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— Sex Preselection — Not Yet Practical

This **Population Report** on sex determination was prepared by Ward Rinehart on the basis of published reports and articles, unpublished papers, personal interviews, and correspondence.

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SUMMARY

For centuries prospective parents have sought ways to influence the sex of their children before birth, but a reliable method acceptable for general use has yet to be found. Many methods have been studied in the last 50 years, and, while most have proved disappointing, research continues. Three types of sex preselection methods are being tried:

- Timing of coitus, douching, and other changes in human behavior or environment intended to influence the sex of the child conceived;
- Manipulation of sperm in vitro;
- Selective abortion.

Although pre-coital douches and timing of coitus have been widely popularized, neither has been proved effective as a sex preselection method. Recent epidemiological evidence suggests that timing of coitus does affect sex of offspring, with intercourse close to the time of ovulation favoring conception of a female, but the effect is slight. Thus, even if a workable sex preselection method can be based on coital timing, it would have little appeal to most people.

In vitro techniques attempt to separate human or animal sperm into male-engendering and female-engendering fractions. Centrifugation, sedimentation, electrophoresis, sperm motility, and immunologic phenomena have all been tried as means of separating sperm. Results have varied, and successes have been difficult to repeat. Nevertheless, research will continue because an effective method would be valuable to cattle breeders. While it might be highly reliable, a separation method is likely to require special skills and sophisticated facilities. Its technical complexity—and the necessity of artificial insemination—would limit human use of a sperm separation method, especially in developing countries where sex of child preferences are strongest.

The only effective preselection method now available is selective abortion after identifying the sex of the fetus. The method can be used only relatively late in pregnancy because fetal sex cannot be determined earlier. Since late abortion is expensive and somewhat risky, its use for sex preselection seems unlikely to become popular, and may remain limited to cases of sex-linked hereditary diseases like hemophilia.

In summary, medical science is still exploring and may be close to finding methods of determining sex at conception. Probably, however, simple methods will have only marginal effect, while methods offering greater effectiveness will be technically complex and so not widely used.

Impact Uncertain

There have been predictions that the use of sex determination would slow population growth. If couples could choose, it is argued, many would have one or several sons and fewer daughters, and families would be smaller. Then in the following generation the shortage of marriageable females would reduce the population's total reproductive capacity, further slowing population growth. Some also contend that an imbalance in the sex ratio, resulting from the use of sex preselection, would cause radical social changes. Such predictions are highly speculative; the demographic and social effects of a sex preselection method cannot be foreseen.

At the moment no generally acceptable and effective method of sex determination is available. Therefore,

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family planning programs can best respond to sex of child preferences by helping couples to value children of both sexes equally and to emphasize the quality of life for daughters and sons alike.

PAST THEORIES

Throughout history, folk methods, most "scientific" methods, and chance alone have been equally successful at determining sex—they produce a child of the desired sex approximately half the time (30,129). But the desire for an effective sex preselection method has helped to keep some techniques popular in both lay and scientific circles for years, even centuries, often despite evidence of their ineffectiveness or physiological improbability.

The only failure-proof folk method for controlling the sex of offspring was selective infanticide (72). It was employed, usually against female infants, by various cultures ranging from the Eskimo to the Maori of New Zealand and the Toda of India (9). During the Tokugawa period (1600-1868 A.D.) in Japan, some districts reportedly registered nine male births for every female birth, implying that seven or eight out of every nine female infants were destroyed (176).

Innumerable other folk methods attempted to select a child's sex at or before conception. Examples include reciting chants during intercourse; timing coitus in relation to wind direction, rainfall, temperature, or phases of the moon or tides. One folk prescription advised eating sweet foods to produce girls or bitter or sour foods to produce boys. Another recommended that a man have intercourse with his boots on to have a son. In parts of Austria, midwives buried the placenta under a nut tree to ensure that the next child would be male. In the Palau Islands of the Pacific, a woman wanting to bear a son dressed in man's clothing before coitus. And in some regions of the USA, a man hung his pants on the right side of the bed if he wanted a son; on the left side if he wanted a daughter (101,146). In West Bengal, the belief persists that coitus on even numbered days of the menstrual cycle produces a boy, while coitus on the odd numbered days produces a girl (139).

