a mighty conqueror, would not have made that kind of attack.

Without attempting to condense further this already condensed and very readable little volume written by a distinguished inquirer, I will conclude by saying that it well deserves a place in any general library.

FRANCIS GALTON.

SATELLITE EVOLUTION.

Satellite Evolution. By James Nolan. Pp. 114. (Melbourne, &c.: George Robertson and Co., 1895.)

IN this book Mr. Nolan discusses the part played by tidal friction in the evolution of satellites. Although the subject is one of much scientific interest, his work is hardly likely to attract the attention it deserves, because the unmathematical reader will find the reasoning hard to follow, whilst the mathematician will be repelled by prolixity, due to the author's treatment of the problem by means of general reasoning.[1] The first fifty pages of the book appear to be virtually contained in the single equation which states the effect of tidal friction in increasing the mean distance of a satellite. It might perhaps be interesting to some to discuss the various elements of the problem in detail, but those who are able to comprehend an analytical formula are not very likely to have the patience to follow such a discussion.

I shall not accordingly follow Mr. Nolan in detail, but will pass at once to the conclusion to which he tends. On p. 9 he says:—

"Though Mr. Darwin made elaborate calculations to support his theory respecting the part played by tidal friction on the evolution of the earth and moon, he seems to have dismissed the Jovian and Saturnian systems with the conclusion that their satellites, unlike our moon, could not be traced much further in than the present distances of their respective planets; and that as the relation between the mass of the planet and satellite, or relation of rotational to orbital momentum is very different in the case of the earth and moon to that for other planets and satellites, their modes of evolution may have differed considerably. He seems to have gone something further into the possible effects of solar tidal friction on the planets revolving round the great central body, or at least has come to the correct conclusion that the efficiency of such tides would be too small to effect any appreciable change during the natural lifetime of a solar system."

He then proceeds to show that, if the earth and Jupiter rotate under the influence of tides subject to the same frictional resistance, the proportionate rate of increase of the moon's mean distance is much smaller than that of all of Jupiter's satellites, save one. In other words, four out of five of Jupiter's satellites would have their mean distances increased by, say, one per cent. in a much shorter time than would the moon. He then pursues the same train of reasoning with respect to Saturn and Mars.

It appears to me that Mr. Nolan is correct in these conclusions, and we are thus led to suppose that tidal friction may have played a much more important part in the evolution of satellites than I was disposed to allow it.[1] He points out (p. 70) that the satellites of Jupiter are probably much younger than the moon; "when the moon was younger, her relative rate of recession was faster, as now is the case for some satellites in other systems." He finally concludes (p. 78) that the majority of satellites in each system may be traced to a position corresponding with that of the rings of Saturn.

But before arriving at this result, the author has treated another problem, in which, in my opinion, his conclusion is incorrect. On p. 45, he considers the effects of tidal friction on such a ring as that of Saturn. He says:—

Tidal friction "could have no effect if the ring were perfectly even all round. When composed of individual bodies it could not be or remain so. Each individual would be unaffected by the tides of the others, and would recede at the same rate as if it were the only body in the ring. The moon recedes at exactly the same rate as she would were there no solar tides; and if there were a second moon there would be no interference with the recession of the first . . . Then if the bodies composing the rings are 'as the sand on the sea shore for multitude' tidal friction must still effect the usual progressive change, unless each individual body be small enough to be unaffected at the distance, whether composing a ring or not. This must have a dissolving effect on the ring, or tend to shape certain sections of it into so many bodies, which, having increased their mass at the expense of the ring, finally recede therefrom, either to circle round at a great distance or be precipitated into the planet increasing its rotation speed."

It would seem that the process here sketched is an essential part of Mr. Nolan's theory of the evolution of satellites, but I believe it to be founded on erroneous premises. He omits in fact to notice the necessary condition for neglecting the effects of the tides raised by one satellite on the mean distance of another; this is, that the periodic times of the two shall not be equal to one another. If the periodic times of two satellites are unequal, we need not invoke tidal friction to bring the two bodies near to one another. On the other hand, if four or eight satellites be equally spaced round a planet and revolve with the same periodic time, tidal friction would only influence their motions to a very small extent. I am therefore unable to follow Mr. Nolan in this part of his work.

Several other points in the early history of satellites are considered by Mr. Nolan, but I am unable to touch on them within the limits of a review.

Notwithstanding all that has been written by him and others, we are still far from a consistent theory of the formation of a satellite. In my own papers I have ventured to throw out suggestions (which have but too often been quoted as positive theories), and it still seems to me at least, that neither the present contribution of the author nor the theories of others are adequate.

This work touches on subjects of interest, and although it seems open to much criticism, I for my part welcome the extension given by Mr. Nolan to the part played by tidal friction in evolutionary astronomy.

G. H. DARWIN.

[1] The phraseology is somewhat lax, and it is not always easy to assure oneself of the correctness of the train of reasoning; but where the conclusion is correct, the reasoning probably is so also.

[1] The arguments by which I was led to an erroneous conclusion on this point, will be found in *Phil. Trans.*, part ii., 1881, p. 524.