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The influence of seasonal atmospheric factors on human reproduction

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1. Introduction

In most animal species, the breeding season is firmly set at a particular season specific for each species of animal at the time which is favorable for bringing up their young. It is an established fact that the seasonally changing length of daylight is the most crucial factor in determining the onset of breeding and the pineal is known to be the major site of regulation of the exact circannual photoperiodicity.

In nature, the change of daylight length is decisively related to the change of atmospheric temperature with some time lag and thus is a co-determinant for the characteristics of the seasons. In some animals photoperiodism may be one of the most temperature-sensitive factors in the physiological responses. Hence, changes in atmospheric temperature are also essential factors in determining the time of breeding. In some districts, rainfall is another critical factor which determines the quantity of available plant food for wild animals and thus regulates their reproductive capacity.

In man, the seasonality of birth or conception is not so marked as in wild and domestic animals. However, it is well-known that, in general, babies are born most frequently in the early spring season. In other words, conception occurs most frequently during the period April-June. This phenomenon has been so widely observed in most European countries and in Japan, where vital statistics were available, that it was considered to be a kind of basic rhythm in animal reproduction including man. This type of birth pattern was called by Huntington[26] a 'basic animal rhythm'. The causes of this phenomenon of animal rhythm were quite naturally considered to be the effects of seasonal or solar and atmospheric factors on the comfort and vigor of man[1, 6, 8, 20, 26, 43–45, 49, 65, 77].

Atmospheric pressure has little effect on the reproductive capacity of animals and man, except in some extreme examples at very high altitude in the Andes[49, 63]. On the other hand, the seasonal variation in atmospheric pressure is so small at any given location that it seems likely to be too insignificant to cause any seasonal effects on the reproductive system of man.

Apart from this biological-comfort hypothesis, socio-cultural factors have been proposed as causes for seasonal birth distribution. The rainy season, for instance, might increase or decrease conception in man possibly by changing the content of drinking water[39], by increasing indoor life[61] or by causing stress, for example the fear of damage to crops owing to too much rain[47]. The seasons of festivities[5, 26, 60, 62]; social class[2, 6, 29, 64, 83, 85]; agricultural patterns[69], and race or ethnic differences[7, 34, 50] might also be factors in the variations in seasonality of births. However, in many instances, every explanation involving these factors as the causes or mechanisms of the observed phenomena failed to convince us[36]. Some biological factors such as maternal age or birth order are also found to be related to the birth seasonality[67, 73]. Other investigators suspect other, unknown biological factors[15].

Atmospheric factors which affect the reproductive capacity of man and animals include not only the physical factors, light and heat, but also chemical and biological ones. Among the chemical factors, besides humidity or water vapor, CO_2 is also known to fluctuate seasonally owing to the changing magnitude of photosynthesis of green plants, and to the anthropogenic fuel combustion. The seasonal variation of the atmospheric CO_2 concentration, however, is not known to affect the reproductive capacity of animals. Other chemical or inorganic components of the atmosphere, including air pollutants[38], have rarely been considered to have effects on reproductive capacity.

It is apparent that seasonal variations in the biosphere, or the food available in nature, may affect the reproductive capacity of animals and man. The microbiosphere composed of pollen of plants, spores of fungi and microbes may also change seasonally and some of these microbiospheric organisms can be suspended in the air and may play a role as part of the atmospheric factors which influence the biological functions causing the seasonality in the reproductive capacity of animals and man. All these factors are closely interrelated and it seems impossible to differentiate the effect of each factor.

Many bacterial infections are known to cause abortions in animals. Therefore, it is very likely that the recognized seasonality of prenatal pathology[32] or spontaneous abortions[48, 80] could be caused by seasonal epidemics of certain infectious agents.

This microbiological aspect leads us to propose the hypothesis that certain epidemic infertility factors exist which behave with a seasonal rhythm, as if they were atmospheric factors, or which are influenced by the atmosphere and seasonally affect the birth rate. A similar hypothesis is proposed for the existence of twin-birth promoting factors and for sex-ratio changing factors. If such factors do exist various kinds of seasonality in human births might be explained. This article reports the results of our studies on the collected evidence, which suggest the possible effects of these factors on human reproduction.

