spots, and within Dr. Hunter's "minimum group." He further showed that the rainfall at Madras passed through an eleven years' cycle, corresponding with the cycle of sun-spots. That is to say, the rainfall reaches its minimum in the eleventh year, rises to its maximum about half-way through the cycle in the fifth year, and then declines again to its minimum in the eleventh year. The following condensed table shows the results of the six cycles for which records exist, from 1810 to 1876, the Madras register only having been kept, however, from 1813 :—

Eleven Years' Cycle of Sun-Spots and Rainfall at Madras for Six Cycles, from 1810 *to* 1876.

	Average rainfall in inches, registered at Madras. (1813 76)		Average relative number of sun-spots (Wolf). (1810-60.)
Eleventh series of years in the cycle of eleven years	37·03	...	10·9
First and second series of years in the cycle of eleven years...	42·07	...	10·0
Third and fourth series of years in the cycle of eleven years	49·12	...	39·8
Fifth and sixth series of years in the cycle of eleven years	54·64	...	73·4
Seventh and eighth series of years in the cycle of eleven years ...	52·36	...	53·7
Ninth and tenth series of years in the cycle of eleven years	49·02	...	33·5
Eleventh series of years in the cycle of eleven years	37·03	...	10·9

The general average of rainfall for sixty-four years, from 1813 to 1876, is 48·51 inches.

The average relative number of sunspots, calculated on the fifty-one years then available to Dr. Hunter, from 1810 to 1860, is 38·68.

This statement forms one of a series of eleven tables by which Dr. Hunter exhibited the coincidence of the two cycles. In my opinion, and I believe in the opinion of the other professional meteorologists in this country who have examined the evidence thus submitted, Dr. Hunter has established his conclusions as regards Madras, but he carefully abstains from hasty generalisations with reference to other parts of India. I may add, however, that from a careful examination of the rainfall at Bombay, it is evident that there are the clearest indications of a similar general coincidence, while evidence has recently been adduced of a cyclic character of the Calcutta rainfall, complementary to (although different from) the cycle at Madras. But, adopting Dr. Hunter's cautious estimate of the degree of certitude warranted by his examination (necessarily a partial one) of the Indian rainfall, I think that science may safely make the following replies to your challenge :—

1. That a period of deficient rainfall may be expected to recur in cycles of eleven years at Madras.

2. That the deficiency is of so serious a character that in five out of the seven of these cycles occurring within this century up to the present date, the deficiency has sufficed to cause a great famine in Madras.

3. That the duty imposed by the laws of Nature on the Indian Government is not to make a series of costly spasmodic and unsatisfactory efforts, but to deal with the water-supply in such a way as to meet a regularly recurring deficiency.

4. That the discovery of the cyclic character of the rainfall clearly points, as regards Madras, to the method to be adopted for this end. In the eleven-years' cycle there is a period, at the extremities, of greatly deficient water-supply—namely, in the eleventh, first, and second years of the cycle. There is also a period of excessive water-supply in the middle of the cycle—namely, in the fifth, sixth, seventh, and eighth years ; and half way between these two periods—that is to say, on each side of the maximum central period—there are years of intermediate but ample water-supply—namely, in the third and fourth years on the one side of the central maximum period, and in the ninth and tenth on the other side of it. The following table, taken from Dr. Hunter's paper, very clearly illustrates this :—

	Average rainfall in inches, registered at Madras. (1813-76.)		Average relative number of sun-spots (Wolf). (1810-60.)
Minimum group—eleventh, first, and second years	40·39	...	10·32
Intermediate group—third and fourth with tenth and ninth years	49·07	...	36·71
Maximum group—fifth, sixth, seventh, and eighth years ...	53·50	...	63·61

5. That the permanent remedy for famine in Madras is, therefore, to deal with the rainfall in its cyclic aspect, and to husband and equalise the water-supply, not merely of the individual year, but of the cycle.

It is beyond my province to offer any opinion upon the form of hydraulic engineering best adapted to secure this end. But I would point out that while some of our modern Indian canals are principally useful in husbanding and distributing the water-supply of the year, the old native system of great embanked lakes or reservoirs unconsciously hit the true solution of the difficulty by husbanding and equalising the water-supply of the cycle.

