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Human fecundity: situation and outlook

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Fecundity may have decreased slightly in some industrial countries over recent decades, and concerns have been expressed about potential population decline. Henri Leridon shows that this fear is largely unfounded, and takes a closer look at the question of human fecundity.

For demographers, *fecundity* is the capacity to bear live children (while *fertility* refers to the actual number of births (Box 1). It is a characteristic of human beings that varies between individuals and between populations and which may evolve (slowly) over time. Fermale fecundity is delimited by two physiological boundaries: puberty and menopause. As we shall see, the menopause is a delayed indicator of the end of reproductive life, since women generally become *sterile*, i.e. permanently incapable of reproducing, several years before its onset. Men, for their part, experience puberty but have no upper reproductive age limit. While their reproductive capacity declines progressively with age, they do not experience a biological event equivalent to the menopause.

High fetal mortality

Among human beings, fetal mortality is high; 12-15% of confirmed pregnancies end in a spontaneous abortion that can be detected by the woman concerned (or her physician). An even higher proportion of "products of conception" do not develop normally and are evacuated within a few weeks, before the woman becomes aware of her pregnancy. As many as 50% of all conceptions may end in death *in utero*. Most of these failures are due to severe genetic abnormalities that prevent the fetus from developing normally. In other words, human reproduction has a high error rate, but most of these errors are corrected by eliminating the products of conception.

The main parameters of reproduction

The reproductive period begins at puberty. The median age at puberty has decreased in developed countries over the last century and now stands at around twelve-and-a-half years for girls (first menses) and fifteen years for boys (voice change and growth peak) [1]. This trend is of little significance in these countries, where childbearing begins much later in life. The median age at menopause is around 50 years in western populations, and appears to be relatively stable. But studies of populations which do not practice birth control have shown that mean age at last childbearing is much lower – around 40 years or so – and that *permanent sterility* occurs somewhere between these two ages. The exact moment is difficult to determine, however, as fecundity declines progressively due to oocyte ageing and depletion. We will return to this point later.

During their reproductive lifetime, and even if they have unprotected sexual intercourse, women are not exposed to a 100% risk of conception during each ovulation cycle. A couple with "normal" fecundity and

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CONTENTS

with an "ordinary" sexual life, generally takes several months to obtain a desired pregnancy (although waiting time can be shortened by timing sexual intercourse to coincide with the most fecund days of the cycle). If conception occurs, there is a risk – as we have seen – that the pregnancy will not end in a live birth. Last, a woman's reproductive period may be ended at any time by the onset of permanent sterility (see below).

Fecundity differences between couples

Studies of waiting times to pregnancy show that the probability of conceiving during a given cycle, also known as *fecundability*, is around 20-25% (at ages 20-30) in a population with normal fecundity, and that it varies between couples and by age. If a couple fails to achieve a pregnancy at the desired moment, this may be due to low fecundability of the woman, of the man, or of both partners. This does not signify that the couple is totally sterile; they simply need more time to conceive.

On the basis of numerous observations, a general curve of the distribution of fecundability has been determined (see distribution A, Figure 1). Imagine that we are following 100 women with a partner from the moment they decide to have a child. The distribution of their fecundability – 20-25% on average, as mentioned above – is shown in curve A. After 12 months, 90 of these women have become pregnant and the remaining 10, so far unsuccessful, are still trying. In this latter sub-group, the proportion of couples with low fecundability is higher than in the group as a whole, the mean fecundability is lower (12%) and the distribution now follows curve B in Figure 1. However, a majority of these women – more than two-thirds – obtain a pregnancy in the following 12 months, bringing the total number of women who successfully conceive to 97 after 24 months. Only 3 women fail to become pregnant over this period.

