on April 25, 1809, he successfully concluded the important treaty securing the independence of the Sikh states between the Sutlej and the Jumna. Four years afterwards he was made principal resident at Delhi, and in 1819 he received the appointments of secretary in the secret and political department, and of private secretary to the governor-general (Lord Hastings). From 1820 to 1823 Sir Charles (who succeeded his brother in the baronetcy in 1822) was resident at the court of the nizam, but in the latter year he was compelled by the state of his health to retire from active service; in 1825, however, he was so far restored as to undertake the residency of the Delhi territories. Two years afterwards he obtained a seat in the supreme council, and in February 1835, after he had for some time been governor of Agra, he, as senior member of council, provisionally succeeded Lord William Bentinck in the governor-generalship. During his brief tenure of office (it lasted only till March 28, 1836) he originated or carried out several important measures, including that for the liberation of the press, which, while almost universally popular, complicated his relation with the directors at home to such an extent that he withdrew from the service of the Company in 1838. In the following year he was appointed by the Melbourne administration to the governorship of Jamaica, where the difficulties created by the recent passing of the Negro Emancipation Act had called for a high degree of tact and ability. Sir Charles Metcalfe's success in this delicate position was very marked (see vol. xiii. p. 551), but unfortunately his health compelled his resignation and return to England in 1842. Six months afterwards he was appointed by the Peel ministry to the governor-generalship of Canada, and his success in carrying out the policy of the home Government was rewarded with a peerage shortly after his return in 1845. He died at Malshanger, near Basingstoke, September 5, 1846. See J. W. Kaye's *Life and Correspondence of Charles Lord Metcalfe*, London, 1854.

METELLUS, the name of the most important family of the Roman plebeian gens Cæcilia. They rose to distinction during the Second Punic War, and Nævius satirized them.

QUINTUS CÆCILIUS METELLUS MACEDONICUS, prætor 148 B.C. in Macedonia, defeated Andriscus in two battles, and forced him to surrender. He then superintended the conversion of Macedonia into a Roman province. He tried unsuccessfully to mediate between the Achæan league and Sparta, but, when the Achæans advanced, he defeated them easily near Scarpheia; Mummius soon after superseded him, and returning to Italy he triumphed in 146. Consul in 143, he reduced northern Spain to obedience. In 131 censor with Q. Pompeius (the first two plebeian censors), he proposed that all citizens should be compelled to marry. He was a moderate reformer, and was considered the model of a fortunate man; before his death in 115 three of his sons had been consuls, one censor, and the fourth was a candidate for the consulship.

QUINTUS CÆCILIUS METELLUS NUMIDICUS, whose reputation for integrity was such that when he was accused of extortion the jury refused to examine his accounts, was selected to command against Jugurtha in 109 B.C. He subjected the army to rigid discipline, and aimed solely at seizing Jugurtha himself; he defeated the king by the river Muthul, and next year, after a difficult march through the desert, took his stronghold Thala. Marius, however, accused Metellus of protracting the war, and received the consulate for 107. Metellus returned to Rome and triumphed. Saturninus, whom as censor he tried to remove from the senate, passed in 100 an agrarian law, inserting a provision that all senators should swear to it within five days. All complied but Metellus, who retired to Asia. After Saturninus was killed, he returned, but died shortly after under suspicion of poison.

QUINTUS CÆCILIUS METELLUS PIUS, so called from his efforts to restore his father Numidicus, commanded in the Social War, defeating Q. Pompædius (88 B.C.). Sulla on departing gave him proconsular command over South Italy. When Marius returned, the soldiers, who had no confidence in Octavius, wished Metellus to command, but he refused. Metellus retired to Africa and afterwards to Liguria, resuming his former command on Sulla's return. In 86 he gained a decisive victory over Norbanus at Faventia. In Sulla's proscriptions he pleaded in favour of moderation. Consul in 80 with Sulla, he went to Spain next year against Sertorius, who pressed him hard till the arrival of Pompeius in 76. Next year Metellus defeated Sertorius's lieutenant Hirtuleius at Italica and Segovia, and joining Pompeius rescued him from the consequences of a check at Sucro. From this time Sertorius grew weaker till his murder in 72. Metellus had previously set a price on his head. In 71 he returned to Rome and triumphed. He was an upright man, of moderate ability.

QUINTUS CÆCILIUS METELLUS PIUS SCIPIO, son of Scipio Nasica, was adopted by the preceding. He was accused of bribery in 60 B.C., and defended by Cicero. In August 52 Pompeius procured him the consulate. Scipio in return supported Pompeius, now his son-in-law. On war being resolved on, Scipio was sent to Syria. His extortions were excessive, and he was about to plunder the temple of Artemis at Ephesus when he was recalled by Pompeius. He commanded the centre at Pharsalus, and afterwards went to Africa, where by Cato's influence he received the command. In 46 he was defeated at Thapsus; in his flight to Spain he was stopped by a corsair, and stabbed himelf. His connexion with two great families gave him importance; but he was selfish and licentious, and his violence drove many from his party.

