34 Aging and Old Age

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34.1 Basic Features of the Biological Aging Process

Aging and Life Expectancy

Definition of biological age. The term “age”, when used as a synonym for the advanced stage of life, denotes a condition of reduced adaptation to physical and mental demands that is characteristic of these later years. In this strict sense, the term can be applied only to humans, to higher primates or to social organisms. Age starts around mid-life, with the decline of the ability to reproduce, and progresses until the death of the organism.

Life expectancy. During the entire history of the human race there have been old people; indeed, there have always been some individuals who reached the oldest age attainable in modern times. But as the average life expectancy has risen, the percentage of old people has steadily increased. In 1980 the mean life expectancy was 913 months (76.1 years) for women and 832 months (69.5 years) for men [16]. Fig. 34-1 shows the age composition of the population resident in Germany. Irregularities in the characteristic pyramidal shape [8] of the diagram result from wars and crises (as indicated in Fig. 34-1), and recently have also been introduced by the presence of a subpopulation of immigrant workers with a particular age composition.

Studies of skeletal remains from the Stone Age indicate that at that time the mean human life expectancy was 20 years. By the Middle Ages it had risen to 30 years, and by 1880, to 36 years. Around 1900 the mean life expectancy was still only 46 years, but since then it has steadily increased, except for wartime and postwar periods.

The difference in male and female life expectancy was formerly attributed mainly to the greater occupational demands made on men. At present the differences in smoking habits of the two sexes are also thought to contribute. The greater tobacco consumption of men increases their risk of dying early of circulatory and respiratory diseases. This hypothesis is supported by the finding that among the adherents of nonsmoking religious sects, women have the same life expectancy as men [11].

The maximal human life expectancy, about 115 years, is reached by very few. The earlier death of most individuals is brought about by various endogenous and exogenous influences, including
hereditary factors, accidents and diseases. People whose parents reached a very old age are more likely to come close to the maximal life expectancy themselves.

The Aging Process

Whereas (old) age is a condition specific to one's later years, the biological process of aging begins at birth and continues, irreversibly, throughout life. At first increasing age is associated with an enhancement of physical and mental performance capacity. After a certain level has been reached, new abilities can be acquired only if others are given up. Eventually overall performance capacity begins to decrease, and this deterioration proceeds until death.

Aging used to be regarded as the progressive replacement of physiological functions by pathological processes. But since modern gerontology has come into being, it has become increasingly clear that aging is probably a multifactorial biological event, which is modified to different degrees by pathological factors.

Theories of aging. There is no consensus about the mechanisms involved in aging; indeed, theories abound [2]. Most of them can be assigned to two basic classes:

- the non-genetic (epigenetic) theories, in which structural changes of cells and tissues are regarded as the cause of aging, and
- the genetic theories [4], in which the responsibility for aging is attributed to changes in the transmission of genetic information.

Theories in the two groups often arrive at very similar conclusions, but by different logical steps (i.e., different cause-and-effect relationships).

In the older non-genetic theories, aging was thought to occur as parts of the body wore out [5, 10, 15] or accumulated toxins [1]. In other theories the aging process is ascribed to a change in the degree of hydration and solvation of macromolecules [20], as a result of which the mechanical strength of the tissues would be reduced and various cell functions disturbed. More recently a causative role of the genetic component has been under discussion, since the cellular apparatus for the transmission and expression of information, including DNA, is always found to be involved in the aging process. However, it remains controversial whether the DNA changes are themselves the cause of aging or whether they are simply side effects.

Nucleotide and protein changes as a cause of aging. According to a theory proposed by Szilard [18], radiation damage to the chromosomes produces aging and eventually, when the damage has become extensive, leads to death. Well-founded objections have been raised to this theory, in its various modifications [17]. Radiation is only one of the factors injurious to the genetic information carriers; many other influences (including smoking), most of them at a much lower energy level, can damage the genetic material during the course of a lifetime.

This viewpoint is taken into account in the error catastrophe theory of Orgel [12, 13], which also provides a link between the genetic and non-genetic causes of aging. The proposal here is that various kinds of damaging influences alter molecules of ribonucleic acid (RNA), so that after transcription the wrong proteins are synthesized. If these are proteins that themselves form part of the programmed biosynthesis chain, as in the case of the DNA-dependent RNA polymerase, the error is propagated. The altered copies induce the synthesis of other erroneous ribonucleic acids. Theoretically, once a critical error magnitude is exceeded, the process grows like an avalanche; an error catastrophe would have occurred. However, when experiments showed that the development of error avalanches is prevented by a self-inhibiting process, the theory had to be revised. In the new version, a steady-state level of erroneous synthesis ultimately becomes established.

The protein modifications that accompany aging were subsequently examined more closely, and it was found that the specific activity of certain enzyme proteins decreases sharply as one grows older [7]. That is, the change in the proteins has reduced their enzymatic activity. In old age, more enzyme proteins must be synthesized to achieve the necessary enzymatic effects. The significance of this finding with respect to the aging process is limited, however, in that certain groups of enzymes do not deteriorate with age and others actually show an increase in their specific activities. Furthermore, it has not been possible to isolate or produce pure samples of the altered proteins.

In summary, the aging process is probably a multifactorial phenomenon at the cellular level, in which alterations of the genetic apparatus play an important role.