Dr. J. G. M. Burt
with the Author's Compl^ts

Royal Institution of Great Britain.

WEEKLY EVENING MEETING,

Friday, March 22, 1867.

Sir Henry Holland, M.D. D.C.L. F.R.S. President, in the Chair.

Dr. James Bell Pettigrew, M.D. Edin.
ASSISTANT CURATOR OF THE ROYAL COLLEGE OF SURGEONS OF ENGLAND MUSEUM.

On the Various Modes of Flight in relation to Aeronautics.

The subject of flight, natural and artificial, is one which has occupied the attention of mankind from a very early period.

It involves a more or less intimate acquaintance with Anatomy, Physiology, Mechanics, and the higher branches of Mathematics.

If regarded as a natural movement, it forms one of the three kinds of locomotion by which animals progress—the remaining two being walking and swimming; if regarded as an artificial one, it represents the unsolved problem of that grand trio which has for its integral parts the locomotive, steamboat, and flying machine. Had time permitted, it was my intention to have gone into the subject of locomotion at length. I find, however, I must curtail my remarks under this head, which I do with reluctance, from a feeling that the chain of animal movements, like the great chain of existence, winds in and out and doubles upon itself so completely, as to render a partial examination of it in many respects unsatisfactory.

The movements of animals are adapted either to the earth, the water, or the air. There are others, however, of a mixed character, where they are suited equally to the land and water, or even to the land, water, and air.

The instruments by which locomotion is attained are therefore specially modified.

This is necessary because of the different densities and the different degrees of resistance furnished by the land, water, and air respectively.

As the earth affords a greater amount of support than the water, and the water than the air, it requires a greater degree of muscular exertion to swim than to walk, and a still greater one to fly.

For this reason flight is the most laborious, and in some respects the most complicated and difficult, of all the animal movements.

The peculiarities of the different media, as far as locomotion is concerned, may be briefly stated.

On the land we have the maximum of resistance and the minimum of displaceme nt.

In the air, the minimum of resistance and the maximum of displacement.

The water is intermediate in these respects.

As a consequence, the feet of land animals are small—their bodies large. The horse and deer furnish examples.

In those land animals which take to the water occasionally, or the reverse, the feet are enlarged and usually provided with a membraneous expansion between the toes. Of such, the otter, ornythorynchus, seal, frog, turtle, and crocodile may be cited.

In addition to the land animals which run and swim, there are some which precipitate themselves, parachute fashion, from immense heights, and others which even fly. In these the membraneous expansions are greatly increased—the ribs affording the necessary degree of support in the dragon or flying lizard, the anterior and posterior extremities in the flying lemur, flying cat, and bat.

Although no lizard is at present known to fly, there can be little doubt that the extinct pterodactyles, which are intermediate between the lizards and crocodiles, were possessed of this power.

The bat is interesting as being the only mammal at present enjoying the privilege of flight; it is likewise instructive as showing that flight may be attained without the aid of hollow bones and air-sacs, by purely muscular efforts and by the mere contraction and dilatation of a continuous membrane.

If we now direct our attention to the water we find that the amount of surface engaged in locomotion greatly exceeds that in the amphibia. The fish furnishes the best example.

In it the lower half of the body and the broadly-expanded tail are applied to the water very much as an oar is in sculling. The sea-mammals, as the whale, dugong, manatee, and porpoise, swim in precisely the same manner as the fish, with this difference that the tail strikes from above downwards, or vertically instead of horizontally, or from side to side. The seal is exceptional in this respect.

The animals which furnish the connecting link between the water and the air are the flying fishes on the one hand, and the diving birds on the other: the former sustaining themselves for considerable intervals in the air by means of their enormous pectoral fins, the latter using their wings for flying above and beneath the water, as occasion demands.

I have carefully examined the relations, structure, and action of the fins in the flying-fish, and am of opinion that they act as true pinions; their inadequate dimensions only preventing them from sustaining the fish for an indefinite period in the air, at all events so long as they remain moist. They operate upon the air from beneath, after the manner of a kite or spiralifer, and in so doing, lever the animal upwards and forwards.

