to produce a vacuum in the apparatus in the beginning. The second causes the circulation of the gas in the tubes, which are heated to low redness. In this way, by applying the characteristic properties of calcium noted by M. Moissan, the small quantities of nitrogen and hydrogen are retained by the calcium and the argon comes off in a practically pure state. The gas is collected in bottles of 250 c.c. capacity. To find out whether the argon is pure, it was studied by the spectrum of an induction spark, which showed the characteristic lines for argon, while nitrogen was practically absent. This new method therefore affords a good working process for preparing pure argon in considerable quantities.

SOARING FLIGHT.

BY GARRETT P. SERVISS, JR.

Among the many phenomena exhibited by flying birds, and observed and studied in attempted solution of that most interesting and baffling of all engineering problems, mechanical flight, there is one which is so remarkable in its paradoxical nature, that it has attracted perhaps more attention than all the others together. I refer to soaring, or, as it is sometimes called, sailing, and, in one of its aspects, aspiration. In performing this feat, the bird holds its outstretched wings absolutely motionless, and remains suspended in the air, traveling in any desired direction without, so far as can be observed, the expenditure of the slightest amount of energy. This feat seems so absolutely impossible on first sight that men have doubted their own senses, and have taken photographs of soaring birds, hoping that the camera plate, more rapid than the eye, would be able to detect some lightning-like movement of wing which would account for the bird's support. So far as the writer is aware, no such movement was ever detected. It remains then for us to explain the phenomena on mechanical principles, or else to admit that our theories of the action of elastic fluids, such as the air, are erroneous. Such explanations have been given, it is true, but so many of them are erroneous—indeed, I hope to show that only one of them is entirely reasonable—that it seems desirable to review them, and to endeavor to show that there is one other way in which the birds frequently use the energy of the wind for their support and propulsion.

For convenience in reviewing the explanations already suggested, it will be well to divide them into three general classes:

1. Attempts to explain soaring in uniform horizontal winds.
2. Explanations which require the assumption of ascending wind currents.
3. Explanations depending upon a wind continually varying in velocity or direction, or both.

The advocates of the first class of explanations have held that some particular shape of the bird's wings might have a peculiar action upon the air, so deflecting it that the wing would be forced upward and forward into the teeth of the wind. Others have invented highly ingenious but totally inadequate evolutions, by the performance of which the bird would be enabled to gain elevation, and eventually travel in any direction by sailing down an inclined path. It is not necessary here mathematically to treat in detail these explanations, though it is entirely possible. It will suffice to show by very simple considerations, the essential fallacy involved in any theory of soaring in uniform horizontal air currents. In the first place, consider a bird being supported stationary in the wind. The downward pull of gravity upon the bird must be counteracted by an equivalent upward force. This upward force on the bird has its reaction upon the air particles under the bird's wings, and the downward force on the air produces a downward acceleration of the air particles, which, combining with their forward motion, produces a resulting velocity greater than the original velocity. This means that the air, in passing the bird, has its energy increased, which is contrary to the law of the conservation of energy. In case the bird is performing evolutions instead of remaining stationary, the force upon the bird and air particles varies both in direction and amount, but an integration still shows an increase of total energy in the wind.

This is the basis of an exact treatment, and is given because the increase or non-increase in total energy of the wind when passing the bird furnishes a universal criterion for determining the possible correctness of any explanation of the phenomenon in question. A much simpler conception, however, has been suggested by someone, and we will give this briefly before taking up the next class of explanations. The air confined in a railroad car in motion constitutes a true uniform horizontal wind with regard to the earth. Yet no one could conceive of a bird performing evolutions with motionless wings, and remaining supported indefinitely in the air carried by the car.

