wider heads and more slender noses than the prehistoric, but from 4000 B. C. down to Roman times the form shows no change.

From this union of two able races came one of the finest peoples ever seen, the Egyptians of the Old Kingdom, 4500-3500 B. C. Full of grand conceptions, active, able, highly mechanical, and yet splendid artists, they have left behind them the greatest masses of building, the most accurate workmanship and exquisite sculptures in the grand pyramids and tombs of their cemeteries. They perfected the art of organizing combined labor on the immense public works. In all these respects no later age or country has advanced beyond this early ability. The moral character and ideas are preserved to us in the writings of these people; and we there read of the ability, reserve, steadfastness and kindness which we see reflected in the lifelike portraiture of that age.

After a partial decay about 3000 B. C. this civilization blossomed out again nobly in the twelfth dynasty about 2600 B. C.; though the works of this age hardly reach the high level of the earlier times, yet they are finer than anything that followed them. At this period more contact with other countries is seen; both Syria and the Mediterranean were known, though imperfectly.

To this succeeded another decadence, sealed by the disaster of the foreign invasion of the Hyksos. But this was thrown off by the rise of a third age of brilliance—the XVIIIth dynasty, 1500 B. C.—which, though inferior to early times in its highest work, yet shines by the wide spread of art and luxury throughout the upper classes. Magnificence became fashionable, and the lower classes contented themselves with most barefaced imitations of costly wares. Foreign islands came closely in contact with Egypt. The ships of the Syrian coast and Cyprus continually traded to and fro, exchanging silver, copper and precious stones for the gold of Egypt. Greece also traded its fine pottery of the Mykenæan age for the showy necklace of gold and the rings and amulets with names of Pharaohs. Egypt then dominated the shores of the western Mediterranean, the plains of the Euphrates and the fertile Sudan. But this power and wealth led to disaster. Like Rome, later on, she could not resist the temptation to live on plunder; heavy tribute of corn was exacted, large numbers were employed in unproductive labor, and national disaster was the natural consequence. Egypt never recovered the dominion or the splendor that were hers in this age. Of this period some slight notions are given us from literary remains in the Bible and Greek authors; but archaeology is, so far, our only practical guide, as in the earlier ages. The great temples and monuments of the XVIIIth—XXth dynasties (1600-1100 B. C.) bear hundreds of historical inscriptions, the tombs are covered with scenes of private life, the burials and the ruins of towns furnish us with all the objects of daily use. This age is one of the fullest and richest in all history, and hardly any other is better known even in Greece or Italy. Yet all this has been brought to light in this century, and the knowledge of the foreign relations of Egypt is entirely the result of the last fifteen years.

The final thousand years of the civilization of Egypt is checkered with many changes; sometimes independent, as in the ages of Shishak of Necho, and of the Ptolemies; at other times a prey to Ethiopians, Persians, Greeks or Romans. Its arts and crafts show a constant decay, and there was but little left to resist the influence of Greek taste and design, which ran a debased course in the country. There was, however, a spread of manufactures and of cheap luxuries into lower and lower classes; and the wealth of the country accumulated under the beneficent rule of the earlier Ptolemies (300-200 B. C.).

The principal discoveries about these later ages have been in the papyri, which have been largely found during the last twenty years. The details of the government and life of the country in the Ptolemaic (305-30 B. C.) and Roman (30 B. C.-640 A. D.) periods have been cleared up; and many prizes of classical literature have also been recovered. The archaeology of the Middle Ages in Egypt has also been studied. Many of the Arabic buildings have been recently cleaned and put in good condition, and the splendid collection of manuscripts in Cairo has opened a view of the beautiful art of the thirteenth-fifteenth centuries so closely akin to what was done in Europe at the same time.

Egypt is then before all other lands the country of archaeology. A continuous history of 7,000 years, with abundant remains of every period to illustrate it, and a rich prehistoric age before that, give completeness to the study and the fullest value to archaeological research.

MESOPOTAMIA.

