

the seven days of Genesis. Since then I have labored professionally with geologists for nearly fifty years, have seen the geologic column—the geologist's yardstick—lengthen sixfold, have read of tens of thousands of new species of fossil plants and animals added to our knowledge and have witnessed the pushing backward in time of the origin of the earth from six thousand years to something like two billion. Truly, time and organic creations are without end!

When I became an active collector of fossils, I knew of no public geological museums, and now our country has a great number, and of these a half dozen or so are rated among the best in the world. Then, but few states had geological surveys, and the Federal Government none that was permanent. Today, nearly all the states have such, and the government as well, and they are of immense service to the people in economic and theoretic ways. Then, there was no general geological society, and now there are

several, two of them having a combined membership of upward of 3,000, of whom two thirds are in search of profitable rocks—those containing oil, coal and ores—and the remainder are teachers of geology and research workers. And the oldest of these geological societies now has an endowment of four million dollars, given to it by one of its fellows.

We are now living in the transition period into the age of science, and if humanity continues to apply what science provides, the day will come when no one will need to work more than the decreed thirty hours a week. No one, that is, except the research workers!

In retrospect, I am indeed grateful to that unknown Irishman who threw me my first fossil, since it was the first step in the path that led to this evening's event. Mr. President, I thank the academy, the committee of award and you for the great honor conferred upon me by the award of the Mary Clark Thompson Medal.

## VARIATION AND EVOLUTION AMONG THE STARS<sup>1</sup>

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(1) Variation and evolution are defined. In cosmic problems, the short life of the observer, or even of his civilization, compared with the time of major changes, makes it necessary to infer evolutionary tendencies rather than observe them. Variety in types of objects is an indication of past developments. Theories of stellar evolution are based on studies of variation and varieties.

(2) The clearest direct evidence that stars change and that the universe evolves is in the simple fact that sun and stars shine; for we now know that outgoing radiation is outgoing mass and that a hot radiating body in cold space decreases steadily in material content because of its inevitable radiation. Because it shines, it must change steadily also in temperature, in density, in mass, in all its physical properties. A globular star cluster, for instance, loses through its radiation into empty space a million million tons of matter every second—a loss that not only spells evolution for its thousands of stars, but alters the gravitational structure of the cluster itself.

(3) The varieties of galaxies and the variations in their positions and velocities are direct evidence of the evolution of the whole universe, and are the bases of the expanding universe interpretation. The probability is high that the red shift in the spectra of galaxies indicates an expansion, and the rate is about

one hundred miles a second for every million light years of distance.

(4) The variations that most concern astronomers are the changes in the light of stars. The changes are of three sorts: (a) Periodic variations that perhaps do not directly indicate evolution because of the recurrence indefinitely of the same conditions; (b) irregular variations that have little rhyme or reason; (c) progressive alterations.

(5) The most observed star in the sky during the past several months has been the fourth magnitude (naked eye) eclipsing double star, Zeta Aurigae. A recent study at Harvard, based on about three thousand photographs, gives a history of this thousand-day variable for the past forty years. An eclipse of the sun lasts, at the most, seven minutes; but the total eclipse of Zeta Aurigae persists for thirty days. The double is remarkable in that the masses and luminosities of the two companions are equal, but the volume of the red giant component is thirty thousand times that of its hot, blue associate.

(6) The first results obtained with two large new reflecting telescopes are presented at this time; both instruments have been set in operation during the past year. With the 61-inch Wyeth telescope at the Oak Ridge Station of the Harvard Observatory, Dr. W. A. Calder has measured photo-electrically the variations of an important eclipsing binary,  $\alpha$  Her- culis, and from his work it is found that the orbit is

<sup>1</sup> Abstract of a popular illustrated lecture for the citizens of Cleveland, November 19.

twisting in space. With the 60-inch reflector at the Bloemfontein Station of the Harvard Observatory, Dr. Paraskevopoulos has photographed in red light the giant gaseous nebula, 30 Doradus, in the Large Cloud of Magellan. From photographs with this instrument it now appears that this famous nebula, sometimes called The Tarantula, has in its center a rich cluster of supergiant stars, each ten or twenty thousand times the luminosity of the sun.

