Functional and Anatomic Correlates of Neural Aging in Birds

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KEYWORDS

• Neural aging • Neuroendocrine system aging • Long- and short-lived birds • Aging

KEY POINTS

- Short-lived birds experience reproductive aging, with declining endocrine and neuroendocrine function and behavioral alterations.
- Long-lived birds show negligible reproductive decline; however, there is evidence of behavioral and cognitive changes in individuals.
- Conserved mechanisms underlie age-related changes in the avian brain similar to those observed in mammals suggesting conserved mechanisms for overall aging processes.

INTRODUCTION

Avian species (class Aves) are among the most ubiquitous vertebrates, spanning the globe in a variety of habitats and adaptations. In addition to great variation in lifetime reproductive, physiologic, and adaptive strategies, birds have a number of unique characteristics that allow them to migrate great distances and survive under highly variable and sometimes extreme conditions.[1] More impressive, avian species have a higher metabolism, body temperature, and unique bone and air sac structure to enhance flight capability. Moreover, it would be predicted that the higher body temperature and metabolic rate would result in a shorter lifespan. Many birds, including several species of hummingbirds, parrots, and seabirds, exhibit remarkably long lifespans.[2–8] Although there is evidence that long-lived birds reduced oxidative damage compared with short-lived birds, age-related diseases also occur including cardiovascular disease, cancer, osteoarthritis, and endocrine system decline. This review coalesces the available literature on the aging of neural systems in birds, with a focus on functional impacts as the aging process progresses.

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AN OVERVIEW OF AGING IN BIRDS

There is a very large literature on domestic birds, including many studies that have provided critical information to the poultry industry for the optimization of productivity, breeding and genetics, and disease prevention and management. These studies have also greatly contributed to the overall understanding of the fundamental biology of avian species. Studies in domestic species have concentrated on declining productivity, especially in egg production and fertility as the flock ages.[9–13] Initial studies showed that the characteristics of this age-related decrease in egg production included decreasing egg production accompanied by thinning eggshell, with little discernable change in circulating steroids.[14] Further, the timing in this age-related decline in aging varies with strain of domestic chick in that the Leghorn hens continued high egg production while the heavier Rhode Island Red line showed decreasing egg production with longer interoviposition intervals.[10] Coincident with the declining egg production, other indicators of age-related decline begin to emerge including alterations in neuroendocrine response, shell quality decline, and increasing evidence of metabolic system changes.[9,11–13] Osteoporosis often presents severe problems for aging poultry, especially in egg-laying strains that may produce 300 or more eggs per year. The bones of female birds generally serve as a repository for calcium and other minerals needed for egg production. Female quail develop increasingly fragile bones as they age and have served as an excellent model for poultry layers in understanding the effects of hormones and dietary treatments on.[15] There is evidence that the availability of perches alleviates as well as improves bone and muscle health in egg laying birds.[16] This finding is similar to a large literature in humans and other mammals that reinforce the beneficial effects of exercise, especially weight-bearing exercise on bone health and muscle functionality. Finally, birds with high egg production have a high incidence of ovarian cancers, likely associated with the extensive rupture repair processes with daily ovulations. As such, poultry have an excellent model understanding some of the basic biology of osteoporosis and ovarian cancer.

Short-lived male birds also show evidence of aging, particularly in endocrine and behavioral components of reproduction.[17,18] This includes decreased sperm production and increased sperm abnormalities over time.[11,19] Interestingly, male brain retains plasticity during aging as demonstrated by responsiveness to exogenous testosterone replacement in reproductively senescent males by recovery of reproductive function, including function of specific neuropeptide pathways in the hypothalamus regulating sexual behavior and gonadotropin-releasing hormone. This response, in turn, allows for the investigation of the roles of these molecules in the aging brain–gonadal system.

A number of studies have also focused on short- and long-lived avian species to understand mechanisms underlying the process of aging and also to investigated biomarkers as indices of aging status. The comparison of putative biomarkers has provided valuable information for ascertaining if conserved mechanisms in aging processes span across vertebrate and even invertebrate species. Some of these mechanisms include altered immune system function and other markers of the aging process that seem to occur in tandem with reproductive endocrine decline.[6,8] Further, the link between environmental stressors and healthy aging is clearly critical, affecting both health and longevity.[20] Cellular markers, specifically telomeres and the influence of oxidative damage, have received a great deal of attention, both as bioindicators and contributors to age-related demise in physiologic systems. Species comparisons have shown that avian telomeric DNA sequences are longer than in mammals; however, average telomere length and maximum life span did not seem to be related.[21] Aydinonat and colleagues[22] demonstrated that telomere length decreased with age and