The Valley of the Euphrates might well rival that of the Nile if it were scientifically explored, but unhappily all the excavation has been done solely with a view to inscription and sculpture and no proper record has been made, nor have any towns been examined, the only work being in palaces and temples.

The earliest study on the ground was by Rich (1818-20), who gathered some few sculptures and formed an idea of Assyrian art. The French Consul Botta excavated Khorsabad (founded 700 B. C.) in 1834-35, and Layard excavated Nimrud in 1845-47; these were both Assyrian sites. The older Babylonian civilization was touched at Erech by Loftus in 1849-52; and this age has attracted the most important excavations made since, at Tello by Sarzec (1876-81), and at Nippur by Peters and Haynes of Philadelphia during the last few years.

The cuneiform characters were absolutely unexplained until Grotefend in 1800 resolved several of them by taking inscriptions which he presumed might contain names of Persian Kings and comparing them alongside of the known names; thus—without a single fixed point to start from—he tried a series of hypotheses until he found one which fitted the facts. Bournouf (in 1836) and Lassen (1836-44) rectified and completed the alphabet. But the cuneiform signs were used to write many diverse languages, as the Roman alphabet is used at present; and the short Persian alphabet was only a fraction of the great syllabary of 600 signs used for Assyrian. Rawlinson had independently made out the Persian alphabet, using the Zend and Sanskrit for the language. He next, from

the trilingual Behistun inscription in Persian, Assyrian and Vannic resolved the long Assyrian syllabary, using Hebrew for the language. Since then other more obscure languages written in cuneiform have been worked with more or less success; the most important is the Turanian language, used by the earlier inhabitants of Babylonia before the Semitic invasion; this is recorded by many syllabaries and dictionaries, and translations compiled by the literary Semitic Kings.

The general view of the civilization which has been obtained by these labors of the century shows it to have been more important to the world than any other. Cuneiform was the literary script of the world for at least 6,000 years, the only medium of writing from the Mediterranean to the Indian Ocean. The Babylonian culture was almost certainly the source of the oldest present civilization—that of China. And the arts were developed probably even earlier than in Egypt. The first inhabitants were called Sumirian (or river folk) in distinction from the Accadian (or highland) people who came from Elam down into the Euphrates Valley, bringing with them the use of writing. Their earliest writing was of figure-symbols (like the Egyptian and Hittite); but as in the valley clay tablets were the only material for writing, the figures became gradually transformed into groups of straight lines and spots impressed on the clay; hence the signs were formalized into what we call cuneiform. The Semitic invaders were using cuneiform characters by about 3000 B. C.

The early civilization was intensely religious, the main buildings being the temples, which were placed on enormous piles of brickwork. The sculpture was at a high level in the time of Naram-Sinn, about 3750 B. C.; and yet below his ruins at Nippur there are no less than thirty-five feet depth of earlier ruins, which must extend back to 6000 or 7000 B. C. In early times stone implements were used alongside of copper and bronze, as we find in Egypt 4000 B. C. Pottery was well made, and also reliefs in terra cotta. Personal ornaments of engraved gems and gold work were common.

The main landmarks in the later time of this civilization are the Elamite invasion of Kudur-nan-khundi (2280 B. C.) which upset the Semitic rulers; and the Assyrian invasion of Tiglath-Adar (1270 B. C.), after which interest centers in the Assyrian kingdom and its development of the Mesopotamian culture which it borrowed. The main buildings of the Assyrian kings were their enormous palaces, the mass of which was of unbaked bricks, faced with alabaster slabs; such were the works of Assurnazir-pal (Nimrud, 880 B. C.), Sargon (Khorsabad, 710 B. C.), Sennacherib and Assurbanipal (Kouyunjik, 700 B. C.). The later, Assyrian, form of the civilization was to the earlier Chaldean much what Rome was to Greece, a rather clumsy borrower who laboriously preserved the literature and art. Some of the Assyrian sculpture of animals is, however, perhaps unsurpassed for vivid action. The systematic libraries, containing copies of all the older literature for general study, were most creditable, though the Assyrian himself composed nothing better than chronicles. Nearly all that we possess of Babylonian religion, and much of the history, is in the copies scrupulously made from the ancient tablets by the Assyrian scribes, who noted every defect in the original with critical fidelity.