If they did not act as true pinions within certain limits it is difficult and indeed impossible to understand how such small creatures could obtain the momentum necessary to project them a distance of 200 or more yards, and that sometimes at an elevation of 20 feet above the water.

In birds which fly indiscriminately above and beneath the water the wing is generally provided with stiffer feathers than usual, and reduced to a minimum as regards size. In subaqueous flight the wings may act by themselves, as in the guillemots, or in conjunction with the feet, as in the grebes; but in either case it is the back or convex surface of the wing which gives the effective stroke, the wing in such birds as the great auk, which are incapable of flight, being for this purpose twisted completely round, in order that its concave surface which takes a better hold of the water may be directed backwards.

The wing therefore operates very differently in and out of the water.

In the water it acts as an auxiliary of the foot, and both strike backwards and downwards.

In the air, on the contrary, it strikes *downwards and forwards*, and this is a point deserving of attention as showing that the oblique surfaces presented by animals to the water and air are made to act in opposite directions. This is owing to the greater density of the water as compared with the air; the former supporting or nearly supporting the animal acting upon it; the latter permitting the animal to fall through it in a downward direction.

But to come to the subject more particularly in hand, *viz.*:—

Flight in its relation to Aeronautics.—The atmosphere, because of its great tenuity, mobility, and comparative imponderability, presents little resistance to bodies passing through it at low velocity. If, however, the speed be greatly increased, the action of even an ordinary cane is sufficient to elicit a recoil.

This comes of the action and reaction of matter, the resistance experienced varying according to the density of the atmosphere and the shape, extent, and velocity of the body acting upon it. While, therefore, almost no impediment is offered to the progress of an animal in motion, it is often exceedingly difficult to compress the air with sufficient rapidity and energy to convert it into a suitable fulcrum for securing the onward impetus. This arises from the fact that bodies moving in this medium experience the minimum of resistance and occasion the maximum of displacement. Another and very obvious difficulty is traceable to the great disparity in the weight of air as compared with any known solid (this in the case of water being nearly as 1000 to 1), and the consequent want of buoying or sustaining power which that disparity necessitates. To meet these peculiarities the insect and bird are furnished with extensive surfaces in the shape of pinions or wings, which they can apply with singular velocity and power at various angles, or by alternate slow and sudden movements, to obtain the necessary degree of resistance and non-resistance. Their bodies, moreover, are constructed on strictly mechanical principles: lightness, strength, and durability of frame; and power, rapidity and precision of action being indispensable. The cylindrical method of construction is consequently carried to an extreme; the bodies and legs of insects displaying numerous unoccupied spaces, while the muscles and solid parts are tunnelled in every direction by innumerable air-tubes which communicate with the surrounding medium by a series of apertures termed spiracles.

A somewhat similar disposition of parts is met with in birds, these being in many cases furnished not only with hollow bones, but also (especially the aquatic ones) with a liberal supply of air-sacs. They are also provided with a dense covering of feathers or down, which adds greatly to their bulk without materially increasing their weight. The air-sacs are well seen in the swan, goose, and duck; and I have in several instances carefully examined them with a view to determining their extent and function. They appear to me to be connected with the function of respiration, a view advocated by Hunter in 1774, and within the last year or so by Drosier, of Cambridge. That they have nothing whatever to do with flight is proved by the fact that some excellent flyers, take the bats *e.g.*, are destitute of them, while the wingless running birds, such as the ostrich and apteryx, which are incapable of flight, are provided with them. The same may be said of the hollow bones: some really admirable flyers, as the swallows, martins, and snipes, having their bones filled with medullary substance, while the bones of the running wingless birds alluded to are filled with air. Furthermore, and finally, a living bird weighing 10lbs. weighs the same when dead minus a very few grains; and all know what effect a few grains of heated air would have in raising a weight of 10lbs. from the ground.