I need hardly say that we are only at the beginning of this inquiry. What science asks from the Indian Government is the means of prosecuting it, and foremost among such means is a small solar observatory, for which it is understood that the necessary instruments were sent out to India some years ago, although they have not yet been utilised for this purpose.

ALEXANDER BUCHAN, Secretary of the Scottish Meteorological Society.

THE IRON AND STEEL INSTITUTE

THIS Association, one of the most active in the kingdom, and which has already done so much to bring the discoveries of science to bear on the iron and steel industries, commences its annual autumn meeting at Newcastle, on Monday, as we have already intimated. As usual, while several important papers are down for reading, much of the time of the meeting, between September 17 and 21, will be devoted to visiting some of the many industrial establishments in and around Newcastle.

The president of the meeting will be Dr. C. W. Siemens, F.R.S., and we notice that in succession to the late Mr. Jones, Mr. James S. Jeans has been appointed general secretary. On the first day the usual formal business will be transacted, the real work of the session commencing on Tuesday, when the Mayor of Newcastle will receive the members in the lecture-room of the Literary and Philosophical Society at half-past 10 A.M., and during the forenoon a selection of papers will be read. After luncheon the remainder of the day will be devoted to visits to various establishments, including Consett Ironworks, the works of Stephenson and Co., R. and W. Hawthorn, Hawks, Crawshay, and Co., the Newcastle Chemical Works, and others. A number of collieries will also be open to the inspection of members, and should a sufficient number be found willing to join in an excursion to the Roman Wall, it is proposed to organise a party, on Tuesday afternoon, to visit that interesting object, near the residence of Mr. John Clayton, the well-known antiquarian, who has kindly promised to receive the members.

The forenoons of Wednesday and Thursday will also be devoted to the reading of papers, and the afternoons to visits and excursions. On Wednesday the New Swing Bridge, one of the largest of its kind in the world, will be opened, and afterwards two steamers will take the

members on excursions up and down the Tyne, the first steamer proceeding up the river as far as the New Cut, for the purpose of affording members an opportunity of witnessing the extensive dredging operations of the Tyne Improvement Commissioners, and thence sailing down again to the shipping spouts, the new Coble Dene Dock, and the piers, while the second steamer will take another party to some of the most important works down the river, as Leslie's and Mitchell's ship-building yards, Forster and Co.'s lead-works, the Jarrow chemical works, &c. On Wednesday evening a *conversazione* will be held in the Town Hall, Newcastle, when it is hoped that the telephone will be exhibited.

Doubtless one of the most interesting excursions will be that of Thursday afternoon, when a special train will convey the members to the Elswick Works (Sir W. G. Armstrong and Co.), thence proceeding to the Steel Works of Messrs. John Spencer and Sons, at Newburn. Friday will be entirely devoted to an excursion to Middlesbrough and the works on Tees-side. In the forenoon the new Browney Colliery Works and the Clarence Works of Messrs. Bell will be visited, and the Eston Steel Works and Blast Works of Bolckow, Vaughan and Co. After luncheon in the Royal Exchange, Middlesbrough, ten different works will be visited, including the Tees-side Iron Works, where the first Danks' rotary furnaces constructed in this country will be seen in full operation; the Ayresome Iron Works; the Tees Iron Works; the Tees-side Engine Works (Hopkins, Gilkes, and Co.); the Linthorpe Iron Works (Lloyd and Co.); the Newport Rolling Mills (Fox, Head, and Co.); the Ayrton Rolling Mills (Jones, Brothers, and Co.); the Middlesbrough Wire Works (Hill and Co.); the Newport Ironworks (B. Samuelson and Co.); the Middlesbrough Tube Works.

Among the papers to be read are the following: I. L. Bell, M.P., F.R.S.—Part II. of paper on the Separation of Carbon, Silicon, Sulphur, and Phosphorus in the Refining and Puddling Furnace and in the Bessemer Converter. Dr. Percy, F.R.S.—On some Scientific Facts connected with the Manufacture of Iron, &c. R. Howson.—On Mechanical Puddling. T. W. Plum, Old Park, Salop.—On Improvements in Blast Furnace Water-Cooled Tuyeres. A. L. Steavenson.—On the Manufacture of Coke in relation to the Iron Trade of the North of England. Mr. Greenwell.—On the Geological Features of the Great Northern Coal Field. Chas. Wood.—On Four Years' Improvements in the Utilisation of Slag. F. Giesbers.—On the Removal of Phosphorus from the Materials used in Smelting Pig Iron under M. Stein's Patent. A. Thomas.—On the Latest Improvements in Belgian Merchant Rolls. William Walker.—On a New Machine for Drilling Ironstone. M. Gautier, C.E.—Results of Experiments with Cannon manufactured from Steel without Blows.

