metallurgical engineering, Case School of Applied Science; John F. Eckel, A.B., chemistry, University of Kansas; Hyman Freeman, B.S., engineering chemistry, Georgia School of Technology; Frank C. Norris, B.S., chemical engineering, University of Illinois, and Harold E. White, E.M., mining and metallurgy, Lehigh University. The research fellows will begin their work on August 15 for a period of ten months. Two advisory boards, one composed of mining engineers and operators, and the other of metallurgical engineers and steel executives, will assist in selecting the problems for study. Each research fellow will conduct his studies under the direction of a senior investigator from the Bureau of Mines. At the completion of their studies they will be eligible to receive the degree of master of science from the Carnegie Institute of Technology. As in the past, reports of the investigations to be made during the coming college year will be published in bulletin form for public distribution.

UNIVERSITY AND EDUCATIONAL NOTES

BY the will of Randolph McNutt, a furniture dealer of Buffalo, N. Y., Dartmouth College receives the residuary estate, valued at more than $750,000, to be used for general educational purposes.

AN annual appropriation of $10,000 for five years has been given to Princeton University by the Public Service Electric and Gas Company of New Jersey for the advance of "pure scientific research."

THE Burma Oil Company has offered £100,000 to the new Rangoon University, India, for a college of mining and engineering, to be associated with the name of the company.

DR. BARNETT SURE, of the College of Agriculture of the University of Arkansas, has been promoted to a professorship and has been appointed head of the department of agricultural chemistry.

DR. JAMES B. KENDRICK, of the department of botany of Purdue University Agricultural Experiment Station, has been appointed associate professor in the division of plant pathology of the University of California, at the experiment station at Davis, California.

DR. G. L. CLARK, assistant professor of chemistry in the chemical engineering department of the Massachusetts Institute of Technology, will succeed Dr. G. D. Beal next year at the University of Illinois, where he has been appointed associate professor.

S. F. BIBB, of the University of North Dakota, has been appointed professor of mathematics at the Armour Institute of Technology.

DR. I. DE BURGH DALY, lecturer in experimental physiology in the Welsh National School of Medicine of the University of Wales, Cardiff, has been appointed to the chair of physiology in the University of Birmingham to succeed Professor E. Wace Carlier, who has retired.

DISCUSSION AND CORRESPONDENCE

THE STACKABILITY OF TETRAKAIDECAHEDRA

IN the issue of SCIENCE for June 18, 1926, Frederic T. Lewis, in a communication entitled "An Objective Demonstration of the Shape of Cells in Masses," makes the following statement: "Meanwhile Lord Kelvin had found that a fourteen-sided figure—a cube truncated by an octahedron[1]—having six quadrilateral and eight hexagonal surfaces, solves the problem of dividing space without interstices into uniform bodies of minimal surface."

In the issue of SCIENCE for September 3, 1926, John Millis, in a communication under the title, "The Shape of Cells in Masses," begins his paper with the above quotation from the article by Lewis. Millis continues as follows: "The statement is a correct expression of Lord Kelvin's claim as set forth in the somewhat famous Baltimore lectures of several years ago. But the claim is entirely wrong. Having been myself perplexed by so direct and confident an announcement from such an eminent source, let me ask that a definite correction of a serious error be now made in order that others may be saved from being misled and perhaps from consequent mistakes. The volume described, called the tetrakaidecahedron, does not possess the properties as stated. Equal volumes of this pattern will not fit together without voids, as a brief consideration of the dihedral angles or the angles between the faces and the relations of the faces or a practical trial with models would at once have shown."

Such a positive and detailed criticism, pointing out the claimed "error" in Lord Kelvin's equally positive statement, supported by Lewis, might have settled the matter, except that the writer took the suggestion made by Millis in the last sentence quoted above and considered the dihedral angles and even constructed models as advised. If one consider the cross-sectional plane through the center of the volume (passing the sectioning plane perpendicularly through a face of the figure), the resulting section is a hexagon. If we consider the angles in the hexagon we find that they are equal to the corresponding dihedral angles of the volume in question and are as follows:

[1] "The edges of a regular octahedron are trisected. Each vertex of the octahedron is then cut off by a plane passing through the points of trisection adjacent to the vertex. The resulting solid is a regular tetrakaidecahedron."—Graustein.

