"3. In the perturbations of declination which I have observed for 28 years, I have been unable to recognise any general law.

"4. The perturbations of horizontal intensity commence in general by an increase of that force, and finish always by a diminution, which lasts for two or three days.

"5. In all perturbations there is a *constant relation* between changes of inclination and the simultaneous changes of horizontal intensity, such that an augmentation of intensity of $\frac{1}{10000}$ corresponds to a diminution of inclination of 8°·28 (for Munich).

"6. In telegraphic wires we cannot observe the existence of a constant terrestrial current, since the conductivity of the soil is infinitely greater than that of the telegraphic wire, and it is only *sudden changes* that manifest themselves. In consequence, during magnetic perturbations in the galvanometer of a telegraphic wire, we only see irregular deflections to right or left, succeeding each other at intervals of a few minutes.

"In 1850 and 1851 we made electrical observations from hour to hour, from 7 A.M. to 6 P.M., without being able to see any connection between the atmospheric electricity and the magnetic perturbations. Later I abandoned these observations, because the indications of the electrometers depended too much on local and accidental circumstances."

It should be noted here that the horizontal component of magnetic force varies with the inclination as well as with the intensity of the total force, and the ratio noted above is almost exactly that which would be produced by a change in the inclination alone; and it would appear as if the actual horizontal force, independent of the inclination, was subject to comparatively little variation. This is not improbable, since variations in the horizontal force could correspond only to electro-magnetic easterly or westerly currents, while changes in declination, inclination, and vertical force *might* correspond to currents from the magnetic north and south, which there is reason to believe are most frequent in auroral displays.

To give some idea of the extent of magnetic perturbations, we may mention that during the aurora of 13th May 1869, the declination at Greenwich varied 1° 25′, while the vertical force experienced four successive maxima, and the greatest oscillation amounted to 0·04 of its total mean value. The horizontal force at the same time only varied 0·014 of its mean value. During the aurora of the 15th April of the same year the declination at Stonyhurst varied 2° 23′ 14″ in nine minutes.

The electric currents produced at such times in telegraph wires, though transient, are often very powerful. Loomis (*Sill. Jour.*, vol. xxxii.) mentions cases where wires had been ignited, brilliant flashes produced, and combustible materials kindled by their discharge. It often happens that the ordinary signals are completely interrupted during their continuance.

Electrical character of aurora

In addition to the resemblance between the auroral phenomena and those of electric discharges in rarefied gases which we have already mentioned, we have seen that auroral displays are accompanied by marked disturbances both in the direction and force of terrestrial magnetism. This fact is in itself almost proof of their electrical character, and, taken in conjunction with the strong "earth-currents" which are at such times produced in lines of telegraph, and with the manifest polarisation of the arches and rays with regard to the magnetic meridian, may be considered as conclusive that the aurora is some sort of electric discharge. There are still some points with regard to the origin of this electricity which are unexplained, and it is uncertain whether the magnetic disturbance causes the electrical phenomena, or *vice versa*. It has been shown by Prof. Plücker that when an electric discharge takes place through rarefied gas in the field of a magnet, it is concentrated in the magnetic curves, which are the only paths in which it can move without being disturbed by the magnet. This is well shown in De la Rive's well-known experiment, in which an electro-magnet is enclosed in an electric egg. As soon as the magnet is set in action, the discharge, which had before filled the egg, is concentrated into a defined band of light, which rotates steadily round the magnet,—the direction of its rotation being changed by reversal either of the current or of the polarity of the magnet. If we suppose that the aurora is an electric discharge passing from one magnetic pole to the other, and following the terrestrial magnetic curves, we shall find that the theory agrees with observed facts even in its lesser details. In these latitudes the magnetic curves are sensibly straight and parallel, and are inclined S.E. at an angle of about 70° from the perpendicular, and, by the well-known laws of perspective, will appear to converge towards this point, as, in fact, the auroral streamers do. The streamers should move from east to west, or from west to east, according as the discharge is from north to south, or *vice versa*, and, in fact, they are in constant motion. Professor Loomis (*Sill. Jour. of Sc.*, xxxiv. 45) gives a catalogue of forty-six cases of such movement, of which thirty-one were from E. to W. and only fifteen in the opposite direction; and as part of these apparent motions are due to a real motion from N. to S., he concludes that the actual motion of the streamers is from about N.N.E. to S.S.W. This would make the north pole the negative electrode, which is most likely usually the case. Prof. Loomis has shown that during auroral displays electrical currents traverse the earth's surface in the same general direction, though subject to great variation in intensity and even to reversal. Waves of magnetic disturbance are also propagated in the same direction (*ibid.*, xxxii. 318).