2. *Season of births*

Basic pattern of birth seasonality

The early-spring excess or major maximum of monthly births in man has been considered as a fundamental pattern in the seasonality of human births (fig. 1A). Any deviation from this pattern was explained as being caused by social or cultural factors. The minor maximum of monthly births, mostly observed in September, has been attributed to the Christmas-New Year festivity season (fig. 1B). However, an important exception to this pattern was found in the United States in Massachusetts, from 1840–1930[26] (fig. 1C). There the major maximum of births was in the summer-fall season as a low peak and no excess was found in the early spring. This phenomenon was explained by Huntington[26] as resulting from the pleasant summer weather, following the severely cold winter in North America, which could stimulate and maintain the vigor of the population even during and after the summer season, whereas in most European countries, and especially in Japan, the unpleasant or hot summer

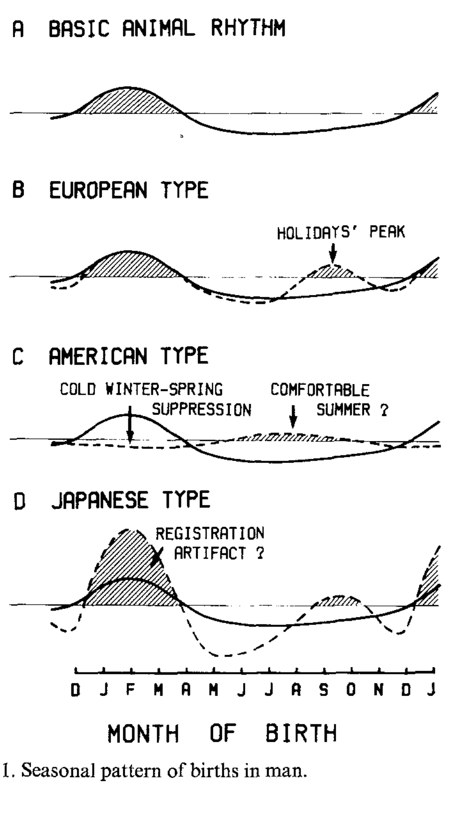

Figure 1. Seasonal pattern of births in man.

weather damages vigor during this season and the following months. This kind of explanation is not convincing, but no alternative explanations have ever been proposed for this phenomenon.

Changes in birth seasonality

Up to the 1950s, the Japanese population had the greatest amplitude of birth seasonality among all the nations for which vital statistics were available. The maximum of births in Japan was in January or March with a 60–70% excess and the minimum in July with about 30% less than the average. The ratio of the maximum to the minimum was 2.0 or more. In some districts of Japan, the ratio exceeded 3.0 in the 1920s and 1930s. Huntington[26] noted that this kind of large amplitude was only found in the Russian population in the 1870s with a ratio of 1.7 or a 25% excess of the maximum. For most European countries this ratio was within the range 1.1–1.3 during the late 19th and early 20th centuries.

This large amplitude in seasonal variation of Japanese births did not attract adequate attention from demographers, because the phenomenon was simply attributed to an artifact of registration caused by the desire of Japanese parents to lower the age of their children by registering December born children as being born in January or, in order to enroll them for public school one year earlier, by registering April born children as being born in March, just before the school year begins in Japan[26,75] (fig. 1D).

The birth excess in the early spring was most prominent in the 1920s and 1930s; between 1940 and 1963 it gradually became less pronounced and in 1964 this spring excess disappeared completely and the maximum of monthly births shifted from January to September with a low peak in summer just as in the United States (fig. 2). Cowgill[4] reported a similar shift in birth seasonality in Puerto Rico in the 1940s, and she explained this phenomenon by a rapid cultural transition of Americanization after World War II. In the 1970s, a similar rapid shift was reported from Bremen, Germany[18], which was assumed to have been caused by the increased proportion of the population which had immigrated from foreign countries. This kind of rapid change or local variation in birth seasonality has been explained as being due to changes of differences in socio-cultural habits or living accommodation, but the evidence is not convincing.