QUINTUS CÆCILIUS METELLUS CELER, prætor 63 B.C., was sent to cut off Catiline's retreat northward. Consul in 61, his personal influence prevented the holding of the Compitalia, which the senate had forbidden and the tribunes permitted. He opposed the agrarian law of the tribune L. Flavius, and stood firm even though imprisoned; the law had to be given up. He also tried, though fruitlessly, to obstruct Cæsar's agrarian law in 59. He died that year under suspicion of poison given by his wife Clodia.

METEMPSYCHOSIS, the transmigration of the soul, as an immortal essence, into successive bodily forms, either human or animal. This doctrine, famous in antiquity, and one of the characteristic doctrines of Pythagoras, appears to have originated in Egypt. This indeed is affirmed by Herodotus (ii. 123):—"The Egyptians are, moreover, the first who propounded the theory that the human soul is immortal, and that when the body of any one perishes it enters into some other creature that may be born ready to receive it, and that, when it has gone the round of all created forms on land, in water, and in air, then it once more enters a human body born for it, and this cycle of existence for the soul takes place in three thousand years."

Plato, in a well-known passage of the *Phædrus*, adapts, as was his wont, the Pythagorean doctrine to his myth or allegory about the soul of the philosopher. That soul, he says, though it may have suffered a fall in its attempt to contemplate celestial things, still is not condemned, in its first entrance into another form, to any bestial existence, but, according to its attainments, *i.e.*, to the progress which it has made in its aspiration for celestial verities, it passes, in nine distinct grades, into the body of some one destined to become a philosopher, a poet, a king, a general, a seer, &c.; or, if very inferior, it will animate a sophist or an autocrat (*τύραννος*). Plato extends the cycle of existence to ten thousand years, which is subdivided into periods of a thousand years, after the lapse of which the souls undergo

judgment, and are admitted to everlasting happiness or condemned to punishment.[1] It is after the period of a thousand years, he adds, that the human soul comes into a beast, and from a beast again into a man, if the soul originally was human.

Pythagoras, who was said to have travelled in Egypt,[2] brought this fantastic doctrine into Magna Græcia, and made it a prominent part of his teaching. He declared that he had himself been Euphorbus, the son of Panthus, in the time of the Trojan War, and had successively inhabited other human bodies, the actions of all which he remembered.[3] Closely connected with his theory of metempsychosis was his strict precept to abstain from animal food, even from eggs, from some kinds of fish, and (for some unknown, probably symbolical, reason) from beans.[4] There can be no doubt that the Egyptian custom of preserving the mummies of cats, crocodiles, and some other creatures had its origin in the notion that they had been inhabited by souls which might some day claim these bodies for their own. We cannot suppose that Plato or the later Greeks really believed in the transmigration of souls, though there are many allusions to it, generally of a somewhat playful character. Thus Menander, in the play called *The Inspired Woman*[5] (Θεοφορουμένη), supposes some god to say to an old man, Crato, "When you die, you will have a second existence; choose what creature you would like to be, dog, sheep, goat, horse, or man." To which he replies, "Make me anything rather than a man, for he is the only creature that prospers by injustice."

Absurd and fantastic as such a doctrine as metempsychosis appears at first sight to be, it was in reality a logical deduction from primitive ideas about the nature of the soul. It is necessary to explain these ideas (which have important bearings on other questions) in order to show that metempsychosis was almost a necessary corollary to the belief that the soul was the vital or animating principle,—that the one distinction between organic and inorganic was the existence in the former of a *ψυχή*.

The difference between a dead body and a living body—or rather, one principal difference—was that the living animal breathed; and it was observed that, as soon as the breath left the body, not only did warmth and motion cease, but the body began to decay. Life, therefore, was breath, an opinion tacitly expressed by the Greek and Roman vocabulary, *animus*, *anima* (ἄνεμος), ψυχή, πνεῦμα, *spiritus*. But breath is air, and air is eternal and imperishable in its very nature. Therefore the "soul," or portion of air which gave animation to the body, did not perish at the dissolution of the body, but it was returned to the element of which it was composed, and out of which it came. It followed that, from the countless millions of "souls" emancipated from bodies in all time, and still flitting about invisibly in space, the air must literally swarm with souls,—a doctrine taught by Pythagoras.[6] Hence, any creature, human or bestial, that first drew the breath of life, might, so to say, swallow a soul, *i.e.*, take in with the act of respiration the very same particles of air which had animated some former body. For, although the soul was air, and returned to its kindred element, it was supposed to retain a peculiar character in intelligence (φρόνησις), remembrance of the past, and knowledge and experience gained in some former existence. Any creature which first breathed might or might not inhale this or that soul, just as a net thrown into the water may catch this or that fish, or no fish at all. But if no "soul" was inhaled the creature was believed for that reason to die; and the different degrees of intelligence observed in different men and animals led to the notion that there must have been a difference in the souls that first animated them. Even the belief that the soul, especially near the time of dissolution from the body, could foretell future events was based on the notion of intelligence and consciousness resulting from experiences of the past.[7]

