cles (the more uninformed the circle, the more prevalent the opinion), that these men are either villains or fools. In my experience they are generally able, well-intentioned, and politically sophisticated.

Nevertheless, I believe they have been mistaken, and that they risk their long-term interests in pursuit of immediate gain. I would, in particular, charge those scientists who review research proposals and help set prevailing research standards with (for the best of motives) failing to meet their professional obligation to maintain high quality in federal research grants. Nothing would be more effective toward this end than an increased rate of rejection in certain federal programs, accompanied, if necessary (and I believe it would be necessary, initially, in some programs), by the return of unexpended funds to the treasury.

Five years ago a distinguished committee of the National Science Board, composed mainly of presidents of leading private and public universities, enunciated the following as the first principle for federally sponsored research (*13*):

> Problems of Government-university relationships in the Federal support of research at colleges and universities should be explicitly and completely dissociated from the budgetary needs and crises of the institutions and from the general issue of Federal aid to higher education. In the consideration and administration of these relationships there should be no implication that Federal sponsorship of research is a convenient subterfuge for Federal aid to institutions of higher learning.

The more this principle is breached, the more apparent will become its merit in directing us toward two vital but separate national goals: the maintenance and improvement of quality in scientific research and the maintenance and improvement of quality in higher education. To merge these goals out of political expediency is to endanger both.

Summary

The great expansion of federal scientific research expenditures and their concentration at a few leading universities and institutes of technology has brought enormous benefits to higher education, science, and the nation. It has also contributed to a devaluation of undergraduate teaching and to an expansion of mediocre research. Some reorientation of expenditures toward state universities, liberal arts colleges, science education, and the humanities, and a reaffirmation of standards of quality rather than of mere competence in research, are needed.

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Child Spacing: The Mathematical Probabilities

The chances of spacing children by the rhythm method are analyzed theoretically and experimentally.

André J. de Bethune

In an address delivered 26 November 1951, Pope Pius XII stated (*1*), "We have affirmed the legitimacy as well as the . . . limits of a regulation of offspring which . . . is compatible with the law of God. One can even hope . . . that medical science will succeed in giving to this licit method a sufficiently secure foundation *(una base sufficientemente sicura)*, and the most recent information appears to confirm such a hope." The licit method referred to by Pope Pius XII was described elsewhere by him (*2*) as "the taking advantage of natural temporary sterility *(la mise à profit de la stérilité temporaire naturelle)*."

The hope expressed by Pope Pius XII that natural methods may be given a more secure foundation—that is, made less uncertain, less subject to the vagaries of chance—justifies an investigation into the mathematical probability of the spacing of children for normally fertile couples, particularly for those who choose to use natural methods only.

The spacing of children has itself been approved by Cardinal Suenens, formerly professor of moral theology at the Catholic University of Louvain, who says (*3*, p. 99) that it can "help a mother get used to the duties of motherhood in a more balanced way and aid her in taking on responsibilities with a greater reserve of generosity and, at the same time, more physical strength."

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The Monthly Security Factor q

Let us define q as the probability that a nonpregnant, normally fertile married woman can go through one single specified monthly cycle without conceiving. Obviously, q is a variable dependent upon many factors, such as the frequency and timing of coitus, the natural fertility of the woman and her husband, and the presence or absence of safeguards against conception. If there is no coitus during the specified cycle, q is exactly 1. If there is coitus, q will be somewhat less than 1, even with safeguards. Further on, an attempt will be made to evaluate q. For the present, let us merely assume that this factor q exists, and that it remains substantially constant, from cycle to cycle, for a given couple using a particular method of child spacing.

The probability q may be conveniently referred to as the monthly security factor, in deference to Pope Pius XII's expressed hope for a more *secure* foundation for natural methods. In an extremely valuable paper, Potter (*4*) has introduced the concept of the monthly risk p of pregnancy—that is, the probability p that conception will occur during a single specified monthly cycle. The monthly security factor q is clearly $q = 1 - p$. Potter has also given the mathematical equations that permit projection of the monthly security factor q into a security factor Q for a longer period [Q in this article is $F(0, n)$, in Potter's notation].

