This building is a ziggurat, and thereby is proved the continuity of Sumerian architecture from the Third Dynasty of Ur back to the close of the al 'Ubaid period.

A more detailed stratification was again found at Ur, where a cutting showed an unbroken rubbish layer dated by seal impressions of Mesannipadda to the First Dynasty of Ur, overlying the Royal cemetery : this has given for the cemetery a *terminus ante quem*. Below the cemetery is a stratum rich in seal impressions and inscribed tablets older than the royal graves, but demonstrably later than Jemdet Nasr. Below this were found graves of three sorts, differentiated by level and by content:

(1) Graves with clay pots of 'reserved slip ware'.

(2) Graves with pots having simple decorations of pinkish-red paint on light clay.

(3) Jemdet Nasr graves with three-colour pottery, characteristic stone vessels, etc.

These graves were cut into soil rich in al 'Ubaid potsherds which continue, except for a break of clean flood deposit, down to virgin soil. At Warka the section shows 19 metres of al 'Ubaid stratified culture underlying the period Archaic VI to which the early ziggurat belonged.

The sequence thus is :—The Plano-convex period, starting about 2700 B.C. It includes the Second Dynasty of Ur, the First Dynasty, the Cemetery period, the "reserved slip" ware period and that of the pinkish-red paint on a light ground. It must have been a very long period. The Jemdet Nasr period seems at present more important for its character than its length. The Uruk period, with its succession of great buildings at Warka, must represent a considerable lapse of time, as also that of al 'Ubaid, with its tremendous deposit.

Short dating is impossible : the finds are spread over the whole period between 2700 B.C. and the beginning of human occupation of the Lower Valley. Throughout this, in spite of marked changes, there is a link of continuity which can only be due to the presence of Sumerians in the land from the very outset. The changes seem to be due to incursions by people of similar stock but in different phases of the kindred culture, differently evolved beyond the borders of Mesopotamia, and there is, therefore, modification but no revolutionary change : the history is continuous and through it all can be traced the development of the great Sumerian civilisation.

The Spherical Pendulum*

By CYRIL H. H. FRANKLIN, Electrical Engineering Department, University of Birmingham

A PENDULUM which is free to swing over a segment of a sphere has possible paths which vary from a rotation resembling an engine governor ball to the swing of a simple pendulum in a plane ; which plane appears to rotate very slowly but really indicates the rotation of the earth beneath it (Foucault pendulum effect).

The intermediate orbits between the circular and the linear paths are ellipses, which latter precess at a rate dependent on the maximum and minimum angles of the pendulum and corresponding ratio of major and minor elliptical axes (see Fig. 1). This precession of the ellipse produces a pattern which it will be seen resembles that produced by two opposed rotations having a ratio near unity (such as 100 : 101, with appropriate amplitude) ; which may be drawn by harmonograph, etc. Virtually, the pendulum behaves as if it had two frequencies : which is in agreement with the facts that the effective length of a pendulum swinging in a circle is $L \cos \alpha$, where α is the angle of the swing maintained and L is the length of the pendulum ; and that in tracing a single ellipse a maximum and minimum angle and corresponding minimum and maximum effective length are reached twice.

It will be seen that the greater the angle reached, the greater the variation of effective length of the pendulum ; and it is found that the rate of precession increases rapidly as the angle increases. Also, if the ratio of major and minor axes of the ellipse is high (which, in the limit, becoming infinite, means the pendulum swinging in a plane), the rate of precession is small, in the limiting case becoming zero. As the ratio of the major and minor axes approaches 1, the rate of precession becomes a maximum for the angles involved.

When the pendulum is capable of swinging over a hemisphere, and is oriented to a maximum and minimum angle of 180° and 90° (which is a 2 : 1 ellipse), the vertical projection of the orbit becomes

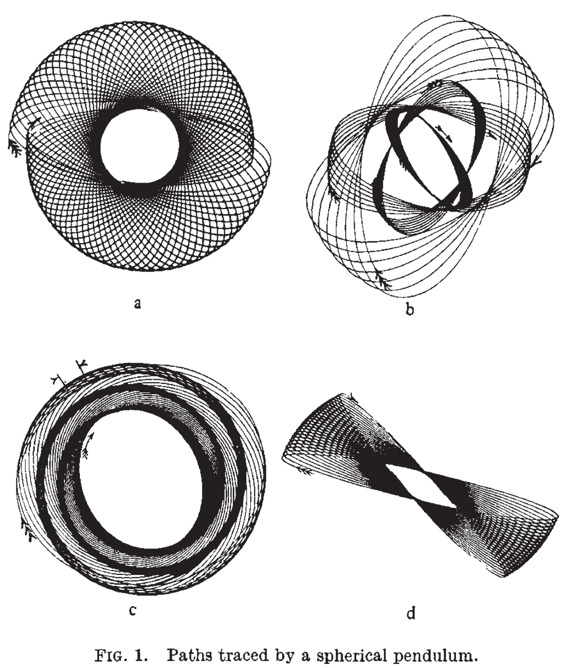

FIG. 1. Paths traced by a spherical pendulum.

a, ellipse axes, 1 : 3 ; major angle, 41° ; precession, 5°.
b, ellipse axes, 1 : 2 ; major angles, 44°, 32°, 24°, 19° ; corresponding approximate precessions, 9°, 4°, 2½°, 1¼°.
c, ellipse axes, 13 : 15 ; minor angle, 33° 50′ ; major angle, 39° 20′ ; approximate precession, 10° per cycle.
d, ellipse axes, 1 : 10 ; minor angle, 4° 20′ ; major angle, 44° 22′ ; approximate precession, 2°

a five loop figure, corresponding to the 3 : 2 figure with opposed rotations as produced by the twin-elliptic pendulum, etc., with appropriate amplitudes.