As all the science of modern times cannot say precisely what life is, nor how it first came upon this earth, it is not wonderful that so obvious, though wholly erroneous, an explanation should have presented itself to primitive man when first he began to inquire into the causes of things. The extension of life, by the same term ψυχή, to plants and apparently non-breathing things, which, however, had birth, growth, and death, was a development of a philosophic age, and we are not surprised to find Aristotle recognizing one form of life as *vegetable*, φυτικόν.[8] The irrational confusion of "soul" with sentient bodily functions, the attribution to spirits (εἴδωλα) of motion, speech, or other muscular and material action, though still common, while metempsychosis is derided or forgotten, is in reality, perhaps, a less excusable superstition.

The Romans inherited the doctrine of metempsychosis from Ennius, the poet of Calabria, who must have been familiar with the Greek teachings which had descended to his times from the cities of Magna Græcia. In his *Annals*, or Roman history in verse, Ennius told how he had seen Homer in a dream, who had assured him that the same soul which had animated both the poets had once belonged to a peacock, a story that might seem to indicate Indian traditions. The *Pavo Pythagoreus* and the *Somnia Pythagorea* are referred to by Persius and Horace, as well as by Lucretius.[9]

Theories suggesting element-worship naturally led to the notion that air and ether (upper air) were divine.[10] Hence every soul, as being but a portion of it, was in itself divine, and therefore immortal. We thus see that the doctrine of the immortality of the soul, whether attained by a sound or a vicious course of reasoning, was an inevitable conclusion for early thinkers. Pantheism taught that all the universe was pervaded by a divine mind, and Virgil cites the opinion of some, that the intelligence of bees was due to a portion of this universal mind residing in them, a view closely allied to the doctrine of metempsychosis.[11] A divine thing might be polluted, but not destroyed; hence the notion of purifying souls by airing them or burning away a material defilement is enlarged upon by Virgil in the sixth book of the *Æneid* (724 *sq.*). (F. A. P.)

METEOR, METEORITE. The term meteor, in accordance with its etymology (μετέωρος), meant originally something high in the air. It has been applied to a large variety of phenomena, most of them of brief duration, which have place in the atmosphere. Disturbances in the air are aerial meteors, viz., winds, tornadoes, whirlwinds, typhoons, hurricanes, &c. The vapour of water in the atmosphere creates by its forms and precipitations the aqueous meteors, viz., clouds, fogs, mists, snow, rain, hail,

1 P. 249 A. Comp. Rev. xx. 2, 13; Virg., *Æn.* vi. 745, "Donec longa dies, perfecto temporis orbe, concretam exemit labem," &c.

2 Diogen. Laert., viii. 1, 3; Lucian, *Gallus*, § 18 *sq.*, where the doctrine of metempsychosis and the stories about the pre-existence of Pythagoras are wittily satirized.

3 Lucian, *Gallus*, §§ 4, 5; Diodor. Sic., x. §§ 9, 10; Hor., *Od.* i. 28, 10, "habentque Tartara Panthoiden iterum Orco demissum."

4 *Gallus*, 19, 33. For fanciful reasons for the prohibition of beans, see Lucian, *Vitarum Auctio*, § 5.

5 Frag. 222, Meineke.

6 Diogen. Laert., viii. 1, § 32, εἶναι πάντα τὸν ἀέρα ψυχῶν ἔμπλεων.

7 Diodor. Sic., xviii., § 1.

8 *Ethics*, lib. i. 13.

9 Pers., *Sat.* vi. 9; Hor., *Epist.* ii. 1, 52; Lucret., i. 124.

10 ὦ δῖος αἰθήρ. Prometheus exclaims, Æsch., *Prom.*, 88.

11 *Georg.* iv. 219—

His quidam signis, atque hæc exempla secuti,
Esse apibus partem divinæ mentis et haustus
Ætherios dixere; deum namque ire per omnes
Terrasque tractusque maris cælumque profundum

The effect of light upon the atmosphere and its contents causes certain luminous meteors, viz., rainbows, halos, parhelia, twilight, mirage, &c. Discussion of all these, and of like phenomena, belongs to METEOROLOGY (*q.v.*).

Another class of luminous meteors, known as shooting or falling stars, fireballs, bolides, &c., have their place in the upper parts of the atmosphere. But, by reason of their origin from without they, and the aerolites or meteorites which sometimes come from them, belong properly to astronomy. The term meteor is often used in a restricted sense as meaning one of these latter phenomena. The present article will treat of them alone.