Let us consider a normally fertile, normally affectionate married couple at the beginning of one specified monthly cycle. The probability of their going through that cycle without conception is the monthly security factor q, defined above. Let Q be the probability that no conception will occur within some specified interval in the immediate future. Take the next two or three cycles, for example. The probability Q that no conception will occur within the next two cycles is q^2; within the next three cycles, q^3. The probability Q that no conception will occur within the next n cycles is q^n, according to Potter's law (Eq. 1, below).

If, for example, the monthly security factor q is 0.90, the probability that no conception will occur within the next single cycle is 0.90, and the odds against conception are 9 to 1. The probability Q that no conception will occur during the next two cycles is $q^2 = 0.81$, and the odds against conception are now shortened to 9 to 2. The probability Q for the next three cycles is $q^3 = 0.729$, and the odds against conception are shortened further to 8 to 3. For the next six and seven cycles, $Q = q^6 = 0.531$ and $Q = q^7 = 0.478$, respectively, and the odds are about even. For the next 12 and 13 cycles, $Q = q^{12} = 0.282$ and $Q = q^{13} = 0.255$, respectively, and the odds now *favor* conception by about 3 to 1. From this simple statistical law it becomes evident that, for a couple whose monthly security factor is 0.90, there is an *even* chance that conception will occur within the next 6 months or so, and a 3-to-1 chance that conception will occur within the next year or so.

From Potter's law it is possible to ascertain how low q can be allowed to go before the couple has less than an even chance of spacing its children (from birth to birth) by an interval of N calendar months. The equations for this purpose are

$$Q = q^n \qquad (1)$$

with $Q = \frac{1}{2}$, and

$$N = (28/30.5)n + 9, \qquad (2)$$

where n is the number of cycles from the birth of the last child to the conception of the next child, 28 is arbitrarily taken as the typical number of days in a cycle, 30.5 is the average number of days in a calendar month, and 9 months is the normal period of pregnancy before the birth of the next child. Equations 1 and 2 can be solved for various values of N and q to yield the results given in Table 1. They are based on the assumption that fertility returns soon after childbirth.

Table 1 is quite revealing in that it shows that spacings of 2 years or more cannot reasonably be expected if the monthly security factor is allowed to drop more than a few percentage points below unity. A monthly security factor of 97 percent or better must be maintained with unremitting vigilance to achieve just an *even* chance of spacing the birth of the next child 2½ years away from that of the last.

Table 1. Values of the monthly security factor q needed to give an even (1-to-1) chance of spacing births by N calendar months.

Desired spacing between births, N (in months)	Monthly security factor q (%)
12	80.9
18	93.2
24	95.8
30	97.0
36	97.7
48	98.4
60	98.8

Thus, Table 1 explains in a rational way the repeated disappointments experienced by many couples who have endeavored to regulate births by means of the rhythm method alone. A number of such couples (*5*) have found that the rhythm method, as practiced by them, results at best in spacings of 1 to 2 years between births. If 18 months is taken as a median, this observation would place the monthly security factor of the rhythm method, as practiced by these couples, at about 93 percent.

In order to lengthen the spacings from 18 months to 2½ to 3 years, the monthly security factor must be raised consistently to the 97- to 98-percent level. The vigilance demanded of a couple, using the rhythm method alone, to attain and to maintain such a high security level, can prove quite taxing emotionally. This vigilance requires a degree of personal and conjugal asceticism that can make severe demands on the emotional stability of two people legitimately united in marriage and naturally impelled biologically, physically, psychologically, spiritually to heed the scriptural injunction (*6*): "Defraud ye not one the other." Any deviations from vigilance will significantly lower the q value and greatly shorten the spacing that can reasonably be expected (Table 1).

