civilized. Yet the physicist reduces all musical instruments to combinations of resonators with strings, membranes, bars, plates and horns. The mathematical theory of strings was given by Euler two hundred years ago, of bars and plates less than a hundred years, of resonators by Helmholtz and Rayleigh, and I have recently added a theory of horns which, while only approximate, works well in practice, and investigations are now being carried out by such methods on vowels and the violin.

ARTHUR GORDON WEBSTER

## SCIENCE AND PHILOSOPHY IN VIRGIL

RELIGIOUS superstition once borrowed such a large portion from the works of Virgil, though it was accomplished in a way as inexplicable as it was unwarranted, that we are apt, from the standpoint of science, to dismiss him altogether as a source from which to gather anything useful in the history of scientific thought. It is no wonder, however, that the ardent early fathers of the Christian church found in the fourth Ecologue an indication, pregnant with prophecy, conscious or unconscious on the part of the poet, of the coming of Christ and the regeneration of the world, a return to its golden age. Other interpretations have of course been made of the lines, but the ready credulity of a budding faith had every temptation to accede to the conviction that Virgil was a herald of the approaching light of the world. But the reputation Virgil had in the Middle Ages partook of that of a man of science. He was a wizard, the happy man who knew the causes of things,

> Felix qui potuit rerum cognoscere causas.[1]
> How blest the sage! whose soul can pierce each cause
> Of changeful Nature, and her wondrous laws.

As a matter of fact this was no boast of Virgil, it was only his sigh that he did not understand them all and it is difficult to see, in spite of Comparetti's monumental work,[2] what could have given the mind of the middle ages that respect for Virgil as a man of science, of which we find so many traces in the authors of the pre-Renaissance. For them he was not so much the necromancer of verse, recognized by a later and an earlier age, as a wizard of knowledge in natural science. The lines however which precede[3] the one above, so often quoted, give us a glimpse of the kind of things he had in mind when he longed for a knowledge of their causes.

> The muses [he declares] . . . will show me the paths of heaven and the stars, the various eclipses of the sun and the changes of the moon, whence comes the quaking in the earth, by what force the sea swells high on the rocky shores and again sinks back upon itself, why the winter sun rushes on to plunge beneath the ocean wave, what it is lengthens out the tedious nights, but if I could not draw nigh to these parts of Nature the cold blood would gather round my heart.

That is, as I take it, for Sotheby certainly goes astray here, if he could not imagine some rational explanation of these things he would stand terror stricken in the presence of God. That is the reason, it seems to me, he exclaims, "fortunate indeed is he who perceives the causes of things."

In Virgil, as in all ancient writers, we get a far franker acceptation than we do to-day, a much plainer indication of the all pervading pantheism in the fundamental beliefs of men. It is probably as widespread to-day, but it is hidden beneath a reticence which the mystic faith of Christ, quite in contrast to the ancient pagan tendencies, imposes on its communicants. Still it peeps out now and then, not in science alone where it has the support of physics, but in religious pedagogy with the maxim that God is everywhere. The haruspices and the augurs thought or, in Virgil's day, pretended to think that the birds bore the impress of the will of the gods on their in-

[1] Georgicon II. 490. I use Sotheby's translation here, but the classics are immortal because they have a message for each generation, otherwise they would have perished. Only from the text can the modern critic judge if the references from it are valid for the scientific thought of this generation. There can be no doubt Virgil is here referring to Lucretius whose De Rerum Natura was his model in youth.

[2] Virgilio Nel Medio Evo, per Domenico Comparetti, Fierenze, 1896.

[3] Me vero primum dulces ante omnia Musae,
quarum sacra fero ingenti percussus amore,
accipiant caelique vias et sidera monstrent,
defectus solis varios lunaeque labores;
unde tremor terris, qua vi maria alta tumescant
obicibus ruptis rursusque in se ipsa residant,
quid tantum Oceano properent se tinguere soles
hiberni, vel quae tardis mora noctibus obstet,
sin has ne possim naturae accedere partis
frigidus obstiterit circum praecordia sanguis:

But, most beloved, ye Muses! at whose fane
Tranced by deep zeal I consecrate my strain,
Me first accept! and to my search unfold
Heaven and her host in beautious order roll'd;
Th' eclipse that dims the golden orb of day,
And the moon labouring through her changeful way;
Whence rocks the earth, by what vast force the main
Now bursts its barriers, now subsides again;
Why wintry suns in ocean swiftly fade,
Or what delays night's slow-descending shade.
But if chill blood, long lingering in my vein,
From Nature's secret lore my search restrain,

ternal viscera and in their actions manifested an understanding of it in preparing for future events. Now Virgil disdained such supercheries, patching out the superstitions of the time when they were universal, for use at a time when they were employed only to sway the minds oppressed by ignorance and credulity. He concluded that it was the rarefaction and condensation of the atmosphere which agitated the bodies of twittering birds and bellowing cattle,

et laetae pecudes et ovantes gutture corvi.

