

latitudes on both sides the Atlantic. It appears that an arctic fauna, specifically resembling that of the present seas, extended farther to the south than now. This opinion is derived partly from the known habitations of the corresponding living species, and partly from the abundance of certain genera of shells and the absence of others.* The date of the refrigeration thus inferred appears to coincide very nearly with the era of the dispersion of erratic blocks over Europe and North America, a phenomenon which will be ascribed in the sequel (ch. 16.), to the cold then prevailing in the northern hemisphere. The force, moreover, of the German critic's objection has been since in a great measure destroyed, by the larger and more profound knowledge acquired in the last few years of the ancient carboniferous flora, which has led the ablest botanists to adopt the opinion, that the climate of the coal period was remarkable for its warmth, moisture, equability, and freedom from cold, rather than the intensity of its *tropical heat*. We are therefore no longer entitled to assume that there has been a constant and gradual decline in the absolute amount of heat formerly contained in the atmosphere and waters of the ocean, such as it was conjectured might have emanated from the incandescent central nucleus of a new and nearly fluid planet, before the interior had lost, by radiation into surrounding space, a great part of its original high temperature.

Astronomical causes of fluctuations in climate.— Sir John Herschel has lately inquired, whether there are any astronomical causes which may offer a possible explanation of the difference between the actual climate of the earth's surface, and those which formerly appear to have prevailed. He has entered upon this subject, he says, "impressed with the magnificence of that view of geological revolutions, which regards them rather as regular and necessary effects of great and general causes, than as resulting from a series of convulsions and catastrophes, regulated by no laws, and reducible to no fixed principles." Geometers, he adds, have demonstrated the absolute invariability of the mean distance of the earth from the sun; whence it would at first seem to follow, that the mean annual supply of light and heat derived from that luminary would be alike invariable: but a closer consideration of the subject will show, that this would not be a legitimate conclusion; but that, on the contrary, the *mean* amount of solar radiation is dependent on the excentricity of the earth's orbit, and therefore liable to variation. †

Now the excentricity of the orbit, he continues, is actually diminishing, and has been so for ages beyond the records of history. In consequence, the ellipse is in a state of approach to a circle, and the

* See papers by Mr. Smith of Jordanhill, F.G.S., and the author, Proceedings Geol. Soc. No. 63., 1839, also that of Prof. E. Forbes, before cited, p. 88, note.

† The theorem is thus stated:—"The excentricity of the orbit varying, the total quantity of heat received by the earth from the sun in one revolution is

inversely proportional to the minor axis of the orbit. The major axis is invariable, and therefore, of course, the absolute length of the year: hence it follows that the mean annual average of heat will also be in the same inverse ratio of the minor axis."—Geol. Trans. second series, vol. iii. p. 295.