We thus observe a substantial increase over time in the proportion of sub-fecund couples among those who have not yet conceived. At the outset, 10% of couples have a fecundability below 10%. After 12 months of non-conception the proportion increases to 45% and after 24 months it reaches an estimated 72%. This decrease in mean fecundity of the couples who have not yet conceived does not mean that they have no chance of doing so within a "reasonable" time: while 90% of the initial couples conceive within 12 months, as we have seen, 71% of the unsuccessful couples will conceive in the following 12 months, and 57% of those unsuccessful after 24 months will do so in the following year [1].

This shows that "failure to conceive within 12 months" is not synonymous with sterility, as is sometimes suggested.

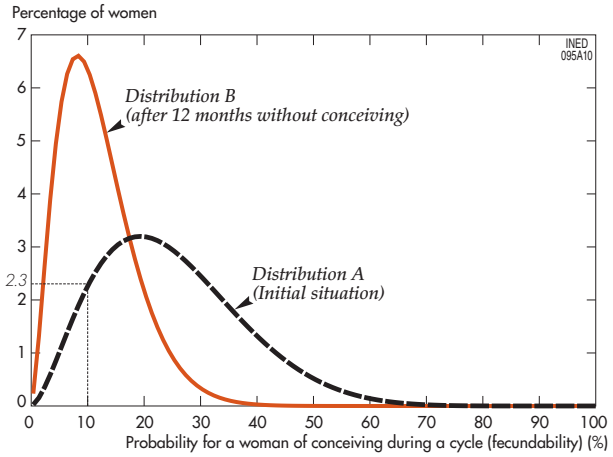
[1] These figures are partly derived from those of the late Daniel Schwartz [2], (deceased in 2009) who studied the questions of fecundity and infecundity in depth.

Box 1

Definitions

– *Fertility* measures the number of liveborn children (and infertility the absence of children), either for a particular age group (for example, to calculate an age-specific fertility rate), or for all ages (for example, in the total fertility rate, which is the sum of age-specific rates observed in a given year, or in the completed fertility of a birth cohort).
– *Fecundity* measures the capacity to reproduce, independently of individual intentions.
Persons or couples with low fecundity are "sub-fecund".
– *Sterility* or *infecundity* is the inability to conceive or bear children. It may be temporary (for example during pregnancy and part of the breast-feeding period) or permanent.
– *Fecundability* is the probability of conceiving per ovulation cycle (without contraceptive protection).

Figure 1 – Distribution of fecundability

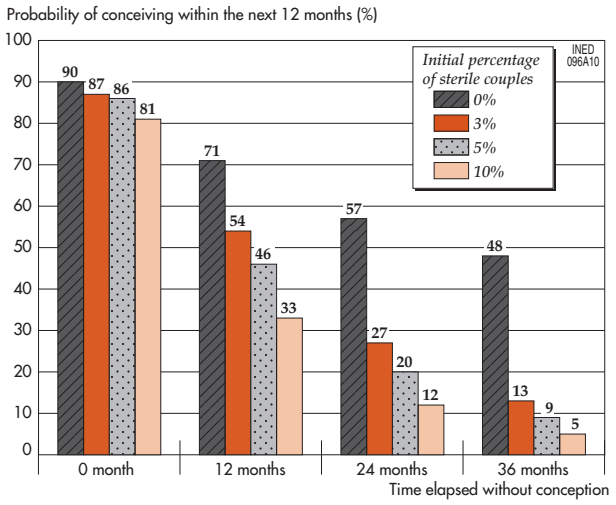


Interpretation: 100 classes of conception probability are defined, from 0%, 1%, 2%, etc. up to 100% (horizontal axis). The vertical axis gives the percentage of women in each class. For example, among women who decide to have a child, 2.3% have a 10% probability of conceiving in the next cycle, 2.5% have an 11% probability, etc. (distribution A). A beta distribution is used here, with a mean of 0.25 and with parameters a = 2.75 and b = 8.25. After n months of conception failure, the distribution of couples who still have not conceived follows a new beta distribution with parameters a and b + n. The figure shows the distribution after 12 months without conception (B).

