait) has led to a 90 percent reduction in the occurrence of Tay-Sachs among Jewish infants born in North America. The Tay-Sachs program has been cited as a model of how genetic screening can help curtail certain devastating medical conditions (Mange and Mange 1999).

When life and limb are not in jeopardy, however, genetic screening is less extolled. In orthodox Judaism, a man must father at least one boy and one girl before he has fulfilled his duty to “be fruitful and multiply,” and some have asked whether this task might be facilitated by sex selection. When questioned about this, however, most rabbis deem sex selection for nonmedical purposes unacceptable (Wahrman 2002). In a September 2003 meeting, the Israeli Ministry of Health ruled sex selection for nonmedical purposes to be illegal (Shalev 2003).

**Ethical positions among the medical community**

The official position of both the American College of Obstetricians and Gynecologists and the International Federation of Gynecology and Obstetrics opposes sex selection except for medical reasons. The American Society of Reproductive Medicine, however, takes the stand that preconception sex selection to achieve family balance—that is, to provide a couple with a child of a different sex than their existing children—is ethically sound as long as the techniques used are safe and effective (Wahrman 2002; Jain et al. 2005).

Dr. Jeffery Steinberg, head of the Fertility Institutes in Los Angeles, argues that much of the current disapproval is merely a result of the newness of the technology, and that as it becomes more ubiquitous, attitudes will tend towards acceptance (Kalb 2004). This trend has proven true among the geneticist community in the United States. In the mid-1970s—long before PGD was a reality—only 1 percent of medical geneticists approved of prenatal diagnosis for sex selection and the abortion of fetuses of the “wrong” sex; by 1989, a *New York Times* poll reported that 20 percent approved of the practice (Leo 1989). A 1985 study showed that 62 percent of U.S. geneticists would either perform prenatal diagnosis for the purpose of sex selection themselves or refer the couple to someone else who would (Wertz 1989).

Thus there appears to be widespread acceptance of therapeutic sex selection, and many members of the medical community also endorse family balancing. However, doctors must face the question of whether a potential parent has reasons beyond family balance for wanting to choose their child’s sex. The possibility of “ulterior motives” is of deep concern to medical ethicists.

**Gender stereotyping, discrimination, and “commodification”**

Many ethicists believe that there is something inherently wrong in the ability to choose the sex of one’s child, and they have articulated their arguments against those who call for wider distribution of the technology.
Rebecca Dresser, professor at Washington University Schools of Law and Medicine and a member of the President’s Council on Bioethics, argues that sex selection can cause irreparable damage to the mother-child relationship—a relationship, she states, that should be one of unconditional love, not based on the child’s gender (Human Genetics Alert Campaign 2002).

Another major issue is the perception that choosing one sex is rejecting the other. What message does it send to a mother’s sons if she is willing to spend thousands of dollars just to ensure that she does not have another boy? What message does a little girl get from parents who are searching for ways to make sure their next child is a son? While some people point out that a person can choose one sex over the other without necessarily thinking that either sex is “superior,” it is clear that societal discrimination goes beyond personal preference to forces much larger and more unwieldy (Ethics Committee 2001).

To choose to have a child of a selected sex relegates both parent and child to predetermined roles in the relationship, and pressure is placed on the child to behave in a certain gender-specific manner (Ethics Committee 2001; President’s Council on Bioethics 2003). Gender stereotypes pervade society, and represent another major argument of those who assert that sex selection is unethical. The Human Genetics Alert Campaign dubs prenatal sex selection as “the exercise of sexism at the most profound level, choosing who gets born, and which types of lives are acceptable.” Many ethicists see sex selection as treating embryos as commodities, and believe that this “commodification” of children is unacceptable (Roberts 2002). Michael Sandel of Harvard University and the President’s Council on Bioethics argues against what he terms “product selection.” When we select a product at the grocery store, we do so because we expect it to have certain characteristics and be of a certain quality. Similarly, in choosing a child’s sex, we are expecting the child to conform to our preconceived ideas of how the particular sex behaves (President’s Council on Bioethics 2003). Any variation may lead to disappointment.

