in Greek Lands," F. H. Marshall; and "Life and Labour in the 19th Century," C. R. Fay. *Messrs. Constable and Co., Ltd.*, announce "Montessori Experiments," Miss Blackburn. Prof. Patrick Geddes has written a volume, which *Messrs. Longmans and Co.* will issue shortly, on the life and work of Sir Jagadis Chandra Bose, the founder of the Bose Research Institute in Calcutta.

OUR ASTRONOMICAL COLUMN.

FIREBALL ON DECEMBER 25.—A brilliant fireball was visible on Christmas night at 10h. 21m. at Bristol. It must have very much exceeded Venus in lustre, for it gave a flash which illumined the whole sky, and in that section of its flight where the greatest outburst occurred it left a streak about 3° long for 40 seconds. The apparent path was from 115°+34° to 105½°+1°. The motion was rather swift, the course of about 35° being traversed in 2 seconds. The radiant point is doubtful; it may have been at 165°+73°, 219°+75°, 245°+72°, or 261°+62°. If the second is the correct position, the meteor may quite possibly be considered to have been a fragment of Mechain-Tuttle's comet, which has a period of about 13½ years. Further observations of the object would be valuable, and should be sent to Mr. W. F. Denning, 44 Egerton Road, Bristol.

COMETS.—The following continuation of the ephemeris of Finlay's comet is for Greenwich midnight, from the elements in Lick Bull. 325:—

	R.A. h. m. s.	N. Decl. ° ′	Log r	Log Δ
Jan. 2 ...	3 3 35	21 47	0·1703	9·8160
6 ...	3 12 57	22 24	0·1806	9·8510
10 ...	3 22 24	22 58	0·1911	9·8849
14 ...	3 31 21	23 27	0·2013	9·9173
18 ...	3 40 9	23 55	0·2114	9·9485

The comet will traverse the Pleiades on January 18.

It is calculated that Holmes's comet passed perihelion about November 30, and a search ephemeris was published. The comet is probably too faint to give much hope of its recovery. It has not been seen for two revolutions.

RADIATION PRESSURE.—The *Astrophysical Journal* for October last contains an article by Mr. Megh Nad Saha in which the opinion is expressed that the quantum theory of light will explain the repulsion of particles much more minute than those the dimensions of which are of the order of a wave-length. In the undulatory theory the repulsion is a maximum for particles of that order of magnitude, and becomes practically zero for those of the dimensions of molecules. Mr. Saha quotes the results of spectrum analysis of comets' tails, and some laboratory experiments by Lebedew (*Ann. der Physik*, 1910), for the fact that gaseous molecules actually do suffer repulsion by radiation pressure, which he considers an argument in favour of the quantum theory.

Assuming that a pulse of light gives all its momentum to a hydrogen atom, the velocity imparted to the latter by each "kick" would be 60 cm./sec. Some calculations are given, from which the author deduces that by repeated "kicks" the atom might acquire a velocity of 6×10^7 cm./sec., which has sometimes been observed in the solar prominences.

THE ORION NEBULA.—We lately noted Dr. Bergstrand's estimate of the parallax of this object, 0·0078″. Prof. W. H. Pickering (Pubns. Ast. Soc. Pac., April, 1919) contends for the value 0·0020″. This is deduced from assumptions of the absolute magnitudes of a number of faint stars which appear to be associated with the nebula. By comparing their photographic with their visual magnitudes, he concludes that their spectral type is A or B, whence their absolute magnitude is unlikely to be very low. But this involves the conclusion that the brighter stars in Orion are super-giants. Rigel in particular would have 87,000 times the luminosity of the sun. But perhaps it is nearly as easy to accept this as the value 5000 times the sun, which results from Dr. Bergstrand's parallax. Prof. Pickering estimates for the masses of the faint B7 stars in the nebula only four times that of Jupiter, using his parallax. With Kapteyn's parallax 0·0054″, the mass would be one-twentieth of this. Either value seems far too small for a body to attain the temperature necessary to shine as a B star.

SPHERICAL SHELL CRYSTALS IN ALLOYS.

AT the autumn meeting of the Institute of Metals recently held in Sheffield, Dr. J. E. Stead presented an account of his investigations on some ternary alloys of tin, antimony, and arsenic, one of which was noticed by him to crystallise in a most unusual and remarkable way.