Evaluation of the Monthly Security Factor q

The estimate of 93 percent for the monthly security factor with the rhythm method, as practiced by certain couples, can be compared with two theoretical calculations of the probabilities of no conception for couples who use no contraceptive safeguards.

In a recent paper, C. Tietze (*7*) suggested that the probability of no conception after c acts of unprotected coitus within a given cycle should be given by the formula

$$q = [(25 - f)/25]^c \qquad (3)$$

where f is the fertile period (in days) and 25 is taken as the number of days normally open to coitus. Tietze calculated values of p ($= 1 - q$) for values of f of 0.5, 0.75, 1, 1.5, and 2 days, and for values of c ranging from 4 to 12. He also calculated q by a more complicated formula that yielded slightly lower but not significantly different values. Tietze then compared his results with the observation that couples desirous of achieving conception have, on the average, a probability p of conception of 0.2 to 0.3 per cycle. By assuming that such couples could reasonably have 7 to 11 copulations during the cycle, he showed that a pregnancy rate of 0.2 to 0.3 per cycle is consistent with an f value of 0.5 to 1.0 day. He thus concluded, as very probable, that fertilization is possible only during 12 to 24 hours per cycle, and that the probability that conception will result from a single act of unprotected coitus appears to lie between 1 in 50 (2 percent) and 1 in 25 (4 percent).

Tietze's formula (Eq. 3), with f values of 0.5 day and 1.0 day, gives the limits within which q should fall as a function of frequency of coitus when no contraceptive safeguards are used. These values are given in Table 2.

Table 2. Values of the monthly security factor q derived from Tietze's formula (Eq. 3). (f) Length of fertile period (in days); (c) number of acts of unprotected coitus.

c	q	
	$f = 0.5$ day	$f = 1$ day
1	0.980	0.960
2	.964	.922
3	.941	.885
4	.922	.850
5	.904	.815
6	.886	.783
8	.850	.722
10	.817	.665
12	.784	.612

Thus, on the basis of Tietze's formula (Eq. 3), a 93-percent monthly security level would be consistent with about three to four acts of coitus per cycle if the fertile period is only 12 hours, and with only one to two acts of coitus per cycle if the fertile period is as long as 24 hours. Three to four acts of coitus per cycle appear to be a reasonable estimate for the couples, discussed earlier (*5*), who use the rhythm method. Yet with a monthly security factor of 93 percent, these couples cannot reasonably hope, on statistical grounds alone, to space their children by more than about 18 months between births, as shown by Potter's law (Table 1). If they wish to space their children by 2½ years or more—that is, to maintain a q value of better than 97 percent (Table 1)—statistics indicate that they must limit themselves to one, or two at the very most, acts of coitus per cycle if the fertile period is 12 hours, and to a maximum of one act of coitus per cycle if the fertile period is as long as 24 hours.

Tietze's formula (Eq. 3) is based on two assumptions: (i) the fertile period occurs randomly during the cycle; (ii) any unguarded coitus on a fertile day must lead to conception. These assumptions are, however, open to question. As regards assumption i, the theory of the Ogino-Knaus method is that the fertile period, which coincides with the onset of ovulation, occurs toward the middle of the cycle. Coitus occurring more than 72 hours before or 24 hours after the (unknown) time of ovulation should not lead to conception. Therefore, a single act of coitus should be less likely to lead to conception if it occurs early or late in the cycle than if it occurs in the middle. To this extent Tietze's formula is too pessimistic, from the standpoint of spacing births, when couples can be reasonably certain that ovulation will occur regularly in the middle of the cycle. Basal temperature charts, when normal in pattern, indicate the 3- to 4-day period during which ovulation probably did occur during a given cycle (but they give only statistical indication as to when ovulation will probably occur during the current cycle). When the temperature charts (*5, 8*) show no rise, or show two or more distinct rises per cycle, the timing of ovulation during past cycles becomes highly conjectural, and almost hopeless during the current and future cycles. The evidence from temperature charts suggests that ovulation sometimes occurs early in the cycle (on the 9th day) or late in the cycle (on the 5th day before the mensis) as well as in the middle, and it suggests a situation in which assumption i tends to be more nearly valid than the Ogino-Knaus theory. Moreover, assumption ii is not necessarily valid. Nelson (*9*) has reviewed some of the natural factors inimical to fertilization. Coitus at the time deemed optimum for fertility does not necessarily result in conception. Furthermore, frequent coitus reduces the fertility potential of each act, since it takes several days to rebuild the sperm count. To the extent that assumptions i and ii are not valid, Tietze's formula yields values of the monthly security factor q that are too low, and too pessimistic from the standpoint of spacing births (see *10*).