When we have said that cylinders and hollow chambers increase the area of the insect and bird, and that an insect and bird so constructed is stronger, weight for weight, than one composed of solid matter, we may dismiss the subject, flight being, as I shall endeavour to show by-and-by, not so much one of weight as of power properly directed, *i.e.* power directed on strictly mechanical principles. Those who subscribe to the heated-air theory are of opinion that the air contained in the cavities of insects and birds is so much lighter than the surrounding atmosphere, that it must of necessity contribute materially to flight, but the quantity of air imprisoned, is to begin with, so infinitesimally small and the difference in weight which it experiences by increase of temperature so inappreciable, that it ought not to be taken into account by any one endeavouring to solve the difficult and important problem of flight. The Montgolfier or fire baloons were constructed on the heated-air principle, but as these have no analogue in nature and are apparently incapable of improvement, they need not detain us at this stage of the inquiry. The area of the insect and bird when the wings are fully expanded is, with the single exception of the bats, greater than that of any other class of animals, their weight being proportionably less. It ought, however, never to be forgotten that even the lightest insect or bird is immeasurably heavier than the air, and that there is no fixed relation between the weight of body and the expanse of wing in either class. We have thus light-bodied and large-winged insects and birds, as the butterfly, heron, and albatross; and others, whose bodies are comparatively heavy, while their wings are insignificantly small, as in the sphinx-moth and stag-beetle among insects, and the grebe, quail, and partridge among birds. Those apparent inconsistencies are readily explained by the greater muscular development of the heavy-bodied short-winged insects and birds, and the increased power and rapidity with which the wing is made to oscillate. This is of the utmost importance in the science of aerostation, as showing that flight may be attained by a heavy, powerful animal with comparatively small wings, as well as by a lighter one with enormously enlarged wings. While, therefore, there is apparently no correspondence between the area of the wing and the animal to be raised, there is an unvarying relation as to the weight and number of oscillations, so that the problem of flight seems to resolve itself into one of weight, power, velocity, and small surfaces; *versus* buoyancy, debility, diminished speed, and extensive surfaces: weight in either case being a *sine qua non.*

In order to utilize the air as a means of transit, the body in motion, whether it moves in virtue of the life it possesses, or because of a force superadded, must be heavier than it. If it were otherwise, if it were rescued from the operation of gravity on the one hand, and bereft of independent movement on the other, it must float about uncontrolled and uncontrollable, as happens in the ordinary gas balloon. The difference between an insect or bird and a balloon here insisted upon was, I have learned since writing the above, likewise pointed out by His Grace the Duke of Argyll, in his very able and eloquent article in 'Good Words,' entitled "The Reign of Law"* —an article whose merits cannot be too widely acknowledged or too universally known. The wings of insects and birds are, as a rule, more or less triangular in shape, the base of the triangle being directed towards the body, the sides anteriorly and posteriorly. They are also conical on sections from within outwards and from before backwards, this shape converting the pinion into a delicately-graduated instrument, balanced with the utmost nicety to satisfy the requirements of the muscular system on the one hand, and the resistance and resiliency of the air on the other. While all wings are graduated as explained, innumerable varieties occur as to their general contour, some being

* 'Good Words' for February, 1865. This article I am glad to find has been reprinted in a separate form with numerous illustrations, and should be read by all interested in the subject of aeronautics.—J. B. P.

falcated or scythe-like, others oblong, others rounded or circular, some lanciolate, and some linear.