The Mesopotamian civilization has left its mark on the modern world. Its religion greatly influenced Hebrew, and thence Christian, thought, the Psalms, for instance, being a Babylonian form of piety. Its science fixed the signs of the Zodiac, the months of the year, the days of the week, and the division of the circle in degrees, all of which are now universal. And its art, carried by the Phœnicians, was copied by the Greeks and Etruscans, and thus passed on into modern design.

(To be continued.)

SATURN'S RINGS.

By HAROLD JACOBY, Professor of Astronomy in Columbia University.

THE sudden death of James E. Keeler, Director of the Lick Observatory in California, recalls to mind one of the most interesting and significant of recent advances in astronomical science. Only five years have elapsed since Keeler made the remarkable spectroscopic observations which gave for the first time an ocular demonstration of the true character of those mysterious luminous rings surrounding the brilliant planet Saturn. Although these observations were carried out five years ago, they have not yet been made sufficiently accessible to the public at large, nor have they been generally valued at their true worth. We have called this work of Keeler's interesting, because the problem of the rings has been a classic one for many generations; and we have been particular, also, to call it significant, because it is pregnant with the possibilities of newer methods of spectroscopic research, applied to the older departments of observational astronomy.

The troubles of astronomers with the rings began with the invention of the telescope itself. They date back to 1610, when Galileo first turned his new instrument to the heavens. It may be imagined easily that the bright planet Saturn was among the very first objects scrutinized by him. His "powerful" instrument magnified only about thirty times, and was doubtless much inferior to our pocket telescopes of today. But it showed at all events that something was wrong with Saturn. Galileo put it, "Ultimam planetam tergemina observavi," "I have observed the furthest planet to be triple." It is easy to see now how Galileo's eyes deceived him. For a round luminous ball like Saturn, surrounded by a thin flat ring seen nearly edgewise, really looks as if it had two little attached appendages.

A PUZZLING PLANET.

Galileo's further observations of Saturn bothered him more and more. The planet's behavior became much worse as time went on. "Has Saturn devoured his children, according to the old legend?" he inquired soon afterward. For the changed positions of earth and planet in the course of their motions around the sun in their respective orbits had become such that the

ring was seen quite edgewise, and was, therefore, perfectly invisible to Galileo's "optic tube." The puzzle remained unsolved by Galileo; it was left for another great man to find the true answer. Huygens, in 1656, first announced that the ring was a ring.

The manner in which this announcement was made is characteristic of the time; today it seems almost ludicrous. Huygens published a little pamphlet in 1656 called "De Saturni Luna Observatio Nova," or, "A New Observation of Saturn's Moon." He gave the explanation of what had been observed by himself and preceding astronomers in the form of a puzzle, or "logograph." Here is what he had to say of the phenomenon in question: "aaaaaaa ccccc d eeeee g h iiii llll mm nnnnnnnnnn oooo pp q rr s tttt uuuu." It was not until 1659, three years later, in a book entitled "Systema Saturnium," that Huygens rearranged the above letters in their proper order, giving the Latin sentence: "Annulo cingitur, tenui plano, nusquam coherente, ad eclipticam inclinato." Translated into English, this sentence informs us that the planet "is girdled with a thin, flat ring, nowhere touching Saturn, and inclined to the ecliptic!" This was a perfectly correct and wonderfully sagacious explanation of those complex and exasperatingly puzzling phenomena that had been too difficult for the masterhand of Galileo himself. It was an explanation that explained.

But of far greater interest than the mere fact of their existence is the important cosmic question as to the constitution, structure, and, above all, durability of the ring system. Astronomers often use the term "stability" with regard to celestial systems like the ring system of Saturn. By this they mean permanent durability. A system is stable if its various parts can continue in their present relationship to one another, without violating any of the known laws of astronomy. Whenever we study any collection of celestial objects, and endeavor to explain their motions and peculiarities, we always seek some explanation not inconsistent with the continued existence of the phenomena in question. For this there is perhaps no sufficient philosophical basis. Probably much of the great celestial procession is but a passing show, to be but for a moment in the endless vista of cosmic time.