The most remarkable of the meteors (and the most instructive) are those which are followed by the falling of stones to the earth. These have since the beginning of the present century attracted so much attention, and the phenomena have been so frequently examined and described by scientific men, that they are very well understood. The circumstances accompanying the fall of stones are tolerably uniform. A ball of fire crosses the sky so bright as to be visible, if it appears in the daytime, sometimes even at hundreds of miles from the meteor; and if it appears in the night it is bright enough to light up the whole landscape. It traverses the sky, generally finishing its course in a few seconds. It suddenly goes out, either with or without an apparent bursting in pieces, and after a short period a loud detonation is heard in all the region near the place where the meteor has disappeared. Sometimes only a single stone, sometimes several are found. For some falls they are numbered by thousands. About three thousand were obtained from the fall of L'Aigle in 1803, scattered over a region about 7 miles long and of less breadth. A like number was obtained from the fall of Knyahinya on June 9, 1866. At Pultusk a still larger number were collected, scattered over a larger space, by a fall in January 1868. From the Emmet county (Iowa) fall, May 10, 1879, a similarly large number have been secured.

These meteors leave behind them in the air a cloud or train that may disappear in a few seconds, or may remain an hour. They come at all times of day, at all seasons of the year, and in all regions of the earth. They come irrespective of the phases of the weather, except as clouds conceal them from view.

Let us describe one or two of these meteors more in detail. On the evening of the 2d of December 1876, persons in or near the State of Kansas saw, about eight o'clock in the evening, a bright fireball rising from near where the moon then was in the western sky. It increased in brilliancy as it proceeded, becoming so bright as to compel the attention of every one who was out of doors. To persons in the northern part of the State the meteor crossed the southern sky going to the east, to those in the southern part it crossed the northern heavens. To all it went down near to the horizon a little to the north of east, the whole flight as they saw it occupying not over a minute.

The same meteor was seen to pass in nearly the same way across the heavens from west-south-west to east-north-east by inhabitants of the States of Nebraska, Iowa, Missouri, Wisconsin, Illinois, Michigan, Kentucky, Indiana, Ohio, Pennsylvania, and West Virginia. But besides this there were heard near the meteor's path, four or five minutes after its passage, loud explosions like distant cannonading, or thunder, or like the rattling of empty waggons over stony roads. So loud were these that people and animals were frightened. East of the Mississippi river these explosions were heard everywhere within about 60 miles of the meteor's path; and in Bloomington, Indiana, sounds were heard supposed to come from the meteor even at a distance of nearly 150 miles from it. Over central Illinois it was seen to break into fragments like a rocket, and over Indiana and Ohio it formed a flock or cluster of meteors computed to be 40 miles long and 5 miles broad. The sky in New York State was wholly overcast. Persons in Ohio and Pennsylvania, who from their situation could look over the cloud last, saw the meteor passing on eastward over New York. From many places in the State itself came accounts of rattling of houses, thundering noises, and other like phenomena, which at the time were attributed to an earthquake.

At one place in northern Indiana a farmer heard a heavy thud as of an object striking the ground near his house. The next morning he found on the snow a stone of very peculiar appearance weighing three-quarters of a pound, which from its character there is every reason to believe came from the meteor. By putting together the various accounts of observers, the meteor is shown to have become first visible when it was near the north-west corner of the Indian Territory, at an elevation of between 60 and 100 miles above the earth. From here it went nearly parallel to the earth's surface, and nearly in a right line, to a point over central New York. During the latter part of its course its height was 30 or 40 miles. It thus traversed the upper regions of the air through 25° of longitude and 5° of latitude in a period of time not easily determined, but probably about two minutes. A part of the body may have passed on out of the atmosphere, but probably the remnants came somewhere to the ground in New York, or farther east.

A somewhat similar meteor was seen in the evening of July 20, 1860, by persons in New York, Pennsylvania, New England, &c., which first appeared over Michigan, at a height of about 90 miles. The light was so brilliant as to call thousands from their houses. It passed east-south-east, and over New York State, at a height of about 50 miles, broke into three parts which chased each other across the sky. At New York city it was seen in the north, while at New Haven it was in the south. At both places the apparent altitude was well observed, and its true height proved to be about 42 miles above the earth's surface between the two cities. It finally disappeared far out over the Atlantic Ocean. It is doubtful whether any one heard any sound of explosion that came from this meteor, and no part of it is known to have reached the ground. The velocity was at least 10 or 12 miles per second, or fifty times the velocity of sound. These two meteors were evidently of the same nature as those which have furnished so many stones for our museums, except that the one was so friable that it has given us but one known fragment, while the other was only seen to break in two, not even a sound of explosion being known to have come from the meteor.

Next to the stone-producing meteor is the fireball, or bolide, which gives generally a less brilliant light than the former, but in essential appearances is like it. The meteor of July 20, 1860, above described, though unusually brilliant, was one of this class, and represents thousands of bolides which have been seen to break in pieces. The bolides leave trains of light behind them just as the stone meteors do; they travel with similar velocities both apparent and actual, and in all respects exhibit only such differences of phenomena as would be fully explained by differences in size, cohesion, and chemical constitution of stones causing them.

