Two organisms may also act in antagonism to one another. Mr. Brooks's experiments on various species of *Stereum* show that oak wood attacked by *S. hirsutum* is not a suitable habitat for the more harmful *S. purpureum*. Fawcett and Lee[6] could not obtain any effect on the walnut tree by inoculating it with two parasitic fungi, each of proved pathogenicity. Millard and Taylor[7] also found that the organism causing common scab of potatoes lives in antagonism with a harmless species. The latter can be stimulated by the addition of organic matter to the soil, thus controlling the disease. Weindling[8] found that *Trichoderma lignorum*, a saprophytic fungus, produces a substance which is toxic to the hyphæ of *Rhizoctonia solani*, and, indeed, the depredations of the latter can be curtailed if spores of *T. lignorum* are added to the soil. The old saying "Set a thief to catch a thief" seems to be justified even in the realm of plant pathology.

Many disorders of plants appear for which no definite causal agent can be demonstrated. Certain crops, for example, do not make good growth if the element boron is absent from the soil. Heart-rot of sugar beet and mangolds seems to be due to such lack. Manganese deficiency is responsible for grey leaf or grey-speck of oats, whilst insufficient sulphur produces a serious disease of tea bushes in Nyasaland[9]. Several diseases of apples during storage are due to inordinately large amounts of carbon dioxide in the atmosphere. Brown heart is such a disease which can be overcome entirely by proper ventilation[10]. Injury by frost can also produce symptoms which are similar to those caused by some fungi. Canker of the larch tree, for example, may be caused either by frost, or by the depredations of *Dasyscypha*[11], both of which, in all probability, kill groups of active cambium cells.

Many of the researches outlined in Mr. Brooks's address have added to general botanical knowledge. It is often necessary for the pathologist to study a new phase of plant physiology, and alternatively, the physiologist can supply knowledge which is useful to the pathologist. The address was pre-eminently what we have come to desire of a sectional president—a point of view, emanating from his own specialist knowledge, and linking up with other branches comprised within his Section ; the orientation of scattered facts into one harmonious whole.

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Speed*

By Prof. B. Melvill Jones

THE factors which have limited speed in the past can be grouped under two main heads, which may be roughly described by the words *Track* and *Power*. To move rapidly over the ground a smooth track is necessary in order to prevent the vehicle from bumping itself to pieces and from overturning, while power is required to overcome the internal friction of the mechanism and the head resistance which must always oppose motion, until we can arrange to do our travelling entirely outside the earth's atmosphere. These two factors, track and power, have alternately imposed limits on the speed of travel, one coming into operation whenever the other was temporarily removed.

The power to fly through the air at a height sufficient to be clear of the irregular air flow near the ground has at last disposed of the track problem as a factor limiting speed. For although the aeroplane has to lay its own track, in the sense that it has to expend power in doing something to the air in order to keep itself from falling, that power becomes continually less the greater the speed of flight and, of itself, is incapable of placing any limit on speed.

In the early days of flying, we were unable to separate the power essentially required for support—for track laying as we may describe it—from the power required merely to drag the aeroplane through the air. That this can now be done is due to the work of Prof. L. Prandtl, which was itself founded on some earlier work of that amazing mechanical genius, Dr. F. W. Lanchester. Looking back from our present point of view, Lanchester's insight into this very difficult problem seems almost miraculous, but he did not put his ideas into a form which appealed to the conventional man of science, and it was not until

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* From a Friday evening discourse delivered before the Royal Institution on March 22.

they had been developed and given greater precision by Prandtl that they received any wide recognition.

The Lanchester-Prandtl calculations, as they are now called, may become very complicated, but the ideas behind them are not difficult to grasp. Everyone is familiar with the idea that when a body is projected suddenly in any direction the apparatus which does the projecting experiences a recoil. The rocket, for example, obtains the lifting force which sends it up by generating gas within itself and continually projecting the gas downwards, so that there is a continuous recoil which drives it upwards. The aeroplane obtains the lift which supports it in a manner similar to the rocket, except that it does not itself generate the gas which it projects downwards, but uses the air through which it is passing. The wings, driven through the air in an attitude slightly inclined to the direction in which they are moving, force down the air directly below them and suck down the air immediately above them, and in so doing experience the continuous recoil which keeps the aeroplane from falling. The air, however, forms a continuous medium around the aeroplane, and a downward current in one part implies an upward current in other parts, with outward cross currents below to relieve the congestion there, and inward cross currents above to fill the partial vacuum which would otherwise be formed.