(7) Announcement is made of the discovery in our own galaxy of about seven hundred new variable stars, the study of which contributes slowly to our increasing knowledge of galactic dimensions as well as to the central problem of the evolution of stars and of the stellar universe.

(8) In the nearest of external galaxies, the Large Cloud of Magellan, periods of pulsation have been measured on Harvard plates for many of the supergiant variables of the Cepheid class. These stars are important in the improvement of the period-luminosity law, which is fundamental in the measurement of the distances of galaxies.

(9) In the Small Cloud of Magellan, which is also a relatively near external galaxy, a thousand new variable stars have been found within the past few months through an examination of new photographs made at the Bloemfontein Station of the observatory.

(10) An indication of development throughout the Metagalaxy is found in the peculiarities of the distribution of galaxies throughout the enormous spaces covered by the surveys carried on at Mount Wilson and at Harvard. The Harvard census of new faint galaxies has now gone beyond 125,000. About a third of the sky has been covered in this survey; the discovered irregularities prove important for considerations of expanding regions, collapsing regions and places where the Metagalactic developments appear to be at a standstill. One of these apparently non-expanding regions is the Twin Supergalaxies in Hercules, a double group that contains several hundred individual galaxies, and extends over a region more than three million light years in diameter at a distance from the sun of about a hundred million light years.

## ABSTRACTS OF PAPERS PRESENTED AT THE AUTUMN MEETING OF THE NATIONAL ACADEMY OF SCIENCES<sup>1</sup>

*An x-ray study of grain-growth in metals produced by heat treatment:* CHRISTIAN NUSBAUM (introduced by Dayton C. Miller).

*The measurement of the absorption coefficients of x-rays of very short wave-length:* F. K. RICHTMYER, T. R. CUYKENDALL and M. T. JONES. Almost no measurements have been previously made of the absorption of monochromatic x-rays of wave-length less than 100 x-units. The present program of investigation was undertaken in order to obtain such measurements, partly because of their importance in connection with current theories of physics; partly because such data are needed in high-voltage roentgenology. The high-voltage generating plant is capable of producing 600 K.V. The two-crystal spectrometer is of the direct-reading type, the x-rays passing through the crystals and being reflected from internal planes, instead of from crystal surfaces, as is usual at longer wave-lengths. A resolving power of 30 at 50 x.u. and of 160 at 200 x.u. is obtained. The ionization chamber contains argon at a pressure of 80 atmospheres. The ionization current is amplified by an FP54 tube. Measurements are now being made on various elements in the wave-length range  $30 < \lambda < 150$  x-units with a precision of the order of 1 to 2 per cent. Sample data on the mass absorption coefficient,  $\mu/\rho$  for carbon and for lead, are as follows:

	Wave-length	$\mu/\rho$
Carbon	100 x.u.	0.142
	60	0.121
Lead	30	0.22
	60	0.90
	100	3.30
	135	7.15
	145	2.03

*Evaporated surfaces on gratings for the vacuum ultra-violet:* R. C. GIBBS and H. M. O'BRYAN (introduced by Ernest Merritt). On account of the greater permanence of its reflecting power, the glass grating has found general acceptance over the speculum metal grating for spectral studies involving wave-lengths less than 2,000 Å. However, the reflecting power of glass is small for wave-lengths less than 1,000 Å and falls to less than 1 per cent. below 400 Å. Recent progress in the technique of preparing evaporated metal surfaces has made it possible to apply these metal films to already ruled glass gratings without loss of definition in the spectral lines. By suitably choosing the metal for the desired spectral region a greatly increased reflecting power of considerable permanence can be secured, thus reducing the time of exposure several fold. In most cases these films can be removed by chemical treatment without injury to the quality of the grating, thus making it possible readily to renew the surface with a film of the same or another metal. For stability and permanence of reflecting power

<sup>1</sup> Cleveland, November 19, 20 and 21.