announced that the first buildings will cost $1,000,000 and these will later be added to, bringing the total cost to $3,000,000. This expenditure is what Premier King had reference to when he told a delegation from the Trades and Labor Congress that the government's contribution to technical research would exceed by many times what it had been contributing to technical education.

FRANCIS P. GARVAN, head of the Chemical Foundation, has given $10,000 to the Johns Hopkins University for the enlargement of the laboratory of Dr. Joseph Colt Bloodgood for the study of human cancer, particularly in reference to the use of dyes and stains in its diagnosis in its earlier stages and treatment and in the investigation of such problems as may arise.

MR. AND MRS. GEORGE H. ROOS, San Francisco, have given the University of California $100,000 in memory of Mrs. Roos' parents, J. J. and Nettie Mack, to be used in the medical school for the study of cancer and surgical diseases of the chest. Only the interest will be used for research. The fund, which will be known as the J. J. and Nettie Mack Memorial Foundation, will be governed by a committee of the medical faculty. The Hooper Foundation will cooperate in this work.

THE National Geographic Society has made a grant of $10,000 to continue its expedition in cooperation with the Smithsonian Institution at Mt. Brukkaros, South West Africa, for the study of solar radiation. Dr. Abbot has had general supervision of the construction of a 12-inch square stellite plane mirror for the laboratory under Dr. D. T. MacDougal's care at Tucson, Ariz. This, the largest stellite mirror which has ever been made, was figured by Mr. M. E. Kahler, of Georgetown. The advantage over the ordinary silver-on-glass optical mirror is in its freedom from tarnishing. Several stellite mirrors 12 years old in the possession of the Astrophysical Observatory are as bright as ever.

THE Carnegie Foundation has made a grant of $25,000 to Princeton University for the study of light conditions under which atoms exist. The research, to be carried on by the Princeton department of physics and astronomy, is to supplement that now going on at the Mount Wilson Observatory under the auspices of the Carnegie Foundation.

UNIVERSITY AND EDUCATIONAL NOTES

A BEQUEST of $225,000 for building a new wing to the Yale Medical School is contained in the will of the late Dr. Thomas F. Smallman, a Brooklyn surgeon. The bequest is effective after the death of the widow, Mrs. Jane U. Smallman, who receives the income during her life. The proposed building is to be known as "The Jane Smallman Wing for the Treatment of the Sick."

DARTMOUTH COLLEGE is named as the ultimate beneficiary of the estate of Mrs. Jeannette I. Cummings, who died on December 12. The bulk of the estate, estimated in excess of $500,000, is to be turned over to the college on the death of her sister for the erection of a memorial to her husband.

DR. FRANK CLIFFORD WHITMORE, head of the department of chemistry at Northwestern University, has been appointed dean of the school of chemistry and physics at the Pennsylvania State College. Dr. Whitmore succeeds Dr. G. L. Wendt, who has been appointed assistant to the president in charge of research.

DR. JOSEPH TRELOAR WEARN, associate professor of medicine in the Harvard Medical School, associate director of the Thorndike Memorial Laboratory and visiting physician to the Boston City Hospital, has been appointed director of medicine at Lakeside Hospital and head of the department of medicine of the school of medicine of Western Reserve University. Dr. Wearn's appointment will fill the vacancy left in June, 1927, by the death of Dr. Charles Franklin Hoover, who had occupied the chair of medicine since 1909.

DR. MILO HELLMAN, associate in physical anthropology in the American Museum of Natural History and hitherto professor of comparative dental morphology, has been appointed professor of orthodontia and head of the department at the New York University College of Dentistry.

C. B. HUTCHISON has been appointed director of the Giannini Foundation of Agricultural Economics, professor of agriculture at the University of California and associate director of research at the station.

DR. H. S. JACKSON, of Purdue University, has accepted a professorship in mycology and cryptogamic botany at the University of Toronto.