With regard to the arches it is evident that they are generally circles concentric to the magnetic pole, and it is very probable that they are analogous to the striæ often seen in discharges in rarefied gases. Gassiot, quoted by B. V. Marsh (*Sill. Jour.*, xxxi. 316, and *Roy. Soc. Proc.*, vol. x. Nos. 38 and 39), describes an experiment with his great Grove's battery of 400 cells, in which the exhausted receiver was placed between the poles of the large electro-magnet of the Royal Institution:—"On now exciting the magnet with a battery of ten cells, effulgent strata were drawn out from the positive pole, and passed along the under or upper surface of the receiver according to the direction of the current. On making the circuit of the magnet and breaking it immediately, the luminous strata rushed from the positive, and then retreated, cloud following cloud with a deliberate motion, and appearing as if swallowed up by the positive electrode." This, as Mr Marsh remarks, bears a very considerable resemblance to the conduct of the auroral arches, which almost invariably drift slowly southward; and we cannot do better than sum up his theory in his own words:—"The foregoing considerations seem to render it probable that the aurora is essentially an electric discharge between the magnetic poles of the earth leaving the immediate vicinity of the north magnetic pole in the form of clouds of electrified matter, which float southward through the atmosphere at a height of 40 miles or more from the earth, sometimes to a distance of more than 30° from the pole; that whilst they are thus moving forward, with a comparatively slow and steady motion, or sometimes even remaining almost stationary for a long time, bright streams of electricity are from time to time suddenly shot out from them in a nearly vertical direction, that is to say, in the magnetic curves corresponding to the points from which they originate; that these curves, ascending to a great height beyond the atmosphere, then bending more and more southward and downward until they finally reach corresponding points in the southern magnetic hemisphere, are the pathways by which the electric currents pass to their destination; and that for several hundred miles from the earth these curves are thus 'traced through space and illuminated with bright electric light;' and further, that the magnetism of the earth also causes these luminous currents and the electrified matter composing the arch to revolve round the magnetic pole of the earth, giving them the motion from east to west, or from west to east, which the components of the arch are observed to have."