Cyclic changes in birth seasonality

Dates of births are recorded in many of documents, especially in Christian countries, where churches kept parish records which registered all baptisms, often with the date of birth. By investigating these parish records, we can reconstruct the monthly birth number since the 16th or 17th century up to date. Besides these collective records, many personal histories often contain the birth date and those of prominent persons are recorded in 'Biographical Dictionaries' in many countries.

By using these data, Cowgill[5] investigated the seasonal births in York, England, since the 16th century. She reported that the births in York between 1538 and 1600 were more frequent in fall than in spring, while in later centuries the peak of births was higher in spring. She also found that the birth dates in biographical dictionaries

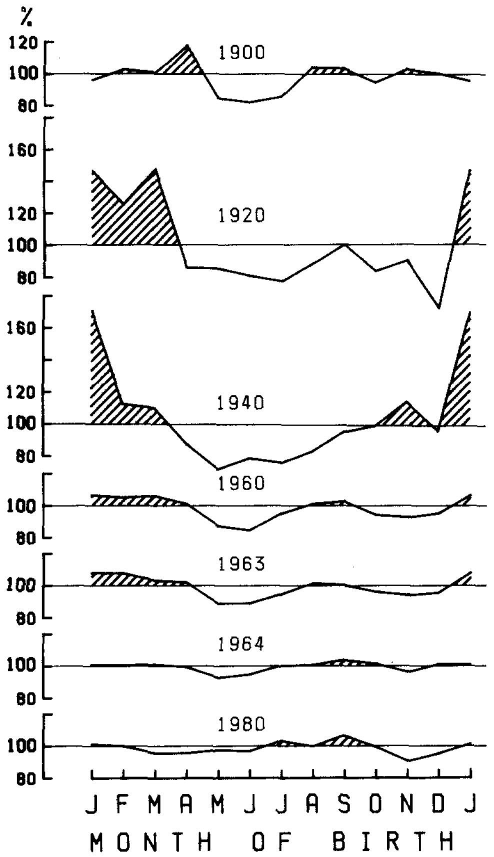

Figure 2. Secular changes in the monthly distribution of births in Tokyo, during the period between 1900 and 1980.

before 1700 showed bimodal seasonal patterns of birth with two peaks of nearly the same magnitude, in spring and in fall. We[57] found for London, a distinctly dominant fall peak in the 16th century and a mild dominancy in the fall peak of the earlier half of the 18th century.

In Germany, the births in the 19th century showed in general a distinct spring peak[18,23,79]. However, in Görlitz, East Germany, we[54,57] detected repeated appearances of a fall peak dominant pattern among the births in parish records since the 16th century. Similar fall peaks were found in a village in East Germany in the 17th and 18th centuries[72] and in Poland in the 19th century[21].

In Japan, the fall excess of births was also observed in Osaka in the latter half of the 18th and in the middle of the 19th centuries[51,70]. In a biographical dictionary of historical Japanese persons, the fall excess of births was also observed in the earlier half of the 19th century and also during the period between 1651 and 1750[57].

The births in Massachusetts, USA, also showed a spring peak pattern in the 17th century as in the European countries. The typical American pattern of birth appeared only after the 18th century.

Figure 3 demonstrates that the spring peak pattern of births, or the animal rhythm, can be the dominant pattern of human births, in general. However, it is also likely that the other pattern or fall excess is not a rare exception only due to certain socio-cultural conditions but represents a cyclic change to another type of normal pattern which repeatedly occurred in almost every country in the past and also in recent years. In our opinion, it is unlikely, therefore, that the recent changes of birth seasonality or the disappearance of the prominent spring peak of birth in Japan can be caused simply by the recent so-called deseasonalization caused by the changes in, or improvement of, accommodation and sanitary conditions.