Next to the bolide is a smaller meteor which appears as if one of the stars were to leave its place in the heavens, shoot across the sky, and disappear—all within the fraction of a second. Some meteors of this class are as bright as Venus or Jupiter. Some are so small that though you look directly at the meteor, you doubt whether you see one or not. In the telescope still smaller ones are seen that are invisible to the naked eye. Meteors comparable in brightness to the planets and the fixed stars are usually called shooting stars.

These various kinds of meteors differ from all other luminous phenomena so as to stand in a group entirely alone. Though they have been sometimes regarded as separable among themselves into three or four different species, and for purposes of description may still be so divided, yet they all seem to have a like astronomical character, and the differences are only those of bigness, chemical constitution, velocity, &c. There appears to be no clear line of distinction between the stone-producing and the detonating meteors, nor between those heard to explode and those seen to break in pieces, nor between these and the simple fireballs, nor between the fireball and the faintest shooting star.

Altitudes of Meteors.—The first important fact about the meteors is the region in which they become visible to us. In hundreds of instances observations have been made upon the luminous path of a meteor at two or more stations many miles apart. When such stations and the path are properly situated relatively to each other, observations carefully made will show a parallax by which the height of the meteor above the earth, the length and direction of the path, and other like quantities may be computed. The general result from several hundred instances is that the region of meteor paths may be in general regarded as between 40 and 80 miles above the earth's surface. Some first appear above 80 miles, and some descend below 40 miles. But an altitude greater than 100 miles, or one below 25, except in the case of a stone-furnishing meteor, must be regarded as very doubtful. Thus the meteor paths are far above the usual meteorological phenomena, which (except auroras and twilight) have not one-tenth of the height of the meteors. But with reference to all other astronomical phenomena they are very close to us. The comets, for example, are well-nigh a millionfold, and even the moon is a thousandfold, more distant from us.

Velocities of Meteors.—When the length of a luminous path is known, and the time of describing it has been observed, it is easy to compute the velocity in miles. Unfortunately the large meteors, describing long paths, come at rare intervals, and unexpectedly, and it is a happy accident when one is observed by a person accustomed to estimate correctly short intervals of time. On the other hand, the total time of visibility of the shooting stars, which come so frequently that they may be watched for, is usually less than a second. It is not easy to estimate correctly such an interval, where the beginning and ending are not marked by something like a sharp click. Hence all estimates and computations of velocities of meteors are to be received with due regard to their uncertainty. We may only say in general that the velocities computed from good observations are rarely if ever under 8 or 10 miles a second, or over 40 or 50 miles, and that some have far greater velocities than others. The average velocity seems to be nearly 30 miles.

What makes the Luminous Meteor.—The cause of a meteor is now universally admitted to be something that enters the earth's atmosphere from without, with a velocity relative to the earth that is comparable with the earth's velocity in its orbit, which is 19 miles per second. By the resistance it meets in penetrating the air the light and other phenomena of the luminous train are produced. Under favourable circumstances, portions of these bodies reach the earth's surface as meteorites.

Meteoroids.—A body which is travelling in space, and which on coming into the air would under favourable circumstances become a meteor, may be called a meteoroid.

The meteoroids are all solid bodies. It would hardly be possible for a small quantity of gas out in space to retain such a density as would enable it on coming into the air to go 10 or 100 miles through even the rare upper atmosphere, and give us the clear line which a shooting star describes. Even if a liquid or gaseous mass can travel as such in space, it would be instantly scattered on striking the air, and would appear very unlike a shooting star or bolide.

Numbers of Meteors.—Of the larger meteors there are in the mean six or eight per annum which in the last fifty years have furnished stones for our collections. A much larger number have doubtless sent down stones which have never been found. Thus Daubrée estimates for the whole earth an annual number of six or seven hundred stone-falls.

But of the small meteors or shooting stars the number is very much larger. Any person who should in a clear moonless night watch carefully a portion of the heavens would, in the mean, see at least as many as eight or ten shooting stars per hour. A clear-sighted and practised observer will detect somewhat more than this number. Dr Schmidt of Athens, from observations made during seventeen years, obtained fourteen as the mean hourly number on a clear moonless night for one observer during the hour from midnight to 1 A.M. A large group of observers, as has been shown by trial, would see at least six times as many as a single person. By a proper consideration of the distribution of meteor paths over the sky, and in actual altitude in miles, so as to allow for mists near the horizon, it appears that the number over the whole globe is a little more than ten thousand times as many as can be seen in one place. This implies that there come into the air not less than twenty millions of bodies daily, each of which, under very favourable conditions of absence of sunlight, moonlight, clouds, and mists, would furnish a shooting star visible to the naked eye. Shooting stars invisible to the naked eye are often seen in the telescope. The numbers of meteors, if these are included, would be increased at least twentyfold.