The principal difficulties and deficiencies of this hypothesis, which was first suggested by De la Rive, are that it makes no attempt to account for the origin of such an electrical discharge, and that it is difficult to understand how an electric current can traverse vast spaces of the almost perfect vacuum which must exist at the distance from the earth (many hundreds of miles) which is attained by the magnetic curves, since, in the best vacuums of our Sprengel pumps, discharge will not take place even across the interval of a few centimetres. It is not, however, certain that stellar space is an insulator, and it is possible, moreover, that the auroral currents do not follow the magnetic curves through their whole course, since electric discharge is always in the path of least resistance, and this is modified not only by the magnetic forces, but by atmospheric density, and it is possible that on attaining a certain height the current may proceed horizontally on a stratum of least resistance. It need create no surprise that the discharge is generally invisible in the intermediate zone of low latitudes, since this is well accounted for not only by the large surface over which it is spread at great heights, but because this part of its course is at right angles to the line of sight, while in higher latitudes we look at the streamers almost "end-on," and thus have before our eyes a very great depth of luminous gases. It is common enough, too, in discharges in rarefied gases to see the two poles surrounded by luminous auræ, while the intermediate space is almost or quite dark, or consists of luminous disks or striæ separated by dark spaces. It seems probable that this "glow" discharge in rarefied gases is really a sort of electrical convection, which is propagated comparatively slowly, and from particle to particle; and that the striæ are surfaces at which the difference of potential of the moving molecules is so great as to cause discharge between them, while in the intermediate dark spaces the electric force is carried mechanically and silently by the particles moving in regular currents under the repulsive and attractive forces of electrification. On this hypothesis the auroral discharge becomes comprehensible, since we have only to suppose that the electricity is carried mechanically, as it were, through the vacuous spaces, which, if they contain no matter to conduct electricity, can contain none to impede the motion of the molecules. It is, moreover, by no means certain that the bright rays indicate actual currents. They may simply consist of matter rendered luminous in the arches, and projected by magnetic or electrical repulsion in the curves of magnetic force, since Varley (*Roy. Soc. Proc.*, xix. 236) shows that when a glow discharge in a vacuum tube is brought within the field of a powerful magnet, the magnetic curves are illuminated beyond the electrodes between which the discharge is taking place as well as within the path of the current; and also that this illumination is caused by moving particles of matter, since it deflected a balanced plate of talc on which it was caused to impinge. It has also been shown that in electrical discharges in air at ordinary pressures, while the spark itself was unaffected by the magnet, it was surrounded by a luminous cloud or aura, which was drawn into the magnetic curves, and which might also be separated from the spark by blowing upon it. It is evident, therefore, that any mechanical force may separate the luminous particles from the electric discharge which produces them.

Geographical distribution.

With regard to the geographical distribution of aurora, Prof. Loomis (*Sill. Jour.*, xxxi.) has laid down a series of zones of equal auroral frequency, and in Petermann's *Mittheilungen* for October 1874, Prof. Fritz has given a chart embodying the results of his extensive researches on the same subject. He finds, like Prof. Loomis, that the frequency of auroral display does not continue to increase to the pole, but reaches a maximum in a zone which, for the northern hemisphere, passes through the Faroe Islands, reaches its most southern point, about 57°, nearly south of Greenland, passes over Nain on the Labrador coast, then tends northwards, across Hudson's Bay (60° N. lat.), and through great Bear Lake, and leaves the American continent slightly south of Point Barrow. It then skirts the northern coast of Asia, reaching its most northerly point, about 76° N., near Cape Taimyr, passing through the north of Nova Zembla, and skirting the N.W. coast of Norway. Not only are auroral displays less frequent in Iceland and Greenland than further south, but it is found that while south of this zone auroræ appear usually to the north of the observer, north of it they are generally to the south, and within it, north or south indifferently. South of this lie other zones approximately parallel to it, and of constantly diminishing frequency. That in which the average yearly number of auroræ is 100 passes through the Drontheim, the Orkneys, and the Hebrides, and reaches the American coast just north of Newfoundland. South of this the frequency diminishes rather rapidly. At Edinburgh the annual average is 30, at York 10, in Normandy 5; while at Gibraltar the average is about 1 in ten years.

These curves, which Prof. Fritz calls *isochasmen*, are nearly normal to the magnetic meridians, and bear a close relation to the curves of equal magnetic inclination, especially with those laid down by Hansteen in 1730, while they noticeably diverge in some places from those of Sabine of 1840. They also approximate to the isobaric curves of Schouw, and Prof. Fritz remarks that the curves of greater frequency tend towards the region of lowest atmospheric pressure. It is not unlikely that there may be such a connection, since Prof. Airy has showed a relation between barometric and magnetic disturbances.

