Letters

Could Pterosaurs Fly?

I have noted with much interest Douglas A. Lawson's report "Pterosaur from the latest Cretaceous of West Texas: Discovery of the largest flying creature" (14 Mar., p. 947). I have no basis for quarreling with Lawson's conclusions or with his dimensional extrapolations, but if they are valid, it must follow that the wing architecture of his pterosaur is substantially different from that found in flying animals today. It would seem to me not only appropriate, but essential, to consider the aerodynamic consequences of this rather extraordinary difference.

Magnan, in 1922, published a remarkable paper (*1*) in which he reported measurements made of more than 200 species of birds covering all of the important taxonomic classes and the complete avian size range. He produced data on every conceivable avian dimension, among which were weight, wingspan, and the length of the humerus. In an article, "The flight of birds" (*2*), I have divided Magnan's birds into three models based upon wing loading, that is to say, weight per unit of wing area. These I have called the passeriform, the shorebird, and the duck models. For purposes of the present discussion, the differences between them are not important.

I have made a regression analysis relating the length of the humerus to the total wingspan for the 139 species comprising the passeriform model. The result is expressed in the power function

$$H = 0.0419\,b^{1.138}$$

where H and b are, respectively, the length of the humerus and the wingspan in centimeters. Since the error of estimate for the exponent 1.138 is 0.0162, the probability that the exponent could be as low as unity is negligible, hence the humerus will become a greater fraction of the wingspan as size increases.

If we insert the length (52 cm) of the pterosaur's humerus into this equation, we get a wingspan of 525 cm, about one-third of the value (15.5 meters) postulated by Lawson. To state the result in another way, twice the length of the humerus is 20 percent of the total wingspan for a living bird with a humerus 52 cm long. For Lawson's pterosaur, twice the humerus is only 6.7 percent of the total wingspan, which means, in effect, that the length of the humerus is almost negligible as a feature of wing architecture.

Magnan (*1*) also measured weight as well as wingspan, and I have calculated a regression for the passeriform model in which weight and wingspan are related. Applying that relationship to a wingspan of 15.4 m produces a total weight for the animal of 440 kilograms, a very heavy bird indeed. If, on the other hand, we take the weight as calculated from the length of the humerus for Magnan's passeriform model, we come out with a weight of about 30 kg, a much more reasonable figure.

Still another way of looking at it is to consider large living birds. The albatross, *Diomedea exulans*, has a humerus 40 cm long and a wingspan of 341 cm. The European vulture, *Gyps fulvus*, has a humerus 26.5 cm long and a wingspan of 256 cm. One sees immediately that the extrapolation to a 52-cm humerus is not very great when it comes to living birds.

The architecture of the pterosaur's wing must have been substantially different from that which we now encounter in living birds. It would be a worthwhile exercise to consider how, in fact, birds with such huge wings, indeed such huge hands, could possibly have flown and maneuvered in the air with any degree of efficiency.

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References

1. A. Magnan, *Ann. Sci. Nat.* 5, 125 (1922).
2. C. H. Greenewalt, *Trans. Am. Phil. Soc.*, in press.

Greenewalt is correct, particularly concerning the structural differences between pterosaurs and bats and birds. Large pterodactyloids, unlike birds and bats, had a scapula that articulated with the axial skeleton by means of a ball-and-socket joint between the proximal end of the scapula and the fused neural spines of the dorsal vertebrae called the notarium. The distal end of the coracoid articulated with the sternum, which in turn was attached to the vertebral column through the ribs. In birds and bats, the proximal end of the scapula is free. The coracoid in birds and the clavicle in bats articulate with the sternum, which is connected to the vertebral column via the ribs. The pectoral girdle of bats has been further strengthened by the fusion of the last cervical, the first two thoracic vertebrae, and two ribs to form the manubrium. The more nearly spherical proximal head of the humerus and free scapula in birds and bats indicate that there is greater freedom of movement of the upper arm than there was in pterodactyloids. Pterosaurs generally had a greatly elongated deltopectoral crest that extended downward and forward normal to the shaft of the humerus, providing a large moment arm for the pectoral muscles. The long moment arm of the deltoid crest enabled the pterodactyl to rotate the forearm to adjust the wing's angle of attack. Lateral movements of the humerus and hind legs, as described by Hankin and Watson (*1*), adjusted the camber. In birds and bats the humerus is the fundamental unit for the transmission of power to the wing, and the movement of the scapula provides the fine adjustment for the wing's camber and angle of attack (*2*). Finally, the humerus in pterodactyls contributed only a small part to the total wingspan, being the second shortest bone in the appendage, whereas the same bone makes a substantial contribution to the wingspan of birds and bats.