Wing of Insect.—The wings of insects may consist either of one or two pairs; the anterior or upper pair, when two are present, being in some instances greatly modified and presenting a corneous condition. When so modified they cover the under-wings when the insect is reposing, and have from this circumstance been named elytra from the Greek ἔλυτρον, a sheath. The elytra or wing cases as they are sometimes called, are dense, rigid, and opaque in the beetles; solid in one part and membraneous in another in the cockroaches; more or less membraneous throughout in the grasshoppers; and completely membraneous in the dragon-flies. The superior or upper wings are indirectly connected with flight in the beetles, cockroaches, and grasshoppers, and actively engaged in this function in the dragon-flies and butterflies. The true wings, and by this I mean the membraneous ones, present different degrees of opacity; those of the moths and butterflies being non-transparent; those of the dragon-flies, bees, and common flies presenting a delicate, filmy, gossamer-like appearance. They have, however, this feature in common, and it is fundamental; both pairs are composed of a duplicature of integument, or investing membrane, and are strengthened in various directions by a system of hollow, horny tubes, known to entomologists as the neuræ or nervures. These nervures taper towards the extremity of the wing, and are strongest towards its root and anterior margin, where they supply the place of the arm in bats and birds.

The neuræ are arranged at the axis of the wing after the manner of a fan or spiral stair; the anterior one occupying a higher position than that farther back, and so of the others. As this arrangement extends also to the margins, the wings are more or less twisted upon themselves, and present a certain degree of convexity on their superior or upper surface, and a corresponding concavity on their inferior or under surface; their free edges supplying these fine curves which act with such efficacy upon the air in obtaining the maximum of resistance and the minimum of displacement. As illustrative examples of the form of wing alluded to, that of the beetle, bee, and fly may be cited: the pinion in those insects acting as hĭlicēs, or twisted levers and elevating weights, much greater than the area of the wing would seem to warrant. The insects adverted to fly, as a rule, with great accuracy and speed, and frequently in a straight line.

From the foregoing account it is evident that the wings of insects vary as regards their number, size, and shape. They also differ as regards their surfaces, margins, venation, degree of consistence and position, so that it might naturally be asked, Do the several orders of wings act according to a common principle, or does each wing act according to a principle of its own? There can, I think, be but one answer to this question. All wings obtain their leverage by presenting oblique surfaces to the air, the degree of obliquity gradually increasing in a direction from behind, forwards and downwards, during extension when the sudden or effective stroke is being given, and gradually decreasing in an opposite direction during flexion, or when the wing is being more slowly recovered preparatory to making a second stroke. The effective stroke in insects, and this holds true also of birds, is therefore delivered *downwards and forwards*, and not, as the majority of writers believe, vertically, or even slightly backwards. This arises from the curious circumstance that insects and birds when flying actually fall through the medium which elevates them, their course being indicated by the resultant of two forces, *viz.*: that of gravity, pulling vertically downwards, and that of the wing, acting at a given angle in an upward direction. The wing of the bird acts after the manner of a boy's kite, the only difference being that the kite is PULLED FORWARDS upon the wind by the string and the hand, whereas in the bird the wing is PUSHED FORWARDS on the wind by the weight of the body and the life residing in the pinion itself. The angle at which the wing acts most efficaciously as an elevator, as proved by an examination of the pinion of the living insect, bat and bird, when fully extended and ready to give the effective stroke, is an angle of 45° with the horizon. As, however, this angle could not be uniformly maintained without a rotatory motion which would wrench the wings from their fixings, a compromise is adopted, the wing being made to rotate on its axis to the extent of a quarter of a turn in one direction during extension, and the same amount in an opposite direction during flexion. That the wing rotates upon its axis as explained may be readily ascertained by watching the movement in the larger domestic fly. If the insect be contemplated either from above or beneath, the blur presented by the rapidly oscillating wing will be found to be concave, the depressed portion representing the wing when its plane of least resistance is parallel with the plane of progression. Of this I have had the most convincing proof, particularly in semi-torpid insects where the wing was plied with less vigour than usual. To confer on the wing the multiplicity of movement which it requires, it is supplied with a double hinge or compound joint which enables it to move not only in an upward, downward, forward, and backward direction, but also at various intermediate degrees of obliquity. An insect furnished with wings thus hinged may, as far as steadiness of body is concerned, be not inaptly compared to a compass set upon gimbals, where the universality of motion in one direction ensures comparative fixedness in another.