It will be noticed that, eastward from England, the isochasmic curves tend rapidly northward, Archangel being only on the same auroral parallel as Newcastle. Prof. Fritz points out that they bear some relation to the limit of perpetual ice, tending most southward where, as in North America, the ice limit comes furthest south. He also endeavours to establish some connection between the periods of maximum of auroræ and those of the formation of ice, and considers ice as one of the most important local causes which influence their distribution. He quotes a curious fact mentioned by several Arctic voyagers, that aurora was most frequently seen when open water was in sight, and usually rather in the direction of the water than of the magnetic north. In this connection it may be well to remind our readers that the water of the Arctic regions is always warmer than the ice fields, and must cause upward currents of damp air. For the southern hemisphere there are not yet sufficient observations to make any determination of geographical distribution.

With regard to distribution in time Loomis and Fritz and Wolf have shown that there are periodical maxima about every ten or eleven years, and that these maxima coincide both with those of sun spots, and of magnetic disturbance. The following are Fritz and Wolf's dates of maxima:—

Sun Spots.	Auroræ.	Sun Spots.	Auroræ.
1706	1707	1788	1788
1718	1721	1804	1804
1728	1728	1817	1816
1739	1738	1830	1830
1750	1749	1837	1839
1761	1760	1848	1848
1770	1769	1860	1860
1779	1779	1871	1872

The annexed chart from Prof. Loomis's paper (*Sill. Jour.*, April 1873) shows, in a very striking manner, the correspondence of auroræ, magnetic variation, and sun-spot area since 1776. It is not improbable that there may also be changes of longer period which our observations are yet insufficient to determine.

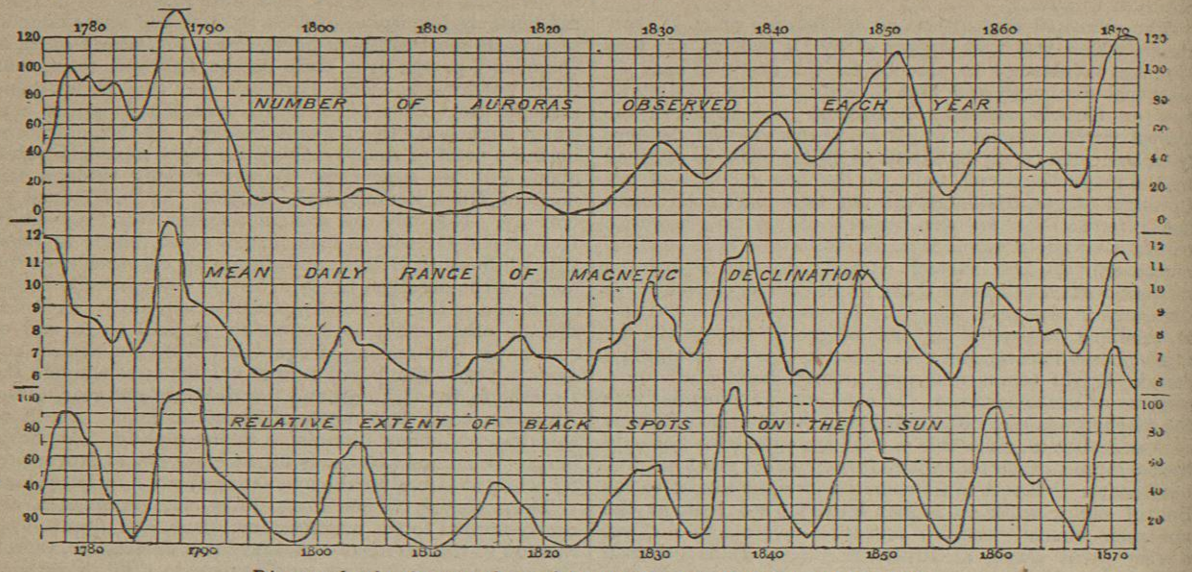

Diagram showing Correspondence of Auroræ, Magnetic Variation, and Sun Spots.