DISCUSSION AND CORRESPONDENCE

THE MISSING LINK IN STELLAR EVOLUTION

I HAVE read with unusual interest the leading article "Available Energy" by Professor Millikan, in SCIENCE of September 28, and wish to add an astronomical

"bit" on the following points: (*A*) An atom-creating process continually taking place in interstellar space; (*B*) the relation between mass and energy.

For many years I have been actively interested in the evolutionary processes in our stellar universe, and due to the paralysis of our improvements here during and after the war, additional time for these problems has been available. From force of circumstances, and from the nature of the problem itself, these investigations covered a wide field, were often disconnected and in little-trodden paths.

It very early became obvious that there must be building-up processes of some kind, at least of matter already formed. For how else could be explained the changes in a system where so much cosmical matter existed? And where has this matter come from? As evidence of such processes it is only necessary to cite what is probably the most outstanding example, the case of Lockyer's meteoritic theory of stellar formation which is now generally accepted as best satisfying observed phenomena. Comets, meteor swarms and probably the asteroids are other examples. If the stars (and sun) are built-up bodies it would be difficult to deny a similar origin to the planets and satellites.

The disintegration of matter into energy seems to be satisfactorily established and we must either reject the evidence of building-up processes or admit the logic of reversibility or of assuming that the energy which is being radiated constantly from the stars is transformed in some way in the interstellar regions. No one-way hypothesis is in harmony with many of nature's processes which come under observation in our everyday experience, such, for example, as the cycles of life in the animal and vegetable worlds.

The farther my vision extended the more logical and necessary seemed an evolutionary cycle or orbit, in which we might liken degeneration or disintegration as corresponding to perihelion, periastron or pericosmon and regeneration to aphelion, apastron or apicosmon.

I have been unable to find any logical objection or definite evidence against a regeneration of matter—that it had not actually been detected was not considered crucial.

Such in outline is the reasoning which gradually took shape from consideration of the facts of observation, and led tentatively to the hypothesis of transformation of radiation into fundamental matter or its predecessor, in the outer spaces, and which finally became a definite conception of the connecting link. But I could find no direct evidence of such a transformation until some two years ago, when I encountered relationships among the periods of celestial bodies which seemed to bear on the general problems of atomic structure and motion.

These will be considered under *B*.

Now, however, Millikan and his associates find powerful, penetrating rays which, by a process of exclusion, they conclude must come from interstellar space. They have gone further and have determined the energy emitted in the creation of atoms of the most common elements and their absorptions, which agree satisfactorily with observations of the absorptions of these cosmical rays.

From this they infer that these cosmic rays are the evidence of the formation of matter in the interstellar spaces. I have little doubt they are right and as already stated my experience and investigations along different lines led me to a similar hypothesis.

The object of this communication is not to offer my hypothesis of the formation of matter in interstellar spaces except as a modest confirmation but to call attention to other evidence.

A

There is a class of body which is very much of an anomaly to astronomers and one which is difficult to locate satisfactorily in almost any scheme of cosmogony, the cosmical nebulae (spiral and globular, often called the white, nebulae).

The peculiar relation of these nebulae to the galaxy and their high velocities of recession have been difficult to explain. The most rational explanation which has yet been offered is that they have been formed from matter which has been ejected from the galactic stars by light pressure.

One difficulty which that hypothesis seems to encounter is the amount of matter which must have been so ejected—perhaps as much as the present galactic system of stars contains—and which also leaves the destiny of the enormous amount of energy radiated from the stars still unexplained.

If, however, these nebulae are composed of matter which was ejected as simple radiation or energy or motion, and that, by the atom-building process in the interstellar spaces which Millikan and his associates are tracking down, were built up out there, some of these difficulties disappear. For the quantity of radiation sent out seems to be of a far higher order than the cosmical matter that could be so ejected.

These cosmical nebulae and the hypothesis of atom-building in the interstellar spaces appear, therefore, to mutually support each other.

B

While investigating periodic preferences among the Cepheid variables and spectroscopic binaries I was led to examine the periods of revolution and rotation

of the planets and satellites of our solar system and the periods of revolution of visual binary stars. More than an accidental number of preferences for the same periods were found in a variety of these motions. In addition it was found that there was a tendency in many if not all of them for the periods to fall into series and sequences of one half or two times the adjacent periods.