In addition to the psychological and ethical concerns inherent in the idea of child commodification, the very term “commodification” connotes a for-profit industry built around sex selection. A survey conducted in 2001 by Fortune magazine found that 25–35 percent of prospective parents might consider sex selection (Wadman 2001). Even if only 2 percent of this 25 percent were to actually use the technology, pre-selection could easily become a $200 million per year industry in the United States. Theologian Brent Waters bemoans the “growing perception of children as commodities satisfying the desires of their parents,” writing that “sex selection technology is
Preimplantation Genetic Diagnosis: Toward GATTACA?

Today it is possible to select the sex of one's child through preimplantation genetic diagnosis. With PGD, it is a simple matter to check a 4-cell embryo for the presence of a Y chromosome, which indicates the child is male. Potential parents can then choose to implant only those embryos with a Y chromosome if they want a boy, or only those without a Y chromosome if they want a girl. The same preimplantation techniques are also used routinely to screen embryos for the presence of genes that are known to cause certain deadly or seriously debilitating medical conditions, thereby circumventing the birth of children who would suffer from these conditions.

But what about the genes that are responsible for, say, height, or eye color, or curly hair? As researchers locate and describe more and more human genes (see Chapter 9), what if we can pinpoint genes that bias a person's intelligence, or athletic prowess, or sexual preference? It is certainly possible that we will someday—perhaps even soon—be able to select for other physical and mental traits in much the same way we can currently select for sex.

The 1997 movie GATTACA depicts a future society in which any imperfection of the human body or mind is abhorred and discriminated against. After all, if genetic techniques allow people to insure their child receives only the “best” traits, can’t it be seen as antisocial not to take advantage of these procedures? Is the movie sheer science fiction, or could such a social scenario actually come to exist?

GATTACA’s premise is that if a trait is perceived as undesirable, and if it then proves possible to prevent or eliminate that trait, society will inevitably discriminate against people who possess the trait, relegating even normal human variation (poor eyesight; short stature, heavy body frame) to the status of “diseases” (see Paul 1995). It has been argued that the mere decision to prevent the birth of a child with a given trait—whether the trait is the child’s sex or height or hair color—is in itself a form of discrimination. Others see nothing wrong with biasing one’s odds of having a “normal” or “superior” child (Dahl 2003; Roberts 2003). It is not hard to see that the ethical arguments over preimplantation genetic diagnosis for sex selection may be just the tip of a very large iceberg.

but one more tool for developing a market in desirable children” (Waters 2003). Indeed, there are already numerous websites devoted to “selling” the procedure to parents, and radio, magazine, and newspaper ads flashily offer the services of various prenatal diagnosis clinics (President’s Council on Bioethics 2003).

The Ethics Committee of the American Society for Reproductive Medicine tries to combat the “free market” mentality by arguing that, when the health of the child is not a risk, sex selection is “inappropriate control over trivial characteristics” (Ethics Committee 2001). And if health is not a concern in the arena of social sex selection, it can be argued that the process then becomes a matter of enhancement, and the door to “eugenics driven by the free market” is “thrown wide open” (Human Genetics Alert Campaign 2002).
Government Policy: Rights versus Regulation

Over 40 European nations and several countries in Asia (including India) have banned all nonmedical sex selection (Mudar 2002; Human Genetics Alert Campaign 2002). In the United States, however, there has not even been much debate on the issue up to this point. The novelty and financial inaccessibility of the technology have kept demand for regulation low, and there are currently no federal or state laws that deal expressly with sex selection.

One argument by those in favor of prenatal sex selection in the United States invokes the concept of human rights. According to the U.S. Constitution, citizens have the “right to be free from undue interference,” and some feel that sex selection of children is “a logical extension of parents’ rights to control the number, timing, spacing, and quality of their offspring” (Wertz 1989). Rachel Remaley cites the 1972 Supreme Court decision upholding the “right to privacy and freedom from intrusion affecting the decision to bear or beget a child.” Remaley argues that if a woman currently has the right to choose whether or not to have a child, she should also be allowed to choose which sex the child will be (Remaley 2000). Others cite the Universal Declaration of Human Rights (1948), which includes among the enumerated human rights “the right to marry and found a family” (this particular passage in the Declaration arose in response to Nazi laws prohibiting reproduction by disabled people).

Others, however, feel that sex selection is not among the inalienable rights alluded to in the Declaration of Independence, nor is it included among the “reproductive rights” upheld in Supreme Court decisions. In response to those who cite the Universal Declaration, the Human Genetics Alert Campaign points out that people are already legally disallowed from certain potential reproductive activities, for example marrying close family members (Human Genetics Alert Campaign 2002). They contend that reproduction with whomever we choose through any technological means available is not necessarily a human right, and sex selection should be evaluated as a separate case.