How densely Space is filled with Meteoroids.—By assuming that the absolute velocity of the meteors in space is equal to that of comets moving in parabolic orbits (we have good reason to believe that this is nearly their true velocity), we may prove from the above numbers that the average number of meteoroids in the space that the earth traverses is, in each volume equal to that of the earth, about thirty thousand. In other words, there is in the average to every portion of space equal to a cube whose edge is about 210 miles one meteoroid large enough to make a shooting star bright enough to be visible to the naked eye. Such meteoroids would, upon an equable distribution, be each in round numbers 250 miles from its near neighbours. All these numbers rest upon Dr Schmidt's horary number fourteen, and for a less practised observer and a less clear sky they would be correspondingly changed. How much they would need to be altered to represent other parts of space than those near the earth's orbit is a subject of inference rather than of observation.

Motion in Space.—The meteoroids, whatever be their size, must by the law of gravitation have motions about the sun in the same way as the planets and comets, that is, in conic sections of which the sun is always at one focus. The apparent motions of the meteors across the sky imply that these motions of the meteoroids relative to the sun cannot as a rule be in or near the plane of the ecliptic. For if they were there, since the motion of the earth is also in the ecliptic, the motion of the meteoroids relative to the earth would be in the same plane. This would involve that all the meteor paths as seen on the sky would if produced backward cross the ecliptic above the horizon. In fact there is no tendency of this kind. Hence the meteoroids do not move in orbits that are near the ecliptic as the planets do, but like the comets they may and usually do have orbits of considerable inclinations.

Numbers through the Night.—There are more meteors seen in the morning hours than in the evening. If the meteors had no motion of their own in space, the earth would by its motion receive the meteors only on the hemisphere that was in front. There would be no meteors seen in the other hemisphere. On the other hand, if the meteors had such large velocities of their own as that the earth's velocity might be neglected in comparison, and if the directions of the meteors' motions were towards all points indiscriminately, then as many would be seen in one part of the night as another. In fact there are about three times as many seen in the morning hours as in the evening. The law of change from evening to morning gives a means of proving that the mean velocity of meteors is so great that they must in general be moving in long orbits about the sun. In this respect also the meteoroids resemble comets, and are unlike planets, in their motions. Of the stone-furnishing meteors more are seen in the day than in the night, and more in the earlier hours of the night than in the later. This is probably due to the fact that more persons are in a position to see the stone-falls at the periods of greater abundance.

Star Showers.—While the average number of shooting stars for a single observer at midnight may be regarded as tolerably constant, there have been special epochs when many more have been seen. In certain instances the sky has been filled with the luminous trains, just as it is filled by descending snowflakes in a snowstorm, making a veritable shower of fire. One of the best-observed, though by no means the most brilliant, of these showers occurred on the evening of the 27th of November 1872. Some of the observers of that shower, counting singly, saw at the rate of eight or ten thousand shooting stars in the course of two hours. The distances of the meteoroids in the middle of the swarm which the earth then passed through, each from its nearer neighbours, would be 30 or 40 miles.

The following quotations show the impression made by star showers in times past :—

"In the year 286 [of the Hegira] there happened in Egypt an earthquake on Wednesday the 7th of Dhu-l-Ḳa'dah, lasting from the middle of the night until morning; and so-called flaming stars struck one against another violently while being borne eastward and westward, northward and southward, and no one could bear to look toward the heavens on account of this phenomenon."

"In the year 599 [of the Hegira], on the night of Saturday, on the last day of Muharram, stars shot hither and thither in the heavens, eastward and westward, and flew against one another like a scattering swarm of locusts, to the right and left; people were thrown into consternation, and cried to God the Most High with confused clamour."

"These meteors [November 12, 1799] might be compared to the blazing sheaves shot out from a firework."

"The phenomenon was grand and awful; the whole heavens appeared as if illuminated with sky rockets."

November 13, 1833. "Thick with streams of rolling fire; scarcely a space in the firmament that was not filled at every instant."

"Almost infinite number of meteors; they fell like flakes of snow."

November Meteors or Leonids.—These quotations all refer (except possibly the first) to a shower which has appeared in October and November of many different years since its first known occurrence on the 13th of October 902 A.D. Dates of these showers are given in the following table :—

Oct. 13, 902.	Oct. 17, 1101.	Oct. 28, 1602.	Nov. 13, 1833.
Oct. 15, 931.	Oct. 19, 1202.	Nov. 9, 1698.	Nov. 14, 1866.
Oct. 14, 934.	Oct. 23, 1366.	Nov. 12, 1799.	Nov. 14, 1867.
Oct. 15, 1002.	Oct. 25. 1533.	Nov. 13, 1832.	Nov. 14, 1868.