However this may be, we are bound to assume that Saturn has always had these rings, and will always have them; and it is for us to find out how this is possible. The problem was first attacked mathematically by various astronomers, including Laplace; but no conclusive mathematical treatment was obtained until 1857, when James Clerk Maxwell proved in a masterly manner that the rings could be neither solid nor liquid. He showed, indeed, that they would not last if they were continuous bodies like the planets. A big solid wheel would inevitably be torn asunder by any slight disturbance, and then precipitated upon the planet's surface. Therefore, the rings must be composed of an immense number of small detached particles, revolving around Saturn in separate orbits, like so many tiny satellites.

THE "ASTEROIDS" ANALOGY.

This mathematical theory of the ring system being once established, astronomers were more eager than ever to obtain a visual confirmation of it. We had indeed a sort of analogy in the assemblage of so-called "minor planets" or "asteroids," which are known to be revolving around our sun in orbits situated between Mars and Jupiter. Some hundreds of these are known to exist, and probably there are countless others too small for us to see. Such a swarm of tiny particles of luminous matter would certainly give the impression of a continuous solid body, if seen from a distance comparable to that separating us from Saturn. But arguments founded on analogy are of comparatively little value. Astronomers need direct and conclusive telescopic evidence, and this was lacking until Keeler made his remarkable spectroscopic observations in 1895. The spectroscope is a peculiar instrument, different in principle from any other used in astronomy; we study distant objects with it by analyzing the light they send us, rather than by examining and measuring the details of their visible surfaces. The reader will recall that according to the modern undulatory theory, light consists simply of a series of waves. Now the nature of waves is very far from being understood in the popular mind. Most people, for instance, think that the waves of ocean consist of great masses of water rolling along the surface. This notion doubtless arises from the behavior of waves when they break upon the shore, forming what we call "surf." When a wave meets with an immovable body like a sand-beach, the wave is broken and the water really does roll upon the beach. But this is an exceptional case. Farther away from the shore, where the waves are unimpeded, they consist simply of particles of water moving straight up and down. None of the water is carried by mere wave action away from the point over which it was situated at first. Tides or other causes may move the water, but not simple wave motion alone. That this is so can be proved easily. If a chip of wood be thrown overboard from a ship at sea it will be seen to rise and fall a long time on the waves, but it will not move. Similarly, wind waves are often quite conspicuous on a field of grain; but they are caused by the individual grain particles moving up and down. The grain cannot travel over the ground, since each particle is fast to its own stalk.

But while the particles do not travel, the wave disturbance does. At times it is transmitted to a considerable distance from the point where it was first set in motion. Thus, when a stone is dropped into still water, the disturbance (though not the water) travels in ever-widening circles, until at last it becomes too feeble for us to perceive. Light is just such a traveling wave disturbance. Beginning, perhaps, in some distant star, it travels through space, and finally the wave impinges on our eyes like the ocean wave breaking on a sand beach. Such a light-wave affects the eye in some mysterious way we call "seeing."

KEELER AND THE SPECTROSCOPE.

The spectroscope enables us to count how many waves reach us each second from any given source of light. No matter how far away the source of stellar light may be, the spectroscope examines the character of that light, and tells us the number of waves set up