Early, ostensibly scientific methods of sex preselection arose largely from faulty assumptions about reproductive physiology. The Greek philosopher Anaxagoras (500?-428 B.C.) contended that sperm from the right testicle produced male offspring, while sperm from the left testicle produced females. Therefore, tying off one testicle before coitus would determine sex (39,204). This notion persisted at least until the 18th century, when French noblemen were advised that surgical removal of the left testicle would guarantee them an heir (62).

Other theories asserted that the female determined sex of offspring. Parmenides of Elea (c. 5th century B.C.) and Hippocrates (460?-377? B.C.), assuming by analogy with animals that women had two-horned uteri, concluded that males developed in the right horn; females, in the left (101,146). Based in part on this theory, Aristotle (384-322 B.C.) offered a complex prescription for choosing a child's sex, which Lawrence summarizes:

> The woman wanting a male child should lie on her right side after intercourse, in order that this side might be the place of conception, "for therein is the greatest generative heat, which is the chief procuring cause of male children." The method was said to fail only rarely, especially if the woman kept warm and with little motion, also drinking hissop and saffron in a glass of malaga. In order to have a female child the woman should lie on the left side and think strongly of a female, for Aristotle believed that imagination of the mother might often determine the sex (101).

Similar theories persisted into this century. In 1917 Dawson contended that the child's sex depended upon which ovary had ovulated and, furthermore, that the ovaries produced alternately. A couple, by calculating from the birthdate and sex of the previous child, could control their child's sex by choosing the correct month for procreative intercourse (34).

Timing of Intercourse Theories

The theory that sex of offspring depends on the timing of intercourse in the menstrual cycle may have been first put forth by Empedocles (494-434 B.C.) in ancient Greece (39). The theory has persisted to the present day. A 19th century version contended that an unripe ovum produces females; a ripe ovum, males. Therefore, conception soon after menstruation, when ovulation was thought to take place, was likely to result in a female. In 1898 Schenk, director of the Embryologic Institute in Vienna, refined this hypothesis into a practical sex control technique. The ripeness of the ovum depended on nutrition, Schenk contended. Because a high protein diet supposedly promoted maturation of the ovum, a woman wanting a son should eat more meat (129). The Empress of Russia reportedly used this method, but, like many other devotees of sex preselection before and since, without success (34).

PRESENT KNOWLEDGE

Since early in this century the chromosomal mechanism has been recognized as the primary determinant of sex (39). Theoretically, if chromosomes alone controlled sex at birth, an exactly equal number of males and females would be born (84). The fact that the sex ratio at birth varies somewhat in association with certain variables has prompted a search for other factors which might also be involved.

The Chromosomal Mechanism

Whether an individual begins development as a male or a female depends upon chromosomes (the gene-carrying material in cell nuclei) in the gametes which join at fertilization. The gametes (sperm and ovum) form through the divisions of a parent cell (gametocyte), each gamete receiving half the gametocyte's chromosomes. In female mammals all body cells, including the gametocytes, contain two identical sex chromosomes, known as X-chromosomes. Therefore, every female gamete contains one X-chromosome. All male body cells contain one X-chromosome and one Y-chromosome. When a male's gametocyte divides, it forms an equal number of X-bearing and Y-bearing sperm. At fertilization, when ovum and sperm join, the full complement of chromosomes is restored. If the X-bearing ovum combines with an X-bearing sperm, the result will be a female. If the X-bearing ovum combines with a Y-bearing sperm, the result will be a male, who will carry in all his cells the XY combination, thereby preserving into the next generation the sex determination mechanism (see Fig. 1). Thus, it is the man, not the woman, whose gamete determines the sex of the child, a fact which should be made clear to men in areas where a wife can be divorced or forced to accept a second wife in the home if she "fails" to produce a son.

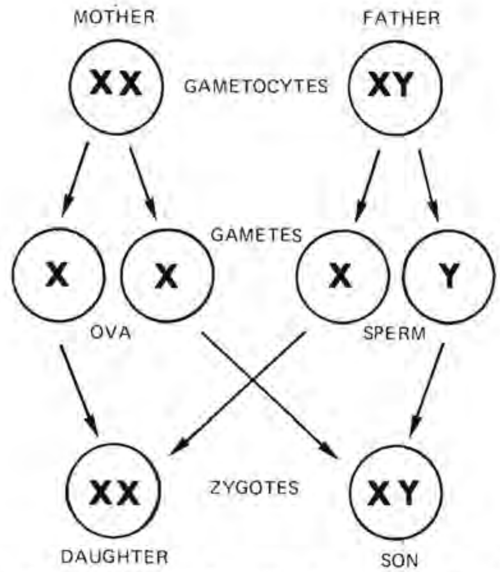

Fig. 1. Simplified schematic representation of the chromosomal mechanism of sex determination.

