From the fact of its being necessary to use monochromatic light, and also from the limited range owing to the short distance between the spectra, it would appear that the use of the new spectroscope will of necessity be somewhat confined to special branches of research. For the investigation of the Zeeman effect, and the resolution of hitherto undivided multiple lines, it should prove of great service, the relatively bright spectrum obtained rendering it possible to examine the fainter lines which have heretofore been neglected up to the present.

Naturally, the first essay in constructing such an entirely new piece of optical work was fraught with many difficulties; but, encouraged by his success, Mr. Hilger expresses himself as quite prepared to undertake the building up of echelons of much higher power than the one he has just completed. CHARLES P. BUTLER.

FLIGHT OF BIRDS.

“THE way of a bird in the air” has been for ages a perplexing one; and, until recently, its mechanical explanation has been too much left to persons whom the more sober members of the body scientific were apt to class as “cranks,” to use an Americanism. If confirmation of such judgment were necessary, it was afforded by a report, made to the Institute of France about 1830 by Navier, who was no “crank,” member and reporter of a commission of eminent scientific men, in which the subject was discussed. Navier drew a distinction, since generally accepted, between hovering, in which the bird remains stationary in the air, as a hawk or kite “winnowing,” on the one hand, and progressive flight, accompanied by flapping of the wings, in which the bird moves forward rapidly, as a carrier pigeon or swallow on a journey, on the other. A third mode of flight, called soaring, has, of late, attracted much attention. It consists in the bird maintaining forward motion, straight or circling, sometimes for minutes together, with very occasional and slight flaps of the wing; in some cases with none at all. In these three kinds of flight, observations easily made by any one show that soaring appears to require the least exertion, though not many birds can manage it well; progressive flapping flight is common, and many birds can keep it up for hours; while only a few can manage hovering, which appears to involve much exertion, and, as the Duke of Argyll expresses it, seems to be the most difficult feat of wingmanship a bird can execute. Navier, however, concluded hovering to be far easier than progressive flight, requiring only about one-twentieth of the exertion of this latter; soaring he does not appear to have considered. His results, moreover, made very heavy demands on the animal, considered as a machine. According to him, a bird must be able to give out energy at, or exceeding, the rate of 1000 foot pounds per second per pound of its own weight, whereas no ordinary land animal whose work is directly measurable gives out continuously for hours more than about half a foot pound per second per pound of its own weight. This excessively disproportionate activity of birds, in the proportion of over two thousand to one, as compared with other animals, seems sufficient to invalidate the basis of calculation; but the argument is further strengthened on finding that a carrier pigeon, for instance, does not contain enough combustible matter to maintain its own flight, and live, for anything like an hour, if Navier be right. A thousand foot pounds is rather more than one British thermal unit, so that one heat unit, if wholly converted into useful mechanical power, would carry a pound weight for somewhat less than four-fifths of a second. The bird’s feathers and bones must be preserved, and water or blood are not combustibles, so that not more than four ounces in the pound of its weight can be reckoned as available combustible matter. If this be as good fuel as paraffin oil

(and some birds are oily), each pound of the bird’s body can supply about 5000 heat units, able to carry it for 4000 seconds or thereabouts, or less than an hour and ten minutes. At the end of this time the bird would be a wet feathered skeleton with a few ashes inside, rattling among the bones, perhaps. On the other hand, Langley’s experiments, which were very carefully made, and agree in all material points with others of the same nature, conclusively show that what is often called an *aéroplane*—that is, a plane slightly inclined to the direction of its motion in air—can, at reasonable velocities, be made to soar while carrying a load of one pound, by an expenditure of from 5 to 10 foot pounds of work per second. He also shows that the power required to sustain a given weight varies almost exactly inversely as the velocity of flight of the *aéroplane*; while Navier, in his calculations, made it vary directly as the cube of the velocity. On all accounts, then, it appears highly probable that the flight of birds is effected, in ordinary cases, by a process much more nearly allied to that of the soaring of Langley’s planes than that investigated by Navier. The wings must be taken to act principally as *aéroplanes*, and the flapping action be used to enable the bird to supply the comparatively small power required for the propulsion of soaring *aéroplanes*. In confirmation of this view, which the present writer takes to be that now recognised as affording the best explanation of birds’ flight, he has shown, in a paper recently read before the Royal Society, that a machine consisting of a vertical cylinder and piston, with a nearly horizontal *aéroplane* attached to the rod, could, by the reciprocation of the piston, sustain and propel itself in horizontal flight, with an expenditure of energy little exceeding, perhaps falling below, that found requisite in Langley’s experiments. In cases comparable to those of birds, rapidity of reciprocation affects the result but slightly, agreeing with the known fact that some birds able to fly long distances flap slowly, while others flap quickly; whereas this would be improbable if any considerable intrinsic difference in economy of labour existed between slow and quick flapping. As to hovering, the conditions are too far removed from those of experiments on soaring to allow reliance to be placed on numerical results; there does not appear any absolute necessity for a higher rate of energy-expenditure than in ordinary flight, but the conditions of economical working, particularly as to a sufficiently quick flapping, seem to be more difficult of attainment. In prolonged soaring flight it appears likely, from theoretical investigations by Lord Kelvin, as well as consistent with observation, that local air currents may be largely concerned, as a skilful bird might, by gliding in and out among currents having different velocities, appropriate for his own use and support enough of the extra energy of the quicker currents, to keep himself going continuously, without any exertion, beyond that involved in steering, on his own part.

With respect to the very interesting, though probably not very practical, question of man’s mechanical flight, Langley’s and Maxim’s experiments show it to be at least within the range of possibility; but, if the conclusions of the paper above alluded to be correct, the most economical method of effecting it would involve using the supporting *aéroplanes* as birds use wings—that is, as propellers and *aéroplanes* combined in one. Purely constructive difficulties interfere seriously with designs for movable wings of any considerable size, especially if their motion is a reciprocating one, while there is another whole tribe of difficulties connected with the balancing and steering, very possibly greater than those which beset the beginner on a bicycle; so that, on the whole, we can scarcely feel as if we were within any very measurable distance of emulating the feats of *Dædalus*, without almost certainly suffering the fate of his less fortunate son.

MAURICE F. FITZGERALD.