Annual distribution. It has frequently been stated that the aurora returned periodically on certain days in the same manner as meteors. On the 3d of February brilliant auroræ occurred in 1750 and 1869, and on the 4th in 1869, 1870, 1871, 1872, 1873, and 1874; on the 13th February in 1575, 1821, 1822, 1865, and 1867; on the 6th March in 1716, 1777, 1843, 1867, and 1868; on the 9th September in 1776, 1827, 1835, 1866, 1868, 1872, and on the 29th in 1828, 1840, 1851, 1852, 1870, and 1872. This conclusion, however, is not supported by systematic investigation. A considerable catalogue of auroræ was divided into decennial periods, and it was found that the maxima of one period rarely coincided with those of others, and that the larger the number of years taken into account the less prominent the maxima appeared,—evident proof that they were only accidental. It may be, however, that if only prominent auroræ had been considered, more periodicity might have been found, or that the periodicity is constant for very short periods only.

Although no daily periodicity can be affirmed, there are two well-marked annual maxima in March and October, of which the latter is the greater, and two minima—the greater in June and the less in January. In this respect the aurora differs from the sporadic meteors, which have a maximum in autumn and a minimum in spring. It also differs from meteors in the hours of its appearance, the former being most frequent before and the latter after midnight.

Although the electric hypothesis is the one generally accepted by scientific men, it is only fair to allude to one that has been recently proposed independently by Dr Zehfuss (*Physikalische Theorie*, Adelman, Frankfort) and by H. J. H. Groneman of Gröningen (*Astronomische Nachrichten*, No. 2010–2012). According to this view, the light of the aurora is caused by clouds of ferruginous meteoric dust, which is ignited by friction with the atmosphere. Groneman has shown that these might be arranged along the magnetic curves by action of the earth's magnetic force during their descent, and that their influence might produce the observed magnetic disturbances. The arches may be accounted for by the effects of perspective on columns suddenly terminated at a uniform height by increase of atmospheric density, while the correspondences with iron lines in its spectrum are sufficiently close to favour the idea. Ferruginous particles have been found in the dust of the Polar regions (E. A. Nordenskiold, *Ast. Nach.*, 1874, § 154), but whether they are derived from stellar space or from volcanic eruption is uncertain. The yearly and eleven-yearly periodicity of auroræ tends to support the theory, but it is a formidable difficulty that, while shooting stars are more frequent in the morning, or on the face of the earth which is directed forwards in its orbit, the reverse is the case with auroræ. Groneman meets this difficulty by supposing that in the first case the velocity may be too great to allow of arrangement by the earth's magnetic force, and that, consequently, only diffused light can be produced. He accounts for its unfrequency in equatorial regions by the weakness of the earth's magnetic force, and the fact that, when it does occur, the columns must be parallel to the earth's surface. Without pronouncing in favour of this hypothesis, it must be admitted that it furnishes a plausible explanation of the phenomenon, although we have no evidence that meteoric dust, even if it exists, would produce the observed spectrum, and, as has been already remarked, the iron coincidences are of little weight.

Although we must confess that the causes of the aurora are very imperfectly explained, we may hope that the rapid progress which the last few years have witnessed in bringing terrestrial magnetism under the domain of cosmical laws may soon be extended to the aurora, and that we shall see in it fresh evidence that the same forces which cause hurricanes in the solar atmosphere thrill sympathetically to the furthest planets of our system in waves, not only of light and heat, but of magnetism and electricity.

The following is a list of the most important papers, treatises, and works on this subject:—*Berlin Mem.* 1710, i. 131; Halley, *Phil. Trans.* 1716, 1719, xxix. 406 xxx. 584; Hearne, *Phil. Trans.*, xxx.