If, therefore, Tietze's estimate of the probability of conception from a single act of unprotected coitus were to be cut in half, to 1 to 2 percent, it would still take only four to seven acts of coitus per cycle to attain the 93-percent monthly security level attained in practice by a number of couples using the rhythm method and these couples would then have to restrict themselves to two to three acts of coitus per cycle to maintain the 97-percent level demanded by a spacing of 2½ years between births.

On the other hand, Ogino and Knaus have suggested that fertilization can occur only during certain "unsafe" days in the middle of each cycle (*11*). From several cycles of observation, a woman's shortest and longest cycles are to be determined. The first unsafe day is computed from the number of days of the shortest cycle minus 17 (Knaus) or 18 (Ogino); the last unsafe day, from the number of days of the longest cycle minus 13 (Knaus) or 11 (Ogino). Recently, Tietze and Potter (*11*) have presented an analysis of the reliability of this calendar method based on a number of statistical models of the menstrual cycle. Take, for example, a woman whose cycles exhibit medium variability (standard deviation, ± 2 days—that is, 95 percent of the cycles do not vary in length by more than 8 days); whose ovulation date, counted from the beginning of the cycle, exhibits a standard deviation of ± 1⅔ days (that is, 95 percent of all ovulation dates fall within a span of 6⅔ days); and who can undergo fertile coitus on her day of ovulation and the two preceding days with an assumed 50-percent chance of success. Tietze and Potter calculate that this hypothetical model woman could achieve a monthly security level q of better than 99 percent with either the Knaus or the Ogino calendar after 13 cycles of observation. However, when the Ogino-Knaus calendars are based on only a few monthly cycles of observation (1 to 4 cycles), the monthly security q drops catastrophically—to the 71- to 94-percent level for the Knaus formula and to the 87- to 98-percent level for the Ogino formula. These model calculations show that the 93-percent security level estimated earlier from the rhythm-method experience of a number of couples is realistic.

Many couples who use the rhythm method cannot achieve 13 cycles of observation without encountering a pregnancy first. To them, the higher security levels potentially attainable by the calendar method after prolonged observation are of only academic interest. Since the menstrual pattern changes after childbirth and can become increasingly erratic after repeated pregnancies, the mother of many children, who is most in need of a reliable method of child spacing, is the one for whom the calendar method is most likely to fail. Furthermore, with the menstrual rhythm, as with the weather or the stock market, past performance is no guarantee of what is going to happen in the immediate future. No matter how long or how regular the base of observation, the Ogino-Knaus method is never proof against the vagaries of an erratic fluctuation in the current cycle.

The use of contraceptives should raise the monthly security factor q, and the fact that many married couples consistently space their children 3 to 4 years apart by using contraceptives indicates that security factors q of 98 percent or better are readily attainable (Table 1). Here again, the security factor q will drop with an increase in the frequency of coitus and, more significantly, will drop markedly with any relaxation of vigilance. Tietze and Potter (*11*) report monthly security factors q of better than 99.8 percent when contraceptive safeguards are consistently applied. However, Potter (*4*) reports an observed monthly q value of only 97.5 percent for a group of normal urban two-child couples who use contraceptives. This finding suggests that these couples omit safeguards perhaps once (or twice) in each cycle and are willing to tolerate the risk of having another baby within the next 2½ to 3 years (Table 1).