Having found that the alloys of antimony and tin crystallise in what appear to be cubic crystals, and those of in and arsenic in rhombohedral flat plates, he made trials with the object of finding how the metals would arrange themselves when the three elements were fused together and the melt allowed to cool. The results obtained were astonishing, for the crystals found in the matrix had the form of incomplete spherical shells, the radii of which were small or great, according to the time allowed for development. With rapid freezing the radii were less than half a millimetre; when it was protracted for one hour they were 5 mm. or more. The most perfect structural arrangement of the crystals was obtained in an alloy containing from 70–85 per cent. of tin, 25–15 per cent. of antimony, and 4–5 per cent. of arsenic. Whether cooled slowly or quickly, the polished surface of the alloys, after dissolving away the matrix, is very suitable for printing blocks, since the hard crystals stand out in bold relief (see Fig. 1). The alloys are very brittle, and the fracture was found to travel midway along the shell walls. An alloy containing tin 70 per cent., antimony 25 per cent., and arsenic 5 per cent. gave the following arrests on cooling:—

(1) First separation of crystals ... 440° C.
(2) Retardation in cooling between 325° and 320° C.
(3) Solidification of the eutectic ... 244·9° C.

The last-named temperature agrees closely with that of the eutectic of the tin-antimony alloys. The conclusion is, therefore, warranted that the eutectic cannot contain more than a trace of arsenic, an inference confirmed by experiment. It was afterwards shown by analysis that the primary crystals contain a maximum amount of arsenic, and that, as crystallisation proceeds, the deposits contain less and less of this metal.

A large number of ternary alloys were prepared. It was found that, while it required 2·5 per cent. of arsenic in the presence of 25 per cent. of antimony to produce slightly curved crystals, 0·5 per cent. of arsenic in the presence of 3·75 per cent. of antimony yielded curved segments in the upper layers. In an alloy containing 1·65 per cent. of arsenic, 14·35 per cent. of antimony, and 85 per cent. of tin, spherical crystals were found in the top layers, below these smaller segments, under the latter cuboidal crystals, while the lowest stratum consisted of the eutectic. It was evident that the compound richest in arsenic was the first to freeze and floated upwards to the surface. As yet the analyses have given no decisive results as to the composition of these shells. Further details have been promised by Dr. Stead, and will be published in due course.

FIG. 1 (Nature-prin).

In the instance just quoted, four distinct stages of crystal growth can be observed. When, however, the proportion of antimony is between 20 and 25 per cent. and that of arsenic about 5 per cent., the primary crystals are distributed evenly through the whole alloy and there is no stratification.

That the primary crystals which form in such alloys are spherical shell crystals was shown by chilling

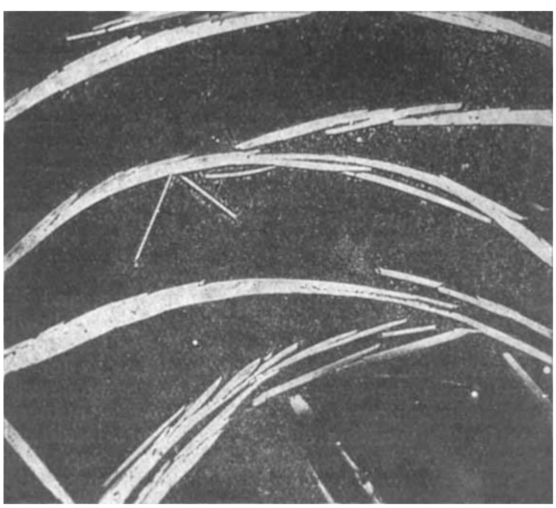

FIG. 2 (Photograph).

them just below the first thermal arrest. Fig. 2 depicts the structure after this operation. Sections of the shells are visible which are smooth on the concave, but slightly broken on the convex, side, due possibly to the stresses set up during quenching. With somewhat slower cooling, as shown in Fig. 3, both surfaces of the shells are seen to be smooth. That these are composite and contain a hard primary core was shown by grinding and polishing experiments.