Variations in the Sex Ratio at Birth

In theory, the testes form an equal number of X- and Y-bearing sperm (84,86). If no other factors intervened between sperm formation and birth, an exactly equal number of boys and girls would be born. In fact, however, in most regions of the world slightly more boys are born than girls (172). For example, in Europe and the USA the ratio for white births is between 105 and 106 males to 100 females (150). Ratios as high as 116.2 males per 100 females in Gambia and as low as 90.2 males per 100 females in Montserrat have been reported (191). Furthermore, the sex ratio appears to vary slightly in relation to certain characteristics of the parents and their environment. Researchers have suggested more than 30 variables associated with variations in the sex ratio (179,181). It has been noted that:

- The percentage of male births rises during and after wars (112,151).
- The percentage of female births increases with increase in age of the mother (104,150), father (128), or both (101,177).
- The percentage of female births increases with birth order (101,111,125,150,151,172,180,183). First births are more likely to be male than subsequent births (101,151).
- A higher percentage of sons is born to couples of higher socio-economic status (101,151,180,181, 182,200,201).
- The ratio of sons to daughters is slightly lower among Negroes than among Caucasians (150,172, 180,181,182,190).
- The ratio of sons to daughters is higher for couples with higher coital rates (75,76,78).
- The sex ratio varies with the season (109,130,151). In the USA, the ratio of male to female births is highest in June (108).
- The ratio of male to female births has been lower after certain disasters such as flood, smog (106), and hepatitis outbreak (143).

Many of these findings have been contested (173,181), and such disputes are difficult to resolve. Many births must be studied in order to determine whether slight variations—and most are very slight—are significant or chance. Methods of ascertaining relationships between variables differ, and so do their results. Essential variables may escape identification or may be left unstudied due to lack of data (180,181).

Variations in the sex ratio at birth imply that one or both of two factors may be influencing the sex ratio. First, conditions of the male and/or female reproductive tracts may favor survival of and fertilization by sperm carrying a particular sex chromosome (73,109,130,144,163,164, 165). Second, after fertilization conditions in the uterus may favor the implantation or fetal survival of one sex over the other (88,101,107,113,151,172,200,201). Presumably, a sex determination technique would have to affect one of these two factors. But the complexity of statistical analysis of sex ratio variations makes it difficult for such studies to reveal the biological factors involved, and, at this point, the discovery of any mechanism which might be manipulated to preselect sex seems more likely to come from laboratory and clinical investigations.

CURRENT RESEARCH

Research on sex preselection has concentrated on five areas:

- timing of coitus in relation to ovulation
- altering conditions in the female reproductive tract
- separating X- from Y-bearing sperm in vitro
- immunizing females against Y-bearing sperm
- determining the sex of the fetus in utero.

The first four approaches depend on the existence of consistent differences in the morphology or behavior of X- and Y-bearing sperm. Much sex determination research has been a search for such differences. Some have been found, but utilizing them to affect sex of offspring has proved to be another matter (15). Success has been achieved in the fourth area of research; reliable methods of ascertaining the sex of a fetus are available, but they are limited to use when pregnancy is relatively advanced.

Timing of Insemination

The most popular of modern sex preselection techniques rests on the hypothesis that timing of coitus in relation to ovulation affects the sex of offspring. Since almost a century ago, when data to support this theory were first presented, researchers have disputed over whether such an effect exists and, if it does, whether insemination close to intercourse favors the conception of males or females.

Most studies with rodents, rabbits, and cattle have found that the timing of insemination in estrus did not affect the sex ratio of offspring (6,11,33,69,131,189), although some report otherwise (31,70). Human births are much more difficult to study because records of coital timing may be unreliable and because many births must be recorded if small changes are to be detected.

Regarding the effect of timing of insemination on the sex of human offspring, two opposing claims exist. The older theory contends that a male child is more likely when insemination takes place early in the menstrual cycle. Statistical evidence to this effect was reported by German researchers in the late 19th and early 20th centuries, before it was known that ovulation occurs not during menstruation, but in mid-cycle (56,138,168). Recently James has presented indirect evidence (76) to back up the early data, including, for example, his observation that in Israel a lower ratio of male to female births occurs among Jews than among non-Jews. James attributes this to the practice by Orthodox Jews of *niddah*—abstinence from coitus for a week after menstruation (80). No biological explanation for this effect has been offered.