Statistical Probability of a Given Birth Spacing

Let the probability factor Q be defined as the probability that a birth will not occur during the next N calendar months. The corresponding number n of cycles during which no conception should occur is then given by Eq. 2. Let these cycles be numbered consecutively 1, 2, 3, . . . n. If the monthly security factors of these cycles are q_1, q_2, q_3, . . . q_n, respectively, the desired probability is

$$Q = q_1 q_2 q_3 \ldots q_n \qquad (4)$$

If the security factor is maintained constant during all of the cycles, Eq. 4 reduces to Potter's law—Eq. 1. Equation 1 has been used, in conjunction with Eq. 2, to construct Table 3, which shows the probability Q of attaining birth spacings of N = 12, 18, 24, 30, 36, 48, and 60 calendar months with monthly security factors q ranging from 80 to 99 percent. For each probability Q in Table 3 are given (in parentheses) the corresponding odds against a birth occurring within the specified N months.

For example, with a monthly security factor of 95 percent, the probability of spacing the next birth at least 18 months from the preceding one is 0.605, and the odds against a birth occurring in this period are therefore 3 to 2. But for a spacing of 24 months, the probability drops to 0.432, and the odds are now 4 to 3 in favor of at least one birth during the given period. A broken horizontal line divides Table 3 into two regions. Above the line, the odds favor no birth in the given interval. Below the line, the odds favor at least one birth in the given interval. Table 3 shows, for example, that a monthly security factor of 99 percent must be maintained in order to have a 2-to-1 chance of spacing the next child 4 years away from the preceding one. Such a high security factor is not attainable with the rhythm method alone, to judge from the experience of the couples discussed earlier (*5*).

Simulated Statistical Experiments of Child Spacing

The child spacings to be expected, on statistical grounds alone, with a certain monthly security factor, can also be determined experimentally by means of a simple game of chance with children's marbles. Take g green marbles and r red marbles of the same size. Let each green marble denote a cycle in which conception occurs, and let each red marble denote a cycle in which conception does not occur. The monthly security factor can be adjusted by changing g and r. In the set of experiments described below, the numbers chosen were $g = 2$ green marbles and $r = 26$ red marbles, corresponding to a monthly security factor q of $26/28 = 93$ percent. Now, mix the marbles and draw one at random; if it is red, return it to the pot, mix and draw again. The object of the experiment is to count the number of draws needed to draw a green marble. This number is statistically equivalent to the total number of cycles in a sequence of cycles without conception, terminating in a cycle in which conception occurs.

In the actual series of 200 experiments, the numbers of draws were, re-

Table 3. Statistical probability Q of achieving a spacing of N calendar months between births at different levels of the monthly security factor q. The numbers in parentheses are corresponding approximate odds *against* a birth occurring within the specified N months. Odds above the line favor no birth within N months; odds below the line favor at least one birth.