* Demonstration before Section A (Mathematical and Physical Sciences) of the British Association at Leicester on September 12.

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If the pendulum is taken above the equator of its sphere of rotation, a further reduction in the number of possible loops in the orbit appears to occur, but this is deceptive because there is now a loop above and a loop below the equator, which correspond. Also the figuring can now be dependent on velocity, the angle of initial swing not necessarily deciding the pattern, as in small spherical angle orbits.

If the speed of projection of the pendulum is high, the orbit tends to become a great circle on its sphere, which orbit precesses in the same direction as would be the case with a gyroscope.

It follows that if the orbit is nearly in the horizontal plane, precession occurs rapidly for any given mean velocity of pendulum; and as approaching the vertical plane precession becomes relatively slow, it should, in the limit, become zero again when the pendulum rotates completely in a vertical plane.

The rate of precession for any given inclination of great circle orbit now depends on the velocity of the pendulum bob, in the same way that the rate of precession of an unbalanced gyroscope at a given slope depends on the velocity of rotation.

A sphere rolling in a hemispherical saucer can be shown to have orbits resembling those of the hemispherical pendulum, but modified by the unavoidable gyroscopic rotation of the sphere as it rolls. These orbits can be modified by giving an initial spin to the sphere, causing it to run up or down the slope and form open or closed loops accordingly.

Spinning the pendulum bob will, of course, also modify the orbits.

Probably the orbits of electrons in the structure of the atom will be found to display similar phenomena.

Mathematics of Inheritance

AS an outcome of his prolonged and elaborate studies of the inheritance of racing capacity in the thoroughbred horse, Dr. Harry H. Laughlin has put forward a mathematical expression termed "The General Formula of Heredity" which he has discussed in a recent paper under the same title (*Proc. Nat. Acad. Sci.*, 19, 787; 1933). He remarks that the majority of characters in which practical men are interested are too complex genetically for their inheritance to have been analysed in terms of genes:

". . . Practically all of the structural and functional qualities of the many species with which students of evolution work belong to this same category of qualities too complex to be resolved by the theory of the gene. Also, in the same class we must list most of the inborn human qualities with which anatomy, physiology, medicine, psychology, education, the fine arts, athletics and religion are concerned. As anatomical or physiological entities, many of these qualities have been accurately measured or diagnosed, with due allowance for the effects of environment. But only an occasional one has been analyzed into its constituent genes. The fact is that a structural quality like stature in man, or a functional quality like racing capacity in the Thoroughbred horse, far from being based upon a single or a few genes, is the developmental end-product of a great many genes, possibly a score, but more likely a thousand. In the course of development these genes interact, some accelerating their fellows, others cancelling what otherwise would be plus-values in the individual. The result is that the offspring from a given antecedent type often possess the subject-quality in end-values ranging over a scale from very low to very high."

The practical procedure which Dr. Laughlin advocates is to find a formula which shall give in terms of the antecedent information available as to parents or more remote ancestry, the frequency among the offspring not of the different possible genotypes, but of the different values for the measurable character in question. He rightly stresses, and illustrates from his racing data, both the difficulty and the possibility of arriving at a satisfactory basic measure. The general formula given involves fifteen 'basic constants' which are to be fitted to the data.

Such a formula, though very laborious to construct, should on good data give a satisfactory basis for practical prediction. The difficulty which most geneticists will feel lies in deciding whether Dr. Laughlin's formula is better than others equally complicated which could be constructed, and in discussing the genetic interpretation of its ingredients. However, the first step is clearly for Dr. Laughlin to explain his actual procedure and this he has done in some detail in this condensed paper. R. A. FISHER.

Oceanographical Research in Japan

IN recent numbers of "Records of Oceanographic Works in Japan" compiled by the Committee on Pacific Oceanography of the National Research Council of Japan (vol. 4, No. 2, Dec. 1932, and vol. 5, No. 1, Jan. 1933) a list of researches is given showing that a large amount of important work has been done on various subjects. A classified list of papers and reports bearing on oceanography published in Japan during 1930 and 1931 is included. These are entered under the heads "Physical and Chemical Oceanography" and "Fundamental Marine Biology".

In the December number there is a short abstract of a paper by E. Sawano read before the twenty-fifth meeting of the Committee on the Progress of Researches on the Biology of Corals carried on in the South Sea Islands, Zappu and Palau. This includes studies of growth by T. Tanura and Y. Hada, classification of corals at Palau Island by Y. Hada, respiration of corals by T. Mimura, and the digestive enzymes of corals by E. Sawano.

In the January number, besides a paper by K. Okamura on the Algæ from Alaska collected by Y. Kobyashi, there is a long report by F. Hiro on the Cirripedia collected on the continental shelf bordering Japan by the surveying ships of the Imperial Fisheries Experimental Station. This is fully illustrated and contains descriptions of twenty-five species belonging to thirteen genera, the greater part of which were obtained on the Pacific Ocean side while only a few came from the Japan Sea. They

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