The binary stars also showed preferences for certain periods, and—what was the most astonishing of all—there appeared to be some kind of correlation between these periodic phenomena and the atomic weights of the elements.

In a paper "On the Nature of Stellar Variability"[1] were published some of the results for the different classes of variable stars and reference was made to preliminary examination of the planets and satellites of the solar system. The results for the binary stars and the apparent correlation with atomic phenomena have not yet been published.

It is not possible to give here the evidence on which the relationships referred to rest, and circumstances over which I had no control have prevented up to the present further prosecution of those investigations or attempts to publish them. I hope to go further with this work and to publish what has already been done. Time has not weakened the strength of the data.

Briefly, the correlations referred to are between the periodic phenomena of widely divergent kinds, such as pulsations in stellar envelopes and orbital periods, and these in turn with atomic phenomena. Such correlations, if real, must have some kind of underlying relationship of a very fundamental nature. Although the mechanism and the steps are not evident, the idea is at once suggested that some form of motion may be the link, that here we may be encountering the relationships between mass and energy or motion, or perhaps simply transformations of energy. Such apparent relationships recall the speculation that matter is only frozen motion.

These correlations, if general, would imply an intimate relationship between widely differing units, such as the day, year and atomic properties. It is to be remembered, however, that these all reduce to time and motion.

The transformation of matter into energy appears to be satisfactorily established, and with the cosmic rays indicating the building up of atoms, it seems no far cry to a relationship between atomic motions and those of large aggregations of atoms. The law of gravity applies to the smallest meteoric particle as well as to the largest star.

For the present I can do no more than call attention to these periodic phenomena and their possible bearing on some of the fundamental problems of cosmogony. To the future must be left the final decision as to their reality and their nature.

CORDOBA, ARGENTINA, C. D. PERRINE
OCTOBER 30, 1928

[1] *Ast. Nach.*, 5505, Band 230, 1927.

RESONANCE RADIOMETRY

THE limiting sensitivity of any radiometric system is reached when spurious deflections become comparable with real deflections. Beyond this point optical magnification, increased period, etc., are of no avail. An attempt is here made to reduce the relative effect of spurious disturbances by causing the radiations from a real source to be intermittent with a definite period, and to "tune" the entire system to be period of intermittency. The system, though not limited to any definite radiometric device, does make use of the principle of resonance—hence the name "resonance radiometry."

To be specific: a single-junction thermopile (I) of the type developed by the writer was exposed to radiation at intervals of 0.75 seconds by means of a pendulum having a period of 1.5 seconds. The thermopile (I) was connected to a low-resistance, underdamped D'Arsonval galvanometer (I) tuned to a period of 1.5 seconds. A concave mirror attached to this galvanometer made it possible to project the image of a coarse grid (consisting of bars 2 mm wide and 2 mm apart) on a second grid of the same spacing. This second grid was "split" centrally so that the image of the first grid, when in motion, would increase the amount of light transmitted on one side and decrease the light on the other side. By means of a split lens, the light passing through the second grid was brought to two foci on the respective junctions of a three-element compensating thermopile (II), also of small heat capacity. This thermopile (II) was connected to a second D'Arsonval galvanometer (II) having the same period of 1.5 seconds. The light falling on thermopile (II) was derived from a small auto headlight lamp.

Both galvanometers were of rugged construction and of relatively low sensitivity. Due to the circumstance that the entire system was "tuned," a high degree of immunity from spurious (non-intermittent) disturbances was realized.

The sensitivity actually obtained is as follows: With a candle at one meter from thermopile (I), the radiation passing through an aperture of one square millimeter at the above distance occasioned a deflection of 2,000 mm on the meter-scale of galvanometer (II). This sensitivity already rivals that of the best instruments now employed.

In later experiments, thermopile (II) was replaced by a vacuum-tube amplifier embodying a photoelectric cell. By means of this, the above sensitivity was increased, approximately 1,000 times. At the present