The opposite hypothesis, and a basis for the sex determination method popularized by Shettles (146,147), is that a male child is more likely when coitus takes place close to ovulation. Shettles derives his theory from reports by Kleegman (89,90,91) and others (70,153) on the outcomes of artificial inseminations. To explain the effect of timing of insemination, Shettles hypothesizes that Y-bearing sperm, having slightly less nuclear material than X-bearing sperm, move more rapidly but lose fertilizing capacity more quickly. Therefore, he argues, if insemination occurs at the time of ovulation, when cervical mucus is most easily penetrated by sperm, a Y-bearing sperm is more likely to reach the ovum first, producing a male child. If insemination takes place several days before ovulation, most Y-bearing sperm will have died before the ovum becomes available, making fertilization by an X-bearing sperm—and the conception of a female—more likely (146,147,163,164,165,167).

Shettles claims that when the last insemination takes place two or three days before ovulation, the children conceived will be female in 80 percent of the cases, while insemination within a few hours of ovulation will produce 80 percent males. As evidence of the effectiveness of his sex determination method, which also includes recommendations about coital position, pre-coital douching, and desirability of female orgasm, Shettles cites 19 successes in 22 attempts to conceive boys and 16 successes in 19 attempts to conceive girls (164). Séguy reports 77 successes in 100 cases with a similar method (160).

Coitus or Artificial Insemination

Guerrero claims to have resolved the conflict between the opposing versions of the timing theory by finding opposing trends for coitus and artificial insemination. In a study of 875 pregnancies among users of the rhythm method of contraception and 443 pregnancies following artificial insemination, he relates the sex of offspring to the time

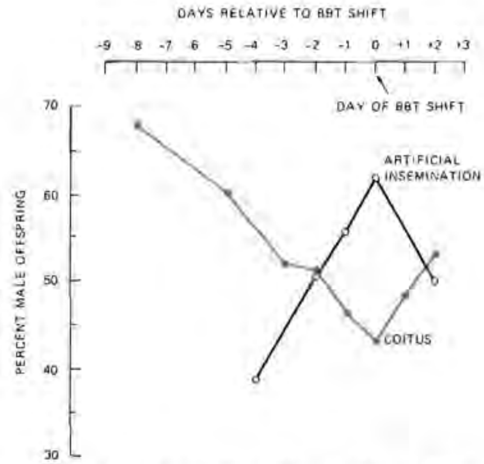

Fig. 2. Sex ratio of children born, by day of coitus or of artificial insemination relative to basal body temperature (BBT) shift, as reported by Guerrero (66). Reprinted with permission from the New England Journal of Medicine (291: 1057, 1974).

interval between insemination and the slight rise in basal body temperature (BBT) which usually accompanies ovulation (see **Population Report** I-1). Guerrero finds that, among the offspring of rhythm users, the percentage of males was highest when the interval between insemination and BBT shift was longest. For example, when coitus took place six to nine days before ovulation, 68.3 percent of all births were male. When coitus took place the day of ovulation, 43.5 percent were male. Among infants born after artificial insemination, the opposite trend appeared (66) (see Fig. 2). Both trends were statistically significant for the period before the BBT shift. Biological mechanisms responsible for the difference in the trends have yet to be found (118).

While Guerrero's study finds a significant relationship between sex of offspring and interval between insemination and BBT shift, it also illustrates the difficulty of using coital timing as a sex preselection technique. The day of BBT shift is not predictable (149), so a couple can never know exactly how soon ovulation will occur. Because the chances for conceiving a girl apparently rise as high as 2 out of 3 only when intercourse occurs on the day of the BBT shift, a couple wanting a girl might be able to use coital timing effectively for sex preselection—provided they could correctly guess that an observed rise in BBT signaled ovulation. The chances of conceiving a boy apparently rise as high as 2 out of 3 only when the coitus responsible for fertilization occurs four or more days before the BBT shift. But, since usually sperm live no more than two days in a woman's reproductive tract (17), coitus four days before ovulation seldom results in fertilization. According to Marshall's calculations, the chance of pregnancy due to insemination on the fourth day before ovulation is only 13 percent and on earlier days is far less (117). Couples desiring a boy might have to wait several years for a live birth and then would face a 1 in 3 chance that the child would be female (141). Using coital timing in the hope of conceiving a boy might prove moderately effective as a contraceptive technique, but disappointing as a sex determination method.