Many instances might be quoted of the marvellous powers of flight residing in insects as a class. The male of the silkworm moth (Attacus Paphia) is stated to travel more than 100 miles a day;* and an anonymous writer in Nicholson Journal calculates that the common house-fly (Musca domesticus) in ordinary flight makes 600 strokes per second, and advances 25 feet; but that the rate of speed, if the insect be alarmed, may be increased six or seven fold, so that under certain circumstances it can outstrip the fleetest racehorse. Leeuwenhock

* Linn. Trans. vii. 40.

relates a most exciting chase which he once beheld in a menagerie about 100 feet long, between a swallow and a dragon-fly (mordella). The insect flew with such incredible speed and wheeled with such address, that the swallow, notwithstanding its utmost efforts, completely failed to overtake it. *

Wing of Bird.—There are few things in nature more admirably constructed and where design can be more readily traced than in the wing of the bird. Its great strength and extreme lightness, the manner in which it closes up or folds during flexion, and opens out or expands during extension, as well as the method according to which the feathers are strung together, and slate each other in divers directions to produce at one time a solid resisting surface, and at another an interrupted and comparatively non-resisting one, present a degree of fitness to which the mind must necessarily revert with pleasure. The wing of the bird, like that of the insect, is concavo-convex, and more or less twisted upon itself when extended, so that the upper or thick margin of the pinion presents a different degree of curvature to that of the nether or thin margin: the curves of the two margins in some instances even intersecting each other. This twisting is in a great measure owing to the manner in which the bones of the wing are twisted upon themselves, and the spiral nature of their articular surfaces, the long axes of the joints always intersecting each other at right angles. As a result of this disposition of the articular surfaces the wing may be shot out or extended, and retracted or flexed in nearly the same plane, the bones composing the wing rotating on their axes during either movement. This secondary action, or the revolving of the component bones upon their own axes, is of the greatest importance in the movements of the wings, as it communicates to the hand and forearm, and consequently to the primary and secondary feathers which they bear the precise angles necessary for flight. It in fact ensures that the wing, and the curtain or fringe of the wing which the primary and secondary feathers form, shall be screwed into and down upon the wind in extension, and unscrewed or withdrawn from the wind during flexion. The wing of the bird may therefore be compared to a huge gimlet or auger, the axis of the gimlet representing the bones of the wing, the flanges or spiral thread of the gimlet the primary and secondary feathers. As the degree of rotation made by the bones of the forearm and hand during extension amounts as nearly as may be to a quarter of a turn of a spiral, it follows that in flexion the wing presents a knifelike edge to the wind; whereas in extension the curtain of the wing is rotated in a downward direction until its anterior or concave surface makes an angle of 45° with the horizon. From this description it will be evident that by the mere rotation of the bones of the forearm and hand the maximum and minimum of resistance is secured much in the same

* The hobby falcon which abounds in Bulgaria is equal to this task—the dargon-fly forming a principal constituent of its food.

way that this object is attained by the alternate dipping and feathering of an oar.

In the majority of quick-flying birds—at all events in such as do not glide or skim—considerable advantage is gained by the primary and secondary feathers being thrown out of position during flexion, this arrangement preventing retardation, by diminishing the amount of air displaced. This slating or overlapping and unslating action of the feathers during extension and flexion is, however, one of the peculiarities or refinements, and not necessarily an essential in flight, as this function can be efficiently performed by the insect and bat where no feathers are present, and where consequently no opening or closing of them can possibly occur. The wing of the bird may be said to act in three different ways:—1st, During extension, when it gradually makes an angle of 45° with the horizon; 2nd, During the downward stroke, when it maintains the angle of 45° with the horizon, and makes a variable angle with the body; and 3rd, During flexion, when it acts at a gradually decreasing angle in virtue of its being carried against the wind by the body of the bird which is in motion; it being a matter of indifference whether the wing acts on the air or the air on the wing, so long as the body bearing the latter is under weigh; and this is perhaps the chief reason why the albatross, which is a very heavy bird,* can sail about for such incredible periods without apparently moving the wings at all. Captain Hutton thus graphically describes the sailing of this magnificent bird:—"The flight of the albatross is truly majestic, as with outstretched motionless wings he sails over the surface of the sea, now rising high in air; now, with a bold sweep and wings *inclined at an angle* with the horizon, descending until the tip of the lower one all but touches the crest of the waves as he skims over them." †

> "Tranquil its spirit seemed, and floated slow,
> Even in its very motion there was rest."