Season of twin-births

Seasonal variation of twin-births is reported from several countries[9,13–16,24,27,28,30,31,35,37,56,66,81,84]. In Japan, Imaizumi et al.[28], using the figures for births in 1974 recorded by the National Survey, reported that January was the peak month, with 12,392 twin-births. However, we[56] found that in most of the other years between 1924 and 1980, the twin-births were more often in the latter half of a year, with the exception of the years between 1973 and

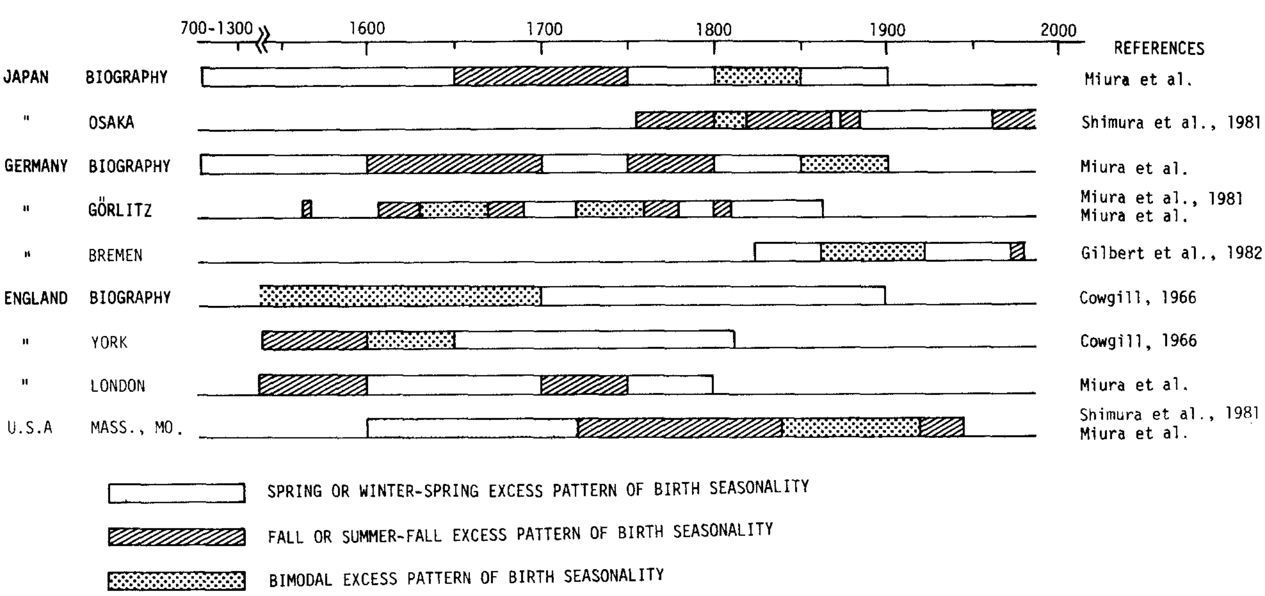

Figure 3. Cyclic changes of spring excess and fall excess patterns of birth seasonality.

1975. In Görlitz, Germany, the seasonal twinning rate was investigated by Richter et al.[66] for 250 years since 1611. Cyclic changes in the seasonality of the twin-birth rate were found. The seasonality of the twin-birth rates in Görlitz seems to be related to the magnitude of the twinning rate in each decade.

These findings may implicate that twinning may be regulated, as a rule, by certain seasonal factors and that these factors can change in seasonality during particular years. Since the seasonality of twinning seems to be a nationwide phenomenon, it is more likely that common factors which exist ubiquitously and behave like atmospheric factors are involved, rather than local weather conditions like temperature and humidity.