1107; Langworth, Huxham, Hallet, and Callendrini, *Phil. Trans.* xxxiv. 132, 150; Mairan, *Traité de l'Aurore Boréale*, 1733, 1754; Weidler, *De Aurora Boreali*, 4to; Wargentin, *Phil. Trans.* 1751, p. 126, 1752, p. 169, 1753, p. 85; Bergmann, *Schw. Abh.*, 200, 251; Wiedeburg, *Ueber die Nordlichter*, 8vo, Jena, 1771; Hüpsch, *Untersuchung des Nordlichts*, 8vo, Cologne, 1778; Van Swinden, *Recueil de Mémoires*, Hague, 1784; Cavallo, *Phil. Trans.* 1781, p. 329; Wilke, "Von den Neuesten Erklärungen des Nordlichts, *Schwedisches Mus.*, 8vo, Wismar, 1783; Hey, Wollaston, Hutchinson, Franklin, Pigott, and Cavendish, *Phil. Trans.* 1790, pp. 32, 47, 101; Dalton's *Meteorological Observations*, 1793, pp. 54, 153; Chiminello, "On a Luminous Arch.," *Soc. Ital.*, vii. 153; Loomis, "Electrical and Magnetic Relations," *Sill. Jour.* 2d ser., xxxii. 324, xxxiv. 34, Sept. 1870; on "Catalogue, Geog. dist., Sun spots," &c., *ibid.*, 3d ser. v. 245, &c.; B. V. Marsh, "Electrical Theory," *ibid.* 3d. ser., xxxi. 311; Oettingen and Vogel on "Spectrum," *Pogg. Ann.*, cxlvi. 284, 569; Galle and Sirks on "Crown," *ibid.*, cxlvi. 133, cxlix. 112; Silbermann, *Comptes Rendus*, lxviii. 1049, 1120, 1140, 1164; Prof. Fritz, "Geog. Distrib.," *Petermann's Mitt.*, Oct. 1874; Zehfuss, *Physikalische Theorie*, Adelman, Frankfort; Balfour Stewart, *Phil. Mag.* 4th ser., xxxix. 59; A. S. Davis, *ibid.*, xl. 33; C. Piazzi Smyth, *Ed. Ast. Observations*, xiii. R. 85, *Phil. Mag.*, 4th ser., xlix., Jan. 1875; A. S. Herschel, *Nat.*, iii. 6; Sir W. R. Grove and J. R. Capron, *ibid.*, 28; Webb, Glaisher, &c., "Daylight Auroræ," *ibid.*, 104, 126, 348, 510, iv. 209, &c; Heis, "Auroras at Melbourne," *ibid.*, iv. 213; Prof. C. A. Young, *ibid.*, iv. 345; Kirkwood, "Periodicity," *ibid.*, iv. 505; H. R. Procter, *ibid.*, iii. 7, 346, &c.; P. E. Chase, "On Auroras and Gravitating Currents," *ibid.*, iv. 497; H. A. Newton, "Height," *Sill. Jour.* 2d ser., xxxix. 286, 371; Angström, *Pogg. Ann.* ("Jubelband") and *Nat.*, x. 211; J. R. Capron, "Spectrum," *Phil. Mag.*, 4th ser., xlix., April 1875. (H. R. P.)

AURUNGABAD, or AURANGÁBÁD, a city of India, in the native state of Haidarábád, or the Nizám's dominions, situated in 19° 51′ N. lat., and 75° 21′ E. long., 138 miles from Púna, 207 from Bombay *via* Púna, and 270 from Haidarábád. It was founded about the year 1620, under the name of Gurka, by Malik Ambar, an Abyssinian, who had risen from the condition of a slave to great influence. Subsequently it became the capital of the Moghul conquests in the south of India. Aurungzebe made it the seat of his government during his viceroyalty of the Deccan, and gave it the name of Aurungábád. It thus grew into the principal city of an extensive province of the same name, stretching westward to the sea, and comprehending nearly the whole of the territory now comprised within the northern division of the presidency of Bombay. Aurungábád long continued to be the capital of the succession of potentates bearing the modern title of Nizám, after those chiefs became independent of Dehli. They abandoned it subsequently, and transferred their capital to Haidarábád, when the town at once began to decline. It is now greatly fallen from its ancient grandeur. The city is but half-peopled, and is half in ruins, presenting everywhere the melancholy appearances of desertion and decay. The population is, however, still considerable, and in the bázár, which is very extensive, various rich commodities, particularly silks and shawls, are exposed for sale. The walls of the town are similar in their construction to those of all the other cities in this quarter of India, being rather low, with round towers.