N (months)	Q										
	$q = 0.80$	$q = 0.85$	$q = 0.90$	$q = 0.92$	$q = 0.93$	$q = 0.94$	$q = 0.95$	$q = 0.96$	$q = 0.97$	$q = 0.98$	$q = 0.99$
12	0.482 (14/15)	0.588 (7/5)	0.708 (7/3)	0.762 (3/1)	0.789 (4/1)	0.817 (9/2)	0.846 (11/2)	0.875 (7/1)	0.905 (9/1)	0.936 (15/1)	0.968 (30/1)
18	.112 (1/8)	.203 (1/4)	.356 (5/9)	.441 (4/5)	.492 (1/1)	.545 (6/5)	.605 (3/2)	.670 (2/1)	.742 (3/1)	.820 (9/2)	.906 (9/1)
24	.027 (1/36)	.070 (1/13)	.179 (2/9)	.256 (1/3)	.305 (3/7)	.364 (4/7)	.432 (3/4)	.513 (20/19)	.608 (3/2)	.719 (5/2)	.848 (11/2)
30	.006 (1/160)	.024 (1/41)	.090 (1/10)	.148 (1/6)	.190 (1/4)	.242 (1/3)	.309 (4/9)	.392 (2/3)	.498 (1/1)	.630 (5/3)	.794 (4/1)
36	.0014 (1/700)	.008 (1/120)	.045 (1/21)	.086 (1/11)	.118 (1/7)	.162 (1/5)	.222 (2/7)	.301 (3/7)	.408 (2/3)	.552 (5/4)	.744 (3/1)
48	.00008 (1/12000)	.001 (1/1000)	.011 (1/90)	.029 (1/33)	.046 (1/20)	.072 (1/13)	.114 (1/8)	.177 (2/9)	.275 (3/8)	.425 (3/4)	.653 (2/1)
60	.000004 (1/250000)	.00014 (1/7000)	.0028 (1/350)	.010 (1/99)	.018 (1/55)	.032 (1/30)	.058 (1/16)	.103 (1/9)	.184 (2/9)	.325 (1/2)	.562 (9/7)

spectively, as follows: 1, 24, 21, 13, 6, 1, 4, 1, 9, 4, 6, 2, 17, 8, 12, 11, 1, 5, 9, 12, 29, 19, 2, 2, 14, 3, 2, 63, 10, 14, 23, 10, 13, 6, 28, 16, 8, 56, 4, 12, 15, 2, 3, 2, 21, 9, 7, 3, 3, 32, 1, 2, 2, 13, 1, 8, 22, 10, 3, 20, 18, 5, 10, 34, 25, 46, 22, 40, 12, 6, 3, 1, 7, 12, 7, 3, 6, 21, 3, 21, 9, 11, 17, 1, 1, 5, 10, 27, 3, 2, 28, 1, 1, 16, 9, 2, 37, 2, 6, 14, 1, 24, 10, 2, 36, 21, 19, 16, 2, 4, 24, 33, 6, 16, 9, 3, 7, 11, 44, 1, 2, 13, 13, 9, 16, 2, 3, 11, 37, 1, 12, 4, 59, 5, 26, 21, 4, 25, 5, 5, 1, 21, 2, 14, 6, 19, 7, 31, 8, 7, 33, 3, 11, 22, 7, 6, 7, 1, 1, 17, 48, 41, 25, 13, 26, 3, 26, 22, 1, 6, 11, 18, 7, 2, 2, 9, 15, 15, 50, 27, 13, 6, 3, 7, 3, 3, 23, 36, 10, 23, 17, 30, 23, 28, 1, 17, 34, 15, 45, 12.

The distribution obtained from these 200 experiments with a monthly security factor of 93 percent, is shown in Table 4. The total number of draws in all 200 experiments was 2686, and the average number of draws per experiment (the average number of cycles to conception) was 13.4, close to the statistically expected average of exactly 14.

The experiment with the marbles gave a statistical indication for conception in the first cycle in 19 out of 200 cases (9.5 percent, as compared with an expected 7 percent at 93-percent security); in the first six cycles in 76 out of 200 cases (38 percent, as compared with an expected 36 percent); in the first 12 cycles in 118 out of 200 cases (59 percent, as compared with an expected 59 percent); in the first 18 cycles in 145 out of 200 cases (72.5 percent, as compared with an expected 73.4 percent); in the first 24 cycles in 167 out of 200 cases (83.5 percent, as compared with an expected 82.8 percent); in the first 30 cycles in 180 out of 200 cases (90 percent, as compared with an expected 89 percent); and after the first 30 cycles in 20 out of 200 cases (10 percent, as compared with an expected 11 percent). The expected percentage is derived from the statistical formula $1 - q^n$, with $q = 26/28$.

The probable number of cycles to conception was found, from the experiments, to be between 9 and 10 (1 to 9 draws were required in 98 cases; 10 to 63 draws, in 102 cases), as compared with 9.3 cycles from the statistical formula $\frac{1}{2} = 1 - q^n$. This corresponds to a probable spacing of 17.5 months between births.