(1) between quadrilateral and hexagonal
(2) between hexagonal and hexagonal
(3) between hexagonal and quadrilateral
(4) between quadrilateral and hexagonal
(5) between hexagonal and hexagonal
(6) between hexagonal and quadrilateral faces.

It will be seen further that there are two angles of type A (between hexagonal and hexagonal faces) and four angles of type B (between hexagonal and quadrilateral faces) and these angles of the polygon (a hexagon) sum up to 720 degrees. It follows then that:

$$A + 2B = 360 \text{ degrees.}$$

It must be evident that the volume is stackable if the dihedral angles around any and every line at the intersection of planes can be shown to be three in number, one of which is of type A and two of which are of type B. Perhaps at this stage it would be well to heed Millis's advice and construct a model. This can be rather easily done by paper-folding, or by taking a fairly stiff copper wire and a pair of pliers and weaving the desired pattern. It is then quite easily shown that, when stacked, any line of intersection in the mass is at once the side of an equilateral quadrilateral and of two adjacent equilateral hexagons. The dihedral angles are therefore: one of type A (hexagon-hexagon) and two of type B (hexagon-quadrilateral).

It should be pointed out that the octahedron should truncate the cube in such a way that equilateral hexagons result, *i.e.*, all sides of quadrilaterals and hexagons are equal. If this is not done, the 1, 3, 5 sides of a hexagon will not be the same length as the 2, 4, 6 sides. Experimentation will show that in stacking the volumes the 1, 3, 5 sides of a hexagon in one figure must coincide with the 2, 4, 6 sides of a hexagon in a second figure, etc. Obviously, if they are of unequal length, this becomes an impossibility and therein may lie a meager basis for Millis's error.

There is no doubt that the figure mentioned by Lewis is stackable.[2]

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[2] When the letter from Colonel Millis was brought to the attention of Professor W. C. Graustein, he wrote out a brief mathematical demonstration that Lord Kelvin was right; tetrakaidecahedrons are space-filling. Meanwhile Colonel Millis, quite independently, had arrived at the same conclusions. The publication of their letters was not requested. A further treatment of the same subject may be found in the *Bulletin of the Torrey Botanical Club,* 1927, Vol. 54, pp. 341–348.—EDITOR.

EARTHWORMS AND LIGHT

IN a previous note printed in SCIENCE I have mentioned the effect that ordinary light, such as that emitted by a three-celled electric flashlight, has on earthworms. When such a light is thrown at close range on the anterior or pigmented portion of the worm's body it usually causes instant withdrawal of the creature into its burrow. It seems quite possible that sensitivity to light in the earthworms is associated with this pigment, which is of a purplish hue and in sunlight glistens with iridescent color. It occurs most densely on the anterior fourth of the body, which region quite obviously is most sensitive to light.

Recently I have experimented with lights of various colors to determine the reaction of the worms (*Lumbricus terrestris* Linn.), to them and was much interested to discover that light transmitted through a red glass of the sort commonly used for photographic dark-room lamps had no visible effect on them, as apparently they did not perceive it. A 40-watt electric light bulb was used in the red lamp and even when this was brought within four inches of the worms they continued undisturbed in their ordinary occupations of feeding and dragging various objects into their burrows. Quite a different reaction was caused by rays from the opposite end of the spectrum, as when a blue light of a dark shade was flashed upon them they withdrew rapidly to the earth. By use of a suitable red light it is possible to observe accurately the behavior of such worms, and I am publishing this information for the benefit of those investigators who are interested in the problem of the origin of the sounds recently discovered to be emitted by earthworms.

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RESPIRATION OF INSECTS

IN SCIENCE for May 6, 1927, appeared a note under the above title by D. A. MacKay. The general conclusions drawn in this note would not seem to be warranted by the data presented, especially in view of the fact that contrary results have been reported previously.[1] In reference to the idea that in the grasshopper air is alternately inhaled and exhaled through all of the spiracles, the statement is made that "the same thing is probably true of all insects." As a matter of fact in a number of species of insects (the blowfly, Dytiscus and Cybister beetles), in which the mechanics of respiration have been studied, certain spiracles have been shown to be inspiratory and others expiratory.

[1] Lee, M. O., *Jour. Exp. Zool.,* 1925, XLI, 125.