Douches

Pre-coital douches have been recommended as a sex determination method, but they have not been proved effective. Such douches are intended to alter the acidity (pH) of the vagina in order to create an environment favorable to sperm bearing one sex chromosome and hostile to the others.

Altering vaginal pH by douching was first recommended as a sex preselection method in the 1930s (30,159), after Unterberger's report that an alkaline vaginal environment inactivated X-bearing sperm (186). The report had no factual basis (159). Recently one researcher claimed to have demonstrated the effect of altered vaginal pH on sex ratios in rabbits (193), but in vitro tests show no difference in the rates at which X- and Y-bearing human sperm move through fluids of various pHs (37). Despite lack of conclusive evidence, recommendations for douching have persisted. Shettles suggests douching with diluted white vinegar to create a more acid environment, favoring conception of a girl, or with a baking soda solution, which is slightly alkaline, to favor boys (164). Any effect of these mild douches, however, is probably obscured by the alkalinity of the ejaculate (119).

Sperm Separation

Sedimentation, centrifugation, natural sperm motility, and electrophoresis have been used in attempts to separate X- from Y-bearing sperm in vitro. Some experiments have been successful, but they have been difficult to repeat because many uncontrolled variables exist in most procedures (170). Sperm separation techniques are still at a primitive stage of development, but, if a practical method is developed, it could be highly effective.

Until recently, the study of sperm separation has proceeded slowly because no X- and Y-bearing sperm could be distinguished in vitro. Animal sperm fractions must be tested by inseminating females, then determining the sex of offspring. The process requires time and money, and, due to the limited number of animals which can be conveniently studied, it cannot clearly reveal small shifts in the sex ratio (159).

A major advance came several years ago, when researchers discovered an in vitro technique for distinguishing X- from Y-bearing human sperm. When human sperm are stained with quinacrine, quinacrine mustard, or quinacrine hydrochloride, the Y-chromosome fluoresces more brilliantly under a mercury vapor light source than does other cell material (13,175,203) (see Fig. 3). This technique should speed research into separation methods because it can be used to screen human sperm fractions before trying insemination. Quinacrine staining does not identify the Y-chromosome in nonprimate species, however, so experimentation is still limited.

Separation by Sedimentation or Centrifugation

Because X-bearing sperm contain 3 or 4 percent more chromosomal material (175) and therefore may have a higher specific gravity and/or volume than Y-bearing sperm (102), attempts have been made to separate sperm by sedimentation or by centrifugation. In some experiments, rabbit and bull sperm fractions have produced significantly altered sex ratios (23,24,92,97,102,103, 154,155,169,170), but other experiments have failed (14,18,19,25,32,100,102,105). The successful techniques have proved difficult to standardize, and other researchers have been unable to duplicate them (10). Rohde et al., using quinacrine staining to check results, recently reported separating human sperm according to sex chromosomes by centrifuging (145).

Some researchers conclude that no sedimentation or centrifugation method can consistently separate X- and Y-bearing sperm. They point out that any differences in volume or specific gravity of sperm resulting from weight and size differences between the sex chromosomes are obscured by much greater variation among individual sperm, in different ejaculates from the same donor, and among sperm from different donors (10,142). On the other hand, some researchers attribute the success of their experiments not directly to volume or specific gravity differences, but to greater damage to X-bearing sperm due to centrifugal force (103) or to greater agglomeration of X-bearing sperm during sedimentation (97).

Separation by Sperm Motility

Several attempts to separate X- from Y-bearing sperm have been based on the hypothesis of differential sperm motility—that is, that Y-bearing sperm swim faster than X-bearing sperm. This has been demonstrated in vitro in human cervical mucus (82,144), but not enough Y-bearing sperm could be obtained by the techniques involved to make them practical as sperm separation methods (144). Ericcson et al. recently reported separating X- from Y-bearing human sperm by placing a solution of sperm on a column of bovine serum albumin. Apparently, Y-bearing sperm moved more quickly into the albumin. The researchers hypothesize that Y-bearing sperm swim faster and are better able to penetrate the boundary between solution and albumin than are X-bearing sperm (43). Although others have been unable to duplicate the experiment (46,148), Ericcson has recently established a company—named "Gametrics"—in California which will specialize in separating both human and animal sperm.