When we state that in addition to what we have mentioned, an exhibition of various objects connected with the Iron and Steel Trades will be held in the Wood Memorial Hall, it will be seen that the members of the Institute have plenty of work before them, and that the meeting is likely to be one of great interest and practical importance.

OUR ASTRONOMICAL COLUMN

THE OUTER SATELLITE OF MARS.—As a guide to those who may be examining the immediate vicinity of Mars, with the view to detecting the exterior satellite, an ephemeris of its positions from September 8 to 18, for 8h. 30m. and 11h. om. each evening is subjoined. It will enable an opinion to be formed as to the chance of any object glimpsed within ninety seconds' distance from the centre of the planet, being the satellite or not. The elements employed in the calculation are the following:—

Passage of Ascending Node, 1877, Aug. 11·7495 Greenwich M.T.

Longitude of the node	82 48′
Inclination of orbit to ecliptic	25 24
Daily motion in orbit	285 26′928
Logarithm of the radius of orbit in seconds, at the mean distance of Mars from the sun	1·32795

The angles of position in the ephemeris are reckoned as in double-star measures—

		At 8h. 30m. P.M.		At 11h. om. P.M.	
		Pos.	Dist.	Pos.	Dist.
		°	″	°	″
Sept.	8	82	76	71	85
,,	9	199	30	125	40
,,	10	251	85	240	74
,,	11	298	37	269	65
,,	12	60	73	40	46
,,	13	89	66	76	83
,,	14	218	44	149	28
,,	15	256	82	246	79
,,	16	325	28	277	53
,,	17	65	77	50	56
,,	18	96	54	81	76

The apparent diameter of Mars according to Kaiser's measures is 25″·0 on the 8th and 24″·0 on the 18th.

M. Leverrier characterises Prof. Asaph Hall's discovery of the satellites of Mars as "une des plus importantes observations de l'astronomie moderne." It is in the highest degree an honour to American science. The magnificent instrument with which they have been detected, a masterpiece of mechanical skill, is of American construction, and we think every astronomer must admit that since it was mounted at the Naval Observatory, Washington, the national astronomical institution, admirable discernment has been shown in the selection of a class of observations upon which its extraordinary optical power could be brought to bear with the greatest advantage in the actual state of the science. Already our knowledge of the motions of the four satellites of Uranus and of the satellite of Neptune has been greatly advanced, and tables to facilitate the calculation of their positions have been skilfully prepared by Prof. Newcomb, with the aid of measures made with this instrument. The period of rotation of Saturn has been determined, and a series of observations of all the eight satellites of this planet has been vigorously prosecuted, which must soon allow of a much more intimate acquaintance with their motions than we yet possess. The notable discovery of two satellites of Mars is a fitting achievement in the same interesting branch of astronomy.

In striking illustration of the truth of the assertion of Sir W. Herschel, that when a very faint object has been once discovered with a large telescope, it may be seen with a much smaller one, we receive, since the above was written, a communication from Mr. Wentworth Erck, of Sherrington, Bray, dated September 8, in which he writes: "The outer satellite has been seen here three times; 1st, on September 2, at 22h. 40m. G.S.T., when the position was about 290°, and distance from limb something less than three diameters of the planet; 2nd, on September 3, at 23h. om. G.S.T., when the position was 64°; this position is pretty accurate; on this occasion I watched the satellite for two hours, during which I saw it move from 64° to 55°; at the latter position its distance from limb was equal to two diameters of the planet; 3rd, on September 8, at 22h. 35m. G.S.T., when the position was about 78°. It was steadily visible with 7-inches aperture on my Alvan Clark, and was, I should say, something brighter than Enceladus, the second satellite of Saturn."

On comparing these observations with positions calculated from the above elements (which closely represent the Paris observation of August 27), it is evident the object observed on September 2 was a star, the satellite at the time being on an angle of 325°, and only fifteen seconds from the limb, but it appears beyond doubt that