As an antithesis to the apparently lifeless wings of the albatross, the ceaseless activity of those of the humming bird might be adduced. "In those delicate and exquisitely beautiful birds, the wings, according to Mr. Gould, move so rapidly when the bird is poised before an object that it is impossible for the eye to follow each stroke, and a hazy circle of indistinctness on each side of the bird is all that is perceptible."

The various movements involved in ascending, descending, wheeling, gliding, and progressing horizontally are all the result of muscular power, properly directed and acting upon appropriate surfaces—that apparent buoyancy in birds, which we so highly esteem, arising not

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* The average weight of the albatross, as given by Gould, is 17lbs. 'Ibis,' 2nd series, vol. i. 1865, p. 295.

The Pelicanus onocrotalius weighs 25lbs. Roget's 'Bird's Jour.' vol. i. p. 490.

† On some of the birds inhabiting the Southern Ocean, by Captain W. F. Hutton. 'Ibis,' 2nd series, vol. i. 1865, p. 282.

from superior lightness but from their possessing that degree of weight which enables them to subjugate the air; weight and independent motion being the two things indispensable in successful aerial progression. The weight in insects and birds is in great measure owing to their greatly-developed muscular system—this being in that delicate state of tonacity which enables them to act through its instrumentality with marvellous dexterity and power, and to expend or reserve their energies, which they can do with the utmost exactitude in their lengthened and laborious flights. The elastic structures which receive or draw back the wing in the insect and bird during flexion are of the utmost consequence in the movements of the wings; these by their mere contraction enabling the muscles of the wing to rest nearly half the time they are in action. In this we have a probable explanation of the extraordinary power of endurance displayed by insects and birds on the wing.

The foregoing remarks on the wings of insects and birds lead me to speak of the inclined plane as applied to the air, but before doing so, it will be advisable to allude briefly to the balloon.

Balloon.—This, as my audience is aware, is constructed on the obvious principle that a machine lighter than the air must necessarily rise through it. The Montgolfier Brothers invented such a machine in 1782. Their balloon consisted of a paper-globe or cylinder, the motor power being superheated air supplied by the burning of vine twigs under it. The Montgolfier or fire balloons, as they were called, were superseded by the hydrogen-gas balloon of MM. Charles and Robert, this being, in turn, supplanted by the ordinary gas balloon of Mr. Green. Since the introduction of coal gas in the place of hydrogen gas no radical improvement has been effected; all attempts at guiding balloons having signally failed. This arises from the vast extent of surface which they necessarily present, rendering them a fair conquest to every breeze that blows, and because the power which animates them is a mere lifting power which, in the absence of wind, must act in a vertical line, all other motion being extraneous and foreign to it. It consequently rises through the air in opposition to the law of gravity, very much as a dead bird would fall in a downward direction in accordance with it. Having no hold upon the air, this cannot be employed as a fulcrum for regulating its movements, and hence the cardinal difficulty in ballooning as an art.

Any one attempting to control the movements of a balloon is very much in the position of a boatman who endeavours to steer his craft, which is drifting with the current, by pushing against the stern.

If ever the balloon is to be utilized as a means of transit, this will probably be achieved by converting part of its lifting power into a horizontal propelling power, which possibly could be done by affixing a horizontal screw, like a small windmill, to the car; this apparatus receiving its motion by being forced against the air from beneath during its ascent (the air playing upon it from above), and communicating its movements to a similar and smaller screw placed vertically or at right angles, which could be made to revolve with great celerity as a driving screw. To prevent rotation in the balloon itself, it might to be armed with plates of some light material placed at right angles to the plane of rotation. The great expense, however, involved in the construction and filling of the balloon will always operate against its being used otherwise than as a luxury; while the enormous expanse and delicacy of the material employed, as well as the change in volume of the contained gas arising from increase or decrease of temperature, cannot fail to prove troublesome, not to say dangerous.