(H. Leridon, *Population & Societies*, 471, INED, October 2010)

It is true, however, that all populations include a proportion of couples who will never be able to have a child without medical intervention. This *permanent sterility* may affect couples from the start of their reproductive life, or may occur later on: the proportion of sterile couples increases with age, ultimately reaching 100%. First, we will focus on *primary sterility*, i.e. sterility which affects couples from the start of their conjugal life, or from their first attempts to achieve a pregnancy. In ancient populations with a "natural" fertility regime, i.e. with no voluntary birth control, and in developing countries just before their demographic transition, the proportion of married women who are childless at ages 45-49 is always below 10%, and generally equal to or below 5% (especially if only women who married before

Figure 2 - Chances of conceiving in the next 12 months by time elapsed without conception and initial proportion of sterile couples



Note: In the absence of sterile couples, for 100 couples seeking to conceive, 10 will not have succeeded after 12 months, 3 after 24 months and 1 after 36 months. With 10% of sterile couples in the initial group, these numbers increase to 19, 13 and 11, respectively.

Source: From Schwartz [2] and author's calculations.

(H. Leridon, *Population & Societies*, 471, INED, October 2010)

age 25 are counted). These proportions can be seen as maximum estimations of the sterility rate at around age 25, under the health conditions of the time.

The selection effect induced by the distribution of fecundability levels is thus reinforced by the existence of totally sterile couples. In Figure 2 we have added a proportion of totally sterile couples equal to 3%, 5% or 10% of the total. After 12 months, the chances of conceiving naturally over the next 12 months remain high (close to 50%) with 3% or 5% of sterile couples, but are lower (around one-third) with 10% of sterile couples. After 24 months, the probability drops to around one-quarter if 3% or 5% of couples are sterile, and to one-eighth if 10% are sterile. In an actual population, in particular that of couples consulting for infertility, the proportion who are sterile is not known exactly. Indirect methods give an estimate of 3-5% of sterile couples at age 25 (woman's age), and 10% at age 30, so Figure 2 gives a good idea of the possible "prognosis" for the future fertility of this population.

The increase in sterility with age

It is important to highlight the precise reasons why sterility increases with age. It has been shown that the main cause of this increase is a rapid rise in the intra-uterine (or fetal) mortality rate [3]. The table compares the proportion of *permanently sterile* couples according to two definitions: the likelihood of not conceiving again, and that of not obtaining a desired live birth.

At age 35, for example, 17% of women will no longer be able to have a child, but only 5% will not even conceive; at age 40 the proportions are 33% and 17%, respectively. These differences explain why the success rate of assisted reproductive technologies expressed as "successful fertilizations" or "clinical pregnancies" – as is often the case – is misleading, since couples want a live child, not just a pregnancy. We can also see that, whatever the definition used, the median age of sterility is much earlier than that of the menopause, preceding it by around five years.

All available studies confirm the increase in intra-uterine mortality with age. Based on a dozen populations, we have calculated average levels of fetal mortality observable by women, i.e. miscarried pregnancies producing physiological changes (such as absence of menstruation) detected by the women concerned. The rate ranges from 12-15% before age 30, to 20% at ages 30-34, 25% at ages 35-39, almost 30% at ages 40-44 and close to 40% at ages 45-49 [3]. We have seen above that the failure rate is much higher in the early weeks, but these short-lived pregnancies go unnoticed. Their effect is included in the notion of fecundability used above.

Table - Increase in female permanent sterility with age

Exact age (years)	Probability of no longer achieving	
	a live birth (%)	a conception (%)
25	5	1
30	10	2
35	17	5
40	33	17
45	62	55

Note: model-based estimates.