Thus, the simulated statistical experiments carried out with marbles show that the laws of mathematical statistics are indeed applicable to the problem and indicate typical numbers of cycles to conception (at 93 percent security level) that might be expected in actual cases, to the extent that the occurrence of conception is governed by the laws of mathematical statistics alone. These laws are themselves nothing more than the laws governing the numerical relationships of repetitive probable events.

This series of simulated experiments can also be used to check the spacing expectancy table (Table 3) at the 93-percent security level. By converting from the number of cycles to pregnancy to the number of months between births (Eq. 2), the odds against the next birth occurring within N months of the preceding birth can be calculated from results of the 200 simulated experiments, and these odds can be compared with the approximate odds given in Table 3, which are based on the statistical formulas (Table 5).

The two sets of odds are virtually the same, except for minor deviations attributable to the limited number (200) of the experiments performed with the marbles. The marbles experiments also illustrate the statistical fluctuations to be expected, whereby an occasional long sequence of cycles without conception becomes possible with the rhythm method and does not "prove" the reliability of the method.

Discussion

There are many national or ethnic groups whose members, on religious, moral, cultural, or economic grounds, find contraception unacceptable, unesthetic, too expensive, or impossible in practice (*12*). The needs of these people make the appeal of Pope Pius XII for more "secure" methods (*1*), based on "taking advantage of natural temporary sterility" (*2*), more urgent now than when it was uttered by that great Pontiff in 1951. This appeal was echoed by Cardinal Suenens (*3*, pp. 144, 149) at the Brussels Health Congress of 1958. American Roman Catholic churchmen have, in their turn, propounded the doctrine of responsible parenthood and denounced "unreasoned, unlimited, unrestrained, uncontrolled biological fertility" (*13*). The challenge to today's researcher remains more urgent than ever.

Pius XII distinguishes (*1*, *2*) between what he terms direct sterilization, indirect sterilization, and the taking advantage of natural temporary sterility. Direct sterilization he condemns on moral grounds. Indirect sterilization he approves, for good and sufficient reasons, by the moral principle of actions with a double effect (*14*). The taking advantage of natural temporary sterility he approves for serious motives such as those "found . . . in the medical, eugenic, economic and social indication" (*15*).

The taking advantage of natural temporary sterility has, heretofore, meant the use of methods based on the natural regular or irregular rhythmic cycle of fertility and sterility of the wife. The crux of the method resides in finding as accurately as possible the exact timing of ovulation. When this timing is to be determined from an extrapolation, to the current cycle, of the pattern of previous cycles, whether by the Ogino-Knaus method or from the record of temperature charts, the success of the rhythm method in spacing children will always be limited by the laws of statistics: Potter's law (Eq. 1) and Tietze's equation (Eq. 3). Even if the fertile period is as brief as 12 hours, these laws show that a couple who

Table 4. Distribution of draws in 200 experiments with marbles at the 93-percent security level.

Number n of draws	Number of times observed in 200 experiments
1	19
2	18
3	16
4	6
5	6
6	11
Ranges	
1–6	76
7–12	42
13–18	27
19–24	22
25–30	13
31–36	8
37–42	4
43–48	4
49–54	1
55–60	2
Over 60	1

Table 5. Odds from the experiments with marbles compared with the odds from Table 3.

N months	Odds	
	Experiments with marbles	From Table 3 (93% security)
12	147/53	4/1
18	102/98	1/1
24	62/138	3/7
30	40/160	1/4
36	21/179	1/7
48	8/192	1/20
60	3/197	1/55

desire a 2-year spacing are limited, statistically, to two acts of coitus per cycle. Couples who desire a 4-year spacing are limited to a maximum of one act of coitus per cycle. It is not surprising that the rhythm method has become a source of mental torture to many couples.