On several years after 1833, and before and after 1866–68, there were unusual numbers of those meteors seen on the mornings of November 13, 14, and 15, though perhaps they would have been unnoticed had there not been special watching for them. It will be seen that all these showers are at intervals of a third of a century, that they are at a fixed day of the year, and that the day has moved steadily and uniformly along the calendar at the rate of about a month in a thousand years. The change of twelve days in the 17th century is due to the change from old to new style.

The only explanation of this periodical display that is now seriously urged, and the one which is universally accepted by astronomers, is that there is a long thin stream of meteoroids, each of which is travelling about the sun in a conic section. These conic sections are all nearly parallel, and have nearly the same major axis, extending out about as far as to the orbit of Uranus, and each requiring the common period of thirty-three and a quarter years. The length of the stream is such that the most advanced members are six or eight years ahead of the hindermost, and they all cross the earth's orbit with a velocity of about 26 miles a second. Since the earth plunges through the group nearly in the opposite direction, the velocity with which they enter the air is 44 miles a second. One of the facts which have greatly aided us in arriving at this explanation is that these meteors in all the years and through all hours of the night cross the sky as we look at them in lines which diverge from a point near the centre of the sickle in the constellation Leo; hence the paths in the air are parallel. This implies that their velocities relative to the sun are all parallel and equal to each other. The radiation from Leo has given to them the name *Leonids.*

Orbit of the Leonids.—This orbit, common to all the Leonid meteors, is inclined to the ecliptic at an angle of 17° (or rather 163°, since the motion is retrograde), has a major axis of 10·34, a periodic time of 33·27 years, and a perihelion distance a little less than unity.

The above orbit, and that alone, explains the several appearances of the November meteors, the annual and the thirty-three year periods, the radiation from Leo, and the change of day of the month in the course of the centuries. This it does so completely that the result has never been questioned by astronomers. Shortly after the publication by Professor Adams in 1867 of the last link in the chain of the proof of this orbit, there was also published the definitive orbit of the comet 1866 I. That the comet was running almost exactly in the orbit of the meteors was at once recognized. In fact the comet is itself, in a sense, a meteoroid, and the principal member, so far as we know, of the group. Leonids had been seen in 1863, two years and two months in advance of the comet, while those of 1866 were ten months behind it. Those of later years (a few Leonids were seen even in 1870) were extended along the line of the comet's path behind it. The leaders of this long file of meteoroids had passed up beyond the orbit of Jupiter long before those which brought up the rear had crossed that planet's orbit going down toward the sun. The thickness of the stream is less than the ten-thousandth part of its length. In the densest part that we have recently passed through—namely, that traversed in 1833—the density of the stream may be expressed by saying that each meteoroid must in the mean have been 10 or 20 miles from its nearest neighbours.

What makes this Comet and these Meteors describe the same Orbit about the Sun?—Its path might have been inclined to the ecliptic at any angle instead of 163°. Or, with this inclination, its plane might have cut the earth's orbit at any other place than where the earth is on the 14th

of November. Or, happening to have these two elements in common, it might have passed the earth's orbit nearer the sun or farther away from it than the earth is. Or, having these three things in common, it might, by a slight difference in velocity, have had a periodic time much more or much less than thirty-three years. Or, with all these in common, it might have crossed the earth's orbit at a far different angle than the meteors. These several independent elements for the comet and the meteors are substantially identical, and this identity proves almost beyond doubt that between the two either there is now an actual or else there has been in the past a causal connexion. That there is now any physical connexion is thoroughly disproved by the immense magnitude of the stream, and by the isolation and distances from each other of the individual components. It seems difficult to find any cause that should bring into such a strangely shaped group bodies that had originally orbits distributed at random. Hence we are apparently forced to conclude that these meteoroids have something common in their past history. In fact they seem to have been once parts of a single body, and these common elements are essentially those of the parent mass. By some process not yet entirely explained they have become separated from the comet, thrown out of the control of its attractive power, and so left to travel each one in its own orbit. If the cause of separation was not too violent, each new orbit would necessarily be but slightly different from that of the comet. Very small variations in velocity, and hence in periodic time, would in the course of ages scatter the several individuals along the orbit even to the length of many hundreds of millions of miles.

The Meteor Group is not the Comet's Tail.—These meteoroids must be carefully distinguished from the comet's tails. The former follow or precede the comet exactly in the comet's path; the particles that compose the latter are driven off by the sun's repulsion directly away from the comet's path. The meteoroids and the comet have orbits with nearly common elements; the orbits of the particles of the tail have elements that are unlike each other, and unlike those of the comet. The meteoroids are undoubtedly solid masses; the tails are pulverulent or gaseous.