Separation by Electrophoresis

Electrophoresis of sperm is based on the hypothesis that X- and Y-bearing sperm carry opposite electrical charges (93). Sperm in solution are placed in a chamber, direct current is run through the solution, and sperm which may collect at the electrodes are drawn off to be tested by insemination or quinacrine staining (see Fig. 4).

Schröder, who performed the first electrophoresis experiment in the 1930s in Moscow, claimed that under certain conditions 80 percent females were conceived from rabbit sperm drawn off at the negative electrode (157,158). Gordon, in the 1950s, also claimed some success with rabbit sperm (60,61), but other studies have failed to demonstrate conclusively that electrophoresis separates X- from Y-bearing sperm (67,68,96,110,162) or, more fundamentally, that X-bearing and Y-bearing sperm possess different surface charges (12,126,132,188). Despite the apparent lack of agreement, researchers now studying electrophoresis still believe the technique will work if proper in vitro conditions can be discovered (184).

Passing sperm through an ion-exchange resin to separate X- from Y-bearing sperm on the basis of electrical charges has not succeeded. A large European trial with bull sperm treated in this way failed to produce the desired sex ratio shift (86). Black reports that he could not consistently separate human sperm in ion exchange resins, partly because sperm from different donors reacted differently and because many other variables, some difficult to control, affected the experimental process (26).

Fig. 3. Y-chromosomes are identified by bright spots (see arrows) in human sperm stained with quinacrine hydrochloride and observed through a fluorescence microscope, at approximately 2,500 X magnification. (Courtesy of Dr. Peter W. Barlow) Photograph has been retouched to make the spots more visible.

Other attempts at separating X- from Y-bearing sperm include froth flotation, which was unsuccessful (123), and subjection of sperm to reduced atmospheric pressure, which appeared to have some effect in one study (49) but could not be confirmed (87). Schilling and Petac report altering sex ratios by treating rabbit and swine sperm with various enzymes and chemicals. Significant shifts toward a higher proportion of males—up to 65 percent—were produced by treating rabbit sperm with the hormone estradiol, with the enzyme esterase, and with ammonium sulfate; and by treating swine sperm with sodium hydroxide and with ammonium sulfate. A lower proportion of males—as low as 33 percent—resulted from rabbit sperm treated with hypotonic extender (a sodium chloride solution) and with the enzymes asparaginase and hyaluronidase; and from swine sperm treated with ascorbic acid. The researchers found that the sex ratio of offspring depended not only on the substance used to treat sperm, but also on the proportion of sperm remaining motile in the treated sample (156).

Immunologic Means

The possibility of altering sex ratios by immunologic means has been recognized since the 1950s (47,152), when the Y-linked histocompatibility (H-Y) antigen was discovered (42). This antigen causes female mice to produce antibodies and reject skin transplants from male mice of the same inbred strain. Its presence on mouse sperm (58,95) and on cells from other male mammals, including men, (192) has recently been demonstrated. Since more of the antigen resides on Y-bearing than on X-bearing sperm (58,95), theoretically a serum from females immunized with male cells would inactivate mostly Y-bearing sperm.

So far, most attempts to immunize female mice or rabbits by injecting them with sperm or other sources of male antigens have failed to alter the sex ratio of offspring (16, 76,120,121,122). Immunization against Y-sperm may be unsuccessful not because anti-Y antibodies do not develop, but because sperm in the female reproductive tract are inaccessible to the antibodies (20). Furthermore, male fetuses are unaffected by immunization of the mother (121). Since a maternal immune response to paternal antigens occurs in normal pregnancies, maternal recognition of and immunologic tolerance to male cells may also be a normal part of pregnancy (88). Lappé and Schalk hypothesize that, at least in some mouse strains, normal immunologic responses act to maintain a balanced sex ratio at birth. By removing the spleen, which is essential for the production of certain antibodies, they were able to increase significantly the percentage of males in mouse litters (98).

The attempt to use immunologic means to affect mouse sperm in vitro has been moderately successful. Researchers at the Memorial Sloan-Kettering Cancer Center in New York City, after treating mouse sperm with H-Y antiserum and inseminating females, found that offspring showed a slightly altered sex ratio—approximately 45 percent were male (20).