Season and sex ratio

It is well known that the male/female sex ratio at birth varies by season[17,25,26,46,71,74,75]. Several factors have been considered to influence the seasonality of the sex ratio. Lyster[42] and Lloyd et al.[38] noted that air pollution may cause a deviation in the sex ratio in polluted areas. Rainfall is also found to change the sex ratio seasonally, possibly by changing the composition of drinking water[39,40]. Seasonal virus infections, like HB virus infection[11,12,22] or influenza virus infection[19] may also influence the sex ratio. However, causes for the seasonality of the sex ratio still remain obscure[3,15,33,41,46,67,78].

3. *Hypothetical epidemic immunogenic factors as a cause regulating the seasonality of human reproduction*

Seasonal infertility factors

In our studies we proposed the hypothesis that seasonally determined epidemic infertility factors exist. If such factors do exist, the seasonal change of the birth rate could be attributed to their effect. Likewise, the regional variation or even the rapid or cyclic shifts in birth seasonality in Japan and other countries could be explained by this hypothesis.

If we assume that these factors are seasonally determined epidemic infectious agents, and that most of the embryos infected at a certain stage of development are damaged and aborted, this could result in a distinct loss of births some months later and thus cause the apparent birth seasonality. If such infections take place just after fertilization or when the fertilized egg is about to implant in the uterine wall, the loss might not be recognized as an abortion but might be considered as a slightly delayed menstruation.

If so, the offspring born in the season with the least births could be those who were infected by the same agent but survived. This offspring might be immunized. When they become pregnant in turn, the immune females might be resistant to those agents which affected them at the embryonic stage while other females are infected and lose the embryo throughout that epidemic season. Consequently the birth rate is low in a certain season among the other non-immune females and the so-called animal rhythm appears (fig. 4).

Figure 4 demonstrates our hypothesis of the effect of epidemic and immunogenic infertility factors on the seasonality of births. The different birth seasonality of offspring of mothers who were born in the lower birth rate season was tested and confirmed in 6218 births in two maternity hospitals in Tokyo and 2162 births in questionnaires, both during the 1930s, when the birth seasonality was the most prominent in Japan[52,53].

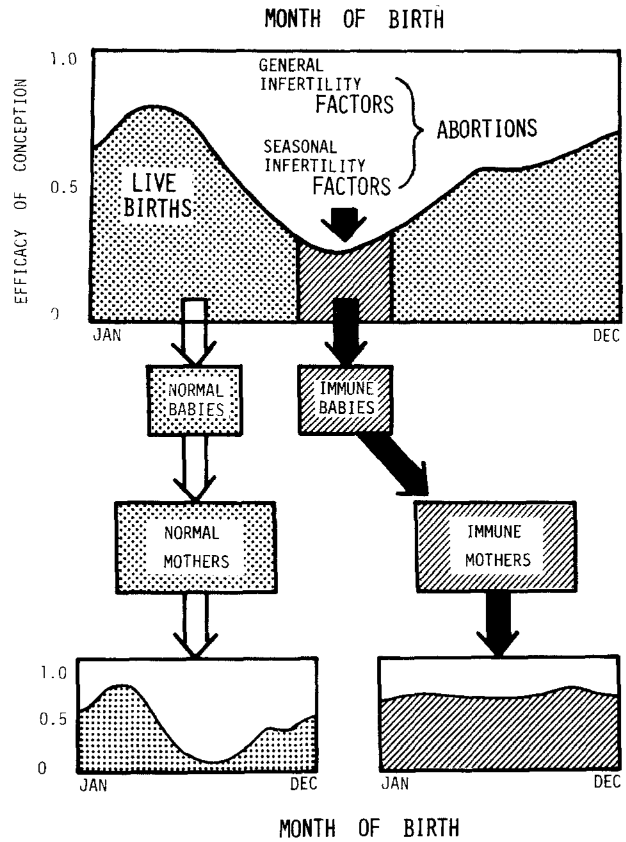

Figure 4. Seasonal infertility hypothesis for the cause of birth seasonality in man.