AURUNGZEBE, one of the greatest of the Moghul emperors of Hindustan, was the third son of Shah Jehan, and was born in October 1618. His original name, Mahomet, was changed by his father, with whom he was a favourite, into Aurungzebe, meaning ornament of the throne, and at a later time he assumed the additional titles of Mohi-eddin, reviver of religion, and Alam-gir, conqueror of the world. At a very early age, and throughout his whole life, he manifested profound religious feeling, perhaps instilled into him in the course of his education under some of the strictest Mahometan doctors. He was employed, while very young, in some of his father's expeditions into the country beyond the Indus, gave promise of considerable military talents, and was appointed to the command of an army directed against the Usbeks. In this campaign he was not completely successful, and soon after was transferred to the army engaged in the Deccan. Here he gained several victories, and in conjunction with the famous general, Meer Jumla, who had deserted from the king of Golconda, he seized and plundered the town of Haidarábád, which belonged to that monarch. His father's express orders prevented Aurungzebe from following up this success, and, not long after, the sudden and alarming illness of Shah Jehan turned his thoughts in another direction. Of Shah Jehan's four sons, the eldest, Dara, a brave and honourable prince, but disliked by the Mussulmans on account of his liberality of thought, had a natural right to the throne. Accordingly, on the illness of his father, he at once seized the reins of government and established himself at Dehli. The second son, Soojah, governor of Bengal, a dissolute and sensual prince, was dissatisfied, and raised an army to dispute the throne with Dara. The keen eye of Aurungzebe saw in this conjuncture of events a favourable opportunity for realising his own ambitious schemes. His religious exercises and temperate habits gave him, in popular estimation, a great superiority over his brothers, but he was too politic to put forward his claims openly. He made overtures to his younger brother Murad, governor of Guzerat, representing that neither of their elder brothers was worthy of the kingdom, that he himself had no temporal ambition, and desired only to place a fit monarch on the throne, and then to devote himself to religious exercises and make the pilgrimage to Mecca. He therefore proposed to unite his forces to those of Murad, who would thus have no difficulty in making himself master of the empire while the two elder brothers were divided by their own strife. Murad was completely deceived by these crafty representations, and at once accepted the offer. Their united armies then moved northward. Meanwhile Shah Jehan had recovered, and though Dara resigned the crown he had seized, the other brothers professed not to believe in their father's recovery, and still pressed on. Soojah was defeated by Dara's son, but the imperial forces under Jesswunt Singh were completely routed by the united armies of Aurungzebe and Murad. Dara in person took the field against his brothers, but was defeated and compelled to fly. Aurungzebe then, by a clever stroke of policy, seized the person of his father, and threw him into confinement, in which he was kept for the remaining eight years of his life. Murad was soon removed by assassination, and the way being thus cleared, Aurungzebe, with affected reluctance, ascended the throne in August 1658. He quickly freed himself from all other competitors for the imperial power. Dara, who again invaded Guzerat, was defeated and closely pursued, and was given up by the native chief with whom he had taken refuge. He was brought to Dehli, exhibited to the people, and assassinated. Soojah, who had been a second time defeated near Allahabad, was attacked by the imperial forces under Meer Jumla and Mahomet, Aurungzebe's eldest son, who, however, deserted and joined his uncle. Soojah was defeated and fled to Aracan, where he perished; Mahomet was captured, thrown into the fortress of Gwalior, and died after seven years' confinement. No similar contest disturbed Aurungzebe's long reign of forty-six years, which has been celebrated, though with doubtful justice, as the most brilliant period in the history of Hindustan. The empire certainly was wealthy and of enormous extent, for there were successively added to it the rich kingdoms of