Immunologic sperm treatment is far from having practical application. The alternation of the sex ratio is slight. Also, because almost all mouse sperm carry H-Y antigens in varying amounts, treatment with H-Y antiserum apparently inactivates 70 to 80 percent of the sperm (58,95), creating a sample rich in X-bearing sperm but low in fertility. In order to make the method practical, ways must be found not only to increase the alteration in the sex ratio, but also to concentrate surviving sperm in a more fertile sample (5). The method allows only selection for females.

Fetal Sex Identification and Induced Abortion

The sex of the fetus in utero can be identified and selective induced abortion used to assure that only a child of the desired sex is born alive. Methods of ascertaining fetal sex have been available since the mid-1950s. They are used on a limited scale to identify the possible victims of sex-linked hereditary diseases (such as hemophilia), which in most cases strike only males, but their use for sex preselection probably will not be widely adopted.

Fetal sex can be identified by examining fetal cells found in amniotic fluid. The cells, obtained by amniocentesis (the withdrawal of amniotic fluid by a needle inserted through the abdominal wall) can be checked for the presence of sex chromatin, a mass of stainable nuclear material seen in some body cells from females (36,55, 74,83,113,166), or of fluorescent Y-bodies (85,187), or analyzed by karyotyping, an examination of individual chromosomes to determine which sex chromosomes are present. Amniocentesis can only be safely performed after 16 weeks' gestation (114), past the period when relatively safe and simple early abortion methods can be employed. It seems unlikely, therefore, that fetal sex determination and induced abortion will be widely adopted as a sex preselection technique. Only five percent of US doctors recently surveyed would perform amniocentesis for sex preselection (44).

Searching for a simpler way to determine fetal sex, researchers have examined maternal blood for fetal lymphocytes (a type of white blood corpuscle) which may pass through the placenta. The presence of Y-chromosomes in the lymphocytes indicates a male fetus. Preliminary work looks promising, but the method cannot be used before the 12th week of pregnancy (35,64,65). Another technique, which attempts to determine fetal sex by examining cells in cervical mucus taken from pregnant women in the first (59) or second trimesters (114), has not succeeded.

Edwards and Gardner have developed an alternate method of postfertilization sex selection (41,57). They have been able to determine the sex of rabbits at the blastocyst stage—after fertilization but before implantation—by recovering the blastocyst, removing a few cells, checking them for the presence of sex chromatin, then, if the blastocyst is of the desired sex, transferring it to a recipient female. Removing a few cells apparently does not damage the blastocyst (57,194). Edwards and Gardner have not yet conducted detailed work involving human embryos (40). The technical difficulties of recovering the blastocyst, removing a few cells, and returning it to the uterus will probably keep the technique from ever becoming a practical sex preselection method.

POTENTIAL EFFECTS

Some social scientists and demographers predict that sex determination would result in smaller families, a surplus of males, slowed population growth, and dramatic social change. Others claim the effects would be slight or short-lived. The debate cannot be resolved; the effects of sex determination remain a subject for intriguing but largely unverifiable speculation.

Possible Demographic Effects

Two arguments support the contention that the use of sex determination would reduce population growth. First, at present, it is argued, some couples will continue having children until their desires for offspring of a certain sex—usually for one or more sons or for at least one child of each sex—are satisfied. Sex preselection would make such "gambling" unnecessary and thus would allow smaller families. Second, many couples want more boys than girls, while few want the reverse. If sex preselection allowed these desires to be translated into fact, and a great preponderance of boys were born, there would be a shortage of females when those children grew up. The total reproductive capacity of the population would then be less than if an equal number of both sexes had been born (133). If a preference for a majority of male offspring persisted for several generations, the effect could eventually be substantial (161).

Evidence about couples' sex of child preferences comes mainly from three sources:

- Attitude surveys, in which couples were asked about family sex composition and size ideals or child-bearing expectations.
- Analyses of fertility behavior, which study, for example, whether those with few sons at low parities went on to have more children than other couples did.
- Studies which examine whether current contraceptive practice is related to the sex of the acceptor's children.

Attitude surveys reveal the widespread desire for at least one child of each sex (51,53,137,174) or for at least one son (53,94). Perhaps the strongest desire for sons is reported from Korea, where 53 percent of the women polled in a 1971 survey said they would continue having children until they bore a son and 25 percent in Seoul would permit their husbands to take concubines if they themselves produced no sons (28). Attitude surveys show that couples with few or no sons (21,52,53,94,124) or whose children are all of the same sex (7,51,137,195 196) intend or expect to have more additional children than do other couples. Polls also report that many people prefer a majority of boys among their offspring (7,28,38, 48,52,94,99,115,116,174,198).