every second. It is this characteristic of the instrument that has enabled us to make some of the most remarkable observations of modern times. If the distant star is approaching us in space, more light-waves per second will reach us than we should receive from the same star at rest. Thus, if we find from the spectroscope that there are too many waves, we know that the star is coming nearer; and if there are too few, we can conclude with equal certainty that the star is receding. Keeler was able to apply the spectroscope in this way to the planet Saturn and to the ring system. The observations required dexterity and observational manipulative skill in a superlative degree. These Keeler had; and this work of his will always rank as a classic observation. He found by examining the light-waves from opposite sides of the planet that the luminous ball rotated; for one side was approaching us and the other receding. This observation was, of course, in accord with the known fact of Saturn's rotation on his axis. But with regard to the rings, Keeler showed in the same way the existence of an axial rotation, which appears not to have been satisfactorily proved before, strange as it may seem. But the crucial point established by the spectroscope was that the interior part of the rings rotates faster than the exterior. The velocity of rotation diminishes gradually from the inside to the outside. This fact is absolutely inconsistent with the motion of a solid ring; but it fits in admirably with the theory of a ring composed of a vast assemblage of small separate particles. Thus, for the first time, astronomy comes into possession of an observational determination of the nature of Saturn's rings, and Galileo's puzzle is forever solved.—New York Evening Post.

METEOROLOGICAL INSTRUMENTS.

By Prof. HANS HARTL.

THE world is completely surrounded by an envelop of air, some twenty miles in thickness. This envelop, which we call the atmosphere, consists primarily of

FIG. 1.—A CENTIGRADE THERMOMETER.

oxygen and nitrogen, mingled with small quantities of various other gases and with considerable moisture in the form of watery vapor. Like terrestrial solids and fluids, the atmosphere is held in place by the attraction of the earth. By reason of this attraction the envelop of air exerts a certain pressure on the earth, which pressure is termed atmospheric pressure. Per square inch, the atmospheric pressure amounts to about fifteen pounds. Since the surface of the earth has an area of two trillion square inches it follows that the total weight of the atmosphere is about thirty trillion pounds.*

By reason of its extreme expansibility and mobility, the atmosphere is subject to constant changes which give rise to variations in the pressure. Besides these changes, there are also variations in temperature and humidity.

Since the organic life which flourishes at the bottom of the ocean of air is influenced by atmospheric conditions, it is of great interest as well as of importance accurately to study these conditions. Our senses are most untrustworthy in scientific research. To be sure, we feel plainly enough whether the air be warm or cold, whether the velocity of the wind be small or great, whether the atmosphere be humid or dry. But these sensations are not sufficiently well defined to enable us to gauge accurately the condition of the air. The temperature, pressure, humidity and velocity of the air can be measured only by means of meteorological instruments. Such instruments can be divided into four classes—those which measure heat (thermometers), those which measure pressure (barometers), those which measure humidity (hygrometers), those which measure wind velocities (anemometers).

Thermometers are based upon the principle that bodies expand when heated and contract when cold. The ordinary thermometer (Fig. 1) consists of a glass tube provided at its lower end with a bulb. The tube is partially filled with mercury; and above the mercury is a vacuum. The tube is attached to a scale. If the thermometer be placed in melting ice, the mercury sinks in the tube to the point marked 0 on the scale (the freezing-point of water on the centigrade thermometer). If the thermometer be placed in boiling water or in steam, the mercury rises to the point marked 100 on the scale (the boiling-point of water on the centigrade scale). The space between these two points is divided into 100 equal parts, the graduation being also continued below the zero mark. The degrees above zero register heat; those below, record the degree of cold. The ther-

mometer illustrated in Fig. 1 is indicating 16 deg. C. It will be observed that, in this instrument, which is used only in measuring the temperature of the air, the maximum and minimum points of the scale are + 50 deg. and - 30 deg. Instead of mercury colored spirals or creosote can be employed.

In the maximum and minimum thermometer shown in Fig. 2* the heat measurer used is creosote or alcohol. The instrument consists of a U-shaped glass tube, *a b*, formed with enlargements, *A B*. The lower portion of the tube contains mercury, above which is a layer of creosote in both legs. The enlargement, *A*, constituting a receptacle, is filled with creosote down

FIG. 2.—MAXIMUM AND MINIMUM THERMOMETER.