In the second class of explanations, it is assumed that the lower strata of air moving over the earth's surface are retarded by friction and piled up, thus deflecting the strata above, and giving the wind a slight trend upward. Marked upward wind currents also exist over natural wind breaks, and on the slopes of hills when the wind is blowing toward the higher ground. Soaring birds, it has been stated by careful observers, seem to prefer such places in which to perform their aerial evolutions. Granting the existence of upward wind currents, we can understand one way in which soaring is accomplished.

Consider a kite against which a horizontal wind is blowing. The pressure of the air is normal to the kite surface, and is thus a force directed upward and backward. If now the backward component is neutralized by the pull of the string, the kite will remain suspended in the air through the vertical component of the wind's pressure. If we release the string, the kite will drift backward by virtue of the horizontal component of pressure, and sink to the ground. Suppose, however, that the wind takes an upward trend. The kite may now be tipped down in front; and if the wind is rising at a sufficient angle, the kite may even take a horizontal position, and still present the same angle to the wind. In this case the pressure upon the kite, always normal, will become a vertical force. If the wind tends upward at a still greater angle, the kite may be tipped down in front until the front edge is lower than the back, in which case the horizontal component of the pressure is directed forward opposite to the direction of the wind. If the kite could maintain equilibrium, it would advance into the wind under these conditions, and remain in the air indefinitely. Kite experimenters have observed this very action at times, and it is a true case of soaring, or better, aspiration.

Thus we see that the existence of upward wind currents is sufficient to render flight without exertion possible, but that soaring is always or even frequently due to such currents is very doubtful. We must then look to our third class of explanations to complete the theory.

Prof. Langley, by careful measurements of air velocities, has shown that all winds are extremely variable, his readings having indicated changes in velocity of ten miles or more per hour in a small fraction of a second. His investigations are fully described in his paper, "The Internal Work of the Wind," but his theory will be briefly stated here. A bird flying in such a variable wind would be carried along at the average velocity of the air, while the alternate puffs of high and low velocity would constitute alternate virtual winds, first blowing by him in the direction of his motion, and then against him in the contrary direction, his inertia preventing him from following the rapid fluctuations. Under these conditions, the bird by facing about first toward the virtual wind in one direction, and then toward that in the other, could always present his inclined wings to a current of air, and obtain a supporting reaction. The facing about might be accomplished by sailing in circles, an evolution often observed. This in brief was Langley's theory, and highly ingenious it is. It may under exceptional conditions be the manner in which soaring is accomplished, but in ordinary winds the variations in velocity certainly cannot exceed fifteen miles an hour, and even if these variations occurred extremely rapidly, the bird would only be subjected to a virtual wind of less than seven miles per hour, which is totally inadequate to support any known soarer.

Looked at in a slightly different way, however, the writer believes that the variations in velocity of the wind may be shown to be sufficient to account for all the observed phenomena of soaring. In the first place, the relative velocity of the bird to the air, which is effective in supporting the former, must be quite high. Langley has shown that at certain velocities a plane may support as much as three hundred pounds per horse-power expended, but this velocity is much higher than the five or six miles an hour which is secured in the action just described. The bird, then, cannot drift with the same velocity as the average wind, but must possess a velocity of perhaps twenty miles an hour with regard to it, to obtain support with the energy available. How, then, can this internal energy existing in the wind by virtue of its streakiness be utilized to propel a body traveling at twenty miles an hour with regard to it? Obviously, only by taking advantage of changes in velocity occurring at *right angles* to the direction of the bird's motion. Each time such a change occurs, the bird has added to its velocity a perpendicular component, which, combining with the motion which it already had, produces a resultant velocity greater than the initial. Since the kinetic energy due to the bird's motion is proportional to the square of the velocity, and since the square of the resultant velocity is the sum of the squares of the initial and the impressed velocities (being perpendicular to each other) it is evident that the bird has absorbed all the energy which the variation in the velocity of the wind could impart, and converted it into energy of motion in its new path. Of course, if the acquired energy is being continually used for support, no increase in velocity will result.

