15, and earlier. Since the last report the following awards have been made. At the meeting of April 30, $300 was awarded to Dr. Christianna B. Smith, Mount Holyoke College, for a study of the origin of red corpuscles in the liver in tissue cultures; $200 to Dr. Edward Girden, Brooklyn College, for a study of the problem of reorganization of the functions of hearing in the central nervous system; and $80 to Dr. H. D. Doolittle, Trinity College, for a study of an electrode-less discharge as a more prolific source of hydrogen ions. The trustees of the fund are as follows: G. B. Baxter, *president;* Jeffries Wyman, Jr., *secretary;* Charles P. Curtis, *treasurer;* G. B. Wislocki, J. C. Slater, A. C. Redfield, *trustees.* The next meeting will be held in April, 1938, and applications for grants should be made to the secretary, Biological Laboratories, Harvard University, Cambridge, Mass.

THE establishment of a group of scholarships at the Carnegie Institute of Technology by the Westinghouse Electric and Manufacturing Company as part of a cooperative engineering plan between the company and the college has been announced by Dr. Webster N. Jones, director of the College of Engineering. These scholarships are in engineering, are undergraduate in character and are to be known as the George Westinghouse Scholarships. Normally there will be fifty scholarships, of which ten will be vacated each year upon the graduation of the student. Each has a value of $3,000 payable monthly at the rate of $50 for the five-year period of the course. The first ten scholarships will go into effect on June 1. Appointment will be made jointly by the institute and the Westinghouse Company. Applications should be made to the Manager of Technical Employment and Training, Westinghouse Electric and Manufacturing Company, Union Bank Building, Pittsburgh. Students who receive scholarships will take the regular engineering course at the Carnegie Institute, and in addition will spend the summer months and two college semesters at the Westinghouse plant. The course will be organized and managed by a George Westinghouse professor of engineering, who will be appointed. The Westinghouse Company made an appropriation of $200,000 in October to the endowment of the institute. Under an arrangement with the Carnegie Corporation of New York this amount will be increased by $400,000 in 1946.

DURING the past year the College of Medicine of the University of Illinois has received for the library a valuable collection of some 1,500 selected books, also numerous separates and reports in the field of dermatology, presented by Dr. William Allen Pusey. This collection has now been placed in the library and is available for the use of students and physicians. A collection made by Dr. Arthur E. Hertzler, of Halstead, Kansas, consisting of about 7,000 volumes and 8,000 separates, largely in the field of surgery and surgical pathology, has also been deposited in the library.

DISCUSSION

THE SHAPE OF COMPRESSED SPHERES

THE brief report by Mr. J. W. Marvin on the shape of compressed lead shot[1] is of unusual interest. It presents an observation contrary to the expectation of Lord Kelvin, Sir D'Arcy Thompson and all physicists who have adverted to that topic, so far as we know. The reason why dodecahedral bodies were believed to arise whenever a stack of spheres of equal volume was compressed until all interstices had been eliminated is very simple. Place spheres of uniform size in a compact layer upon a plane surface, and each will be in contact with six others. Establish an overlying layer by placing spheres of the same size in the depressions presented by the layer below, and every sphere in the basal layer will be brought into contact with three above. When there is an underlying layer there are likewise three contacts below, which makes twelve contacts altogether for any sphere within the heap. Such is the "normal piling" of engineers—the arrangement of cannon balls as usually stacked. Twelve contacts under compression would seem to yield twelve facets, converting each sphere into a rhombic dodecahedron. Such dodecahedra are uniform bodies, stacking without interstices, and they were once regarded by French and German botanists as the basic shape of cells.

But if the plastic "spheres" are not quite uniform in size or perfect in shape, will they still yield dodecahedra? In the appendix to his Baltimore Lectures (1904, p. 625), after referring to Reynolds' experiments with rubber bags of small shot, Lord Kelvin remarks:

> But it is possible, it almost seems probable, that in bags of sand or powder, of some kinds of smooth rounded bodies of any shape, not spherical or ellipsoidal, subjected persistently to unequal pressures in different directions, and well shaken, stable positions of equilibrium are found with almost all the particles each touched by twelve others.

Sir D'Arcy Thompson believed that plastic spheres would yield dodecahedra on compression, expressing that opinion on his recent visit to Boston for a memorable course of Lowell Institute lectures. In his "Growth and Form" (p. 339) he debated whether cells in masses would take the 14-hedral form of

[1] SCIENCE, November 26, 1937.

bubbles in foam or the dodecahedral shape of compressed solids, thus introducing a new phase of cytology; but he concluded that "it is very probably the case that, in the parenchymatous tissue, under the actual conditions of restraint and of very imperfect fluidity, it is after all the rhombic dodecahedral configuration which, even under perfectly symmetrical conditions, is generally assumed."