An accurate ovulation-prediction test is needed. As Rock points out (*16*), such a test should give a dependable signal 3 days in advance of ovulation. Alternatively, an accurate method of precipitating the occurrence of a late ovulation on a controlled day is also needed. This has recently been done by means of certain hormone injections, but only on an experimental basis (*16*). The moral objections to the suppression of ovulation as a direct sterilization (*2*) do not apply to control of the timing of ovulation. H. J. O'Connell, a distinguished Roman Catholic professor of moral theology (*17*), has proposed the use of anovulant pills, not to suppress ovulation but to restrict its occurrence to the first 14 days of each cycle. This proposal merits careful scrutiny by doctors, physiologists, and psychologists as a potential solution to the problem of making the rhythm method reliable for those couples who are motivated to use it.

Much work remains to be done on the natural temporary sterility of the husband. Nelson (*9, 12*) has described the various stages in the development and evolution of the male germ cell. A man's fertility has been found to undergo variations in a purely natural way. Nelson (*18*) has pointed out the correlation between small variations in scrotal temperature and inverse variations in fertility. Such variations occur naturally in the course of a man's normal round of activities: working, exercising, dressing, bathing. Hartmann (*19*) has suggested that dietary factors and psychological factors may play a role, as yet unknown, in relation to fertility.

The laws of nature governing the reproductive processes involve the contributions not only of physiology, of psychology, and of ethics but also of mathematical statistics, since the reproductive processes are the consequents of repetitive probable events. If the monthly security factor q of methods based on natural temporary sterility is to be raised, in accordance with Pius XII's expressed wish, to a level (97 to 99 percent) such that effective child spacing (as described by Cardinal Suenens) is no longer a statistical impossibility for many couples, the natural variations in the fertility and sterility of man and of woman will have to be learned and mastered, so that mankind can, in Pius XII's own words, take advantage of them.

References and Notes

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3. Cardinal Suenens, *Love and Control, The Contemporary Problem* (Newman, Westminster, Md., 1961).
4. R. G. Potter, Jr., *Milbank Mem. Fund Quart.* **38**, 255 (1960).
5. Private communications from five families of 7, 8, 8, 9, and 11 children, respectively. One family reported spacings of 14, 22, 17, 16, 16, 16, 17, and 17 months. Another family reported an average spacing of 17.0 months (8 children including one set of twins). The other families' experiences paralleled these.
6. I Cor. 7 : 5.
7. C. Tietze, *Fertility and Sterility* **11**, 485 (1960).
8. Centre d'Etudes Laennec (Paris Catholic Medical Study Centre), *La Regulation des Naissances* (Lethielleux, Paris, 1961), pp. 121–144, 175–179.
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13. G. A. Kelly, *America* **107**, 207 (1962); J. A. O'Brien, *Christian Century* **80**, 1050, 1361 (1963).
14. The ethical principle of actions with a double effect considers the morality of actions with both good and evil consequences. This principle proposes that such actions may be morally acceptable if the good sought outweighs the evil suffered, and if the evil is not intended as a means, nor as an end (see *2*). Classic examples include killing in self-defense, and the surgical removal of diseased organs. The Centre d'Etudes Laennec (Paris) suggests that the use of anovulant drugs as a method of regularization of irregular female cycles can be morally acceptable because the sterilization is indirect (see *8*).
15. Pius XII, address to the Convention of the Italian Union of "Obstetrices" (Midwives), 29 Oct. 1951; *Acta Apostolicae Sedis* **43**, 845 (1951).
16. J. Rock, *The Time Has Come* (Knopf, New York, 1963), chap. 15, 16.
17. H. J. O'Connell, *Liguorian* **1961**, 23 (Oct. 1961); K. C. O'Brien, *Cosmos* **5**, 62 (1963).
18. W. O. Nelson, *Fertility and Sterility* **12**, 109 (1961).
19. C. J. Hartmann, *J. Reprod. Fertility* **1**, 283 (1960).