Seasonal twin-birth promoting factors

A similar hypothesis was proposed for the rate of twinning; in other words, certain twin-birth promoting factors may exist in nature in a particular season. Future mothers, born in a particular season could be immunized at the embryonic stage, as was assumed in the preceding section for infertility factors. Those mothers could be immune to the twin-promoting factors and consequently have twins with less seasonality than other mothers. This hypothesis was tested on the 324 twin-births in the Tokyo district from members of the Twin Mothers' Club who had twins between 1971 and 1980. An exception was made for the three years 1973–1975 when the twin-prone season was different from the other years of the 1970s[56]. We found that 83 mothers born in the May–July season showed significantly less seasonal variation in twinning than the other 241 mothers (table).

One explanation could be that certain epidemic and immunogenic twin-birth promoting factors exist in nature, which induce in mothers a twin-prone state probably for a few months after infection. Fetuses can also be infected by these agents and can be immunized and stay immune. Consequently, during an epidemic of the same agents, these females, when they become pregnant themselves, are immune to the twin-birth promoting factors[58]. These factors may increase twinning by increasing multiple ovulation or by increasing early splitting of a fertilized ovum to make monozygotic twins. Since the May–July born mothers seem to be the most strongly affected by the hypothetical twin-birth promoting factors, there may be a possibility that these factors are identical with the infertility or aborting factors, which also seem to affect most frequently mothers born in the same May–July season. Further investigations with a larger number of cases are required to elucidate these problems.

Seasonal sex-ratio changing factors

Huntington[26] and others[74, 75] noted that the offspring born in months with a greater number of births have a lower sex ratio. These findings might imply that the increased births are caused by decreased abortions, and it could be that certain seasonal factors related to the rate of conception or abortion may also influence the sex ratio by differentiating the ratio of abortion per sex. These factors could also determine mothers through their own month of birth for having a different sex ratio in their offspring. A higher sex ratio in births between 1924 and 1928 was found in 1669 mothers born in the spring (April–May)[55]. A similar phenomenon was observed among 1865 mothers who had their babies in 1933-37; however, of 1510 mothers who had their offspring in the years 1929–1932, a higher sex ratio was found in the offspring of mothers born in the winter (December–February). Again the hypothesis is proposed that certain, seasonally determined, sex ratio changing factors exist responsible for a changed sex ratio. The female offspring which survive could be immunized in the embryonic stage and will then be resistant to the sex ratio changing factors during their own pregnancy[59].

Effects of the month of birth of the father

In the preceding sections it has been shown that the month of birth of the mother affects her pregnancy in various ways, possibly through the effects of hypothetical seasonal environmental factors.

The month of birth of the father seems to affect his offspring little. The month of birth distribution of 966 fathers of twins in Japan had no significant deviation from that of the general population.

This seems to be natural, because the mother produces the ovum and provides its environment, and supplies nutrients etc., which can affect the embryo and fetus throughout its development, while the father can affect it through the sperm cell or chromosomal factors only. Therefore, effects of the month of birth of the father could be expected only in chromosomal aberration.

4. Discussion

It is quite apparent that there is a distinct seasonality in human births. However, geographical variations or secular changes in the seasonality of human births have never been given any reasonably convincing explanations. For instance, the comfort of the climate is a priori believed to increase human vigor and human fertility. Many examples have been reported which seem to agree with this idea[1, 45, 73, 76, 78]. Another explanation is that increased opportunities for sexual intercourse, e.g. during seasons of festivity, increase the birth rate[26, 62]. However, the evidence for these ideas is contradictory[82]. Although the influence of these factors on the rate of conception and birth is likely, the many examples of rapid or secular cyclic changes in birth seasonality observed in various countries are difficult to explain by these conventional ideas. It is not too far-fetched to assume the existence of some 'natural' control[15] although we do not have any precise knowledge. A kind of natural abortion[8, 10, 48], which could occur seasonally, could be an explanation. Our observations that the month of birth of the mother is significantly related to the seasonal changes in the rate of births and twin-births, and the sex ratio in the offspring, strongly suggest that these phenomena might be caused by certain epidemic and immunogenic seasonal environmental factors; agents like viruses or other microbes are the most likely candidates. If we assume that certain microbiological agents influence the human reproductive capacity seasonally, some of the so far enigmatic phenomena in the seasonality and also in the fundamental physiological mechanisms of human reproduction might be elucidated. Unless the agents can be isolated and identified, this hypothesis will remain only as an elusive argument. It includes not only the existence of seasonally determined epidemic immunogenic agents, but also very wide epidemics of fetal infections which provide a long lasting immunity after birth. At present each of these hypotheses may seem highly unlikely. Our findings, however, must have some reasonable explanation, and the above mentioned series of hypotheses is the most likely one at present. Therefore, experimental evidence will probably be found for all these biological stages after further investigation.