Finding that no marked improvement has been made in the balloon since its introduction in 1782, we naturally turn our attention to some other method of traversing the air; and here I would add my independent testimony in favour of the helice or screw, not only as a lifting power, but also as a propelling power. When I commenced my inquiries into the structure and uses of wings, I was early struck with the curious manner in which they are twisted upon themselves, and how they are rotated on and off the wind during flexion and extension, after the manner of screws; and without knowing (for the subject of artificial flight is not much in my way) that the helice had been proposed as a means for raising inanimate bodies, I had actually constructed a double screw, with a view to testing its efficacy in this respect.* I have therefore unwittingly laid anatomy and physiology under contribution in support of what I find is not a new doctrine.† I was impelled in this direction by detecting the principle in nature, and from knowing that a body to rise and progress in the air need not necessarily be lighter than it; in fact, that the balloon is constructed on a principle diametrically opposed to that on which the bat, insect, and bird is constructed, and is from this circumstance open to serious, and in some respects, insuperable objections.

The efficacy of the screw in water is well known, and the action of the child's toy, usually called the spiralifer, will illustrate its utility as applied to the air. This toy, for toy it has hitherto been, consists of two inclined planes, produced by simply twisting the enveloping wires in opposite directions. It therefore represents the most primitive form of screw. This apparatus, simple as it may appear, curiously enough furnishes the mechanical appliance by which a body may be elevated, or elevated and carried in a horizontal direction at one and the same time. By applying the necessary power the spiralifer can be made to act vertically or horizontally, or at any intermediate angle, so that we have in it an easily regulated and perfect driving power. The position taken up by the advocates of the screw is the reverse of that occupied by the advocates for the balloon,

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* This screw had four fans or blades, two of which revolved from left to right; the remaining two from right to left. This I found to be necessary to prevent rotation in the driving apparatus, which consisted of a steel spring and clockwork.

† Paucton the engineer, predicted the future importance of the screw in aerial navigation, as early as 1768.

so that the aeronaut promises at no distant day to be fairly impaled on the horns of a dilemma, by having on the one hand, a motor power which (because of the space occupied by it) no human ingenuity can direct; and on the other a thoroughly manageable and docile elevating and driving apparatus, minus an adequate motor power. The problem of flight will probably be solved by one employing a certain proportion of gas to assist him in overcoming the inertia of his machine while he uses the screw as a propeller and partial elevator. Of the two systems propounded, if they be judged separately, I incline to that which proposes to employ the screw both in elevating and propelling, and this for two reasons: 1st, Because the screw or a modification of it is the instrument by which, as I have shown, the insect, bat, and bird rises and progresses; and 2nd, Because a certain degree of weight is necessary to overcome the air and make it useful for the purposes of aerostation.

That the principle of the helice as applied to the air is correct, is proved by the very remarkable experiments of MM. Pontin d'Amécourt and De la Landelle, both of whom have constructed within the last three years helicopteric models, which not only rise by themselves into the air, but also carry graduated weights.* The difficulties therefore attending aerial locomotion by means of the screw are already partially surmounted.

The advantages which will accrue from the employment of the screw in aerostation may be briefly stated.

It occupies little space, is strong without being heavy, and is prodigiously powerful.

It rigidly economizes the motor power by keeping the inclined planes of which it is composed closely applied to the air throughout its entire revolution.

The speed of the screw can be increased at pleasure—increased velocity, as I have shown in the insect and bird, conferring enormously increased propelling and lifting power.

By a judicious combination of horizontal, vertical, and oblique screws, almost any degree of speed may be attained, and any course, whether upwards, downwards, or forwards, pursued.