Source: [3]

(H. Leridon, *Population & Societies*, 471, INED, October 2010)

Signs of declining fecundity

There have been signs of a possible decline in fecundity among certain western populations in recent years. A detailed examination of these purported signs, and their possible causes (such as environmental factors, notably endocrine disruptors [4]) is beyond the scope of this article, but we will focus on the most robust findings, namely the observed decline in sperm quality among certain donors (providing sperm for artificial insemination). This decline is not universal, but a clear trend has been identified, among Parisian donors between 1975 and 1995 for example [5]. The consequences in terms of fecundity are not easily foreseeable. It is likely, for example, that a lower sperm count has very little impact on fecundity so long as it remains above a certain threshold.

The 21% drop in sperm concentration observed among French donors over a period of around 15 years

Box 2

Model

The model used here is a "Monte Carlo" simulation in which individual life histories are constructed on the basis of the monthly probabilities that the various events of interest will occur. These probabilities depend on either biological data (risks of conception, of miscarriage, etc.) or behavioural data (age at marriage or at start of exposure, desired number of children, etc.). The lives of several thousand women aged 15-50 are simulated and the results are aggregated. It is as if we had collected a sample of reproductive event histories in the population. See [7] and [8] for further details.

could reduce their fecundability by 7% [6]. By extrapolation, this could represent a decrease of 47% over a period of 40 years, which would reduce fecundability by 15%. This is an extreme hypothesis, however, based on data observed in a limited number of studies and on a specific sub-population (sperm donors). But how would a decrease of this magnitude affect fertility, i.e. the actual number of children born?

Potential demographic impact

There is no simple answer to this question, given the probabilistic nature of fecundability and its variation among couples. We studied it using a simulation model of human reproduction that captures a wide range of factors: the biological variables already described, but also behavioural data such as desired number of children, desired birth spacing, preferred age for having children, etc. (Box 2). To simulate the two chosen scenarios of mean fecundability decline (7% and 15%) several methods can be used. We could, for example, envisage a proportional reduction in all values of fecundability ("homogeneous" scenario), or concentrate the decline on the lowest fecundabilities to take account of the possible threshold effect mentioned above ("heterogeneous" scenario) [7]. Starting from a completed fertility of 2.00 children, we see that the reduction would be very limited: just 0.02 children (1%) for a 7% reduction in sperm count. A 15% reduction (extrapolating the Parisian trend over a long period) would have a more substantial impact (up to 4%, or 0.08 children) under the heterogeneous scenario.

The model can also be used to measure the potential compensatory effect of assisted reproductive technologies (ART) such as intracytoplasmic sperm injection (ICSI). Practically all the negative effects on fertility would be wiped out if all the couples concerned sought ART (a somewhat unrealistic hypothesis), but also, in the case of a 7% fecundability decline, if only half of all couples did so. Hence, when the only problem is a decline in fecundability (we are not assuming an increase in permanent sterility here), ART can be effective in demographic terms: if the only factor involved is the waiting time to pregnancy, in a context where couples do not want large families (just above two children on average), couples should have enough time to achieve their desired family size.

Things would be different if the proportion of totally sterile couples increased, and this is indeed the case when couples delay their childbearing. The frequency of sterility is higher at older ages, so completed fertility may be affected [7] [8]. For these couples, ART is a less effective solution, since failure rates increase with age.

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ABSTRACT

The probability that a woman having unprotected sexual intercourse will conceive over an ovulation cycle, also known as fecundability, is no more than 20-25% on average. A couple with "normal" fecundity generally takes several months to achieve a pregnancy. This long waiting time is due in part to high fetal mortality, since more than half of all conceptions do not result in a live birth.

Fecundability varies from one couple to another. Out of 100 couples who decide to have a child, 90 obtain a pregnancy within 12 months. The 10 remaining unsuccessful couples have a lower mean fecundability, but most will nonetheless conceive within the following 12 months. So an inability to conceive within 12 months does not signify sterility, as is sometimes suggested.

Fecundity may have declined among certain western populations, notably because of lower sperm quality. This should not reduce fertility, i.e. the actual number of children born, but may simply lengthen the waiting time to pregnancy.

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