What limits the size of birds?

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Why aren't birds larger? Fifteen-kilogram swans hold the current upper size record for flying birds, although the extinct Argentavis of the Miocene Epoch in Argentina is estimated to have weighed 70 kilograms, the size of an average human. In a forthcoming article in *PLoS Biology*, Sievert Rohwer, and his colleagues at the Burke Museum at the University of Washington, provide evidence that maximum body size in birds is constrained by the amount of time it takes to replace the flight feathers during molt. As bird size increases, feather growth rate fails to keep up with feather length until, eventually; feathers wear out before they can be replaced. This fundamental relationship requires basic changes in the molt strategy as size increases, ultimately limiting the size of flying birds.

Feathers deteriorate with continued exposure to ultra-violet light and bacterial decomposition, and must be replaced periodically to maintain adequate aerodynamic support for flight. Small birds accomplish this in an annual or twice-annual molt, during which the 9 or 10 primary flight feathers are replaced sequentially, taking about three weeks for each feather. Large species of birds need different approaches to feather replacement. These involve several alternative strategies: prolonging the total molt to two or even three years; simultaneously replacing multiple feathers from different molt-origination points in the feather sequence; and, in species that do not require flight to feed or escape enemies (ducks and geese, for example), replacing all feathers simultaneously.

With increasing body size, the length of the primary feathers increases as the one-third power of mass, approximately doubling with each 10-fold increase in mass. However, the rate of feather growth increases only as the one-sixth power of mass, meaning that the time required to replace each feather increases by a factor of about 1.5 for each 10-fold increase in mass, until 56 days are required to replace a single flight feather in a 10-kg bird. The cause of this discrepancy is not known, but the authors speculate that it probably depends on the geometry of producing a two-dimensional feather structure from a one-dimensional growing zone in the feather shaft.

The avian feather is one of the most striking adaptations in the animal world, and yet its growth dynamics are poorly understood. It might be possible to achieve more rapid feather growth with a larger growth zone, but this could also weaken the structure of the growing feather, resulting in frequent breakage in large birds. Understanding the engineering complexities of the growing feather will require further study of the dynamics and structure of the growing zone. And what about Argentavis? The authors speculate that this giant bird most likely molted all its feathers simultaneously during a long fast, fueled by accumulated fat deposits much in the same way as emperor penguins do today.

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