These structural differences, which are adaptive consequences of aerial competition, are reflected in the difference in the relations of humeral length and mass to wingspan in birds and in pterosaurs. A regression equation for the relation between humerus length and wingspan in *Pterodactylus antiquus* indicates that the wingspan increased more rapidly than the humerus length

$$W = 13.909H^{1.0548}$$

where W is the wingspan and H the humerus length in centimeters. In the regression equation for the same relation in *Pteranodon*

$$W = 22.191H^{1.0116}$$

the same condition obtains. However, in birds, Greenewalt's equation

$$H = 0.0419b^{1.138}$$

where H is the length of the humerus and b the wingspan in centimeters, which is equivalent to

$$W = 16.2405H^{0.8787}$$

indicates that the humerus increases more slowly than the total wingspan. Therefore

a bird with a humerus length of 52 cm would have a wingspan of 523 cm, whereas *P. antiquus*, had it ever attained this humerus size, would have had a 1019-cm wingspan, and *Pteranodon* would have had a 1241-cm wingspan.

The Texas pterosaur, hereafter to be referred to as *Quetzalcoatlus northropi*, is represented by the type Texas Memorial Museum No. 41450-3, which consists of a left humerus and partial radius, ulna, proximal and distal carpals, metacarpal, and first and second phalanges of the fourth digit. An approximate regression equation for the relation of its wingspan to its humerus length

$$W = 29.70H^{1.0116}$$

can be based on a more nearly complete, smaller specimen of the same species and on the regression coefficient of *Pteranodon*. The solution of this equation for a humerus of 52 cm gives a wingspan of approximately 1600 cm.

As for the relation between mass and wingspan, Bramwell and Whitfield (*3*) list five estimates for the mass of *Pteranodon* with a wingspan of 6.95 meters that range from 12.9 to 29.8 kilograms. These estimates are based on attempts to flesh out the animal, not on a calculated relation between mass and wingspan. However, using Greenewalt's (*4*) equation for the relation between mass and wingspan in birds and insects

$$W = cl^3$$

where W is weight, l is the length of the arm, and c is a constant of proportionality, the mass of a bird with a wingspan of 695 cm would be 100 kg, and for a bird with a wingspan of 1550 cm, it would be 440 kg. Once again, the relation between some anatomical feature and wingspan does not seem to have been the same in pterosaurs as it is in birds. Both of these departures from the relation seen in birds ultimately reflect the differences in mode of locomotion. It seems that, although study of present-day flying creatures provides insight into possible structural solutions to a common problem, it does not dictate that a particular solution must be practiced by all flying creatures.

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Sea-Floor Exploration

In the otherwise excellent article by Allen Hammond, "Submersibles: A research technology whose time has come?" (Research News, 7 Mar., p. 824), one error should be corrected. Hammond remarks that "even ordinary echo-sounding gear is almost nonexistent on most university-operated research ships." As best as I can determine, every U.S. university-operated research ship (barring rowboats) can boast an "ordinary" echo sounder adequate to determine depth on the continental shelf. All of the "blue-water" oceanographic ships in the University-National Oceanographic Laboratory System have at least one precision deep-water sounding system capable of determining the water depth to an accuracy of 1 fathom. Most have more than one system. What they don't have are "extraordinary" systems with multiple, high-power, directionally stabilized, narrow-beam transducers designed to map a strip of the bottom rather than a line at one pass. The Navy has a few of these.

U.S. academic research ships are currently suffering from a whole set of problems caused by rapidly escalating costs, limited funding, expanded claims of jurisdiction by coastal states, and a maze of red tape, but they are not in as bad shape as Hammond implies.

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DOD Sponsored Research

In the article "Department of Defense R & D in the university" (22 Nov. 1974, p. 706) by Stanton A. Glantz and Norm V. Albers, my response to a DDC (Defense Documentation Center) statement was presented as evidence of "Two different perceptions" of DOD (Department of Defense) sponsored research. It is a pity that the authors used this as an example, since my strong response was due to a misreading of the DDC statement. While the authors were very open in preparing the material included in volume 1 of their Stanford report (*1*), they used extreme secrecy in preparing volume 2 (*2*), upon which much of their *Science* article is based. As a result, I was not able to correct my error until after the report was published and issued to the public late in 1971. Early in 1972, the Stanford Workshop on Political and Social Issues (SWOPSI) policy board approved an addendum to the report giving this correction and the reasons for it. Part of this addendum is included as refer-