Seasonal distribution for the years 1971–1972 and 1976–1980 for two groups of mothers with different birth seasons ($X^1_2 = 4.62$; $p < 0.05$)

Month of mother's birth	Month of twins' birth Jan.–Aug.	Sept.–Dec.	Total
May–July	55 (66.3%)	28 (33.7%)	83 (100%)
Aug.–April	127 (52.7%)	114 (47.3%)	241 (100%)
Total	182 (56.2%)	142 (43.8%)	324 (100%)

5. Conclusions

The effect of atmospheric factors on animal reproduction seems to be evident. The effect on man, however, is ambiguous and the seasonality in human births may be more strongly affected by social behavior and also by unknown seasonal factors. Since the effect of the biosphere cannot be excluded in nature, we may assume that some microorganisms, as part of the microbiosphere, are influenced by atmospheric factors.

Our recent investigations revealed that the seasonalities in human births, twinning and the male/female sex ratio are closely related to the month of their mother's birth. These phenomena can be explained by the hypotheses of certain seasonally epidemic infertility factors[52, 53], twin-birth promoting factors[58], and sex ratio changing factors[55, 59]. These factors could be certain microbiological agents which infect at a particular fetal stage and may induce a life-long immunity. Biological effects of seemingly atmospheric factors may be considered as possibly being caused by some microbiological agents.

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Response to meteorological stress as a function of age

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1. Introduction

The process of aging in humans has two aspects: 1) with increasing age the traces of illnesses, accidents and injuries increase. All such traces can, in a way, be considered as scars. 2) Absence of illness or injuries cannot stop the process of senescence which starts in the third decade of life. With advancing years many changes in the body occur: decrease of endurance, of muscular power, of pulse frequency – at rest and especially under stress – and of the metabolic rate; an increase of the systolic blood pressure and of the occurrence of degenerative rheumatic diseases, etc. Physical training may delay the aging process but cannot stop it.

It is evident that these physiological changes in the aging process must affect the reaction of the organism to the physical environment and thus to meteorological influences. However, significant research on the impact of the environment on the senescent organism is scarce.

The results of the studies reviewed below are largely based on laboratory tests and less on observations of direct meteorological effects. Nevertheless, they may be of use for future research on the effects of weather and climate on the aging organism.

2. Influence of weather on old people

According to Faust[8], who carried out a study in Basel (Switzerland), 20% of young people less than 20 years old considered themselves weather-sensitive; in the age group of 20–60, 30%; and in the age group above 60 it was 40%. Females are more sensitive to weather changes than males, especially during the climacterium.

Weather-sensitivity obviously increases with age. These subjective reports are in line with the studies of Daubert and Schubert[4], on mortality in the University Medical Centre of Tübingen and in Baden-Württemberg from 1953–1956. They found for the age group over 60 a maximum mortality during active warm fronts accompanying atmospheric low pressure, and a minimum with atmospheric high pressure.

The seasonality in mortality with a maximum from January to March and a minimum in September was confirmed in this study, although it was only pronounced in old subjects, not in the young. At a daily level a difference was found as well: old people often died between 05.00 and 07.00 h whereas the times at which younger subjects died were rather evenly spread over the day. As the weather itself is not pathogenic, a possible explana-