A machine elevated and propelled by screws will be necessarily a compact machine—a machine which will navigate the air as a master; its weight and the small surface occupied by it rendering it superior even to moderately high winds.

The nearer such machine is kept to the earth and the greater the density of the atmosphere, the greater will be its facility and power—the inconveniences arising from temperature and excessively rarefied air being thus avoided.

The aerial screw machine should be constructed whenever practicable of hollow cylinders fixed into a floor, composed of one or more

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* Extract from a paper, by Mons. Nadir, 1863, quoted in 'Astra Castra.' By Hatton Turner, London, 1865, p. 340.

flattened cylindroid chambers filled with hydrogen or other gas to diminish weight. The flattened cylinders, if laid horizontally or inclined in a slightly upward direction, would act mechanically as sustainers and gliders, as do the wings in sailing and gliding birds. It is just possible that the motor power required for the helicopteric flying-machine may be derived from compressed atmosphere, the air being compressed by the aid of an engine on *terra firma*, and stowed away in the cylinders comprising the floor or other portions of the machine before starting.

When and where such a machine will be successfully launched no one can of course predict. The subject of artificial flight, however, has been so frequently discussed of late years, and has excited so much interest in America, France, and other portions of the Old and New World, that it must obviously receive a settlement in one direction or other at no distant date. Even Britain, involved as she is in business and politics, and caring little about science which is not directly remunerative, has made a move in this direction, and we have now the "Aeronautical Society of Great Britain," presided over by His Grace the Duke of Argyll, himself a Goliath in aeronautical matters. It were much to be desired that those who can afford the time or the means requisite for conducting experiments on a scale commensurate with the importance of the subject would lend their aid to this great public movement.

Homo Volans.—Whether the genus homo will ever be able, by his unaided exertions, to leave the scene of his joys and sorrows for the fields etherean, time only can determine. Borelli, a great anatomical authority,* made elaborate calculations to prove the absurdity of such an attempt. His calculations, however, will not deter the more sanguine and speculative portions of mankind from renewing their exertions in this direction as opportunity permits, and I may state, for their guidance in the matter, that if man ever flies it will not be by employing his arms simply, but by concentrating the energies of his entire muscular system—by transferring in fact the movements of his arms and legs to a central axis or shaft, surmounted by one or more horizontal and vertical screws of appropriate size and shape; these being made to revolve with a velocity to be determined by experiment. The value of this hypothesis could be readily tested, and at a trifling expense, by a machine constructed after the manner of a velocipede, which need not be of a very complicated character.

In order to construct a successful flying machine, it is not necessary to imitate the filmy wing of the insect, the silken pinion of the bat, or the complicated and highly differentialed wing of the bird, where every feather may be said to have a peculiar function assigned to it; neither is it necessary to reproduce the intricacy of that machinery by which the pinion in the bat, insect, and bird is moved: all that is required is to distinguish the form and extent of the surfaces

* 'De Motu Animal.'

and the manner of their application, and this has, in a great measure, been already done. When Vivian and Trevithick constructed the locomotive, and Symington and Bell the steamboat, they did not seek to reproduce a quadruped or a fish ; they simply aimed at producing motion adapted to the land and water in accordance with natural laws, and in the presence of living models. Their success is to be measured by an involved labyrinth of railroad which extends to every part of the civilized world, and by navies whose vessels are despatched without the slightest trepidation to navigate the most boisterous seas at the most inclement seasons. The aeronaut has the same task before him in a different direction, and in attempting to produce a flying machine he is not necessarily attempting an impossible thing. The countless swarms of flying things testify as to the practicability of the scheme, and nature at once supplies him with models and materials. If artificial flight were not attainable, the insects and birds would afford the only examples of animals whose movements could not be reproduced. The outgoings and incomings of the quadruped and fish are, however, already successfully imitated, and the fowls of the air, though clamorous and shy, are not necessarily beyond our reach. Much has been said and done in clearing the forest and fertilizing the prairie, can nothing be done in reclaiming the boundless regions of the air?

[J. B. P.]