Twin Comets of 1366.—The comet 1866 I. is probably not the only one that has been connected with the November meteors. In 1366, a few days after the earth went through the meteor stream, a comet appeared in the northern heavens, and, passing directly in the line of the stream so close to the earth as to describe an arc of 90° in a single day, disappeared in the constellation Aquarius. Immediately upon its disappearance a second comet was seen in the north, which followed nearly in the same path. The Chinese accounts are not sufficiently exact to furnish independent orbits for them, but both comets were undoubtedly members of the Leonid stream. The comet 1866 I. may be identical with one of them.

The Andromeds and Biela's Comet.—Mention has been made of the star shower of November 27, 1872. The periodical comet known as Biela's, which makes three revolutions in twenty years, passes very near the earth's orbit at a longitude corresponding to November 27, but by reason of its direct motion the node has had considerable motion in longitude as the result of perturbations. Meteors having the same orbits as Biela's comet would have a radiant in the constellation Andromeda, that is, would cross the sky in lines diverging from a point in that constellation. They might, however, be at dates after or even before November 27.

Unusual numbers of meteors were seen December 7, 1798, by Brandes. A like abundance was seen December 7, 1838; and, as they had been expected, and radiation was now looked for, they were found to diverge from a point in Andromeda. Hence they have been called Andromeds. Since 1852 Biela's comet itself has been entirely lost. The star shower of November 27, 1872, previously referred to, had a radiant in Andromeda, and in every way appeared as though its meteors had once been parts of Biela's comet. A sprinkle three days earlier, on the night of November 24, had the same radiant, and came from a less dense outlying parallel stream. A small comet was seen in the southern sky by Pogson in the direction opposite to the radiant shortly after the shower. Biela's comet had been found in 1845–46 to be in two parts, which at its next return to perihelion in 1852 had separated to eight times their former distance. But the meteor streams of 1872 could hardly have been separated from the comet so recently, and the Pogson comet if of the same origin must also have left the parent mass at an earlier date than 1845. No ordinary perturbations would in a short period have so changed the orbits. The parts of the small stream traversed by the earth, December 1838 and December 1798, were far from the comet, and these fragments must have been thrown off much earlier.

The Perseids and the Comet 1862 III.—There is a third epoch when meteors appear in unusual numbers, viz., the 9th to 11th of August. This "sprinkle," as it may be called, has been seen constantly at the time named for nearly fifty years, and there are on record accounts of similar appearances in the earlier years before its annual character had been discovered. Some observers have thought that there were evidences of a variation having a long period, but the proof seems as yet unsatisfactory, and the display may be regarded as tolerably constant from year to year. On every 10th of August we may confidently expect a display of meteors that shall be at least four or five times as numerous as those of ordinary nights. The radiant is in the constellation Perseus, and hence the name Perseids.

The comet 1862 III., which has a period of more than a hundred years, passes close to the earth's orbit, nearly cutting it at the place of this shower, and has a velocity and direction corresponding to this radiant. Hence a connexion of the Perseid meteors with this comet is presumed, like that which the Leonids and Andromeds have with the comet 1866 I. and Biela. The meteors are distributed along this orbit more regularly than along either of the other two, and at the same time the breadth of this group is a hundred times greater than that of the Leonids. We must for the present regard it rather as a meteor ring, the meteoroids being scattered along the entire conic section which the comet describes. This ring has an inclination of 113° with the ecliptic.

Meteors of April 20–21—*Lyraids.*—About the 20th of April there have been several quite brilliant star showers, the earliest on record having been in the year 687 B.C. On that day meteors have been observed which radiated from Lyra, and to these the name Lyraids has been given. The comet 1861 I. passes near the earth's orbit in that longitude, and any meteors having such a connexion with it as is proved for the Leonids with comet 1866 I. would also radiate from Lyra.

Again, at several other periods of the year, meteors have been seen in unusual numbers which seem to be connected with certain comets.

Meteor Radiants.—We have thus definite proof that the earth at certain epochs plunges through meteor streams, and that these streams travel along the same track as certain comets. The question is at once asked—Do not the sporadic meteors, those which are seen on any and all nights of the year, belong to similar streams? An immense amount of labour has been spent in observing the paths of meteors, and classifying them, so as to detect and prove the existence of radiant points. As many as a thousand such radiants have been suggested by the different investigators. Some of these are duplicates, some will prove to be accidental coincidences; but a goodly number may reasonably be expected to endure the test of future observations. Such will show the existence of meteor streams, and perhaps will be connected with comets that are now known, or that may hereafter be discovered.

The radiants have been spoken of as if they were points in the heavens. This is so nearly true as to justify all the conclusions that have been deduced above. But in fact a radiant, even in the star showers in which it is most sharply defined, must be regarded as a small area. The apparent meteor paths when produced backward do not exactly meet in a point. If they be treated as proceeding from a small area, it does not appear that this is a long narrow one. Hence it may be shown that the paths of the meteors in the air are not exactly parallel either to a line or to a plane. This can hardly be due to a want of parallelism of the paths before the meteoroids meet the earth, but is rather due to their glancing as they strike the