In the latter part of his paper Dr. Stead quotes the opinion of Mr. L. J. Spencer, to whom specimens of the alloy containing spherical shells were submitted for his opinion, and who furnished Dr. Stead with important data regarding the curvature of crystals in minerals. Mr. Spencer's complete notes on the subject have been communicated to the Mineralogical Society. In them he refers to various instances of apparent curvature classified under these headings:—

(1) Curved crystallites; (2) capillary habit; (3) aggregations of crystals; (4) interfacial oscillations; (5) vicinal faces; (6) bent crystals; (7) twisted crystals; and (8) cylindrical and spherical crystals.

It would appear that, according to his view, the last-named constitutes the closest analogy to the alloy in question. "The mineral kylindrite is a sulphur salt of tin, lead, antimony, and iron. . . . It has the appearance of consisting of tightly wound rolls of foil with a smooth surface and a brilliant metallic lustre. The ore consists of large numbers of these rolls, with a more or less radial grouping. . . . The rolls have a diameter of a few millimetres up to one centimetre,

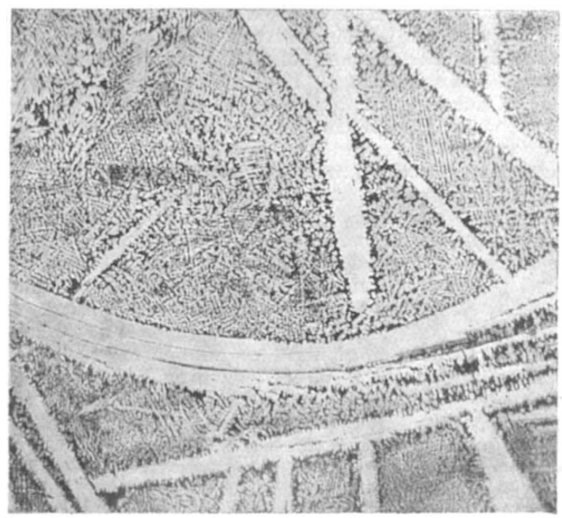

FIG. 3 (Photograph).

and reach a length of three to four centimetres. They flake off in concentric cylindrical shells with all the appearance of a perfect cleavage, very similar to that of the allied minerals, franckeite and teallite. These cylindrically curved cleavage flakes are perfectly bright and smooth and show no visible signs of being built up of smaller elements. Spherical aggregates of crystals possessing a perfect cleavage are, however, met with, but here a radial grouping is much more common than a concentric arrangement. Examples of radiating spherical aggregates of lamellar crystals with platy cleavages are pyrophyllite, zeophyllite, gyrolite, faröelite, tyrolite, etc."

With reference to the cases of curvature in mineral crystals thus referred to, Dr. Stead contends that none approach in character or form the spherical shell crystals obtained in his ternary alloys; that radial crystallisation round a nucleus is common in minerals, but the spherical form finally produced is an aggregation of many crystals, and not a single crystal; and that kylindrite consists of a number of cylindrical crystals which have formed round a central axis and are not independent cylinders. He states that no case is known to him in which the idiomorphic forms of the crystals are segments of spherical shells which have crystallised out of a liquid except in the ternary alloys referred to. The reason why idiomorphic shell crystals develop under such conditions and the laws which govern their formation await further research. Meantime, Prof. Bragg, to whom some of the separated crystals have been sent, has kindly promised to study them. H. C. H. C.

FORECASTING FROSTS.

IN most countries during the spring, and to a lesser extent in the autumn, there are periods in which the meteorological conditions result in a frost. Leaving out of the question spells of cold weather, the prediction of which is the concern of a Meteorological Service, there remains the possibility of local frosts in isolated districts, occurring on clear, windless nights and lasting for a portion of the night and early morning. These frosts are capable of doing great damage to fruit-trees, etc., and the possibility of forecasting them in time for the fruit-growers to take precautions is of interest and importance.

It has long been recognised that local cooling of the soil can be largely prevented by a smoke pall produced by the burning of damp materials such as straw. Boussingault ("Economie Rurale," Paris, 1844) discusses this, and records an observation on the point by Pliny. In America definite systems of frost prediction have been in operation for some years, and practical methods have been evolved by which the grower can economically combat the danger to his crops. A study of these preventive measures is instructive in showing that several causes are concerned in producing a frost. The methods are varied. Leaving out those which attempt to delay the flowering-time until the danger period is past, they fall into four main classes:—(1) Increasing the water-content of the area (spraying or flooding); (2) "smudge" burning (damp smoke from wet straw, etc.); (3) temporary roofing; and (4) dry heating. The last method supplies additional heat mainly; the other three are largely indirect, and aim at reducing the rate of temperature fall either by increasing the heat capacity of the soil by the added water or by restricting the radiation from the soil.