After years of patient reconstruction, cells were found to be 14-hedral, so that bubbles, liquid drops and semi-fluid bodies in aggregates which fill space could all be said to be of that one form. Yet there remained the anomalous conclusion that compressed solids were dodecahedral. The writer sought explanation for this strange diversity from his physicist colleagues without the usual enlightenment obtainable from that source, and an unfortunate experiment seemed to confirm this distinction. Dry peas, when moistened, swell: they were placed in a stender dish, which they burst, and subsequently in a brass cylinder, in which they expanded until all interstices were considered eliminated. Two hundred peas were found to have an average of 12.13 contacts with their neighbors, and a recent repetition of the procedure scarcely changed the average—12.14 for the 400. In elder pith there are the familiar intercellular spaces which follow the edges of the 14-hedral cells without altering the number of facets. Consequently crevices of similar relative size were disregarded among the peas, and hence the fallacious count of 12 facets. For upon reflection, after Mr. Marvin's actual count of 14, it is clear that fourteen facets must be present, for the following considerations.

A rhombic dodecahedron has six tetrahedral angles at each of which, when they are assembled in masses, six shot or peas must meet at a mathematical point. This, however, is a geometrical abstraction, incapable of realization. At every tetrahedral angle two opposite peas will acquire a facet apiece, and the other four will not. Just as in the case of Plateau's wire skeleton-cube dipped in soap solution, there are equal chances that the two which acquire the facet will be in any one of three planes—horizontal, vertical-tangential, or vertical-radial. That means that at any one of its tetrahedral angles, a compressed sphere has one chance in three of obtaining a facet. Since there are six tetrahedral angles, with one chance in three at each of them, there will be an average gain of two facets per pea, changing the 12-hedron to a 14-hedron. Mr. Marvin reports 14-hedral shot, and in retrospect it is seen to be inevitable. There is, therefore, no difference in the number of facets for solids, semi-solids, liquids or bubbles in foam, when assembled without interstices. All have an average of 14 facets, and it is strange indeed that this should be established first for bubbles; then, by reconstruction, for microscopic cells; and at last for such gross objects as balls of lead or putty.

The shapes of the swollen peas are extremely varied and irregular. A 14-hedron may have, for example, two quadrilateral facets, eight pentagons and four hexagons. But invariably there will be 36 edges for the 14-hedron, provided that unstable tetrahedral angles have all been eliminated. Swollen peas and fat cells are indistinguishable in their multifarious forms under these fixed requirements, and were so reported at the Milan Congress of Anatomists. The prevalence of pentagonal facets was as evident in the peas as in cells of elder pith, fat and precartilage, in all of which it had been figured and discussed. Pentagonal dodecahedra have less surface per volume than the orthic 14-hedra, but they can not be stacked without interstices. In the irregular bodies, such as peas and cells, pentagonal facets may be freely introduced, thereby doubtless diminishing the surface area. The minimal or orthic 14-hedron of Lord Kelvin remains, however, the type pattern for mathematically regular uniform cells of minimal surface, being recognizably approached in elder pith. It can readily be disguised by the substitution of pentagons for alternating squares and hexagons, and seems altogether lost in precartilage and the peas.

A necessary deviation from the ideal pattern is occasioned by confining the peas or shot in a cylindrical vessel. A row of shot arranged in a straight line will be in contact with an equal number of shot in an adjoining straight line. But if they are aligned in a circle the outermost rank will be longer than that next within, and so on toward the center of the cylinder where a single shot may be surrounded by six others. Although compression at the center might yield a typical 14-hedron, the increasing circumference peripherally tends to allow additional contacts, and it is therefore not surprising that Mr. Marvin reports an average of 14.17 faces per ball. In the outermost row in the cylinder, where, as in epithelium, a free surface replaces four facets, peas with an average of eleven facets would be expected; but the diminished circuit of the row next within, in the circular vessel, would tend to reduce that number to ten and a decimal. We can hardly expect "normal piling" with an average of *precisely* fourteen, within any cylinder.

The outstanding result of this investigation in Professor Matzke's laboratory, as thus far reported by Mr. Marvin, is the convincing demonstration that compressed solid spheres, like uniform bubbles in foam, or aggregates of animal or vegetable cells of whatever consistency, are typically tetrakaidecahedral—there is no competing form. It is readily understood how

8-faced cells may arise, as in the septa of cow-lily stems; or 11-faceted cells, as in a simple epithelium resting on a layer of cells of the same diameter; or 12-rayed cells, in Juncus pith, by loss of the vertical contacts; or 18- and 22-hedral fibers, as in pine wood, from elongation and bending—all these are accountable deviations from the 14-hedral type. Whatever hesitancy one might have in accepting this conclusion seems removed by Mr. Marvin's clear-cut observations, which clarify the entire situation.