It was the "Jupiter Uvidus" who rarefied the air and condensed it, so no reverence was lost. When the winds of heaven blew the ethereal disturbance was conveyed to the minds of men, the subtle pneuma gliding past their hearts, and governed the flights of the birds of the air[4] and the tossing heads of the beasts of the field. We are unable still to add much to this except our indifferent skepticism, but we should remember we have as yet hardly lifted a corner of the veil of the ignorance which prevails in modern science as to the atmospheric influences exerted on living beings. We know nothing of the changes in the psychical state by virtue of which the animal does this or that. We put them all down to heat and cold, "dense and rare" and Virgil did as much.

Virgil's pantheism was the pantheism of his day and that it filled the air all around him we can see in his youthful poem, the Culex. The whole theme is the feeling of the gifted boy that the poor gnat which he destroyed at a blow was a possessor like himself of a shred of the soul of the Infinite. It was the sting of the insect which was the interference of God and it saved the sleeping shepherd, in whose name Virgil sings, from the venom of a spotted snake. This philosophy Virgil found in his youth and it dwelt with him through life, but it in no way distinguished him from his contemporaries, however well it fitted in with the beliefs of Dante's time. It is seen in the work of his earlier manhood in the way he speaks in his bucolics[5] of the bees and the phenomena they exhibit as an evidence of the workings of the universal mind. I believe we call it instinct now, though perhaps there has been little left of that term in the recent overturn in biology. We find the mystic theory at the maturity of his marvelous powers in the Aeneid[6] where the hero, visiting his father in Hades, learns from him the nature of creation, how even in the beginning, Anchises says, "heaven and earth and the flowing fields of the sea and the blazing sun, the moon and the Titanian stars are animated by the spirit within them." Unless we keep before us this saturation of the ancient mind with this philosophy, far beyond the point of our own vague thoughts, we will find it difficult to understand how so many, indeed nearly all, clear minds of antiquity adopted vitalistic doctrines as a part of their science. Even Aristotle, deeply analytical as was his mind, saw no skulking, no begging the question in his use of the "entelechy."

However, as we have seen, even Virgil's poetic mind had a touch of practical materialism and he placed the density and the rarefaction of the air in between the cawing of crows and the divine mind. As it was these which explained for him the state of the weather and the fluttering of the birds, so it is the rarity and compactness of the soil which tells the farmer whether the field is adapted to grape growing or wheat culture. The same words—densa and rara—are used for the soil as for the air.[7] But there is something more to be learned from an examination of the soil than this and it is by a method curiously in accord with a part of the modern technique of soil analysis, rudimentary though it is. There is a touch of his wonderful art in its description which I will not attempt to give. A salt and bitter earth is bad for fruits and it is not helped by plowing. To make a test of the condition, put the bad soil carefully ground up into a basket or sieve and through it filter sweet water from the spring. As the drops of water emerge on the wicker work of the primitive filter their quality may be tested by the tongue. The acidity or the alkalinity of the soil is thus betrayed to one of the senses, that of taste, instead of by the visible reactions of the modern test tube. The richness, the "fatness of the soil," betrays itself to the sense of touch as it is exercised between the fingers when it is finely pulverized. Such beginnings then as were possible for scientific endeavor Virgil records and his theory of atmospheric pressure was singularly near the results obtained by the barometer as to the processes of nature which precede atmospheric disturbances more evident then than now to the unaided senses.

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[4] Georgicon I. 417–422.

[5] Georgicon IIII. 219–222.

[6] Aeneis VI. 724 seq.

[7] Georgicon II. 226–228.

## TRANSITION ZONES

THE thesis here presented is that the indefinite territory existing between two faunal areas should be considered primarily as a transition zone, not as a unit faunal area or sub-area.

A faunal area may be defined as an area characterized by certain animals and thus differentiated from other faunal areas characterized by other animals. The arctic, temperate and tropic zones are so characterized and may be treated as primary faunal