These air movements can be calculated and, at the moment when the aeroplane is passing, they take the form shown in Fig. 1, where the aeroplane is seen from behind passing through the vertical plane represented by the paper. The curved lines show the directions of flow; the distances between them being inversely proportional to the speed of flow. As soon as the aeroplane has passed, the flow pattern which is left behind begins to modify itself and ultimately takes the form shown in Fig. 2, which is simply the system of flow known as the *vortex pair*. These vortices, which are generally described as the *trailing vortices*, because they trail behind the aeroplane, remain in the air for several minutes after the aeroplane has passed, and are the cause of the bump which one feels on flying through the track of another aeroplane. It is by continually setting these air whirls, or vortices, into motion, that the aeroplane supports itself, and it is because these whirls have to be continually created that power must be expended to obtain support. In effect, therefore, the aeroplane has to use some of its available power to create its own track, which is left behind in the air after it has passed.

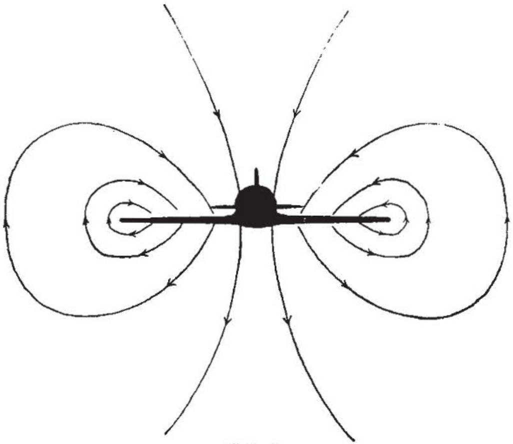

FIG. 1.

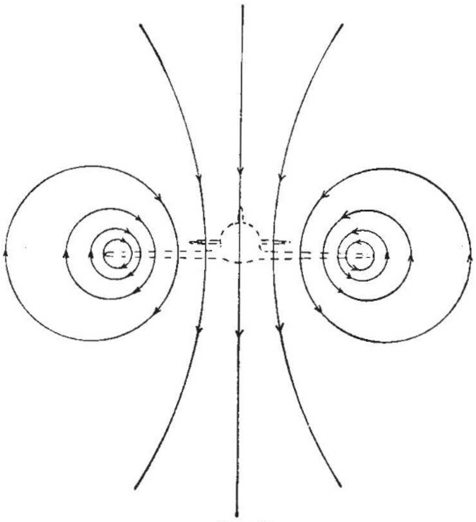

FIG. 2.

The Lanchester-Prandtl calculations enable the power expended merely in supporting an aeroplane to be calculated with considerable accuracy; they show, for example, that the power required for this purpose, for every thousand pounds of weight of a modern civil transport aeroplane, ranges from about eight horse-power at one hundred miles per hour, to four horse-power at two hundred miles per hour, and is still less at higher speeds. Since the power actually available in civil aircraft of the present day, after allowing for losses in the screw propulsion, is of the order 60–70 horse-power per thousand pounds weight, it is clear that, although the aeroplane must pay for the elimination of the track problem by the expenditure of extra power, the amount of this extra power and the way in which it varies with change of speed are such as to place no final limits upon speed.

Having reached this conclusion, we are free to turn our whole attention to the remaining factor which does, and probably always will, limit speed: the resistance which has to be overcome merely to drag the aeroplane through the air.

Anyone who has ridden a bicycle must know that the air can exert a very considerable resistance to the passage of a man through it, even when the speed is so low as 15–20 miles per hour. Since the power required to overcome this resistance increases about eight-fold every time the speed is doubled, it is at once apparent that very great powers may be required at high speeds. The following table shows approximately the power required to push a man in a sitting posture through the air near the ground at various speeds.