Because the fear of new technology often increases the desire for its regulation, it is expected that legislation governing prenatal genetic diagnosis and sex selection in the United States will not be long in coming (Roberts 2002), although some feel that the regulation of PGD is outside governmental territory and should be done on an independent basis.

*For a concise summary of current international legal regulations regarding sex selection technology, see http://www.bionetonline.org/English/Content/db_leg2.htm#sex.

*The 1972 Supreme Court decision in Eisenstadt v. Baird struck down laws prohibiting the distribution of contraceptives to unmarried persons. It was one of a series of decisions on reproductive freedom that paved the way for Roe v. Wade in 1973.
One group asking for regulation of this technology has been a coalition of women’s rights and technology assessment organizations. In 2002, they published a letter to the American Society of Reproductive Medicine in response to the Society’s endorsement of prenatal sex selection (Center for Genetics and Society 2002). The letter expressed deep concerns about the inherent potential for gender discrimination posed by the practice of sex selection: “While motivations for desiring a child of a particular sex may vary, there are no non-sexist reasons for pre-selecting sex except in cases of preventing serious sex-linked diseases. This is true even in the United States, where economic and social pressures to raise male children are minimized in comparison to other societies.” However, there is ambivalence among feminists over the question of sex selection (Macklin 1995). On one hand, feminists traditionally have defended a woman’s reproductive liberty in all cases; on the other, some feminists uphold the argument of the coalition’s letter, that sex selection will encourage sex discrimination.

In anticipation of laws that might be enacted, Liu and Rose (1996) proposed these guidelines for family balancing clinics:

- The couple must demonstrate that they have a stable relationship, as well as report the number and sexes of the children they already have.
- Because PGD would only be used for family balancing, the couple must already have at least one child, and the sex chosen should be of the underrepresented sex.
- The couple would be told that sex selection is not completely accurate, and would be required to sign an agreement that a child of the unwanted sex would not be aborted.

To deal with more multifaceted issues and to rein in a potentially mushrooming business, Judith Daar, a professor of both law and medicine, has proposed three areas in which policies might be enacted. First, Daar posits that a license and certification could be required of providers, thus limiting the number of facilities offering sex-selection services. Second, informed consent should be required on the consumer’s part, and third, criminal penalties would be imposed on those consumers and facilities who do not comply with licensing and consent regulations (Remaley 2000).

In this same vein, the Recombinant DNA Advisory Committee (RAC), created in 1974 to advise the NIH on matters of human gene technology, might be given accreditation and licensing powers to regulate the spread of prenatal diagnosis technology (Roberts 2002). The RAC would thus become analogous to the Human Fertilisation and Embryology Association (HFEA) in Britain, a governmental group that has the power to enact laws. It was the HFEA that in 1993 banned prenatal diagnosis for nonmedical reasons in Britain (Ethics Committee Report 2001).

Indeed, an alternative to regulating sex selection is to ban it completely. However, some feel a blanket prohibition would prevent therapeutic sex
selection, would create a dangerous black market for the technology, and might be more difficult to enforce than carefully thought out incentives and regulations. In addition, policy regarding sex selection cannot be limited to simple prohibition or permission. Questions of whether it would be covered by health insurance or whether those who morally oppose it would be exempt from paying for any mandatory insurance coverage also come into play (President’s Council on Bioethics 2003).

**In Conclusion**

There are many questions yet to be answered regarding sex selection. Is it justifiable to choose the sex of your child simply because you want to? Does permitting control over sex determination open the door to eugenics and the control over traits such as height, eye and hair color, and even intelligence?

Sex selection by infanticide and abortion has been common in certain areas of the world for centuries; the resulting changes in sex ratios, known as the gender gap, have become apparent in some regions. It is doubtful that the cultural pressures present in most Western societies would lead to the same type of stratification, but other questions arise. For example, how does sex selection influence the parent-child relationship or the expectations that parents hold for their children? What political, economic, and social repercussions would widespread sex selection have? These and other questions lead to amorphous, unanswered gray areas. However, the recent advent of powerful technologies that will almost certainly become more and more available in a free market economy attest that, for better or worse, we may be on the verge of obtaining concrete answers.