Some evidence suggests that sex of child preferences affect fertility behavior. Some studies report that couples whose first several children were of the same sex (51,63,185,195) or predominantly female (53,199,202) tended to have another child sooner or to have larger completed families than did other couples. Reports from several developing countries show that contraception acceptance rates or particularly sterilization and IUD acceptance rates were low among those with few or no sons (4,27,53,54,94, 133).

Not all studies find evidence that the lack of sons leads to larger families. Data from north India, Morocco, and East Pakistan (now Bangladesh) show that couples with a high percentage of sons tended to have more children than did others (140). Repetto concludes that, because sons brought in more income or burdened family resources less than did daughters, couples with sons may have felt able to afford more children.

Fig. 4. Electrophoresis device used in attempt to separate bull sperm. (Courtesy of Dr. H. D. Hafs)

SOURCE: Reprinted from Hafs & Boyd (67) with the permission of H. D. Hafs and the American Society of Animal Science.

Although methodological problems make drawing conclusions from these data risky (199), in general the evidence seems to indicate a strong preference for sons in some developing areas, no apparent strong preference in other developing areas, and some desire for at least one child of each sex in developed countries (53). Such desires probably affect fertility behavior, but, because so many factors interact to influence childbearing, it is difficult to assess the role that sex of child preferences actually play. A consistent relationship between son preference and fertility behavior cannot be assumed (199).

It is even more difficult to predict how couples might behave if sex determination were available (197). Much would depend upon the method and its effectiveness (80,81,197). For example, if a sperm separation technique is developed, its use would be limited by the acceptance of artificial insemination. In a small sample of US college students, 17 percent of those who in general approved of sex determination would not use a method that required artificial insemination; an additional 33 were "not sure" (116). Furthermore, techniques affecting sex at conception could be used only with planned pregnancies, and many pregnancies are unplanned (44 percent in the USA between 1966 and 1970, for example) (197).

Whether sex control would have long-term demographic effects due to an unbalanced sex ratio also cannot be assessed because many interrelated factors influence fertility decisions. If boy preference in one generation resulted in a shortage of women in the next, would the "value" of girls then rise, encouraging couples to have more girls and in the long run returning the sex ratio to approximately 50:50 (136,197)? Or would long-standing cultural attitudes perpetuate boy preference for many generations, whatever the social consequences (45)?

Possible Social Effects

Despite the fact that no sex preselection method is likely to be completely effective or universally used, both proponents and opponents of sex determination have predicted extreme social consequences if an effective method became available (45,127,134,135). Etzioni foresees that in the USA a sex ratio shift as small as seven percent (or a ratio of 54.75 males to 45.35 females) would bring later marriage, more prostitution and male homosexuality, an increased number of men who never marry, less cultural activity, and more crime (45). Postgate, considering the effect of sex control on the developing countries especially, speculates that:

> All sorts of taboos would be expected and it is probable that a form of *purdah* [the Hindu practice of secluding women] would become necessary. Women's right to work, even to travel alone freely, would probably be forgotten transiently. Polyandry might well become accepted in some societies; some might treat women as queen ants, others as rewards for the most outstanding (or most determined) males. Masculine homosexuality would almost certainly become accepted. . . . Substitutes for normal sex, mechanical and pictorial, would be widely used . . . (127).

Even if the use of sex preselection did not unbalance the sex ratio, it might have some social consequences. Where the desire for a male first child prevails, academic and economic success, susceptibility to social pressure, and other characteristics more common to firstborn than to subsequent children would fall increasingly to males (3, 197).

Since no effective and generally acceptable sex determination method exists, speculations about demographic and social effects are hypothetical. If, at present, boy preference does lead to larger families, family planning programs which seek to encourage parents to plan and space their offspring can best respond by encouraging an equal appreciation of children of both sexes. This has already begun in some countries. In Korea the Planned Parenthood Federation has started an education campaign to change the strong preference for sons. Its slogans now appear on posters, hand fans, and bus window stickers: "Daughter or son, without distinction"; "Daughter or son, stop at two and bring them up well" (1,2). For the foreseeable future this approach can make a more practical and positive contribution to family welfare than claims that modern science can help parents preselect the sex of their children.

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