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Flying Ability of *Archaeopteryx*

YALDEN, in calculating the flying speed of *Archaeopteryx*, states¹ that he includes the areas of the body strip and tail, and assumes the same lift coefficient for both the wing and tail surfaces. Heptonstall in an earlier letter² does not include the body strip because "it does not behave like an aerofoil in generating high lift".

The accepted definition of the lift coefficient and wing area, given by Etkin³ and others⁴, is

$$C_L = C_{L(\text{wing})} + C_{L(\text{tail})}, A_{\text{tail}}/A_{\text{wing}}$$

where $C_{L(\text{wing})}$ refers to the wing plus body combination only, and A_{wing} includes the body strip but excludes the tail area, by definition. $C_{L(\text{tail})}$ may be either positive or negative, depending on an analysis of the tail angle required to balance the pitching moment from the wing-body combination^{3,4}.

Inclusion of the body strip in the wing area is important for two reasons. First, wing lift depends on the total (wing span)² according to Glauert⁵ and others^{6,7}, and, second, the presence of a body increases the lift of an isolated wing through mutual interference effects which become significant at low aspect ratios as shown, for example, by Flax and Lawrence⁷.

Good design practice requires that the tail should stall after the wing so that the tail operates at a lower lift coefficient than the wing, in general, but it is doubtful if the refinement which results from including the tail lift is justified by the accuracy of the data available, or the difficulty in estimating $C_{L(\text{tail})}$. The error in flying speed as a result of neglecting the tail lift is certainly no greater than that arising from an incorrect definition of wing area.

My own estimate of the minimum flying speed of *Archaeopteryx*, based on a wing lift coefficient of 1.3 but neglecting tail lift, varies from 7 m s⁻¹ at a wing loading of 0.4 g cm² to 11 m s⁻¹ at a wing loading of 1.0 g cm².

Bramwell claims⁸ that the tail lift of *Archaeopteryx* cannot be ignored because it contributes a 20% reduction in stalling speed. If this were true, it can be shown that the tail lift must support 36% of the total weight and is equal to 56% of the wing lift. Because the tail area is only 29% of the wing area⁸, it follows that the tail must operate at nearly twice the lift coefficient of the wing, and must have evolved with significantly better high lift characteristics.

There is another objection to the importance which Bramwell attaches to the tail lift. If the tail contributes a significant proportion of the total lift, then even a small deflexion of the tail surface for longitudinal control purposes will alter the balance of lift and weight forces, and result in an oscillatory motion which will be difficult to control. *Archaeopteryx* would be a difficult machine to fly. In practice, the tail lift force is designed to be as small as possible in order to minimize the total lift induced drag, the weight of tail structure, and changes in total lift resulting from one of its primary functions as a control surface.

The other essential function of the tail surface is to provide positive stability, as was pointed out by both Bramwell and Heptonstall. If, as they suggest, the tail does contribute some positive lift, then, from balance considerations, the centre of gravity must be located behind the aerodynamic centre of the wing-body combination (excluding the tail). This is a basically unstable configuration. Furthermore, the low aspect ratio of

the tail indicates that it is aerodynamically less effective (that is, it has a lower lift gradient) than a broad tail configuration.

A large tail area will be required simply to shift the aerodynamic centre to a stable position behind the centre of gravity, and also to provide effective pitch control at low flying speed. Many aircraft have a large tail surface for this reason.

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Experiments on Mimicry: Gestalt Perception and the Evolution of Genetic Linkage

POLYMORPHIC mimicry in butterflies requires that their potential predators, either birds, lizards or monkeys, should be able to exercise Gestalt perception. We here describe a simple experiment showing that wild birds are indeed able to perceive a pattern as a whole, rather than responding only to single elements of it.

Accurate batesian mimicry (the close resemblance of a palatable insect to an unpalatable one) can evolve gradually rather than by a single step, for even poor mimics are to some extent protected from predators^{1,2}. Mimicry probably did evolve in this way, in lepidoptera, for geographical races which mimic different models are usually differentiated by several genetic loci in different linkage groups; this is true of the batesian mimic *Papilio dardanus*³ and of the muellerian mimics *Zygaena ephialtes*⁴ and *Heliconius melpomene*⁵. But in breeding experiments with a polymorphic mimetic species, however, several forms which occur in the same population differ by major alleles at a single genetic locus even though their patterns may have few features in common (as in the batesian mimics *Papilio memnon*⁶ and *P. dardanus*⁷).

Clarke and Sheppard⁸ have explained this anomaly by suggesting that the apparently single mutations are in fact clusters of closely linked loci, and that the gradual evolution of mimicry has been accompanied by the evolution of close linkage, because natural selection acts against recombinant genotypes. If, for example, *Papilio memnon* had forms mimicking two model species, *A* and *B*, with differently coloured bodies and differently patterned wings, a form of *P. memnon* having the *A* body with the *B* wings, or vice versa, would resemble neither model, and would be at a selective disadvantage, so that selection would act to increase the linkage between genes controlling body colour and wing pattern⁹.

Only predators who perceive the butterfly as a whole will produce this disruptive selection, for predators, noticing only the colour of the body or only the wing-pattern, will avoid all four kinds of mimic, without especially eliminating those with the wrong combinations of bodies and wings. Clarke and Sheppard¹⁰ give biometrical evidence that such Gestalt perception is affecting the variance of tail-length in the Abyssinian race of *Papilio dardanus*, but there is no direct evidence of this behaviour by insectivorous birds.