to *a*, in the right portion of the instrument. The enlargement or receptacle, *B*, is only partially filled with creosote. The upper portion of the receptacle, *B*, contains air mingled with creosote vapors. The creosote in the receptacle, *A*, is the actual thermometric body, the mercury serving only to indicate upon the scale the degree of expansion to which the creosote is subjected by heat. The creosote in the receptacle, *A*, expands, causing the mercury to fall in the leg, *a*, and to rise in the leg, *b*. On the scales of both legs the same degree of heat is indicated (in Fig. 2, 15 deg.). In the right leg the mercury stands above zero, in the left leg below zero. When the temperature falls the creosote in the receptacle, *A*, contracts; and the mercury, by reason of the pressure of the creosote vapors in the receptacle, *B*, is forced up into the leg, *a*.

A hasty examination of this instrument might lead one to infer that it is but a very awkwardly constructed creosote-thermometer with a double scale. The instrument is, however, thus constructed for the purpose, not only of marking the temperature of the moment, but also of indicating the minimum temperature registered during the night and the maximum temperature attained on the previous day. In both legs of the ther-

forces the floating steel index to the 20 deg. mark. If the mercury fall, the index clings to the glass and indicates the maximum temperature of the day. If in the following night the temperature drop to +8C. the mercury rises in the left leg and pushes the index in that leg up to the mark + 8. If the temperature then rise, the mercury falls in the left leg, leaving the index in position at the mark + 8. On the following morning it will be seen that the maximum temperature attained in the previous twenty-four hours was

FIG. 3.—PFISTER-HERRMANN METALLIC THERMOMETER.

20 deg., the minimum temperature + 8. The instrument is therefore very properly called a maximum and minimum thermometer.

The mean between the maximum and minimum temperature ($20 + 8 \div 2 = 14$ deg. in the present case) will as a general rule, be found approximately equal to the temperature at 8 A. M. of the twenty-four hours under consideration. For this reason the temperature read at 8 o'clock in the morning is usually taken in weather forecasts, as the mean temperature of the day.

In another class of thermometers, the difference in expansion of two metals is employed as a means of measuring heat. A rod of iron, for example, one meter in length when removed from a vessel of ice water and plunged into a vessel of boiling water, will expand only one millimeter; whereas a rod of zinc, also one meter in length, will, under similar conditions, expand three millimeters. If two such straight rods or straps of iron and zinc be riveted or soldered together, and plunged in boiling water, they must assume such a form that the zinc strap will become 1003 millimeters long and the iron strap 1001 millimeters long. But since the solder or rivets prevent the straps from sliding on each other, the form assumed must of ne-

FIG. 4.—A THERMOGRAPH.

cessity be an arc with the zinc strap forming the longer, outer curve. The higher the temperature the more pronounced will be the curve of the arc.

The metallic thermometer of Pfister and Herrmann (Fig. 3) consists of a coiled zinc ribbon, the inner end of which is fastened to a backboard. When the temperature rises, the ribbon bends more sharply inward, the free outer end moving to the right. A pivoted finger, the shorter arm of which is connected with the end of the coil, plays over a scale and multiplies the variations in the length of the spiral to such an extent that they may be read off in degrees of heat on the scale. Sometimes two auxiliary fingers are employed, which are not connected with the coil, and which are

meter small steel indices floating on the mercury are contained, about which indices elastic glass threads are wound, the glass threads having sufficient resiliency to engage the glass walls of the corresponding legs of the thermometer. It follows, therefore, that the one steel index will remain at the maximum point to which it has been pushed by the mercury in the one leg. Every morning the steel indices are brought into contact with the mercury by means of magnets. If during the course of the day the temperature rises to 20 deg. C. the mercury mounts in the right leg and

* Only the portion below the line, *m n*, is visible, the parts, *A B*, being incased.

* Of the enormity of these values, some idea may be obtained by instituting a few interesting comparisons. One million trains each composed of one million powerful locomotives would represent but the hundredth part of the weight of the atmosphere. A leaden ball equal in weight to the atmosphere would have a diameter of 12½ miles. If the earth were covered with a layer of mercury 760 mm. (30 inches) high, the superimposed weight would equal that of the atmosphere.