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EFFECTS ON TISSUE CULTURES OF INTER-CELLULAR HORMONES FROM INJURED CELLS

As a part of the investigation of substances influencing cell metabolism found by us to be produced by injured cells,[1] and to which we propose to give the name "inter-cellular hormones,"[2] we have tested the effects of such factors on tissue cultures.

Fragments of embryonic chicken heart were grown on culture slides in Drew's solution and embryo juice. The six-day chicken embryos used in preparing the culture fluid were minced, mixed and divided into two portions, one of which was subjected to prolonged injury by full u.v. radiation. The "test" groups of cultures, receiving fluid from the u.v. injured cells, showed markedly greater growth and less degeneration at the end of 5 to 7 days than the control groups, to which fluid from uninjured cells was added.

Our investigations indicate the production of proliferation-promoting factors by injured cells to be a general biologic phenomenon associated with the repair after injury of such cell communities as plant and animal tissues.

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FISH REMAINS FROM THE TULLY FORMATION

AT rare intervals fragments of fossil fish have been reported as occurring in the Middle Devonian Tully formation of central New York.

During the last two years several new quarries have been opened in the Tully for road material and a few old ones reopened. In these the writer has collected a number of fossils, among them a series of specimens representing several species of different types of fish.

The finding of the first arthrodiran specimen in June, 1936, in the reopened Randall Quarry at the head of Skaneateles Lake (Cortland County), a nearly perfect left externo-basal plate of a dinichthyd closely resembling that of *D. ? oviformis* Gross 1933 of the Eifelian of Gerolstein led to careful search for more. To date, the Randall Quarry has yielded no more, but a new quarry in the extreme northeastern part of Cortland County, several miles from Cuyler, has proved richer. Ten specimens have been obtained indicative of two different arthrodires, one species of *Rhynchodus* and one bothriolepid. The arthrodiran remains consist of two large but rather badly damaged median dorsal plates of a species of *Dinichthys,* the surfaces of which are marked by fine pustules, one measuring 15×15 cm, showing a short sensory groove posteriorly, the other 13.5×23 cm; both very thick medially; the right anterior corner of another m.d. ornamented by larger pustules, exquisitely preserved as vivianite and pyrite; and several fragments of ventral plates of *Aspidichthys ? notabilis* Whiteaves, a species first described from the Upper Devonian of Lake Winnipegosis, later reported from the Hamilton of Ontario and western New York and the Genundewa limestone (Genesee) of western New York. The plates of *Aspidichthys,* even when fragmentary, are readily identified by the large pustules. The *Rhynchodus* specimen is like that figured by Eastman ('07, pl. 1, f. 6). The bothriolepid plate, poorly preserved, is a small (1.1×2 cm) median nuchal somewhat like that of *B. canadensis.*

The arthrodiran plates listed by Dr. Burnett Smith ('35, p. 111) have been kindly lent by him to the writer for study, and prove to be fragments of several large, thick plates (probably ventral) of *Aspidichthys ? notabilis.* They were collected about 1919 from a now disused and much overgrown quarry in Dutch Hollow (Skaneateles Quadrangle).

Just south of Fillmore Glen State Park, in Cayuga County, a new quarry has been opened. In it one small specimen was collected last summer containing 8 poorly preserved thin plates or scales averaging 0.5×1 cm apparently of *Rhadinichthys.*

In the large quarry of the Penn-Dixie Cement Company, east of Portland Point on Cayuga Lake, the Tully is not especially fossiliferous but after careful search on several occasions, several fish plates were found in large blocks of massive limestone blasted from the upper layers. They consist of fragments of

[1] Fardon, Norris, Loofbourow and Ruddy, *Nature,* 139: 589, 1937. Fardon, Carrol and Ruddy, *Studies Inst. Divi Thomae,* 1: 17, 1937. Fardon and Ruddy, *ibid.,* 1: 41, 1937. Norris and Ruddy, *ibid.,* 1: 53, 1937. Sperti, Loofbourow and Dwyer, *Nature,* 140: 643, 1937. Sperti, Loofbourow and Dwyer, *Studies Inst. Divi Thomae,* in publication.

[2] Loofbourow and Morgan, *Studies Inst. Divi Thomae,* in publication.