In performing such an evolution, the bird would be forced to bring its wings into a more or less vertical position, to take full advantage of these horizontal puffs of wind, and this probably accounts for the frequency with which soaring birds move in circles, for while moving thus, the centrifugal force allows them to tip up the plane of their wings. In describing this path, the center of the circle may drift with the average wind, while the bird takes advantage of every favorable puff to produce an acceleration perpendicular to the tangent at the time it occurs. The writer has many times observed sea-gulls soaring in just such distorted circles as would be produced by this action. In this action the bird takes full advantage of the "internal work of the wind" to maintain the velocity for support which its ratio of weight to wing surface renders most efficient.

Whether or not this proves to be the final solution of the problem, it is evident that soaring is much too complicated for man to imitate, at least until he has had long experience with motor-driven machines.

SCIENCE NOTES.

E. Salvioni has devised and accurately examined a microbalance which consists of a thin thread or very thin ribbon of glass or other material, fixed at one end and placed in a closed case; the case also contains a number of small weights (the larger of platinum wire, the smaller of silk thread) which, with the aid of a handle, can be placed on the flexible thread or ribbon. The flexure of the thread when loaded is observed by means of an ocular micrometer, and, as verified by the author for his instrument, is proportional to the weight which produces it; a conveniently placed spider thread serves as a sight-line for the measurement of the displacements. A glass thread 10 centimeters long, and one of two-tenths of a millimeter in diameter, will support by flexure a weight of more than 100 milligrammes, and, if provided with an optical arrangement which magnifies one hundred times, will serve to weigh to one-thousandth of a milligramme. To avoid the inconvenience caused by subsequent elasticity, the balance is provided with a stop, which enables the flexure to be maintained after unloading. Salvioni finds that the loss of weight of musk by volatilization is clearly demonstrated by this instrument. The loss is proportional to the time.

In a study of the circulation of the atmosphere of the sun, in the Monthly Weather Review, Prof. Frank H. Bigelow presents a mass of data and observations showing that "the sun should be regarded as an incipient binary star." Recent scientific work in investigating the circulation of the solar atmosphere in accordance with the laws governing the convective and radiative action of a large mass of matter contracting by its own gravitation, have led Prof. Bigelow to the hypothesis, that "the single fiery envelope conceals two disks." A series of observations extending over many years on the period of solar rotation at various points on the surface shows that "the same meridian of the sun is seen twice in a single rotation of the entire mass, first as the eastern limb, and second, thirteen days later, as the western limb. Whatever may be the intrinsic activity of the sun at a given zone and on a given meridian, that display becomes visible twice, first to the east, and second, to the west." The tables prepared by Prof. Bigelow giving the rate of angular rotation of various zones of the sun's surface show that it is far from uniform, being increased in proportion to the distance from the equator. As yet little has been done regarding "the fundamental problem of the mode of the internal solar circulation." This difference of external activity of the sun "on two opposite sides of its mass, as if a certain diameter had greater energy than the one at right angles to it," is similar to a recent discovery of Prof. Bigelow in regard to the earth's atmosphere, and leads him to the conclusion already stated, that "this persistent excess of outflowing energy on two opposite sides of the sun suggests the possibility that the sun should be regarded as an incipient binary star where the dumbbell figure of rotation prevails instead of the spheroidal. If this is really the case, and the evidence suggests it, then there would be a reason for the existence of the two primary centers of activity of the sun instead of its having a single center. From this we would expect to find that the sun has two magnetic and two meteorological systems, and indeed some double-acting system appears to impress itself generally upon the solar cosmical relations. This view is quite in harmony with the well-known fact of the existence of numerous binary systems of suns more or less widely separated, and it can not be regarded as unlikely that the sun is developing in the same way. The enormous mass of the sun would seem to entice its constituents to group themselves preferably about two centers for the physical processes involved in circulation and radiation, rather than about one, and I suspect that this is the correct explanation of several well-known phenomena."