Miles per hour	*Horse-power*
10	1/25
20	1/3
50	5
100	40
200	320
300	1,100
400	2,600

Such figures make it clear that unless head resistance can be very considerably reduced below these figures, economical transport at high speeds is impossible. Everyone nowadays knows that this reduction can be made by what is usually called *streamlining*, and our next task therefore must be to consider why streamlining is so effective in reducing head resistance.

We have now to begin from the point of view of the mathematicians who, some fifty years or more ago, studied the basic problems of fluid motion. They observed that water and air are very slippery substances, and they conceived the idea of studying an ideal fluid which they imagined to be absolutely slippery. Almost at once they reached the astonishing conclusion that solids of any shape whatever would be expected to move through such a fluid—if it could exist—without any resistance whatever. Impressed by this paradox they, for the most part, gave up any attempt to apply their theory to practical purposes; but fortunately for us this did not in any way damp their enthusiasm for the subject itself, which they pursued, one must suppose, for the sheer love of the game, or perhaps with the idea of providing problems for university examinations. But whatever the impulse behind their work, Providence has, as usual, seen to it that their efforts were not wasted, for they laid the foundations of the science which has enabled us to seek for and obtain the very great reductions of resistance which are essential for high speed transport. For it so happens that when bodies are given the now familiar streamline shapes, the flow around them takes almost exactly the form imagined by the mathematicians for their ideal fluid, and the pressures exerted by the fluid on the surface of the body are so nearly the same as those given by the theory, that their net effect in resisting motion is, as the theory suggests, practically zero. Fig. 3 shows the theoretical flow and pressure distribution of the ideal fluid about a good streamline body; the real flow and pressure distribution for this body would be almost indistinguishable from these theoretical values.

Why then does a perfect streamline shape experience any resistance at all to motion ? It is because the air, unlike the ideally slippery fluid, cannot actually slip over the body, but must exert a very slight dragging force along its surface, and it is this dragging force, or *skin friction* as it is called, which alone offers any appreciable resistance to the passage through the air of the best streamline shapes. Here then is a curious situation, for while everyday experience makes it seem 'natural' for us to suppose that the air should strongly resist the rapid passage of bodies through it, the difficulty, when the matter is approached from the theoretical end, is to explain why the resistance of any body is greater than the exceedingly small force which can be applied by the mere rubbing of the air over its surface. The wide gulf between the two points of view is shown by the fact that at the speed of modern aerial transport, the resistance of a badly shaped body may be as much as fifty times greater than that of a good streamline body of the same frontal area.

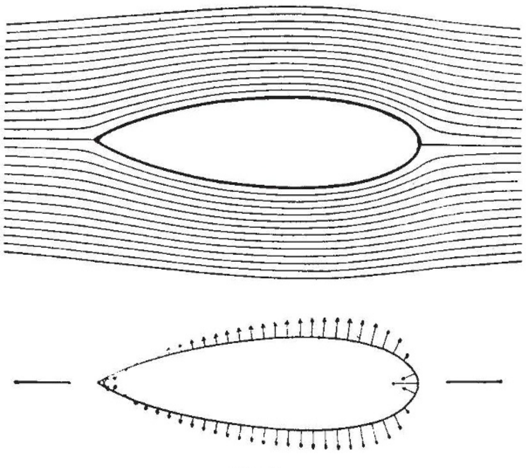

FIG. 3.

Now we have to find an explanation for the high resistances of unstreamlined bodies. This is due to a curious feature in the behaviour of the air flow, which would be impossible in the ideally slippery fluid; for the real air streams have the power of leaving a curved surface and forming pockets of what is called *dead air* behind the bodies. Within these pockets the pressure is low and so the bodies are, as it were, sucked backwards. On closing up behind these pockets the air stream becomes very turbulent and full of regular or irregular eddies which continually carry away the energy corresponding to that expended in moving the body against the high resistance.

(*To be continued.*)