Up to the present no complete correlation has been made of frost in any particular locality and its causes. For this purpose an examination by statistical methods of a series of continuous observations (of the automatic recording type) of meteorological factors is needed. The published papers deal usually with one factor, such as dew-point or air temperature, and the number of daily observations made is small. This is, no doubt, due to the necessity of keeping the cost of apparatus and working as low as possible for the sake of the growers. However, a general idea of the factors concerned can be obtained from a broad survey of the various papers.

The effect of an overcast sky on air temperatures near the ground has been studied by Hellman (*Preuss. Akad. Wiss.*, Berlin, 38, 1918, p. 806), who on clear nights found an exponential decrease of temperature with height, the average difference from ground-level to a height of 50 cm. being 3·7° C. An increase of cloudiness by 1° of scale (0=clear, 10=overcast) diminished this difference by at least $\frac{1}{3}$° C. There was no temperature gradient when the sky was overcast, while windy and rainy weather resulted in a slight reversal of the gradient. Schubert (*Met. Ztsch.*, 32, 1915, p. 343) considers that during the last half of the night the fall of temperature is relatively greater with dry than with moist air, owing to the formation of dew, and frost from the latter resulting in latent heat being set free by the condensation. The presence of water-vapour in the atmosphere also retards the radiation cooling of the soil.

J. Warren Smith (*U.S. Monthly Weather Review*, 42, 1914, p. 573; 45, 1917, p. 402) has examined the accuracy of various methods of temperature prediction. The first, and simplest, is to subtract from the maximum temperature of the day the known average fall in temperature on clear, still afternoons and evenings for the appropriate period of the year. This temperature range varies in different months, but is remarkably uniform under similar topographical conditions and at similar seasons of the year. It has been used by Church (Nevada Station Report, 1915, p. 46).

The second method is due to Smith, and involves two temperature readings daily. Smith discovered that the daily temperature curves showed marked similarity in periods of calm, clear weather when a high-pressure system was centred over the district and conditions were favourable for strong insolation during the day and free radiation at night. For these curves the half-way point in the temperature fall from the maximum of one day to the minimum of the next morning (the "median") occurred at very nearly the same time. Hence a forecast of the probable minimum can be made by subtracting from the maximum the temperature shown at the time previously ascertained to be that of the median. and then subtracting this difference in turn from the observed median temperature. The values thus obtained agreed much more closely with the observed minima than those given by the original dew-point method, which is mentioned immediately below.

The third method, as developed by Smith, is an elaboration of the dew-point determination. This, as used by Hazen (Minn. Expt. Sta. Bull. 12, 1890), and by O'Gara (U.S. Farmers' Bull. No. 401, 1915), consists simply in determining the dew-point in the early evening (6–10 p.m.), and assumes the dew-point temperature will be the probable minimum temperature reached. Smith found that the prediction could be made much more accurately if the relative humidity of the atmosphere was also determined, and he used the correlation method to show that with high relative humidity the minimum temperature falls below the determined dew-point, while with low relative humidity the reverse is true. A satisfactory equation expressing this relation was obtained,

$$Y = 18{\cdot}314 - 0{\cdot}39R,$$

where R=relative humidity in the evening, and Y is departure of minimum temperature of the following morning from evening dew-point. A determination of R gives the value of Y, which added to (or subtracted from) the dew-point gives the probable minimum temperature to be expected. The numerical terms in the equation differ for different localities.

Recently T. B. Franklin (Proc. Roy. Soc. Edin., 39, 1919, p. 120) has published some observations on the cooling of the soil at night, with special reference to late spring frosts, and has arrived at a number of important conclusions, which will help considerably in developing methods for forecasting the minimum surface-soil temperature in this country. As a result of observations of temperatures in the air, on the soil, and at a depth of 4 in., Franklin concludes that a prediction of frost depends on assessing the value of:—(1) Average relative humidity during the night; (2) the temperature of a given depth (4 in.) at the time of surface minimum temperature; (3) the conductivity of the layer between the assigned depth